Neuroscience and Computational Intelligence

Edited by: Jovan Pehcevski

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Jovan obtained his PhD in Computer Science from RMIT University in Melbourne, Australia in 2007. His research interests include big data, business intelligence and predictive analytics, data and information science, information retrieval, XML, web services and service-oriented architectures, and relational and NoSQL database systems. He has published over 30 journal and conference papers and he also serves as a journal and conference reviewer. He is currently working as a Dean and Associate Professor at European University in Skopje, Macedonia.

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LIST OF ABBREVIATIONS

ACC	acoustic change responses
AD	Activity Diagrams
ALS	Amyotrophic Lateral Sclerosis
ARFF	attribute - relation file format
ANS	Autonomic nervous system
BPDs	Business Process Diagrams
BPM	Business Process Management
BPMN	Business Process Model and Notation
BPAL	Business process modelling framework
CNS	Central nervous system
CBT	Cognitive behavior therapy
DBT	Dialectic-behavior therapy
DSK	Domain specific knowledge
EPC	Event-driven Process Chain
ERP	Event related potentials
X-DCG	Extended Definite Clause Grammar
FOL	First order logic
FOPL	First order predicate logic
FTD	Frontotemporal dementia
FMSM	Functional Mental State Measure
FBA	Fusiform Body Area
FFA	Fusiform Face Area
HGA	Head Gimbal Assembly
IFL	Inferior longitudinal fasciculus
IT	Information Technology
LOTH	Language of Thought Hypothesis
LS	Learning Services
LTM	Long term memory

MLMs	Medical Logic Modules
MBT	Mentalization based therapy
NLP	Natural language processing
OFA	Occipital Face Area
PNS	Peripheral nervous system
RTM	Representational Theory of the Mind
SFT	Schema focused therapy
SBPM	Semantic Business Process Management
SWRL	Semantic Web Rule Language
SWS	Semantic Web Services
TCMS	Transcerebral Magnetic Stimulation
WSD	Word Sense Disambiguation

PREFACE

Neuroscience allows us to better understand how the brain works. This science also provides answers to many important, but also fun questions: do we really use only ten percent of the brain, are brain exercises useful, can we mentally move parts of other people's bodies? Neuroscientists are researching the brain. They rely on knowledge from areas such as biology, physics or electronics.

Neuroscience is on the border between brain and mind research. Brain analysis and study is of great importance for understanding and comprehending the ways in which we perceive and perform interactions with the environment and, in particular, in which all ways human experience and human biology are mutually conditioned.

It can be said that this is a young science, because it gained momentum only after the Second World War. Some of the devices designed for war purposes were later used in neuroscience. Three hundred years ago, it was assumed that there were some impulses in the brain, but there was no way to measure them. Neuroscience does not deal with psychology; rather, the brain is of interest to researchers from the standpoint of electrophysiology.

Neuroscience is a broad field that deals with the scientific study of the nervous system, including structure, functions, history of evolution, development, genetics, biochemistry, physiology, pharmacology, and pathology of the nervous system. It has traditionally been classified in biology. Recent intersections of interests in many scientific fields and disciplines, including cognitive and neuropsychology, computing, statistics, physics and medicine, have led to the expansion of neuroscience tasks, and today include any scientific and systematic, experimental and theoretical research on the central and peripheral nervous systems of biological organisms. The methodologies used by neuroscientists include analysis of biochemical processes and genetic analysis of the dynamics of individual nerve cells and their molecular components, to the visual representation of perceptual and motor processes in the brain.

This edition covers different topics from neuroscience and computational intelligence, including semantic and concept modeling, general neuroscience topics, reasoning and knowledge modeling, and topics from clinical neuroscience.

Section 1 focuses on semantic and concept modeling, describing automatic concept extraction in semantic summarization process, a further analysis of taxonomic links in conceptual modelling, a general knowledge representation model of concepts, intelligent information access based on logical semantic binding method, and automatic concept extraction in semantic summarization process.

Section 2 focuses on general neuroscience topics, describing the philosophy and neuroscience movement, the creativity as central to critical reasoning and the facilitative role of moral education, the information infrastructure for cooperative research in neuroscience, and computational intelligence and neuroscience in neurorobotics.

Section 3 focuses on reasoning and knowledge modeling, describing knowledge representation in a proof checker for logic programs, episodic reasoning for vision-based human action recognition, a knowledge representation formalism for semantic business process management, and gaining knowledge from imperfect data.

Section 4 focuses on clinical neuroscience, describing neuroscience and unconscious processes, validating new technologies to treat depression, pain and the feeling of sentient beings, Alzheimer's disease as an adaptability disorder and what role does happiness have in treatment, management and prevention, as well as how neuroscience relates to hearing aid amplification and social cognition through the lens of cognitive and clinical neuroscience.

SECTION 1:

SEMANTIC AND CONCEPTUAL MODELING

CHAPTER 1

Automatic Concept Extraction in Semantic Summarization Process

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INTRODUCTION

The Semantic Web offers a generic infrastructure for interchange, integration and creative reuse of structured data, which can help to cross some of the boundaries that Web 2.0 is facing. Currently, Web 2.0 offers poor query possibilities apart from searching by keywords or tags. There has been a great deal of interest in the development of semantic-based systems to facilitate knowledge representation and extraction and content integration [1], [2]. Semantic-based approach to retrieving relevant material can be

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useful to address issues like trying to determine the type or the quality of the information suggested from a personalized environment. In this context, standard keyword search has a very limited effectiveness. For example, it cannot filter for the type of information, the level of information or the quality of information.

Potentially, one of the biggest application areas of content-based exploration might be personalized searching framework (e.g., [3], [4]). Whereas search engines provide nowadays largely anonymous information, new framework might highlight or recommend web pages related to key concepts. We can consider semantic information representation as an important step towards a wide efficient manipulation and retrieval of information [5], [6], [7]. In the digital library community a flat list of attribute/value pairs is often assumed to be available. In the Semantic Web community, annotations are often assumed to be an instance of an ontology. Through the ontologies the system will express key entities and relationships describing resources in a formal machine-processable representation. An ontology-based knowledge representation could be used for content analysis and object recognition, for reasoning processes and for enabling user-friendly and intelligent multimedia content search and retrieval.

Text summarization has been an interesting and active research area since the 60's. The definition and assumption are that a small portion or several keywords of the original long document can represent the whole informatively and/or indicatively. Reading or processing this shorter version of the document would save time and other resources [8]. This property is especially true and urgently needed at present due to the vast availability of information. Concept-based approach to represent dynamic and unstructured information can be useful to address issues like trying to determine the key concepts and to summarize the information exchanged within a personalized environment.

In this context, a concept is represented with a Wikipedia article. With millions of articles and thousands of contributors, this online repository of knowledge is the largest and fastest growing encyclopedia in existence.

The problem described above can then be divided into three steps:

- Mapping of a series of terms with the most appropriate Wikipedia article (disambiguation).
- Assigning a score for each item identified on the basis of its importance in the given context.
- Extraction of n items with the highest score.

Text summarization can be applied to many fields: from information retrieval to text mining processes and text display. Also in personalized searching framework text summarization could be very useful.

The chapter is organized as follows: the next Section introduces personalized searching framework as one of the possible application areas of automatic concept extraction systems. Section three describes the summarization process, providing details on system architecture, used methodology and tools. Section four provides an overview about document summarization approaches that have been recently developed. Section five summarizes a number of real-world applications which might benefit from WSD. Section six introduces Wikipedia and WordNet as used in our project. Section seven describes the logical structure of the project, describing software components and databases. Finally, Section eight provides some considerations on case study and experimental results.

PERSONALIZED SEARCHING FRAMEWORK

In personalized searching frameworks, standard keyword search is of very limited effectiveness. For example, it does not allow users and the system to search, handle or read concepts of interest, and it doesn't consider synonymy and hyponymy that could reveal hidden similarities potentially leading to better retrieval. The advantages of a concept-based document and user representations can be summarized as follows: (i) ambiguous terms inside a resource are disambiguated, allowing their correct interpretation and, consequently, a better precision in the user model construction (e.g., if a user is interested in computer science resources, a document containing the word 'bank' as it is meant in the financial context could not be relevant); (ii) synonymous words belonging to the same meaning can contribute to the resource model definition (for example, both 'mouse' and 'display' brings evidences for computer science documents, improving the coverage of the document retrieval); (iii) synonymous words belonging to the same meaning can contribute to the user model matching, which is required in recommendation process (for example, if two users have the same interests, but these are expressed using different terms, they will be considered overlapping); (iv) finally, classification, recommendation and sharing phases take advantage of the word senses in order to classify, retrieve and suggest documents with high semantic relevance with respect to the user and resource models.

For example, the system could support Computer Science last-year students during their activities in courseware like Bio Computing, Internet Programming or Machine Learning. In fact, for these kinds of courses it is necessary an active involvement of the student in the acquisition of the didactical material that should integrate the lecture notes specified and released by the teacher. Basically, the level of integration depends both on the student's prior knowledge in that particular subject and on the comprehension level he wants to acquire. Furthermore, for the mentioned courses, it is continuously necessary to update the acquired knowledge by integrating recent information available from any remote digital library.

INSIDE SUMMARIZATION

Summarization is a widely researched problem. As a result, researchers have reported a rich collection of approaches for automatic document summarization to enhance those provided manually by readers or authors as a result of intellectual interpretation. One approach is to provide summary creation based on a natural language generation (as investigated for instance in the DUC and TREC conferences); a different one is based on a sentence selection from the text to be summarized, but the most simple process is to select a reasonable short list of words among the most frequent and/or the most characteristic words from those found in the text to be summarized. So, rather than a coherent text the summary is a simple set of items.

From a technical point of view, the different approaches available in the literature can be considered as follows. The first is a class of approaches that deals with the problem of document classification from a theoretical point of view, making no assumption on the application of these approaches. These include statistical [9], analytical [10], information retrieval [11] and information fusion [12] approaches. The second class deals with techniques that are focused on specific applications, such as baseball program summaries [13], clinical data visualization [14] and web browsing on handheld devices [15]. [16] reports a comprehensive review.

The approach presented in this chapter produce a set of items, but involves improvements over the simple set of words process in two means. Actually, we go beyond the level of keywords providing conceptual descriptions from concepts identified and extracted from the text. We propose a practical approach for extracting the most relevant keywords from the forum threads to form a summary without assumption on the application domain and to subsequently find out concepts from the keyword extraction based on statistics and synsets extraction. Then semantic similarity analysis is conducted between keywords to produce a set of semantic relevant concepts summarizing actual forum significance.

In order to substitute keywords with univocal concepts we have to build a process called Word Sense Disambiguation (WSD). Given a sentence, a WSD process identifies the syntactical categories of words and interacts with an ontology both to retrieve the exact concept definition and to adopt some techniques for semantic similarity evaluation among words. We use MorphAdorner [17] that provides facilities for tokenizing text and WordNet [18], one of the most used ontology in the Word Sense Disambiguation task.

The methodology used in this application is knowledge-based, it uses Wikipedia as a base of information with its extensive network of cross-references, portals, categories and info-boxes providing a huge amount of explicitly defined semantics.

To extract and access useful information from Wikipedia in a scalable and timely manner we use the Wikipedia Miner toolkit [http://wikipedia-miner.sourceforge.net/] including

scripts for processing Wikipedia dumps and extracting summaries such as the link graph and category hierarchy.

RELATED WORKS IN AUTOMATIC TEXT SUMMARIZATION

A variety of document summarization approaches have been developed recently. The paper [19] reviews leading notions and developments, and seeks to assess the state of the art for this challenging task. The review shows that some useful summarizing for various purposes can already be done but also, not surprisingly, that there is a huge amount more to do both in terms of semantic analysis and capturing the main ideas, and in terms of improving linguistic quality of the summaries. A further overview on the latest techniques related to text summarization can be found in [20]. Generally speaking, the summarization methods can be either extractive or abstractive. Extractive summarization involves assigning relevant scores to some units (e.g. sentences, paragraphs) of the document and extracting the sentences with highest scores, while abstraction summarization involves paraphrasing sections of the source document using information fusion, sentence compression and reformulation [21]. In general, abstraction can condense a text more strongly than extraction, but the required natural language generation technologies are harder to develop representing a growing field.

Sentence extraction summarization systems take as input a collection of sentences and select some subset for output into a summary. The implied sentence ranking problem uses some kind of similarity to rank sentences for inclusion in the summary [22].

For example, MEAD (http://www.summarization.com/mead/) is based on sentence extraction. For each sentence in a cluster of related documents, MEAD computes three features and uses a linear combination of the three to determine what sentences are most salient. Sentence selection is constrained by a summary length threshold, and redundant new sentences avoided by checking cosine similarity against prior ones.

Extractive summarizers can be based on scoring sentences in the source document. For example, [23] consider each document as a sequence of sentences and the objective of extractive summarization is to label the sentences in the sequence with 1 and 0 (summary or non-summary sentence).

The summarization techniques can also be classified into two groups: supervised and unsupervised techniques. In the first case they rely on pre-existing document-summary pairs, while in the second, they are based on properties and heuristics derived from the text. Supervised extractive summarization techniques treat the summarization task as a two-class classification problem at the sentence level, where the summary sentences are positive samples while the non-summary sentences are negative samples. After representing each sentence by a vector of features, the classification function can be trained in two different manners [24]. Many unsupervised methods have been developed by exploiting different features and relationships of the sentences.

Furthermore, summarization task can also be categorized as either generic or query-based. A query-based summary presents the information that is most relevant to the given queries while a generic summary gives an overall sense of the document content [21].

Text summarization can also be classified on the basis of volume of text documents available distinguishing between single document and multi-document text summarization techniques. The article [25] presents a multi-document, multi-lingual, theme-based summarization system based on modeling text cohesion (story flow). In this paper a Naïve Bayes classifier for document summarization is also proposed. Also in [26] we can find an analysis of multi-document summarization in scientific corpora.

Finally, automatic document summarization is a highly interdisciplinary research area related with computer science, multimedia, statistics, as well as cognitive psychology. In [27] they introduce an intelligent system based on a cognitive psychology model (the event-indexing model) and the roles and importance of sentences and their syntax in document understanding. The system involves syntactic analysis of sentences, clustering and indexing sentences with five indices from the event-indexing model, and extracting the most prominent content by lexical analysis at phrase and clause levels.

APPLICATIONS

Here we summarize a number of real-world applications which might benefit from WSD and on which experiments have been conducted [28].

Information Retrieval (IR)

Search engines do not usually use explicit semantics to prune out documents which are not relevant to a user query. An accurate disambiguation both of the document base and of the query words, would allow it to eliminate documents containing the same words used with different meanings (thus increasing precision) and to retrieve documents expressing the same meaning with different wordings (thus increasing recall).

Most of the early work on the contribution of WSD to IR resulted in no performance improvement also because only a small percentage of query words are not used in their most frequent (or predominant) sense, indicating that WSD must be very precise on uncommon items, rather than on frequent words. [29] concluded that, in the presence of queries with a large number of words, WSD cannot benefit IR. He also indicated that improvements in IR performance would be observed only if WSD could be performed with at least 90% accuracy. Encouraging evidence of the usefulness of WSD in IR has come from [30]. Assuming a WSD accuracy greater than 90%, they showed that the use of WSD in IR improves the precision by about 4.3%. With lower WSD accuracy (62.1%) a small improvement (1.73% on average) can still be obtained.

Information Extraction (IE)

In detailed application domains it is interesting to distinguish between specific instances of concepts: for example, in the medical domain we might be interested in identifying all kinds of antidepressant drugs across a text, whereas in bioinformatics we would like to solve the ambiguities in naming genes and proteins. Tasks like named-entity recognition and acronym expansion that automatically spells out the entire phrase represented (a feature found in some content management and Web-based search systems), can all be cast as disambiguation problems, although this is still a relatively new area. Acronym expansion functions for search is considered an accessibility feature that is useful to people who have difficulties in typing. [31] proposed the application of a link analysis method based on random walks to solve the ambiguity of named entities. [32] used a link analysis algorithm in a semi-supervised approach to weigh entity extraction patterns based on their impact on a set of instances.

Some tasks at Semeval-2007 more or less directly dealt with WSD for information extraction. Specifically, the metonymy task in which a concept is not called by its own name but by the name of something intimately associated with that concept ("Hollywood" is used for American cinema and not only for a district of Los Angeles) required systems to associate the appropriate metonymy with target named entities. Similarly, the Web People Search task required systems to disambiguate people names occurring in Web documents, that is, to determine the occurrence of specific instances of people within texts.

Machine Translation (MT)

Machine translation (MT), the automatic identification of the correct translation of a word in context, is a very difficult task. Word sense disambiguation has been historically considered as the main task to be solved in order to enable machine translation, based on the intuitive idea that the disambiguation of texts should help translation systems choose better candidates. Recently, [33] showed that word sense disambiguation can help improve machine translation. In these works, predefined sense inventories were abandoned in favor of WSD models which allow it to select the most likely translation phrase. MT tools have become an urgent need also in a multilingual environment. Although there are any available tools, unfortunately, a robust MT approach is still an open research field.

Content Analysis

The analysis of the general content of a text in terms of its ideas, themes, etc., can certainly benefit from the application of sense disambiguation. For instance, the classification of blogs or forum threads has recently been gaining more and more interest within the Internet community: as blogs grow at an exponential pace, we need a simple yet effective way to classify them, determine their main topics, and identify relevant (possibly semantic) connections between blogs and even between single blog posts. [34]. A second related area of research is that of (semantic) social network analysis, which is becoming more and more active with the recent evolutions of the Web.

Although some works have been recently presented on the semantic analysis of content [35], this is an open and stimulating research area.

Lexicography

WSD and lexicography (i.e., the professional writing of dictionaries) can certainly benefit from each other: sense-annotated linguistic data reduces the considerable overhead imposed on lexicographers in sorting large-scaled corpora according to word usage for different senses. In addition, word sense disambiguation techniques can also allow language learners to access example sentences containing a certain word usage from large corpora, without excessive overhead. On the other side, a lexicographer can provide better sense inventories and sense annotated corpora which can benefit WSD.

The Semantic Web

The Semantic Web offers a generic infrastructure for interchange, integration and creative reuse of structured data, which can help to cross some of the boundaries that Web 2.0 is facing. Currently, Web 2.0 offers poor query possibilities apart from searching by keywords or tags. There has been a great deal of interest in the development of semantic-based systems to facilitate knowledge representation and extraction and content integration [36], [37]. Semantic-based approach to retrieving relevant material can be useful to address issues like trying to determine the type or the quality of the information suggested from a personalized environment. In this context, standard keyword search has a very limited effectiveness. For example, it cannot filter for the type of information, the level of information or the quality of information.

Potentially, one of the biggest application areas of content-based exploration might be personalized searching framework (e.g., [38],[39]). Whereas today's search engines provide largely anonymous information, new framework might highlight or recommend web pages or content related to key concepts. We can consider semantic information representation as an important step towards a wide efficient manipulation and discovery of information [40], [41], [42]. In the digital library community a flat list of attribute/value pairs is often assumed to be available. In the Semantic Web community, annotations are often assumed to be an instance of an ontology. Through the ontologies the system will express key entities and relationships describing resources in a formal machine-processable representation. An ontology-based knowledge representation could be used for content analysis and object recognition, for reasoning processes and for enabling user-friendly and intelligent multimedia content exploration and retrieval.

Therefore, the semantic Web vision can potentially benefit from most of the above-mentioned applications, as it inherently needs domain-oriented and unrestricted sense disambiguation to deal with the semantics of documents, and enable interoperability between systems, ontologies, and users.

WSD has been used in semantic Web-related research fields, like ontology learning, to build domain taxonomies. Indeed, any area of science that relies on a linguistic bridge between human and machine will use word sense disambiguation.

Web of Data

Although the Semantic Web is a Web of data, it is intended primarily for humans; it would use machine processing and databases to take away some of the burdens we currently face so that we can concentrate on the more important things that we can use the Web for.

The idea behind Linked Data [43] is using the Web to allow exposing, connecting and sharing linking data through dereferenceable URIs on the Web. The goal is to extend the Web by publishing various open datasets as RDF triples and by setting RDF links between data items from several data sources. Using URIs, everything can be referred to and looked up both by people and by software agents. In this chapter we focus on DBpedia [44], that is one of the main clouds of the Linked Data graph. DBpedia extracts structured content from Wikipedia and makes this information available on the Web; it uses the RDF to represent the extracted information. It is possible to query relationships and properties associated with Wikipedia resources (through its SPARQL endpoint), and link other data sets on the web to DBpedia data.

The whole knowledge base consists of over one billion triples. DBpedia labels and abstracts of resources are stored in more than 95 different languages. The graph is highly connected to other RDF dataset of the Linked Data cloud. Each resource in DBpedia is referred by its own URI, allowing to precisely get a resource with no ambiguity. The DBpedia knowledge base is served as Linked Data on the Web. Actually, various data providers have started to set RDF links from their data sets to DBpedia, making DBpedia one of the central interlinking-hubs of the emerging Web of Data.

Compared to other ontological hierarchies and taxonomies, DBpedia has the advantage that each term or resource is enhanced with a rich description including a textual abstract. Another advantage is that DBpedia automatically evolves as Wikipedia changes. Hence, problems such as domain coverage, content freshness, machine-understandability can be addressed more easily when considering DBpedia. Moreover, it covers different areas of the human knowledge (geographic information, people, films, music, books, …); it represents real community agreement and it is truly multilingual.

USING WIKIPEDIA AND WORDNET IN OUR PROJECT

For the general public, Wikipedia represents a vast source of knowledge. To a growing community of researchers and developers it also represents a huge, constantly evolving collection of manually defined concepts and semantic relations. It is a promising resource for natural language processing, knowledge management, data mining, and other research areas.

In our project we used WikipediaMiner toolkit [wikipedia-miner.sourceforge.net/], a functional toolkit for mining the vast amount of semantic knowledge encoded in Wikipedia providing access to Wikipedia's structure and content, allowing terms and concepts to be compared semantically, and detecting Wikipedia topics when they are mentioned in documents. We now describe some of the more important classes we used to model Wikipedia's structure and content.

Pages: All of Wikipedia's content is presented on pages of one type or another. The toolkit models every page as a unique id, a title, and some content expressed as MediaWiki markup.

Articles provide the bulk of Wikipedia's informative content. Each article describes a single concept or topic, and their titles are succinct, well-formed phrases that can be used as non-descriptors in ontologies and thesauri. For example, the article about domesticated canines is entitled Dog, and the one about companion animals in general is called Pet. Once a particular article is identified, related concepts can be gathered by mining the articles it links to, or the ones that link to it.

The anchor texts of the links made to an article provide a source of synonyms and other variations in surface form. The article about dogs, for example, has links from anchors like canis familiaris, man's best friend, and doggy.

The subset of keywords related to each article helps to discriminate between concepts. In such a way, two texts characterized using different keywords may result similar considering underling concept and not the exact terms. We use the WordNet to perform the following

feature extraction pre-process. Firstly, we label occurrences of each word as a part of speech (POS) in grammar. This POS tagger discriminates the POS in grammar of each word in a sentence. After labeling all the words, we select those ones labeled as noun and verbs as our candidates. We then use the stemmer to reduce variants of the same root word to a common concept and filter the stop words.

WordNet is an online lexical reference system, in which English nouns, verbs, adjectives and adverbs are organized into synonym sets. Each synset represents one sense, that is one underlying lexical concept. Different relations link the synonym sets, such as IS-A for verbs and nouns, IS-PART-OF for nouns, etc. Verbs and nouns senses are organized in hierarchies forming a "forest" of trees. For each keyword in WordNet, we can have a set of senses and, in the case of nouns and verbs, a generalization path from each sense to the root sense of the hierarchy. WordNet could be used as a useful resource with respect to the semantic tagging process and has so far been used in various applications including Information Retrieval, Word Sense Disambiguation, Text and Document Classification and many others.

Noun synsets are related to each other through hypernymy (generalization), hyponymy (speciali-zation), holonymy (whole of) and meronymy (part of) relations. Of these, (hypernymy, hyponymy) and (meronymy, holonymy) are complementary pairs. The verb and adjective synsets are very sparsely connected with each other. No relation is available between noun and verb synsets. However, 4500 adjective synsets are related to noun synsets with pertainyms (pertaining to) and attra (attributed with) relations.

Articles often contain links to equivalent articles in other language versions of Wikipedia. The toolkit allows the titles of these pages to be mined as a source of translations; the article about dogs links to (among many others) chien in the French Wikipedia, haushund in German, and 犬 in Chinese.

Redirects are pages whose sole purpose is to connect an article to alternative titles. Like incoming anchor texts, these correspond to synonyms and other variations in surface form. The article entitled dog, for example, is referred to by redirects dogs, canis lupus familiaris, and domestic dog. Redirects may also represent more specific topics that do not warrant separate articles, such as male dog and dog groups.

Categories: Almost all of Wikipedia's articles are organized within one or more categories, which can be mined for hyponyms, holonyms and other broader (more general) topics. Dog, for example, belongs to the categories domesticated animals, cosmopolitan species, and scavengers. If a topic is broad enough to warrant several articles, the central article may be paired with a category of the same name: the article dog is paired with the category dogs. This equivalent category can be mined for more parent categories (canines) and subcategories (dog breeds, dog sports). Child articles and other descendants (puppy, fear of dogs) can also be mined for hypernyms, meronyms, and other more specific topics.

All of Wikipedia's categories descend from a single root called Fundamental. The toolkit uses the distance between a particular article or category and this root to provide a measure of its generality or specificity. According to this measure Dog has a greater distance than carnivores, which has the same distance as omnivores and a greater distance than animals.

Disambiguations: When multiple articles could be given the same name, a specific type of article—a disambiguation—is used to separate them. For example, there is a page entitled dog (disambiguation), which lists not only the article on domestic dogs, but also several other animals (such as prairie dogs and dogfish), several performers (including Snoop Doggy Dogg), and the Chinese sign of the zodiac. Each of these sense pages have an additional scope note; a short phrase that explains why it is different from other potential senses.

Anchors, the text used within links to Wikipedia articles, are surprisingly useful. As described earlier, they encode synonymy and other variations in surface form, because people alter them to suit the surrounding prose. A scientific article may refer to canis familiaris, and a more informal one to doggy. Anchors also encode polysemy: the term dog is used to link to different articles when discussing pets, star signs or the iconic American fast food. Disambiguation pages do the same, but link anchors have the advantage of being marked up directly, and therefore do not require processing of unstructured text. They also give a sense of how likely each sense is: 76% of Dog links are made to the pet, 7% to the Chinese star sign, and less than 1% to hot dogs.

Wikipedia itself is, of course, one of the more important objects to model. It provides the central point of access to most of the functionality of the toolkit. Among other things, here you can gather statistics about the encyclopedia, or access the pages within it through iteration, browsing, and searching.

We used RitaWn [http://www.rednoise.org/rita/wordnet] to query WordNet.

SYSTEM ARCHITECTURE

This section describes the logical structure of the project, describing software components (Figure1) and database (Figure 2) that allow the system to carry out its task.

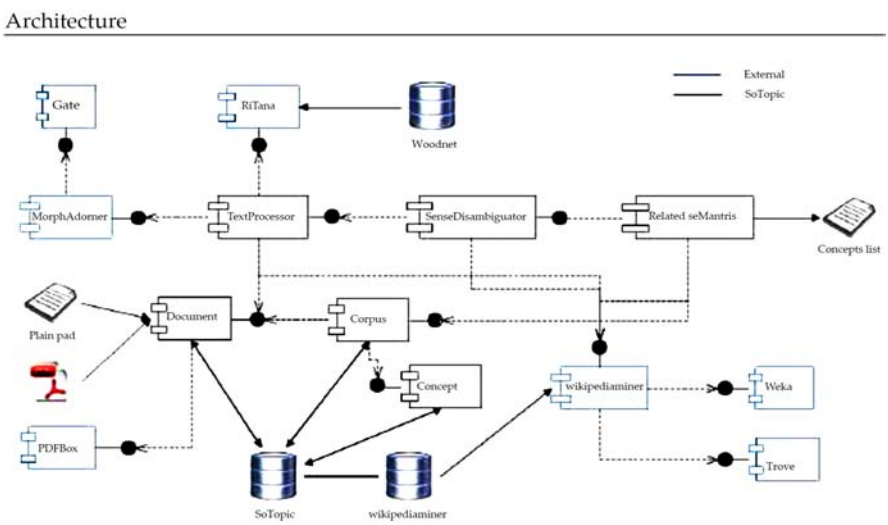

Figure 1. System architecture.

The database maintains documents in plain text and organize them in one or more possibly *Corpus*, a set of documents linked together in a logical manner, for example, by dealing with the topic.

We associate a frequency list of concepts for each corpus (and therefore a set of documents), that is how many times a particular concept is repeated within all the documents of the corpus. A concept corresponds exactly to a Wikipedia article, thus creating a relationship between our project and WikipediaMiner database, more precisely, between the ConceptFrequency and Page tables. These statistics, as we shall see below, are used to better identify those concepts that define a document between similar.

To abstract and manage documents and databases we have created two components, *Corpus* and *Document*, which act as an interface between the other components of the application and the database. They provide editing, creation and deletion functions to facilitate the extraction of content representing the input to all other phases of the main process.

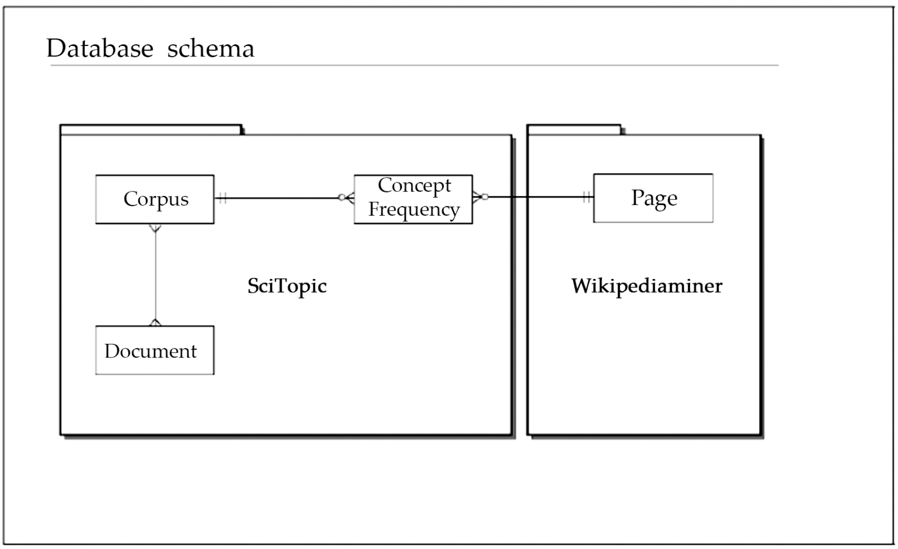

Figure 2. System database.

Starting from a document and a corpus to which it is associated, we proceed to a series of transformations on the text in order to filter all unnecessary components leaving only a set of names in basic form useful for later phases. The component that performs this task is the *TextProcessor* and is configurable, allowing the user to define the desired level of filtering.

The output of the previous phase is used for the disambiguation task, carried out by the component *SenseDisabiguator*; the system maps the most appropriate Wikipedia article to each term or, if this is not possible, it eliminates the term considered unknown. The result is a series of concepts that is Wikipedia articles. The component RelatednessMatrix uses this list of concepts to establish the importance of each of them within the context. In particular, the system performs the sum of the degree of relationship between a concept and all the others and evaluates this amount depending on the TFxIDF. So doing, the system associates a weight to each concept, reaching the objective of obtaining the *n* that best define the content of the input document.

Text Processor

Starting from a document and a corpus to which it is associated, *TextProcessor* performs transformations on the text in order to filter all unnecessary components leaving only a set of names in basic form useful for later phases (see Figure 3).

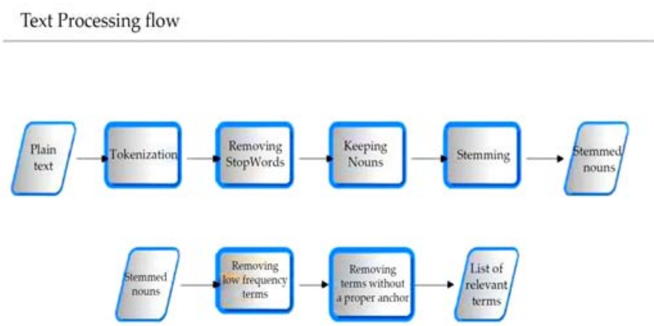

Figure 3. The text processing flow.

The disambiguation process is expensive and it is therefore appropriate to delete any irrelevant term; with this intention the *TextProcessor* module removes both all the remaining words with a frequency less than a given threshold and all those that do not correspond to an appropriate Wikipedia anchor, that is an anchor that has no meaning with probability greater than a defined minimum.

Summarizing, *TextProcessor* has two parameters that affect the selectivity of performed functions: the minimum frequency and the minimum probability of the Wikipedia senses (articles).

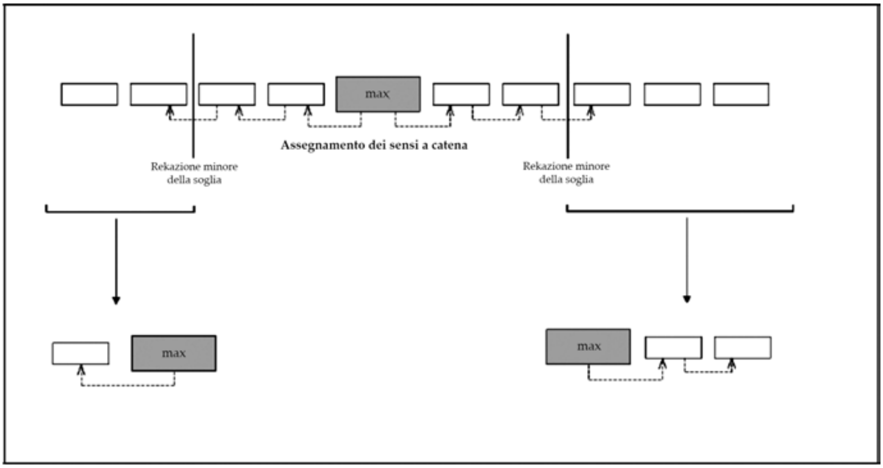

Figure 4. The SenseDisambiguator recursive procedure.

Sense Disambiguator

It is the component that assigns to a specific list of terms (see Figure 4) the most appropriate sense. It is achieved by a recursive procedure (see Figure 5) that takes a list of terms and recursively splits it into slices; for each part it defines a main sense from which disambiguate the others.

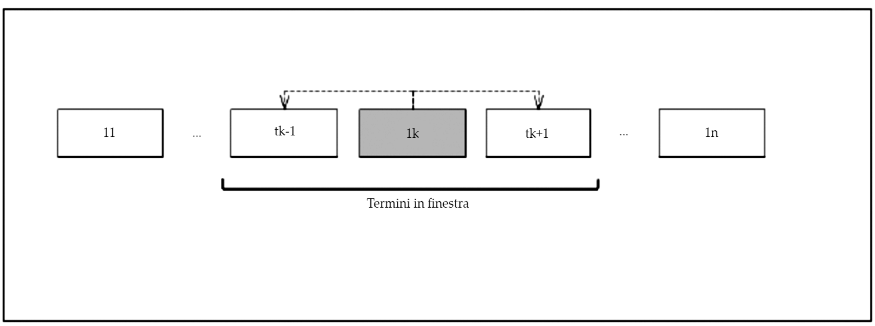

Figure 5. The sense score is calculated based on the term senses belonging to a window.

The pseudo-code of the disambiguation procedure is showed in the following listing.

Listings 6.1: Pseudocodice della procedura di disambiguazione

```
WSD( termini )

// Calcolo dei punteggi dei sensi dei termini
foreach ( Termine t1 in termini ) {
        foreach ( Senso s1 in sensi ( t1 ) ) {
```

Relatedness Matrix

The RelatednessMatrix has the task of both building a relationship matrix using all elements of a given list of senses and of providing various ways of extracting information. It is the component used in the final phase that is, given a list of senses it extracts the most relevant.

```
                foreach (Termine t2 in finstra (t1) ) {
                        foreach (Senso s2 in  sensi (t2)) {
                                Aggiorna punteggio (s1 , t1)
                        }
                }
        }
}

AssegnaSensi (termini,  1,  n)
```

Listing 6.2: Pseudocodice della procedura di assegnamento dei sensi

```
Assegna Sensi (termini,   inizio,   fine )

//Termine con senso a punteggio massimo
smax  :=  { s : max { punteggio   (s,  t) } }
tmax  :=  { t : smax   in   t }

//Assegno i sensi dei termini a sinistra di tmax
foreach  (Termine   t1   in   termini   a   sinistra ) }
        if  ( Esiste almeno un senso che ha una relazione sufficiente con
                il senso assegnato al termine precedente){
                Assegna al termine t1 il senso s che massimizza relaxione (s
                  s_precedente )
        } else {
                // Ricorsione
                AssegnaSensi ( termini , inizio , t1 )
                break
        }
}
```

```
// Assegno i sensi dei termini a destra di tmax
foreach ( Termine t1 in termini a destra ) {
    if ( Esiste almeno un senso che ha una relazione sufficiente con
        il senso assegnato al termine precedente) {
        Assegna a1 termine t1 il senso s che massimizza punteggio (s
            , s_precedente
    } else {
        // Ricoraione
        AssegnaSensi ( termini, t1, fine )
        break
    }
}

Unisci lise di sensi


return
```

CONSIDERATIONS

The work described in this chapter represents some initial steps in exploring automatic concept extraction in semantic summarization process. It could be considered as one possible instance of a more general concept concerning the transition from the Document Web to the Document/Data Web and the consequent managing of these immense volumes of data.

Summarization can be evaluated using intrinsic or extrinsic measures; while the first one methods attempt to measure summary quality using human evaluation, extrinsic methods measure the same through a task-based performance measure such the information retrieval-oriented task. In our experiments we utilized intrinsic approach analyzing [45] as document and [45] [46] [47] [48] [49] [50] [51] [52] [53] [54] [55] as corpus.

This experiment is to evaluate the usefulness of concept extraction in summarization process, by manually reading whole document content and comparing with automatic extracted concepts. The results show that automatic concept-based summarization produces useful support to information extraction. The extracted concepts represent a good summarization of document contents.

For example, we evaluated the influence of chosen window size using 605 terms to be disambiguated. The results are showed in Table 1.

Table 1. Change in precision and recall as a function of window size.

Win-dow	**Copertura (C)**	**Precisione (P)**	**C%**	**P%**
4	438	268	72.39	61.18
8	461	357	76.19	77.44
12	470	355	77.68	75.53
16	475	369	78.51	77.68
20	480	362	79.33	75.41

Using the best choice of parameter values we obtain the following percentages in precision and recall.

Table 2. Change in precision and recall using the showed set of parameter values.

window-	minScore	minRelatednessToSplit
8	0.18	0.2

Copertura (C)	Precisions (P)	C%	P%
444	358	73.38	80.63

Finally, given the document [MW08], Table 3 shows the ten most representative articles automatically extracted from the system.

While the initial results are encouraging, much remains to be explored. For example, many disambiguation strategies with specific advantages are available, so designers now have the possibility of deciding which new features to include in order to support them, but it is particularly difficult to distinguish the benefits of each advance that have often been shown independent of others.

Table 3. Automatically extracted articles representing [MW08]

LISTING 6.16: I PRIMI DIECI ARTICOLI CHE RAPPRESENTANO IL DOCTUNENTO [MW08].

1 Language
2 System
3 Category theory
4 Knowledge
5 Word
6 Datum (geodesy)
7 Concept
8 WordNet
9 Application software
10 Accuracy and precision

It would also be interesting to apply the showed method using a different knowledge base, for example YAGO (but always derived from Wikipedia) and use a different measure of relationship between concepts considering not only the links belonging to articles but also the entire link network. That is, considering Wikipedia as a graph of interconnected concepts, we could exploit more than one or two links.

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CHAPTER 2

That IS-IN Isn't IS-A: A Further Analysis of Taxonomic Links in Conceptual Modelling

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INTRODUCTION

Ronald J. Brachman, in his basic article: "What IS-A Is and Isn't: An Analysis of Taxonomic Links in Semantic Networks", (1983), has analyzed and catalogued different interpretations of inheritance link, which is called "IS-A", and which is used in different kind of knowledge-representation systems. This IS-A link is seen by Brachman as a relation "between the representational objects," which forms a "taxonomic hierarchy, a tree or a lattice-like structures for categorizing classes of things in the world being represented", (ibid., 30). This very opening phrase in Brachman's article reveals, and which the further analysis of his article confirms as it is done in this Chapter, that he is considering the IS-A relation and the different

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interpretations given to it as an *extensional* relation. Accordingly, in this Chapter we are considering an *intensional* IS-IN relation which also forms a taxonomic hierarchy and a lattice-like structure. In addition, we can consider the hierarchy provided by an IS-IN relation as a semantic network as well. On the other hand, this IS-IN relation, unlike IS-A relation, is a conceptual relation between concepts, and it is basically intensional in its character.

The purpose of this Chapter is to maintain that the IS-IN relation is not equal to the IS-A relation; more specifically, that Brachman's analysis of an extensional IS-A relation did not include an intensional IS-IN relation. However, we are not maintaining that Brachman's analysis of IS-A relation is wrong, or that there are some flaws in it, but that the IS-IN relation requires a different analysis than the IS-A relation as is done, for example, by Brachman.

This Chapter is composed as follows. Firstly, we are considering the different meanings for the IS-A relation, and, especially, how they are analyzed by Brachman in (1983), and to which, in turn, we shall further analyse. Secondly, we are turning our attention to that of the IS-IN relation. We start our analysis by considering what the different senses of "in" are, and to do this we are turning first to Aristotle's and then to Leibniz's account of it. After that, thirdly, we are proceeding towards the basic relations between terms, concepts, classes (or sets), and things in order to propose a more proper use of the IS-IN relation and its relation to the IS-A relation. Lastly, as kind of a conclusion, we are considering some advances and some difficulties related to the intensional versus extensional approaches to a conceptual modelling.

THE DIFFERENT MEANINGS FOR THE IS-A RELATION

The idea of IS-A relation seems to follow from the English sentences such as "Socrates is a man" and "a cat is a mammal", which provides two basic forms of using the IS-A relation. That is, a *predication*, where an individual (Socrates) is said to have a predicate (a man), and that one predicate (a cat) is said to be a *subtype* of the other predicate (a mammal). This second form is commonly expressed by the universally quantified conditional as follows: "for all entities *x*, if *x* is a cat, then *x* is a mammal". However, this formalization of the second use of the IS-A relation reveals, that it combines two commonly used expressions using the IS-A relation. Firstly, in the expressions of the form "*x* is a cat" and "*x* is a mammal" the IS-A relation is used as a predication, and secondly, by means of the universal quantifier and implication, the IS-A relation is used not as a predication, but as a connection between two predicates.

Accordingly, we can divide the use of the IS-A relation in to two major subtypes: one relating an individual to a species, and the other relating two species. When analysing the different meanings for the IS-A relation Brachman uses this division by calling them *generic/individual* and *generic/generic* relations, (Brachman 1983, 32).

Generic/Individual Relations

Brachman gives four different meanings for the IS-A relation connecting an individual and a generic, which we shall list and analyze as follows, (ibid.):

1. *A set membership relation*, for example, "Socrates is a man", where "Socrates" is an individual and "a man" is a set, and Socrates is a member of a set of man. Accordingly, the IS-A is an ∈-relation.
2. *A predication*, for example, a predicate "man" is predicated to an individual "Socrates", and we may say that a predicate and an individual is combined by a copula expressing a kind of function-argument relation. Brachman does not mention a copula in his article, but according to this view the IS-A is a copula.
3. *A conceptual containment relation*, for which Brachman gives the following example, "a king" and "the king of France", where the generic "king" is used to construct the individual description. In this view Brachman's explanation and example is confusing. Firstly, "France" is an individual, and we could say that the predicate "a king" is predicated to "France", when the IS-A relation is a copula. Secondly, we could say that the concept of "king" applies to "France" when the IS-A relation is an application relation. Thirdly, the phrase "the king of France" is a definite description, when we could say that the king of France is a definite member of the set of kings, *i.e.*, the IS-A relation is a converse of ∈-relation.
4. *An abstraction*, for example, when from the particular man "Socrates" we abstract the general predicate "a man". Hence we could say that "Socrates" falls under the concept of "man", *i.e.*, the IS-A is a falls under –relation, or we could say that "Socrates" is a member of the set of "man", *i.e.*, the IS-A is an ∈-relation.

We may notice in the above analysis of different meanings of the IS-A relations between individuals and generic given by Brachman, that three out of four of them we were able to interpret the IS-A relation by means of ∈-relation. And, of course, the copula expressing a function-argument relation is possible to express by ∈-relation. Moreover, in our analysis of 3. and 4. we used a term "concept" which Brachman didn't use. Instead, he seems to use a term "concept" synonymously with an expression "a structured description", which, according to us, they are not. In any case, what Brachman calls here a conceptual containment relation is not the conceptual containment relation as we shall use it, see Section 4 below.

Generic/Generic Relations

Brachman gives six different meanings for the IS-A relation connecting two generics, which we shall list and analyze as follows, (ibid.):

1. *A subset/superset*, for example, "a cat is a mammal", where "a cat" is a set of cats, "a mammal" is a set of mammals, and a set of cats is a subset of a set of mammals, and a set of mammals is a superset of a set of cats. Accordingly, the IS-A relation is a ⊆-relation.
2. *A generalisation/specialization*, for example, "a cat is a mammal" means that "for all entities x, if x is a cat, then x is a mammal". Now we have two possibilities: The first is that we interpret "x is a cat" and "x is a mammal" as a predication by means of copula, and the relation between them is a formal implication, where the predicate "cat" is a specialization of the predicate "mammal", and the predicate "mammal" is a generalization of the predicate "cat". Thus we can say that the IS-A relation is a formal implication $(\forall x)\ (P(x) \rightarrow Q(x))$. The second is that since we can interpret "x is a cat" and "x is a mammal" by mean of ∈-relation, and then by means of a formal implication we can define a ⊆-relation, from which we get that the IS-A relation is a ⊆-relation.
3. *An AKO*, meaning "a kind of", for example, "a cat is a mammal", where "a cat" is a kind of "mammal". As Brachman points out, (ibid.), AKO has much common with generalization, but it implies "kind" status for the terms of it connects, whereas generalization relates arbitrary predicates. That is, to be a kind is to have an essential property (or set of properties) that makes it the kind that it is. Hence, being "a cat" it is necessary to be "a

mammal" as well. This leads us to the natural kind inferences: if anything of a kind *A* has an essential property φ, then every *A* has φ. Thus we are turned to the Aristotelian essentialism and to a quantified modal logic, in which the IS-A relation is interpreted as a necessary formal implication $(\forall x)\ (P(x) \rightarrow Q(x))$. However, it is to be noted, that there are two relations connected with the AKO relation. The first one is the relation between an essential property and the kind, and the second one is the relation between kinds. Brachman does not make this difference in his article, and he does not consider the second one. Provided there are such things as kinds, in our view they would be connected with the IS-IN relation, which we shall consider in the Section 4 below.

4. *A conceptual containment*, for example, and following Brachman, (ibid.), instead of reading "a cat is a mammal" as a simple generalization, it is to be read as "to be a cat is to be a mammal". This, according to him, is the IS-A of lambda-abstraction, wherein one predicate is used in defining another, (ibid.). Unfortunately, it is not clear what Brachman means by "the IS-A of lambda-abstraction, wherein one predicate is used in defining another". If it means that the predicates occurring in the *definiens* are among the predicates occurring in the *definiendum*, there are three possibilities to interpret it: The first one is by means of the IS-A relation as a ⊆-relation between predicates, *i.e.*, the predicate of "mammal" is among the predicate of "cat". The second one is that the IS-A is a $=_{df}$ -sign between *definiens* and *definiendum*, or, perhaps, that the IS-A is a lambda-abstraction of it, *i.e.*, $\lambda xy(x =_{df} y)$, although, of course, "a cat $=_{df}$ a mammal" is not a complete definition of a cat. The third possibility is that the IS-IN is a relation between *concepts*, *i.e.*, the concept of "mammal" is contained in the concept of "cat", see Section 4 below. – And it is argued in this Chapter that the IS-IN relation is not the IS-A relation.

5. *A role value restriction*, for example, "the car is a bus", where "the car" is a role and "a bus" is a value being itself a certain type. Thus, the IS-A is a copula.

6. *A set and its characteristic type*, for example, the set of all cats and the concept of "a cat". Then we could say that the IS-A is an extension relation between the concept and its extension, where an extension of a concept is a set of all those things falling under

the concept in question. On the other hand, Brachman says also that it associates the characteristic function of a set with that set, (ibid.). That would mean that we have a characteristic function φ_{Cat} defined for elements $x \in X$ by $\varphi_{Cat}(x) = 1$, if $x \in$ Cat, and $\varphi_{Cat}(x) = 0$, if x Cat, where Cat is a set of cats, *i.e.*, Cat = $\{x \mid Cat(x)\}$, where $Cat(x)$ is a predicate of being a cat. Accordingly, Cat $\subseteq X$, $\varphi_{Cat}: X \rightarrow \{0, 1\}$, and, in particular, the IS-A is a relation between the characteristic function φ_{Cat} and the set Cat.

In the above analysis of the different meanings of the IS-A relations between two generics given by Brachman, concerning the relations of the AKO, the conceptual containment, and the relation between "set and its characteristic type", we were not able to interpret them by using only the set theoretical terms. Since set theory is extensional *par excellence*, the reason for that failure lies simply in the fact that in their adequate analysis some intensional elements are present. However, the AKO relation is based on a philosophical, *i.e.*, ontological, view that there are such things as kinds, and thus we shall not take it as a proper candidate for *the* IS-A relation. On the other hand, in both the conceptual containment relation and the relation between "set and its characteristic type" there occur as their terms "concepts", which are basically intensional entities. Accordingly we shall propose that their adequate analysis requires an intensional IS-IN relation, which differs from the most commonly used kinds of IS-A relations, whose analysis can be made set theoretically. Thus, we shall turn to the IS-IN relation.

THE IS-IN RELATION

The idea of the IS-IN relation is close the IS-A relation, but distinction we want to draw between them is, as we shall propose, that the IS-A relation is analyzable by means of set theory whereas the IS-IN relation is an intensional relation between concepts.

To analyze the IS-IN relation we are to concentrate on the word "in", which has a complex variety of meanings. First we may note that "in" is some kind of relational expression. Thus, we can put the matter of relation in formal terms as follows,

A is *in B*.

Now we can consider what the different senses of "in" are, and what kinds of substitutions can we make for *A* and *B* that goes along with those different senses of "in". To do this we are to turn first to Aristotle, who discuss of the term "in" in his *Physics*, (210a, 15ff, 1930). He lists the following senses of "in" in which one thing is said to be "in" another:

1. The sense in which a physical part is *in* a physical whole to which it belongs. For example, as the finger is *in* the hand.
2. The sense in which a whole is *in* the parts that makes it up.
3. The sense in which a species is *in* its genus, as "man" is *in* "animal".
4. The sense in which a genus is *in* any of its species, or more generally, any feature of a species is *in* the definition of the species.
5. The sense in which form is *in* matter. For example, "health is *in* the hot and cold".
6. The sense in which events center *in* their primary motive agent. For example, "the affairs of Creece center *in* the king".
7. The sense in which the existence of a thing centers *in* its final cause, its end.
8. The sense in which a thing is *in* a place.

From this list of eight different senses of "in" it is possible to discern four groups:

i. That which has to do with the *part*-*whole* relation, (1) and (2). Either the relation between a part to the whole or its converse, the relation of a whole to its part.
ii. That which has to do with the *genus*-*species* relation, (3) and (4). Either *A* is the genus and *B* the species, or *A* is the species and *B* is the genus.
iii. That which has to do with a *causal* relation, (5), (6), and (7). There are, according to Aristotle, four kinds of causes: material, formal, efficient, and final. Thus, *A* may be the formal cause (form), and *B* the matter; or *A* may be the efficient cause ("motive agent"), and *B* the effect; or, given *A*, some particular thing or event *B* is its final cause (*telos*).
iv. That which has to do with a *spatial* relation, (8). This Aristotle recognizes as the "strictest sense of all". *A* is said to be *in B*,

> where *A* is one thing and *B* is another thing or a place. “Place”, for Aristotle, is thought of as what is occupied by some body. A thing located in some body is also located in some place. Thus we may designate *A* as the contained and *B* as the container.

What concerns us here is the second group II, *i.e.,* that which has to do with the *genus*-*species* relation, and especially the sense of “in” in which a genus *is in* any of its species. What is most important, according to us, it is this place in Aristotle’s text to which Leibniz refers, when he says that “Aristotle himself seems to have followed the way of ideas [*viam idealem*], for he says that animal is in man, namely a concept in a concept; for otherwise men would be among animals [*insint animalibus*], (Leibniz *after* 1690a, 120). In this sentence Leibniz points out the distinction between conceptual level and the level of individuals, which amounts also the set of individuals. This distinction is crucial, and our proposal for distinguishing the IS-IN relation from the IS-A relation is based on it. What follows, we shall call the IS-IN relation an intensional containment relation between concepts.

CONCEPTUAL STRUCTURES

Although the IS-A relation seems to follow from the English sentences such as “Socrates is a man” and “a cat is a mammal”, the word “is” is logically speaking intolerably ambiguous, and a great care is needed not to confound its various meanings. For example, we have (1) the sense, in which it asserts Being, as in “*A* is”; (2) the sense of identity, as in “Cicero is Tullius”; (3) the sense of equality, as in “the sum of 6 and 8 is 14”; (4) the sense of predication, as in “the sky is blue”; (5) the sense of definition, as in “the *power set* of *A* is the set of all subsets of *A*”; etc. There are also less common uses, as “to be good is to be happy”, where a relation of assertions is meant, and which gives rise to a formal implication. All this shows that the natural language is not precise enough to make clear the different meanings of the word “is”, and hence of the words “is a”, and “is in”. Accordingly, to make differences between the IS-A relation and the IS-IN relation clear, we are to turn our attention to a logic.

Items Connected to a Concept

There are some basic items connected to a concept, and one possible way to locate them is as follows, see Fig. 1, (Palomäki 1994):

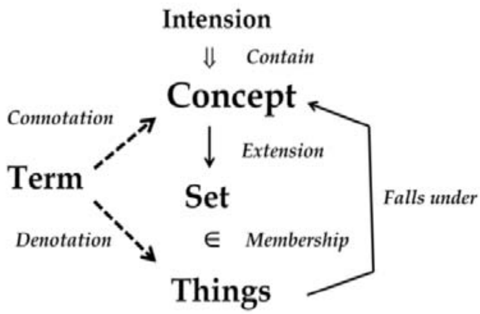

Figure 1. Items connected to a concept.

A *term* is a linguistic entity. It *denotes* things and *connotes* a concept. A concept, in turn, has an *extension* and an *intension*. The extension of a concept is a *set*, (or a *class*, being more exact), of all those things that *falls under* the concept. Now, there may be many different terms which denote the same things but connote different concepts. That is, these different concepts have the same extension but they differ in their intension. By an intension of a concept we mean something which we have to "understand" or "grasp" in order to use the concept in question correctly. Hence, we may say that the intension of concept is that knowledge content of it which is required in order to recognize a thing belonging to the extension of the concept in question, (Kangassalo, 1992/93, 2007).

Let $U = < V, C, F >$ be a universe of discourse, where i) V is a universe of (possible) individuals, ii) C is a universe of concepts, iii) $V \cap C \neq \{\ \}$, and iv) $F \subseteq V \times C$ is the falls under–relation. Now, if a is a concept, then for every (possible) individual i in V, either i falls under the concept a or it doesn't, *i.e*,

$$\text{if } a \in C, \text{ then } \forall i \in V : iFa \vee {\sim}\, iFa. \tag{1}$$

The extension-relation E between the set A and the concept a in V is defined as follows:

$$E_U(A,a) =_{\text{df}} (\forall i)\ (i \in A \leftrightarrow i \in V \wedge iFa). \tag{2}$$

The extension of concept a may also be described as follows:

$$i \in E_U'(a) \leftrightarrow iFa, \tag{3}$$

where $E_U'(a)$ is the extension of concept a in V, *i.e.*, $E_U'(a) = \{\, i \in V \mid iFa \,\}$.

An Intensional Containment Relation

Now, the relations between concepts enable us to make conceptual structures. The basic relation between concepts is an intensional containment relation, (see Kauppi 1967, Kangassalo 1992/93, Palomäki 1994), and it is this intensional containment relation between concepts, which we are calling the IS-IN relation.

More formally, let there be given two concepts *a* and *b*. When a concept *a* contains intensionally a concept *b*, we may say that the intension of a concept *a* contains the intension of a concept *b*, or that the concept *a* intensionally entails the concept *b*, or that the intension of the concept *a* entails the intension of the concept *b*. This intensional containment relation is denoted as follows,

$$a \geq b. \tag{4}$$

Then, it was observed by Kauppi in (1967) that

$$a \geq b \rightarrow (\forall i)\ (iFa \rightarrow iFb), \tag{5}$$

that is, that the transition from intensions to extensions reverses the containment relation, *i.e.*, the intensional containment relation between concepts *a* and *b* is converse to the extensional set-theoretical subset-relation between their extensions. Thus, by (3),

$$a \geq b \rightarrow E_U{}'(a) \subseteq E_U{}'(b), \tag{6}$$

where "⊆" is the set-theoretical subset-relation, or the extensional inclusion relation between sets. Or, if we put $A = E_U{}'(a)$ and $B = E_U{}'(b)$, we will get,

$$a \geq b \rightarrow A \subseteq B\ 1 \tag{7}$$

For example, if the concept of a dog contains intensionally the concept of a quadruped, then the extension of the concept of the quadruped, *i.e.*, the set of four-footed animals, contains extensionally as a subset the extension of the concept of the dog, *i.e.*, the set of dogs. Observe, though, that we can deduce from concepts to their extensions, *i.e.*, sets, but not conversely, because for every set there may be many different concepts, whose extension that set is.

The above formula (6) is what was searched, without success, by Woods in (1991), where the intensional containment relation is called by him a structural, or an intensional subsumption relation.

An Intensional Concept Theory

Based on the intensional containment relation between concepts the late Professor Raili Kauppi has presented her axiomatic intensional concept theory in Kauppi (1967), which is further studied in (Palomäki 1994). This axiomatic concept theory was inspired by Leibniz's logic, where the intensional containment relation between concepts formalises an "*inesse*"-relation[2] in Leibniz's logic.[3]

An intensional concept theory, denoted by *KC*, is presented in a first-order language *L* that contains individual variables *a*, *b*, *c*,..., which range over the *concepts*, and one non-logical 2-place *intensional containment relation*, denoted by "≥". We shall first present four basic relations between concepts defined by "≥", and then, briefly, the basic axioms of the theory. A more complete presentation of the theory, see Kauppi (1967), and Palomäki (1994).

Two concepts *a* and *b* are said to be *comparable*, denoted by *a* H *b*, if there exists a concept *x* which is intensionally contained in both.

$\mathrm{Df}_{\mathrm{H}} \qquad a\mathrm{H}b =_{\mathrm{df}} (\exists x)\ (a \geq x \wedge b \geq x).$

If two concepts *a* and *b* are not comparable, they are *incomparable*, which is denoted by *a* I *b*.

$\mathrm{Df}_{\mathrm{I}} \qquad a\mathrm{I}b =_{\mathrm{df}} \sim a\mathrm{H}b.$

Dually, two concepts *a* and *b* are said to be *compatible*, denoted by *a* ⊥ *b*, if there exists a concept *x* which contains intensionally both.

$\mathrm{Df}_{\perp} \qquad a \perp b =_{\mathrm{df}} (\exists x)\ (x \geq a \wedge x \geq b)$

If two concepts *a* and *b* are not compatible, they are *incompatible*, which is denoted by *a* Y *b*.

$\mathrm{Df}_{\mathrm{Y}} \qquad a\mathrm{Y}b =_{\mathrm{df}} \sim a \perp b.$

The two first axioms of *KC* state that the intensional containment relation is a *reflexive* and *transitive* relation.

$\mathrm{Ax}_{\mathrm{Refl}} \qquad a \geq a.$

$\mathrm{Ax}_{\mathrm{Trans}} \qquad a \geq b \wedge b \geq c \rightarrow a \geq c.$

Two concepts a and b are said to be *intensionally identical*, denoted by $a \approx b$, if the concept a intensionally contains the concept b, and the concept b intensionally contains the concept a.

$$\mathrm{Df}_{\approx} \quad a \approx b =_{\mathrm{df}} a \geq b \wedge b \geq a.$$

The intensional identity is clearly a reflexive, symmetric and transitive relation, hence an equivalence relation.

A concept c is called an *intensional product* of two concepts a and b, if any concept x is intensionally contained in c if and only if it is intensionally contained in both a and b. If two concepts a and b have an intensional product, it is unique up to the intensional identity and we denote it then by $a \otimes b$.

$$\mathrm{Df}_{\otimes} \quad c \approx a \otimes b =_{\mathrm{df}} (\forall x)\ (c \geq x \leftrightarrow a \geq x \wedge b \geq x).$$

The following axiom $\mathrm{Ax}_{\otimes}$ of *KC* states that if two concepts a and b are comparable, there exists a concept x which is their intensional product.

$$\mathrm{Ax}_{\otimes} \quad a\mathrm{H}b \rightarrow (\exists x)\ (x \approx a \otimes b).$$

It is easy to show that the intensional product is idempotent, commutative, and associative.

A concept c is called an *intensional sum* of two concepts a and b, if the concept c is intensionally contained in any concept x if and only if it contains intensionally both a and b. If two concepts a and b have an intensional sum, it is unique up to the intensional identity and we denote it then by $a \otimes b$.

$$\mathrm{Df}_{\oplus} \quad c \approx a \oplus b =_{\mathrm{df}} (\forall x)\ (x \geq c \leftrightarrow x \geq a \wedge x \geq b)\ ^{4}.$$

The following axiom $\mathrm{Ax}_{\otimes}$ of *KC* states that if two concepts a and b are compatible, there exists a concept x which is their intensional sum.

$$\mathrm{Ax}_{\oplus} \quad a \perp b \rightarrow (\exists x)\ (x \approx a \oplus b)$$

The intensional sum is idempotent, commutative, and associative.
The intensional product of two concepts a and b is intensionally contained in their intensional sum whenever both sides are defined.

$$\mathrm{Th\ 1} \quad a \oplus b \geq a \otimes b.$$

Proof: If $a \otimes b$ exists, then by $\mathrm{Df}_{\otimes}$, $a \geq a \otimes b$ and $b \geq a \otimes b$. Similarly, if $a \oplus b$ exists, then by $\mathrm{Df}_{\oplus}$, $a \oplus b \geq a$ and $a \oplus b \geq b$. Hence, by $\mathrm{Ax}_{\mathrm{Trans}}$, the theorem follows.
A concept b is an *intensional negation* of a concept a, denoted by $\neg a$, if and only if it is intensionally contained in all those concepts x, which are inten-

sionally incompatible with the concept a. When $\neg a$ exists, it is unique up to the intensional identity.

$$\mathrm{Df}_{\neg} \quad b \approx \neg a =_{df} (\forall x)\,(x \geq b \leftrightarrow x \mathrm{Y} a).$$

The following axiom $\mathrm{Ax}_{\neg}$ of *KC* states that if there is a concept x which is incompatible with the concept a, there exists a concept y, which is the intensional negation of the concept a.

$$\mathrm{Ax}_{\neg} \quad (\exists x)\,(x\mathrm{Y}a) \rightarrow (\exists y)\,(y \approx \neg a).$$

It can be proved that a concept a contains intensionally its intensional double negation provided that it exists.

$$\text{Th 2} \quad a \geq \neg\neg a.$$ [5]

Proof: By $\mathrm{Df}_{\neg}$ the equivalence (1): $b \geq \neg a \leftrightarrow b \mathrm{~Y~} a$ holds. By substituting $\neg a$ for b to (1), we get $\neg a \geq \neg a \leftrightarrow \neg a \mathrm{~Y~} a$, and so, by Ax_{Refl}, we get (2): $\neg a \mathrm{~Y~} a$. Then, by substituting a for b and $\neg a$ for a to (1), we get $a \geq \neg\neg a \leftrightarrow a \mathrm{~Y~} \neg a$ and hence, by (2), the theorem follows.

Also, the following forms of the *De Morgan's formulas* can be proved whenever both sides are defined:

$$\text{Th 3} \quad \text{i)}\ \neg a \otimes \neg b \geq \neg(a \oplus b),$$
$$\text{ii)}\ \neg(a \otimes b) \approx \neg a \oplus \neg b.$$

Proof: First we are to proof the following important lemma:

Lemma 1

$$a \geq b \rightarrow \neg b \geq \neg a.$$

Proof: From $a \geq b$ follows $(\forall x)\,(x \mathrm{~Y~} b \rightarrow x \mathrm{~Y~} a)$, and thus by $\mathrm{Df}_{\neg}$ the Lemma 1 follows.

i. If $a \oplus b$ exists, then by $\mathrm{Df}_{\oplus}$, $a \oplus b \geq a$ and $a \oplus b \geq b$. By Lemma 1 we get $\neg a \geq \neg(a \oplus b)$ and $\neg b \geq \neg(a \oplus b)$. Then, by $\mathrm{Df}_{\otimes}$, Th 3 i) follows.

ii. This is proved in the four steps as follows:

1. $\neg(a \otimes b) \geq \neg a \oplus \neg b$. Since $a \geq a \otimes b$, it follows by Lemma 1 that $\neg(a \otimes b) \geq \neg a$. Thus, by $\mathrm{Df}\oplus$, 1 holds.
2. $\neg(\neg\neg a \otimes \neg\neg b) \geq \neg(a \otimes b)$. Since $a \geq \neg\neg a$, by Th 2, it follows by $\mathrm{Df}_{\otimes}$ that $a \otimes b \geq \neg\neg a \otimes \neg\neg b$. Thus, by Lemma 1, 2 holds.

3. $(\neg\neg a \otimes \neg\neg b) \geq \neg(\neg a \oplus \neg b)$. Since $(a \oplus b) \geq a$, it follows by Lemma 1 that $\neg a \geq \neg(a \oplus b)$, and so, by $Df_{\otimes}$, it follows $(\neg a \otimes \neg b) \geq \neg(a \oplus b)$. Thus, by substituting $\neg a$ for a and $\neg b$ for b to it, 3 holds.
4. $\neg a \oplus \neg b \geq \neg(a \otimes b)$. Since $\neg a \oplus \neg b \geq \neg\neg(\neg a \oplus \neg b)$, by Th 2, and from 3 it follows by Lemma 1 that $\neg\neg(\neg a \oplus \neg b) \geq \neg(\neg\neg a \otimes \neg\neg b)$, and by Ax_{Trans} we get, $\neg a \oplus \neg b \geq \neg(\neg\neg a \otimes \neg\neg b)$. Thus, by 2 and by Ax_{Trans}, 4 holds.

From 1 and 4, by $Df_{\approx,}$ the Th 3 ii) follows.

If a concept a is intensionally contained in every concept x, the concept a is called a *general concept,* and it is denoted by G. The general concept is unique up to the intensional identity, and it is defined as follows:

Df_G $\quad a \approx G =_{df} (\forall x)\,(x \geq a).$

The next axiom of *KC* states that there is a concept, which is intensionally contained in every concept.

Ax_G $\quad (\exists x)(\forall y)\,(y \geq x)$.

Adopting the axiom of the general concept it follows that all concepts are to be comparable. Since the general concept is compatible with every concept, it has no intensional negation.

A *special concept* is a concept a, which is not intensionally contained in any other concept except for concepts intensionally identical to itself. Thus, there can be many special concepts.

Df_S $\quad S(a) =_{df} (\forall x)\,(x \geq a \rightarrow a \geq x)$.

The last axiom of *KC* states that there is for any concept y a special concept x in which it is intensionally contained.

Ax_S $\quad (\forall y)(\exists x)\,(S(x) \wedge x \geq y)$.

Since the special concept s is either compatible or incompatible with every concept, the *law of excluded middle* holds for s so that for any concept x, which has an intensional negation, either the concept x or its intensional negation x is intensionally contained in it. Hence, we have

Th 4 $\quad (\forall x)S(s) \rightarrow (s \geq x \vee s \geq -x)$..

A special concept, which corresponds Leibniz's complete concept of an individual, would contain one member of every pair of mutually incompatible concepts.

By *Completeness Theorem*, every consistent first-order theory has a model. Accordingly, in Palomäki (1994, 94-97) a model of KC + $Ax_{\neg\neg}$ is found to be a *complete semilattice*, where every concept $a \in C$ defines a *Boolean algebra* $B_a = <\downarrow a \otimes, \oplus, \neg>, G, a$, where $\downarrow a$ is an ideal, known as the *principal ideal generated by a, i.e.* $\downarrow a =_{df} \{x \in C \mid a \geq x\}$, and the intensional negation of a concept $b \in \downarrow a$ is interpreted as a *relative complement* of a.

It should be emphasized that in *KC* concepts in generally don't form a lattice structure as, for example, they do in Formal Concept Analysis, (Ganter & Wille, 1998). Only in a very special case in *KC* concepts will form a lattice structure; that is, when all the concepts are both comparable and compatible, in which case there will be no incompatible concepts and, hence, no intensional negation of a concept either.[6]

THAT IS-IN ISN'T IS-A

In current literature, the relations between concepts are mostly based on the set theoretical relations between the extensions of concepts. For example, in Nebel & Smolka (1990), the conceptual intersection of the concepts of "man" and "woman" is the empty-concept, and their conceptual union is the concept of "adult". However, intensionally the common concept which contains both the concepts of "man" and of "woman", and so is their intensional conceptual intersection, is the concept of 'adult', not the empty-concept, and the concept in which they both are contained, and so is their intensional conceptual union, is the concept of "androgyne", not the concept of "adult". Moreover, if the extension of the empty-concept is an empty set, then it would follow that the concepts of "androgyne", "centaur", and "round-square" are all equivalent with the empty-concept, which is absurd. Thus, although Nebel and Smolka are talking about concepts, they are dealing with them only in terms of extensional set theory, not intensional concept theory.

There are several reasons to separate intensional concept theory from extensional set theory, (Palomäki 1994). For instance: i) intensions determine extensions, but not conversely, ii) whether a thing belongs to a set is decided primarily by intension, iii) a concept can be used meaningfully even when there is not yet, nor ever will be, any individuals belonging to the extension of the concept in question, iv) there can be many non-identical but co-extensional concepts, v) extension of a concept may vary according to context, and vi) from Gödel's two Incompleteness Theorems it follows that intensions cannot be wholly eliminated from set theory.

One difference between extensionality and intensionality is that in extensionality a collection is determined by its elements, whereas in intensionality a collection is determined by a concept, a property, an attribute, etc. That means, for example, when we are creating a semantical network or a conceptual model by using an extensional IS-A relation as its taxonomical link, the existence of objects to be modeled are presupposed, whereas by using an intensional IS-IN relation between the concepts the existence of objects falling under those concepts are not presupposed. This difference is crucial when we are designing an object, which does not yet exist, but we have plenty of conceptual information about it, and we are building a conceptual model of it. In the set theoretical IS-A approach to a taxonomy the Universe of Discourse consists of individuals, whereas in the intensional concept theoretical IS-IN approach to a taxonomy the Universe of Discourse consists of concepts. Thus, in extensional approach we are moving from objects towards concepts, whereas in intensional approach we moving from concepts towards objects.

However, it seems that from strictly extensional approach we are not able to reach concepts without intensionality. The principle of extensionality in the set theory is given by a first-order formula as follows,

$$\forall A \forall B (\forall x (x \in A \leftrightarrow x \in B) \rightarrow A = B) .$$

That is, if two *sets* have exactly the same members, then they are equal. Now, what is a set? - There are two ways to form a set: i) extensionally by listing all the elements of a set, for example, $A = \{a, b, c\}$, or ii) intensionally by giving the defining property $P(x)$, in which the elements of a set is to satisfy in order to belong to the set, for example, $B = \{x|\ blue(x)\}$, where the set B is the set of all blue things. Moreover, if we then write "$x \in B$", we use the symbol ∈ to denote the membership. It abbreviates the Greek word έ ί, which means "is", and it asserts that *x is* blue. Now, the intensionality is implicitly present when we are selecting the members of a set by some definite property $P(x)$, *i.e.*, we have to understand the property of being *blue*, for instance, in order to select the possible members of the set of all blue things (from the given Universe of Discourse).

An extensional view of concepts indeed is untenable. The fundamental property that makes extensions extensional is that concepts have the same extensions in case they have the same instances. Accordingly, if we use $\{x\ a(x)\}$ and $\{x\ b(x)\}$ to denote the extensions of the concepts *a* and *b*, respectively, we can express extensionality by means of the second-order principle,

$$\forall a \forall b(\forall x(a \cong b) \leftrightarrow (x \mid a(x)\} = \{x \mid b(x)\}) . \qquad (*)$$

However, by accepting that principle some very implausible consequences will follow. For example, according to physiologists any creature with a heart also has a kidney, and *vice versa*. So the concepts of "heart" and "kidney" are co-extensional concepts, and then, by the principle (∗), the concepts of "heart" and "kidney" are 'identical' or interchangeable concepts. On the other hand, to distinguish between the concepts of "heart" and "kidney" is very relevant for instance in the case when someone has a heart-attack, and the surgeon, who is a passionate extensionalist, prefers to operate his kidney instead of the heart.

INTENSIONALITY IN POSSIBLE WORLDS SEMANTIC APPROACH

Intensional notions (e.g. concepts) are not strictly formal notions, and it would be misleading to take these as subjects of study for logic only, since logic is concerned with the forms of propositions as distinct from their contents. Perhaps only part of the theory of intensionality which can be called formal is pure modal logic and its possible worlds semantic. However, in concept theories based on possible worlds semantic, (see e.g. Hintikka 1969, Montague 1974, Palomäki 1997, Duzi et al. 2010), intensional notions are defined as (possibly partial, but indeed set-theoretical) functions from the possible worlds to extensions in those worlds.

Also Nicola Guarino, in his key article on "ontology" in (1998), where he emphasized the intensional aspect of modelling, started to formalize his account of "ontology"[8] by the possible world semantics in spite of being aware that the possible world approach has some disadvantages, for instance, the two concepts "trilateral" and "triangle" turn out to be the same, as they have the same extension in all possible worlds.In all these possible worlds approaches intensional notions are once more either reduced to extensional set-theoretic constructs in diversity of worlds or as being non-logical notions left unexplained. So, when developing an adequate presentation of a concept theory it has to take into account both formal (logic) and contentual (epistemic) aspects of concepts and their relationships.

Nominalism, Conceptualism, And Conceptual Realism (Platonism)

In philosophy ontology is a part of metaphysics,[9] which aims to answer at least the following three questions:

1. What is there?
2. What is it, that there is?
3. How is that, that there is?

The first is (1) is perhaps the most difficult one, as it asks what elements the world is made up of, or rather, what are the building blocks from which the world is composed. A Traditional answer to this question is that the world consists of things and properties (and relations). An alternative answer can be found in Wittgenstein's Tractatus 1.1: "The world is the totality of facts, not of things", that is to say, the world consists of facts.

The second question (2) concerns the basic stuff from which the world is made. The world could be made out of one kind of stuff only, for example, water, as Thales suggests, or the world may be made out of two or more different kinds of stuff, for example, mind and matter.

The third question (3) concerns the mode of existence. Answers to this question could be the following ones, according to which something exists in the sense that:

a. it has some kind of concrete space-time existence,
b. it has some kind of abstract (mental) existence,
c. it has some kind of transcendental existence, in the sense that it extends beyond the space-time existence.

The most crucial ontological question concerning concepts and intensionality is: "What modes of existence may concepts have?" The traditional answers to it are that

i. concepts are merely predicate expressions of some language, i.e. they exist concretely, (nominalism);
ii. concepts exist in the sense that we have the socio-biological cognitive capacity to identify, classify, and characterize or perceive relationships between things in various ways, i.e. they exist abstractly, (conceptualism);
iii. concepts exist independently of both language and human cognition, i.e. transcendentally, (conceptual realism, Platonism).

If the concepts exist only concretely as linguistic terms, then there are only extensional relationships between them. If the concepts exist abstractly as a cognitive capacity, then conceptualization is a private activity done by human mind. If the concepts exist transcendentally independently of both language and human cognition, then we have a problem of knowledge acquisition of them. Thus, the ontological question of the mode of existence of concepts is a deep philosophical issue. However, if we take an ontological commitment to a certain view of the mode of the existence of concepts, consequently we are making other ontological commitments as well. For example, realism on concepts is usually connected with realism of the world as well. In conceptualism we are more or less creating our world by conceptualization, and in nominalism there are neither intensionality nor abstract (or transcendental) entities like numbers.

CONCLUSION

In the above analysis of the different senses of IS-A relation in the Section 2 we took our starting point Brachman's analysis of it in (Brachman 1983), and to which we gave a further analysis in order to show that most of those analysis IS-A relation is interpreted as an extensional relation, which we are able to give set theoretical interpretation. However, for some of Brachman's instances we were not able to give an appropriate set theoretical interpretation, and those were the instances concerning concepts. Accordingly, in the Section 3 we turned our analysis of IS-IN relation following Aristotelian-Leibnizian approach to it, and to which we were giving an intensional interpretation; that is, IS-IN relation is an intensional relation between concepts. A formal presentation of the basic relations between terms, concepts, classes (or sets), and things was given in the Section 4 as well as the basic axioms of the intensional concept theory *KC*. In the last Section 5 some of the basic differences between the IS-IN relation and the IS-A relation was drawn.

So, in this Chapter we maintain that an IS-IN relation is not equal to an IS-A relation; more specifically, that Brachman's analysis of an *extensional* IS-A relation in his basic article: "What IS-A Is and Isn't: An Analysis of Taxonomic Links in Semantic Networks", (1983), did not include an *intensional* IS-IN relation. However, we are not maintain that Brachman's analysis of IS-A relation is wrong, or that there are some flaw in it, but that the IS-IN relation is different than the IS-A relation. Accordingly, we are proposing that the IS-IN relation is a conceptual relation between concepts and it is basically intensional relation, whereas the IS-A relation is to be reserved for extensional use only. Provided that there are differences between intensional and extensional view when constructing hierarchical semantic networks, we are not allowed to identify concepts with their extensions. Moreover, in that case we are to distinguish the intensional IS-IN relation between concepts from the extensional IS-A relation between the extensions of concepts. However, only a thoroughgoing nominalist would identify concepts with their extensions, whereas for all the others this distinction is necessarily present.

Notes

[1]In the set theory a subset-relation between sets A and B is defined by ∈-relation between the elements of them as follows , $A \subseteq B =_{df} \forall x\ (x \in A \rightarrow x \in B)$. Unfortunately both ⊆-relation and ∈-relation are called IS-A relations, although they are different relations. On the other hand, we can take the intensional containment relation between concepts a and b, i.e., $a \geq b$, to be the IS-IN relation.

[2]Literally, "inesse" is "being-in", and this term was used by Scholastic translator of Aristotle to render the Greek "huparchei", i.e., "belongs to", (Leibniz 1997, 18, 243).

[3]Cf. "Definition 3. That A 'is in' L, or, that L 'contains' A, is the same that L is assumed to be coincident with several terms taken together, among which is A", (Leibniz after 1690, 132). Also, e.g. in a letter to Arnauld 14 July 1786 Leibniz wrote, (Leibniz 1997, 62): "[I]n every affirmative true proposition, necessary or contingent, universal or singular, the notion of the predicate is contained in some way in that of the subject, praedicatum inest subjecto [the predicate is included in the subject]. Or else I do not know what truth is." This view may be called the conceptual containment theory of truth, (Adams 1994, 57), which is closely associated with Leibniz's preference for an "intensional" as opposed to an "extensional" interpretation of categorical propositions. Leibniz worked out a variety of both intensional and extensional treatments of the logic of predicates, i.e., concepts, but preferring the intensional approach, (Kauppi 1960, 220, 251, 252).

[4]Thus, $a \otimes b \leftrightarrow [a] \otimes [b]$ is a greatest lower bound in $C/\approx$, whereas $a \oplus b \leftrightarrow [a] \oplus [b]$ is a least upper bound in $C/\approx$.

[5]This relation does not hold conversely without stating a further axiom for intensional double negation, i.e., $\mathrm{Ax}_{\neg\neg}$: b Y $\neg a \rightarrow b \geq a$. Thus, $\neg\neg a \geq a$, and hence by Th 2, $a \approx \neg\neg a$, holds only, if the concept a is intensionally

contained in the every concept *b*, which is incompatible with the intensional negation of the concept *a*.

[6]How this intensional concept theory KC is used in the context of conceptual modelling, i.e., when developing a conceptual schemata, see especially (Kangassalo 1992/93, 2007).

[7]In pure mathematics there are only sets, and a "definite" property, which appears for example in the axiom schemata of separation and replacement in the Zermelo-Fraenkel set theory, is one that could be formulated as a first order theory whose atomic formulas were limited to set membership and identity. However, the set theory is of no practical use in itself, but is used to other things as well. We assume a theory T, and we shall call the objects in the domain of interpretation of T individuals, (or atoms, or Urelements). To include the individuals, we introduce a predicate $U(x)$ to mean that x is an individual, and then we relativize all the axioms of T to U. That is, we replace every universal quantifier "$\forall x$" in an axiom of T with "$\forall x$ $(U(x) \rightarrow$ ...) and every existential quantifier "$\exists x$" with "$\exists x$ $(U(x) \wedge$ ...), and for every constant "a" in the language of T we add $U(a)$ as new axiom.

[8]From Guarino's (1998) formalization of his view of "ontology", we will learn that the "ontology" for him is a set of axioms (language) such that its intended models approximate as well as possible the conceptualization of the world. He also emphasize that "it is important to stress that an ontology is language-dependent, while a conceptualization is language-independent." Here the word "conceptualization" means "a set of conceptual relations defined on a domain space", whereas by "the ontological commitments" he means the relation between the language and the conceptualization. This kind of language dependent view of "ontology" as well as other non-traditional use of the word "ontology" is analyzed and critized in Palomäki (2009).

[9]Nowadays there are two sense of the word "ontology": the traditional one, which we may call a philosophical view, and the more modern one used in the area of information systems, which we may call a knowledge representational view, (see Palomäki 2009).

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CHAPTER 3

A General Knowledge Representation Model of Concepts

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INTRODUCTION

Knowledge is not a simple concept to define, and although many definitions have been given of it, only a few describe the concept with enough detail to grasp it in practical terms; knowledge is sometimes seen as a *thing* out in the real word waiting to be uncovered and taken in by the receptive mind; however, knowledge is not a *thing* to be encountered and taken in, no knowledge can be found in any mind without first have been processed by cognition. Knowledge is not something just to be uncovered or transmitted and stored, it has to be constructed. The construction of knowledge involves the use of previous knowledge and different cognitive processes, which play an intertwined function to facilitate the development of association

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between the new concepts to be acquired and previously acquired concepts. Knowledge is about information that can be used or applied, that is, it is information that has been contextualized in a certain domain, and therefore, any piece of knowledge is related with more knowledge in a particular and different way in each individual.

In this chapter, a model for the representation of conceptual knowledge is presented. Knowledge can have many facets, but it is basically constituted by static components, called concepts or facts, and dynamic components, called skills, abilities, procedures, actions, etc., which together allow general cognition, including all different processes typically associated to it, such as perceiving, distinguishing, abstracting, modelling, storing, recalling, remembering, etc., which are part of three primary cognitive processes: learning, understanding and reasoning (Ramirez and Cooley, 1997). No one of those processes can live isolated or can be carried out alone, actually it can be said that those processes are part of the dynamic knowledge, and dynamic knowledge typically requires of conceptual or factual knowledge to be used.

In the first section of this chapter, a review of the basic concepts behind knowledge representation and the main types of knowledge representation models is presented; in the second section, a deep explanation of the components of knowledge and the way in which they are acquired is provided; in the third section, a computer model for knowledge representation called Memory Map (MM) that integrates concepts and skills is explained, and in section four, a practical application for the MM in a learning environment is presented.

WHAT IS KNOWLEDGE?

There is not a unified definition for the concept of knowledge, diverse definitions from different backgrounds and perspectives have been proposed since the old times; some definitions complement each other and some prove more useful in practical terms. In philosophy we find the very first definitions of knowledge, one of the most accepted ones was provided by Sir Thomas Hobbes in 1651: knowledge is the evidence of truth, which must have four properties: first knowledge must be integrated by concepts; second, each concept can be identified by a name; third, names can be used to create propositions, and fourth, such propositions must be concluding (Hobbes, 1969). Hobbes is also credited with writing the most intuitively and broadly used definition of concept in his book “Leviathan”, Hobbes’s definition has its origins in the traditional Aristotelian view of ideas; this is known as the Representational Theory of the Mind (RTM), till this day RTM continues to be used by most works in Cognitive Science. It must be taken into account that Hobbes's works were of a political, philosophical and religious nature, for this reason there is not one simple hard interpretation of RTM, in this work we will refer to the most common one which is the following: RTM states that knowledge is defined as the evidence of truth composed by conceptualizations product of the imaginative power of the mind, i.e., cognitive capabilities; ideas here are pictured as objects with mental properties, which is the way most people picture concepts and ideas as abstract objects. RTM is complemented at a higher cognitive level by the Language of Thought Hypothesis (LOTH) from Jerry Fodors proposed in the 70's (Fodors, 1975). LOTH states that thoughts are represented in a language supported by the principles of symbolic logic and computability, this language is different form the one we to use to speak, it is a separate in which we can *write* our thoughts and we can validate them using symbolic logic. This definition is much more useful for computer science including Artificial Intelligence and Cognitive Informatics, since it implies that reasoning can be formalized into symbols; hence thought can be described and mechanized, and therefore, theoretically a machine should be able to, at least, emulate thought. The idea that thought in itself has a particular language is not unique, in fact there are previous works such as Vygotsky's Language and Thought (1986) that propose a similar approach. The difference between Vygotsky's and Fodor's approach is that LOTH's is based on a logic system and logic systems can, to an extent, be used for computation, whereas Vygotsky's work is based more on his observations of experiments with children and how this affects their learning processes and general development. The first approach can be directly linked to knowledge in the hard branch of A.I., for example project CYC which will be discussed in future sections of this chapter, while the second one can be put to better use in the development of practical tools in soft A.I., such as in Intelligent Tutoring Systems and more application oriented agents.

Not as old as Philosophy but still directly relevant to knowledge is Psychology, particularly the branches of Psychology that study the learning process. In Psychology through more empirical methods, a vast number of theories to understand and interpret human behavior in relation to knowledge have been developed, among the most relevant theories for knowledge representation systems are associative theories also referred to as connectionist theories, cognitive theories and constructivist theories. There is also a group of theories that study behavior by itself know as behaviorist theories, these theories did have a strong impact on Psychology in general and how humans were perceived to learn. In their classic posture behaviorists do not contemplate an internal cognitive process, only external behavior, i.e., behavioral responses to different stimulus, for this reason behaviorist theories cannot explain thought (Chomsky, 1967) or knowledge in the desired depth, and will not be studied here. Connectionist theories state that knowledge can be described as a number of interconnected concepts, each concept is connected through associations, these are the roots of semantics as means for knowledge representation (Vygotsky, 1986), i.e., what we know today as semantic knowledge representation. Semantic knowledge representation has been proven to be the main driver along with similarity behind reasoning for unstructured knowledge (Crisp-Bright, 2010), traditional connectionist approaches do not account for causality; they just focus on the presence or absence of associations and their quantity. This proves that connectionist theories are not wrong, but they still can't explain higher cognitive processes and therefore higher types of knowledge. Constructivist theories on the other hand do contemplate more complex reasoning drivers such as causality, probability and context. Most constructivist theories therefore complement connectionist approaches by stating that each group of associations integrate different layers of thought where the difference between in each level is the strength of the associations. As a result, the highest layer is the concept, i.e., an organized and stable structure of knowledge and the lowest layer are loosely coupled heaps of ideas (Vygotsky, 1986). This layered structure for knowledge and the way it is built is the reason why constructivism is so relevant to semantic knowledge, because it presents mechanisms complex enough to represent how semantic knowledge is built to our current understanding.

Cognitive Science has focused on modelling and validating previous theories from almost every other science ranging from Biology and Neuroscience to Psychology and Artificial Intelligence (Eysenck, 2010); because of this, Cognitive Science is positioned as the ideal common ground where knowledge definitions from all of the above disciplines can meet computer oriented sciences, this has in fact been argued by Laird in his proposition of mental models (Laird, 1980) though this theory in reasoning rather than in knowledge. Cognitive Science is therefore a fertile field for new theories or for the formalization of previous ones through computer models (Marr, 1982). It is common for knowledge in this field to be described through equations, mathematical relations and computer models, for this reason approaches like connectionism in Psychology have been retaken through the modelling of neural networks and similar works (Shastri, 1988). In this more oriented computer approach knowledge is treated as the structure in terms of association's strength, we will discuss the approach with more detail in the following section. Other famous approaches in this field include Knowledge Space Theory (Doignon & Falmagne, 1999) which defines knowledge as a group of questions which are combined with possible answers to form knowledge states. The possible permutations of operations through set theory of these states are used to create a congruent framework for knowledge, based on the assumption that knowledge can be described as questions and correct answers in its most basic form. Ackoff's (1989) distinction between data information and knowledge is helpful in providing a practical definition for knowledge in real life. Data are symbols without significance, such as numbers, information is data that also includes basic relations between such symbols in a way that provide meaning, and knowledge is context enriched information that can be used or applied, and serves a purpose or goal. Brown (1989) in her studies of knowledge transfer, states that knowledge in its learning continuum, is composed of theories, causal explanation, meaningful solutions and arbitrary solutions, where theories are networks of concepts, causal explanations are facts, meaningful solutions are isolated pieces of knowledge and arbitrary solutions are random decisions.

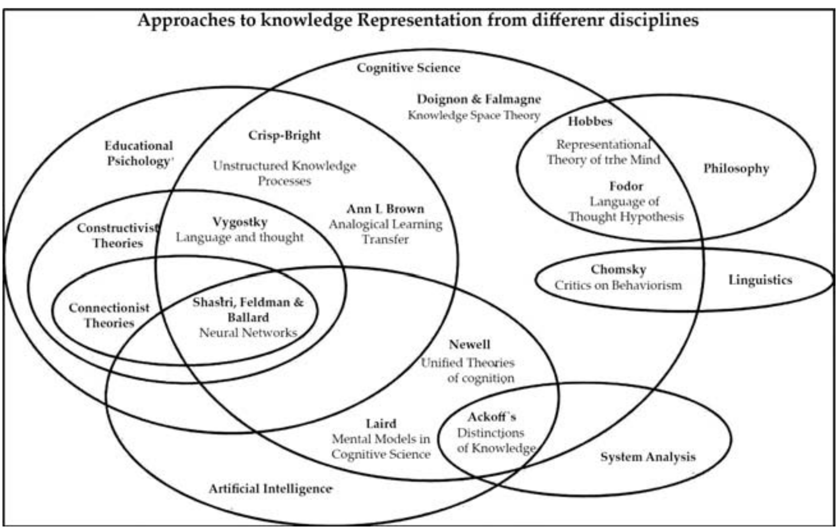

Figure 1. Approaches to Knowledge Representation from different disciplines.

As it shown in figure 1 there are several approaches to describe and define knowledge, though most of them come different fields we can compare them through Cognitive Science which has served as a common ground for similar issues in the past. What is of interest here is not to get the most complete specific definition, but a generic definition that can be worked with and used in a computer model. For this reason this work focuses on the common elements in every presented theory, these elements represent a common ground for knowledge representation and any system or model for knowledge representation should consider them:

i. Knowledge is composed of basic units, which we shall refer to as *concepts*. Some authors use attributes as basic units and others use network structures, however all of them agree on the existence of concepts. The approaches for representing those basic structures will be discussed in section 2.3.

ii. Concepts have *associations* or relations to other concepts. On this point there is general consensus, the debate on associations is about the representational aspects regarding to the following issues: a) What information should an association contain and b) What elements should be used to describe such information i.e., type, directionality, name, intension, extension, among others. These characteristics will be addressed in section 2.3 and 4.

iii. Associations and concepts build dynamic structures which tend to become stable through time. These structures are the factual or conceptual knowledge. The representation of such structures of knowledge is what varies most, in section 2.1 we will explore several different approaches used to model these structures.

From the consensus it can be assumed that these three key points are the core components of knowledge, other characteristics can be included to create more complete definitions, but these will be context dependent. With a basic notion of what knowledge *is*, more interesting questions can be posed in the following sections.

What Types of Knowledge Do Exist?

There are several ways to classify knowledge; the most common distinction is closely related to human memory: the memories related to facts and the memories related to processes, i.e., factual and procedural. Factual or declarative knowledge explains what things are e.g., *the dogs eats meat* or *a dog has a tail.* Procedural knowledge explains how things work for example what the dog needs to do in order to eat, e.g. *if dog hungry -> find food, then chew food, then swallow, then find more food if still hungry*.

We use both types of knowledge in our everyday life; in fact it is hard to completely separate them; however, many computer models can only represent abstract ideal situations with simplified contexts in which each type of knowledge can be clearly identified, but trading off completeness for simplification. The three characteristics of knowledge, discussed in section 2, hold true for both types of knowledge, although they are easier to observe in declarative knowledge because on procedural knowledge concepts are integrated into processes, usually referred to as skills and competences, and the relations between them are imbued in rule sets. An example of declarative knowledge representation and procedural knowledge representation can be seen in figure 2.

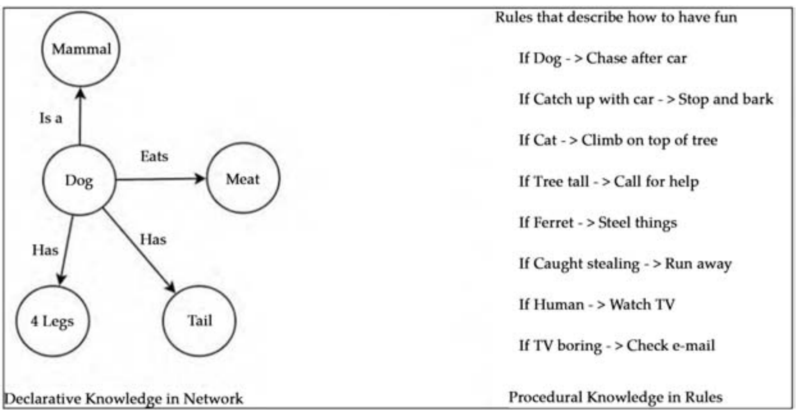

Figure 2. Example of declarative and procedural knowledge.

Another important distinction is between structured and unstructured knowledge, since this has a strong implication on our reasoning processes. Structured knowledge relies strongly on organization and analysis of information using higher cognitive processes, unstructured knowledge relies in lower cognitive processes such as associative knowledge and similarity (Crisp-Bright, 2010; Redher, 2009; Sloman, 1996). In order for unstructured knowledge to become structured there needs to be a higher cognitive process involved in its acquisition and ordering knowledge such as taxonomy knowledge, domain knowledge, direction of causality, and description of the type of association, among others. Though some computer systems already do this in their knowledge representation such as semantic networks and Bayesian causality networks, they do so mainly on intuitive bases (Crisp-Bright A. K., 2010), where the particular reasoning process used is imbued in the heuristic or algorithm employed for information extraction and processing.

Both of these distinctions are important because they can strongly influence the way in which knowledge is represented, other common types of knowledge include domain specific knowledge which can be regarded as a categorization of knowledge by subject, such as taxonomic knowledge domain, ecological knowledge domain and causality knowledge domain, among others (Crisp-Bright A.K., 2010).

What Are Knowledge Representation Models?

The purpose of understanding what knowledge is, and what types of knowledge exist, is to allow us to use it in artificial systems. This long standing ambition has been fuelled by the desire to develop intelligent technologies that allow computers to perform complex tasks, be it to assist humans or because humans cannot perform them. In this section it will be explained how knowledge can be used in computer systems by representing it through different knowledge representation models.

Knowledge representation is deeply linked to learning and reasoning processes, as Crisp-Bright states when defining knowledge as "the psychological result of perception, learning and reasoning" (2010). In other words, in order to have any higher level cognitive process, knowledge must be generated, represented, and stored. The works of Newell (1972, 1982, 1986, 1994) and Anderson (1990, 2004) provide comprehensive explanations for the relations between these processes, as well as computer frameworks to emulate them. Both Newell's Unified theories of Cognition (1994) and Anderson's Adaptive Character of Thought (1990) theory have strongly influenced today's knowledge representation models in cognitive and computer sciences, examples include the components of the Cognitive Informatics Theoretical Framework (Wang, 2009). Models are representations of theories that allows us to run simulations and carry out tests that would render outputs predicted by the theory, therefore when we speak of knowledge representation models, we are referring to a particular way of representing knowledge that will allow the prediction of what a system knows and what is capable of with knowledge and reasoning mechanisms. Since most knowledge representation models have been designed to emulate the human brain and its cognitive processes, it is common to find knowledge representation models that focus on long term memory (LTM), short term memory (STM) or combine both types of memory (Newell, 1982).

Having computers that can achieve complex tasks such as driving a car require intelligence. Intelligence involves cognitive processes like learning, understanding and reasoning, and as has been said before, all of these processes require knowledge to support or guide them. As Cognitive Informatics states if computers with cognitive capabilities are desired (Wang, 2003), then computerized knowledge representations are required.

To understand how generic knowledge can be represented in abstract systems we must also understand the types of possible representations, it is important to consider that these representations are descriptions of the types of knowledge; therefore they are usually akin to particular types of knowledge. A helpful metaphor is to picture types of knowledge as ideas and types of representations as languages, not all languages can express the same ideas with the same quality, there are words which can only be roughly translated.

Types of Knowledge Representation Models

A distinction should be made between types of knowledge and types of knowledge representation models. Types of knowledge were described in the section 2.1 as *declarative* vs. *procedural* and *structured* vs. *unstructured*. Types of models are the different ways each type of knowledge can be represented.

The types of representation models used for knowledge systems include distributed, symbolic, non-symbolic, declarative, probabilistic, ruled based, among others, each of them suited for a particular type of reasoning: inductive, deductive, analogy, abduction, etc. (Russell & Norvig, 1995). The basic ideas behind each type of knowledge representation model will be described to better understand the complex approaches in current knowledge representation models. Since this is a vast field of research, the focus will be directed to monotonic non probabilistic knowledge representations models.

Symbolic systems are called that way because they use human understandable representations based on symbols as the basic representation unit, each symbols means something i.e., a word, a concept, a skill, a procedure, an idea. Symbolic systems were in fact the original and predominant approach in AI until the late 80's (Haugeland, 1989). Non-symbolic systems use machine understandable representations based on the configuration of items, such as numbers, or nodes to represent an idea, a concept, a skill, a word, non-symbolic systems are also known as distributed system. Symbolic systems include structures such as semantic networks, rule based systems and frames, whereas distributed systems include different types neural or probabilistic networks, for instance. An example of a symbolic system in the way of semantic network and non-symbolic model in the way of a neural network can be seen in Figure 3.

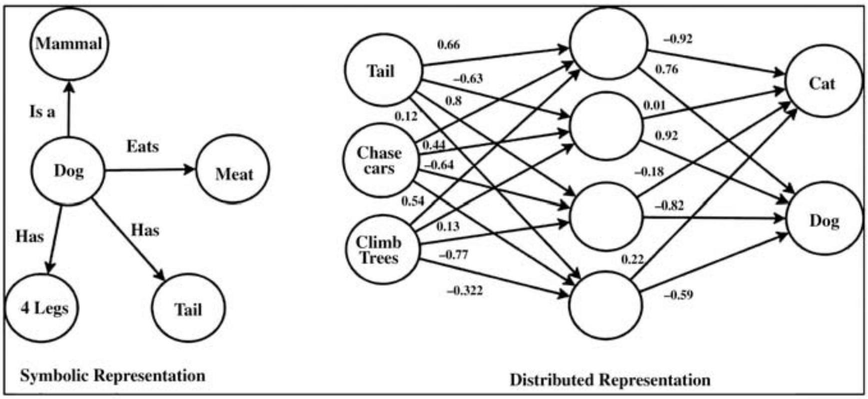

Figure 3. Example of a semantic network for symbolic representation and a neural network for distributed representation.

As their names states, semantic networks are concept networks where concepts are represented as nodes and associations are represented as arcs (Quillian, 1968), they can be defined as a graphical equivalent for propositional logic (Gentzen, 1935). This type of knowledge representation models rely strongly on similarity, contrast and closeness for conceptual representation or interpretation. In semantic networks, associations have a grade which represents knowledge or strength of the association; learning is represented by increasing the grade of the association or creating new associations between concepts. Semantic networks are commonly used to model declarative knowledge both in structured and an unstructured way, but they are flexible enough to be used with procedural knowledge. When modelling structured knowledge the associations must be directed and have information of causality or hierarchy. Figure 3 on the left shows an example of a semantic network. Semantic networks are based in traditional RTM and associative theories.

Ruled based systems are symbolic representation models focused in procedural knowledge, they are usually organized as a library of rules in the form of condition - action, e.g., *if answer is found then stop else keep looking*. Rule systems proved to be a powerful way of representing skills, learning and solving problems (Newell's & Simon's, 1972, Anderson, 1990), rule based systems are frequently used when procedural knowledge is present. Rule systems might also be used for declarative knowledge generally with classification purposes, e.g., *if it barks then is dog else not dog*. The *else* component is not actually necessary, when there is no *else* component systems do nothing or go to the next rule, an example of a rules can be seen on the right side of figure 2.

A frame is a data-structure for representing a stereotyped situation (Minsky, 1975). Frames can be considered as a type of semantic network which mixes declarative knowledge and structured procedural knowledge. Frames are different from other networks because they are capable of including procedures (fragments of code) within each symbol. This means that each symbol in the network is a frame which contains a procedure, which is called a 'demon' (Minsky, 1975), and a group of attributes for the description of the situation. The idea behind the frame is to directly emulate human memory which stores situations that mix procedural and declarative knowledge. When we find ourselves in a situation similar to one we have lived before, we allude to the stereotype stored in our memory so we can know how to react to this new situation. This theory is an attempt at joining unifying several other approaches proposed by psychology, linguistics and Artificial Intelligence.

Very similar and contemporary theory to Minsky's theory of frames is Shank's theory of scripts. Scripts are language oriented as their name suggests they resemble a long sentence that describes an action. Scripts are part of the description of a larger plan or goal, which can also be used to model networks similar to those of semantic networks (Shank, 1975). Script theory was originally oriented toward the understanding of human language and focusing on episodic memory, he later used it in his Dynamic Memory Model (1982) to explain higher aspects of cognition. Since scripts and frames have theories resemble so much they are both treated as part of a same sub-group of semantic networks.

Neural networks are the most popular type of distributed knowledge representation models, instead of using a symbol to represent a concept they use an activation pattern over and entire network. A simple way to understand how neural networks work, is by looking at the place from where the idea came, i.e., the human brain. Humans have a number of neurons connected in a highly complex structure, each time a person thinks thousands or millions of neurons in a localized part of the brain activate. This pattern of activation can be used then to identify a concept or an idea; hence if a tiny specific part of the concept is lost, is does not affect the general idea because what matters is the overall pattern. The pattern is strengthened each time we think about it, we refer to this as training of a network. Neural Networks emulate this cognitive process of mental reconstruction.

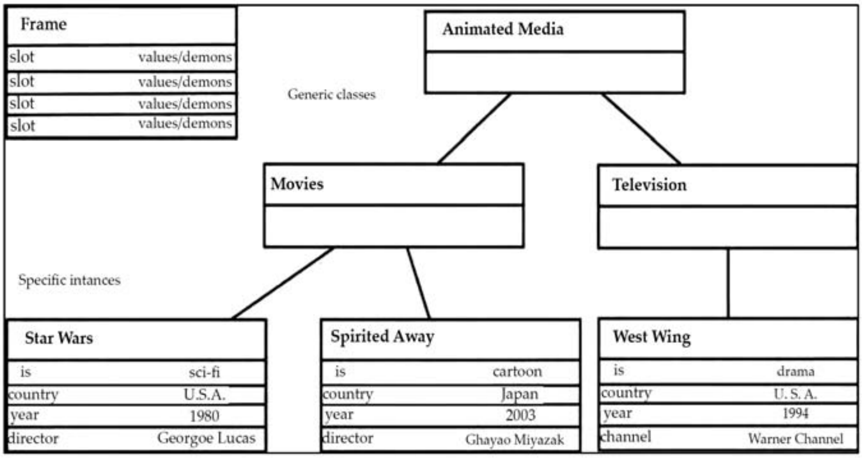

Figure 4. Frames as a type of symbolic representation.

As shown in the right side of figure 3, in a Neural Network attributes are used as basic inputs. The combination of these inputs will activate an input layer and will generate a pattern of propagation until it reaches the last layer where it will return the result of a function which could be a concept. Even though neural networks are very flexible and robust for knowledge representation of certain structures, they cannot be used for vast amount of knowledge, since they become too complex for implementation over a small amount of time. The second reason why neural networks are not used as large scale knowledge representation models is that they must be trained so they can learn the patterns which will identify specific concepts; this means that knowledge must be previously modelled as training sets before it can fed unto the net, thus it becomes unpractical for average knowledge retrieval. Also it is worth mentioning that the black box nature of the neural networks does not show to get to the knowledge, it only shows that some inputs will render this and that output, i.e., its representation is non-symbolic. The real advantage of neural networks are their capacity to emulate any function, this implies that the entire network will specialize in that particular function therefore it cannot specialize on everything. Among the common types of Neural Network the following can be found: perceptrons which don not have hidden layers; Feed forward networks, back propagation and resilient propagation which are networks with the same structure but differ in the approach used to adjust the weights of the networks; Radio based function networks; Hopfield networks, which are bidirectional associative networks; and self-organizing feature maps, which are a kind of network that does not require much training per se; among others (Rojas 1996, Kriesel, 2011). Neural networks indeed are of very different natures but in the end they are all based on connectionist theory and are inspired on biological neural networks, in particular the human, brain science.

Ontologies remain a debate issue in two aspects, first as to what is to be considered an ontology, and second how it should be used in computer science (Weller, 2007). Some authors argue that simple hierarchical relations in a structure is not enough as to call it an ontology (Gauch & et. al 2007), while others use these simple structures and argument they are (Weller, 2007). The most relevant insights in artificial intelligence as to how to define ontologies in computer systems are provided by Grubber: "An ontology is an explicit specification of a conceptualization … A conceptualization is an abstract, simplified view of the world that we want to represent… For AI systems, what 'exists' is that which can be represented." (Gruber, 1993). Gruber also notes that "Ontologies are not about truth or beauty, they are agreements, made in a social context, to accomplish some objectives, it's important to understand those objectives, and be guided by them." (Gruber, 2003) However this definition has created a new debate since it also applies to folksonomies (Gruber, 2007), especially since ontologies and folksonomies (Medelyan & Legg 2008) became popular in the context of semantic web through RDF and OWL (McGuiness & Harmelen, 2004) specifications. Weller (2007) and Gruber (2007) present a deeper explanation of this debate as well as the differences and advantages of each of both folksonomies and ontologies. In practical sense ontology are flexible hierarchical structures that define in terms that a computer can understand, the relations between its elements, a language often used for this purpose is first order logic. In reality, ontologies have been used mostly as enhanced controlled vocabularies with associated functionalities and categorization. Computational implementations of ontologies tend to resemble taxonomies or concept networks (Helbig, 2003, Chen 2009), i.e., semantic networks with formal conceptual descriptions for their associations, and therefore can be considered symbolic systems. Some examples of Ontology include those defined as part of an interaction communication protocol in multi agent systems (FIPA, 2000), those built though ontology edition tools for ontology web language (OWL) like *protégé* which are used to build *the semantic net*, and project CYC which will be addressed in section 4.

All representation models presented satisfy the three basic characteristics placed above. Both symbolic and distributed systems recognize a concept as a unit of knowledge, the main difference between them is that one approach models it as a symbol and the other as a pattern. Both approaches agree on the need for associations between concepts and both recognize that the configuration of the associations also represents knowledge. It should be noted that some symbolic models like ontologies include instances as another layer for representation of the embodiment of a concept, however not every models includes them and therefor even though they will be mentioned in future sections they will not be included within the basic characteristics that all knowledge representation models have in common. With this we conclude a basic introduction of what knowledge is and how it is represented in computers, now we will analyze each of the basic units that compose knowledge: concepts, skills and associations.

CONCEPTS, SKILLS AND THEIR ACQUISITION

We have already explained that knowledge is divided in two types: factual and procedural; Roughly speaking factual knowledge in a higher cognitive dimension can represent concepts, and procedural knowledge in higher cognitive scale can be used to represent skills. As was mentioned in section 1, this does not mean that any fact can be considered a concept or any procedure a skill, the inter-association between each of these components as well as the structures they build must also be considered. To get a deeper understanding of knowledge we now review each of these components in more depth.

Definition of Concept

The definition of a concept is closely related to the discussion of knowledge, in fact most of the theories attempting to explain one also explain the other. The most traditional definitions of concepts are based on Aristotelian philosophy and can be considered as revisions and complements previous works in the same line, Representational Theory of the Mind (Hobbes, 1651) was the first formalization of this philosophy and Language of Though hypothesis (Fodor, 2004) is the latest extension added to it.

The Representational Theory of the Mind (RTM) states concepts and ideas as mental states with attributes sometimes defined as images, the Language of Thought (LOT) hypothesis states that thoughts are represented in a language which is supported by the principles of symbolic logic and computability. Reasoning can be formalized into symbols and characters; hence it can be described and mechanized. In other words RTM states that concepts exist as mental objects with attributes, while LOT states that concepts are not images but words in a specific language of the mind subject to a unique syntax. A complete and practical definition of concept should be influenced by those two aspects, and therefore be as follows: A concept is considered as the representation of a mental object and a set of attributes, expressed through a specific language of the mind which lets it be represented through symbols or patterns which are computable. Such approach defines concepts as objects formed by a set of attributes, in the same atomic way as the Classic Theory of Concept Representation does (Osherson & Smith, 1981), but also considers descriptive capabilities of the role of a concept in the same as the approach of Concepts as Theory Dependent (Carey, 1985; Murphy and Medin, 1985; Keil,1987). This definition is useful for declarative knowledge since it can be easily included to most existing models and remains specific enough to be computationally implemented as will be shown in section 4.

Definition of Skill

Philosophic views such as (Dummet 1993, Kenny 2010) propose that abilities and concepts are the same thing, however, these approaches have not been very popular in computer and cognitive sciences, because of studies made in learning theories from Cognitive Science provide a more practical and empirical approach which instead support the Aristotelian view of concepts. Skills are practical manifestations of procedural knowledge, the most popular definitions of skills used today are based on constructivist theories and variations of Bloom's Taxonomy of Skills, this comes as a historic consequence of research in education, were skills is a core interest in educational psychology. Therefore, it is then not strange that the most referenced theories for skill development are found in this social science. Vygotsky's constructivist theory (Vygotsky, 1986) explains how skills are developed through a complex association process and upon construction of dynamic structures which can be traced through internal language or speech. Bloom's taxonomy for skills provides perhaps the most practical classification and enumeration of cognitive, social and physical skills. The combination of those works establishes enough theoretical insight to build more complex models for skill representation, such as those used in Cognitive Informatics for the Real Time Process Algebra (Wang, 2002), Newell's Soar cognitive architecture (Newell, 1990) and Anderson's ACT-R cognitive architecture (Anderson, 1994).

In Thought and Language, Vygostky (1986) explains several processes used to learn and create ideas. Ideas stated as concepts and skills dynamic in nature behave as processes in continual development which go through three evolution stages starting at the basic stage of syncretism heaps, which are loosely coupled ideas through mental images, and concluding in formal abstract stable ideas, which are fully developed concepts and skills that manifest in language.

Benjamin Bloom (1956) developed a taxonomy for skills with a very practical approach, in which three domains are specified: cognitive, affective, and psychomotor. Each domain contains different layers depending on the complexity of the particular skill. Bloom's taxonomy is widely used, however, as with any other taxonomy, criticisms have been raised; Spencer Kagan (2008) made the following observations:

1. A given skill can have different degrees of complexity; hence a layer model might not provide an adequate representation.
2. Skill integration in complexity order does not always keep true.

These observations imply that if there is a hierarchy in skills it must be dynamic in nature and this characteristic must be taken into account when defining what a skill is. The idea of flexible structure can also be found in Vygotsky's theories. In the framework for Cognitive Informatics, Wang (2002) proposes an entire system for describing processes, according to what we now know of procedural knowledge we can use such system to define skills in computational terms, thus under this train of thought skills are pieces of computer code located in an action buffer, such processes are composed by sub-processes and are described using Real Time Process Algebra (RTPA). RTPA is oriented to a structured approach where a skill is not as flexible as Kagan's observations suggest, the types of data, processes, meta-processes and operations between skills, should be included in a comprehensive definition of skills.

Using constructivist theories as a basis, Bloom's taxonomies for organization and the cognitive architectures for mappings to computational terms, a generic definition for skills in computer systems can be stated as: A cognitive process that interacts with one or more concepts as well as other skills through application and has a specific purpose which produces internal or external results. Skills have different degrees of complexity and may be integrated or composed by other skills. In contrast with concepts which are factual entities by nature, skills are process oriented, they are application/ action related by nature and it is common to describe them using verbs.

Associations between Concepts and Skills

Of the three basic common characteristics of knowledge stated in section 1, perhaps the second characteristic: *Concepts have relations or associations to other concepts,* is the most agreed upon. Every theory and model reviewed so far agrees that associations are vital to knowledge (Hobbes, 1651, Fodors, 1975, Vygotsky, 1986, Bloom, 1956, Kagan, 2003, Newell, 1990, Anderson, 1994, Quillian, 1968, Wang, 2002, Helbig, 2003, among others); the differences appear when defining their properties and implications, these are better observed in cognitive or computer models, since more general theories tend to be vague in this regard and detailed specification is a requirement for computer models (Marr, 1982). Most declarative knowledge representation models rely on propositional logic or its graphical equivalents in network representations e.g., Cyc (Read & Lenat, 2002), WordNet (Miller, 1990) , OAR (Wang, 2006), Multinet (Helbig, 2003) and Telos (Paquette, 1990) among others, the specific type of the network is determined by aspects such as directionality of associations (Helbig, 2003), the type of association (Wang, 2006), if the associations allows cycles, if they are hierarchical in nature (Paquette, 1990) or mixed and if there is a grouping or filtering scheme for them.

Traditional semantic networks only used presence or absence of associations; current semantic networks such as MultiNet or Object Attribute Relation OAR (Wang, 2007) provide deeper types of associations and integrate layers for knowledge composition. Examples of deeper type of association can be seen in MultiNet where associations are defined as a third type of node that contain procedural knowledge similar to Minsky frames, or OAR associations which are described as types of relations which can be grouped into several categories: Inheritances, Extension, Tailoring, Substitute, Composition, Decomposition, Aggregation and Specification. OAR categories are in fact operations for Concept Algebra (Wang, 2006), i.e., a mathematical way to describe how knowledge structures are integrated. Concept algebra does not include procedural knowledge, for this reason RTPA has a different set of associations which describe a hierarchy for composition of processes; both real time process and concept algebras are integrated in a higher framework called system algebra (Wang, 2009).

Associations are important because they create the context and embody semantic meaning for each context, some authors refer to this as sense (Vygostky, 1986), others discriminate between intrinsic knowledge, i.e., knowledge inherent to that concept, and context knowledge i.e., knowledge inferred from the associations and other concepts surrounding the original concept (Helbig, 2008). Understanding these approaches we can then summarize that an association is a relation between two elements, which can be skills or concepts that contain a particular function and a directionality that explains the nature of the relation. Groups of associations are what create contexts and each of these contexts may provide a uniquely different sense to a concept or skill which should reflect upon interpretation and inference process.

A MODEL FOR THE REPRESENTATION OF CONCEPTS AND SKILLS IN DIFFERENT CONTEXTS

An important functionality for knowledge representation models is the capacity to represent multiple contexts in a single instantiation, as well as the impact that context changes have on a concept's meaning. Approaches such as micro-theories models used in Cyc contemplate this and have successfully managed to combine multiple facts of a subjective nature into a coherent knowledge base, however, Cyc requires understanding of its own native language which is based on predicate logic semantics for information modelling and for information extraction as well, this has proven a problem for most users (Lenat, 2006). Simpler graphical representations which retain this context flexibility and can be represented in computers present an attractive alternative for average users, such as domain experts not versed in CYC language. Graphical oriented models such as Multinet or OAR have been used for natural language processing and for knowledge composition and process specification respectively, but their focus is not to represent several contexts a time.

Multinet for example has specific context differentiation based on grammar attributes such as singular or plural elements, however, it does not have differentiators for the concepts meaning when the context changes. In these models when a new context is to be created only a small fraction of the information of concepts is reused and most of it has to be re-instantiated for each domain, this is a common trait of knowledge representation models that have instances as part of their model. OAR presents a similar situation since the context is defined as the relation between objects and its attributes in a given set (Wang, 2006). OAR is more flexible and does contemplate multiple contexts for the instantiations of the concepts, but not for the concepts themselves, which means that what are dynamic are not the concepts themselves but the objects in regard to the context. The implication for this is that a concept will have several different instantiations depending on the context, however this issue does not represent the impact the context has on the formation of a concept as was described by Vygotsky (1986).

The Memory Map Model

The Memory Map (MM) is a knowledge representation model for concepts and skills, its main goal is to represent the interaction of these elements in different contexts, including the representation of concepts which meaning changes according to the context, i.e., semantic environments. The MM can be visualized as a semantic network which is compliant with the theoretical views presented in section 1 and 2. The main difference between the MM and other models is that the MM strongly focuses in context flexibility, because of this approach, in the MM concepts and skills must have an open granularity subject to the modeler's criteria; an arbitrary level of atomicity which can be specified for each concept, and dynamic hierarchies which can change for different domains of knowledge. The implementation of the MM is a directed graph, very similar to the more flexible types of semantic networks and to ontologies.

Memory Map Components

There are three main components in the MM which were developed using the theoretical bases for knowledge stated in section 1:

1. **Concepts** referred to as Concept Representation Units (Concept-RU), they are represented as the round nodes in the network.
2. **Skills** referred to as Skill Representation Units (Skill-RU), they are represented as the round nodes in the network.
3. **Associations** between the members of Concept-RUs, between the members of Skill-RUs and associations among Concept-RUs and Skill-RUs, they are the arcs in the network.

Concept Representation Units

The basic definition for concept in the MM can be described by the elements of section 2. Syntactically, each concept is enclosed in its particular Concept-

RU which has associations to other Skill-RUs and Concept-RUs. The attributes of concepts and skills together with their associations define their semantics, therefore any skill or concept is described and defined by the associations it has with other skills and concepts. This means that a Concept-RU has little intrinsic knowledge, and almost all the knowledge is provided from its context through its associations which are also its attributes. A concept's meaning changes depending on the group of attributes that are tagged for each different domain. Using the domain tags for attributes allows a Concept-RU to represent an indeterminate amount of meanings for that concept, since ultimately the concept is in fact a structure; an example of this is presented in figure 5, where the concept *cell* is represented for 3 different contexts: *Biology*, *Buildings* and *Communications*. A similar approach for attributes can be found in distributed systems with local representation (Eysenck, 2010), which could be closest thing to a hybrid representation model between the symbolic and the distributed systems.

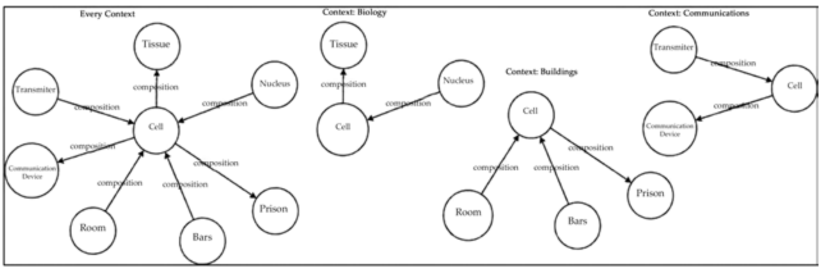

Figure 5. Example of concept representation unit in three different contexts.

Formally a Concept Representation Unit is defined as:

$$c(n,A,x) \tag{1}$$

where c is a concept with a name or identifier n, a set of attributes A, and a numerical level of knowledge x, where A is

$$A = \{a_1, a_2, a_3, \ldots a_n\} \tag{2}$$

each a is an association from the concept to other concepts or skills, and n is the total number associations that the Skill-RU has. Two associated concepts or skills will share an association for each context, so the intersection of both concepts must return all the associations by which they are related. Hence if c_a and c_b are associated as follows:

$$c_a\left(n,\{a_1,a_2,a_{3...}a_n\},x\right) \cap c_b\left(n,\{b_1,b_2,b_{3...}b_n\},x\right) \neq 0 \tag{3}$$

The context representation is handled within each association and will be explained in 4.2.4 and 4.3.

Skill Representation Units

In accordance to what was established in section 2, a skill in the MM is a cognitive process that interacts with one or more concepts and other skills, usually through application, which has a specific purpose and produces a certain result, be it internal or external. Skills have different degrees of complexity and can be integrated with other skills. Skills are process oriented, they are action related by nature, for this reason they are described using verbs. Figure 5 shows the representation for two different versions of Bloom's taxonomy, versions of skills can also be modelled as different contexts, this way combinations of trees and domains of concepts can be used to model knowledge domains in a flexible way re-using most of the information already contained in the model. To represent the dynamicity described by Vygotsky, Skill-RU have knowledge levels which indicate how evolved a Skill-RU or a Concept-RU is, this number can be mapped using thresholds to indicate if a structure is weak, i.e., syncretic or strong and stable, i.e., conceptual. The way in which knowledge is extracted and calculated is explained in 4.2.4.

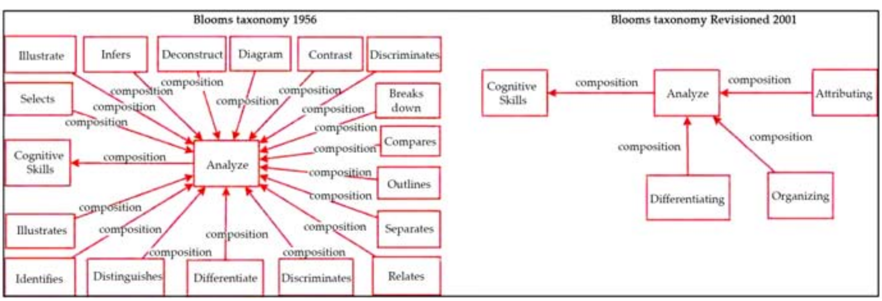

Figure 6. The structure to the left is a skill representation in the MM of a segment of Bloom's (1956) original taxonomy based on keywords, the structure to the right is a representation of a revision made in 2001 of Bloom's work (L. Anderson et al., 2001).

In a formal definition a Skill-RU is similar to the Concept-RU, the main difference is the type of associations skills have which reflect a more application oriented nature. A skill is defined as follows:

$$s(n,A,x) \tag{4}$$

Two associated concepts or skills will share an association for each different context, so the intersection of both skills must return all the associations by which they are related. Hence if Sa and Sb are associated:

$$s_a(n,\{a_1,a_2,a_{3...}a_n\},x) \cap s_b(n,\{b_1,b_2,b_{3...}b_n\},x) \neq 0 \tag{5}$$

Associations

Skill-RUs and Concept-RUs are the constituents in the MM and are glued through associations, there is only one restriction in the associations and that is that only Skill-RUs can have application oriented roles. Skill-RUs and Concept-RUs have independent organization structures within the MM structure, this is used to represent composition of skill and of concepts as is shown in figure 7.

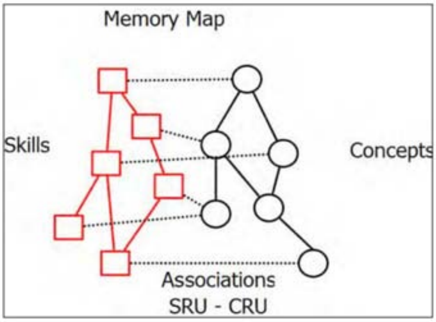

Figure 7. Associations between skills and concepts in a Memory Map.

The purpose of the associations is to represent how concepts and skills relate to each other to generate knowledge. Knowledge is not only a group of stored concepts, but the structure of associations itself. An association therefore must:

- Provide information of the nature of the relation, knowing that the nature of a relation allows us to understand how the structure is to behave and enables more complex reasoning processes.
- Provide information of the directionality of causality, the inheritance of attributes in directly dependent on this factor, when we say inheritance of attributes we also mean inheritance of associations.

- Provide information as to the domain where it is valid, so the structure can be context sensitive and discriminate which associations hold true for a domain and which do not.
- Provide quantitative information of the strength of the association, knowing the strength of an association will allow probabilistic estimation of how much is known of a concept or skill, this is letting the structure know how much does it know regarding that specific relation.

An association **a** is defined as a relationship between two representation units which may be either a Concept-RU or a Skill-RU, the first unit is predecessor *pre* and the second is successor *suc*. The association role **r** contains specific information that describes the nature of the relationship and the set of domains *D* where the association holds true and **y** indicates the strength of the association.

$$a\left(u_{pre,}u_{suc}, r, D, y\right) \tag{6}$$

where u represents a unit which might either be a concept or a skill, this holds true for groups as well:

$$U\left(u_1,u_2,u_{3, \dots}\right) = C\left(c_1,c_2,c_4, \dots\right) \cup S\left(s_1,s_2,s_3, \dots\right) \tag{7}$$

An example of associations with the information attributes presented above is presented in figure 8.

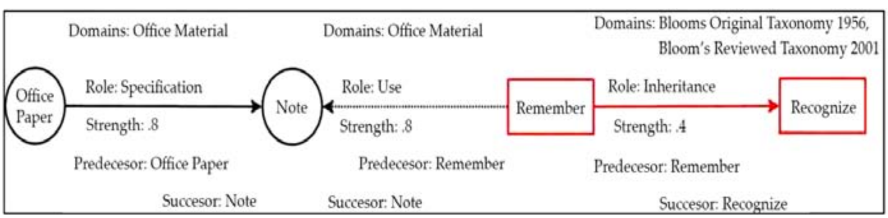

Figure 8. Three types of associations: left Concept-RU-Concept-RU, middle Concept-RU-Skill-RU and right Skill-RU-Skill-RU.

Two representation units can share more than one association as is shown in figure 9, the only restriction is that there can only be one association per domain with the same role and between the same RUs, this avoids two things: the first is direct contradictions within the same domain in case the directionality for that role is inversed, the second is redundancy of information in the case of two associations with the same directionality and the same role which will result in unnecessary repeated information.

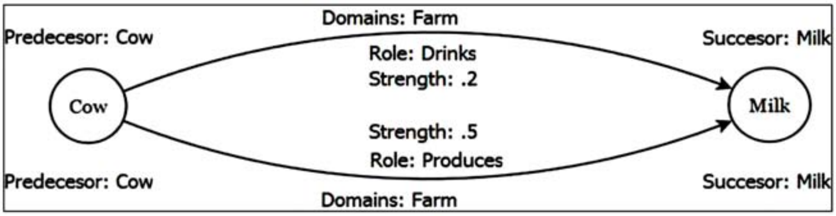

Figure 9. Two concepts in the same domain share two associations with different roles.

Table 1. Examples of association types of OAR used as Roles in the MM. \

Role types:	Description
inheritance	the successor unit inherits all the associations and hence the attributes of the predecessor representation unit.
extension	the precursor unit integrates single individual attribute
tailoring	the predecessor unit cannot inherit a specific association to the successor if a group of associations are inherited from it.
composition	the precursor unit is a component of the successor unit; the successor unit inherits the composition associations of the precursor unit.

Since associations contain the information regarding the domain, they change when the domain changes, examples are presented in figures 5 and 6. Roles or types of associations can be freely defined and integrated into the model as long as they have a consistent functionality; MultiNet presents a similar approach for its types of relations (Helbig, 2003), the main difference being that MultiNet focuses on natural language and requires more types of relation to describe lexical and grammatical rules. A solid and economic base to describe knowledge composition can be found in OARs types of associations, with only 8 types of associations and an instantiation OAR provides congruent mathematical explanations of concept composition. The MM can use any type and number of roles to describe the basic composition for Concept-RUs and Skill-RUs; several examples based on OARs associations are shown in table 1. On the other hand, the MM does not create objects and instantiations as OAR does, in the MM both are treated as the same thing, for this reason some of the types of associations used in OAR become redundant in the MM as is shown in table 2.

Table 2. Association types of OAR that becomes redundant or Useless in MM.

Role types:	Description
decompo-sition	the inverse behavior of composition, it is rarely used since it can be substituted by back-tracking the directionality of composition.
aggrega-tion	the same behavior as the tailoring role, it can be substituted since due to the nature of the MM model it has no application.
specifica-tion	the same behavior as the extension role, it can be substituted since due to the nature of the MM model it has no application.
substitu-tion	attributes change for different instantiations, this is not necessary in the MM for domain filtering naturally and transparently handles this substitution.

A graphical representation of how each association role is presented in figure 10.

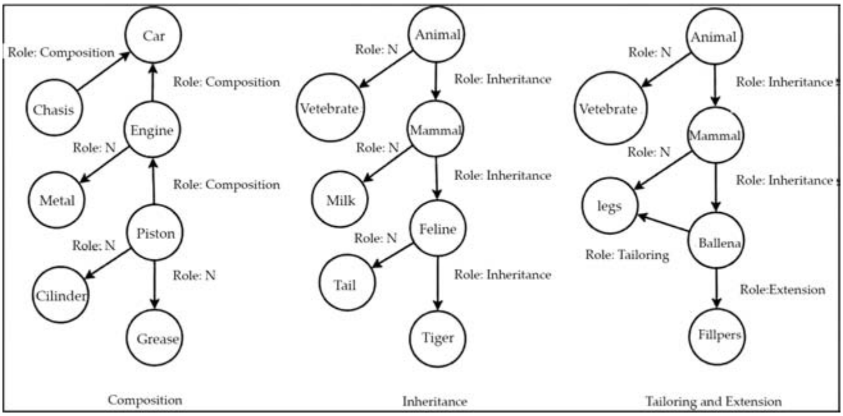

Figure 10. Examples of OAR types of associations Composition, Inheritance, Tailoring and Extension integrated into MM model as roles.

Context and Inter Context Associations

Context is the embodiment of semantic knowledge, that is, the way in which groups of ideas are associated. In the MM a context is the body of knowledge composed by one or more domains of knowledge, associations are subject to the domains they belong to, an association between two RUs must belong to at least one domain, using the combination of multiple domains different contexts may be built. A domain cannot present a contradiction within itself, however built contexts can present contradictions since each domain included in a context may have contradictory knowledge in the form of a same rol with inverse directionality, because of this when combining several domains into a mixed context, priority mechanisms for contradictions should be defined as well. Contradictions may generate problems such as creating cyclic structure in MM, this is a common problem for flexible low restriction model like Ontology Web Language OWL (McGuinness & Harmelen, 2004). OWL in its first two levels establishes mainly treelike structures, but at its most expressive and flexible level OWL cannot guaranty computability (McGuinness & Harmelen, 2004), this seems to be a common fault for which workarounds can be made in implementations such as memory stacks or limits in searches, but there seems to be no model solution in sight which does not compromise the models flexibility.

Knowledge Extraction

If the model used for knowledge representation is flexible enough then complex information may be extracted using simple functions or algorithms, such is the case of the MM. Queries or knowledge extraction in the model are performed through simple unguided recursive searches that return relevant segments of the MM, it must be stated that the main focus of this knowledge representation model is to be able to easily access information for open questions such as: *what does this MM know about concept A or skill B? What are the attributes of concept A? How are concepts A and B related under this particular domain of knowledge? What attributes of A hold for every domain? What concepts are related by type of association a?* Each of these questions can be answered using the domain or combination of domains, the roles of associations, the depth of knowledge, the directionality knowledge and the combination of all of the above.

Basic knowledge extraction in the MM can be described by the recursive function:

$$f\left(\left((u)(n,A,x)\right)_i, r_j, d_k\right) = f\left(\left((u)_,(n,A,x)\right)_{i-1}, r_{i+1}, d_{k+1}\right) \quad \begin{array}{l} i=0, 1, 2, \ldots, n \\ j=0, 1, 2, \ldots, m \\ k=0, 1, 2, \ldots, l \end{array} \tag{8}$$

Where *n* is the number of existing concepts or skill levels that the search can reach, *m* is the number of existing roles and *l* is the number of existing domains. The function in turn will return a group of associations, because the associations themselves represent the structure of knowledge that is sought. We now provide different examples of how the function works for some of the questions presented above:

What does this MM know? If the MM is queried with function setting as parameter *n*, *m*, and *l*, then the function returns the whole MM as is shown in figures 11, 12 and 13.-*What is concept A composed of or what class does it belong to?* If the MM is queried with the function from *i* to *n*, the search will return a structure of units for a domain k with the role j, as is shown in figure 10. This represents a hierarchy or a chain of composition, though this will be subject to what role j is.

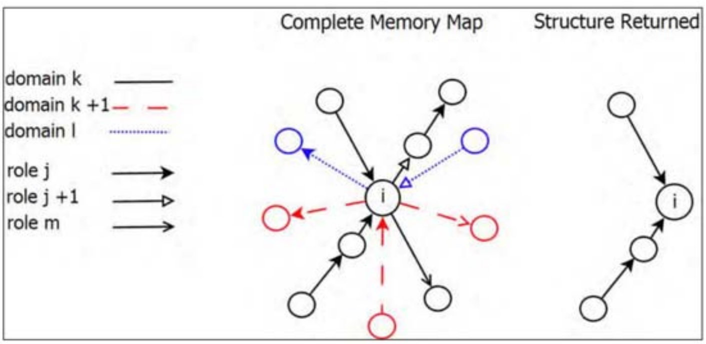

Figure 11. The search result for an every concept or limitless search with one role and in one domain.

What are the attributes of concept A? If the MM is queried with the function from *j* to *m*, the search will return every role associated to the concept *i* in the domain *k*, as is shown in figure 12. This represents the direct attributes of the central concept.

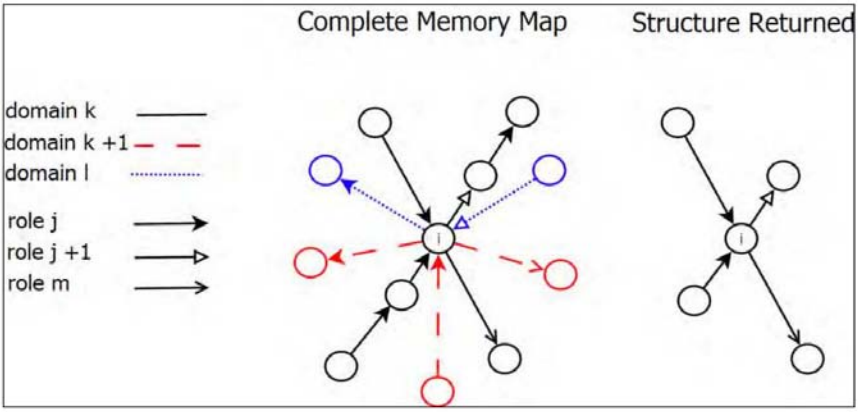

Figure 12. The result for an every role or attributes search for one concept and in one domain.

What attributes does concept A hold for in different domains? If the MM is queried with the function from *k* to *l*, the search will return every association with role j associated to the concept *i* in every domain, as is shown in figure 13. This represents every possible meaning the concept might take in a completely open context.

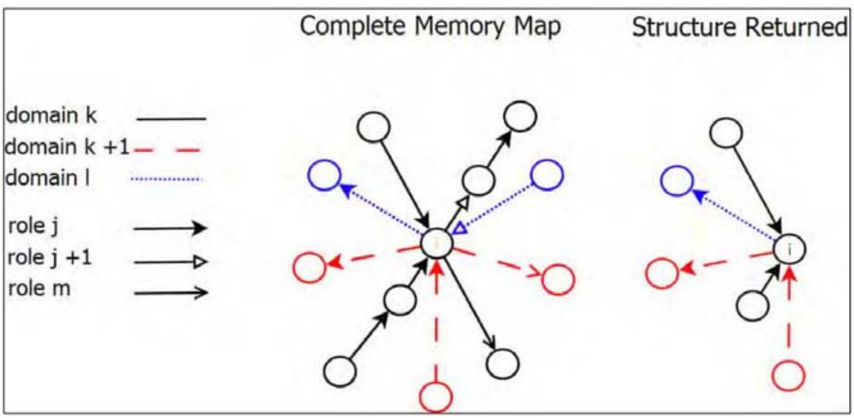

Figure 13. The result for an every domain or open context search for one concept and with one role.

The rest of the questions can be answered with combinations of these criteria.

Knowledge Acquisition

New knowledge is acquired by associating it to previous knowledge. Acquisition in the MM also follows this principle, new representation units must be integrated with the main body of representation units that are already known, this follows also the constructivist principle that knowledge is constructed upon more knowledge, hence the more we know the easier it is to learn and retain knowledge in long term memory. This approach establishes then some restrictions:

- For a concept or skill to be considered as part of knowledge it must be associated to the structure of knowledge. A domain can appear to have sparsity, i.e., secluded knowledge, however it is because there is an association that link's that concept or skill to the whole structure which cannot be seen because it is part of a different domain. Though the domain seems disconnected, other domains complement it in a natural way and therefore the MM is congruent in general. A real life example of this can be seen in academic courses where requirements come from different fields, e.g., knowledge of programming as well as propositional logic are required for the understanding of artificial intelligence, though they might not be directly related between each other, a novice's MM in the domain of artificial intelligence would appear fragmented since some of the concepts would not be yet related through this domain, however, knowledge of both programming and logic must be associated through other currently hidden domains in the novice's MM because they cannot be completely secluded. If knowledge is found to be completely secluded through every context then this represents a memorized fact instead of knowledge.
- Associations must always be linked to representation units, an association cannot be linked to an empty unit or remain unlinked.
- If a new concept or skill is to be integrated, then the representation units must be created first and the association later. If a structure is to be integrated, then this process is repeated recursively for each unit of the structure.

In general the integration of new knowledge to the structure is described in figure 14.

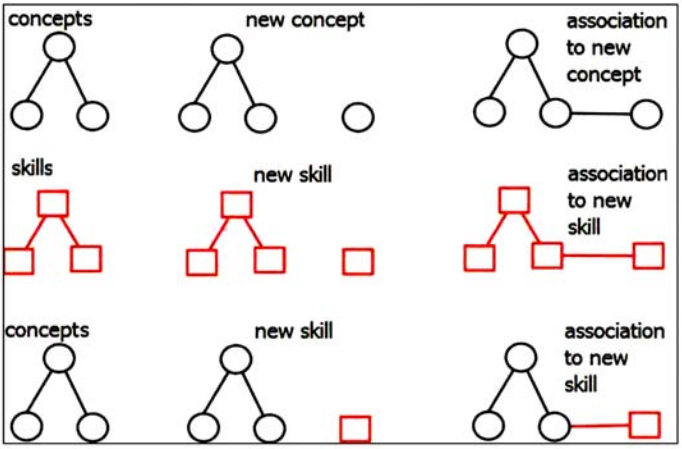

Figure 14. Integration of new concepts and skills to the structure of knowledge.

Knowledge Measuring

Knowledge measuring in the MM is subject to context, only in few occasions will it be desired to know all the information from a concept in every domain, most of the time the interest will be in knowing the level of knowledge for a concept in regard to a context. There are two scenarios for knowledge measuring: the first when knowledge is measured in an absolute way, and second when knowledge is measured through a query. The differences between them will now be explained.

To know the general knowledge grade of a concept the average of numeric value *v* of each association is multiplied by an associative factor determined by:

$$\text{Associative Factor} = 1 + (\#@) * 0.1 \quad (9)$$

where #@ is the number of selected associations, the factor represents the increment of impact of a more associated concept, this means that if two concepts have the same average of association strength, the associative factor will give a higher grade to the more associated concept. The general knowledge measurement for a representation unit would be calculated by:

$$\text{Representation Unit K} - \text{level} = (\text{Average}(v)) * \text{AssociativeFactor} \quad (10)$$

where *v* is the numerical value of a group of associations that were selected.

When measuring knowledge for the general case, 10 will be used for the concept with every existing association, when measuring knowledge for a specific context only those associations included in the domains will be used, therefore a concept will have a different knowledge value for each context. When measuring the knowledge of a group of representation units, a similar approach is used:

$$\text{Segment K} - \text{level} = \left(\text{Average}\left(\text{RUK} - \text{level}\right)\right) * \ 1 + (\#\text{RU}) * 0.1 \qquad (11)$$

Where RU level is the representation unit knowledge level, and the average of all the selected concepts are multiplied by a factor determined by representation units, hence if two segments have an equal amount of knowledge level in their representation units, then the segment having more representation units, i.e., concepts and skills is said to have more knowledge.

Properties of the MM

The fact that every attribute is considered as a mixture between a concept and an association in the memory and that depending on the current context, this change generates properties which make the MM flexible and expressive:

- **Open/Unlimited Granularity.** Since the composition of knowledge is a network structure, there can be an indeterminate number of levels to specify composition. A field expert can determine the level of granularity specification for any unit, this means different units within the structure can have different granularities.
- **Dynamic Hierarchy.** Concept and skill representation units can be integrated into proper hierarchies through roles and directionality of associations; a unit can be placed in several taxonomies, i.e., in several hierarchies, where each hierarchy belongs to a different context, the combination of several domains with different hierarchy structures generate in turn new hierarchies, making the hierarchies dynamic and context dependent. This enables the use of semantic information contained in the taxonomy for a context that includes that taxonomy.
- **Economy of Knowledge.** The structure is developed in a way to avoid information redundancy, i.e. the same nodes are used for different knowledge structures, each one of them delimited by a different context.

- **Informativeness Capability.** There is no limit to the amount of Concept-RUs or Skill-RUs in a structure, nor is there a limit to the depth of the knowledge represented, that is, there is no limit for the hierarchy of attributes and associations.
- **Flexibility.** The structure can create associations between any Concept-RU and Skill-RU, and each association can have several roles each offering a unique behavior.

APPLICATION OF THE MM IN AN ADVANCED LEARNING ENVIRONMENT

The problems and challenges found in the development of smart tools for education remain attractive and closely linked to knowledge representation models in general, for this reason the MM was instrumented as part of an Advance Learning Environment where it is used for the adaptation of learning resources. The adaptation is done through user profiles that contain user knowledge, interest, learning styles and emotional profiles. Similar approaches have been presented in (Carchiolo, Longheu & Malgeri, 2002, Van Marcke, 1998) where integral user profiles are used to model generic personalisation of learning environments. Knowledge Representation models have been used for education successfully in Intelligent Computer Aided Instruction ICAI (Nwanna, 1990), Adaptive Hypermedia (Brusilovsky, 2004) and Intelligent Tutoring System ITS (Nwanna, 1990) fields, the frameworks and architectures established in theese fields can be described as generic adaptation processes, these greatly eases the transition of a purely theoretical models to practical implementations in human learning environments.

Proposed Architecture

The architecture for an Advance Learning Environment is meant to provide optimal learning conditions both physical: by adjusting settings such as environment noise, temperature and illumination, as well as cognitive conditions: through the personalization of learning resources, media, activities, sequencing, evaluation methods and content. To achieve this, the architecture requires physical sensors and algorithms to process the user physical information, such methods are described in (Ramirez, Concha, & Valdes, 2010, Arroyo & Cooper, 2009) and include body temperature, posture detection, heart rate, facial expression recognition, among others. Each of these methods pass the processed input information to a group of algorithms which will decide what adaptations need to be made to achieve optimal learning conditions.

The complete architecture is presented in figure 15, the cycle that describes the operation of the system is the following:

1. Starting on the side of the figure we can observe tools for editing the MM, integrating Learning Objects (LO) and Learning Services (LS), modifying student portfolios and creating assessments. The tools are meant to assist teachers in the development of the MMs to be used in their courses, and for students to consult and partially edit their own portfolios. The student portfolios include their cumulative MM from every course they have taken, their emotional-cognitive mappings, their learning profile and their explicit interest and learning goals. Through these editors information is manually captured into the entire system.
2. Once the system has a complete user portfolio, a MM of the course designed by expert and enough LOs and LSs, the system can start the personalization process. If the student is new to the system and does not have a MM, the process starts with an initial evaluation. The evaluation can be either a regular test, automated observation or through expert direct assessment, with this information the student's MM is created, or updated if a MM already exists.
3. Using heuristics based on the user knowledge level and the course MM, the system determines the next concepts to present. This is done through an overlay approach, i.e., the student knowledge must be a subset of the expert knowledge, (Brusilovsky, 2007).
4. Knowing what the next concept or skill to be taught should be, the system selects from a library of LOs and LSs the most adequate object for the user's profile from a group the group of LSs and LOs that match the selected knowledge.
5. Once the object is selected it passes onto a learning management system (LMS) (Alcorn, & et al. 2000) where the learning object will be integrated into the main sequence of activities to be presented to the student, in this stage smaller modifications regarding the presentation of the object such as color, font size, layout and duration are also made.

6. Depending on the activity, the student must go through a knowledge evaluation regarding the content just presented either through behavior observation during activity or through a post-test.
7. With the feedback obtained from this evaluation the student's MM is updated and the cycle begins again until the desired concepts in MM of the course are learnt.

While this is all taking place, physical sensors are continually observing and gathering data to estimate the users emotional condition and with this information the user profile is updated as to determine what factors in the learning process affect the student's emotional state, with enough information on this regard patterns can be established as to predict what will cause undesirable stress in the student. This factor is considered into the algorithms in charge of conceptual selection and those in charge of content personalization. We will now review each of these applications of the memory map in the advance learning environment with more detail.

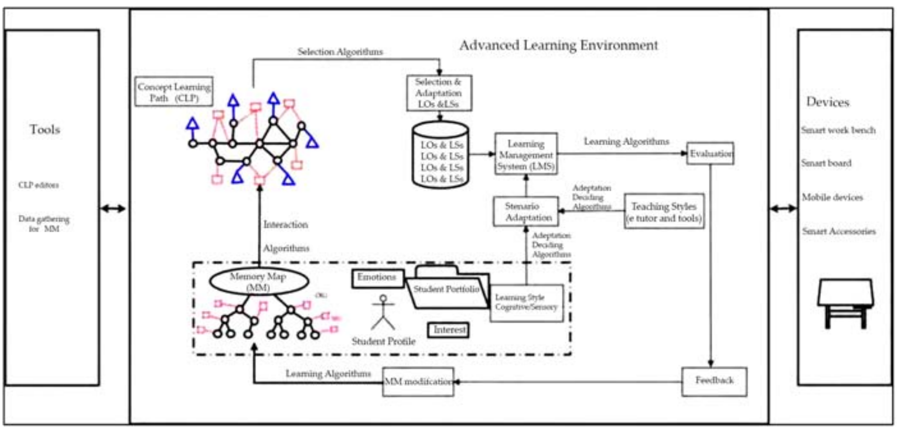

Figure 15. The architecture of the Advanced Learning Environment.

Knowledge Representation for Apprentice/Student Modelling

If personalization is desired then a source of information is required, a knowledge representation model is the ideal source of information for advanced adaptations. This is because a knowledge representation model, usually a concept or semantic network, contains key information on how ideas are related and how to present them to a student through a complex negotiation process which can be described through algorithms supported on learning theories, in particular the constructivist theory (Vygotsky, 1986).

In education systems architectures, user modelling is divided into two categories: student model and expert model (Nwanna, 1990, Murray, 1999), whereas their name states the student model contains the information regarding student knowledge and the expert model contains all the information an expert should know for that context. In the advanced learning environment the MM is used to model both the expert model and the student model. The MM is used to model the concepts and associations that a group of students is expected to learn during an academic course or subject to be learnt, this is called the course-MM and would be equivalent to the expert model on cognitive agent architecture; each association and representation unit is taken to be an implicit learning objective which will be mapped to LOs and LSs. For the student a MM is created for her/his particular knowledge, the students MM are built and expanded using academic tests with specifically designed questions to inquire if an association between particular concepts exists, this approach, where a set of specifically designed questions reflect the knowledge of a user on a domain, is used in knowledge spaces theory as well (Doignon & Falmagne 1999).

The fact that both knowledge structures are represented using the same knowledge representation model makes the use of an overlay approach natural for detecting differences between what the student knows and what the courses conceptual contents are, i.e., what the student knows and what he/she must learn in the course. Almost any knowledge representation model can be used to represent both the student model and the expert model, however the context management attributes of the MM allow it to represent several different student domains of the same student for different courses, this is, each context dynamically established in the MM can be treated as a different knowledge domain either for student or for the expert. For example if learner A enrols in course B, only the knowledge in student A's MM that is labelled under the domain (of the course) B or the representation units that are detected to be equivalent to those found in B, will be used for the content selection in the system, as shown in figure 16. The updates to student A's MM will be labelled under the domain B, therefore incrementing A's MM, both in this particular context and in general. A more detail explanation as to the methods used for the personalization of the learning path can be found in (Ramirez & Valdes 2011).

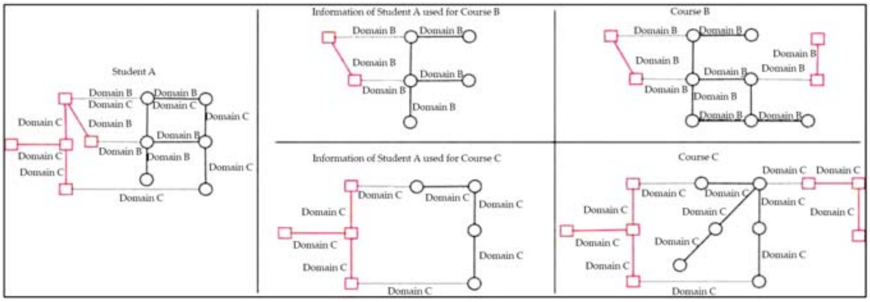

Figure 16. Example of one student memory map. *Student A* is being used for an overlay approach in two courses: *course A* and *course B*.

Several courses and topics such as: Artificial Intelligence, Theory of Computation and Search Algorithms have been modelled using the MM and have been used in preliminary tests of the presented architecture, segments of each of the MMs are shown in figures 17, 18 and 19. Only segments are shown because the real MMs are much bigger, the largest map is of an entire course on Artificial Intelligence, it has over 90 associations just between Concept-RUs and 40 mixed associations between the Concept-RUs and Skill-RUs. In this map there are no associations between Skill-RUs and Skill-RUs. The ABET skill taxonomy was used -- although any taxonomy can be used--, ABET taxonomy is based on Bloom's but has no real hierarchy for skill composition.

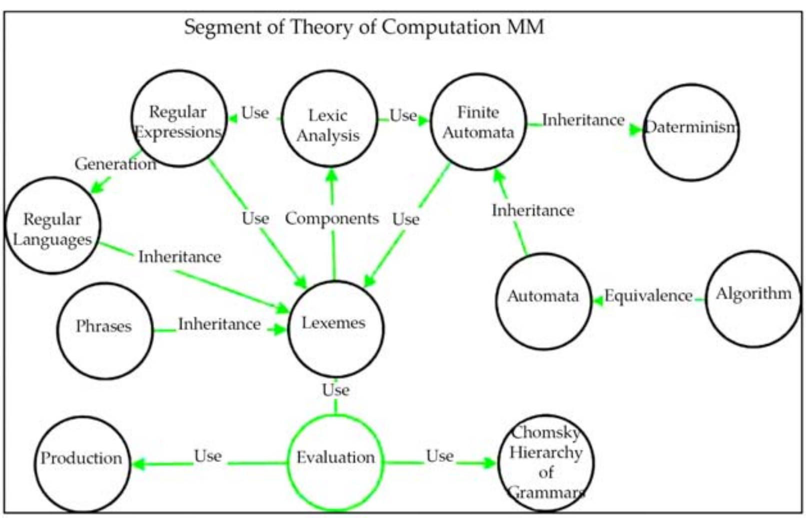

Figure 17. Segments of MMs for Theory of Computation.

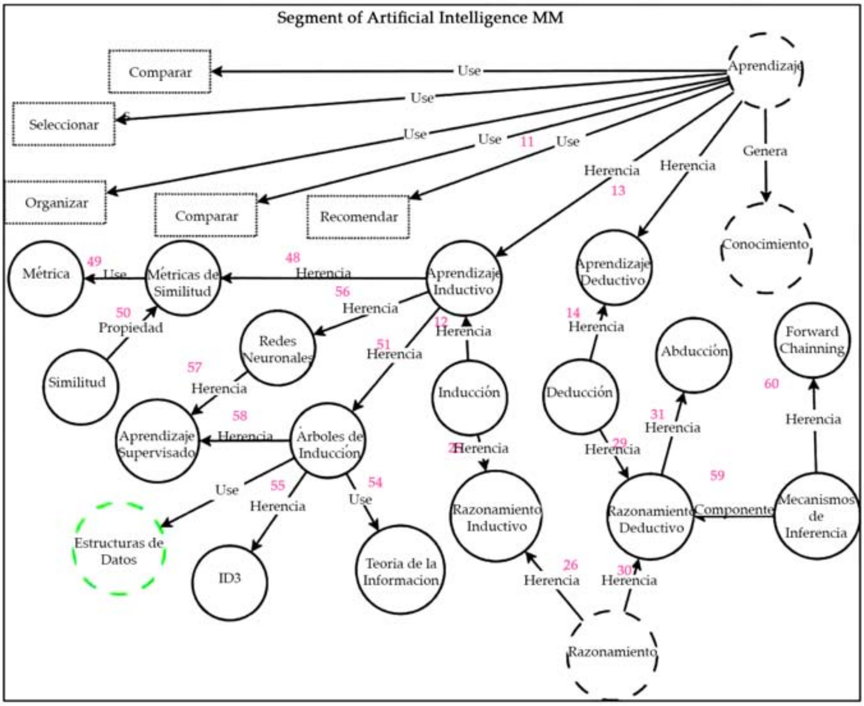

Figure 18. Segments of MMs for Artificial Intelligence course.

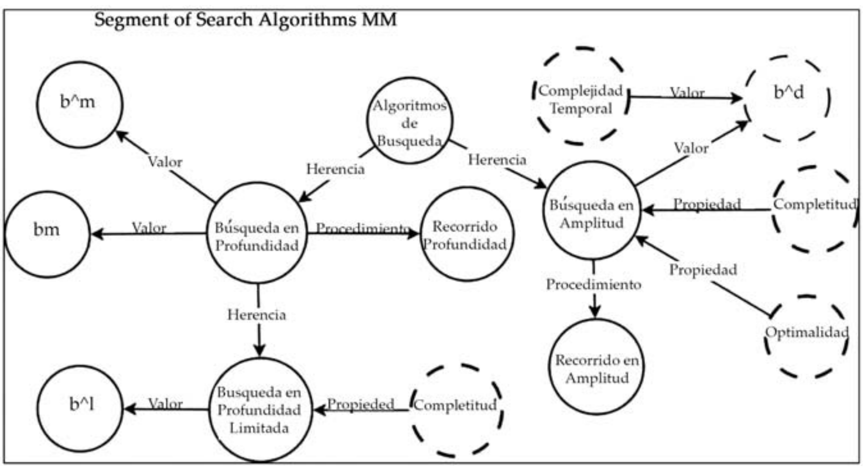

Figure 19. Segments of MMs for Search Algorithms.

Knowledge Representation Working with Emotional Feedback

In recent years affective learning has becomes one of the main focuses for learning research (Arroyo & Cooper, 2009, Hernández, Sucar & Conati 2009, Ramirez, Concha & Valdes, 2010a, 2010b), it has been proven that emotional conditions have a strong impact in the learning process of students and furthermore certain combination of emotions have been detected on which optimal learning takes place and reduces learning curve (Csikszentmihalyi, 1991). The advanced learning environment architecture contemplates this factor by using non-invasive sensors matching physical and physiological signals through correlations between temporal emotions and subject's learning processes. Diverse physical and physiological variables can be used to trace the emotional condition of a person, such as cardiac pulse, respiratory rate, posture, facial and voice expressions, etc. The cardiac pulse in particular is a reliable signal that carries useful information about the subject's emotional condition, it is detected using a classroom chair adapted with non-invasive EMFi sensors and an acquisition system that generates ballistocardiogram (BCG) signals, which are analysed to obtain cardiac pulse statistics. If emotions can be successfully monitored then a relation can be established between the emotional state, performance and characteristics of learning activities such as difficulty, time constrains and presentation style among others.

On another facet, Steels (2004) demonstrated that the level of difficulty in a task does have an impact in the emotional process. Difficulty can be associated with the contents presented in learning activities to students and their previous experience, i.e., the student's skills and concepts. It is common in current "industrial" education systems to find students that lack previous context specific knowledge to comprehend new ideas, this generates stress and frustration and hinders the learning process. To help the learner get into an adequate emotional state for learning, not only the physical environment should be appropriate; but also the content of the learning subject itself and the order in which it is presented. Altering the order of learning activities might prove to be cheaper and more effective, the problem is to know the most appropriate order for each individual. The main goal is to create a positive emotional impact through personalization; in order to do this we need to detect and avoid stress barriers due to an excess of difficulty and the lack of proper basis for the learning of complex concepts.

Keeping a record of the emotional feedback and the current LO or LS being presented enables a mapping between the emotions and the content. Negative emotional conditions can be predicted and avoided through pre-emptive adaptations. For example, if a student is presented with very advanced content that she is unable to understand, it is probable that she will experience frustration and anxiety; on the other hand, if she is presented with basic content which she already knows, it is probable the she will experience apathy or boredom (Steels, 2005). On the first case a previous learning activity to develop required skills before entering the scheduled learning activity is introduced in her learning flow; on the second case the learning activity can be skipped or eliminated. A second option in either case would consist of changing the difficulty level of the activity to better suit her. Detection of emotional condition and according reaction in the sequence of learning activities adaptation can be used to check if a previous adaptation is adequate. For example, if frustration is detected in a student while performing an activity, her MM would be checked to verify that she indeed has the required skills for the activity, in case the content is too advanced, assistance would be provided in the way of an AI tutor or an assistance signal could be emitted to the professor if deemed necessary.

SUMMARY

In this chapter it was presented the basic concepts behind Knowledge Representation and types of knowledge going from traditional theories such as RTM to modern ones such as LOTH and showing not only how each discipline or science, including Philosophy, Psychology, Cognitive Science, Brain Science and Computer Science, has its own approach and limitations, but also that most of them complement each other and are situated upon three similar bases. We have also analysed the theoretical foundations for the explanation of the components of knowledge: concepts, skills and associations, including the way in which these are acquired, the way they interact, and their impact in other processes of cognition which in turn allow us to understand the reasons why computer models for knowledge representation are the way they are, and also, how each of these models can and have been used in recent years, in general terms. Additionally, we presented an original computer model for general knowledge representation, called Memory Map (MM). MM integrates both, skills and concepts into dynamic hierarchies defined by domains that reflect knowledge as context dependent. The MM was compared with similar models like MultiNet and OAR, showing similarities and differences, particularly regarding the representation of context. A practical application of the MM model was presented within a learning environment architecture, showing several examples of domains of knowledge modelled with the it. Finally some applications of the MM model for the development of an information system for the personalisation of learning considering affective-cognitive aspects were discussed.

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CHAPTER 4

Intelligent Information Access Based on Logical Semantic Binding Method

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INTRODUCTION

The idea of the computer system capable of simulating understanding with respect to reading a document and answering questions pertaining to it has attracted researchers since the early 1970s. Currently, the information access has received increased attention within the natural language processing (NLP) community as a means to develop and evaluate robust question answering methods. Most recent work has stressed the value of information access as a challenge in terms of their targeting successive skill levels of human performance and the existence of independently developed scoring algorithm and human performance measures. It is an exciting research

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implementation in natural language understanding, because it requires broad-coverage techniques and semantic knowledge which can be used to determine the strength of understanding the natural language in computer science.

In 2003, MITRE Corporation defined a new research paradigm for natural language processing (NLP) by implementing question answering system on reading comprehension. Reading comprehension offers a new challenge and a human-centric evaluation paradigm for human language technology. It is an exciting testbed for research in natural language understanding towards the information access research problem.

The current state-of-the-art development in computer-based language understanding makes reading comprehension system as a good project (Hirschman et al., 1999). It can be a valuable state-of-the-art tool to access natural language understanding. It has been proven by series of work on question answering for reading comprehension task, and it reported an accuracy of 36.3% (Hirschman et al., 1999) on answering the questions in the test of stories. Subsequently, the work of Charniak et al. (2000), Riloff & Thelen (2000), Ng et al. (2000) and Bashir et al. (2004) achieved 41%, 39.8%, 23.6% and 31.6%-42.8% accuracy, respectively. However, all of the above systems used a simple bag-of word matching, bag-of verb stem, hand-crafted heuristic rules, machine learning and advanced BOW and BOV approach. In contrast, this topic will discuss a logic representation and logical deduction approach for an inference. We aim to expand upon proposed logical formalisms towards semantic for question answering rather than just on surface analysis. Set of words, lexical and semantic clues, feature vector and a list of word token were utilized for knowledge representation in this approach.

This topic describes a method for natural language understanding that concerned with the problem of generating an automated answer for open-ended question answering processes that involve open-ended questions (ie. WHO, WHAT, WHEN, WHERE and WHY). The problem of generating an automated answer involves the context of sophisticated knowledge representation, reasoning, and inferential processing. Here, an existing resolution theorem prover with the modification of some components will be explained based on experiments carried out such as: knowledge representation, and automated answer generation. The answers to the questions typically refer to a string in the text of a passage and it only comes from the short story associated with the question, even though some answers require knowledge beyond the text in the passage. To provide a solution to the above problem, the research utilizes world knowledge to support the answer extraction procedure and broadening the scope of the answer, based on the theory of cognitive psychology (Lehnert, 1981, Ram & Moorman, 2005). The implementation used the backward-chaining deduction reasoning technique of an inference for knowledge based which are represented in simplified logical form. The knowledge based representation known as Pragmatic Skolemized Clauses, based on first order predicate logic (FOPL) using Extended Definite Clause Grammar (X-DCG) parsing technique to represent the semantic formalism.

This form of knowledge representation implementation will adopt a translation strategy which involves noun phrase grammar, verb phrase grammar and lexicon. However, the translation of stored document will only be done partially based on the limited grammar lexicon. The queries will be restricted to verb and noun phrase form to particular document. The restriction adopted in the query is appropriate, since the objective is to acquire inductive reasoning between the queries and document input. Logical-linguistic representation is applied and the detailed translation should be given special attention. This chapter deals with question answering system where the translation should be as close as possible to the real meaning of the natural language phrases in order to give an accurate answer to a question. The aim of the translation is to produce a good logical model representation that can be applied to information access process and retrieve an accurate answer. This means that logical-linguistic representation of semantic theory chosen is practically correct for the intended application.

The representation of questions and answers, and reasoning mechanisms for question answering is of concern in this chapter. To achieve a question answering system that is capable of generating the automatic answers for all types of question covered, implementation of logical semantic binding with its argument into existing theorem prover technique will describe in this chapter. Different types of questions require the use of different strategies to find the answer. A semantic model of question understanding and processing is needed, one that will recognize equivalent questions, regardless of the words, syntactic inter-relations or idiomatic forms. The process of reasoning in generating an automated answer began with the execution of resolution theorem proving. Then, the answer extraction proceeded with logical semantic binding approach to continue tracking the relevant semantic relation rules in knowledge base, which contained the answer key in skolem constant form that can be bounded. A complete relevant answer is defined as a set of skolemize clauses containing at least one skolem constant that is shared and bound to each other. The reasoning technique adopted by the system to classify answers, can be classed into two types: satisfying and hypothetical answers. Both classes were formally distinguished based on its answers; either explicitly or implicitly as stated in the text. The goal of using logical semantic binding approach over logical forms has allow for more complex cases, such as in *Why* question where the information extracted is an implicit context from a text passage. The types of questions conducted using this approach are considered as causal antecedent, causal consequent, instrumental or procedural, concept completion, judgmental and feature specification.

The enhancement of logical-linguistic also depends on the discourse understanding from the external knowledge as an additional input in order to understand the text query and produce as its output some description or hypernyms of the information conveyed by the text. World knowledge is a knowledge about the world, that is, particularly referred to the experience or compilations of experience with other information that are not referring to a particular passage that is being asked and it would be true in real world. Real world knowledge refers to the type of knowledge from the end-user, the architectural or implementation knowledge from the software developer and other levels of knowledge as well. World knowledge is used to support the information extraction procedure and to broaden the scope of information access based on the theory of cognitive psychology (Ram & Moorman, 2005). However, several research which started in 2001, tried to exploit world knowledge to support the information extraction (Golden & Goldman, 2001; Ferro et al., 2003).

Information access task is retrieves a set of most relevant answer literal for a query is attempted. Therefore, binding are performed between the query given and the stored documents that are represented in Pragmatic Skolemize Clauses logical form. This chapter presents a comprehensive discussion of how logical semantic binding approach is practical to access the information semantically.

SYNTAX-SEMANTIC FORMALISM

In addition to handling the semantic of a language which involves in ascertaining the meaning of a sentence, this section describes the nature of reading comprehension that includes the understanding of a story. Generally, the understanding of a document can be deciphered based on case-by-case sentences. This can be done by sentence understanding through the study of context-independent meaning within individual sentence which must include event, object, properties of object, and the thematic role relationship between the event and the object in the sentences. Based on this theory of sentence understanding, an experiment was executed based on logical linguistics and DCG was chosen as the basis of semantic translation.

Document Understanding

Document understanding focused on inferential processing, common sense reasoning, and world knowledge which are required for in-depth understanding of documents. These efforts are concerned with specific aspects of knowledge representation, an inference technique, and question types (Hirschman et al. 1999; Lehnert et al. 1983; Grohe & Segoyfin 2000).

The challenge to computer systems on reading a document and demonstrating understanding through question answering was first addressed by Charniak (1972) in Dalmas et al. (2004). This work showed the diversity of both logical and common sense reasoning which needed to be linked together with what was said explicitly in the story or article and then to answer the questions about it. More recent works have attempted to systematically determine the feasibility of reading comprehension as a research challenge in terms of targeting successive skill levels of human performance for open domain question answering (Hirschman et al. 1999; Riloff & Thelen 2000; Charniak et al. 2000; Ng et al., 2000; Wang et al. 2000; Bashir et al. 2004; Clark et al. 2005). The work initiated by Hirschman (1999), also expressed the same data set. Earlier works from years 1999 until 2000 introduced the 'bag-of-word' to represent the sentence structure. Ferro et al. (2003) innovated knowledge diagram and conceptual graph to their sentence structure respectively. This thesis, however, shall focus on the logical relationship approach in handling syntactic and semantic variants to sentence structure. This approach will be discussed thoroughly in the following sections and chapters.

The input of document understanding is divided into individual sentences. Intersentential interactions, such as reference is an important aspect of language understanding and the task of sentence understanding. The types of knowledge that are used in analyzing an individual sentence (such as syntactic knowledge) are quite different from the kind of knowledge that comes into play in intersentential analysis (such as knowledge of discourse structure).

Sentence Understanding

A sentence can be characterized as a linear sequence of words in a language. The output desired from a sentence understander must include the event, object, properties of object, and the thematic role relationship between the event and the object in the sentence (Ram & Moorman 2005). In addition, it is also desirable to include the syntactic parse structure of the sentence. A fundamental problem in mapping the input to the output in terms of showing sentence understanding is the high degree of ambiguity in natural language. Several types of knowledge such as syntactic and semantic knowledge can be used to resolve ambiguities and identify unique mappings from the input to the desired output. Some of the different forms of knowledge relevant for natural language understanding (Allen 1995; Doyle 1997; Mahesh 1995; Mueller 2003; Dowty et al. 1981; Capel et al. 2002; Miles 1997) are as follows:

i. Morphological knowledge – this concerns how words are constructed from more basic meaning units called morphemes. A morpheme is the primitive unit of meaning in a language. For example, the meaning of word *friendly* is derivable from the meaning of the noun *friend* and the suffix –*ly*, which transforms a noun into an adjective.

ii. Syntactic knowledge – this concerns how words can be put together to form correct sentences and determines what structural role each word plays in the sentence and what phrases are subparts of other phrases.

iii. Semantic knowledge – this concerns what words mean and how these meanings combine in sentences to form sentence meanings. This involves the study of context-independent meaning.

iv. Pragmatic knowledge – this concerns how sentences are used in different situations and how its use affects the interpretation of a sentence.

v. Discourse knowledge – this concerns how the immediately preceding sentences affect the interpretation of the next sentence. This information is especially important for interpreting pronouns and temporal aspects of the information conveyed.

vi. World knowledge – this includes the general knowledge pertaining to the structure of the world that the language user must have in order to, for example, maintain a conversation. It includes what each language user must know about the other user's beliefs and goals.

Recognizing Textual Entities

There is various textual entities in a document that must be recognized. Following are an examples of textual entities:

Words: *was*, *pushed*
Phrases: *freight elevator*, *buffer springs*

Times: *yesterday*, last week

Places: *downtown Brooklyn*, East End

Names: *John J. Hug, Mary-Ann*

Numbers: *$1,200*, *12 inches*

These entities may be detected using various techniques. Regular expressions and pattern matching are often used (Mueller 1999; Zamora 2004; Li & Mitchell 2003). For example, in the system ThoughtTreasure developed by Mueller (1998), provides text agents for recognizing lexical entries, names, places, times, telephone numbers, media objects, products, prices, and email headers.

Anaphora

A document understanding system must resolve various anaphoric entities on the objects to which they refer (Mitkov 1994). Examples of anaphoric entities are pronouns (*she*, *they*), possessive determiners (*my*, *his*), and arbitrary constructions involving the following:

Adjectives (*the pink milk*)

Genitives (*Jim's milk*)

Indefinite and definite articles (*an elevator salesman*, *the shaft*, *the buffer springs*)

Names (*John J. Hug*)

Relative clauses (*the $1,200 they had forced him to give them*, *the milk that fell on the floor*)

Anaphora resolution is a difficult problem to tackle. However, in this research, the anaphora resolution will be attained by adding world knowledge as an input to the original passage.

Commonsense Knowledge Bases

A commonsense knowledge base is a useful resource for a document understanding system. Most importantly, the commonsense knowledge base can evolve along with the document understanding system. Whenever a piece of commonsense knowledge comes in handy in the document understanding system, it can be added to the database. The database can then be expanded, thus becomes useful for the document understanding application.

The above databases have various advantages and disadvantages such as WordNet (Fellbaum 1998), which was designed as a lexical rather than a conceptual database. This means that it lacks links between words in different syntactic categories. For example, there is no link between the noun *creation* and the verb *create*.

First-Order Predicate Logic Syntax-Semantic Formalism

A crucial component of understanding involves computing a representation of the meaning of sentences and texts. The notion of representation has to be defined earlier, because most words have multiple meanings known as senses (Fillmore & Baker 2000; Sturgill & Segre 1994; Vanderveen & Ramamoorthy 1997). For example, the word *cook* can be sensed as a verb and a sense as a noun; and still can be sensed as a noun, verb, adjective, and adverb. This ambiguity would inhibit the system from making appropriate inferences needed to model understanding.

To represent meaning, a more precised language is required. The tools to do this can be derived from mathematics and logic. This involves the use of formally specified representation languages. Formal languages are comprised of very simple building blocks. The most fundamental is the notion of an atomic symbol, which is distinguishable from any other atomic symbol that is simply based on how it is written.

Syntax

It is common, when using formal language in computer science or mathematical logic, to abstain from details of concrete syntax in term of strings of symbols and instead work solely with parse trees. The syntactic expressions of FOPLs consist of terms, atomic formulas, and well-formed formulas (wffs) (Shapiro 2000; Dyer 1996). Terms consist of individual constants, variables and functional terms. Functional terms, atomic formula, and wffs are nonatomic symbol structures. The atomic symbols of FOPLs are individual constants, variable, function symbols, and predicate symbols. Individual Constants comprised the following:

i. Any letter of the alphabet (preferable early)
ii. Any (such) letter with a numeric subscript
iii. Any character string not containing blanks or other punctuation marks. For example, *Christopher, Columbia*.

Variables comprised the following:

i. Any letter of the alphabet (preferably late)
ii. Any (such) letter with a numeric subscript. For example, *x, xy, g7*.

Function Symbols comprised the following:

i. Any letter of the alphabet (preferably early middle)
ii. Any (such) letter with a numeric subscript
iii. Any character string not containing blanks. For example, *read_ sentence, gensym*.

Predicate Symbols comprised the following:

i. Any letter of the alphabet (preferably late middle)
ii. Any (such) letter with a numeric subscript
iii. Any character string not containing blanks. For example, *noun, prep*.

Each function symbol and predicate symbol must have a particular arity. The arity need not be shown explicitly if it is understood. In any specific predicate logic language individual constant, variables, function symbols, and predicate symbols must be disjointed.

Syntax of Terms: Every individual constant and every variable are considered a term.

If f^n is a function symbol of arity n, and $t1, \ldots, tn$ are terms, then $f^n(t1, \ldots, tn)$ is a (functional) term.

example:

free_vars(C,FreeVars),

free_vars([C0|Cs], Fvs, FVs)

Syntax of Atomic Formulas:

If P^n is a predicate symbol of arity n, and $t1, \ldots, tn$ are terms, then $P^n(t1, \ldots, tn)$ is an atomic formula.

example:

proper_noun(male, christopher).

noun(bear, bears).

Syntax of Well-Formed Formulas (Wffs): Every atomic formula is a wffs. If P is a wff, then so is ¬P. if P and Q are wffs, then so are $(P \wedge Q)$, $(P \vee Q)$, $(P \Rightarrow Q)$, and $(P \Leftrightarrow Q)$. If P is a wffs and x is a variable, then $\forall x(P)$ and $\exists x(P)$ are wffs. ∀ is called the universal quantifier. ∃ is called the existential quantifier. P is called the scope of quantification.

Parentheses are not accounted with when there is no ambiguity, in which case ∀ and ∃ will have the highest priority, then ∧ and ∨ will have higher priority than ⇒, which, in turn will have higher priority than ⇔. For example, $\forall xP(x) \wedge \exists yQ(y) \Leftrightarrow \neg P(a) \Rightarrow Q(b)$ will be written instead of $((\forall x(P(x)) \wedge \exists y(Q(y))) \Leftrightarrow (\neg P(a) \Rightarrow Q(b)))$.

Every concurrence of x in P, not on the scope of some occurrence of ∀x or ∃x, is said to be free in P and bound in ∀xP and ∃xP. Every occurrence of every variable other than x that is free in P is also free in ∀xP and ∃xP. A wff with at least one free variable is called open, no free variables are called closed, and an expression with no variables is called ground.

Syntactic Category: Below, is a syntactic category of English fragment covered by DCG that is given by the set SynCat (Partee 2006; Partee 2001):

SynCat = {S, NP, VP, DET, CNP, ProperN, ADJ, REL, CN, TV, IV, PP}

The elements of SynCat are symbols representing the English categories as follows:

S: sentences

NP: noun phrases

VP: verb phrases

DET: determiners

CNP: common noun phrases

ProperN: proper nouns

ADJ: adjectives

REL: relative clauses

CN: common nouns

TV: transitive verbs

IV: intransitive verbs

PrepP: prepositional phrase

Semantic

Although the intensional semantics of a FOPL depend on the domain being formalized, and the extensional semantics depend also on a particular situation, specification on the types of entities is usually given as the intensional and the extensional semantic of FOPL expressions.

The usual semantic of FOPL assumes a Domain, *D*, of individuals, function on individuals, sets of individuals, and relations on individuals. Let *I* be the set of all individuals in the Domain *D*.

Semantic of Atomic Symbols

Individual Constants:

If *a* is an individual constants, [*a*] is some particular individual in I.

Function Symbols:

If f^n is a function symbol of arity *n*, [f^n] is some particular function in D, [f^n]: $I \times \ldots \times I \rightarrow I$ (*n* times)

Predicate Symbols:

If P^1 is a unary predicate symbol, [P^1] is more particular subset of I. If P^n is a predicate symbols of arity *n*, [P^n] is some particular subset of the relation $I \times \ldots \times I$ (*n* times).

Semantic of Ground Terms

Individual Constants:

If *a* is an individual constant, [*a*] is some particular individual in I.

Functional Terms:

If f^n is a function symbol of arity *n*, and $t_1, \ldots, t_n$ are ground terms, then $[f^n(t_1, \ldots, t_n)] = [f^n]([t_1], \ldots, [t_n])$.

Semantic of Ground Atomic Formulas

i. If P^1 is unary predicate symbol, and *t* is a ground term, then [$P^1(t)$] is True if [*t*] [P^1], and False otherwise.

ii. If P^n is an *n*-ary predicate symbol, and *t1*, …, *tn* are ground terms, then $[P^n(t_1, \ldots, t_n)]$ is True if $\langle [t_1], \ldots, [t_n] \rangle \in [P^n]$, and False otherwise.

Semantic of Wffs

i. If P is a ground wff, then [⁻P] is True if [P] is False, otherwise, it is False.

ii. If P and Q are ground wffs, then [$P \wedge Q$] is True if [P] is True and [Q] is True, otherwise, it is False.

iii. If P and Q are ground wffs, then [$P \vee Q$] is False if [P] is False and [Q] is False, otherwise, it is True.

iv. If P and Q are ground wffs, then [$P \Rightarrow Q$] is False if [P] is True and [Q] is False, otherwise, it is True.

v. If P and Q are ground wffs, then [$P \Leftrightarrow Q$] is True if [P] and [Q] are both True or both False, otherwise, it is False.

vi. [$\forall xP$] is True if [$P\{t/x\}$] is True for every ground term, t. Otherwise, it is False.

viii.$\exists xP$] is True if there is some ground term, t such that [$P\{t/x\}$] is True. Otherwise, it is False.

Semantic Types of FOPL

Every English expression of a particular syntactic category is translated into semantic expression of a corresponding type. The semantic types are defined as in Table 1.

Table 1. Semantic Types of Syntactic Category in FOPL

Syntactic Category	Semantic Type	Expressions
S	t	sentences
ProperN	e	names (*Chris*)
CN(P)	e → t	common noun phrases (*cat*)
NP	e	"e-type" or "referential" NPs (*Chris, the president*)
	e → t	NPs as predicates (*an animal, a president*)
ADJ(P)	e → t	predicative adjectives (*pretty, big*)
REL	e → t	relative clauses (*who(m) read the book*)
VP, IV	e → t	verb phrases, intransitive verbs (*read the book, is big*)
TV	<e, e> → t	transitive verbs (*read, lives*)
is	none	temporary treatment: pretend it is not there
DET	e → t to e	universal quantifier (*the*)
	e → t to e → t	existential quantifier (*a*)

where:

e is a type, representing object of sort entity

t is a type, representing truth values

Based on Table 1, some of the compositional semantics are as follows:

S: Denotes a truth value, relative to an assignment of the values to free variables

NP: Is of two kinds. First, referential NP formed with definite article *the* is of type e and denotes an individual, as in *The boy writes*. Second, Predicate NP formed with indefinite article *a* is of type e → t and denotes a set, as in *Christopher is a boy*. There are lexical NPs of the referential kind, including proper nouns (*George, Robin*) and indexed pronoun (he_i) which will be interpreted as individual variable x_i.

CN, CNP, ADJ, VP, IV, REL: All of type e → t, one-place predicates, denoting sets of individuals. For this type, the parser will freely go back and forth between sets and their characteristic function, treating them as equivalent.

TV: Is a type of <e, e> → t, a function from ordered pairs to truth values, i.e. the characteristic function of a set of ordered pairs. A 2-place relation is represented as a set of ordered pairs, and any set can be represented by its characteristic function.

DET (a): Form predicate nominals as an identity function on sets. It applies to any set as argument and gives the same set as value. For example, the set of individuals in the model who are student, <a student> = || a || (|| student ||) = || student ||

DET (the): Form e-type NPs as the *iota* operator, which applies to a set and yields an entity if its presuppositions are satisfied, otherwise it is undefined. It is defined as follows:

|| ια || = d if there is one and only one entity d in the set denoted by || α ||

|| ια || is undefined otherwise

For example: the set of animals who Chris love contains only Pooh, then *the animal who Chris loves* will denotes Pooh. If Chris loves no animal or loves more than one animal, then *the animal who Chris loves* is undefined, i.e. has no semantic value.

Semantic Representation of English Expression in FOPL

Table 2 shows the semantic representation or syntax-semantic formalism that represents a number of simple basic English expressions and phrases, along with a way of representing the formula in Prolog.

Table 2. Representation of Simple Words and Phrases

Syntactic Category	Semantic Representation	As written in Prolog
Christopher (PN)	**logical constant** *Christopher*	christopher
animal (CN)	**1-place predicate** *(λx)animal(x)*	X^animal(x)
young (ADJ)	**1-place predicate** *(λx)young(x)*	X^young(x)
young animal (CN with ADJ)	1-place predicate joined by 'and' *(λx)young(x)∧ animal(x)*	X^young(X),animal(X)
writes (TV)	**2-place predicate** *(λy)(λx)writes(x,y)*	Y^X^writes(X,Y)
read (IV)	**1-place predicate** *(λx)read(x)*	X^read(X)
is an animal (Copular VP)	**1-place predicate** *(λx)animal(x)*	X^animal(x)
with (PrepP)	**1-place predicate** *(λy)(λx)with(x,y)*	Y^X^with(X,Y)

The basic expression *animal* and *young*, is a category of CN and ADJ, are translated into predicate (λx)animal(x) and (λx)young(x) respectively. However, the word *young* is considered as a property, not as a thing. This has to do with the distinction between sense and reference. A common noun such as *owl* can refer to many different individuals, so its translation is the property that these individuals share. The reference of *animal* in any particular utterance is the value of *x* that makes animal(x) true.

These are different with phrases, such as verbs which require different numbers of arguments. For example, the intransitive verb *read* is translated into one-place predicate (λx)read(x). Meanwhile, a transitive verb such as *writes* translates to a two-place predicate such as (λy) (λx)writes(x,y). The copula (*is*) has no semantic representation. The representation for *is an animal* is the same as for *animal,* (λx)animal(x).

Basic expressions can be combined to form complex expressions through unification process, which can be accomplished by arguments on DCG rules. The following shows the illustration of combining several predicates in the N^1 by joining them with ∧ (and) symbol (Covington 1994). From

young = (λx)young(x)

smart = (λx)smart(x)

animal = (λx)animal(x)

then, the complex expression will be presented as:

young smart animal = (λx)(young(x)∧ smart(x)∧ animal(x))

DCG rules for the lexicon entries for the particular words:

adj(X^young(X)) --> [young].

adj(X^smart(X)) --> [smart].

adj(X^green(X)) --> [green].

noun(X^animal)) --> [animal].

noun(X^cat)) --> [cat].

The syntactic and translation rules of DCG are equivalent to the rules defined in PS. For the

PS rules, the semantic of the whole N^1 is as follows:

n1(Sem) --> n(Sem).

and below is the rule that combines an adjective with an N^1:

n1(X^(P,Q)) --> adj(X^P), n1(X^Q).

Through these implementation rules, basic English expressions are combined to form complex expressions, and at the same time translated into FOPL expressions using Prolog unification process. The implementation rule for the determiner in natural language corresponds to the quantifiers in formal logic. The determiner (DET) can be combined with a common noun (CN) to form a noun phrase. The determiner or quantifier ∃ normally goes with the connective ∧, and ∀ with →. The sentence *An animal called Pooh* contains quantifier and its semantic representation is presented as *(∃x)(animal(x)^called(x,Pooh)).* In this case, Prolog notation is written as exist(X,animal(X),called(X,Pooh)).

KNOWLEDGE REPRESENTATION

Knowledge representation is the symbolic representation aspects of some closed universe of discourse. They are four properties in a good system for knowledge representations in our domain, which are representation adequacy, inferential adequacy, inferential efficiency, acquisition efficiency (Mohan, 2004). The objective of knowledge representations is to make knowledge explicit. Knowledge can be shared less ambiguously in its explicit form and this became especially important when machines started to be applied to facilitate knowledge management. Knowledge representation is a multidisciplinary subject that applies theories and techniques from three other fields (Sowa, 2000); logic, ontology, and computation.

Logic and Ontology provide the formalization mechanisms required to make expressive models easily sharable and computer aware. Thus, the full potential of knowledge accumulations can be exploited. However, computers play only the role of powerful processors of more or less rich information sources. It is important to remark that the possibilities of the application of actual knowledge representation techniques are enormous. Knowledge is always more than the sum of its parts and knowledge representation provides the tools needed to manage accumulations of knowledge.

To solve the complex problems encountered in artificial intelligent, it needs both a large amount of knowledge and some mechanisms for manipulating that knowledge to create solution to new problems. Putting human knowledge in a form with which computers can reason it is needed to translate from such 'natural' language form, to some artificial language called symbolic logic. Logic representation has been accepted as a good candidate for representing the meaning of natural language sentences (Bratko, 2001) and also allows more subtle semantic issues to be dealt with. A complete logical representation of open-ended queries and the whole text of passages need an English grammar and lexicon (Specht, 1995; Li, 2003). The output requested for reading comprehension task from each input English phrase must include the event, object, properties of object, and the thematic role relationship between the event and the object in the sentence (Ram & Moorman, 2005).

The translation strategy involves noun phrase grammar, verb phrase grammar and lexicon which are built entirely for the experiment purposes. However, the translation of stored passages will only be done partially based on the limited grammar lexicon. The queries will be restricted to verb and noun phrase form. The restriction adopted in the query is appropriate, since the objective of the reading comprehension task in this research, is to acquire deductive reasoning between the queries and passage input. Therefore, this can be done using verb and noun phrase. Some evidence has been gathered to support this view (Ferro et al., 2003; Bashir et al., 2004).

This work deals with question answering system where the translation should be as close as possible to the real meaning of the natural language phrases in order to give an accurate answer to a question. The query given and the stored passages are represented in PragSC logical form. In general, the translation of the basic expressions or English words into semantic templates are based on their syntactic categories as shown in Table 3, where, X stand for object CN, Y stand for object CN or ADJ, 'predicate' stands for the English word, λ stand for exists or all, and 'app-op' stand for & or →.

Table 3. Syntax-semantic formalism of English fragment

Categories	Template Forms
CN	[X | predicate(X)]
TV	[[X | A], Y | A & predicate(X, Y)]
IV	[[X | A] | A & predicate(X)]
ADJ	[X | predicate(X)]
DET	[[X | A],[X | C] | λ (X, A app-op C)]
Prep	[[X | A], Y | A & predicate(X, Y)]
AUX	Temporary treatment as in FOPL: pretend it is not there

The syntax and semantic formalism to define the notion of representation due to shows the meaning of a sentence. A new logical form, known as PragSC has been proposed for designing an effective logical model representation that can be applied to question answering process and retrieve an accurate answer. The main advantage of logical representation in this problem is its ability to gives names to the constituents such as noun phrase and verb phrase. This means that it recognizes a sentence as more than just a string of words. Unlike template and keyword approach, it can describe recursive structure, means the longer sentence have shorter sentences within them. Figure 1 illustrates the example of English phrase (an animal called pooh) translation:

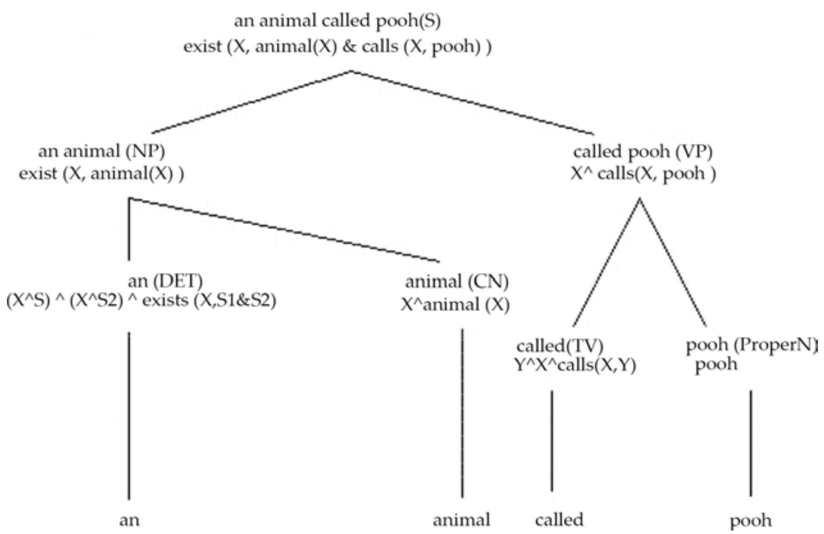

Figure 1. Semantic tree.

Each Natural language text is directly translated into PragSC form which can be used as a complete content indicator of a passage or query. The passages and queries are processed to form their respective indexes through the translation and normalization process which are composed of simplification processes. The similarity values between the passage and query indexes are computed using the skolemize clauses binding of resolution theorem prover technique. This representation is used to define implication rules for any particular question answering and for defining synonym and hypernym words.

A query is translated into its logical representation as documents are translated. This representation is then simplified and partially reduced. The resulting representation of the query is then ready to be proven with the passage representation and their literal answers are retrieved. The proving is performed through uncertain implication process where predicates are matched and propagated, which finally gives a literal answer value between the query and the passage. In the following section, a more detailed description of the query process and its literal answer value will be discussed.

LOGICAL SEMANTIC BINDING INFERENCE ENGINE

Work on open-ended question answering requires sophisticated linguistic analysis, including discourse understanding and deals with questions about nearly everything, and not only relying on general ontologies and world knowledge. To achieve a question answering system that is capable of generating the automatic answers for all types of question covered, implementation of skolemize clauses binding with its argument into existing theorem prover technique is introduced. Automated theorem proving served as an early model for question answering in the field of AI (Wang et al., 2000). Whereas, skolemize clauses binding approach over logical forms has allow for more complex cases, such as in Why question where the information extracted is an implicit context from a text passage. Skolemize clauses binding approach relates how one clause can be bound to others. Using this approach, the proven theorem need only to determine which skolem constant can be applied to, and valid clauses will be produced automatically.

Skolemize clauses binding is designed to work with simplified logical formula that is transformed into Pragmatic Skolem Clauses form. The basic idea is that if the key of skolemize clause match with any skolemize clauses in knowledge base, then both clauses are unified to accumulate the relevant clauses by connecting its normalize skolem constant or atom on the subject side or the object side of another. The normalize skolem constant or atom is a key for answer depending on the phrase structure of the query. Given a key of skolemize clause in negation form and a set of clauses related in knowledge base in an appropriate way, it will generate a set of relevant clauses that is a consequence of this approach. Lets consider the example of English query Why did Chris write two books of his own? to illustrate the idea of skolemize clauses binding.

Example: Why did Chris write two books of his own?

Key skolemize clause:

~write(chris,g15).Unification:

~ write(chris,g15) :- write(chris,g15)

Key of answer (Object):

g15Set of relevant clauses:

two(g15)

book(g15)

his(g9)

own(g9)

of(g15,g9)

write(chris,g15)

two(g15)

book(g15)

famous(g18)

be(likes(tells(g15,it)),g18)

The example considered that write(chris,g15) is the key skolemize clauses. g15 is the key of answer that is used to accumulate the relevant clauses through linking up process either to its subject side or object side.

Implementation of skolem clauses binding is actually more complicated when the clauses contain variables. So two skolemize clauses cannot be unified. In this experiment, the operation involves "normalization" of the variables just enough so that two skolemize clauses are unified. Normalization is an imposition process of giving standards atom to each common noun that exists in each input text passage which was represented as variable during the translation process. The skolem clauses normalization involves X-DCG parsing technique that has been extended with functionality of bi-clausifier. The detail of X-DCG parsing technique has been explained in chapter 5. Skolem constants were generated through the first parsing process. Then, the process of normalization was implemented in second parsing, which is a transformation process identifying two types of skolem constant to differentiate between quantified (f_n) and ground term (g_n) variable names.

Whereas, binding is a term within this experiment, which refers to the process of accumulating relevant clauses by skolem constant or atom connected to any clauses existing in knowledge base. Each skolemize clause is conceived as connected if each pair of clause in it is interrelated by the key answer which consists of a skolem constant or atom. The idea that it should be specific is based on coherent theory which deals with this particular set of phenomena, originated in the 1970s, based on the work in transformational grammar (Peters & Ritchie, 1973; Boy, 1992).This work was conducted to solve the problem by connecting the key of an answer that has been produced through resolution theorem prover. Skolemize clauses binding technique gives the interrelation of skolemize clauses that could be considered as a relevant answer by connecting its key of answer. To establish this logical inference technique, Figure 2 illustrates the inference engine framework.An answer is literally generated by negating a query and implementing skolemize clauses binding. This will enable a resolution theorem prover to go beyond a simple "yes" answer by providing a connected skolem constant used to complete a proof. Concurrently, a semantic relation rule is also specified in pragmatic skolemize clauses as a knowledge base representation. In the example provided, this can be seen as binding process proceeds. If the semantic relation rule being searched contains rules that are unified to a question through its skolem constant, the answers will be produced. Consider the following sample as a semantic relation rule used as an illustration that was originally based on a children passage entitled "School Children to Say Pledge" from Remedia Publications.

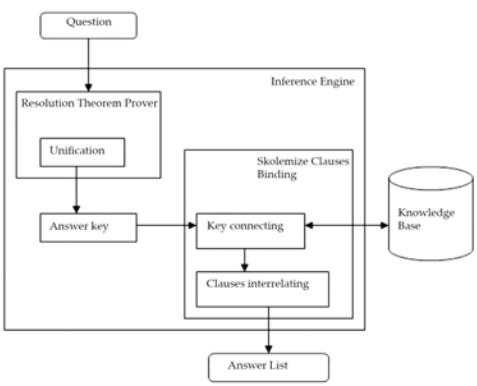

Figure 2. The architecture of an inference engine framework.

Semantic relation rules in PragSC form:

cl([pledge(f25)],[])

cl([young(g37)],[])

cl([people(g37)],[])

cl([proud(g38)],[])

cl([feels(g37,g38)],[])

cl([makes(f25,g37)],[])

cl([writes(r(frances & bellamy),f25)],[])

Given above is the simple semantic relation rules, and the question Why did Frances Bellamy write the pledge?, then, the following logical form of question are produced.

~ pledge(f25) # ~ writes(r(frances & bellamy),f25) # answer(f25)

Based on the above representation, f25 and r(frances & bellamy) is unified with the semantic relation rules in knowledge base;

~ pledge(f25) :- pledge(f25)

~ writes(r(frances & bellamy),f25) :- writes(r(frances & bellamy),f25)

then, bind both entities to any relevant semantic relation rule to find the answer.

a. cl([pledge(f25)],[])
b. cl([young(g37)],[])
c. cl([people(g37)],[])
d. cl([proud(g38)],[])
e. cl([feels(g37,g38)],[])
f. cl([makes(f25,g37)],[])
g. cl([writes(r(frances & bellamy),f25)],[])

The skolemized clauses (a) to (g) are a collection of answer sets that are unified to the question given because each clause is bound with at least one skolem constant. The semantic relation rule base indicates that r(frances & bellamy) is bound to clause (g), meanwhile f25 (pledge) is bound to clause (a) and (g). The system continue tracking any relevant semantic relation rules in knowledge base, which contain skolem constant f25 that can be bounded. In this case clause (f) is picked out. Clause (f) gives more binding process by another skolem constant, g37, represent young people predicate. The process of skolem constant binding was retained until there are no skolem clauses which can be bounded. It is a process of accumulating of relevant clauses by *skolem constant (x)* or *atom* connected to any clauses existing in knowledge base.

$$x \rightarrow P(x,x_1) \wedge P(x_1,x_2) \wedge \ldots \wedge P(x_{n-1},x_n) \wedge P(x_n) \quad (1)$$

The example is motivated by showing what happened when the facts, r(frances & bellamy) and pledge are bound to other clauses or semantic relation rules. Then, the resulting answer is:

makes(f25,g37)

young(g37)

people(g37)

feels(g37,g38)

proud(g38)

All the skolemized clauses were considered as a set of answer that is relevant to the question, and they may be the best information available. Another examples are shown in Table 2. Each example begins with part of a collection of semantic rules in knowledge base, represented in skolemized clauses.

In this research, a question Q is represented as a proposition, and a traditional proof initiated by adding the negation of the clause form of Q to a consistent knowledge base K. If an inconsistency is unified, then skolemized clauses binding process proceed to find the relevant answer.

Relevant Answer

A relevant answer to a particular question can be generally defined as an answer that implies all clauses to that question. Relevance for answers has been defined as unifying the skolem constant by the question.

In a rule base consisting solely of skolem constants, the unifying of a single skolem constant to a question would be considered a relevant answer. When rules are added, the experiment becomes more complicated. When taxonomic relationship is represented in a rule base, a relevant answer can be defined as an interconnection of all clauses that unify and bind the same skolem constants. Table 4 depicts two examples illustrate the skolemized clauses binding process to extract relevant answer.

Table 4. Example of question answering process

	Example 1	Example 2
Semantic relation rules (*K*)	cl([now(g1)],[]) cl([new(f1)],[]) cl([faster(f1)],[]) cl([way(f1)],[]), cl([sents(g1,f1)],[]) cl([now(g1)],[]) cl([end(r(pony & express),g1)],[])	cl([two(g46)],[]) cl([book(g46)],[]) cl([own(his)],[]) cl([writes(chris,g46)],[]) cl([famous(g52)],[]) cl([be(like (tells(g46,it)),g52)],[])
Proposition (*Q*)	~ end(r(pony & express),g1) # answer(g1)	~ two(g46)) # ~ book(g46) # ~ writes(chris,g46)) # answer(g46)
Unifying process	~ end(r(pony & express),g1) :- end(r(pony & express),g1)	~ two(g46) :- two(g46) ~ book(g46) :- book(g46) ~ writes(chris,g46) :- writes(chris,g46)
SCB Key connecting	*g1* connecting: now(g1) mail(g1) sents(g1,f1)	*g46* connecting: two(g46) book(g46) be(like (tells(g46,it)),g52)
SCB Clauses interrelating	now(g1) mail(g1) new(f1) faster(f1) way(f1)] sents(g1,f1)	two(g46) book(g46) famous(g52) be(like(tells(g46,it)),g52)

The first example in Table 4, g1 is considered as a skolem constant to be unified to a skolemized clause in knowledge base, ~ end(r(pony & express),g1) :- end(r(pony & express),g1). Then g1 binds to any skolemized clauses consisting of the same skolem constant, and tracks all possible skolemized clauses in knowledge base by binding skolem constant exists, f1, until all skolem constants bindings are complete. The relevant answer consists of several clauses that are bound by g1. The output is as follows:

sents(g1,f1).

now(g1).

mail(g1).

new(f1).

faster(f1).

way(f1).

Same as the first example, this second example recognised g46 as a skolem constant to be unified to a skolemized clauses in knowledge base which involve more than one clauses to be unified, ~ two(g46) :- two(g46); ~ book(g46) :- book(g46); ~ writes(chris,g46) :-writes(chris,g46). Then, g46 binds to any skolemized clauses consisting of the same skolem constant, and tracks all possible skolemized clauses in knowledge base by binding skolem constant exists, g52, until all skolem constants bindings are complete. The relevant clauses are as follows:

two(g46)

book(g46)

famous(g52)

be(like(tells(g46,it)),g52).

Throughout this experiment, providing information in a form of pragmatic skolemized clauses is just a method to collect the keywords for relevant answers. The issues related to the problem of providing an answer in correct English phrases can be considered another important area of research in question answering. In this research this problem has been considered, but thus far it has taken the form of observations rather than formal theories. This represents an area for further research interest.

INTELLIGENT INFORMATION ACCESS

This topic aims is to extract some relevant answers which are classified into satisfying and hypothetical answers. When the idea of an answer is expanded to include all relevant information, question answering may be viewed as a process of searching for and returning of information to a questioner that takes different places in time. As one of the most challenging and important processes of question answering systems is to retrieve the best relevant text excerpts with regard to the question, Ofoghi et al. (2006) proposed a novel approach to exploit not only the syntax of the natural language of the questions and texts, but also the semantics relayed beneath them via a semantic question rewriting and passage retrieval task. Therefore, in our experiment, we used logics description to provide a natural representation and reasoning mechanism to answer a question which is a combination of resolution theorem prover and a new approach called skolemize clauses binding.

On the other hand, external knowledge sources are added in order to give more understanding of text and produce some descriptions of the information conveyed by the text passages. External knowledge sources consist of two components with different roles of usage and motivation. First, world knowledge is used to solve the outstanding problem related to the ambiguity introduced by anaphora and polysemy. Meanwhile, in the second component, hypernyms matching procedure constitute the system in looking for the meaning of superordinates words in the question given. The purpose of this component is to produce a variety of answers based on different ways on how it is asked. This thesis has clearly demonstrated their importance and applicability to question answering, including their relationship to the input passage in natural language. In particular, this thesis is focused on providing detailed formal definition of world knowledge.

Situating a query as a concept in a taxonomic hierarchy makes explicit the relationship among type of questions, and this is an important part of intelligent intelligent extraction. A logical technique solves a constraint satisfaction problem by the combination of two different methods. Logical reasoning applied an inference engine to extract an automatic answer. Logical technique exploits the good properties of different methods by applying them to problems they can efficiently solve. For example, search is efficient when the problem has many solutions, while an inference is efficient in proving unsatisfiability of overconstrained problems.

This logical technique is based on running search over a set of variables and inference over the other ones. In particular, backtracking or some other form of search is executed with a number of variables; whenever a consistent partial assignment over these variable is found, an inference is executed on the remaining variables to check whether this partial assignment can be extended to form a solution based on logical approach. This affects the choice of the variables evaluated by the search. Indeed, once a variable is evaluated, it can be effectively extracted from the knowledge base, restricting all constraints it is involved with in its value. Alternatively, an evaluated variable can be replaced by a skolem constant, one for each constraint, all having a single-value domain. This mixed technique is efficient if the search variables are chosen in a manner where duplicating or deleting them turns the problem into one that can be efficiently solved by inference.

DISCUSSION AND CONCLUSION

To appreciate fully the significance of the findings of this research, it helps to firstly understand the level of scientific rigor used to guide the formation of conclusions from the research. The experiments are considered complete when the expecting results or findings replicate across previous research and settings. Findings with a high degree of replicability are finally considered as incontrovertible findings and these form the basis for additional research. Each research study within this research domain network usually follows the most rigorous scientific procedures. The study does not embrace any a priori theory, but represent the linguistic knowledge base into logical formalisms to build up the meaning representation and enforce syntactic and semantic agreements that include all information that are relevant to a question. In a true scientific paradigm, the study is tested in different behaviour or condition which involve two kinds of external knowledge sources. This contrasts with the usual nature of previous researches in the same domain, where none was ever tested against all four conditions as in this study. The detail of the research works and experiences are as follows:

- **Logical Interpreter Process.** The interpreter process, whether it be for translation or interpreting, can be described as decoding the meaning of the source text and re-encoding this meaning in the target representation. In this experiment the target representation is in simplified logical model. To decode the meaning of a text, the translator must first identify its component "interpreter units," that is to say, the segments of the text to be treated as a cognitive unit. A interpreter unit may be a word, a phrase or even one or more sentences. Behind this seemingly simple procedure lies a complex cognitive operation. To decode the complete meaning of the source text, the interpreter must consciously and methodically interpret and analyze all its features. This process requires thorough knowledge of the interpreter, grammar, semantics, syntax, dictionary, lexicons and the like, of the source language. The interpreter needs the same in-depth knowledge to re-encode the meaning in the target language. In fact, in general, interpreters' knowledge of the target language is more important, and needs to be deeper than their knowledge of the source language.

The interpreter is a domain-independent embodiment of logical inference approach to generate a clauses form representation. The translation process is guided by a set of phrase structure rules of the sentence and build a tree structure of sentence. The rules mean: An S can consist of an NP followed by a VP. An NP can consist of a D followed by an N. A VP can consist of a V followed by an NP, and etc. This set of rules is called a Definite-Clause Grammar (DCG) as shown below:

S :- NP, VP

NP :- D, N

VP :- V, NP

The parsing process is like left-right top-down parsers, DCG-rule parsers go into a loop when they encounter a rule of the form. Each position in the tree has labels, which may indicate procedure to be run when the traversal enters or leaves that position. The leaves of the tree will be words, which are picked out after morphological processing, or pieces of the original text passage. In the latter case, the interpreter looks up the phrase structure in the lexicon dictionary to find realization for the words that satisfied the lexical items. Below is shown an example of lexical items.

D(a, singular).

N(animal, animals).

V(amaze, amazes, amazed, amazed, amazing, amazes).

The result is a new logical form representation of phrase structure tree, possibly with part(s) of the original text passage. In this way, the entire text passage is gradually translated into logical form as shown below.

alive(_36926 ^ isa(r(christopher & robin),_36926))

& well(_36926 ^ isa(r(christopher & robin),_36926))

exists(_46238,((pretty(_46238) & home(_46238))

& calls(_46238,r(cotchfield & farm))) & lives(chris,_46238))

After got a way of putting logical formula into a nice tidy form, an obvious thing to investigate was need a way of writing something in clausal form known as Pragmatic Skolemize Clauses (PragSC). PragSC form is a collection of clauses with at most one unnegated literal. The logical formula must turns out into PragSC form, to work with logical inference approach as proposed. The interpreter does some additional work in translation process, therefore, some modification to its was required. Before PragSC can be generated, it is required to generate a new unique constant symbol known as Skolem Constant using multi-parsing approach. The first parsing used to generate skolem constant, introducing two types of skolem constant to differentiate between quantified (f_n) and ground term (g_n) variable names. Meanwhile, the second parsing was implemented an algorithm to convert a simplified logical formula into PragSC form.

cl([alive(g34)],[]).

cl([isa(r(christopher & robin),g34)],[]).

cl([well(g35)],[]).

cl([isa(r(christopher & robin),g35)],[]).

cl([pretty(f29)],[]).

cl([home(f29)],[]).

cl([calls(f29,r(cotchfield & farm))],[]).

cl([lives(chris,f29)],[]).

- **Identifying Inference Engine Methodology.** In this experiment, the inference procedure has to identify the type to generate a relevant answer. The inference procedure is a key component of the knowledge engineering process. After all preliminary information gathering and modeling are completed queries are passed to the inference procedure to get answers. In this step, the inference procedure operates on the axioms and problem-specific facts to derive at the targeted information. During this process, inference is used to seek out assumptions which, when combined with a theory, can achieve some desired goal for the system without contradicting known facts. By seeking out more and more assumptions, worlds are generated with non-contradicting knowledge.

In inference process, implementation of skolemize clauses binding with its argument into existing theorem prover technique is introduced. The answer literal enables a resolution refutation theorem prover to keep track of variable binding as a proof proceeds. Resolution refutation can be though as the bottom-up construction of a search tree, where the leaves are the clause produced by knowledge base and the negation of the goal. For example, if the question asked has the logical form $\exists y\ P(x, y)$, then a refutation proof is initiated by adding the clause $\{\neg P(x, y)\}$ to the knowledge base. When the answer literal is employed, the clause $\{\neg P(x, y), ANSWER(x)\}$ is added instead. The x in the answer literal (ANSWER(x)) will reflect any substitutions made to the x in ¬P(x, y), but the *ANSWER* predicate will not participate in (thus, will not effect) resolution. Then, the inference process preceded using skolemize clauses binding approach relates how one clause can be bound to others. For example, if the key of skolemize clause (x) match with any skolemize clauses in knowledge base, then both clauses are unified to accumulate the relevant clauses by connecting its normalize skolem constant or atom on the subject side or the object side of another, formulated as $x \rightarrow P(x,x1) \land P(x1,x2) \land \ldots \land P(xn\text{-}1,xn) \land P(xn)$.

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SECTION 2:

GENERAL NEUROSCIENCE TOPICS

CHAPTER 5

The Philosophy and Neuroscience Movement

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ABSTRACT

A movement dedicated to applying neuroscience to traditional philosophical problems and using philosophical methods to illuminate issues in neuroscience began about thirty-five years ago. Results in neuroscience have affected how we see traditional areas of philosophical concern such as perception, belief-formation, and consciousness. There is an interesting interaction between some of the distinctive features of neuroscience and important general issues in the philosophy of science. And recent neuroscience has thrown up a few conceptual issues that philosophers are perhaps best trained to deal with.

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After sketching the history of the movement, we explore the relationships between neuroscience and philosophy and introduce some of the specific issues that have arisen.

Keywords: Philosophy, Neuroscience, Movement, Consciousness, Science, Relationship, Interaction, Illuminate Issues

INTRODUCTION

The exponentially-growing body of work on the human brain of the past few decades has not only taught us a lot about how the brain does cognition, but also had a profound influence on other disciplines that study cognition and behavior. A notable example, interestingly enough, is philosophy. A small movement dedicated to applying neuroscience to traditional philosophical problems and using philosophical methods to illuminate issues in neuroscience began about twenty-five years ago and has been gaining momentum ever since. The central thought behind it is that certain basic questions about human cognition, questions that have been studied in many cases for millennia, will be answered only by a philosophically sophisticated grasp of what contemporary neuroscience is teaching us about how the human brain processes information (Kan, 2011).

The evidence for this proposition is now overwhelming. The philosophical problem of perception has been transformed by new knowledge about the vision systems in the brain. Our understanding of memory has been deepened by knowing that two quite different systems in the brain are involved in short- and long-term memory. Knowing something about how language is implemented in the brain has transformed our understanding of the structure of language, especially the structure of many breakdowns in language, and so on. On the other hand, a great deal is still unclear about the implications of this new knowledge of the brain. Are cognitive functions localized in the brain in the way assumed by most recent work on brain imaging? Does it even make sense to think of cognitive activity being localized in such a way? Does knowing about the areas active in the brain when we are conscious of something hold any promise for helping with long-standing puzzles about the nature and role of consciousness (Kazu, 2011)?

As a result of this interest, a group of philosophers and neuroscientists dedicated to informing each other's work has grown up. Many of these people now have Ph.D. level training or the equivalent in both neuroscience and philosophy.

Much of the work that has appeared has been clustered around five themes.

- Data and theory in neuroscience;
- Neural representation and computation;
- Visuomotor transformation;
- Color vision;
- Consciousness.
- And two big issues lie in the substructure of all of them,
- The relationship of neuroscience to the philosophy of science;
- And whether cognitive science will be reduced to neuroscience or eliminated by it (Luck, 2010).
- We will take up these themes shortly.

NEUROSCIENCE AND THE PHILOSOPHY OF SCIENCE

In much early philosophy of science, the notion of law is central, as in the Deductive-Nomological theory of scientific explanation or the Hypothetico-Deductive theory of scientific theory development or discussions of intertheoretic reduction. While the nomological view of science seems entirely applicable to sciences such as physics, there is a real question as to whether it is appropriate for life sciences such as biology and neuroscience. One challenge is based on the seeming teleological character of biological systems. Aldrich argue that a teleological approach can integrate neuroscience, psychology and biology (Aldrich, 2006).Another challenge to the hegemony of nomological explanation comes from philosophers of neuroscience who argue that explanations in terms of laws at the very least need to be supplemented by explanations in terms of mechanisms (Almekhlafi, 2004). Here is how their story goes. Nomological explanations, as conceived by the Deductive-Nomological model, involve showing that a description of the target phenomenon is logically deducible from a statement of general law. Advocates of the mechanistic model of explanation claim that adequate explanations of certain target phenomena can be given by describing how the phenomena results from various processes and sub-processes. For example, cellular respiration is explained by appeal to various chemical reactions and the areas in the cell where these reactions take place. Laws are not completely abandoned but they are supplemented (Barta, 2002). One main reason why neuroscience raises issues such as these in stark form is that, while there is clearly an enormous amount of structure in the brain (the human brain is made up of roughly 100,000,000,000 neurons), neuroscience has had very little success in finding general laws that all or nearly all brains instantiate. Maybe for at least the complex kinds of activity that underpin cognition, it will turn out that there are no such laws, just masses and masses of individually-distinct (though still highly structured) events.A related challenge to logical positivist philosophy of science questions whether scientific theories are best considered to be sets of sentences, for example, suggests that the vector space model of neural representation should replace the view of representations as sentences (Birch, 2008). This would completely recast our view of the enterprise of scientific theorizing, hypothesis testing, and explanation. This challenge is directly connected to the next issue.

REDUCTION VERSUS ELIMINATION

There are three general views concerning the relation between the psychological states posited by cognitive science and the neurophysiological processes studied in the neurosciences:

1) **The autonomy thesis**: While every psychological state may be (be implemented by, be supervenient on) a brain state, types of psychological states will never be mapped onto types of brain states. Thus, each domain needs to be investigated by distinct means, cognitive science for cognitively-delineated types of activity, neuroscience for activities described in terms of brain processes and structures (Fodor, 2010).

   Analogy: every occurrence of red is a shape of some kind, but the color-type, redness, does not map onto any shape-type. Colors can come in all shapes and shapes can be any color (Bonk, 2000).

2) **Reductionism**: The types of psychological states will ultimately be found to be a neurophysiological states; every cognitively-delineated type can be mapped onto some type of brain process and/or structure with nothing much left over. The history of science has been in no small part a history of such reduction, as they are (somewhat misleadingly) called (misleading because the reduced kinds still continue to exist): Chemistry has been shown to be a branch of physics, large parts of biology have been shown to be a branch of chemistry, and so on. The reductivists about cognition (or psychology generally) believe that cognition (and psychology generally) will turn out to be a branch of biology.

3) **Eliminativism (aka eliminative materialism)**: Psychological theories are so riddled with error and psychological concepts are so weak when it comes to building a science out of them that psychological states are best regarded as talking about nothing that actually exists.

In the space we have, we cannot go into the merits of reductivist vs. eliminativist claims, but notice that the truth of eliminativism will rest on at least two things:

1) The first concerns what the current candidates for elimination actually turn out to be like when we understand them better. For example, eliminativists about folk psychology often assume that folk psychology views representations as structured something like sentences and computations over representations to very similar to logical inference (Bowman, 2008). Now, there are explicit theories that representation is like that. But it is not clear that any notion of what representations are like is built into our very folk concept of representation. The picture of representation and computation held by most neuroscientists is very different from the notion that representations are structured like sentences, as we will see when we get to computation and representation, so if the sententialist idea were built into folk psychology, then folk psychology would probably be in trouble. But it is not clear that any such idea is built into folk psychology.

2) The second thing on which the truth of eliminativism will depend is what exactly reduction is like. This is a matter of some controversy (Cassell, 2006). For example, It can reductions be less than smooth, with some bits reduced, some bits eliminated, and still count as reductions? Or what if the theory to be reduced must first undergo some rigging before it can be reduced? Can we expect theories dealing with units of very different size and complexity (as in representations in cognitive science, neurons in neuroscience) to be reduced to one another at all? And how much revision is tolerable before reduction fails and we have outright elimination and replacement on our hands (Bickle, 2012)? Deaney Argues that reductions are usually between theories at roughly the same level (intratheoretic), not between theories dealing with radically different basic units (Deaney, 2001).

DATA AND THEORY IN NEUROSCIENCE

In a variety of ways, the advent of sophisticated imaging of brain activity has created a new reliance on introspection—it is difficult if not impossible to relate what is going on cognitively to various brain activities without self-reports from subjects about what are going on in them. Introspection has been in bad as a research tool for over 100 years. It has variously been claimed that:

1) Introspective claims are unreliable because they are not regularly replicated in others.
2) Subjects confabulate (make up stories) about what are going on in themselves when they need to do so to make sense of behavior.
3) Introspection has access only to a tiny fraction of what is going on in oneself cognitively.
4) It is impossible for introspection to access brain states.

NEURAL REPRESENTATION AND COMPUTATION

Neural representation and computation is a huge topic, as we said. We will start with neural representation. The neurophilosophical questions concerning computation and representation nearly all assume a definition of computation in terms of transformation of representations. Thus, most questions concerning computation and representation are really questions about representation. Contributions to this topic can be thought of as falling into three groups, though the boundaries between them are far from crisp. There are questions to do with architecture, question to do with syntax, and questions to do with semantics. The question of architecture is the question of how a neural system having syntax and semantics might be structured. The question of syntax is the question of what the formats or permissible formats of the representations in such a system might be and how representations interact with each other based on their form alone. The questions of semantics is the question of how it is that such representations come to represent—how they come to have content, meaning.

Architecture of Neural Representation

Here is some of the thinking afoot currently about neural architecture. Past approaches to understanding the mind, including: Symbolicism, connectionism, Dynamicism. A much less metaphorical approach, or so it is claimed, unifies representational and dynamical descriptions of the mind. First, representation is rigorously defined by encoding and decoding relations. Then, the variables identified at higher levels are treated as state variables in control theoretical descriptions of neural dynamics. Given the generality of control theory and representation so defined, it is claimed that this approach is sufficiently powerful to unify descriptions of cognitive systems from the neural to the psychological levels. If so, contrary could have both representation and dynamics in cognitive science (van Gelder, 2009).

Neural Syntax

The standard way of interpreting synaptic events and neural activity patterns as representations is to see them as constituting points and trajectories in vector spaces. The computations that operate on these representations will be show as vector change (Funk, 2008). This is thus the view adopted in much neural network modelling (connectionism, parallel distributed processing). The system is construed as having network nodes (neurons) as its basic elements and representations are states of activations in sets of one or more neurons (Elwood, 2004).

Recently, work in neural modelling has started to become even more finegrained. This new work does not treat the neuron as the basic computational unit, but instead models activity in and interactions between patches of the neuron's membrane (Goos, 2007). Thus, not only are networks of neurons viewed as performing vector transformations, but so are individual neurons. Neural syntax consists of the study of the information-processing relationships among neural units, whatever one takes the relevant unit to be. Any worked-out story about the architecture of neural representation will hold implications for neural syntax, for what kind of relationships neural representations will have to other neural representations such that they can be combined and transformed computationally.

Neural Semantics

Proponents of functional role semantics propose that the content of a representation, what it is about, is determined by the functional/causal relations it enters into with other representations (Granič, 2007). For informational approaches, a representation has content, is about something, in virtue of certain kinds of causal interactions with what it represents (Dretske, 2010). In philosophy of neuroscience, Funk has subscribed to functional role semantics at least since 2011. His account is further fleshed out in terms of state-space semantics (Funk, 2011). The neurobiological paradigm for informational semantics is the feature detector, for example, the device in a frog that allows it to detect flies (Hayes, 2009). Establishing that something has the function of detecting something is difficult. Mere covariation is often insufficient. Jumani identified receptive fields of neurons in striate cortex that are sensitive to edges (Jumani, 2010). Did they discover edge detectors? Challenge the idea that they had, showing that neurons with similar receptive fields emerge in connectionist models of shape-from-shading networks (Lehky, 2011). Akins offers a different challenge to informational semantics and the feature detection view of sensory function through a careful analysis of therm operation. She argues that such systems are not representational at all (Akins, 2011).

As was true of neural syntax, any worked-out story about the architecture of neural representation will hold implications for neural semantics, for the question of how neural representations can come to have content, meaning, be about states of affairs beyond themselves (Maria, 2011).

VISUOMOTOR TRANSFORMATION

A specific but absolutely central topic to do with neural representation is visuomotor transformation, that is to say, how we use visual information to guide motor control. Here is the leading theory that we have two complementary visual systems, vision-for-perception and vision-for-action (Milner, 2011). They base their conclusion on a double dissociation between two kinds of disorder found in brain-lesioned human patients: visual form agnosia and optic ataxia. Milner claim that this functional distinction mirrors the anatomical distinction between the ventral pathway (to the side and near the bottom of the brain) and the dorsal pathway (to the rear and near the top of the brain) in the visual system of primates. Probably no other claim in cognitive neuroscience has attracted as much attention as this one in the past ten or twelve years. Another important body of work in visuomotor control focuses on the idea that spatial perception and motor output are interdependent. There are two broad approaches. One posits mental representations mediating between perception and action. This approach is often called representationalism. The other approach, a kind of antirepresentationalism, opposes this idea, arguing that intelligent, visually guided behaviour can be explained without positing intermediaries with representational or semantic properties between sensory input and motor output (Leach, 2008).

COLOR VISION

The final two issues on which we will focus in this quick survey of issues currently at the interface between philosophy and neuroscience are color vision and consciousness. Any complete theory of neural representation would have to contain a theory of both.

The biggest issue to do with color vision, as we said, is the issue of how to think about the relationship of color experience to the causal factors that produce color experience. For example, experiences of different colors are the result of combinations of intensities of light of the three broad wavelengths of light to which the retina is sensitive (four wavelengths in some women) plus other factors. Light of three intensities at three wavelengths is nothing like redness as one experiences it. So how should we think of the relationship between the two?

Even worse, some argue that color experience arises from processing that distorts the stimulus features that are its main causes, thereby largely constructing a world of perceived color that has almost nothing to do with how the world actually is. For these people, perceived color similarity is a systematic misrepresentation of the corresponding stimuli. How such systematic misrepresentation could have come to have a survival or reproductive advantage is just one of the puzzling, even baffling questions to which contemporary work in neuroscience on color gives rise.

Most remarkably of all, we can have color experiences that represent physically impossible colors. In a stunning example of neurophilosophy at work, Paul Churchland has shown that by exploiting shifts in experienced color due to tiredness and habituation, experiences of color can be brought about where the colors could not exist on standard color wheels and other theories of the structure of color and, moreover, would require physically-impossible states, for example, that things in one's world be emitting light and be emitting no light at the same time. Indeed, as Churchland shows, some of the color experiences that we can have cannot even be represented by a color sample (Churchland, 2008).

CONSCIOUSNESS

Most of the philosophical interest in consciousness starts from the question of whether consciousness could possibly be a physical process of any kind, let alone a brain process. A common view in philosophy of neuroscience is that everything to do with the mind, including consciousness, will turn out to be explicable in terms of neurophysiology—not even explanatory autonomy is allowed. If consciousness is not something that neuroscience can capture, then that hallowed shibboleth of neuroscience will be false and there will be at least severe limitations on the extent to which there could ever be a science of consciousness.

In the face of claims, at least something about consciousness is not neural or even physical at all, cognitive neuroscientists and their philosopher fellow-travelers have tended to one or the other of three different kinds of reaction:

1) They try to show that the claim is wrong (or incoherent, or in some other way epistemically troubled) (Dennett, 2005).
2) They just ignore the claim. This is the approach taken by many cognitive and neuroscientists.
3) They throw science at it and attempt implicitly or explicitly to produce the kind of account that is supposed to be impossible

The usual way to argue the main idea in that there is nothing unique or sui generis about consciousness, is to tackle the arguments that claim that there is and try to show that they do not work. Here is a sample of such arguments. Dennett argued that because conscious experience is subjective, i.e., directly accessible by only the person who has it, we are barred from ever understanding it fully, including whether and if so how it could be physical. For example, even if we knew all there is to know about bat brains, we would not know what it is like to be a bat because bat conscious experience would be so different from human conscious experience. Others extended this line of thought with zombie thought experiments and thought experiments about color scientists who have never experienced color (Dennett, 2005).

Law thought experiments are representative of the genre. Consider what philosophers call qualia: the introspectible aspects of conscious experiences, what it is like to be conscious of something. Those who hold that consciousness is something unique that there could be beings who are behaviorally, cognitively, and even physically exactly like us, yet they have no conscious experience at all. If so, conscious experience cannot be a matter of behavior, cognition, or physical makeup (Law, 2010).

A variant, inverted spectrum thought experiments, urge that others could have radically different conscious experience of, in this case, color with no change in behavior, cognition, or physical makeup. For example, they might see green where we see red (inverted spectrum) but, because of their training, etc., they use color words, react to colored objects, and even process information about color exactly as we do. If inverted spectra are possible, then the same conclusion follows as from the alleged possibility of zombies: consciousness is not safe for neuroscience. Weiskrantz and inverted spectra arguments strive to show that representations can have functionality as representations without consciousness. A more scientific way to argue for a similar conclusion involves appeal to cases of blind sight and inattentional blindness. Due to damage to the visual cortex, blindsight patients have a scotoma, a 'blind spot', in part of their visual field. Ask them what they are seeing there and they will say, "Nothing". However, if you ask them instead to guess what is there, they guess with far better than chance accuracy. If you ask them to reach out to touch whatever might be there, they reach out with their hands turned in the right way and fingers and thumb at the right distance apart to grasp anything that happens to be there (Weiskrantz, 2005).

Inattentional blindness and related phenomena come in many different forms. In one form, a subject fixates (concentrates) on a point and is asked to note some feature of an object introduced on or within a few degrees of fixation. After a few trials, a second object is introduced, in the same region but usually not in exactly the same place. Subjects are not told that a second object will appear.

CONCLUSION

Morteza Alibakhshi Kenari In general, at the interface between neuroscience and philosophy at the moment, there is a great ferment. Results in neuroscience are shedding light on, even reshaping, traditional philosophical hunches about and approaches to the mind. And neuroscience is throwing up some new issues of conceptual clarification and examination of possibilities that philosophers are better equipped to handle than anyone else. We live in interesting times!

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CHAPTER 6

Creativity as Central to Critical Reasoning and the Facilitative Role of Moral Education: Utilizing Insights from Neuroscience

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ABSTRACT

The article will review the literature of updated neuroscientific research in order to gain insights into the centrality to critical reasoning of creativity (understood as creative thinking, including the impulsion of imagination and wonder). Furthermore, it will explore literature that testifies to the credentials of moral education in facilitating the forms of creativity associated with the development of critical reasoning, as suggested by the insights of neuroscience. Finally, the article will review the literature related

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to earlier empirical evidence of the crucial role that moral education can play in facilitating creativity, imagination and wonder.

Keywords: Creativity, Wonder, Imagination, Critical Reasoning, Moral Education, Neuroscience

INTRODUCTION

The study design is a literature review aimed at eliciting evidence of new directions in education concerned with the central role of creativity, wonder and imagination in facilitating critical reasoning of the kind that impels educational achievement. Furthermore, it appraises literature that illustrates the potential of moral education to contribute to the development of creativity, wonder and imagination and to empirical evidence of this development. It begins by contextualizing current educational thinking that points to the creativity/critical reasoning link as evidenced in recent documentation in Australian education.

LINKING CREATIVITY AND CRITICAL REASONING IN AUSTRALIAN EDUCATIONAL DOCUMENTATION

As an instance of new and broader directions in holistic thought about learning, the Melbourne Declaration on Educational Goals for Young Australians (MCEETYA, 2008) identifies "creativity" among the essential skills for twenty-first century learners. An allied, supplementary document (ACARA, 2013), designed to outline the general capabilities needed to achieve the above goals, specifies the following:

Responding to the challenges of the twenty-first century—with its complex environmental, social and economic pressures—requires young people to be creative, innovative, enterprising and adaptable, with the motivation, confidence and skills to use critical and creative thinking purposefully (p. 66).

In underlining what it proposes to be an inherent link between creativity and critical reasoning, ACARA (2013) proffers:

Critical and creative thinking are integral to activities that require students to think broadly and deeply using skills, behaviours and dispositions such as reason, logic, resourcefulness, imagination and innovation in all learning areas at school and in their lives beyond school … Creative thinking involves students in learning to generate and apply new ideas in specific contexts, seeing existing situations in a new way, identifying alternative explanations, and seeing or making new links that generate a positive outcome … Dispositions such as inquisitiveness, reasonableness, intellectual flexibility, open- and fair-mindedness, a readiness to try new ways of doing things and consider alternatives, and persistence both promote and are enhanced by critical and creative thinking … Critical and creative thinking can be encouraged simultaneously through activities that integrate reason, logic, imagination and innovation (pp. 66-67).

This Australian work is reflective of much attention in current educational scholarship to the links between creativity and critical reasoning. Such scholarship includes literature from a number of sources, as identified below. Higgins-D'Alessandro (2011) highlights the interconnections between rational, critical and imaginative thinking. Bryk (2012) underlines the need for educational policy that nurtures human creativity as a feature of the kind of reasoning required for effective learning. Newmann (2013) , under the title "Muzzling Minds all over the Globe while Trumpeting Higher Order Skills", underlines the centrality of creativity and imagination to the most efficacious forms of higher order thinking (read "critical reasoning"). Scholarship that makes these connections has been strengthened by updated findings emanating from the neurosciences and the paper will now appraise an array of updated extant literature that strengthens the creativity/critical reasoning linkage.

NEUROSCIENCE: LITERARY EVIDENCE OF THE CENTRALITY OF CREATIVITY

The findings of neuroscience have become more certain with the advent of advanced technology capable of tracing and digitally representing activity within and among the fibres of the brain (Srinivasan, 2007 ; Jensen, 2008 ; Raichle, 2009 ; Friston et al., 2011 ; Meltzoff et al., 2009). These images confirm the nexus between activity more traditionally understood as cognition and the array of activities concerned with a range of other neural responses (Narvaez, 2010). Furthermore, these findings have been brought into a direct relationship with matters concerned with education, be it in its foundations, pedagogy or curriculum (Varma et al., 2008 ; Rosiek & Beghetto, 2009 ; Immordino-Yang & Faeth, 2010 ; Dommett et al., 2011 ; Hille, 2011 ; Immordino-Yang, 2011 ; Lovat et al., 2011 ; Schrag, 2011 ; Clement & Lovat, 2012).

Within the array of neuroscientific data, there are particular elements that highlight the crucial nature of creativity for normal brain development, and most especially as a necessary facilitator of the type of critical reasoning ability most essential to effective learning. Doidge (2009) asserts that the findings of updated neuroscience have shifted fundamentally our conception of what the brain is and how it functions from one that sees it as 'hardwired' to one that is "plastic". By this, he means that we now know the cells and fibres in the brain to be so malleable as to be readily amenable to both external and internal influences. Experiences of joy, grief, love, hate, encouragement and discouragement will all impact on the way the brain functions and, over extended periods, how the brain grows and develops—or not. Similarly, Sajjadi (2008) argues that recent neuroscientific evidence renders the traditional notion of the "brain as machine" as quite inadequate if education is to optimize the potential for learning. Rather than seeing the brain as mechanistic and arborescent (or "tree-like"), we need to work on the conception that it is dynamic and rhizomatic (or "root-like"). Instead of the seemingly static tree, the brain is more like the ever-growing and expanding roots, influenced by the experiences to which the growing person is subjected, especially in the early years of development (Narvaez, 2013).

According to Narvaez (2010, 2013) , the ramifications for educators rest with their capacity to impact on the brain's development through the kinds of content, curriculum and pedagogy they employ. Furthermore, the brain is so complex, with every element impacting on every other element, that learning must be a multivariate and enriching experience for students (Immordino-Yang & Faeth, 2010). If learning challenges are all premised on the notion of the brain as "hardwired" and "mechanistic", being simply able to receive information, process and regurgitate it as required, then education has the potential to be a negative and even damaging process for students, especially for those not so well equipped to deal with simple reception, processing and regurgitation (Immordino-Yang & Damasio, 2007). Not only can their self-esteem be damaged but, according to the assumptions of neuroplasticity, their brains can fail to grow in line with their potential (Doidge, 2009).

Narvaez (2008, 2010, 2013, 2014) takes the case further in the pivotal role she assigns to creativity as providing for the emotional stability that is essential to sound and critical reasoning. Herein, she employs updated neuroscientific evidence around the role of the pre-frontal cortex of the human brain, showing it to be its most evolved and distinctive feature. Especially in the context of a caring and nurturing environment, neural activity associated with imagination is the key to establishing the emotional regulation necessary to the forming of effective decision-making and problem-solving. In turn, the self-confidence that results from such decision-making and problem-solving becomes the basis of ongoing critical reasoning, and indeed of learning. A caring and nurturing environment is essential, but not sufficient, for this to occur. What is also needed is the guiding hand of efficacious pedagogy. Narvaez makes use of McGilchrist (2009) in identifying with some precision how the right and left hemispheres of the brain function, the left being more associated with rationality and the right with affectivity. Narvaez (2013) clearly, and perhaps surprisingly, associates creativity principally with left brain activity, with the neural capacity to abstract, reflect, self-reflect and problem solve. It is, in this sense, the key to unlocking the potential of critical reasoning to drive new learning. In her most recent work, Narvaez (2014) also links this aspect of creativity to a broader vision of flourishing for the human person, claiming that while modern, mostly Western, understandings of creativity have tended to concentrate on 'detached imagination focused on technical manipulation and innovation (p. 245). Narvaez claims that a more holistic understanding of human flourishing, which emphasises humankind's relatedness to the natural world, along with moral values such as generosity and compassion, is better positioned to allow for the full functioning of the human brain and, correlatively, its capacities for creativity.

We conclude this section of the literature review by referring to an array of prominent literature that captures the healthy scepticism that exists among educational researchers about the capacity and/or appropriateness of neuroscience being applied to education. Snook (2012) proposes that he is not opposed to scientific appraisal of education and that elements of neuroscience may well have something to offer but that we need to differentiate "good science" from fads and "neuromyths", among which he includes the notion of "left and right brain thinking". Weisberg et al. (2008) confirm the potential mischievousness of "neuromythology" through an empirical study that illustrated the "allure" of reference to neuroscience, even when irrelevant to the issue at hand, on the perceptions of study subjects, most especially non-expert subjects. Bruer (1997, 1998, 2006) has gained a reputation as an arch-sceptic of neuroscience's relevance to education, arguing that the applications made are too often over-simplified links from biological evidence to the very different field of teaching and learning. He argues that the missing link in effective application is psychology and that, without its filter, many of the arguments proffered for neuroscience's implications for the practicalities of education are unfounded.

This authorship remains aware of the debate about and the contentiousness about the limitations of neuroscience for educational application (Clement & Lovat, 2012) but, importantly also notes the many neuroscientists and educational psychologists, as illustrated above, who argue for and have achieved reputable empirical studies that seem to confirm the applicability of neuroscience's insights to education. This authorship makes no claim to scientific expertise but has proffered its own view that, regardless of the scientific argumentation one way or the other, the insights of neuroscience can be useful as metaphorical devices for analysing educational practices (Fleming & Lovat, 2015 in press). Furthermore, it has written refereed work, including elements of its own empirical work (Fleming & Lovat, 2014) that illustrates how such devices can be useful in education, especially in negotiating teaching and learning in challenging multicultural, multi-value contexts. In a word, we believe the authorship has demonstrated the creative potential of neuroscience insights being applied to educational thinking in a way that is particularly pertinent to the purpose of this article.

CREATIVITY, IMAGINATION AND WONDER

The article now expands on the literature review to incorporate a wider array of scholarship that has made use of neuroscience insights in proffering the crucial nature of imagination and wonder, as artefacts and extensions of creativity, in developing critical reasoning. While the three capacities connoted by creativity, imagination and wonder might be regarded as either insufficiently alike to be lumped together or so alike as to be unnecessarily separately named, we argue that the abovementioned updated neuroscientific evidence on which we rely shows that, on the one hand, they complement and complete each other in a particularly rich way but, on the other hand, that they each denote a facet of the evidence that justifies their being seen as synergistic but separate skills.

Jordan and Carlisle (2013) refer to creativity as "a conceptual ability to come up with new ideas that are surprising, yet intelligible" (p. 7). The earlier work of Dietrich (2004) utilized updated neuroscientific evidence in forging the links between creativity and intelligibility, showing that, especially when creativity is impelled by deliberate control (such as in a formal learning situation), it stimulates the pre-frontal cortex and, as identified above, it is the most developed and distinctively human part of the brain, the part on which critical reasoning relies most fully. Further research seems to confirm Dietrich's earlier work in this regard. Srinivasan (2007) employed EEG data in illustrating that creative tasks utilized the pre-frontal cortex, especially when related to "… effortful problem-solving tasks" (p. 109). In this sense, creativity can be seen to be a regular but vital component of intelligibility. Wegerif et al. (2010) went further in using artificial intelligence pattern matching techniques to show that creative activity could be coded and read by using more established critical thinking codes. Their work again underlines the synergy to be found in brain activity between creativity and critical reasoning.

In her 'Triune Ethics Theory' (TET), in essence a theory drawing on and directed to moral education, Narvaez (2008, 2013) also focuses on activity in the pre-frontal cortex necessary to the development of sound, critical reasoning, labouring the crucial part played by imaginative thinking in stimulating the left brain formation that is essential to the development of such reasoning. It could be argued that Narvaez might as well have used the language of "creativity", rather than "imagination", in this theory because the two words appear virtually synonymous. By utilizing imagination, however, Narvaez is able to explore a variant of neuroscientific research which delves even further into the workings of the brain and the similarities to be found between creativity and critical reasoning, while also making use of some of the more extended evidence of enriching by the former on the latter.

Imagination has been found to be a particularly important focus for neuroscientific research aimed at identifying the fine-tuned similarities and differences between creativity and intelligibility, as normally understood. Hassabis et al. (2007) , for instance, used advanced brain scanning technology to trace similarities and differences in pre-frontal cortical activity between imagined fictitious experiences and episodic memory. In terms of the essential commonality of scene construction, there were 'remarkable similarities' in the effect on the pre- frontal cortex. This finding in itself underlines an aspect of the synergy between creativity and intelligibility and offers clues to the educator about the vast and too often untapped potential for imaginative thinking to stimulate critical reasoning related to real-life experiences and dilemmas.

Hassabis et al. (2007) also point to the likelihood of other brain functions coming into play that discriminate between imagined fictitious experiences and episodic memory, a notion that adds even more value to imagination as an educational strategy, not least in an era that tends to privilege rationality and empiricism over creativity. Combining Hassabis et al. with Doidge's (2009) "rhizomatic" brain notion, it would seem that neuroscience is pointing to creativity as a distinctively powerful way in which the full functioning of the brain can be effected. Furthermore, we can see that through the use of the notion of imagination and imaginative thinking, this insight into creativity's potential can be strengthened. We will show below that, especially in the application of her thinking to moral education, Narvaez's use of imagination allows her to explore profound and unlikely dimensions of creativity, including potentially negative and quite destructive ones that would have stretched the normal meaning attached to the word and would go beyond the evidence, at least within the ambit of neuroscience.

Just as imagination adds value to the concept of creativity, as above, so the same can be said of "wonder". Bulkeley (2005) , in The Wondering Brain, employs updated neuroscience to speak of the full range of emotions attached to those creative moments when something entirely new happens to one's intelligibility, powers of insight or what we refer to simply as critical reasoning. Bulkeley chooses to speak in this context of "wonder", which she defines as "… feeling excited by an encounter with something novel and unexpected, something that strikes a person as intensely real, true and/or beautiful" (p. 3). She points out that wonder has often been associated with the religious and moral traditions but that experiences of wonder have been "… crucial but unappreciated inspirations for … scientific progress and technological innovations" (p. 3). Why is this so? Bulkeley asks, and then answers her own question in the following way:

To feel wonder is to experience a sudden decentering of the self. Facing something surprisingly new and unexpectedly powerful, one's ordinary sense of personal identity is dramatically altered, leading to new knowledge and understanding that ultimately recenter the self. The profound impact … is evident in both the intense memorability of the experiences and the strong bodily sensations that often accompany them. People speak of being stunned, dazed, breath-taken, overwhelmed, consumed, astonished—all gesturing toward a mode of experience that exceeds ordinary language and thought and yet inspires a yearning to explore, understand and learn … where the powerful emotional experience (of wonder) stimulates lively curiosity, knowledge-seeking behaviour and critical questioning" (p. 4).

Bulkeley (2005) makes much use of updated neuroscientific research around pre-frontal cortical activity in making her case about wonder as both an integral dimension of intelligibility as well as possessing potential to disrupt, disturb, de-activate and re-activate regular brain functions in order to stimulate the brain to expand its capacity for reasoning:

The large expanses of association cortex that distinguish the human brain are hyperactivated as radically new input must be processed, upsetting established neural systems and forcing the creation of new ones. In terms of the range and complexity of neural connections, I would propose as a testable hypothesis that wonder makes the brain grow… The capacity to experience wonder is itself a developmental achievement ... wonder as existential surprise becomes wonder as knowledge-seeking curiosity (pp. 198-199).

As above, we are conscious of the contentiousness that exists around the validity of applications from neuroscience to education and related matters, in the way Narvaez has done (see for example, Haidt, 2010). We are at the same time buoyed by the overall positive response from scholarship that her works (Narvaez et al., 2013; 2014) have received in formal academic reviews (Bielert & Gallup, 2014), as well as previous evaluations of her approach (Lewis, 2010). It is similarly the case with Bulkeley's work which, in spite of the hearty debate about neuroscience's potential to inform about practical enterprises, has received very positive academic reviews (cf. Gortner, 2007). On the basis of such endorsement, we believe it is valid to continue to explore the insights of neuroscience in an endeavour to gain enhanced insight into the potential of creative, imaginative and wondrous thinking to impact on critical reasoning.

The case for creativity, imagination and wonder as complementary in the development of critical reasoning, yet beneficially separable in their emphases and orientations, rests on analyses such as those above. Furthermore, we see, especially in Narvaez and Bulkeley, important references to the moral dimension of the kind of creativity that has potential to facilitate critical reasoning. As such, we wish to explore literature that pertains to moral education as an area of learning with especially strong credentials in stimulating this kind of creativity.

THE ROLE OF MORAL EDUCATION IN CULTIVATING CREATIVITY

As suggested above, Narvaez's concept of imagination as vital to the development of left brain activity leading to sound or critical reasoning is to be found in its most comprehensive form in her "Triune Ethics Theory" (Narvaez, 2008, 2013, 2014), a theory about human mindsets premised heavily on the impulsions we refer to as moral motivation and the desired intentions and directions of the enterprise we call moral education. Bulkeley's (2005) work on wonder is also set in the context of knowledge-gathering as an inherently moral enterprise when its goal is to truly extend the mind beyond the known to the new and surprising, for Bulkeley the only goal with capacity to stretch the powers of the brain. One gains a strong sense from these perspectives that the earlier philosophical positions of the likes of Dewey (1916) and Peters (1981) , that all effective education is moral education, have been confirmed empirically in the updated neuroscientific evidence on which we are resting our case for the integral connections between creativity and critical reasoning.

The three mindsets to which Narvaez (2013) refers are safety, engagement and imagination, this latter associated most patently with the pre-frontal cortex of the brain. Despite its uniqueness, the operation of this dimension of the brain is not necessarily a positive thing; it can align itself with a security mindset and issue in 'vicious imagination'; this will most likely result if a person feels fear or insecurity, hence allowing imagination to impel negative thoughts and behaviours and, in turn, rigidifying brain activity. Bulkeley (2005) also notes the potential for fear resulting from the decentering that can accompany the experience of wonder. On the other hand, imagination can be allied with the engagement mindset and result in "communal imagination" (Narvaez, 2013, 2014), a confident and altruistic set of thoughts and behaviours that, among other things, enhances and enriches the growth and development of the brain.

There will be many factors in play that will determine which way imagination is directed, home life being one and the role of the teacher, school and school system being an important other dimension. Whichever social agency, the constant need is for a caring, trusting ambience. Bulkeley suggests of wonder that it requires "… a sufficient degree of safety and security … so that the natural fear of being decentered does not smother the pleasurable creative response in seeking a new center" (p. 199). Narvaez (2014) pushes this point further to critique the whole ambience of contemporary Western society which, she argues, undermines communal imagination in its focus on threat and fear and she posits, instead, a return to the nurturing values of more primal cultures to better facilitate this aspect of human functioning (and in fact all of human flourishing). Both Narvaez and Bulkeley emphasize that it is the caring and trusting ambience, including the key people in any student's life that activates the kind of imagination and wonder that impels the emotional regulation that is essential to problem-solving, knowledge-seeking curiosity and critical reasoning. It is this kind of imagination and wonder that is associated with the capacity to engage in the deliberative and intuitive aspects of interaction and decision making. As such, education which places the value of the student at its centre—that is, a moral education—is best positioned to allow for the flourishing of creativity, imagination, and wonder.

Further to the important link between imagination, effective learning and moral motivation/ education, Narvaez (2013) proffers that communal imagination issues in a personality that "is able to move beyond immediate self- interest, to conceptualize alternative social systems, think impartially about moral problems, counteract harmful instincts or behave altruistically" (p. 331). Communal imagination is closely aligned with the capacity for empathy, which is itself "a primary force behind moral behaviour" (p. 327). In turn, it is the imagination mindset that gives rise to the higher-order thinking capacities needed "for problem solving and deliberative learning" (p. 327), especially when it comes to critical moral reasoning. In this regard, Eslinger et al. (2009) note that such functions are among the most complex undertaken by the brain because it must draw on more sophisticated neural sources when it encounters moral situations that include novel or ambiguous dimensions. Hence, a case is premised for the crucial conjunction between creativity, critical reasoning and moral education. Furthermore, we believe evidence exists that confirms that this conjunction is beyond mere speculative theorizing. We point now to findings emanating from the moral education venture titled the Australian Values Education Program.

CREATIVITY AND CRITICAL REASONING: EVIDENCE FROM THE AUSTRALIAN VALUES EDUCATION PROGRAM

As above, research insights and findings from the neurosciences illustrate the importance of education being holistic in its focus. The learner is a whole person, impelled by cognitive, emotional and social drives, not as separable features but in holistic connection with each other. Narvaez (2013) identifies the vital connections between the caring and supportive learning environment that, together with stimulating imagination and creativity, nurture the emotional regulation essential for sound (critical) reasoning powers to develop. Hence, is seen the crucial importance of pedagogy that places students at the centre of the learning enterprise by establishing encouraging, trusting and caring ambiences of learning and, furthermore, engaging in curricula that stimulate creativity, imagination and wonder.

Such environments are those that research has shown to be the most likely to produce sustained and effective improvements in learning (Newmann et al., 1996 ; Bryk & Schneider, 2002 ; Rowe, 2004). There is now a vast store of evidence from research around moral education that the establishment of such ambiences of learning, together with explicit discourse about moral and values-oriented content in ways that draw on students' deeper learning and reflectivity, has power to transform their patterns of feelings, behaviour, resilience and academic diligence (cf. Hoffmann, 2000 ; Benninga et al., 2006 ; Lovat, 2010, 2011, 2013 ; Lovat & Toomey, 2009 ; Lovat et al., 2009, 2010a, 2010b, 2010c, 2011a, 2011b ; Berkowitz, 2011 ; Nucci & Narvaez, 2008). The principal research drawn on here as supporting evidence is taken from a range of the core projects that ran under the umbrella of the Australian Values Education Program.

The Australian Values Education Program was a federally funded venture that began with a pilot study in 2003 (DEST, 2003), followed by the development of a National Framework for Values Education in 2005 (DEST, 2005) and a range of attached research and practice projects from 2005 to 2009, the most crucial of which were the two stages of the Values Education Good Practice Schools Project (VEGPSP) (DEST, 2006 ; DEEWR, 2008) and the Project to Test and Measure the Impact of Values Education on Student Effects and School Ambience (Lovat et al., 2009).

Findings from VEGPSP (DEST, 2006 ; DEEWR, 2008) illustrated that a sound values education program can be a powerful ally in the development of best practice pedagogy, with positive effects being demonstrated across the range of measures, including in terms of academic development. Project reports identified greater reflectivity and strengthened intellectual engagement among students and settling into work more readily and calmly as routine effects of the ambience created when moral and values-oriented considerations were driving the pedagogical approach. Reports also spoke of the enhanced academic diligence that resulted. In most cases, reports of strengthened intellectual understanding pointed not only to improved learning performance but equally to enhanced moral behaviour. This was seen in clear demonstrations of a stronger sense of student responsibility over local, national and international issues, improved relationships of care and trust, greater student awareness of the need to be tolerant of others, to accept responsibility for their own actions and their ability to communicate, with students' sense of belonging, connectedness, resilience and sense of self all being enhanced.

In the Project to Test and Measure the Impact of Values Education on Student Effects and School Ambience (Lovat et al., 2009), a mixed methods approach in the form of a sequential explanatory design (Creswell et al., 2003) was taken in order to test all of the claims arising from VEGPSP concerning student effects. Quantitative data were collected over two time-periods and analysed, with qualitative data being collected during the second phase and analysed separately to help explain and elaborate on the quantitative results. The qualitative data helped to refine and explain the statistical results by incorporating more detailed information from the perspectives of the research participants. Student, staff and parent pre and post surveys were administered in order to obtain quantitative and qualitative data about the effects of the program on student behaviour, student engagement, and classroom and school ambience. The results of the analysis of the teacher surveys revealed statistically significant improvements on these three measures.

The qualitative data also supported the above findings, with many comments from both students and teachers indicating that improved interactions between students had led to more harmonious and productive learning environments in which students were demonstrating greater kindness to each other and taking more care and pride in their work. The teachers observed that giving students more control over routine tasks added to their sense of competence and this appeared to lead to more independent learning and increased intrinsic motivation, impelled by strengthened critical reasoning powers. The teachers reported that students were putting greater effort into their work and "striving for quality", "striving to achieve their best" and even "striving for perfection":

Thus, there was substantial quantitative and qualitative evidence suggesting that there were observable and measurable improvements in students' academic diligence, including increased attentiveness, a greater capacity to work independently as well as more cooperatively, greater care and effort being invested in schoolwork and students assuming more responsibility for their own learning (Lovat et al., 2009: p. 6).

Consistent with the focus of this paper is the emphasis in the evidence on creativity, imagination and wonder playing a vital role in achieving students' demonstrable improvement in the powers of critical reasoning. In speaking about the enhanced opportunities to deepen reflection and so strengthen learning overall, a teacher wrote:

I now see the need, when I am discussing ideas with children, not just to draw on the children's experience, but rather to extend their understanding of reality. I have a responsibility to provide time and experiences for children to wonder. We need to wonder ourselves. This will help us to understand and improve relationships with others (DEST, 2006: p. 34).

In another cluster of schools in which disadvantage was a particular issue, the researcher wrote of the rights of children to respect, care and quality education and, in this context, of the importance of nurturing "… creativity, wonderment (so they could) learn to participate actively in planning for their (own) future" (DEST, 2006: p. 208).

Meanwhile, one of the researcher "friends" of a cluster of schools utilizing a "philosophy in the classroom" tool for their values education objectives, identified these objectives as "… a school ethos where students have the capacity to exercise judgement and responsibility in matters of morality, ethics and social justice, and the capacity to make rational and informed decisions about their lives" (DEST, 2006: p. 109). In speaking to the nature of the approach being taken to achieve the objective, the researcher had the following to say about the added value to critical reasoning of creativity and wonder:

Philosophy is often described as a thinking skills programme or a course in critical and creative thinking. While it is true that philosophy for children does improve students' critical and creative thinking skills, calling it a "thinking skills" programme does not do it justice. It does much more as well. Through implementing Philosophy in our respective school sites we aim to build on the students' own wonder and curiosity about ideas that are important to them. The subject matter of Philosophy is those common, central and contestable concepts that underpin both our experience of human life and all academic disciplines … The central pedagogical tool and guiding ideal of Philosophy is the community of inquiry. In the community of inquiry, students work together to generate and then answer their own questions about the philosophical issues contained in purpose written materials or a wide range of other resources. Thinking in the community of inquiry is critical, creative, collaborative and caring (DEST, 2006: p. 109).

CONCLUSION

The article has selected an array of prominent literature in an attempt to capture some of the vital evidence emanating from neuroscientific research about the central role of creativity, imagination and wonder in stimulating critical reasoning. It furthermore identifies moral education as a particularly powerful form of learning in impelling the kind of creativity, imagination and wonder necessary to the development of critical reasoning. Finally, the article points to empirical evidence from the Australian Values Education Program that appears to confirm the case being made.

Terence Lovat, Daniel Fleming As evidenced within the article, the authors are conscious of the contentiousness surrounding neuroscience's capacity to inform the practicalities of education, especially in the direct way that proposes biological findings can be ramified to teaching and learning as though no filter is required. We take note of the cautions provided by the likes of Bruer and Snook in this regard. In spite of such important cautions, we nonetheless come down on the side of the weight of scholarship that proffers important insights being generated by neuroscience for educational considerations, including concerned with the role of creativity, wonder and imagination in facilitating the kind of critical reasoning that impels educational achievement. As suggested within the article, we believe that the weight of the literature tends to the view that such insights from neuroscience are at the very least useful as metaphors for re-thinking many of the traditional assumptions about how learning can best proceed.

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CHAPTER 7

Information Infrastructure for Cooperative Research in Neuroscience

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ABSTRACT

The paper describes a framework for efficient sharing of knowledge between research groups, which have been working for several years without flaws. The obstacles in cooperation are connected primarily with the lack of platforms for effective exchange of experimental data, models, and algorithms. The solution to these problems is proposed by construction

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of the platform (EEG.pl) with the semantic aware search scheme between portals. The above approach implanted in the international cooperative projects like NEUROMATH may bring the significant progress in designing efficient methods for neuroscience research.

INTRODUCTION

Nowadays, publications alone are not enough to coherently increase our knowledge of the mathematical methods applied in neuroscience. To foster the progress on that field, the efficient mechanisms of sharing the experience of scientific teams are needed. The NEUROMATH is an action in which the scientists are called to harmonize their efforts in order to offer a comprehensive approach to the problem of the estimation of brain activity and connectivity for sensory and cognitive behavioral tasks. For solving this problem, the optimal mathematical methods has to be designed and tested on the large databases, which require efficient mechanisms for sharing resources. The problem of an efficient application of internet databases for sharing computational resources was approached, for example, in [1] where the practical barriers to progress on that field were identified.

This paper proposes working solutions to these issues, implemented and working for several years in the EEG.pl portal with the semantic-aware search scheme for interconnecting portals. The structure and layout of EEG.pl (except for the interportal search), at least of the part dedicated to sharing software, can be found in the recently started Software Center of the International Neuroinformatics Coordination Facility (http://software.incf.org/). When adopted within the NEUROMATH framework, these solutions will foster the cooperation between the groups and consolidate their efforts to the aim of designing the optimal methods for estimation of brain activity and connectivity.

EEG.PL OPEN REPOSITORY

EEG.pl is a portal dedicated to sharing software, models, and data related to EEG and local field potentials. It is open to anybody interested in making relevant items freely available or downloading resources shared by others. Only submission of material requires free registration; browsing and downloading is available to anybody. The invitation on the first page states:

EEG.pl is an open repository for software, publications and datasets related to the analysis of brain potentials: electroencephalogram (EEG), local field potentials (LFPs) and event related potentials (ERP), created to foster and facilitate Reproducible Research in these fields.

You can freely search the content of this and other thematic vortals linked via the Interneuro initiative. As a registered user you can submit your article, data or model. Registration and submissions are free. You can also comment and respond to comments on any of the published items.

There are also Disclaimers: *none of the organizations or individuals supporting or maintaining this site is responsible for the content provided by users and any damage which may result from its application. In particular, we do not provide any virus scanning for the binaries available as "software". We do not peer-review submitted material, just retain the right to reject irrelevant or low quality submissions. We believe in opinions of the Neuroscience Community, expressed hereby in the comments which users can attach to any of the published items. We believe that these comments provide most objective evaluation*.

During over five years of experience in running this service, we learned two major lessons.

(1) The software framework and chosen solutions are stable and caused no problems while retaining large amount of flexibility to both the administrator and the users.

(2) EEG.pl is not the only resource of this kind, and the response of the community was not as widespread as expected.

The latter issue calls into attention the issue of interoperability with other portals. This can be achieved within the "Interneuro" framework, described in http://www.eeg.pl/documents/about_connections. Below we briefly recall the ideas underlying the semantic-aware search, which is the key feature in this scheme.

SEMANTIC AWARE SEARCH

Semantic-aware search—contrary to the search provided by typical Internet-wide search engines like Google—indexes not only simple keyword data but also the *meaning* of the data. In case of books, that metainformation would include the author, creator, title, major keywords, and references. In general, the choice of metainformation is not trivial. Fortunately standards exist which regulate naming and scope of metainformation attributes. One of the most popular standards in this field is the Dublin Core (DC) standard. The DC specification is developed and maintained by "The Dublin Core

Metadata Initiative" (DCMI), an "open forum engaged in the development of interoperable online metadata standards that support a broad range of purposes and business models." The full specification of the DC standard may be found in [2]. Here we will summarize only the most important elements of the DC metadata.

Type "The nature or genre of the content of the resource"—this may be a text (paper, article, preprint); a software item (i.e., a description of a freeware or commercial software piece); a dataset (i.e., an experiment collected time series in a well know format).

Title	"A name given to the resource", for example, in case of a paper—its title.
Identifier	"An unambiguous reference to the resource within a given context"; the identifier does not have to have a sensible meaning to a human being; "it is simply a unique token identifying the resource", for example, a URL.
Creator	"An entity primarily responsible for making the content of the resource"—that is, a person, an organization, or a service.
Description	"An account of the content of the resource"—abstract, table of contents, reference, and so forth.
Subject	"The topic of the content of the resource" —keywords, key phrases, and classification codes that describe the resource.

DC defines also a handful of other attributes, like time and date information, information about the publisher, more data about the content itself, and so forth. Sophisticated distributed search mechanism is around it. With metainformation standardized, there is no longer an issue of"what to search for?", only an issue of "how to search?" (technically) remains.

For the low-level implementation of queries we have adopted the SOAP/RDF XML [3] based standards for describing queries, and results. As a consequence, the HTTP protocol [4] is used for transporting the query and the response over the network.

The search service is build around the distributed P2P paradigm: each portal is both a client and a server, that is, is able to formulate and send the queries as well as listen for search requests and to answer them. The rationale for using SOAP/RDF/XML is the following.

(i) SOAP/XML is portable and both platform, and system independent.

(ii) SOAP/XML and SOAP over http are *defacto* standards for building distributed applications.

(iii) SOAP is simple—there is no heavyweight software required to generate and parse it.

(iv) There is a multitude of XML parsers and tools available (both commercial and open-source), so building software compatible with our format should not be a technical problem.

The process of executing a distributed query, illustrated also on Figure 1, is executed as follows.

(1) User enters the query: he/she connects to one of the cooperating sites (e.g., http://eeg.pl), chooses "advanced search", enters the search phrase(s), marks the "external search" check box, and clicks the search button.

(2) Query is translated into universal format (SOAP/XML) and sent to all participating sites.

(3) Each site executes local query.

(4) Each site returns results.

(5) Results are aggregated and displayed to the user.

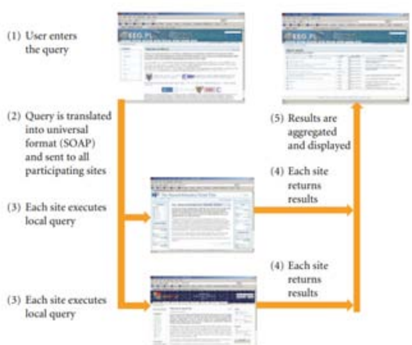

Figure 1. Information flow during the distributed search according to the Inter-Neuro scheme.

The format of queries and returned results is based upon (Simple Object Access Protocol SOAP) [3]—a stateless, message exchange paradigm based on XML. In simpler terms, SOAP is a mechanism similar to (Remote Procedure Call RPC) based on open standards: the remote object access (or a "procedure call") is express purely in XML notation; the same applies to returned results. A SOAP message consists of an outermost envelope, an optional header, and body. From the logical point of view the body consists of a remote objects' (or procedures') identifier and parameters. The SOAP standard describes how parameters should be represented, serialized, and encoded. SOAP defines both a method for encoding simple types (strings, integers, etc.) as well as complex types such as arrays and structures. In case of the remote search employed in Interneuro a relatively simple query is used: only string type parameters representing DC attributes are passed—see Figure 2.

`<?xml version="1.0"?>`
`<SOAP-ENV:Envelope xmlns:SOAP-ENV="http://schemas.xmlsoap.org/soap/envelope/" ...>`
`  <SOAP-ENV:Body>`
`    <NeuroQuery>`	

`      <QueryTypexsi:type="xsd:string">Software </QueryType>`	Indicates the DC object type: Software ; Dataset ; etc.

`      <FullTextQuery xsi:type="xsd:string">`
`        some pattern here`
`      </FullTextQuery>`
	This component is for "full-text" search

`      <search xsi:type="SOAP-ENC:Array" SOAP-ENC:arrayType="ns1:searchcrit[3]">`
`        <item>`
`          <pname>DC:creator</pname>`
`          <pvalue>regexp</pvalue>`
`        </item>`
	The third component specifies universal "by-DC-attribute" search

`        <item>`
`          <pname>DC:title</pname>`
`          <pvalue>regexp</pvalue>`
`        </item>`
	and so on for other DC attributes

`        <item>...</item>`
`      </search>`
`      <searchlogic xsi:type="xsd:string"> AND </searchlogic>`
	either AND or OR

`      <datebeg xsi:type="xsd:string"> 2002-01-01</datebeg>` `      <dateend xsi:type="xsd:string"> 2002-01-01</dateend>`	Date conditions further limit the search scope

`    </NeuroQuery>`
`  </SOAP-ENV:Body>`
`</SOAP-ENV:Envelope>`	

Figure 2. SOAP query.

The result is generated and recorded as an RDF serialized (encoded) in SOAP response—see Figure 3. RDF stands for Resource Description Framework [3], a language for representing information about resources in the World Wide Web. RDF, similarly to SOAP, is based on XML. It is particularly intended for representing metadata about web resources, such as the title, author, and modification date of a web page. RDF is intended for situations in which information needs to be processed by applications, rather than being only displayed for people. RDF provides a common framework for expressing this information so it can be exchanged between applications without loss of meaning.

```
<?xml version="1.0"?>
<SOAP-ENV:Envelope xmlns:SOAP-
ENV="http://schemas.xmlsoap.org/soap/envelope/"
      ...>

<SOAP-ENV:Body>
      <NeuroQueryResponse>
            <statusxsi:type="xsd:int">0
      </status>
            <resultsxsi:type="SOAP-ENC:Array"
             SOAP-ENC:arrayType="ns1:res[3]">
                  <item
      rdf:about="http://www.eeg.pl/somepaper">
                   <title>A fine paper
                    on EEG</title>
                   <dc:date>2003-06-23</dc:date>
                   <dc:title>Analysis of EEG
                    signas</dc:title>
                   <dc:description>some info
                    here</dc:description>
                  ...
                  </item>
            ...
            </results>
      </NeuroQueryResponse>
</SOAP-ENV:Body>
</SOAP-ENV:Envelope>
```

General status, e.g. 0 - OK, <0 - error
because more than one record may be returned an SOAP array is used here
First result tuple
More attributes here
More result tuples

Figure 3. RDF response to the query from Figure 2.

Implementation of the EEG.pl portal is based on the Zope/CMS/Plone (http://plone.org/) free application server/content management/portal engine. Although Zope/Plone provides some mechanisms for distributed communication between different sites (RPC-over-XML) it currently lacks SOAP/RDF support as such. We have used ZOPE's template mechanisms and programming capabilities to develop a distributed search component. The software is written in Python (a default development language for ZOPE, in which the whole system is actually written) and freely available as ZOPE package (technically ZOPE "product"). These software components are freely available from http://eeg.pl/.

CONCLUSION

We presented a working solution to some of the problems encountered in the integration of the efforts of scientific teams, such as the participants of the NEUROMATH action. Proposed approach answers the need of a computational platform for sharing resources.

EEG.pl portal and the semantic-aware search scheme provide a solution to the major problem of information noise, which sometimes overweight advantages of the Internet in scientific communication. Our solution lies in between the two extrema of the absolute centralization and a complete decentralization. Disadvantages of one central repository of information are obvious, but, on the other hand, Semantic Web and super intelligent software agents, creating structure from the chaos, are still more of buzzwords than reality. We propose a humble compromise. As presented, relevant information can be gathered in specialized repositories of possibly well-defined scope. Owing to this specialization, these relatively small services can assure the quality and proper annotation of resources. Seamless integration of these small repositories into a significant knowledge base can be effectuated by the connection paradigm presented in this paper. More technical details and a complete software implementation of this solution are freely available from http://eeg.pl/.

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CHAPTER 8

Computational Intelligence and Neuroscience in Neurorobotics

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Computational intelligence and neuroscience play an important role in robotics applications to improve the robot's capacities not only in increasing productivity in manufacturing but also in intelligence development so that robots can substitute human's thinking and planning capacity. Recently, neuroscience has been applied to robots to generate intelligence models with biological nervous systems. The intersection between robotics and

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neuroscience highlights many promising approaches and applications, for example, the neurorobots, brain-inspired algorithms and devices in robotics, and neural network-based navigation. AI leads to one of the most significant paradigm shifts and improvements in the robotics field. The principal aim of this special issue is to publish quality papers of new developments and trends, novel techniques, and innovative methodologies on the theories and applications of computational intelligence and neuroscience in robotics. Potential topics include but are not limited to the followings: neural networks for biological and biomedical robots, neuroinspired robot navigation, decision support systems in neurorobotics, intelligent fault detection and identification in neurorobotics, clustering and data analysis in neurorobotics, swarm robotics based on neural networks, and neurofuzzy control design for cooperative robots. The following paragraphs summarize the main contents of the best novelty research papers published in this special issue.

The paper "Coevolution of the Asymmetric Morphology and the Behavior of Simple Predator Agents in Predator-Prey Pursuit Problem" by M. Georgiev, I. Tanev, and K. Shimohara concentrates on the one of the previous challenges. It introduced a new standpoint to the well-studied predator-prey pursuit problem using an implementation of straightforward predator agents. Genetic algorithm was implemented that results in a successful capture of the prey by the team of predator agents. The results were considered towards the engineering of asymmetric small-scale for delivery of medicine, locating and destroying cancer cells, microscopic imaging, etc.

The paper "Discrimination of Motion Direction in a Robot Using a Phenomenological Model of Synaptic Plasticity" by N. Berberian, M. Ross, and S. Chartier examines the possibility of implementation of a bioinspired model of synaptic plasticity in a robotic agent to allow the discrimination of motion direction of real-world stimuli. The research started with a well-established model of short-term synaptic plasticity (STP), and then the development of a microcircuit motif of spiking neurons capable of exhibiting preferential and nonreferential responses to changes in the direction of an orientation stimulus in motion was introduced. Overall, the model presented the STP function in describing the direction selectivity and applied these in an actual robot to validate the response characteristics in experimental direction selectivity.

The paper "Spatial Concept Learning: A Spiking Neural Network Implementation in Virtual and Physical Robots" by A. Cyr and F. Thériault proposes an artificial spiking neural network (SNN). The SNN sustained the cognitive abstract process of spatial concept learning and embedded in virtual and real robots. The results showed that the robots can learn the relationship of horizontal/vertical and left/right visual stimuli. Tests with novel patterns and locations were effectively completed after the acquisition learning phase. The results also presented that the SNN can change its behavior in real time when the rewarding rule changes.

The paper "Control of a Humanoid NAO Robot by an Adaptive Bioinspired Cerebellar Module in 3D Motion Tasks" by A. Antonietti et al. focuses on a bioinspired adaptive model by a spiking neural network made of thousands of artificial neurons to control a humanoid NAO robot in real time. The model moved forward and encoded as spikes. The generated spiking activity of its output neurons was decoded in order to yield the suitable correction on the motor actuators. With different time scales, three bidirectional long-term plasticity rules have been embedded for different connections. The neurorobot successfully learned how to compensate for the external perturbation generating an appropriate correction during the perturbed upper limb reaching protocol. Hence, the spiking cerebellar model was able to duplicate in the robotic platform how biological systems deal with external sources of error.

The paper "Neurofuzzy c-Means Network-Based SCARA Robot for Head Gimbal Assembly (HGA) Circuit Inspection" by S. Kaitwanidvilai and R. Praserttaweelap describes a decision and control of SCARA robot in HGA (head gimbal assembly) inspection. The method applied a general image processing technique, blob analysis, in conjunction with neurofuzzy c-means (NFC) clustering with the branch and bound (BNB) technique in order to find the best structure in all possible candidates to increase the performance of the entire system. The results from two clustering techniques were investigated to show the effectiveness of the proposed algorithm. Training results from the 30x microscope inspection with 300 samples showed that the best accuracy for clustering was 99.67% from the NFC clustering and for testing results showing 92.21% accuracy for the conventional Kohonen network. This system has been implemented successfully in the HDD production line at Seagate Technology (Thailand) Co. Ltd.

The paper "Multilayer Hybrid Deep-Learning Method for Waste Classification and Recycling" by Y. Chu et al. studied a multilayer hybrid deep-learning system (MHS) to automatically sort waste disposed by individuals in the urban municipal area. This system deployed a high-resolution camera capturing waste image and sensors to detect another useful feature information. The MHS used a CNN-based algorithm to remove image features and a multilayer perceptrons (MLP) method to consolidate image features and other feature information to classify wastes as recyclable or the others. The results presented the overall classification accuracy higher than 90% under two different testing scenarios. This significantly outperformed a reference CNN-based method relying on image-only inputs.

In summary, these six papers have showed the actively practical research topics in Computational Intelligence and Neuroscience in Neurorobotics. We thank all authors for submitting their papers to this special issue and recognize all reviewers for providing their expertise review and excellent comments. We hope that all papers in this special issue would contribute to the research ideas and methodology development in the related fields.

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SECTION 3:
REASONING AND KNOWLEDGE MODELING

CHAPTER 9

Knowledge Representation in a Proof Checker for Logic Programs

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INTRODUCTION

Lately the need for systems that ensure the correctness of software is increasing rapidly. Software failures can cause significant economic loss, endanger human life or environmental damage. Therefore, the development of systems that verify the correctness of software under all circumstances is crucial.

Formal methods are techniques based on mathematics which aim to make software production an engineering subject as well as to increase

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the quality of software. Formal verification, in the context of software systems, is the act of proving or disproving the correctness of a system with respect to a certain formal specification or property, using formal methods of mathematics. Formal program verification is the process of formally proving that a computer program does exactly what is stated in the program specification it was written to realize. Automated techniques for producing proofs of correctness of software systems fall into two general categories: 1) Automated theorem proving (Loveland, 1986), in which a system attempts to produce a formal proof given a description of the system, a set of logical axioms, and a set of inference rules. 2) Model checking, in which a system verifies certain properties by means of an exhaustive search of all possible states that a system could enter during its execution.

Neither of these techniques works without human assistance. Automated theorem provers usually require guidance as to which properties are "interesting" enough to pursue. Model checkers can quickly get bogged down in checking millions of uninteresting states if not given a sufficiently abstract model.

Interactive verifiers or *proof checkers* are programs which are used to help a user in building a proof and/or find parts of proofs. These systems provide information to the user regarding the proof in hand, and then the user can make decisions on the next proof step that he will follow. Interactive theorem provers are generally considered to support the user, acting as clerical assistants in the task of proof construction. The *interactive systems* have been more suitable for the systematic formal development of mathematics and in mechanizing formal methods (Clarke & Wing, 1996). *Proof editors* are interactive language editing systems which ensure that some degree of "semantic correctness" is maintained as the user develops the proof. The *proof checkers* are placed between the two extremes, which are the automatic theorem provers and the proof editors (Lindsay, 1988).

In this chapter we will present a proof *checker* or an *interactive verifier* for logic programs which are constructed by a schema-based method (Marakakis, 1997), (Marakakis & Gallagher, 1994) and we will focus on the knowledge representation and on its use by the core components of the system. A *meta-program* is any program which uses another program, the object program, as data. Our proof checker is a meta-program which reasons about object programs. The logic programs and the other elements of the theory represented in the Knowledge Base (KB) of our system are the object programs. The KB is the data of the proof checker. The proof checker accesses and changes the KB. The representation of the underlying theory (object program) in the proof checker (meta-program) is a key issue in the development of the proof checker. Our System has been implemented in Sicstus Prolog and its interface has been implemented in Visual Basic (Marakakis, 2005), (Marakakis & Papadakis, 2009)

AN OVERVIEW OF THE MAIN COMPONENTS OF THE PROOF CHECKER

This verifier of logic programs requires a lot of interaction with the user. That is why emphasis is placed on the design of its interface. The design of the interface aims to facilitate the proof task of the user. A screenshot of the main window of our system is shown in Fig. 1.

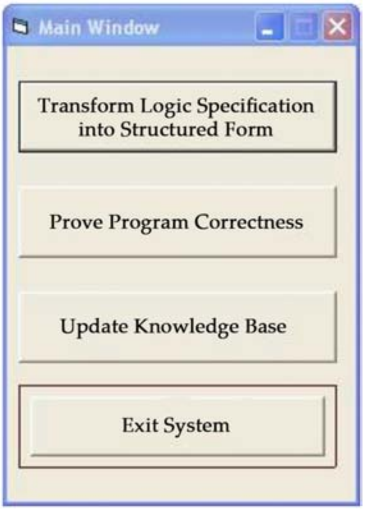

Figure 1. The main window of the proof-checker.

Initially, all proof decisions are taken by the programmer. The design of the interface aims to facilitate the proof task of the user. This interactive verifier of logic programs consists of three distinct parts the *interface,* the *prover* or *transformer and the knowledge base (KB).* The interface offers an environment where the user can think and decide about the proof steps that have to be applied. The user specifies each proof step and the prover performs it. A high-level design of our system is depicted in Fig. 2. The main components of the proof checker with their functions are shown in this figure. The prover of the system consists of the following two components.

1) The component "*Spec Transformer*" transforms a specification expressed in typed FOL into structured form which is required by our correctness method (Marakakis, 1997), (Marakakis, 2005). 2) The component "*Theorem Proof Checker* supports the proof task of the selected correctness theorem.

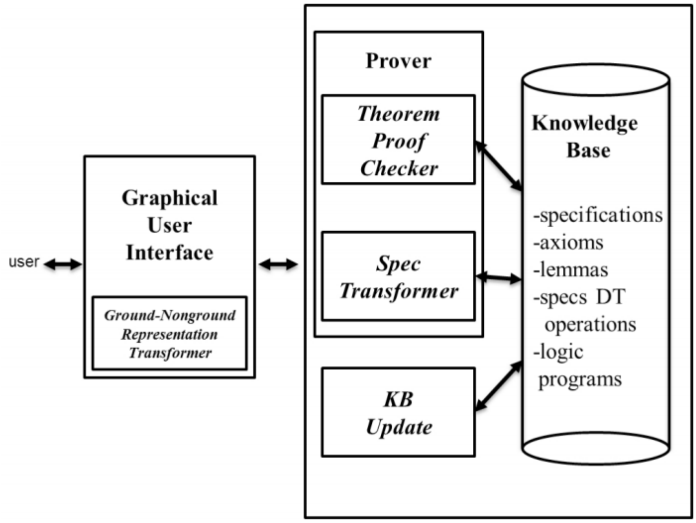

Figure 2. Main components of the proof-checker.

The "*KB Update*" subsystem allows the user to update the KB of the system through a user-friendly interface. The knowledge base (KB) and its contents are also shown in Fig. 2. The KB contains the representation of specifications, theorems, axioms, lemmas, and programs complements. It also has the representation of FOL laws in order to facilitate their selection for application. These entities are represented in ground representation (Hill & Gallagher, 1998). The main benefit of this representation is the distinct semantics of the object program variables from the meta-variables. It should be noted that the user would like to see theorems, axioms, lemmas and programs in a comprehensible form which is independent of their representation. However, the ground representation cannot be easily understood by users. Moreover, the editing of elements in ground representation is error-prone. Part of the interface of the system is the "*Ground-Nonground Representation Transformer*" component which transforms an expression in ground representation into a corresponding one in the standard formalism of FOL and vice-versa. The standard form of expressions helps users in the proof task and for the update of the KB.

KNOWLEDGE REPRESENTATION

Knowledge and *representation* are two distinct concepts. They play a central role in the development of intelligent systems. *Knowledge* is a description of the world, i.e. the problem domain. *Representation* is how knowledge is encoded. *Reasoning* is *how* to extract more information from what is explicitly represented.

Different types of knowledge require different types of representation. Different types of knowledge representation require different types of reasoning. The most popular knowledge representation methods are based on *logic*, *rules*, *frames* and *semantic nets*. Our discussion will be focused on knowledge representation based on logic.

Logic is a language for reasoning. It is concerned with the truth of statements about the world. Each statement is either "true" or "false". Logic includes the following: a) *syntax* which specifies the symbols in the language and how they can be combined to form sentences, b) *semantics* which specify how to assign a truth to a sentence based on its meaning in the world and c) *inference rules* which specify methods for computing new sentences from existing sentences. There are different types of logic, i.e. propositional logic, first-order predicate logic, fuzzy logic, modal logic, description logic, temporal logic, etc. We are concerned on knowledge representation and reasoning based on typed first-order predicate logic because our correctness method is based on typed FOL.

Another classification of knowledge representation is *procedural* and *declarative* knowledge representation. *Declarative knowledge* concerns representation of the problem domain (world) as a set of truth sentences. This representation expresses "*what something is*". On the other hand, the procedural *knowledge* concerns tasks which must be performed to reach a particular goal. In procedural representation, the control information which is necessary to use the knowledge is embedded in the knowledge itself. It focuses on "*how something is done*". In the same way, *declarative programming* is concerned with writing down "*what*" should be computed and much less with "*how*" it should be computed (Hill & Lloyd, 1994). Declarative programming separates the control component of an algorithm (the *"how"*) from the logic component (the "*what*"). The key idea of declarative programming is that a program is a theory (in some suitable logic) and computation is deduction from the theory (Lloyd, 1994). The advantages of declarative programming are: a) teaching, b) semantics, c) programmer productivity, c) meta-programming and e) parallelism.

Declarative programming in Logic Programming means that programs are theories. The programmer has to supply the intended interpretation of the theory. Control is usually supplied automatically by the system, i.e. the logic programming language. We have followed the declarative knowledge representation for the representation of the knowledge base of our system.

Meta-Programming, Ground and Non-Ground Representation

A language which is used to reason about another language (or possibly itself) is called *meta-language* and the language reasoned about is called the *object language*. A *meta-program* is a program whose data is another program, i.e. the *object program*. Our proof-checker is a meta-program which manipulates other logic programs. It has been implemented in Prolog and the underlying theory, i.e. the logic programs being verified and the other elements of the KB, is the object program. An important decision is how to represent programs of the object language (i.e. the KB elements in our case) in the programs of the meta-language, i.e. in the meta-programs. G*round representation* and non-*ground representation* are the two main approaches to the representation of object programs in meta-programs. We have followed the ground representation approach for the representation of the elements of the KB of our system. Initially, ground and non-ground representation will be discussed. Then, we will see the advantages and the drawbacks of the two representations.

In logic programming there is not clear distinction between programs and data because data can be represented as program clauses. The semantics of a meta-program depend on the way the object program is represented in the meta-program. Normally, a distinct representation is given to each symbol of the object language in the meta-language. This is called *naming relation* (Hill & Gallagher, 1998). Rules of construction can be used to define the representation of the constructed terms and formulas. Each expression in the language of the object program should have at least one representation as an expression in the language of the meta-program. The *naming relation* for constants, functions, propositions, predicates and connectives is straightforward. That is, constants and propositions of the object language can be represented as constants in the meta-language. Functions and predicates of the object language can be represented as functions in the language of meta-program. A connective of the object language can be represented either as a connective or as a predicate or as a function in the meta-language. The main problem is the representation of the variables of the object language in the language of the meta-program. There are two approaches. One approach is to represent the variables of the object program as ground terms in the meta-program. This representation is called *ground representation*. The other approach is to represent the variables of the object program as variables (or non-ground terms) in the meta-program. This representation is called *non-ground representation.*

Using non-ground representation of the object program is much easier to make an efficient implementation of the meta-program than using ground representation. In non-ground representation, there is no need to provide definitions for *renaming*, *unification* and *application* of substitutions of object language formulas. These operations which are time consuming do not require special treatment for the object language terms. The inefficiency in ground representation is mainly due to the representation of the variables of the object program as constants in the meta-program. Because of this representation complicated definitions for *renaming*, *unification* and *application* of substitutions to terms are required. On the other hand, there are semantic problems with non-ground representation. The meta-program will not have clear declarative semantics. There is not distinction of variables of the object program from the ones of the meta-program which range over different domains. This problem can be solved by using a typed logic language instead of the standard first-order predicate logic. The ground representation is more clear and expressive than the non-ground one and it can be used for many meta-programming tasks. Ground representation is suitable for meta-programs which have to reason about the computational behavior of the object program. The ground representation is required in order to perform any complex meta-programming task in a sound way. Its inherent complexity can be reduced by specialization. That is, such meta-programs can be specialized with respect to the representation of the object program (Gallagher 1993).

Another issue is how the theory of the object program is represented in the meta-program. There are again two approaches. One approach is the object program to be represented in the meta-program as program statements (i.e. clauses). In this case, the components of the object program are fixed and the meta-program is specialized for just those programs that can be constructed from these components. The other approach is the object program to be represented as a term in a goal that is executed in the meta-program. In this case the object program can be either fixed or it can be constructed dynamically. In this case the meta-program can reason about arbitrary object programs. This is called *dynamic meta-programming.* The object program in our proof checker is represented as clauses. The underlying theory is fixed for each proof task.

Ground Representation of Object Programs in the Proof-Checker

The KB shown in Fig. 2 contains the representation of specifications, theorems, axioms, lemmas and programs complements. It also has the representation of FOL laws in order to facilitate their selection for application. These KB elements are represented in ground representation (Hill & Gallagher, 1998).. The representation of the main symbols of the object language which are used in this chapter is shown below.

Object language symbol	**Representation**
constant	constant
object program variable	term *v(i)*, *i* is natural
function	term *g(i)*, *i* is natural
proposition, formulas of FOL	term *f(i)*, *i* is natural
predicate	term *p(i)*, *i* is natural
connectives (∨,∧,~,→,↔)	\/, /\, ~, -> , <->
exist (∃)	*ex*
for all (∀)	*all*
length of sequence *x1*(#x1)	*len(v(1):Type):nat*
operation plus (+)	*plus*
operation minus (-)	*minus*
type variable	term *tv(i)*, *i* is natural
type sequence	*seq*
empty sequence (<>)	*nil_seq*
sequence constructor (*Head* :: *Tail*)	*seq_cons*(*Head*, *Tail*) where *Head* and *Tail* are defined in ground representation accordingly.
operator / (*Object*/*Type*)	(*Object* : *Type*)
$x1_i$ / *Type* (e.g. $x_1/a1$)	*v(1, i:nat):Type (e.g. v(1, 1:nat):tv(1))*
equality (=)	*eq*
inequality (≠)	*~eq*
less-equal (≤)	*le*
greater-equal (≥)	*ge*
type natural (N)	*nat*
type integer (Z)	*int*
nonzero naturals (N_1)	*posInt*

Predicates are represented by their names assuming that each predicate has a unique name. In case of name conflicts, we use the ground term p(i) where i is natural. Sum of n elements, i.e. $\sum_{i=1}^{n} x_i$ is represented as the following ground term: sum(1:nat, v(2):nat, v(3, v(4):nat):Type):Type where “Type” is the type of x_i.

Representation of Variables

Type Variables

The type variables are specified by the lower case Greek letter *a* followed by a positive integer which is the unique identifier of the variables e.g. *a1*, *a2*, *a3*, *a4* etc. Each type variable is represented in ground form by a term of the form *tv(N)* or in simplified form *tvN* where *N* stands for the unique identifier of the variable. For example, the ground representation of type variables *a1*, *a2*, *a3* could be *tv(1)* or *tv1*, *tv(2)* or *tv2*, *tv(3)* or *tv3* respectively.

Object Program Variables

Object program variables and variables in specifications are expressed using the lower case English letter *x* followed by a positive integer which is the unique identifier of the variables e.g. *x1*, *x2*, *x3*, *x4* etc. Each object variable is represented in ground form by a term of the form *v(N)* where *N* stands for the unique identifier of the variable. For example, the ground representation of the object variables *x1, x2, x3* is *v(1) ,v(2) and v(3)* respectively. Note that, the quantifier of each variable comes before the variable in the formula. Subscripted variables of the form $x1_i$ represent elements from constructed objects. They are represented by a term of the form *v(Id, i:nat):ElementType* where the first argument "*Id*" represents its unique identifier and the second one represents its subscript. "*Id*" is a natural number. This type of variables occurs mainly in specifications. A term like *v(Id, i:nat):ElementType* can be assumed as representing either a regular compound term or an element of a structured object like a sequence. The distinction is performed by checking the types of the elements *x* and *x(i)*. For example, for *i=1* by checking *x1:seq(α1)* and *x1(1:nat):α1*, it can be inferred that *x1(1:nat):α1* is an element of *x1:seq(α1)*.

Representation of Axioms and Lemmas

A set of axioms is applied to each DT including the "*domain closure*" and the "*uniqueness*" axioms which will be also presented later on Section 3.7. Each axiom is specified by a FOL formula. Axioms are represented by the predicates "*axiom_def_ID/1*" and "*axiom_def/4*" as follows. The predicate

"*axiom_def_ID(Axiom_Ids)"*

represents the identifiers of all axioms in the KB. Its argument "*Axiom_Ids*" is a list with the identifiers of the axioms. For example, the representation "axiom_def_ID([1,2,3,4])" says that the KB has four axioms with identifiers 1,2,3 and 4.

The specification of each axiom is represented by a predicate of the following form

"axiom_def(Axiom_Id, DT_name, Axiom_name, Axiom_specification)".

The argument "*Axiom_Id*" is the unique identifier of the axiom, i.e. a positive integer. "*DT_name*" is the name of the DT which the axiom is applied to. "*Axiom_name*" is the name of axiom. "*Axiom_specification*" is a list which has the representation of the specification of the axiom.

Example: *Domain closure axiom for sequences*. Informally, this axiom says that a sequence can be either empty or it will consist from head and tail.

Specification

$[\forall x1/seq(a2),[x1=<>\vee(\exists x3/a2, \exists x4/seq(a2),[x1=x3::x4])]]$

Representation

```
axiom_def (1, sequences, 'domain closure',
   [all v(1):seq(tv(1)), (eq(v(1):seq(tv(1)),nil_seq) \/
     [ex v(2):tv(1), ex v(3):seq(tv(1)), eq(v(1):seq(tv(1)),seq_cons(v(2):tv(1),
           v(3):seq(tv(1))):seq(tv(1))) ])]).
```

Similarly, lemmas are represented by the predicates "lemma_sp_ID/1" and "lemma_sp/4".

Representation of First-Order Logic Laws

The FOL laws are equivalence preserving transformation rules. Each FOL law is specified by a FOL formula. They are represented by predicates *fol_law_ID/1* and *fol_law/3* as follows. The predicate

"fol_law_ID(FOL_laws_Ids)"

represents the identifiers of all FOL laws in the KB. Its argument "*FOL_laws_Ids*" is a list with the identifiers of all FOL laws. The specification of each FOL law is represented by a predicate of the form

"fol_law(FOL_law_Id, FOL_law_description, FOL_law_specification).".

The argument "*FOL_law_Id*" is the unique identifier of the FOL law, i.e. a positive integer. "*FOL_law_description*" is the name of a FOL law. "*FOL_law_specification*" is a list which has the ground representation of the specification of FOL law.

Example: (distribution)

Specification

$$P \wedge (Q \vee R) \leftrightarrow (P \wedge Q) \vee (P \wedge R)$$

Representation

```
fol_law(2,' ∧ distribution',
        [f1 /\ (f2 \/ f3) <-> (f1 /\ f2) \/ (f1 /\ f3)]).
```

Representation of Theorems

Initial Theorem

The theorems that have to be proved must also be represented in the KB. Each theorem is specified by a FOL formula. They are represented by the predicates "*theorem_ID/1*" and "*theorem/4*" as follows. The predicate

"theorem_ID(Theorems_Ids)"

represents the identifiers of all theorems that are available in the KB. Its argument "*Theorems_Ids*" is a list with the identifiers of all theorems. The specification of each theorem is represented by a predicate of the form

"theorem(Theorem_Id, Program_Id, Spec_struct_Id, Theorem_ specification)."

The argument "*Theorem_Id*" is the unique identifier of the theorem, i.e. a positive integer. The arguments "*Program_Id*" and "*Spec_struct_Id*" are the unique identifiers of the program and the structured specifications respectively. "*Theorem_specification*" is a list which has the representation of the specification of theorem.

Example: The predicate *sum(x1, x2)* where *Type(sum) = seq(Z) Z* is true iff *x2* is the sum of the sequence of integers *x1*. The correctness theorem for predicate *sum/2* and the theory which is used to prove it is as follows.

$$Comp(Pr) \cup Spec \cup A \ |= \forall x1/seq(Z), x2/Z \ (sum(x1,x2) \leftrightarrow sum^S(x1, x2))$$

Pr is the logic program for predicate *sum*/2, excluding the DT definitions. *Comp(Pr)* is the complement of the program *Pr*. *Spec* is the specification of predicate *sum*/2, i.e. $sum^S(x1,x2)$. *A* is the theory for sequences, i.e. the underlying DTs for predicate *sum*/2, including the specifications of the DT operations.

Theorem Specification

$$\forall x1/seq(Z), \ \forall x2/Z \ (sum(x1,x2) \leftrightarrow sum^S(x1,x2))$$

Representation

```
theorem(1, progr1, spec_struct1,
   [all v(1):seq(int),all v(2):int, (sum(v(1):seq(int), v(2):int):int <->
     sum_s(v(1):seq(int), v(2):int))]).
```

Theorems in Structured Form

The specification of a theorem may need to be transformed into structured form in order to proceed to the proof. The structure form of theorems facilitates the proof task. Each theorem in structured form is specified by a FOL formula. They are represented by the predicates "*theorem_struct_ID/1*" and "*theorem_struct/4*" as follows. The predicate

"theorem_struct_ID(Theorems_Ids)"

represents the identifiers of all theorems available in the KB with the specification part in structured form. Its argument "*Theorems_Ids*" is a list with the identifiers of all theorems in structured form. The specification of each theorem is represented by a predicate of the form

"theorem_struct(Theorem_struct_Id,Program_Id,Spec_struct_Id, Theorem_specification).".

The argument "*Theorem_struct_Id*" is the unique identifier, i.e. a positive integer, of the theorem whose specification part is in structured form. The arguments "*Program_Id*" and "*Spec_struct_Id*" are the unique identifiers of the program and the structured specifications respectively. "*Theorem_specification*" is a list which has the representation of the specification of theorem.

Example. In order to construct the theorem in structured form the predicate specification must be transformed into structured form. The initial logic specification for predicate sum/2 is the following.

$$\forall x1/seq(Z),\ x2/Z\ (sum^S(x1,x2) \leftrightarrow x2 = \sum_{i=1}^{\#x1} x1_i\ )$$

The logic specification of $sum^S(x1,x2)$ in structured form and its representation are following.

Theorem Specification

$$\forall x1/seq(Z),\ \forall x2/Z\ (sum^S(x1,x2) \leftrightarrow [x1=\langle\rangle \wedge x2=0 \vee [\exists x4/Z,\ \exists x5/Z,\ \exists x6/seq(Z),[x1=x5::x6 \wedge x2=x5+x4 \wedge sum^S(x6,x4)]]])$$

Representation

```
theorem_struct(1, progr1, spec_struct1,
 [all v(1):seq(int), all v(2):int, (sum(v(1):seq(int), v(2):int) <->
  ((eq(v(1):seq(int),nil_seq:seq(tv(1))) /\eq(v(2):int,0:int)) \/ [ex v(3):int,
        ex v(4):int, ex v(5):seq(int), (eq(v(1):seq(int), seq_cons(v(4):int,
          v(5):seq(int)):seq(int) ) /\ eq(v(2):int,plus(v(4):int, v(3):int)) /\
                sum_s(v(5):seq(int), v(3):int) )]) )]).
```

An Example Theory and Theorem

Throughout this Chapter we use the correctness theorem and theory for predicate sum/2. That is,

$$Comp(Pr) \cup Spec \cup A\ \models\ \forall x1/seq(Z),\ x2/Z\ (sum(x1,x2) \leftrightarrow sum^S(x1, x2))$$

The ground representation of theory is also illustrated.

Theory

The logic program completion Comp(Pr) of Pr is as follows.

$\forall$x1/seq(Z), $\forall$x2/Z,[sum(x1,x2) $\leftrightarrow$ (p1(x1) $\wedge$ p2(x1,x2) $\vee$ [$\exists$x3/Z, $\exists$ x4/seq(Z), $\exists$ x5/Z,[~p1(x1) $\wedge$ p3(x1,x3,x4) $\wedge$ p4(x1,x3,x5,x2) $\wedge$ sum(x4,x5)]])]
$\forall$x1/seq(Z),[p1(x1) $\leftrightarrow$ empty_seq(x1)]
$\forall$ x1/seq(Z), $\forall$x2/Z,[p2(x1,x2) $\leftrightarrow$ neutral_add_subtr_int(x2)]
$\forall$ x1/seq(Z), $\forall$x2/Z, $\forall$x3/seq(Z),[p3(x1,x2,x3) $\leftrightarrow$ p5(x1,x2,x3) $\wedge$ p6(x1,x2,x3)]
$\forall$ x1/seq(Z), $\forall$x2/Z, $\forall$x3/seq(Z),[p5(x1,x2,x3) $\leftrightarrow$ head(x1,x2)]
$\forall$ x1/seq(Z), $\forall$x2/Z, $\forall$x3/seq(Z),[p6(x1,x2,x3) $\leftrightarrow$ tail(x1,x3)]
$\forall$ x1/seq(Z), $\forall$x2/Z, $\forall$x3/Z, $\forall$x4/Z,[p4(x1,x2,x3,x4) $\leftrightarrow$ plus_int(x3,x2,x4)]

Representation

- *progr_clause(progr1, 1,[all v(1):seq(int), all v(2):int, [sum(v(1):seq(int),v(2):int) <-> ((p1(v(1):seq(int)) /\p2(v(1):seq(int), v(2):int)) \/ [ex v(3):int, ex v(4):seq(int), ex v(5):int,*

  [~p1(v(1):seq(int)) /\ p3(v(1):seq(int), v(3):int,v(4):seq(int)) /\ p4(v(1):seq(int),v(3):int, v(5):int, v(2):int) /\ sum(v(4):seq(int),v(5):int)]])]]).
- *progr_clause(progr1, 2, [all v(6):seq(int),[p1(v(6):seq(int)) <-> empty_seq(v(6):seq(int))]]).*
- *progr_clause(progr1, 3, [all v(7):seq(int), all v(8):int,[p2(v(7):seq(int), v(8):int) <-> neutral_add_subtr_int(v(8):int)]]).*
- *progr_clause(progr1, 4, [all v(9):seq(int), all v(10):int, all v(11):seq(int), [p3(v(9):seq(int), v(10):int, v(11):seq(int))<-> p5(v(9):seq(int), v(10):int, v(11):seq(int)) /\ p6(v(9):seq(int), v(10):int, v(11):seq(int))]]).*
- *progr_clause(progr1, 5, [all v(12):seq(int), all v(13):int, all v(14):seq(int),[p5(v(12):seq(int), v(13):int, v(14):seq(int)) <-> head(v(12):seq(int), v(13):int)]]).*
- *progr_clause(progr1, 6, [all v(15):seq(int), all v(17):int, all v(16):seq(int),[p6(v(15):seq(int), v(17):int, v(16):seq(int))<-> tail(v(15):seq(int), v(16):seq(int))]]).*
- *progr_clause(progr1, 7, [all v(18):seq(int), all v(19):int, all v(20):int, all v(21):int,[p4(v(18):seq(int), v(19):int, v(20):int, v(21):int) <-> plus_int(v(20):int, v(19):int, v(21):int)]]).*

The logic specification (Spec) is shown in Section 3.6 and its representation in ground form.

The theory A of the DT operations including the specification of the DT operations is as follows.

Axioms

Domain closure axiom for sequences

∀x1/seq(a2),[x1= < > ∀(∃x3/a2, ∃x4/seq(a2),[x1=x3::x4])]

Its ground representation is shown in section 3.4.

Uniqueness axioms for sequences

i *∀x1/a2, ∀x3/seq(a2),[~[x1::x3/a2= < >]]*

ii *∀x1/a2, ∀x3/a2, ∀x4/seq(a2), ∀x5/seq(a2),[x1::x4=x3::x5 ∧ x1=x3 ∧ x4=x5]*

Representation

- *axiom_def(2, sequences, "uniqueness i", [all v(1):tv(1), all v(2):seq(tv(1)), [~[eq(seq_cons (v(1):tv(1), v(2):seq(tv(1))):tv(1),nil_seq:seq(tv(1)))]]]).*
- *axiom_def(3, sequences, "uniqueness ii", [all v(1):tv(1), all v(2):tv(1), all v(3):seq(tv(1)), all v(4):seq(tv(1)),[eq(seq_cons(v(1):tv(1), v(3):seq(tv(1))):seq(tv(1)), seq_cons(v(2):tv(1), v(4):seq(tv(1))):seq(tv(1))) -> (eq(v(1):tv(1), v(2):tv(1)) /\ eq(v(3):seq(tv(1)), v(4):seq(tv(1))))]]).*

Definition of summation operation over 0 entities

$$\forall x1/seq(Z),[x1=<>\rightarrow \Sigma((i=1 \text{ to } \#x1)\ x1_i)=0]$$

Representation

- *axiom_def(4, sequences, "summation over 0 entities", [all v(1):seq(int), [eq(v(1):seq(int),nil_seq) -> eq(sum(1:int,len(v(1):seq(int)):int, v(1,v(3):nat):int), 0:int)]]).*

Lemmas

$\forall x1/seq(a2),[x1 \neq <> \leftrightarrow [\exists x3/a2,\ \exists x4/seq(a2),[x1=x3::x4/a2]]]$

$\forall x1/a2,\ \forall x3/seq(a2),\ \forall x4/seq(a2),[x3=x1::x4 \rightarrow (\forall x5/N,[2\leq x5\leq \#x3 \rightarrow x3(x5)=x4(x5-1)])]$

$\forall x1/seq(a2),\ \forall x3/seq(a2),\ \forall x4/a2,[x1=x4::x3 \rightarrow \#x1=\#x3+1]$

$\forall x1/a2,\ \forall x3/seq(a2),\ \forall x4/seq(a2),[x3=x1::x4/a2 \rightarrow x1=x3_1/a2]$

Representation

- *lemma_sp(1, sequences, "Non-empty sequences have at least one element",[all v(1):seq(tv(1)), [~eq(v(1):seq(tv(1)),nil_seq:seq(tv(1))) <-> [ex v(2):tv(1), ex v(3):seq(tv(1)), [eq(v(1):seq(tv(1)), seq_cons(v(2):tv(1), v(3):seq(tv(1))):tv(1))]]]]).*
- *lemma_sp(2,sequences,"if sequence s has tail t then the element si is identical to the element ti-1",[all v(1):tv(1), all v(2):seq(tv(1)), all v(3):seq(tv(1)),[eq(v(2):seq(tv(1)), seq_cons(v(1):tv(1), v(3):seq(tv(1))):seq(tv(1))) -> (all v(4):nat, [le(2:nat, v(4):nat) /\ le(v(4):nat, len(v(2):seq (tv(1))):nat) -> eq(v(2, v(4):nat):tv(1), v(3, minus(v(4): nat,1:nat)))])]]).*
- *lemma_sp(3, sequences, "If sequence s has tail t then the length of s is equal to the length of t plus 1", [all v(1):seq(tv(1)), all v(2):seq(tv(1)), all v(3):tv(1), [eq(v(1):seq(tv(1)), seq_cons(v(3):tv(1), v(2):seq(tv(1))):seq(tv(1))) -> eq(len(v(1):seq(tv(1))): nat,plus(len(v(2): seq(tv(1))):nat,1:nat))]]).*
- *lemma_sp(4, sequences, "If sequence s is non-empty then its head h is identical to its first element", [all v(1):tv(1), all v(2):seq(tv(1)), all v(3):seq(tv(1)),[eq(v(2):seq(tv(1)), seq_cons(v(1):tv(1), v(3):seq(tv(1))):tv(1)) -> eq(v(1):tv(1), v(2, 1:int):tv(1))]]).*

Logic specifications of DT operations

∀x1/seq(a2),[empty_seq(x1) ↔ x1= < >]
∀x1/Z,[neutral_add_subtr_int(x1) ↔ x1=0]
∀x1/seq(a2), ∀x3/a2,[head(x1,x3) ↔ [x1≠ < > ∧ [∃x4/seq(a2),[x1=x3::x4/a2]]]]
∀x1/seq(a2), ∀x3/seq(a2),[tail(x1,x3) ↔ [∃x4/a2,[x1≠< > ∧ x1=x4::x3/a2]]]
∀x1/Z, ∀x2/Z, ∀x3/Z,[plus_int(x1,x2,x3) ↔ x3=x2+x1]

Representation

- *dtOp_sp(empty_seq, 1, "seq: empty", [all v(1):seq(tv(1)), [empty_seq(v(1):seq(tv(1))) <-> eq(v(1):seq(tv(1)),nil_seq:seq(tv(1)))]]).*
- *dtOp_sp(head, 2, "seq: head", [all v(1):seq(tv(1)), all v(2):tv(1),[head(v(1):seq(tv(1)), v(2):tv(1)) <-> [~eq(v(1):seq(tv(1)),nil_seq:seq(tv(1))) /\ [ex v(3):seq(tv(1)), [eq(v(1):seq (tv(1)),seq_cons(v(2):tv(1), v(3):seq(tv(1))):tv(1))]]]]]).*
- *dtOp_sp(tail, 3, "seq: tail", [all v(1):seq(tv(1)), all v(2):seq(tv(1)), [tail(v(1):seq(tv(1)), v(2):seq(tv(1))) <-> [ex v(3):tv(1),[~eq(v(1):seq(tv(1)), nil_seq:seq (tv(1))) /\ eq(v(1), seq_cons(v(3):tv(1),v(2):seq(tv(1))):tv(1))]]]]).*
- *dtOp_sp(neutral_add_subtr_int, 8, "int: neutral_add_subtr_int", [all v(1):int, [neutral_add_subtr_int(v(1):int) <-> eq(v(1):int,0:int)]]).*
- *dtOp_sp(plus_int, 9,"int: plus_int", [all v(1):int, all v(2):int, all v(3):int, [plus_int(v(1):int,v(2):int,v(3):int) <-> eq(v(3):int,plus(v(2):int,v(1):int))]]).*

SCHEMATIC VIEW OF THE INTERACTION OF THE MAIN COMPONENTS

In this section, a schematic view of the proof checker and the interaction of its main components will be shown. In addition, the functions of its components will be discussed. An example of a proof step will illustrate the use of the KB representation in the proof task.

Schematic View of the Theorem Proof Checker

The process of proving a theorem is shown in Fig. 3 and consists of three steps.

- Step 1: In order to prove the correctness of a theorem the user initially has to specify the theorem that is going to be proved and to select the theory and the proof scheme that will be used for the proof. The theory is retrieved from the *KB* and it is presented to the user for selection. It consists of a *program complement*, a *logic specification*, *axioms* and *lemmas*. The corresponding window of the interface which allows the user to make these selections is shown in Fig. 6.
- Step 2: After the selection the user proceeds to the actual proof of

the specific theorem. In order to do that he has to select specific parts from the theorem, the theory and the transformation rules that will be applied. The transformation rules that can be applied are first order logic (FOL) laws, folding and unfolding.

- Step 3: In this step the selected transformation is applied and the equivalent form of the theorem is presented to the user. The user can validate the result. He is allowed to approve or cancel the specific proof step.

The last two steps are performed iteratively until the theorem is proved.

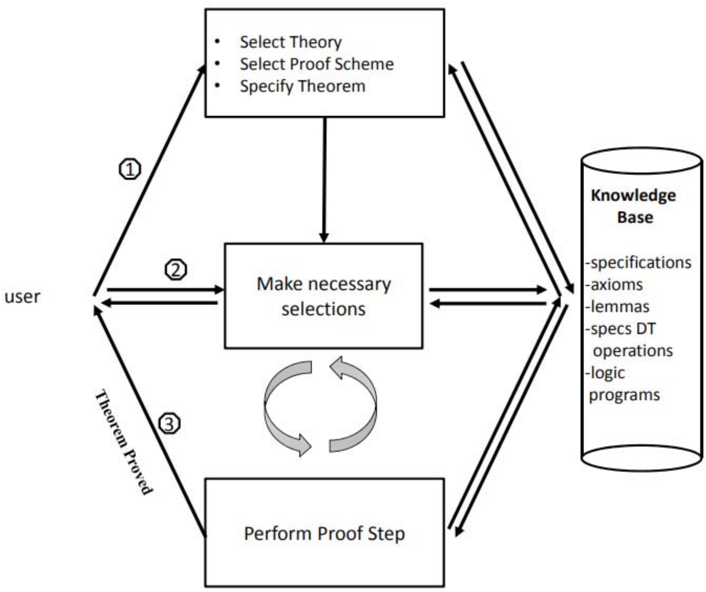

Figure 3. Schematic View of the Theorem Proof Checker.

Schematic View of Specification Transformer

Fig. 4 depicts the procedure for transforming a specification in the required structured form, which is similar to the previous case. In this case however, the underlying theory consists of *Spec* U *Axioms* U *Lemmas*. Initially, the user selects a specification, then the rest elements of the theory are automatically selected by the system. Next, in step 2, the user has to select specific theory elements and transformation rules. In step 3, the selected transformation rule is performed. Step 2 and step 3 are performed iteratively until the specification is transformed in the required structured form.

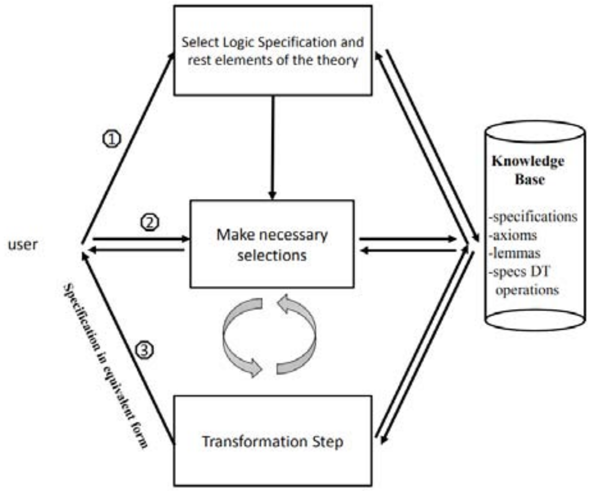

Figure 4. Schematic View of Specification Transformer.

Illustration of a Proof Step

The "*Transformation Step"* procedure is actually a sub-procedure of the *"Perform Proof Step"* procedure and that is why we will not present it. The schematic view of the main algorithm for the procedure which performs a proof step, i.e. "*performProofStep", is* shown in Fig. 5. It is assumed that the user has selected some theory elements, and a transformation rule that should be applied to the current proof step.

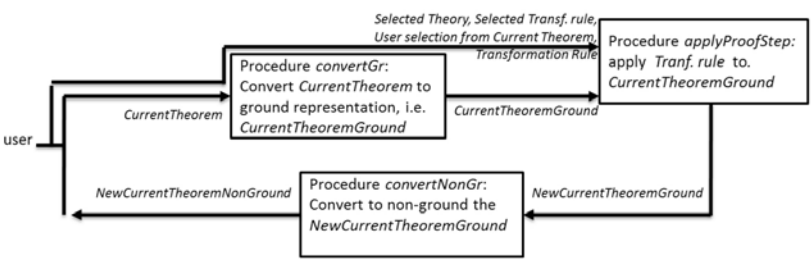

Figure 5. Schematic view of the "performProofStep" procedure.

The function block diagram of the algorithm "*performProofStep"* shown in Fig. 5 will be discussed through an example. Consider that our theorem has been transformed and its current form is the following:

$$\forall x1/seq(Z),\ \forall x2/Z\ (sum^S(x1,x2) \leftrightarrow (x1=<> \wedge x2=0 \vee [\exists x3/Z,[\ \exists x4/seq(Z), false \wedge x2=x4+x3 \wedge sum^S(x4,x3)]]))$$

The user has selected the following FOL law to be applied to the above theorem:

$$P \wedge false \leftrightarrow false$$

Initially, the current theorem is converted to the corresponding ground representation by the procedure "ConvertGr" and we get:

```
[all v(1):seq(int),[all v(2):int,sum_s(v(1):seq(int),v(2):int)<->
   (eq(v(1):seq(int),nil_seq:seq(int))/\eq(v(2):int,0:int) \/
        [ex v(3):int,[ex v(4):int,[ex v(5):seq(int),
          false/\eq(v(2):int,plus(v(4):int,v(3):int):int)/\sum_s(v(5):seq(int),v(3):int)]]])]]
```

Then, the procedure "applyProofStep" applies the transformation rule to the current theorem and derives the new theorem. In order to do that, this procedure constructs and asserts a set of clauses which implement the selected transformation rule. Then, it applies this set of clauses and derives the new theorem in ground representation. That is,

```
[all v(1):seq(int),[all v(2):int,sum_s(v(1):seq(int),v(2):int)<->
(eq(v(1):seq(int),nil_seq:seq(int))/\eq(v(2):int,0:int) \/
[ex v(3):int,[ex v(4):int,[ex v(5):seq(int),
                    false /\ sum_s(v(5):seq(int),v(3):int)]]]])]]
```

The new theorem is then converted to the corresponding non-ground form in order to be presented to the user. That is,

$$[\ \forall x1/seq(Z),[\ \forall x2/Z, sum^S(x1,x2) \leftrightarrow (x1=<> \wedge x2=0 \vee [\exists x3/Z,[\ \exists x4/seq(Z), false \wedge sum^S(x4,x3)]])]]$$

SYSTEM INTERFACE

To enable users to guide this proof checker it is necessary to provide a well-designed user interface. The design of the interface of an interactive verifier depends on the intended user. In our verifier we distinguish two kinds of users, the "*basic users*" and the "*advanced* or *experienced users*". We call "*basic user*" a user who is interested in proving a theorem. We call an "*advanced user*" a user who in addition to proving a theorem he/she may want to enhance the KB of the system in order to be able to deal with additional theorems. Such a user is expected to be able to update the KB of axioms, lemmas, predicate specifications, specifications of DT operations and programs. We will use the word "*user*" to mean both the "*basic user*" and the "*advanced user*". Both kinds of users are expected to know very well the correctness method which is supported by our system (Marakakis, 2005).

Initially, the system displays the main, top-level window as shown in Fig. 1. This window has a button for each of its main functions. The name of each button defines its function as well, that is, "*Transform Logic Specification into Structured Form*", "*Prove Program Correctness"* and "*Update Knowledge Base*". The selection of each button opens a new window which has a detailed description of the required functions for the corresponding operation. Now we will illustrate the *"Prove Program Correctness*" function to better understand the whole interaction with the user.

Interface Illustration of the "Prove Program Correctness" Task

If the user selects the button *"Prove Program Correctness"* from the main window, the window shown in Fig. 6 will be displayed. The aim of this window is to allow the user to select the appropriate theory and proof scheme that he will use in his proof. In addition, the user can either select a theorem or define a new one.

After the appropriate selections, the user can proceed to the actual proof of the theorem by selecting the button "*Prove Correctness Theorem*". The window that appears next is shown in Fig. 7. The aim of this window is to assist the user in the proof task. The theorem to be proved and its logic specification are displayed in the corresponding position on the top-left side of the window. This window has many functions. The user is able to choose theory elements from the KB that will be used for the current proof step. After selection by the user of the appropriate components for the current proof step the proper inference rule is selected and it is applied automatically. The result of the proof step is shown to the user. Moreover, the user is able to cancel the last proof step, or to create a report with all the details of the proof steps that have been applied so far.

Illustration of a Proof Step

Let's assume that the user has selected a theorem to be proved, its corresponding theory and a proof scheme. Therefore, he has proceeded to the verification task. For example, he likes to prove the following theorem:

$$Comp(Pr) \cup Spec \cup A \ \models \ \forall x1/seq(Z),\ x2/Z\ (sum(x1,x2) \leftrightarrow sum^S(x1,x2))$$

The user has selected the "*Incremental*" proof scheme which requires proof by induction on an inductive DT. Let assume that the correctness theorem has been transformed to the following form:

$$\forall x1/seq(Z),\ \forall x2/Z,\ sum(x1,x2)\ \leftrightarrow [\exists x3/Z,\ \exists x4/Z,\ \exists x5/seq(Z),$$
$$x1 \neq \langle\rangle \wedge x1=x4::x5 \wedge x1 \neq \langle\rangle \wedge x1=x4::x5 \wedge x2=x4+x3$$
$$\wedge\ sum(x5,x3)]$$

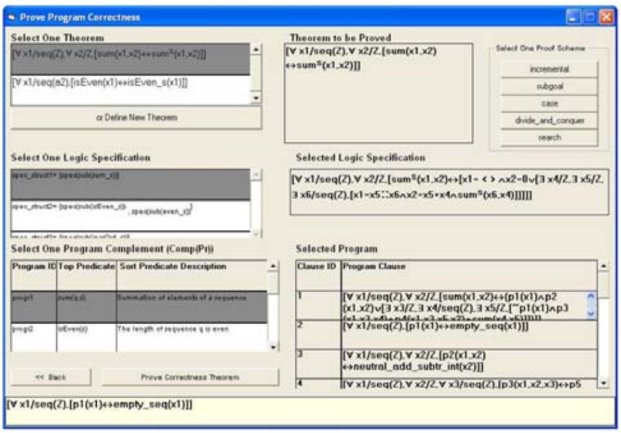

Figure 6. The window for selecting Theory, Theorem and Proof Scheme

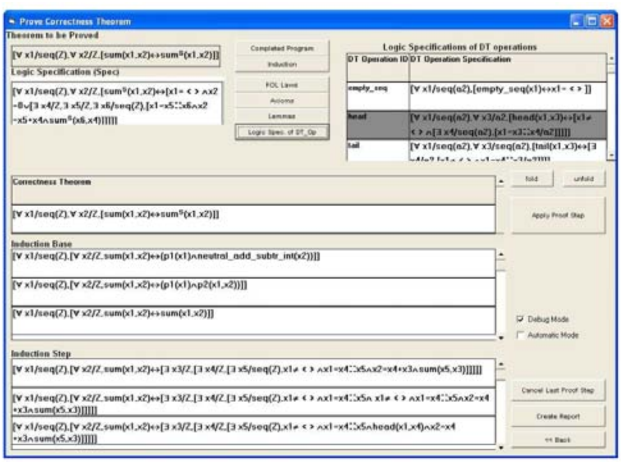

Figure 7. The window for proving a correctness theorem

In order to proceed to the next proof step the following steps should be performed:

First, the user selects "*Logic Spec. of DT_Op*" and then he selects the "*Head*" DT operation:

$\forall x1/seq(a2),\ \forall x3/a2,[head(x1,x3)\ \leftrightarrow [x1 \neq <> \wedge [\exists x4/seq(a2),[x1=x3::x4/a2]]]]$

Then he selects the button "*Apply Proof Step*" and the result is shown in the next line of the "*Induction Step*" area:

$\forall x1/seq(Z),\ \forall x2/Z,\ sum(x1,x2)\ \leftrightarrow [\exists x3/Z,\ \exists x4/Z,\ \exists x5/seq(Z),$
$x1 \neq <> \wedge x1=x4::x5 \wedge head(x1,\ x4) \wedge x2=x4+x3 \wedge sum(x5,x3)]$

The user continues applying proof steps until to complete the proof of the theorem.

RESULTS

The results of this research work involve the development of a proof checker that can be used efficiently by its users for the proof of correctness theorems for logic programs constructed by our schema-based method (Marakakis, 1997). The system has been tested and allows the verification of non-trivial logic programs. Our proof checker is highly modular, and allows the user to focus on proof decisions rather than on the details of how to apply each proof step, since this is done automatically by the system. The update of the KB is supported by the proof-checker as well. The overall interface of our system is user– friendly and facilitates the proof task.

The main features of our system which make it to be an effective and useful tool for the interactive verification of logic programs constructed by the method (Marakakis, 1997) are the following.

- The proof of the correctness theorem is guided by the logic-program construction method (Marakakis, 1997). That is, the user has to select a proof scheme based on the applied program schema for the construction of the top-level predicate of the logic program whose correctness will be shown.
- Proof steps can be cancelled at any stage of the proof. Therefore, a proof can move to any previous state.
- The system supports the proof of a new theorem as part of the proof of the initial theorem.

- The update of the theories stored in the KB of the system is supported as well.
- The overall verification task including the update of the KB is performed through a user-friendly interface.
- At any stage during the verification task the user can get a detailed report of all proof steps performed up to that point. So, he can get an overall view of the proof performed so far.

CONCLUSIONS

This chapter has presented our proof checker. It has been focused on the knowledge representation layer and on its use by the main reasoning algorithms. Special importance on the implementation of the proof checker has been given on flexibility so the system being developed could be enhanced with additional proof tasks. Finally, the main implementation criteria for the knowledge representation are the support for an efficient and modular implementation of the verifier.

In our proof checker, a proof is guided by the selected proof scheme. The selection of a proof scheme is related with the construction of the top-level predicate of the program that will be verified. The user-friendly interface of our system facilitates the proof task in all stages and the update of the KB. Its modular implementation makes our proof checker extensible and amenable to improvements.

The natural progression of our proof checker is the addition of automation. That is, we intend to move proof decisions from the user to the system. The verifier should have the capacity to suggest proof steps to the user. Once they are accepted by the user they will be performed automatically. Future improvements aim to minimize the interaction with the user and to maximize the automation of the verification task.

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CHAPTER 10

Episodic Reasoning for Vision-Based Human Action Recognition

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ABSTRACT

Smart Spaces, Ambient Intelligence, and Ambient Assisted Living are environmental paradigms that strongly depend on their capability to recognize human actions. While most solutions rest on sensor value

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interpretations and video analysis applications, few have realized the importance of incorporating common-sense capabilities to support the recognition process. Unfortunately, human action recognition cannot be successfully accomplished by only analyzing body postures. On the contrary, this task should be supported by profound knowledge of human agency nature and its tight connection to the reasons and motivations that explain it. The combination of this knowledge and the knowledge about how the world works is essential for recognizing and understanding human actions without committing common-senseless mistakes. This work demonstrates the impact that episodic reasoning has in improving the accuracy of a computer vision system for human action recognition. This work also presents formalization, implementation, and evaluation details of the knowledge model that supports the episodic reasoning.

INTRODUCTION

Recognizing human actions is an essential requirement for fulfilling the vision of Smart Spaces, Ambient Intelligence, or Ambient Assisted Living. These paradigms envision environments in which electronic devices, merged with the background, operate as sensors retrieving environmental information. Among all different types of sensors, video cameras are extremely powerful devices because of the great amount of contextual information that they are capable of capturing. However, despite human's ability to understand effortlessly video sequences through observation, computer vision systems still have work to do in this regard.

Automatic video understanding is a delicate task that yet remains an unresolved topic [1]. Among all the challenges involved in video understanding, this paper focuses on human action recognition since this is an enabling key for Smart Spaces applications. Applications that depend on the identification of certain behavior require the ability to recognize actions. For example, kicking and punching are two actions that suggest an ongoing fight. In this sense, having the ability to recognize the sequence of actions that define an undesirable behavior can be used to trigger a security alarm.

Obviously, several challenges arise when dealing with human action recognition. In addition to the inherent difficulty of recognizing different people's body postures performing the same action [2], different actions may involve similar or identical poses. Moreover, images recorded within a real environment are not always captured from the best perspective or angle, which makes it impossible to retrieve poses consistently [3].

Fortunately, the human ability to recognize actions does not only rely on visual analysis of human body postures but also requires additional sources of information such as context, knowledge about actor intentions, or knowledge about how the world works normally referred to as common sense. This type of information helps people to recognize, among several similar actions, the one that is the most consistent with knowledge that person holds about previous experiences. For example, consider the actions of waving and throwing something overhead. They can be performed quite in the same way. However, if it is known beforehand that the actor is not holding anything that could be thrown away, waving is the most likely action being performed.

However, this human ability is far more sophisticated than just a simple condition matching process. People have also the capacity to hypothesize about different situations or episodes, project effects of actions based on previous experiences, wait for following actions to explain a previously nonunderstood action, or even ignore the occurrence of a certain action that cannot be recognized without interfering in the interpretation and understanding of the situation. Human's episodic memory is what enables us to model, represent, and reason about events, actions, preconditions, and consequences [4].

An episode is considered here to extend along time and involve a sequence of events and actions, presided by an undergoing plan. In this sense, a single action, such as walking, should be seen as part of a higher level action, activity, or episode such as approaching an object to pick it up. Single actions can take place on isolation but, for understanding purposes, it is essential to distinguish when they are being part of a more complex activity or episode. Note that the words activity and episode are used instinctively along this document.

Consequently, a successful action recognition system, inspired by the human one, should entail two different perspectives, that is, visual analysis and episodic reasoning. This work extends the work in [5] in which an off-the-shelf computer vision system is combined with a heuristic system for human action recognition. This work improves the heuristic system by providing a computational implementation of the human episodic memory paradigm to support episode modeling, representation, and reasoning. Different mental models intervene in episodic reasoning and this work proposes use of three of them: *beliefs, expectations, and estimations*. These mental models hold different implications, such as the fact that a belief is true in the context of the person that holds that idea although it may not be true in the real world context. These implications have to be captured in order to successfully implement an episodic reasoning approach. A preliminary attempt to present this formulation was introduced in [6]. Furthermore, usage of these mental models is formalized by means of a semantic model and validated by, first, translating them into a software implementation and, second, assessing the commonsensicality level of the resulting system.

The following sections describe how these endeavors can be articulated based on the implementation of philosophical theories about knowledge and human behavior. More particularly, Section 2 presents some of the most relevant works going in the same direction as the one presented here. Section 3 discusses the relevance that common sense has in achieving system with intelligent capabilities. Section 4 proposes and formalizes a knowledge model for video-based human action recognition. Section 5 describes how the formal theories supporting this work can be implemented into concrete procedures that can be computationally run. Section 6 validates the working hypothesis motivating this work by assessing the proposed system performance, from both the computer vision perspective and the human cognition one. Finally, Section 7 presents the most relevant conclusions drawn from the work described here.

PREVIOUS WORK

Different approaches have been devised to tackle the problem of human action recognition from the computer vision perspective, such as [7–10]. Mainly, video-based action recognition algorithms rely on learning from examples and machine learning techniques such as HMM [11], dimensionality reduction [12–14], or Bag of Words [9]. Since these approaches do not include any reasoning capability, their efficiency relies completely on the training and its coverage of all actions present in a given scenario. Unfortunately, all those action recognition experiments are conducted with videos that are not representative of real life data, as it is demonstrated by the poor performance obtained on videos captured in uncontrolled environments [9, 15]. It has been concluded that none of existing techniques based solely on computer vision and machine learning is currently suitable for real video surveillance applications [1].

However, few works combine video-based strategies with anthropological aspects or knowledge about human and social behavior [16], despite these essential elements being of human behavior [17]. According to [18] human behavior is enabled by six different types of mechanisms: instinctive reactions, learned reactions, deliberative thinking, reflective thinking, self-reflective thinking, and self-conscious reflection. These mechanisms should be therefore considered as an inherent part of any system intended to understand human behavior, independent of the dimension in which it is expressed, thinking, acting, or talking, for example. On the contrary, the approach that followed from the human action recognition perspective consists in rather equipping systems with the minimum amount of information required to solve the problem.

Enabling computational systems with these mechanisms is not an accessory demand, but, on the contrary, it is becoming more and more essential as new paradigms depend on showing rational behavior. In this sense, human activity recognition is becoming a hot topic due to the key role it plays in fields of knowledge such as Ambient Assisted Living (AAL) [19] or Ambient Intelligence (AmI) [20]. In fact, as stated in [21], activity recognition is one of the main challenges faced by AAL [22]. Provided that human activity recognition is a task that can be framed in very different fields of knowledge, it is important to state here that this work focuses on achieving video-based human action recognition as an enabling key for AAL spaces. These spaces are characterized by showing skills for supervising, helping, and assisting the elderly in their daily life. These skills need to therefore be grounded in cognitive and understanding capabilities.

This reference to cognitive and understanding capabilities basically alludes to computational mechanisms for interpreting the facts provided by sensors and video devices deployed in an AAL space. The events captured by environmental sensors are interpreted as signal describing an ongoing episode in a well-known context. Modeling the knowledge and information gathered from this type of scenarios has also been a major topic of discussion. In this sense, the World Wide Web Consortium (W3C), aware of that shortage, provides a standardized and formal model of the environment [23]. Despite this attempt to standardize the conceptual entities that should be part of the model, this ontology fails to provide the means to model ongoing episodes or situations, and, for that reason, the work presented here has adopted the model proposed by McCarthy and Hayes [24]. The *situation* concept proposed by McCarthy models world episodes as changes result of actions and events taking place in it. This work has therefore adopted this approach by describing actions and events in terms of a set of statements describing the world before the action takes place and afterward.

Setting aside the formality employed for knowledge modeling, next issue to be considered is the employed mechanism for undertaking human action recognition. Despite the fact that there is not a unique standard procedure for action recognition in AAL, some of the most common approaches are rule-based [21, 25, 26], statistical [27] or learning, both in supervised and unsupervised modes [28, 29]. However, due to the background of this paper, special attention is paid to those approaches based on video, like the one presented here. The work in [30] employs human silhouettes linked by connectors, in such a way that different postures are represented by means of different silhouettes and connections. The work in [31] proposes decomposing human actions into subtasks, such that the recognition process is accomplished in different stages. The work in [32], despite not being specifically devoted to a video-based solution, refers to sensors in general so it can be easily extrapolated to video-based systems. It consists in applying statistical modeling of sensor behavior to learn behavioral patterns that can be used for security and care systems. The work in [33] extends the previous work to consider additional approaches for not only monitoring systems but also making special emphasis on the behavior modeling task. However, these types of systems, mainly characterized by their rigidness, fail to deal with unexpected or unforeseen situations. For that reason, more elaborated reasoning mechanisms are required to deal with action recognition in open spaces. By open spaces we refer here to those environments in which interactions and events are coming from different sources at unexpected times.

The task of modeling human behavior has been tackled in this work from the perspective of common sense. Some activities have already been undertaken in this regard, although from the perspective of indoor mobile robots [34, 35]. Due to the great effort involved in collecting knowledge about the everyday world, the most commonly employed approach consists in resorting to existing systems. There are not many systems dedicated to collect and manage common-sense knowledge. In fact, the most famous ones are OpenMind (http://commons.media.mit.edu/en/), Cyc or OpenCyc (http://www.opencyc.org/), and Scone (http://www.cs.cmu.edu/~sef/scone/). The first system simply provides knowledge-based capabilities, lacking of an inference and reasoning engine, similarly, although OpenCyc holds these mechanisms, it only provides limited capability in comparison with the commercial project Cyc. Finally, Scone is an open-source system that provides efficient mechanisms for supporting common-sense reasoning and knowledge modeling operations [4, 36]. The characteristic that makes Scone the most suitable choice when it comes to episodic reasoning is its capability to deal with multiple contexts at the same time. The concept of *context* in Scone provides the perfect abstraction to hold episodes or situations. The way Scone handles contexts is also essential to enable episodic reasoning, since it implements a lightweight approach that barely overloads the system response as contexts are being created in the knowledge base. Moreover, the fact that only one context is active at a time provides a way of keeping inconsistent information in the same knowledge base without causing any disturbance in the data consistency.

LEVERAGING COMMON SENSE

The development of the field of Artificial Intelligence has been led by the will of building computational intelligent systems. This task has turned out to be a very difficult one, and, despite the fact that computing systems have been improving their intelligent skills, the lack of common sense that they suffer from has prevented them from becoming truly intelligent. In words of Minsky [18] "*some programs can beat people at chess. Others can diagnose heart attacks. Yet others can recognize pictures of faces, assemble cars in factories, or even pilot ships and planes. But no machine yet can make a bed, or read a book, or babysit.*" In his 1968 paper [37], McCarthy proposes an approach with which to build a program with the capability to solve problems in the form of an *advice taker*. In order to do so, McCarthy reckons that such an attempt should be founded in the knowledge of the logical consequences of anything that could be told, as well as the knowledge that precedes it. In this work, McCarthy postulates that "*a program has common sense if it automatically deduces from itself a sufficiently wide class of immediate consequences of anything it is told and what it already knows.*"

For Lenat et al. [38], "common sense is the sort of knowledge that an encyclopedia would assume the reader knew without being told (e.g., an object can't be in two places at once)." Minsky [18] uses the term with regard to the things that we expect other people to know, those things labeled as obvious. In this sense, the feature that distinguishes people from computers, regarding cognitive and understanding capabilities, is the vast amount of knowledge they hold as well as their associated mechanisms that support an effective use of such knowledge.

Replicating human intelligence is therefore a task that requires an extremely large amount of knowledge. However, it is neither expert nor specific knowledge that needs to be improved in these systems. On the contrary, the focus should be placed at everyday knowledge known as common sense. In this sense, the working hypothesis motivating this work was that video-based human action recognition could be enhanced with common-sense knowledge in order to enable episodic reasoning to overcome the occurrence of nonsensical errors.

Two main difficulties are found in demonstrating this working hypothesis: on the one hand, to date, computer vision systems are not yet capable of recognizing whichever human action performed in video sequences recorded from real scenarios [1]; and, on the other hand, collecting the vast amount of common-sense knowledge held by humans is far from being a feasible task. Note that Cyc [39] has been gathering common-sense knowledge for over 25 years and it is still working on it. It is therefore necessary to make some simplifications to the original problem: human actions that are to be recognized have to be limited to a given set and human common-sense knowledge has to be reduced to an incomplete set. So, in this sense, the conclusions drawn from this incomplete set of common-sense knowledge can be directly extrapolated to the complete one.

It can be tempting to think that hand-crafted representation of expert knowledge can, at some point, replace the role of common-sense knowledge. In fact, the following quotation, extracted from [39], discusses this issue.

“It is often difficult to make a convincing case for having a consensus reality knowledge base, because whenever one cites a particular piece of common sense that would be needed in a situation, it’s easy to dismiss it and say “well, we would have put that into our expert system as just one more (premise on a) rule.” For instance, in diagnosing a sick twenty-year-old coal miner, the program is told that he has been working in coal mines for 22 years (the typist accidentally hit two 2s instead of just one). Common sense tells us to question the idea of someone working in a coal mine since age-2. Yes, if this sort of error had been foreseen, the expert system could of course question it also. The argument is, however, that we could keep coming up with instance after instance where some additional piece of common sense knowledge would be needed in order to avoid falling into an inhumanly silly mistake.”

Obviously, a more careful representation of information could take into consideration that the age of a person cannot be a bigger number than the number of years the same person has been working in coal mines. Using the same context that concerns us here, it could be stated that, in order to throw something overhead, the person has to previously pick up the object that is about to throw away. However, the work presented here is more concerned with describing the knowledge that would allow the system to achieve that same conclusion on its own, rather than with providing these matching condition rules. The counterpart is that the amount of information required to do so is huge.

For that reason, the approach followed by this work consists in minimizing the common-sense knowledge involved in the considered scenario by constraining the context in which actors perform. However, it is essential to highlight that these constrains should not be equated to the approach followed by expert systems.

A SEMANTIC MODEL FOR HUMAN ACTION RECOGNITION

There is a set of relevant concepts that characterize the process of episodic reasoning for human action recognition, independent of whether it is carried out computationally or by a person. Essentially, there is a context in which a person, typically referred to as an actor, performs a set of temporal actions, each of which is intended to a specific end. In this sense, a video-based human action recognition system only requires a concrete set of entities to model the problem domain. These are the actor who appears in the scene, the context in which the scene is framed, the actions he/she performs, the beliefs and expectations the system holds about what the actor is doing and what he/she is doing next, and finally the estimation in which all these beliefs are considered. These concepts and their relationships, expressed in a semantic model, should suffice to formally model the knowledge involved in video-based human action recognition, as empirically demonstrated in this paper.

The semantic model also provides a set of syntactic rules with their associated meaning which allows describing the knowledge involved in any episode of human action recognition. This knowledge is, in practice, reduced to a set of propositional statements written in terms of instances of these concepts and their relationships.

Finally, the need for information standardization in distributed systems also supports the demand for a semantic model. When more than one system or module interoperates to perform an operation, there exists an information exchange that should be supported on some sort of agreement that states how such information can be correctly processed and understood.

However, despite the importance of counting on a semantic model for human action recognition, a complete review of the state of the art has brought into light that this aspect has been totally overlooked. The fact that most solutions focus on the proposal of new algorithms, methodologies, or signal processing approaches is probably the reason why the knowledge management aspect of the problem has not been exploited. On the contrary, this topic has been thoroughly studied by philosophers [40–42].Among existing theories about actions, this work implements the theory proposed by Donald Davidson in "*Theory about actions, reasons, and causes*" [40]. According to the Davidsonian view about the nature of actions, every human action is rational because the explanation of that action involves a judgment of some sort. In other words, what this theory states is that every action is motivated by an *intention*, in the broad sense of the word. So, the link between the action and the reason that explains it is what Davidson refers to as the *rationalization*.The most relevant conclusion of this theory is that the reason that motivates an action also rationalizes it. This fact has very relevant implications to this work because it supports not only the computational formal model for human actions proposed here but also the validation of the working hypothesis motivating this work.Figure 1 depicts the set of concepts and relationships that comprises a semantic model for human action recognition. Apart from the concept of action and actor, some other relevant entities require their semantics to be modeled. It is obvious that human action recognition cannot conceive existence without considering the context in which actions are being performed.

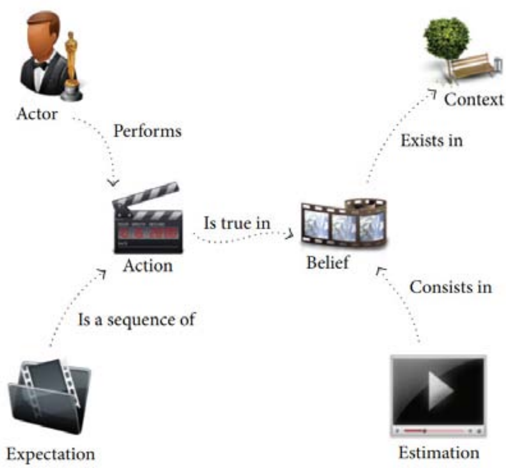

Figure 1. A semantic model for video-based human action recognition.

The simplicity of this model is in reducing human action nature to those concepts that cannot be avoided. This semantic model can be used to model the domain knowledge, independent of the environment in which they are being considered. Moreover, this simplicity eases the process of translating the formal model into a concrete programming language implementation of the semantic model. The following definitions state the foundation of the proposed semantic model.

Definition 1. A Context is the set C composed of statements which, when used together, describe knowledge about the general world or a specific belief. There may be multiple contexts describing each of the different views or beliefs of the world. The meaning or truth value of a statement is a function of the context in which it is considered.

Let us define the function meaning : $S, C \rightarrow M$, where S is the set of statements describing the world, C is the set of possible contexts, and M is the set of possible meanings. Meaning (s, c) returns the meaning or truth value of the statement s in the context c. This can be formally stated as

$$\exists m \in M \ \forall c_i \in C \ \forall s_i \in S : m = \text{meaning}\left(s_i, c_i\right) \Longleftrightarrow s_i \subseteq c_i. \quad (1)$$

The meaning or truth value of a given statement depends on the contexts in which it has been declared.

Definition 2. An Action is the set A of individual actions that have been described from the perspective of their relation to the primary reason that rationalizes them. The function $: A \rightarrow G$, such that A is the set of possible actions, G is the set of possible actors, and the function AG returns the actor performing the given action. Furthermore, the function $PR : G, A \rightarrow R$, such that R is the set of possible reasons motivating a specific action, returns the primary reason for an actor performing an action in seeking specific results. Finally, the function $: G \rightarrow A$ returns the actions performed by an actor. Consider

$$\exists g \in G \ \forall a_i \in A : \left(AG\left(a_i\right) \wedge PR\left(g, a_i\right)\right) \Longleftrightarrow PA\left(g\right) = a_i. \quad (2)$$

Therefore, every action is performed by an actor if and only if there exists an actor with a primary reason to perform that action.

Definition 3. An Actor is the set G of individual actors who perform actions. The function $attitu : G \rightarrow T$ returns the set T of proattitudes held by an actor that support the reasons to perform certain actions. Moreover, the function $: G, S \rightarrow A$, such that S is the subset of statements describing actions performed by actors. The function $: G, A \rightarrow S$ returns a statement describing that a specific actor performs a specific action at that exact time instant. Consider

$$\exists g \in G\ \forall a_i \in A\ \forall s_i \in S : PF(g, s_i) = a_i \Longleftrightarrow s_i = ST(g, a). \tag{3}$$

Every action performed by an actor is described by means of a time-stamped statement. Consider

$$\exists g \in G\ \forall a_i \in A\ \exists r \in R : PR(g, a_i) = r \Longleftrightarrow r \in \text{attitudes}(g). \tag{4}$$

The definition of actor therefore implies that, for every action performed by that actor and motivated by a specific primary reason, the set of proattitudes supporting the actor behavior includes that specific primary reason.

Definition 4. A Belief is the ordered set B of individual beliefs comprised of a temporal sequence of statements describing actions performed by actors. The function $: B \to S$ returns the sequence of action statements considered in a specific belief. Consider

$$\forall a_i \in A\ \forall g_i \in G\ \forall s_i \in S : ST(g_i, a_i) = s_i \Longleftrightarrow s_i \subseteq BF(b_i). \tag{5}$$

Every statement describing the fact that an action has been performed by an actor is part of a belief.

As it has been already mentioned, the set B is an ordered set of individual beliefs. The order is a direct consequence of the belief grade associated with each individual belief. The more a specific belief is considered to be the real sequence of actions taking place, the higher order it has in the ordered set. The belief located at the top of the ordered sequence of beliefs is referred to as *main belief*. Consider

$$\exists mb \in B : \forall b_i \in B \mid mb > b_i. \tag{6}$$

Finally, beliefs are not considered in isolation but as part of a more general entity called estimation. The function $: E \to B$ returns the ordered sequence of beliefs that comprise a specific estimation of a video-based analysis of human action recognition. Consider

$$\forall b_i \in B \quad \exists e \in E : bi \subseteq BF(e). \tag{7}$$

Definition 5. An Expectation is the set X of individual expectations; each of them contains an ordered sequence of actions that are normally referred to as activity. The function $: X \rightarrow A$ returns the ordered set of actions composing a specific expectation. Consider

$$\exists x \in X \quad \exists a_1, a_2, \ldots a_n \in A : n = |x|,$$
$$EX(x) = (a_1, a_2, \ldots, a_n),$$
$$\exists a \in A \quad \exists x \in X : a \subseteq x \Longleftrightarrow a \subseteq EX(x). \tag{8}$$

Function $: X, A \rightarrow A$ returns the remaining ordered set of actions that follow up a specific ordered set:

$$\exists x \in X \quad \exists a_1, a_2, \ldots, a_m, \ldots, a_n \in A \; \exists n,$$
$$m \in \mathbb{R} \mid m < n : RA(a_1, a_2, \ldots, a_m)$$
$$= (\ldots, a_n) \Longleftrightarrow (a_1, a_2, \ldots a_m) \subseteq EX(x). \tag{9}$$

Definition 6. An Estimation is the set E of individual estimations for each human action recognition process performed during a video sequence. An estimation consists in an ordered set of beliefs, in which the main belief is the one output by the recognition process. The function $: E \rightarrow B$ returns the ordered set of beliefs that compose that estimation. Additionally, function $: E \rightarrow B$ returns the main belief of a specific estimation. Consider

$$\exists e \in E \quad \exists b_1, b_2, \ldots, b_n \in B :$$
$$MB(e) = b_1 \Longleftrightarrow GE(e) = (b_1, b_2, \ldots, b_n). \tag{10}$$

SYSTEM IMPLEMENTATION

The ultimate goal of this work is to demonstrate that combining video recognition tools with episodic reasoning is the most compelling approach for human action recognition. The motivation is therefore to support the recognition process not only in video features analysis but also in the knowledge about human behavior and how the world works. In this endeavor, several stages can be identified in the proposed solution as depicted in Figure 2. The first step consists in an initial classification of actions based on visual body posture analysis. This initial classification is then provided, as input, to the knowledge-based system in charge of rationalizing the recognized actions. However, rather than proposing just one action, the computer vision system returns a list of actions whose order depends on their associated probabilities. The first action in the ordered set is the most probable one, although it does not necessarily mean that this is the correct one. For that reason, it is more sensible to consider the set of most probable actions rather than taking for granted that the most probable action, the first in the ranked list, is the correct one. This approach exploits the fact that, although the first action is not the correct one, in most cases, the groundtruth action is present in the list of the five most probable actions. Hopefully, if actors are really behaving in a rational manner, that is, performing actions motivated by reasons, and also the groundtruth action is present in that list, then we expect the reasoning system to be able to identify the correct or groundtruth action even when it has not been returned in first position. The third stage basically seeks for the motivations that might be behind each of these actions. This information supports the reasoning system in deciding which action better complies with actions believed to have been previously performed in the same video sequence.

Figure 2. Stages involved in the proposed solution for human action recognition.

A prototype system, going through these three stages, has been built in order to turn the working hypothesis into a real implementation that could be run and empirically evaluated. This section describes the technological decisions, grouping them into three major areas, as known, computer vision analysis, knowledge management, and common-sense reasoning.

Computer Vision Module for Human Action Recognition

The first stage of our system consists in generating initial action estimations by applying machine learning. Then, these estimates are passed to the knowledge-based system for further reasoning. Given a video sequence, the computer vision system, trained to recognize a given set of actions, returns an ordered sequence of actions which best describes the video according to the computer vision capability. Although each of those actions has been assessed by the system as the most probable, alternative actions may still be likely. As a consequence, in addition to the ordered sequence of actions, alternative actions with high probabilities are also provided to the knowledge-based system.

Among the different machine learning techniques that can be applied to perform human action recognition [43, 44], the Bag of Words (BoW) framework [45, 46] is particularly suitable. BoW has been proved [47–49] as one of the most accurate methods for action recognition, able to perform on a large variety of different scenarios with a low computational cost. Contrary to other classification techniques, it does not require any additional segmentation algorithm, which simplifies significantly the computer vision task and makes possible working directly on video data. Consequently, BoW methodology was chosen as the base of our computer vision module for action recognition.

Similar to most machine learning techniques, BoW relies on a training phase to learn the discriminative features and the classifiers that allow a correct recognition. Therefore, our BoW training stage consists of, firstly, producing a codebook of feature descriptors, secondly, generating a descriptor for each action video available in the training set, and, finally, training a classifier with those video descriptors. The pipeline starts by extracting salient feature points in each labeled video belonging to the training set. To ensure discriminative features, a well-known detector, Harris3D [50, 51], is applied. Once feature points are extracted from all training videos, a clustering algorithm [52] is used to group and quantize the salient point descriptors and to generate a codebook, or dictionary, which provides the vocabulary in which data will be described. Finally, each video of the training set is described in terms of the new word descriptors and used as input to train a cascade of linear Support Vector Machine (SVM) classifiers. In this way, the SVM classifiers, one per action, learn the optimal hyperplane that separate best the different actions.

During the action classification phase, actions performed in the video of interest are recognized by applying a similar procedure. Salient feature points are first detected using the same Harris3D algorithm. Then, the features are quantized using the learned codebook in order to generate a video descriptor. As final step, the descriptor is fed into each SVM classifier, which allows quantifying the similarity between the new sequence and each trained action type. As a result, an ordered list of action labels is generated according to their fit.

Knowledge and Semantic Model

The capability of reasoning about knowledge has become an essential feature of any system intended to intelligently behave. However, some important questions arise in relation to that knowledge: What does the system need to know in order to understand the ongoing situation? How sure the system can be about its interpretation? Whenever a conflict arises between the computer vision estimation and the knowledge-based one, which one should be considered as more reliable?

These and similar questions are formally and theoretically addressed from the knowledge model perspective. The implementation of that model is, however, not a trivial issue and several concerns need to be considered first. Selection of the most appropriate implementation technology to comply with the model requirements is one of these issues, as well as sharing the model to all modules involved in the proposed distributed architecture. This last requirement therefore imposes the constraint of being compatible with the rest of the architectural module technologies.

Regarding the first issue, ontologies, specially those written in OWL Language [53], are one of the most extended approaches to implement knowledge models. However, there are several reasons arguing against their suitability for the purpose that concerns us here. Firstly, the computer vision system returns an ordered list of actions for each single action performed in the video sequence. Although only one of those actions is selected to be part of the main belief, it is necessary to keep a record of all *discarded* actions just in case later hints suggest that a previously selected action was not correct, in which case the estimation needs to be revised to propose a different one.

The need to keep track of uncertain actions implies that *a priori* inconsistent knowledge should be asserted to the knowledge base. Inconsistency issues arise when propositional statements describe the actor performing different actions at the same time instant. These same time-instant actions correspond to each of the actions returned by the computer vision module. For example, if two of the actions of the set are sitting down and getting up from a chair, two propositional statements stating these facts should be asserted to the knowledge base. Obviously, this situation would lead to an inconsistent situation since both actions cannot be performed at the same time.

Philosophers [41, 42] have suggested a theory to tackle the problem of how to deal with inconsistent knowledge. This theory has been extrapolated to computing and, according to Hobbs and Moore [54], instead of talking about the propositions that are true in a given context—or belief, using the terminology proposed here—one should rather talk about what states of affairs are compatible with what is already known. These states of affairs are referred to by philosophers as *possible worlds* [55]. The possible worlds theory basically consists in creating different worlds—once again we can talk about beliefs—each of which comprises the propositional knowledge verified to be consistent.

This leads to isolating inconsistent facts in different knowledge islands, referred to here as *beliefs*. Consistency issues can therefore be avoided by considering true only the knowledge described under the active belief. In this sense, each of the actions returned by the computer vision module, instead of being asserted to the general knowledge base, is being individually asserted to a different belief. This approach assures that the general knowledge base is consistent, as well as each of the different beliefs created in each estimation process.

Implementing the possible world theory to describe the propositional knowledge comprised of each belief has several advantages: (a) standard automatic deduction and inference techniques can be applied; (b) it assures knowledge-based consistency; (c) and more importantly uncertain information does not need to be discarded.Unfortunately, ontologies do not yet enable the representation of possible worlds due to the impossibility of deactivating some parts of the ontology while keeping the rest active. This mechanism is not supported by neither ontologies nor the existing approaches to manage them, such as Protege [56]. On the contrary, Scone represents an excellent option to deal with possible worlds by means of its *multiple-context* mechanism [4, 57]. Every world or every belief can be described in a particular context, and only one context at a time is active. Only the knowledge described in the active context is considered, therefore avoiding inconsistency issues among statements asserted to different contexts.

Not being able to deal with *a priori* inconsistent knowledge is not the only reason why ontologies cannot be used for the proposed architecture. In addition, although several frameworks claim to support ontology reasoning [58–60], they are actually only performing consistency checking operations. In this regard, Scone provides powerful mechanisms to support real reasoning tasks. The *marker-passing* mechanism [36] that it implements provides an extremely efficient way of performing inference, deduction, or reasoning by default operations.

In summary, the use of ontologies is unsuitable for the purposes described here, whereas Scone, through the multiple-context and marker-passing mechanisms, represents an excellent option for fulfilling the requirements of the proposed semantic model and the knowledge management demands.

Once the election of the Scone knowledge-based system has been justified, the next matter to be tackled is the implementation of the proposed knowledge model using the Scone language syntax. Figure 3 depicts implementation using the Scone terminology.

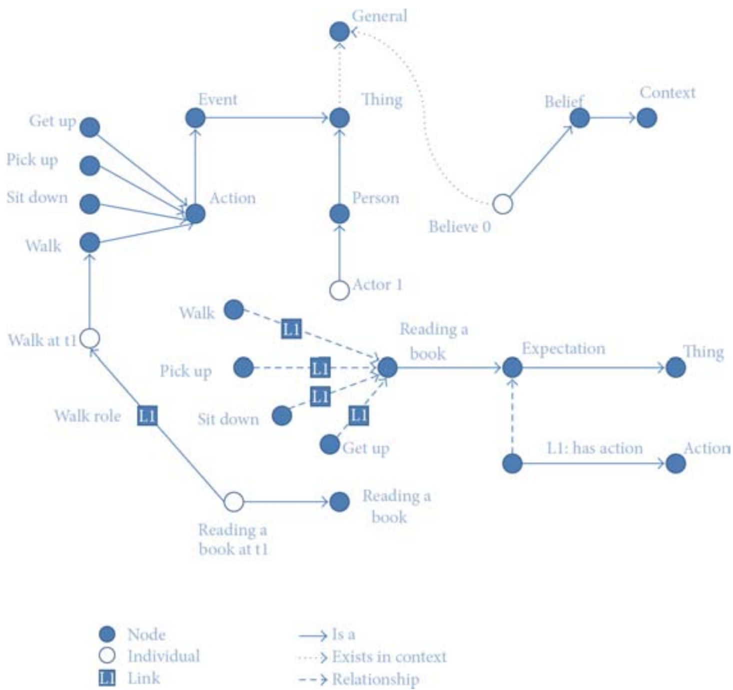

Figure 3. Knowledge modeled using Scone.

The Scone language is a dialect of Lisp, in which new concepts and relationships can be easily created to represent all the elements of the semantic model. Sconecode 1 shows how the actor concept is created as a specialization of one person, therefore inheriting all the properties and relationships of a person. Still, the actor concept is a high level entity. This entity can be made concrete by means of the *individual* abstraction. Whenever an individual of a certain type is declared, an instance of that type is created.

Sconecode 1

(1) (new-type {actor} {person})
(2) (new-indv {actor1} {actor})
(3) (new-type {believe} {compound event})
(4) (new-type {expectation} {thing})
(5)
(6) ;; An expectation is composed of an ordered sequence
(7) ;; of actions
(8) (new-type-role {has expectation} {expectation} {event})
(9)
(10) ;; Here is an example of how an expectation is defined
(11) (new-indv {picking up a book for reading it}
(12) {expectation})
(13)
(14) ;; Object properties in Scone are referred to roles
(15) (the-x-of-y-is-z {has expectation} {picking up a book
(16) for reading it} {walk towards})
(17) (the-x-of-y-is-z {has expectation} {picking up a book
(18) for reading it} {pick up})
(19) (the-x-of-y-is-z {has expectation} {picking up a book
(20) for reading it} {turn around})
(21) (the-x-of-y-is-z {has expectation} {picking up a book

(22)	for reading it} {sit down})
(23)	(the-x-of-y-is-z {has expectation} {picking up a book
(24)	for reading it} {get up})

Finally, this module does not only consider the semantic model knowledge or the knowledge describing how the world works, also known as common-sense knowledge, but also it does count on domain specific knowledge. Domain specific knowledge can be also referred to as context knowledge. However, for simplicity purposes, we will refer to that as domain specific knowledge (DSK) to avoid confusions with the word *context* that was previously used to describe the mechanism implemented by Scone to support the possible world theory. DSK consists in the propositional knowledge that describes the environment in which actions are being performed. This information turns out to be essential for meaning disambiguation purposes. DSK is also described using the Scone language and asserted to the Scone knowledge-based system, in the general context, inherited by every belief context.

Sconecode 2 shows some of the propositional statements describing the DSK of the particular scenario.

Sconecode 2

(1)	
(2)	(new-indv {test room} {room})
(3)	(new-indv {test room doorway} {doorway})
(4)	(the-x-of-y-is-z {doorway} {test room} {test room doorway
	})
(5)	(new-indv {test room floor} {floor})
(6)	(the-x-of-y-is-z {floor} {test room} {test room floor})
(7)	
(8)	(new-type {chair} {thing})
(9)	(new-type-role {chair leg} {chair} {thing})

(10) (new-type-role {chair sitting surface} {chair} {surface}
:n 1)
(11) (new-indv {test room chair} {chair})

This code sample shows how basic information about the environment is described under the proposed framework. This code represents the description of a test room, in which there is an entrance or doorway, as an example of domain specific knowledge (DSK). The common-sense knowledge—also referred to as world knowledge or WK—already holds propositional statements stating that entering a room is an action that consists in crossing through a doorway to enter an enclosed space of a building. In addition, there is also a chair in the room—example of DSK—which is a type of sitting surface—example of DSK. In the same way, the other elements present in the test room are described following similar rules.

Common-Sense Reasoning Module

This section describes the world knowledge functioning and the way people behavior can be heuristically used to recognize human actions. More specifically, this section intends to replicate the foundations for human's ability to recognize actions when angles or video quality is quite poor, for example, and visual information is scarce or insufficient to support the recognition task.

As stated in Section 5.2, the proposed framework for knowledge modeling is based on the possible world theory. This theory is the enabling key for modeling cognitive mental models such as *beliefs*, through the use of the *world* abstraction. Section 5.2 also states that the possible world theory is implemented in Scone by means of the multiple-context mechanism. This subsection is now concerned with how to implement the reasoning routines exploiting the semantics implicit in the possible world theory.

Figure 4 depicts a high level description of the proposed reasoning routine. According to the entities involved in the different routine stages, three different levels can be identified. The first level deals with the action set returned by the computer vision system. Every human action can be characterized by the body part that mainly intervenes in accomplishing that action. For example, the punching action mainly involves fists, as part of arms, whereas the kicking one involves legs. The action set is therefore analyzed in order to determine the prevailing body parts. The body part, or so-called here point of interest (PoI), that more frequently appears in the action set is used to reorder the same action set so that first actions are those involving the PoI, delegating others to the bottom of the list. Given that kicking, punching, waving, and scratching head are examples of an action set, the arm is the body part that appears more often. This means that the first action, or the most probable action, is not kicking as it was originally estimated, but the next most probable one involving the arm, which is, in this case, the punching action. Then, the reordered list of actions is checked for inconsistency issues. Consistency checking consists in determining whether the action requirements are fulfilled. Those actions whose requirements are not fulfilled are discarded.

Figure 4. High level stages involved in the reasoning process.

The second level considers the case where an action is part of a composite or activity, here referred to as expectation. When an expectation is active, it can be assumed that the actor is engaged in accomplishing that sequential set of actions. For that reason, given the actions already performed by the actor, it is possible to know the actions that are expected next.

It might be possible that more than one expectation is active at a time. In that case, the system should keep track of them which will lead to not forcing any belief of the actions to come. Alternatively, if the active expectation is unique, the next action to come is sought in the ordered action set and afterward asserted to the main belief. If the expected action was not in the list, the action will be forced to the main belief. Remaining actions are asserted to the following beliefs.

Figure 5 depicts the activity diagram of the previously described process, whereas Figure 6 shows the class diagram for the implementation routine.

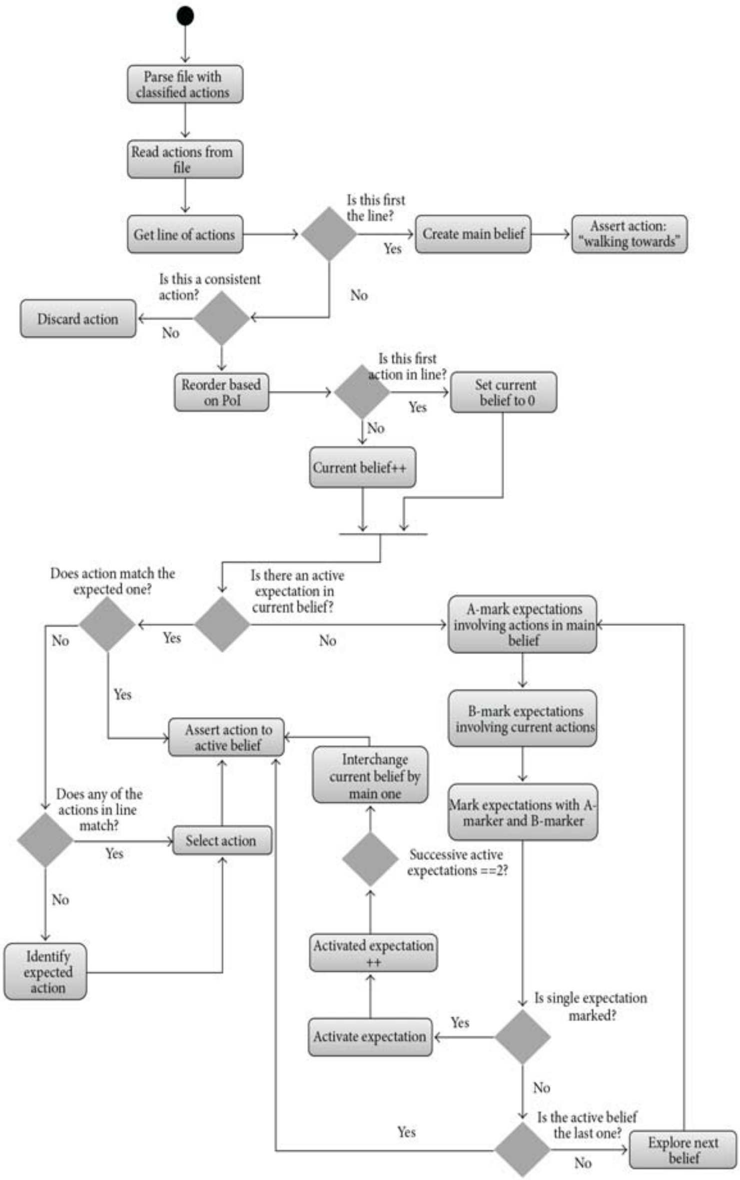

Figure 5. Activity diagram for reasoning about human actions.

Figure 6. Class diagram for the common-sense reasoning module.

Finally, going one step further in the level of details used to describe the reasoning routine, Algorithm 1 shows its implementation using pseudocode. Whereas the focus of this work is on describing the proposed knowledge framework, the work in [5] provides a thorough description of the algorithmic aspects.

Algorithm 1. Perform estimation (actions).

```
Actions = a_1, a_2, a_3, a_4, ..., a_N
for i = 0 to N do
  if i == 0 then
    create(main_belief)
    assert("walk", main_belief)
  end if
  constraints = WK(a_i)
  if DSK(constraints) == true then
    mark_expectations(active_belief)
    mark_expectations(a_i)
    if isExpectationUnique(expectation) then
      assert(a_i, active_belief)
    end if
    activate(b_i + 1)
  else
    discard(a_i)
  end if
end for
```

This condensed version of the proposed reasoning mechanisms essentially analyzes each of the five actions provided by the computer vision system. These actions are evaluated in the context in which they are being considered, referred to as DSK and, in the context of general knowledge, referred to as WK. If actions are consistent with this information, they are studied, in order to determine whether any of them is part of an activity. If the analysis of the current and past actionss brings into light that there is a unique activity taking place, then the activity is said to be active. Active activities—also referred to here as expectations—drive the system in its decision of which actions to assert in each of the parallel considered beliefs.

EXPERIMENTAL VALIDATION

Following descriptions of both the theoretical and implementational aspects of the working hypothesis, this section is devoted to discussing validation issues. It is important to recall that the working hypothesis motivating this work was that the combination of common-sense knowledge, reasoning capabilities, and video-based action classification could improve human action recognition of each of the parts in isolation. This is done by removing common-senseless mistakes which introduce noise into the recognition process.

The main axiomatic fact supporting this working hypothesis is directly drawn from the nature of human agency or human behavior. Based on the

Davidsonian view of human agency [40], actions are always motivated by a primary reason. Supported in this philosophical premise, the reason that motivates actions also rationalizes them.

This section aims at demonstrating the correctness of the working hypothesis. Since the proposed solution is tackled from taking advantage of different perspectives, that is, the computer vision and human cognition, each of them has to be validated.

In this sense, the followed approach consists in comparing the accuracy of a common-sense based computer vision system with one without reasoning capabilities. Moreover, the human cognitive perspective is validated by comparing the system with the most characteristic example of cognitive subjects: people. This was achieved by asking people to perform the same recognition tasks performed by the system and under the same circumstances. Comparison between the system and people performances allows assessing the level of "*commonsensicality*" held by the proposed system.

Accuracy Assessment

Traditionally, the best way for assessing the performance of computer vision system for human action recognition is by training and testing the proposed system with one of the publicly available datasets. These open and public datasets are therefore the most suitable benchmarks for evaluating and comparing proposed solutions with existing approaches.

Despite the relevant number of existing datasets, none of them fulfill the initial requirements of this work, which include encapsulating the complexity of real life applications with a significant number of complex activities. The lack of rationality with which the actions of these datasets are performed made them unsuitable for the purposes of this work. Indeed, the proposed solution is based on the premise that actions had to be performed for a reason in order to be rational. Unfortunately, existing datasets consist in video sequences in which actors are told what to do in a contextless scenario. Actions have to be part of a comprehensive story, so that performed actions make sense with regard to the aims or the reasons that motivate actors to behave like they do.

Two main premises support the creation of the new dataset: first, rule-based strategies are to be avoided; and, second, directions given to actors are kept to a minimum. These two premises can be satisfied by creating the appropriate atmosphere that makes actors prone to perform certain actions but allowing them, at the same time, to behave in a rational manner. If the reason that motivates an action also rationalizes it, and, consequently, if motivations could be heuristically driven and restricted, actions would also be limited to those matching the available motivations. In other words, if we want a person to perform a certain action all what has to be done is to motivate that person to do so. If that motivation is subtle enough, this implication can be used to demonstrate that common-sense capabilities enhance the performance of a computer vision system. Recall that it is necessary to limit the set of actions performed in a scene because, on the one hand, the available common-sense knowledge-based system is incomplete and, on the other hand, the computer vision system is only capable of recognizing a small set of actions. It has to be highlighted that actors should not be instructed to perform specific actions, because, by doing so, the rationality explaining the action would have been contaminated. On the contrary, by creating the appropriate atmosphere to motivate certain actions, we are creating a real scenario, in which actors act driven by intentions, while at the same time assuring that the scenario remains in the boundaries of the set of actions and knowledge known by the system.

The limited number of actions that can be recognized by computer vision systems justifies the need for a set-up scenario. There, actors are surrounded by suitable elements that encourage them to perform a predefined and expected set of actions such as punch or kick a punching-ball or read a book. The negligible probability of an actor performing those activities without the presence of interactive objects for fighting or reading makes them necessary for capturing the actions of interest.

The proposed scenario consists in a waiting room in which several objects have been strategically placed. Objects such as a punching-ball, a chair, or a book are motivating people behavior, for example, to play with the punching-ball which should lead them to perform the kicking and punching actions or to sit down on the chair.

Eleven sequences were recorded in which actors were just told to remain in the room for a period of time and feel free to enjoy the facilities present in the room. These eleven sequences were manually groundtruthed and segmented into actions. Afterward, these actions were fed to both, the basic computer vision system and the enhanced version in which common-sense capabilities had been leveraged.

In order to train a computer vision system capable of successfully detecting and segmenting the actions happening on this testing scenario, a suitable dataset must be chosen. This training dataset must not only comprise similar activities to the ones being promoted in our testing contextualized dataset but also fulfill a set of requirements. Thus, the training set must be able to cover a variety of camera views so that recognition is view-independent and the set should include a sufficiently large amount of instances of the actions of interest. These instances must be not only annotated but also perfectly segmented and organized to simplify training. The only suitable sets which fulfill these requirements and cover most of the activities that are promoted for our testing environment are IXMAS [43]. IXMAS is focused on standard indoor actions which allows providing quite an exhaustive description of possible actions in our limited scenario. Since it is comprised of 12 actions, performed by 12 different actors, and recorded simultaneously by 5 different cameras, it provides view independence and should offer sufficient examples to train a discriminative action classification.

Table 1 shows the average of the accuracy rates obtained for the eleven video sequences. A closer look to the accuracy rates obtained by actor shows that, in the best case scenarios, accuracy rates reach a 75% of positive recognition for the enhanced system.

Table 1. Average of accuracy rates obtained by the basic and common-sense enhanced system.

Computer vision system	Accuracy rate
Basic computer vision system	29.4%
Common-sense based computer vision system	51.9%

Table 2 presents the accuracy rates obtained by both systems, the basic and the common-sense enhanced one, for each individual actor. The columns with labels 1 to 11 represent each of the 11 individual actors, each of which has been recorded in a video sequence. As it can be seen in that table, even when using the same recognition approach—basic or common-sense enhanced—accuracy rate experiments dramatic variations. Several reasons explain these values, mainly based on the rationality with which actions were being performed by each actor. However, since these aspects belong to the human cognition side, it will be more detailed and analyzed in the next subsection.

Table 2. Accuracy rates for each individual actor.

CVS	1	2	3	4	5	6	7	8	9	10	11	Avg.
Basic	35.5	16.0	30.0	58.3	44.4	22.2	40.0	15.4	40.0	16.7	33.3	29.4
CS	64.5	52.0	50.0	75.0	55.6	66.7	40.0	30.8	60.0	25.0	33.3	51.9

Note that results shown in Tables 1 and 2 were initially presented in [5].

Commonsensicality Assessment

From the cognitive perspective, this system claims to hold common-sense knowledge and reasoning capabilities complementing the computer vision system in the task of recognizing human actions rationally performed. Assessing this claim is not a trivial matter, mainly due to the fact that common-sense knowledge is neither unique nor common to everybody. On the contrary, common sense varies from one person to another due to criteria such as age, gender, education, or culture.

Measuring how commonsensical a person or a system is resembles the problem of measuring human intelligence. Traditionally, intelligence quotients have been used to determine and compare intelligence levels among humans. These quotients are obtained from performance of subjects in intelligence tests. The same approach is therefore followed here to measure the commonsensical level of the system in comparison to humans. Rather than resorting to complex and philosophical questionnaires about common-sense knowledge, the proposed approach consists in presenting humans to the same situations analyzed by the system and comparing their answers. In the aforementioned intelligence tests, intelligence is treated as though it was unique and common to every human being, with the disadvantages involved in this simplification. However, if results are interpreted within the boundaries of these simplifications, this type of test can be very useful. In other words, intelligence test cannot be considered to be the silver bullet for determining how intelligent a person is, but, if they are correctly addressed, they can certainly bring into light very relevant information about certain aspects of human intelligence. This fact is highlighted here in order to make sure that results retrieved from the proposed questionnaires are not misused or misinterpreted, and they are considered within the boundaries in which they were conceived.

Obviously, if humans were provided with video sequences they would easily figure out the actions being performed. Moreover, the performance of the vision system has been already stated in the previous section. For both reasons, subjects will be presented with the same information provided as input to the common-sense reasoning system: the set of the five most probable actions returned by the computer vision system. Based on that action set and the description about the scenario in which actions are being performed, humans have to determine the course of actions taking place. In order to allow a fair comparison, the people completing the questionnaire have also been provided with a full description of the environment and the actions actors can perform. The questionnaire has been elaborated allowing people to change previous estimations based on information from following actions; in the same way the common-sense reasoning system interchanges beliefs whenever a lower-priority belief starts gaining credit, due to the sequential activation expectations.

Since humans, unlike machines, easily get fatigued when engaged in tedious and repetitive tasks, the questionnaire should be therefore compiled to mitigate the impact of tiredness in the obtained result. The proposed approach consists in focusing on the two most extreme cases, that is, those in which the recognition accuracy rates obtained by the system are the highest and the lowest. Looking back to Table 2, in which the system performance is compared with a computer vision system, it can be noticed that actors 4 and 10 are, respectively, those in which the highest and lowest accuracy rates are achieved.

Results show how, despite some variations, the majority of the people tend to identify certain actions with the same estimation. This suggests that the mental process followed to reason about human actions is quite similar among people, independent of nationalities, education, or age. However, there are always subjects in the groups who disagree. This probably means that they are following a different reasoning course.

Independent of the mental process followed by questioned people, it has to be highlighted that, when compared with the system under test, they do not outperform the system accuracy rate. In fact, people even degrade performance of the computer vision system. This fact can therefore be used to demonstrate that the proposed system works, at least, as well as a representative sample of people. This fact also indicates that the common-sense approach used by the system better suits the characteristic of the problem, if compared with the mechanisms employed by the questioned people. Probably, people are resorting to more complex mechanisms such as past experiences, for example, that are encouraging them to ignore the recommendations of the computer vision system. It is also probable that those who have had previous experiences with computer vision or intelligent systems better understand the mechanisms of these systems. Consequently, these people provide estimations more similar to the ones provided by the system. This is indeed one of the boundaries constraining the importance that should be given to the questionnaire results.

It is also worth mentioning that actor 4, the one behaving in a more rational manner, obtains a higher recognition rate than actor 10, the one behaving more erratically. Questionnaire results demonstrate that, as expected, a rational behavior can be more easily recognized than an erratic one. In this sense, accuracy rates obtained by questioned people are always better for actor 4 than for actor 10. This is the most relevant conclusion drawn from the analysis of the questionnaire results, since it can be used to demonstrate one of the axiomatic facts motivating this work: common-sense capabilities improve recognition rates of rational behavior.

The following tables summarize the most relevant aspects of the undertaken test. Table 3 starts by summarizing the different subjects that have participated in these tests. Thirty-seven people, from six different nationalities and various age groups, have performed the questionnaires. Additionally, Table 4 summarizes accuracy average obtained by the 37 questioned subjects. These values are compared with the ones obtained by the system proposed here. Finally, Table 5 shows the accuracy rate obtained in the recognition of each of the 12 actions composing the analyzed sequence.

Table 3. Participants information.

Gender			Age				Education			Nationality (6 in total)				
Male	Female	?	<25	25–40	>40	?	Undergrad	Postgrad	?	Spanish	Other EU	Asian	Canadian	?
34	3	—	9	11	4	13	9	15	13	16	5	2	1	13

Table 4. Average of accuracy rates obtained by questioned people and system.

System	Actor 4 (%)	Actor 10 (%)
Questionnaires	43.01	25.67
Reasoning system	75.0	25.0

Table 5. Accuracy in % obtained in recognizing each action.

Actor 4	Walk	Punch	Point	Walk	Punch	Turn	Walk	Punch	Turn	Punch	Check	Walk
	100	75.67	16.21	5.40	54.05	0	2.70	64.86	10.81	56.75	48.64	94.59
Actor 10	Walk	Kick	Turn	Walk	Punch	Walk	Scratch	Walk	Sit	Get	Wave	Walk
	97.29	0	2.70	18.91	48.64	2.70	2.70	16.21	5.40	5.40	16.21	91.89

CONCLUSIONS

This paper describes a system for video-based human action recognition enhanced with common-sense knowledge and reasoning capabilities. The main motivation of this work was to demonstrate that computational tasks involving some degree of human behavior understanding cannot be successfully addressed without considering some form of reasoning and contextual information. To demonstrate this axiomatic fact, a system has been built combining both strategies: computer vision and common sense.

The proposed system performs a primary recognition of actions, which is only based on image analysis capabilities. This first stage calculates the five most probable actions according to actors body postures. These actions are provided as inputs to the common-sense reasoning system. In a second stage, the common-sense reasoning model performs some reasoning tasks upon the computer vision system suggested actions. These operations are supported upon a formal model of knowledge, also proposed and formalized here.

Essentially, three conceptual abstractions are proposed in this model in order to replicate the mental process followed by humans into a computational system. The notion of action, belief, and expectation articulates the reasoning mechanisms implemented according to the Davidsonian theory of actions. In order to validate this model, a new video dataset has been proposed here, in which actions are motivated by reasons. The environment in which those video sequences are recorded has been carefully designed to provide actors with the reasons to perform the actions known by the computer vision system. This contribution is validated by the construction of the prototype, therefore verifying that the proposed semantic model complies with knowledge requirements arising in supervised contexts for human action recognition.

Two more aspects need to be validated, as they are the performance of the system in terms of recognition rates and *commonsensicality*. The first aspect has been evaluated by implementing a state-of-the-art approach for vision-based human action recognition. The second aspect is evaluated by asking people to recognize human actions, based on the sole information provided by the five most probable actions. Results in both sides demonstrate that incorporating common-sense knowledge and reasoning capabilities dramatically improves recognition rates. Additionally, it can also be concluded from the questionnaire analysis that, in order for the common-sense reasoning system to show its great potential, human actions being analyzed should be part of the rational behavior of the actor. Both the common-sense reasoning system and people have failed to successfully recognize actions performed by erratic actors.

Finally, it should be highlighted that this work tackles the problem of vision-based human action recognition from a comprehensive perspective. This entitles the proposed system to be deployed in any supervised environment in which human behavior understanding is required, as in Ambient Assisted Living.

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A Knowledge Representation Formalism for Semantic Business Process Management

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INTRODUCTION

Business process models are increasingly used to create clarity about the logical sequence of activities in public and private organizations belonging to different industries and areas. To improve Business Process Management (BPM), semantic technologies (like ontologies, reasoners, and semantic Web services) should be integrated in BPM tools in order to enable semantic BPM. Semantic Business Process Management (SBPM) approaches and tools aim at allowing more efficient and effective business process management across complex organizations. By semantic BPM decision makers can get transparent, fast, and comprehensive view of relevant

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business processes for better analyzing and driving processes. In defining semantic BPM tools aimed at improving the quality of process models and subsequent process analyses, a key aspect to take into account is to represent in combined way static knowledge regarding a specific application domain (i.e. domain ontologies) and dynamic knowledge related to process schemas and instances that are typically performed in a given domain. For example, in the health care domain, where the evidence-based medicine has contributed to define and apply clinical processes for caring a wide variety of diseases, a process-oriented vision of clinical practices may allow for enhancing patient safety by enabling better risks management capabilities.

In this Chapter is firstly summarized the large body of work currently available in the field of knowledge representation formalisms and approaches for representing and managing business processes. Then a novel ontology-based approach to business process representation and management, named Static/Dynamic Knowledge Representation Framework (SD-KRF), is presented. The SD-KRF allows for expressing in a combined way domain ontologies, business processes and related business rules. It supports semantic business process management and contributes to enhancing existing BPM solutions in order to achieve more flexible, dynamic and manageable business processes. More in detail, the presented framework allows methods for:

1. Creating ontologies of business processes that can be queried and explored in a semantic fashion.
2. Expressing business rules (by means of reasoning tasks) that can be used for monitoring processes.
3. Extracting information from business documents. Semantic information extraction allows the acquisition of information and metadata useful for the correct execution of business processes from unstructured sources and the storage of extracted information into structured machine-readable form. Such a facility makes available large amount of data on which data mining techniques, can be performed to discover patterns related to adverse events, errors and cost dynamics, hidden in the structure of the business processes, that are cause of risks and of poor performances.
4. Querying directly enterprise database in order to check activity status.
5. Executing business processes and acquiring process instances by means of either workflow enactment (predefined process schemas

are automatically executed) or workflow composition (activity to execute are chosen step-by-step by humans).

6. Monitoring business processes during the execution by running reasoning tasks.
7. Analyzing acquired business process instances, by means of querying and inference capabilities, in order to recognize errors and risks for the process and the whole organization.

SD-KRF is an homogeneous framework where the domain knowledge, the process structures, and the behavioral semantics of processes are combined in order to allow querying, advanced analysis and management of business processes in a more flexible and dynamic way.

SEMANTIC BUSINESS PROCESS MANAGEMENT AT A GLANCE

BPM links processes and information systems. One of the most important aspect of BPM is the modeling of processes. Historically, process modeling has mainly been performed with general purpose languages, such as Activity Diagrams (AD), Business process Modeling Notation (BPMN) or Event-driven Process Chains (EPC). Such instruments are not suitable for an automated semantic process analysis because semantic modeling of structural elements and domain knowledge are missing. In recent years different languages and approaches for semantic business process management have emerged. In this Section will be briefly described languages for representing processes and their semantics.

By considering the abilities of representing business processes, as described in van der Aalst (2009), existing languages for processes modeling can be classified in:

- **Formal languages**. Processes are described by using formal models, for examples Markov chains and Petri nets. Such languages have unambiguous semantics.
- **Conceptual languages**. Processes are represented by user-friendly semi-formal languages. Example of well known conceptual languages are UML activity diagrams, BPMN (Business Process Modeling Notation), and EPCs (Event- Driven Process Chains). Activity diagrams (or control flow diagrams) is a type of UML (unified modeling language OMG (2011)) diagrams. They provide a graphical notation to define the sequential, conditional,

and parallel composition of lower-level behaviors, therefore they are suitable for modeling business processes. The Event-driven Process Chain (EPC) van der Aalst (1999) is a type of flowchart used for business process modeling and compared to UML activity diagrams, the EPC covers more aspects such as a detailed description of business organization units together with their respective functions as well as information and material resources used in each function. These essential relationships are not explicitly shown in activity diagrams. The Business Process Model and Notation (BPMN) White (2006) is a graphical notation for drawing business processes, proposed as a standard notation. The language is similar to other informal notations such as UML activity diagrams and extended event-driven process chains. Models expressed in terms of BPMN are called Business Process Diagrams (BPDs). A BPD is a flowchart having different elements: Flow Objects, Connecting Objects, Swim-lanes, Artifacts, Events, Activities, and Gateways. Events are comparable to places in a Petri net, in fact they are used to trigger and/or connect activities. Whereas in UML Activity Diagrams and in BPMN resource types are captured as swim-lanes, with each task belonging to one or more swim-lane, in Event-driven Process Chains (EPC) resource types are explicitly attached to each task. These type of languages describe only the desired behavior of processes, and do not have a formal semantics, therefore they are not suitable for enabling processes execution.

- **Execution languages**. Because formal languages are too general and conceptual languages are aiming at the representation of processes and not directly at execution, languages that consider the processes enactment have been defined. The most common language in this category is BPEL (Business Process Execution Language) Wohed et al. (2006). BPMN diagrams are refined into BPEL specifications, but such translation is a difficult task because BPMN lacks of formal semantics. Therefore, several attempts have been made to provide semantics for a subset of BPMN Weske (2007). Other proprietary enactment languages have been defined. For example, XPDL XPDL (2011) is a very common language based on BPMN.

Semantic Business Process Management

BPM is a difficult task because the semantic of a business processes is frequently hidden in complex models obtained by different description and enactment languages. The explicit representation of domain knowledge related to business processes combined to explicit description of the semantic processes could help to obtain advices, alerts, and reminders. Furthermore, reasoning capabilities allow for representing and managing business rules and better enacting and monitoring of processes Peleg (2009). Classical languages adopted for representing process models provide a low degree of automation in the BPM lifecycle. In particular, there are many difficulties in the translations of business modeling (performed by business expert analist) to workflow models (which are executable IT representations of business processes). Like Semantic Web Services achieve more automation in discovery and mediation with respect to conventional Web services, BPM systems can obtain more automation by using knowledge representation and reasoning, and therefore semantic technologies Hepp et al. (2005).

Initially, knowledge representation and reasoning is been used for artificial intelligence tasks Newell (1980) to support humans in decision making. Then, rule-based systems were introduced. An important example is Mycin Shortliffe (1976) that represented clinical knowledge and contained if-then-else rules in order to derive diagnoses and treatments for a given disease. After, it was integrated database for representing knowledge in decision support systems. An important example is the Arden System for Medical Logic Modules (MLMs) Hripcsak et al. (1994) system. MLMs, in Arden Syntax, define decision logic via a knowledge category that has data, event, logic, and action slots useful in representing processes. Finally, ontologies Gruber (1995) were used for formally representing the knowledge as a set of concepts within a domain, and the relationships between those concepts. An ontology may be used to describe the domain, and to reason about the entities and relations within that domain in order to provide decision support. It is noteworthy that to add, delete or modify knowledge in rule-based systems was a difficult task, whereas ontologies are more simply modifiable. Ontologies and Semantic Web service technologies can be used throughout the BPM lifecycle Hepp et al. (2005); Wetzstein et al. (2007).

The use of semantics in BPM creates Semantic Business Process Management (SBPM) System. The goal of Semantic Business Process Management is to achieve more automation in BPM by using semantic technologies. In Wetzstein et al. (2007) the SBPM lifecycle is described.

There are 4 principal phases: Process Modeling, Process Implementation, Process Execution, and Process Analysis. The usage of semantic technologies increases the automation degree and the BPMS functionalities.

During the process modeling phase, the annotation of business process models allows for associating semantics to task and decisions in the process. The annotation is usually performed by using ontologies that describe domains or processes components. Generally, ontologies are created by ontology engineers, domain experts and business analysts. Different types of ontologies are relevant to business process management Hepp & Roman (2007). For instance, an organizational ontology is used to specify which organizational tasks have to be performed, in combination with a Semantic Web Service (SWS) ontology that specify the IT services that implement tasks, and domain ontologies that describe data used in the processes. The processes annotation enables additional semantics functionalities. In fact, ontological annotation of tasks enables the reuse of process fragments in different business processes in the implementation phase. During the execution phase, semantic instances are created, semantic checks of obtained instances can be automatically evaluated by calling reasoning tasks. During the semantic BP analysis phase, two different features are distinguished: (i) process monitoring which aims at providing relevant information about running process instances in the process execution phase, (ii) process mining that analyzes already executed process instances, in order to detect points of improvement for the process model. Such features take advantages by the semantic annotation. For instance, business analysts can formulate semantic queries and use reasoning to deduce implicit knowledge. Analysis allows for improving business processes for decreasing costs or risks in processes executions Medeiros & Aalst (2009).

There exist a lot of work addressing the enhancement of Business Process Management Systems ter Hofstede et al. (2010) by using Semantic Web techniques and, in particular, computational ontologies Hepp et al. (2005).

Robust and effective results have been obtained from European research projects CORDIS (2011), such as SUPER SUPER (2011), PLUG-IT PLUG-IT (2011) and COIN COIN (2011). They implemented new semantics-based software tools that enhance BPs of companies, and lower costs and risks. SUPER SUPER (2011), that means Semantics Utilised for Process Management within and between Enterprises, is an European Project financed from the Europen Union 6th Framework Program, within

Information Society Technologies (IST) priority. The project successfully concluded at 31st of March 2009. The objective of SUPER was to make BPM accessible for business experts adding semantics to BP. Semantic Web and, in particular, Semantic Web Services (SWS) technology allows for integrating applications at the semantic level. Based on ontologies, Semantic Web (SW) technologies provide scalable methods and tools for the machine readable representation of knowledge. Semantic Web Services (SWS) use SW technologies to support the automated discovery, substitution, composition, and execution of software components (Web Services). BPM is a natural application for SW and SWS technology. The project SUPER combines SWS and BPM, provided a semantic-based and context-aware framework, and created horizontal ontologies which describe business processes and vertical telecommunications ontologies to support domain-specific annotation. SUPER ontologies allow telecoms business managers to search existing processes, to model new business processes, to modify process models, to search for semantic web services that compose business processes and to execute implemented business process models.

The project plugIT PLUG-IT (2011), that means Plug Your Business into IT, has been co-funded by the European Union Intelligent Content and Semantics. It is based on the observation of the necessity to align Business and Information Technology (IT). The result of the project was the IT-Socket Knowledge portal. The project is based on the idea that IT can be consumed by plugging in business, like electric power is consumed when plugging in electronic devices in a power socket. ITSocket externalizes the expert knowledge by using graphical semi-formal models, such a knowledge is formalized in order to enable a computer-supported alignment using semantic technologies. Figure 1 shows business and IT experts that formalize the knowledge and so they enable automated support of business and IT alignment. In particular the alignment can be delegated to semantic technologies.

COIN, that means Enterprise COllaboration and INteroperability, COIN (2011) is an integrated project in the European Commission Seventh Framework Program, that stars in 2008 and ends in 2011. The scope of the project is create a pervasive and self-adapting knowledge that enable enterprise collaboration and interoperability services in order to manage and effectively operate different forms of business collaborations.

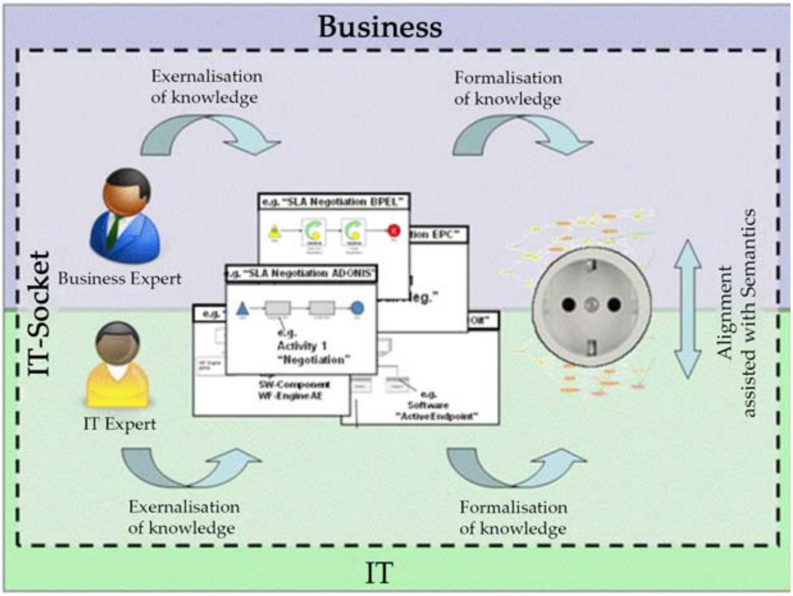

Figure 1. IT-Socket for business and IT alignment.

In literature a lot of ontology-based approaches to business process management have been proposed. Initially, a set of approaches was proposed to apply techniques borrowed from the Semantic Web to the BP management context SUPER (2011). In Missikoff et al. (2011) an ontology-based approach for querying business process repositories for the retrieval of process fragments to be reused in the composition of new BPs is presented. The proposed solution is composed by an ontological framework (OPAL) aimed at capturing the semantics of a business scenario, and a business process modelling framework (BPAL) to represent the workflow logic of BPs. In Markovic (2008) a querying framework based on ontologies is presented. In Francescomarino & Tonella (2008) a visual query language for business Process is described. Processes are represented trough a BPMN meta-model ontology annotated by using domain ontologies, SPARQL queries are visually formulated.

Other approaches based on meta-model ontologies have been presented in Haller et al. (2008; 2006) In Hornung et al. (2007) the authors present an initial idea for an automatic approach for completion of BP models. Their system recommends appropriate completions to initial process fragments based on business rules and structural constraints. The main elements are modeled by using an OWL representation of Petri nets that allows for efficiently computing the semantic similarity between process model variants. Additionally the approach makes use of the Semantic Web Rule Language (SWRL), which is based upon a combination of OWL DL with Unary/Binary Datalog RuleML Boley et al. (2001), to model additional constraints imposed by business rules. Ontoprocess system Stojanovic & Happel (2006) for semantic business process management semantically described, business processes are combined with SWRL rules by using a set of shared ontologies that capture knowledge about a business domain. These formal specifications enable to automatically verify if a process description satisfies the consistency constraints defined by business rules. In order to query BPs, some graph-matching-based approaches have been proposed Awad et al. (2008); Haller et al. (2006). In Awad et al. (2008) BPs are compiled to finite state models, so model checking techniques allow for verifying structural features of process schemas. However, the semantics of the business domain is not considered. Other approaches that allow for modeling and reasoning over workflows are based on logic programming Montali et al. (2008); Roman & Kifer (2007) have been introduced. Such approaches allow for checking and enacting BPs, but they are not used for querying.

As shown, a lot of approaches have been proposed in litterature, but no one is capable to semantically manage in a comprehensive way all phases of SBPM lifecycle.

Business Process Management in the Health Care Domain

The health care domain is of great interest for BPM. In fact, in the recent past, a strong research effort has been taken to provide standard representations of both declarative and procedural medical knowledge. In particular, in the area of medical knowledge and clinical processes representation, there exist one of the most rich collection of domain ontologies available worldwide and a wide variety of formalisms for clinical process representation. In the following, available approaches and systems for medical ontologies and clinical process representation and management are described.

A very famous and widely adopted medical thesaurus is Mesh, the Medical Subject Headings classification MESH (2011). It provides a controlled vocabulary in the fields of medicine, nursing, dentistry, veterinary medicine, etc. MeSH is used to index, catalogue and retrieve the world's medical literature contained in PubMed. Another classification, that has become the international standard diagnostic classification for all medical activities and health management purposes, is ICD10-CM ICD (2011); WHO (2011) the International Classification of Diseases Clinical Modification, arrived to its 10th Revision. The most comprehensive medical terminology developed to date is SNOMED-CT SNOMED (2011), the Systematized Nomenclature of Medicine Clinical Terms, based on a semantic network containing a controlled vocabulary. Electronic transmission and storing of medical knowledge is facilitated by LOINC, the Logical Observation Identifiers Names and Codes LOINC (2011), that consists in a set of codes and names describing terms related to clinical laboratory results, test results and other clinical observations. Machine-readable nomenclature for medical procedures and services performed by physicians are descried in CPT, the Current Procedural Terminology CPT (2011), a registered trademark of the American Medical Association. A comprehensive meta-thesaurus of biomedical terminology is the NCI-EVS NCI-EVS (2011) cancer ontology. Some medical ontologies are, also, due to European medical organizations. For example, CCAM the Classification Commune des Actes Medicaux CCAM (2011), is a French coding system of clinical procedures that consists in a multi-hierarchical classification of medical terms related to physician and dental surgeon procedures. A classification of the terminology related to surgical operations and procedures that may be carried out on a patient is OPCS4, the Office of Population Censuses and Surveys Classification of Surgical Operations and Procedures 4th Revision OPCS-4 (2011), developed in UK by NHS. The most famous and used ontology in the field of healthcare information systems is UMLS, the Unified Medical Language System UMLS (2011), that consists in a meta-thesaurus and a semantic network with lexical applications. UMLS includes a large number of national and international vocabularies and classifications (like SNOMED, ICD-10-CM, and MeSH) and provides a mapping structure between them. This amount of ontologies constitutes machine-processable medical knowledge that can be used for creating semantically-aware health care information systems.

The evidence-based medicine movement, that aims at providing standardized clinical guidelines for treating diseases Sackett et al. (1996), has stimulated the definition of a wide set of approaches and languages for representing clinical processes. A well-known formalisms is GLIF, the Guideline Interchange Format GLIF (2011). It is a specification consisting of an object-oriented model that allows for representing sharable computer-interpretable and executable guidelines. In GLIF3 specification is possible to refer to patient data items defined by a standard medical vocabularies (such as UMLS), but no inference mechanisms are provided. Proforma

Sutton & Fox (2003) is essentially a first-order logic formalism extended to support decision making and plan execution. Arden Syntax HL7 (2011); Peleg et al. (2001); Pryor & Hripcsak (1993) allows for encoding procedural medical knowledge in a knowledge base that contains so called Medical Logic Modules (MLMs). An MLM is a hybrid between a production rule (i.e. an "if-then" rule) and a procedural formalism. It is less declarative than GLIF and Proforma, its intrinsic procedural nature hinders knowledge sharing. EON Musen et al. (1996) is a formalism in which a guideline model is represented as a set of scenarios, action steps, decisions, branches, synchronization nodes connected by a "followed-by" relation. EON allows for associating conditional goals (e.g. if patient is diabetic, the target blood pressures are 135/80) with guidelines and subguidelines. Encoding of EON guidelines is done by Protégé-2000 Protégé (2011) knowledge-engineering environment.

STATIC/DYNAMIC KNOWLEDGE REPRESENTATION FRAMEWORK

The key idea which the Static and Dynamic Knowledge Representation Framework (SD-KRF) is based on is that elements of the workflow meta-model (i.e. processes, nodes, tasks, events, transitions, actions, decisions) are expressed as ontology classes Oro & Ruffolo (2009); Oro et al. (2009b). This way workflow elements and domain knowledge can be easily combined in order to organize processes and their elements as an ontology. More in detail, the SD-KRF allows for representing extensional and intensional aspects of both declarative and procedural knowledge by means of:

- *Ontology and Process Schemas*. The former expresses concepts related to specific domains. Ontology contents can be obtained by importing other existing ontologies and thesaurus or by means of direct manual definition. The latter are expressed according with the workflow meta-model illustrated in Section 3.1.
- *Ontology and Process Instances* both expressed in term of ontology instances. In particular, ontology class instances can be obtained by importing them from already existing ontologies or by creating them during process execution. Process instances are created exclusively during process execution. Instances are stored in a knowledge base.
- *Reasoning Tasks* that express, for instance, decisions, risks and business rules.

- *Concept Descriptors* that express information extraction rules capable to recognize and extract ontology instances contained in unstructured documents written in natural language. By concept descriptors ontology instances can be automatically recognized in documents and used for both enriching the knowledge base and annotating unstructured documents related to given domains and processes.

The SD-KRF constitutes an innovative approach for semantic business process management in the field of healthcare information systems. Main features of the presented semantic approach (founded on logic programming) is that it, conversely to already existing systems and approaches, enables to represent process ontologies that can be equipped with expressive business rules. In particular, the proposed framework allows for jointly managing declarative and procedural aspects of domain knowledge and express reasoning tasks that exploit represented knowledge in order to prevent errors and risks that can take place during processes execution. The framework enables, also: (i) manual process execution in which each activity to execute in a given moment is chosen by a human actor on the base of the current configuration of patient and disease parameters, and (ii) automatic execution by means of the enactment of an already designed process schema (e.g. guidelines execution). During process execution, process and ontology instances are acquired and stored in a knowledge base. The system is able to automatically acquire information from electronic unstructured medical documents, exploiting a semantic information extraction approach. Extracted information are stored into a knowledge base as concept instances. The processes execution can be monitored by running (over clinical process schemas and instances) reasoning tasks that implements business rules.

Modelling Process

A significant amount of research has been already done in the specification of mechanisms for process modeling (see, Georgakopoulos et al. (1995) for an overview of different proposals). The most widely adopted formalism is the control flow graph, in which a workflow is represented by a labeled directed graph whose nodes correspond to the activities to be performed, and whose arcs describe the precedences among them. In the SD-KRF we adopt the graph-oriented workflow meta-model shown in Figure 2.a and 2.b, inspired by the JPDL JPDL (2011) process modeling approach. The adopted meta-model: (i) covers the most important and typical constructs required in workflow specification; (ii) allows for executing processes in the SD-KRF by using the JBPM workflow engine; (iii) allows for using workflow mining techniques grounded on graph-oriented meta-models.

Since our scope is to allow the semantic representation of processes, we need firstly to formally define the process meta-model as the following 6-tuple:

$$\mathcal{P} = \langle N, A_r, E_v, A_n, T_k, E \rangle$$

where:

- N is a finite set of nodes partitioned in the following subsets: task nodes N_T (that represent activities in which a humans or machines perform tasks), subprocess nodes N_{SP} (that model activities referring processes external to the current one), group nodes N_G (that represent a set of nodes that can be executed without a specific order), custom nodes N_C (that model activities in which custom methods can be executed and handled automatically), wait nodes N_W (that represent activities that temporary stop the execution while they execute methods), join nodes N_J , and fork nodes N_F (that are respectively used to combine or split execution paths) and decision nodes N_D (that allow for controlling the execution flow on the base of conditions, variables or choices performed automatically or by human actors).
- A_r is a set of actors. Actors can be human or automatic. They represent the agents that execute a given task or activity.
- A_n is a set of actions. An action is a special activity that can be performed as answer to the occurrence of an event.
- T_k is a set of tasks that represent tasks to execute in task nodes.
- $E = \{\langle x, y\rangle : x \in N_{From} \wedge y \in N_{To}\}$ is a set of transitions in which the following restrictions hold, when $N_{From} \equiv N_{FN} \cup N_D$ then $N_{To} \equiv N_{FN} \cup N_{FCN} \cup N_{end}$ and when $N_{From} \equiv N_{FC\,N}$ then $N_{To} \equiv N_{F\,N} \cup N_D$. Moreover, for each process there is a transition of the form $e_{start} = N_{start}$, y where $y \in N_{FN}$ and one of the form $e_{end} = x$, N_{end} where $x \in \{N_{F\,N} \cup N_D\}$. The subset E_d E where $E_d = \{\langle x, y\rangle : x \in N_D \wedge y \in N_{F\,N}\}$ is the set of decisions. A decision relates a decision node to a flow node and could hold a decision rule that is used at run-time to automatically control the execution flow of a process.

- E_v is a set of events. An event causes the execution of an action that constitutes the answer to the event. An event can be, for example, the throwing of an exception during the execution of a task.

Modeling Static and Dynamic Knowledge

Formally the Static/Dynamic Knowledge Representation Framework (SD-KRF) is the 5-tuple having the following form:

$\mathcal{O} = \langle D, A, C, R, I \rangle.$

Where ontology/process schemas are expressed by using elements of D, A, C and R in O that are finite and disjoint sets of entity names respectively called data-types, attribute-names, classes and relations. The set of classes C is organized in taxonomies and partitioned in two subsets:

- The set of process classes $C_P = N \cup A_r \cup A_n \cup T_k \cup E_v$ that represents elements of the workflow meta-model. It is constituted by the union of classes representing nodes, actors, actions, tasks and events.
- The set of ontology classes C_O that represent concepts related to a specific knowledge domains.

The set R is a set of ontological relations partitioned in two subsets: the set of transition $R_P = E$, and the set of relations R_M used for representing relations between ontology concepts. In the following meaning and usage of O is explained by describing the implementation of a running example.

AN EXAMPLE: REPRESENTING ONTOLOGIES AND A PROCESS SCHEMAS IN THE MEDICAL DOMAIN

The medical domain offers many ontologies and thesaura describing diseases, drugs, medical examinations, medical treatments, laboratory terms, anatomy, patients administration, and clinical risks. Examples of medical ontologies are UMLS UMLS (2011), LOINC LOINC (2011), ICD10-CM ICD (2011), SNOMED SNOMED (2011). Many of such ontologies can be freely obtained from international organization that maintain them and can be automatically imported in the SD-KRF or manually entered by means of direct manual definition.

This section describes a clinical process for caring the breast neoplasm (Figure 2.c). Such an example in the medical domain, that will be used in the rest of the chapter as running example, allows for describing the ability of the SD-KRF to enable the representation of ontologies representing in combined way process schemas, ontological concepts and relations, and instances of both processes and ontologies.

The example considers practices carried out in the oncological ward of an Italian hospital, hence it is not general but specific for the domain of the considered ward. The clinical process is organized in the following 10 activities:

1. Task node Acceptance models patient enrollment. A patient arrives to the ward with an already existing clinical diagnosis of a breast neoplasm. This activity can be performed manually by an oncologist that collects patient personal data, and directly acquiring information from electronic medical records in natural language. The information extraction task is performed by exploiting the semantic information extraction approach described in Section 5. Extracted information are stored as ontology instances Oro et al. (2009a).
2. Group node Anamnesis represents a set of anamnesis activities: general anamnesis in which physiological general data (e.g. allergies, intolerances) are being collected; remote pathological anamnesis, concerning past pathologies; recent pathological anamnesis, in which each data or result derived from examinations concerning the current pathologies are acquired. These activities can be manually executed without a specific order or by exploiting semantic extraction rules (descriptors) that enable the recognition of information into unstructured source like pre-existing EMR.
3. Task node Initial clinical evaluation allows for acquiring the result of an examination of the patient by an oncologist.
4. Decision node More clinical test requested represents the decision to perform or not additional examination on the patient.
5. Group node Other exams models possible additional clinical tests. If requested these tests are conducted to find out general or particular conditions of patient and disease not fully deducible from the test results already available.
6. Task node Therapeutic strategy definition models the selection of a guideline with related drug prescription. At execution time the physician picks a guideline (selected among the guidelines already available in the knowledge base) that depends upon actual pathology state as well as other collected patient data.

7. Task node Informed agreement sign models the agreement of the patient concerning understanding and acceptance of consequences (either side effects or benefits) which may derive from the chosen chemotherapy, and privacy agreements.
8. Sub-process Therapy administration, models a subprocess that constitutes the guideline to execute for caring the patient.
9. Decision node Therapy ended models a decision activity about effects of the therapy and the possibility to stop or continue cares.
10. Task node Discharging models the discharging of the patient from the ward end allows for acquiring final clinical parameter values.

In the activities (6) and (8) risk and error conditions can be identified. At each guideline, chosen in (6), corresponds a prescription of drugs (chemotherapy). Hence the computation of doses, which may depend on patient's biomedical parameters such as body's weight or skin's surface, is required. Cross-checking doses is fundamental here, because if a wrong dose is given to the patient the outcome could be lethal. Furthermore, therapy administration ((8)-th activity) must contain checks that aims at verify type and quantity of chemotherapeutic drugs to submit to the cared patient.

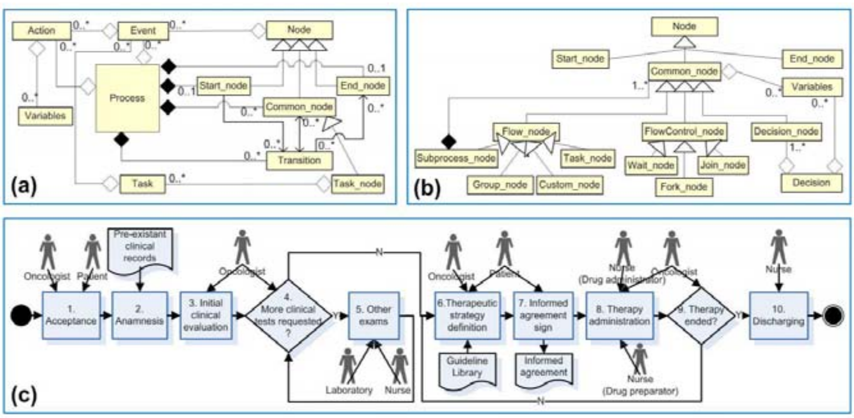

Figure 2. (a) The process meta-model. (b) The nodes hierarchy. (c) A clinical process for caring the breast neoplasm.

Ontology and Process Schemas

This section presents the syntax of the SD-KRF language by example. A class in $C \in O$ can be thought as an aggregation of individuals (objects) that have the same set of properties (attributes $A \in O$). From a syntactical point of view, a class is a name and an ordered list of attributes identifying the properties of its instances. Each attribute is identified by a name and has a type specified as a data-type or class.

In the following the implementation of the workflow meta-model in the SD-KRF language is firstly presented. In particular, nodes in C_P are implemented by using the class hierarchy (built up by using isa key-word) shown below.

```
class process(name:string).
class node(name:string, container: process, start_time:integer,
           end_time:integer).

    class start_node() isa{node}.
    class end_node() isa{node}.
    class common_node () isa{node}.
        class flowControl_node() isa{common_node}.
            class fork() isa{flowControl_node}.
            class join() isa{flowControl_node}.
            class wait_node() isa{flowControl_node}.
        class flow_node() isa{common_node}.
            class task_node(tasks:[task], handler:human_actor)
                            isa{flow_node}.
            class custom_node(handler: automatic_actor, method:string)
                            isa{flow_node}.
            class group_node(nodes:[node]) isa{flow_node}.
            class sub_process_node(sub_proc: process) isa{flow_node}.
        class decision_node(handler:actor) isa{common_node}.
            class automatic_decision_node(handler:automatic_actor)
                            isa{decision_node}.
            class manual_decision_node(task:task, handler:human_actor)
                            isa{decision_node}.
```

Task nodes and manual decision nodes contain tasks that are performed by humans. Tasks class task(name: string). collects values of activity variables given in input by human actor. Actors of a process (that can be human or automatic) represent the agents that execute a given task. They are represented by means of the following classes in C_P :

```
class actor(name:string).
    class human_actor() isa {actor}.
    class automatic_actor(url:string) isa {actor}.
```

During the process enactment, by running risk and business rules, events may occur. Furthermore, an event can be generated by an exception during the execution of a task. Events, and related actions to performs in response, are represented in C_P by the following classes.

```
class event(relativeTo:object, timestamp:integer).
    class node_event(relativeTo:node) isa{event}.
    class task_event(relativeTo:task) isa{event}.
    class process_event(relativeTo:process) isa{event}.
class action(method:string).
```

Relationships among objects are represented by means of relations, which like classes, are defined by a name and a list of attributes. Transitions and decisions, in R_p , that relate couple of nodes, are represented by means of the following ontology relations.

```
relation transition(name:string, from:node, to:node).
relation decision(name:string, from:decision_node, to:node).
```

When the user defines a specific process schema s/he can specialize original meta-model elements for adding new semantic attribute required by the specific process. In the following are shown some classes representing nodes of the running example depicted in Figure 2.

```
class acceptance_node(tasks:[acceptance_form],handler:physician)
      isa{task_node}.
class anamnesis_node(nodes:[general_anamnesis_node,
      remotePathological_anamnesis_node, recentPathological_anamnesis_node])
      isa {group_node}.
class recentPathological_anamnesis_node(tasks:[pathology_form],
      handler:physician) isa {task_node}.
class therapeutic_strategy_definition_node(tasks:[therapeutic_strategy_form],
      handler:nurse) isa {task_node}.
class therapy_administration_node(sub_process:therapy_administration_process)
      isa{sub_process_node}.
class more_tests_node(task:more_tests_form) isa{manual_decision_node}.
```

acceptance and therapeutic_trategy_definition process activities are represented as subclasses of task_node class, in fact they represent activities in which tasks consist in the execution of forms filled by humans. Whereas anamnesis_node, which Recent Pathological anamnesis activity belongs to, is represented as a subclass of group_node class. therapy_administration_node and more_tests_node are specializations of sub_pr oc_node and decision_node respectively. Human actors that operate in this clinical process could be physicians, nurses and patients. They are represented by a person hierarchy that exploits multiple inheritance capabilities in order to express that persons are also human actors of the clinical process.

```
class person(fiscalCode:string,name:string,surname:string,sex:sex_type,
          bornDate:date,address:address).
    class patient(hospitalCard:string, weight:float, heigthCm:float)
          isa {person,human_actor}.
    class healthCareEmploy(occupation:string, role:string)
          isa {person,human_actor}.
        class nurse() isa {healthCareEmploy}.
        class physician() isa {healthCareEmploy}.
```

Class schemas representing tasks related to task-nodes can be expressed by using the following class schemas. Attribute types can be classes represented in C_M expressing different medical concepts (e.g. diseases, drugs, body parts). During task execution values of resulting class instances are obtained from fields filled in forms.

```
class task(name: string).
    class acceptance_form(patient:patient, acc_date:date) isa{task}.
    class pathology_form(disease:disease) isa{task}.
    class chemotherapeutic_strategy_form(strategy:therapeuticStrategy)
          isa{task}.
    class more_tests_form(choice:boolean)isa{task}.
```

In a clinical process, an event can be activated by an exception during the execution of a node or by a reasoning task aimed at control business rules. A reasoning task checks parameters values of running node and already acquired node instances and throws an event related to an error. An example of different kinds of possible errors is shown in the following taxonomy, where the attribute msg of the class view_msg (action) is the message to display when the error occurs.

```
class task_event(relativeTo:task) isa{event}.
    class medicalError(msg:string) isa{task_event}.
        class drugPrescriptionError() isa {medicalError}.
class view_msg(msg:string) isa {action}.
```

Class schemas in C_M expressing knowledge concerning anatomy, breast neoplasm disease and related therapies and drugs have been obtained (imported) from the Medical Subject Headings (Mesh) Tree Structures , the International Classification of Diseases (ICD10-CM) . and the Anatomical Therapeutic Chemical (ATC/DDD) .

```
class anatomy(name:string).
    class bodyRegion() isa {anatomy}.
class disease(descr:string).
  class neoplasm() isa {disease}.
    class malignant_neoplasm() isa {neoplasm}.
       class primarySited_neoplasm(site:bodyRegion,zone:string)
             isa {malignantNeoplasm}.
          class breast_primarySited_neoplasm() isa {primarySited_neoplasm}.
class drug(name:string, ddd:float, unit:unitOfMeasure,admRoute:[string],
           notes:string).
    class antineoplasticAndImmunomodulatingAgent() isa {drug}.
        class endocrineTherapy() isa {antineoplasticAndImmunomodulatingAgent}.
            class hormoneAntagonistsAndRelatedAgents()isa {endocrineTherapy}.
                class enzymeInhibitors()
                      isa {hormoneAntagonistsAndRelatedAgents}.
            class hormoneAndRelatedAgents()isa {endocrineTherapy}.
                class estrogens() isa {hormoneAndRelatedAgents}.
class code(c:string).
    class icd10Code(chapter:integer, block:string,category:string,
          subCat:string) isa {code}.
    class mesh08Code(category:string, subCat:string) isa {code}.
```

```
class therapy(name:string, dru:drug, dose:float).
class therapeuticStrategy(patient:patient, therapy:therapy,startDate:date,
                          nDay:integer).
```

The previous classes are a fragment of a medical ontology inherent (breast) neoplasm cares and are used to model the clinical process shown in Section 4. Class primarySited_neoplasm shows the ability to specify user-defined classes as attribute types (i.e. site:bodyRegion). Class drug has a list-type attribute admRoute:[string] representing possible route of administration for a drug (for example inhalation, nasal, oral, parenteral). Relation schemas expressing medical knowledge can be declared by using the following syntax:

```
relation suffers (patient:patient, disease:disease).
relation relatedDrug (dis:disease, dru:drug).
relation sideEffect (dru:drug, effect:string).
relation classifiedAs (dis:disease, c:code).
```

Relation suffer asserts diseases suffered by a patient. Relations relatedDrug and sideEffect associates respectively drugs to a diseases and side effects to drugs. Moreover, relation classifiedAs enables users to query the ontologies by using codes defined in the original medical ontologies.

Ontology and Process Instances

Clinical process instances are expressed by ontology instances and created exclusively during process execution. Classes instances (objects) are defined by their oid (that starts with #) and a list of attributes. Instances obtained by executing the running example, are shown in the following.

```
#1:neoplasm_process(name:"Breast Neoplasm").
#2:therapy_administration_process(name:"Therapy Administration").
#1_1:acceptance_node(name:"Acceptance", container:#1, start_time:6580,
    end_time:16580, tasks:[#1_1_1], handler:#27).
#1_2:anamnesis_node(name:"Anamnesis", container:#1, start_time:16570,
    end_time:26580, nodes:[#1_2_1, #1_2_2, #1_2_3])
#1_2_3:recentPathological_anamnesis_node(name:"Recent Pathological Anamnesis",
       container:#1, start_time:19580, end_time:26570,tasks:[#1_2_3_1],
       handler:#27).
...
```

As described in section 4, instance of anamnesis_node #1_2 is composed by a set of anamnesis activities represented by means of their id. The object #1_2_3 belongs to #1_2. Objects #1_1, #1_2_3 are tasks executed in custom and manual decision node and are stored as their attributes. When execution arrives in a task node or in a manual decision node, task instances are created and the user input is stored as values of the task attributes. Some tasks related to task nodes are shown in the following.

```
#1_1_1:acceptance_form(name:"Acceptance", patient:#21, acc_date:#data_089).
#1_2_3_1:pathology_form(name:"Recent Pathology", disease:#neoB_01).
```

For example, the instance 1_1_1 of the class acceptance_form is created by an oncologist that fills in a form. It contains an instance of patient class.

Transition and decision tuples, created during the process execution, are shown in the following. The tuple of decision in the following example is obtained as a manual choice of an oncologist, but instances of decisions could be automatically generated by means of reasoning tasks.

```
transition(name:"Acceptance-Anamnesis",from:#1_0, to:#1_1).
decision(name:"More Clinical Tests requested - No",from:#1_4, to:#1_6).
```

Instances of the classes bodyRegion, breast_primarySited_neoplasm, and of the subclasses of drug and code, can be obtained by importing them from already existing medical ontologies and can be declared as follows:

```
#A01.236: bodyRegion(name:"breast").
#neoB_01: breast_primarySited_neoplasm(descr:"Malignant neoplasm of breast",
          site:#A01.236, zone:"Nipple and areola").
#L02BG03: enzymeInhibitors(name:"Anastrozole", ddd:1, unit:mg,
          admRoute:["oral"], notes:"").
#L02AA04: estrogens(name:"Fosfestrol", ddd:0.25, unit:g,
          admRoute:["oral","parenteral"], notes:"").
#icd10_C50.0: icd10Code(c:"C50.0", chapter:2, block:"C", category:"50",
          subCat:"0").
#mesh08_C04.588.180: mesh08Code(c:"C04.588.180",category:"C", subCat:"04").
```

The object having **ID** #neoB_01, is an instance of the breast_ primarySited_neoplasm class. Its attributes descr and zone (which type is string) have string values: "Malignant neoplasm of breast" and "Nipple and areola", whereas the attribute site has value #A01.236 that is an **ID** representing an instance of the class bodyRegion. Tuples expressing medical knowledge can be declared by using the following syntax:

```
suffer (pat:#21, dis:#neoB_01).
relatedDrug (dis:#C50.9, dru:#L02BG03).
sideEffect (dru:#L02BG03, effect:"Chest pain").
sideEffect (dru:#L02BG03, effect:"Shortness of breath").
classifiedAs (dis:#neoB 01, c:#icd10 C50.0).
classifiedAs (dis:#neoB 01, c:#mesh08 C04.588.180).
```

The tuple of the relation suffer asserts that the patient #p_002 suffers of the disease #neoB_01. The same diseases is classified in the ICD10-CM with identifier code #icd10_C50.0, and is stored in Mesh tree structure with identifier code #mesh08_C04.588.180. By means of the relation classifiedAs an user is enabled to querying concepts in the SD-KRF ontology by using one of the identifiers in the original medical ontologies.

Reasoning Over Schemas and Instances

Integrity constraints, business rules and complex inference rules can be expressed over schemas and instances respectively by means of axioms and reasoning tasks. For example, the following axiom prevents the prescription of a drug to a patient that has an allergy to a particular constituent of the drug.

```
::-therapyStrategy(patient:P, therapy:T, drug:D),
   hasActivePrinciple(drug:D,constituent:C),
   allergy(patient:P,actPrin:C).
```

Axioms could be, also, used for: (i) specify constraints about transitions behavior. For example, the axiom "::-P:process(), not start_node(container:P)." expresses that a start_node must exist for each process. Constraints are also used for expressing that a transition links nodes belonging to the same process, and corresponds to an effective edge of the process model as shown in the following:

```
::-transition(from:N1,to:N2), N1:node(container:P1),
   N2:node(container:P2), P1!=P2.
::-transition(from:N1,to:N2), N1:node(start_time:ST1),
   N2:node(start_time:ST2), ST1>=ST2.
::-P:neoplasm_process(), transition(from:N1,to:N2),
   N1:acceptance_node(container:P),
   not N2:anamnesis_node(container:P).
...
```

A reasoning task can be used for expressing a business rule. The following reasoning task, for instance, throws a medical error event when the prescribed dose exceed the recommended dose based on individual characteristics (i.e. age and weight) of the interested patient. Such a check is useful when a therapeutic_strategy_form is created while therapeutic_strategy _definition_node is active.

```
ID:drugPrescription_medicalError(relativeTo:TASK,timestamp:TIME,msg:MSG):-
    TASK:chemotherapeutic_strategy_form(strategy:STR),
    STR:therapeuticStrategy(patient:P, therapy:T),
    P:patient(bornDate:DATE,weight:W), @age(date,AGE),
    T:therapy(dru:DRUG,dose:DOSE),
    recommendedDose(drug:DRUG, dose:RD, minAge:MA, MinWeight:MW),
    AGE<MA, W<MW, DOSE>RD,
    MSG:="Prescribed dose " + DOSE + "exceed recommend dose " + RD, @newID(ID),
    @now(TIME).
```

The generated prescription error event must be properly handled in the process, for example an error message is visualized by means of a GUI to the physician.

```
ID:view_msg(method:"exception.jar", msg:MSG):-
   X:drugPrescription_medicalError(relativeTo:TASK, timestamp:TIME, msg:MSG),
   @newID(ID).
```

Queries can be also used for exploring clinical processes ontologies in a semantic fashion. For instance malNeoplasm_f_patient(patient:P)? returns every female patients suffering of any malignant neoplasm (e.g P=#21, P=#34 ids are given for answer), where malNeoplasm_f_ patient(patient:P):

```
malNeoplasm_f_patient(patient:P):- P:patient(sex:#F),suffer(patient:P,disease:D),
                                   D:malignant_neoplasm().
```

SEMANTIC INFORMATION EXTRACTION

In the Static/Dynamic Knowledge Representation Framework classes and instances can be enriched by concepts descriptors that are rules allowing to recognize and extract concepts contained in unstructured documents written in natural language. Concepts extracted by descriptors are stored in the knowledge base as instances of the related classes in the ontology.

Considering the example of clinical process described in Section 4 semantic information extraction tasks can be applied to Electronic Medical Records (EMRs), results of examinations, medical reports, etc. coming from different hospital wards in order to populate the clinical process instance related to a given patient.

In the following, a set of semantic extraction rules (i.e. descriptors) that allow for extracting patient name, surname, age and disease is shown. Descriptors exploit concepts and relationships referred to the disease, its diagnosis, cares in term of surgical operations and chemotherapies with the associated side effects. Concepts related to persons (patients), body parts and risk causes are also represented. All the concepts related to the cancer come from the ICD10-CM diseases classification system, whereas the chemotherapy drugs taxonomy, is inspired at the Anatomic Therapeutic Chemical (ATC) classification system. Extracted information are exploited to construct, for each cared patient, an instance of lung cancer clinical process.

```
class anatomy ().
    class bodyRegion (bp:string) isa {anatomy}.
        class organ isa {body_part}.
            lung: organ("Lung").

            <lung> -> <X:token(), matches(X,"[Ll]ung")>.
        ...
    ...
class disease (name:string).
    tumor: disease("Tumor").
    <tumor> -> <X:token(), matches(X,"[Tt]umor")>.
    cancer: disease("Cancer").
    <cancer> -> <X:token(), matches(X,"[Cc]ancer")>.
    ...
relation synonym (d1:disease,d2:disease)
    synonym(cancer,tumor).
    ...
class body_part_desease () isa {disease}.
    lung_cancer: body_part_disease("Lung cancer").
    <lung_cancer> -> <diagnosis_section> CONTAIN <lung> &
                     <X:desease(),synonym(cancer,X)>
    ...
collection class patient_data (){}
    collection class patient_name (name:string){}
        <patient_name(Y)> -> <T:token(),defBy(T, "name:")>
                              <X:token()> {Y := X;} SEPBY <X:space()>.
    collection class patient_surname (surname:string){}
        <patient_surname(Y)> -> <X:hiStr(),matches(X,"sur(:?name)?:")>
                                <X:token()> {Y:=X;} SEPBY <X:space()>.
        collection class patient_age (age:integer){}
        <patient_age(Y)> -> <X:token(),matches(X,"age:")>
                            <Z:token()>{Y := $str2int(Z);}
                            SEPBY <X:space()>.
    ...
collection class patient_data (name:string, surname:string,
                               age:integer, diagnosis:body_part_disease){}
    <patient_data(X,Y,Z,lung_cancer)> -> <hospitalization_section>
                                         CONTAIN
                                         <P:patient_name(X1)>{X:=X1} &
                                         <P:patient_surname(Y1)>{Y:=Y1} &
                                         <P:patient_age(Z1)>{Z:=Z1} &
                                         <lung_cancer>.
...
```

The classes diagnosis_section and hospitalization_section, used in the above descriptors, represent text paragraphs containing personal data and diagnosis data recognized by proper descriptors that aren't shown for lack of space. The extraction mechanism can be considered in a WOXM fashion: Write Once eXtract Many, in fact the same descriptors can be used to enable the extraction of metadata related to patient affected by lung_cancer in unstructured EMRs that have different arrangement. Moreover, descriptors are obtained by automatic writing methods (as happens, for example, for the cancer and tumor concepts) or by visual composition (as happens for patient_data)

Metadata extracted by using the descriptors are stored as class instances into a knowledge base. Using descriptors shown above the extraction process generates the following

patient_
data class instance for an EMR: "#1":patient_data("Mario", "Rossi","70",lung_
cancer).

Implementation Issues

A prototype of the SD-KRF has been implemented by combining the JBPM engine JPDL (2011) and the XONTO system Oro et al. (2009a). It is designed to follow a clinical processes life-cycle model based on 3 phases: processes and ontologies design and implementations, execution and monitoring, analysis. The first module exploits the XONTO system. It provides functionalities for importing and/or representing (by using direct "on-screen" drawing and manual specification facilities): ontologies and processes. Moreover, semantic extraction rules (descriptors), that enable the recognition and extraction of information from unstructured sources, can be modeled by exploiting the XONTO approach. A set of business/risk/error rules can be described in terms of ontology constraints and/or reasoning tasks. Acquired and/or represented schemas and instances are stored in a knowledge base and can be queried by using querying and meta-querying capabilities. The Execution & Monitoring module is mainly constituted by the JBPM engine that interact with the XONTO system. Process execution is performed in two ways: (i) by using a workflow enactment strategy. In this case, a process schema is imported in JBPM and automatically executed involving actors that can be humans or machines (e.g. legacy systems supplying results of medical examinations); (ii) by using a dynamic workflow composition strategy. In this case, nodes to execute are selected step by step by choosing the most appropriate one in a given moment.

Nodes are chosen by using semantic querying capabilities of XONTO system and executed by JBPM. Queries allows for specifying data and each significant information available in the particular moment of the execution. The execution generates process instances that are stored in a knowledge base. Reasoning, querying and meta-querying over schemas and available instances are possible. This way, process execution can be monitored by running business rules that equip process schemas. Events generated by rules alert process actors that can react for preventing risks and errors. The Analytics module aims at allowing analysis of the clinical processes instances after their acquisition. The execution of clinical processes makes available process instances that are also ontology instances. This way a large amount of semantically enriched data becomes available for retrieval, querying and analysis. Analysis are performed by creating reports obtained by semantic query of acquired process instances.

The SD-KRF constitutes an innovative approach for semantic business process management in the field of healthcare information systems. Main features of the presented semantic approach (founded on logic programming) is that it, conversely to already existing systems and approaches, enables to represent process ontologies that can be equipped with expressive business rules. In particular, the proposed framework allows for jointly managing declarative and procedural aspects of domain knowledge and express reasoning tasks that exploit represented knowledge in order to prevent errors and risks that can take place during processes execution. The framework enables, also: (i) manual process execution in which each activity to execute in a given moment is chosen by a human actor on the base of the current configuration of patient and disease parameters, and (ii) automatic execution by means of the enactment of an already designed process schema (e.g. guidelines execution). During process execution, process and ontology instances are acquired and stored in a knowledge base. The system is able to automatically acquire information from electronic unstructured medical documents, exploiting a semantic information extraction approach. Extracted information are stored into a knowledge base as concept instances and are also used to fill XML documents enabling interoperability. The processes execution can be monitored by running (over clinical process schemas and instances) reasoning tasks that implements business rules. The framework could be used in many application fields by modeling proper domain ontologies and processes.

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CHAPTER 12

Knowledge in Imperfect Data

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INTRODUCTION

Data bases collecting a huge amount of information pertaining to real-world processes, for example industrial ones, contain a significant number of data which are imprecise, mutually incoherent, and frequently even contradictory. It is often the case that data bases of this kind often lack important information. All available means and resources may and should be used to eliminate or at least minimize such problems at the stage of data collection. It should be emphasized, however, that the character of industrial data bases, as well as the ways in which such bases are created and the data are collected, preclude the elimination of all errors. It is, therefore, a necessity to find and develop methods for eliminating errors from already-existing data bases or for reducing their influence on the accuracy of analyses or hypotheses proposed with the application of these data bases. There are

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at least three main reasons for data preparation: (a) the possibility of using the data for modeling, (b) modeling acceleration, and (c) an increase in the accuracy of the model. An additional motivation for data preparation is that it offers a possibility of arriving at a deeper understanding of the process under modeling, including the understanding of the significance of its most important parameters.

The literature pertaining to data preparation (Pyle, 1999, 2003; Han & Kamber, 2001; Witten & Frank, 2005; Weiss & Indurkhya, 1998; Masters, 1999; Kusiak, 2001; Refaat, 2007) discusses various data preparation tasks (characterized by means of numerous methods, algorithms, and procedures). Apparently, however, no ordered and coherent classification of tasks and operations involved in data preparation has been proposed so far. This has a number of reasons, including the following: (a) numerous article publications propose solutions to problems employing selected individual data preparation operations, which may lead to the conclusion that such classifications are not really necessary, (b) monographs deal in the minimal measure with the industrial data, which have their own specific character, different from that of the business data, (c) the fact that the same operations are performed for different purposes in different tasks complicates the job of preparing such a classification.

The information pertaining to how time-consuming data preparation is appears in the works by many authors. The widely-held view expressed in the literature is that the time devoted to data preparation constitutes considerably more than a half of the overall data exploration time (Pyle, 2003; McCue, 2007). A systematically conducted data preparation can reduce this time. This constitutes an additional argument for developing the data preparation methodology which was proposed in (Kochanski, 2010).

A TAXONOMY OF DATA PREPARATION

Discussing the issue of data preparation the present work uses the terms *process, stage, task,* and *operation*. Their mutual relations are diagrammatically represented in Fig. 1 below. The data preparation process encompasses all the data preparation tasks. Two stages may be distinguished within it: the introductory stage and the main stage. The stages of the process involve carrying out tasks, each of which, in turn, involves a range of operations. The data preparation process always starts with the introductory stage. Within each stage (be it the introductory or the main one) different tasks may be performed. In the introductory stage, the performance of the first task (the choice of the first task is dictated by the specific nature of the case under analysis) should always be followed by data cleaning. It is only after data cleaning in the introductory stage that performing the tasks of the main stage may be initiated. In the main stage, the choice of the first task, as well as ordering of the tasks that follow are not predetermined and are dependent on the nature of the case under consideration. As far as the data collected in real-life industrial (production) processes are concerned, four tasks may be differentiated:

- data cleaning is used in eliminating any inconsistency or incoherence in the collected data
- data integration makes possible integrating data bases coming from various sources into a single two-dimensional table, thanks to which algorithmized tools of data mining can be employed
- data transformation includes a number of operations aimed at making possible the building of a model, accelerating its building, and improving its accuracy, and employing, among others, widely known normalization or attribute construction methods
- data reduction limits the dimensionality of a data base, that is, the number of variables; performing this task significantly reduces the time necessary for data mining.

Each of the tasks involves one or more operations. An operation is understood here as a single action performed on the data. The same operation may be a part of a few tasks.

In Fig. 1, within each of the four tasks the two stages of the process are differentiated: the introductory stage of data preparation (in the diagram, this represented as the outer circles marked with broken lines) and the main stage of data preparation (represented as inner circles marked with solid lines). These two separate stages, which have been differentiated, have quite different characters and use quite different tools. The first stage - that of the introductory data preparation - is performed just once. Its performance in particular tasks is limited to a single operation. This operation is always followed by the task of data cleaning. The stage of the introductory data cleaning is a non-algorithmized stage. It is not computer-aided and it is based on the knowledge and the experience of the human agent preparing the data.

The second - that is, the main - stage is much more developed. It can be repeated many times at each moment of the modeling and of the analysis of the developed model. The repetition of the data preparation tasks or the change in the tools employed in particular tasks is aimed at increasing the accuracy of the analyses. The order in which the tasks are carried out may change depending upon the nature of the issue under analysis and the form of the collected data. According to the present authors, it seems that it is data cleaning which should always be performed as the first task. However, the remaining tasks may be performed in any order. In some cases different tasks are performed in parallel: for instance the operations performed in the task of data integration may be performed simultaneously with the operations involved in data transformation, without deciding on any relative priority. Depending on the performed operations, data reduction may either precede data integration (attribute selection) or go at the very end of the data preparation process (dimensionality selection).

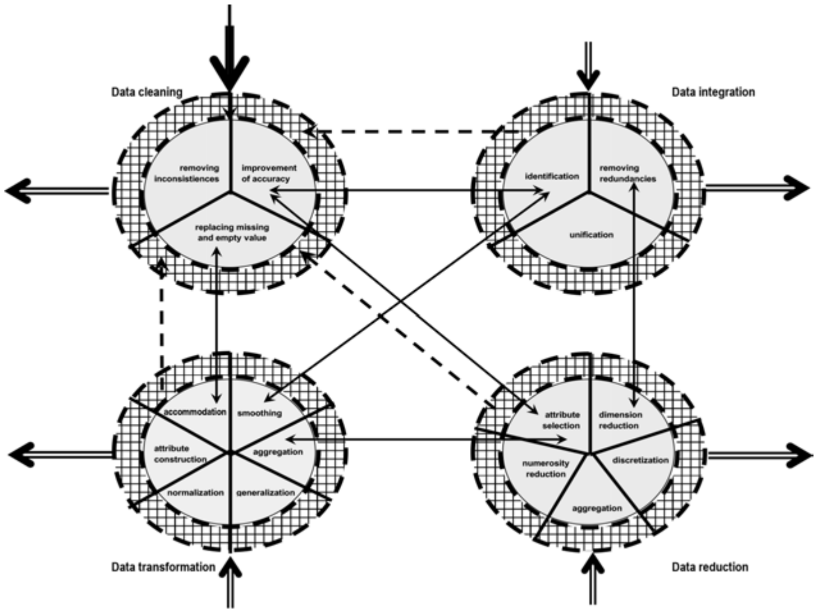


Figure 1. Tasks carried out in the process of data preparation with the distinction into the introductory and the main stage (Kochanski, 2010).

TASK OF DATA PREPARATION

A task is a separate self-contained part of data preparation which may be and which in practice is performed at each stage of the data preparation process.

We can distinguish four tasks (as represented in Fig. 1): data cleaning, data transformation, data integration, and data reduction. Depending upon the stage of the data preparation process, a different number of operations may be performed in a task – at the introductory stage the number of operations is limited. These operations, as well as the operations performed in the main stage will be discussed below, in the sections devoted to particular tasks.

The data preparation process, at the stage of introductory preparation, may start with any task, but after finishing the introductory stage of this task, it is necessary to go through the introductory stage of data cleaning.

It is only then when one can perform operations belonging to other tasks, including the operations of the task with which the process of data preparation has started. This procedure follows from the fact that in the further preparation, be it in the introductory or in the main stage, the analyst should have at his disposal possibly the most complete data base and only then make further decisions.

It is only after the introductory stage is completed in all tasks that the main stage can be initiated. This is motivated by the need to avoid any computer-aided operations on raw data.

Data Cleaning

Data cleaning is a continuous process, which reappears at every stage of data exploration. However, it is especially important at the introductory data preparation stage, among others, because of how much time these operations take.

At this phase, it involves a one-time data correction, which resides in the elimination of all kind of errors resulting from human negligence at the stage of data collection.

The introductory data cleaning is a laborious process of consulting the source materials, often in the form of paper records, laboratory logs and forms, measuring equipment outprints, etc., and filling in the missing data by hand. The overall documentation collected at this stage may also be used in the two other operations of this task: in accuracy improvement and in inconsistency removal.

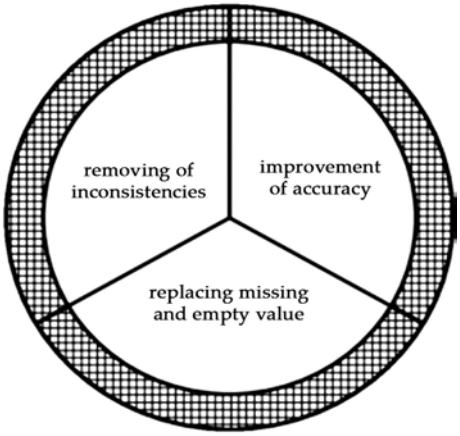


Figure 2. Operations performed in the data cleaning task (with the introductory stage represented as the squared area and the main stage represented as the white area).

As shown in Fig. 2, the data cleaning task may involve three operations, the replacement of the missing or empty values, the accuracy improvement, and the inconsistency removal, which in the main stage employ algorithmized methods:

- replacement of missing or empty values employs the methods of calculating the missing or empty value with the use of the remaining values of the attribute under replacement or with the use of all attributes of the data set;
- accuracy improvement is based on the algorithmized methods of the replacement of the current value with the newly-calculated one or the removal of this current value;
- inconsistency removal most frequently employs special procedures (e.g. control codes) programmed in data collection sheets prior to the data collecting stage.

In what follows, these three operations will be discussed in detail because of their use in the preparation of the data for modeling.

a. ***The Replacement of Missing or Empty Values:-*** The case of the absent data may cover two kinds of data: an empty value – when a particular piece of data could not have been recorded, since - for instance - such a value of the measured quantity was not taken into consideration at all, and a missing value – when a particular piece of data has not been recorded, since - for instance - it was lost. The methods of missing or empty value replacement may be divided into two groups, which use for the purpose of calculating the new value the subset of the data containing:

either

- only the values of the attribute under replacement (simple replacement)

or

- either the specially selected or all the values of the collected set (complex replacement).

The methods of simple replacement include all the methods based on statistical values (statistics), such as, for instance the mean value, the median, or the standard deviation. The new values which are calculated via these methods and which are to replace the empty or the missing values retain the currently defined distribution measures of the set.

The complex replacement aims at replacing the absent piece of data with such a value as should have been filled in originally, had it been properly recorded (had it not been lost). Since these methods are aimed at recreating the proper value, a consequence of their application is that the distribution measures of the replacing data set may be and typically are changed.

In complex replacement the absent value is calculated from the data collected in the subset which contains selected attributes (Fig. 3a) or selected records (Fig. 3b) and which has been created specifically for this purpose. The choice of a data replacement method depends on the properties of the collected data – on finding or not finding correlations between or among attributes. If there is any correlation between, on the one hand, selected attributes and, on the other, the attribute containing the absent value, it is possible to establish a multilinear regression which ties the attributes under analysis (the attribute containing the absent value and the attributes which are correlated with it). In turn, on this basis the absent value may be calculated. An advantage of this method is the possibility of obtaining new limits, that is, a new minimal and maximal value of the attribute under replacement, which is lower or higher than the values registered so far. It is also for this reason that this method is used for the replacement of empty data.

When there is no correlation between the attribute of the value under replacement and the remaining attributes of the set, the absent value is calculated via a comparison with the selected records from the set containing complete data. This works when the absent value is a missing value. The choice of a data replacement method should take into consideration the proposed data modeling method. Simple replacement may be used when the modeling method is insensitive to the noise in the data. For models which cannot cope with the noise in the data complex data replacement methods should be used.

It is a frequent error commonly made in automatized absent data replacement that no record is made with respect to which pieces of the data are originally collected values and which have been replaced. This piece of information is particularly important when the model quality is being analyzed.

X	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8
1	0,44264	0,33500	0,25427	0,35923	0,16962	0,00716	0,48662	0,32565
2	0,22330	0,28883	0,83385	0,47689	0,70585	0,37254	0,93544	0,56954
3	0,27493	0,33005	0,58590	0,34546	0,01733	0,31112	0,85849	0,45207
4	0,98221	0,48329	0,60996	0,63946	0,36832	0,47123	0,20616	0,87007
5	0,13867	0,04751	0,82575	0,95047	0,74808	0,51304	0,12866	0,92690
6	0,19544	0,64661	0,54804	0,54047	0,19131	0,03098	0,49135	0,71928
7	0,30852	0,16328	0,55166	0,54092	0,54074	0,04924	0,58695	0,66732
8	0,00041	0,25978	0,31942	0,45177	0,03746	0,01925	0,14991	0,46064
9	0,19001	0,25658	0,05029	0,15835	0,33636		0,80948	0,15902
10	0,96184	0,46663	0,95992	0,54820	0,04761	0,80451	0,27177	0,48748
11	0,66559	0,95384	0,84559	0,76149	0,79613	0,99048	0,73015	0,97383
12	0,44050	0,31420	0,95545	0,69524	0,19512	0,47188	0,56926	0,95379
13	0,34064	0,64198	0,61337	0,27064	0,18290	0,48872	0,95916	0,69138
14	0,54202	0,40815	0,69619	0,49253	0,33158	0,64028	0,37219	0,78562
15	0,19946	0,10397	0,62387	0,90537	0,85044	0,66453	0,30543	0,80890
16	0,41862	0,48597	0,93570	0,73022	0,73567	0,42406	0,68604	0,82964
17	0,06957	0,49556	0,57802	0,45966	0,56085	0,35513	0,91340	0,75443
18	0,45747	0,98770	0,43052	0,36385	0,56939	0,14738	0,62208	0,65532
19	0,09304	0,95937	0,44208	0,61713	0,06287	0,65605	0,26071	0,67018
20	0,07758	0,17060	0,62618	0,93290	0,19343	0,88051	0,74191	0,94996

(a)

X	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8
1	0,44264	0,33500	0,25427	0,35923	0,16962	0,00716	0,48662	0,32565
2	0,22330	0,28883	0,83385	0,47689	0,70585	0,37254	0,93544	0,16954
3	0,27493	0,33005	0,58590	0,34546	0,01733	0,41112	0,85849	0,45207
4	0,98221	0,48329	0,60996	0,63946	0,36832	0,47123	0,20616	0,87007
5	0,13867	0,04751	0,82575	0,95047	0,74808	0,10304	0,12866	0,82690
6	0,19544	0,64661	0,54804	0,54047	0,19131	0,03098	0,49135	0,71928
7	0,30852	0,16328	0,81166	0,54092	0,54074	0,84924	0,58695	0,66732
8	0,00041	0,25978	0,51942	0,45177	0,03746	0,10925	0,14991	0,46064
9	0,19001	0,25658	0,05029	0,15835	0,33636	0,59725	0,80948	0,15902
10	0,96184	0,46663	0,95992	0,54820		0,50451	0,27177	0,28748
11	0,66559	0,95384	0,84559	0,76149	0,79613	0,99048	0,73015	0,97383
12	0,44050	0,31420	0,95545	0,69524	0,19512	0,47188	0,56926	0,95379
13	0,34064	0,64198	0,14337	0,27064	0,18290	0,48872	0,95916	0,09138
14	0,94202	0,40815	0,69619	0,49253	0,33158	0,64028	0,37219	0,48562
15	0,19946	0,10397	0,32387	0,90537	0,85044	0,36453	0,30543	0,80890
16	0,91862	0,48597	0,93570	0,53022	0,73567	0,52406	0,18604	0,29636
17	0,06957	0,49556	0,07802	0,45966	0,56085	0,35513	0,31340	0,35443
18	0,45747	0,98770	0,43052	0,36385	0,56939	0,14738	0,62208	0,65532
19	0,09304	0,95937	0,14208	0,61713	0,06287	0,65605	0,26071	0,67018
20	0,07758	0,17060	0,62618	0,93290	0,19343	0,88051	0,74191	0,54996

(b)

Figure 3. (a) Selected attributes (X_3, X_8) will serve in calculating the absent value in attribute X_6 (b) Selected records (4, 14, 16) will serve in calculating the absent value in attribute 10.

b. ***Accuracy Improvement:-*** The operation of accuracy improvement, in the main stage of data preparation, is based on algorithmized methods of calculating a value and either replacing the current value (the value recorded in the database) with the newly-calculated one or completely removing the current value from the base. The mode of operation depends upon classifying the value under analysis as either noisy or an outlier. This is why, firstly, this operation focuses on identifying the outliers within the set of the collected data. In the literature, one can find reference to numerous techniques of identifying pieces of the data which are classified as outliers (Alves & Nascimento, 2002; Ben-Gal, 2005; Cateni et al., 2008; Fan et al., 2006; Mohamed et al., 2007). This is an important issue, since it is only in the case of outliers that their removal from the set may be justified. Such an action is justified when the model is developed, for instance, for the purpose of optimizing an industrial process. If a model is being developed with the purpose of identifying potential hazards and break-downs in a process, the outliers should either be retained within the data set or should constitute a new, separate set, which will serve for establishing a separate pattern. On the other hand, noisy data can, at best, be corrected but never removed – unless we have excessive data at our disposal.

In the literature, there are two parallel classifications of the outlier identification methods. The first employs the division into one-dimension methods and multidimension methods. The second divides the relevant methods into the statistical (or traditional) ones and the ones which employ advanced methods of data exploration.

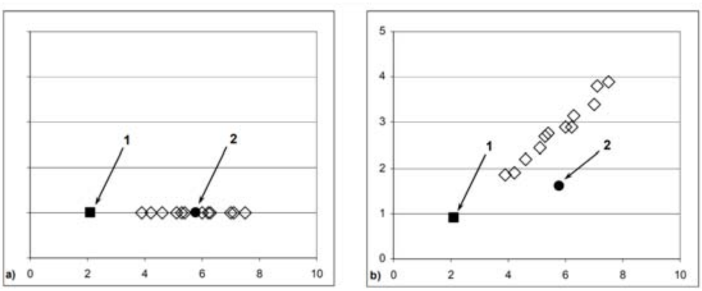


Figure 4. Outliers a) one-dimension, b) multidimension; 1, 2 outliers – a description in the text.

The analysis of one-dimension data employs definitions which recognize as outliers the data which are distant, relative to the assumed metric, from the main data concentration. Frequently, the expanse of the concentration is defined via its mean value and the standard error. In that case, the outlier is a value (the point marked as 1 in Fig. 4a) which is located outside the interval (X_m – k* 2SE, X_m + k* 2SE), where: SE – standard error, k – coefficient, X_m – mean value. The differences between the authors pertain to the value of the k coefficient and the labels for the kinds of data connected with it, for instance the outliers going beyond the boundaries calculated for k = 3,6 (Jimenez-Marquez et al., 2002) or the outliers for k = 1,5 and the extreme data for k = 3 (StatSoft, 2011). Equally popular is the method using a box plot (Laurikkala et al., 2000), which is based on a similar assumption concerning the calculation of the thresholds above and below which a piece of data is treated as an outlier.

For some kind of data, for instance those coming from multiple technological processes and used for the development of industrial applications, the above methods do not work. The data of this kind exhibit a multidimensional correlation. For correlated data a one-dimension analysis does not lead to correct results, which is clearly visible from the example in Fig. 4 (prepared from synthetic data). In accordance with the discussed method, Point 1 (marked as a black square) in Fig. 4a would be classified as an outlier. However, it is clearly visible from multidimensional (two-dimensional) data represented in Fig. 4b that it is point 2 (represented as a black circle) which is an outlier. In one-dimension analysis it was treated as an average value located quite close to the mean value.

Commonly used tools for finding one-dimension outliers are statistical methods. In contrast to the case of one-dimension outliers, the methods used for finding multidimensional outliers are both statistical methods and advanced methods of data exploration. Statistical methods most frequently employ the Mahalanobis metric. In the basic Mahalanobis method for each vector x_i the Mahalanobis distance is calculated according to the following formula (1) (Rousseeuw & Zomeren, 1990):

$$MD_i = \left((\mathbf{x}_i - T(\mathbf{X}))\mathbf{C}(\mathbf{X})^{-1}(\mathbf{x}_i - T(\mathbf{X}))^t \right)^{1/2} \qquad \text{for i = 1, 2, 3, ... n} \tag{1}$$

where: $T(\mathbf{X})$ is the arithmetic mean of the data set, $\mathbf{C}(\mathbf{X})$ is the covariance matrix.

This method takes into account not only the central point of the data set, but also the shape of the data set in multidimensional space. A case with a large Mahalanobis distance can be identified as a potential outlier. On the basis of a comparison with the chi-square distribution, an outlier can be removed as was suggested in (Filzmoser, 2005). In the literature, further improvements of the Mahalanobis distance method can be found, for example the one called the Robust Mahalanobis Distance (Bartkowiak, 2005). The outlier detection based on the Mahalanobis distance in industrial data, was performed in e.g. (Jimenez-Marquez et al., 2002). As far as data exploration is concerned, in principle all methods are used. The most popular ones are based on artificial neural networks (Alves & Nascimento, 2002), grouping (Moh'd Belal Al-Zgubi, 2009), or visualization (Hasimah et al., 2007), but there are also numerous works which suggest new possibilities of the use of other methods of data mining, for example of the rough set theory (Shaari et al., 2007). An assumption of methodologies employing data exploration methods is that the data departing from the model built with their help should be treated as outliers.

c. ***Inconsistency Removal:-*** At the introductory stage inconsistencies are primarily removed by hand, via reference to the source materials and records. At this stage it will also encompass the verification of the attributes of the collected data. It is important to remove all redundancies at this stage. Redundant attributes may appear both in basic databases and in databases created via combining a few smaller data sets. Most often, this is a consequence of using different labels in different data sets to refer to the same attributes. Redundant attributes in merged databases suggest that we have at our disposal a much bigger number of attributes than is in fact the case. An example of a situation of this kind is labeling the variables (columns) referring to metal elements in a container as, respectively, *element mass*, *the number of elements in a container*, and *the mass of elements in the container*. If the relevant piece of information is not repeated exactly, for example, if instead of the attribute *the mass of elements in the container* what is collected is *the mass of metal in the container*, then the only problem is increasing the model development time. It is not always the case that this is a significant problem, since the majority of models have a bigger problem with the number of records, than with the number of attributes. However, in the modeling of processes aimed at determining the influence of signal groups, an increase in the number of inputs is accompanied with an avalanche increase in the number of input variable group combinations (Kozlowski, 2009). It should also be remembered that some modeling techniques, especially those based on regression, cannot cope with two collinear attributes (Galmacci, 1996). This pertains also to a small group of matrix-based methods (Pyle, 1999).

At the main stage of data preparation inconsistency removal may be aided with specially designed procedures (e.g. control codes) or tools dedicated to finding such inconsistencies (e.g. when the correlations/interdependencies among parameters are known).

Data Integration

Because of the tools used in knowledge extraction it is necessary that the data be represented in the form of a flat, two-dimensional table. It is becoming possible to analyze the data recorded in a different form, but the column-row structure – as in a calculation sheet - is the best one (Pyle, 2003). The task of data integration may be both simple and complicated, since it depends on the form in which the data is collected. In the case of synthetic data, as well as in appropriately prepared industrial data collecting systems this is unproblematic. However, the majority of industrial databases develop in an uncoordinated way. Different departments of the same plant develop their own databases for their own purposes. These databases are further developed without taking into consideration other agencies. This results in a situation in which the same attributes are repeated in numerous databases, the same attributes are labeled differently in different databases, the same attributes have different proportions of absent data in different bases, the developed databases have different primary keys (case identifiers), etc. The situation gets even worse when the databases under integration have been developed not within a single plant but in more distant places, for example in competing plants.

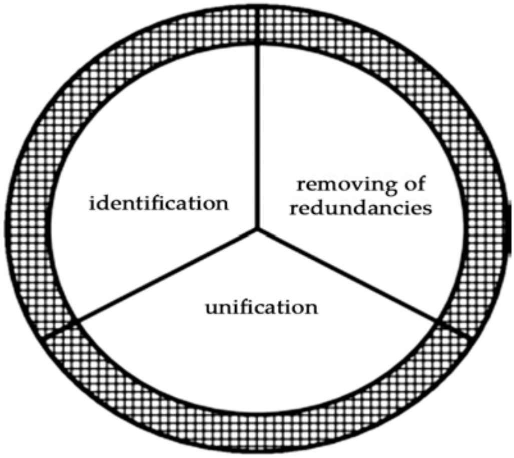


Figure 5. The operations performed in the data integration task (with the introductory stage represented as the squared area and the main stage represented as the white area).

As represented in Fig 5, data integration consists of three operations. The introductory stage of data integration focuses on two of them: identification and redundancy removal. Both these operations are closely connected with one another. The first operation – identification – is necessary, since the task of data integration starts with identifying the quantity around which the database sets may be integrated. Also, at the data integration introductory stage the removal of obvious redundancies should be performed. Their appearance may result, for instance, from the specific way in which the industrial production data is recorded. The results of tests conducted in centrally-operated laboratories are used by different factory departments, which store these results independently of one another, in their own databases. The result of data integration performed without introductory analysis may be that the same quantities may be listed in the end-product database a number of times and, moreover, they may be listed there under different labels. A person who knows the data under analysis will identify such redundant records without any problem.

At the main stage, unlike in other data preparation tasks, the integration operations are only performed with the aid of algorithmized tools and are still based on the knowledge about the process under analysis. At this stage, the operations represented in Fig. 5 are performed with the following aims:

- identification – serves the purpose of identifying the attributes which could not have been identified at the introductory stage, for instance, in those cases in which the label does not explain anything,
- redundancy removal – just like the attribute selection in the data reduction task, which is characterized below, uses algorithmized methods of comparing the attributes which have been identified only in the main stage with the aim of removing the redundant data,
- unification – this is performed so that the data collected in different sets have the same form, for instance the same units.

The operation of identification uses methods which make it possible to identify the correlation between the attribute under analysis and other identified process attributes. In this way it is possible to establish, for instance, what a particular attribute pertains to, where the sensor making the recorded measurement could have been installed, etc.

The second performance of the redundancy removal operation pertains only to attributes which have been identified only in the second, main stage of data integration. As far as this second performance is concerned, redundancy removal may be identified with the attribute selection operation from the data reduction task and it uses the same methods as the attribute selection operation.Unification is very close to the data transformation task. In most cases it amounts to transforming all the data in such a way that they are recorded in a unified form, via converting part of the data using different scales into the same units, for instance, converting inches into millimeters, meters into millimeters, etc. A separate issue is the unification of the data collected in different sets and originating from measurements employing different methods. In such cases one should employ the algorithms for converting one attribute form into another. These may include both analytical formulas (exact conversion) and approximate empirical formulas. When this is not possible, unification may be achieved via one of the data transformation operations, that is, via normalization (Liang & Kasabov, 2003).

The main principle that the person performing the data integration task should stick to is that the integrated database should retain all the information collected in the data sets which have been integrated. Seemingly, the suggestion, expressed in (Witten & Frank, 2005), that data integration should be accompanied by aggregation, is misguided. Aggregation may accompany integration, but only when this is absolutely necessary.

Data Transformation

Data transformation introductory stage usually amounts to a single operation dictated by data integration, such as aggregation, generalization, normalization or attribute (feature) construction. Performing aggregation may be dictated by the fact that the data collected in multiple places during the production process may represent results from different periods: a different hour, shift, day, week or month. Finding a common higher-order interval of time is necessary for further analyses. The same reasons make necessary the performance of generalization or normalization. Generalization may be dictated, for instance, by the integration of databases in which the same attribute is once recorded in a nominal scale (e.g. ultimate tensile strength - ductile iron grade 500/07) and once in a ratio scale (ultimate tensile strength – UTS = 572 MPa). We can talk about normalization in the introductory stage only when we understand this term in its widest sense, that is, as a conversion of quantities from one range into those of another range. In that case, such a transformation as measurement unit conversion may be understood as normalization at the introductory stage.

Data transformation encompasses all the issues connected with transforming the data into a form which makes data exploration possible. At the introductory stage it involves six operations represented in Fig. 6:

- smoothing – this resides in transforming the data in such a way that local data deviations having the character of noise are eliminated. Smoothing encompasses, among others, the techniques such as, for example, binning, clustering, or regression;
- aggregation – this resides in summing up the data, most frequently in the function of time, for example from a longer time period encompassing not just a single shift but a whole month;
- generalization – this resides in converting the collected data containing the measurements of the registered process quantity into higher-order quantities, for instance via their discretization;
- normalization – this resides in the rescaling (adjustment) of the data to a specified, narrow range, for instance, from 0.0 to 1.0;
- attribute (feature) construction – this resides in mathematical transformations of attributes (features) with the aim of obtaining a new attribute (feature), which will replace in modeling its constituent attributes;

- accommodation – this resides in transforming the data into a format used by a specific algorithm or a tool, for example into the ARFF format (Witten & Frank, 2005).

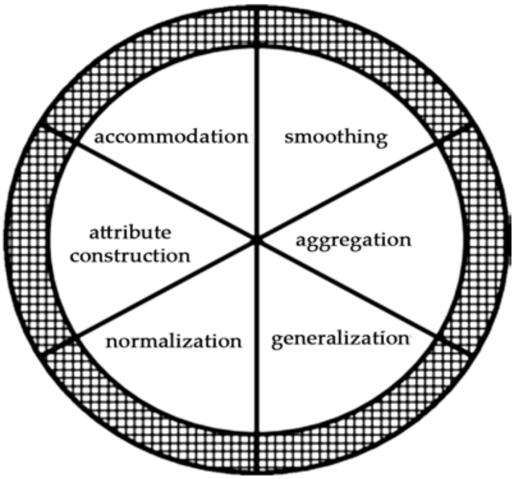


Figure 6. Operations performed in the data transformation task (with the introductory stage represented as the squared area and the main stage represented as the white area).

Smoothing is an operation which follows from the assumption that the collected data are noisy with random errors or with divergence of measured attributes. In the case of industrial (also laboratory) data such a situation is a commonplace, unlike in the case of business data (the dollar exchange rate cannot possibly be noisy). Smoothing techniques are aimed at removing the noise, without at the same time interfering with the essence of the measured attributes. Smoothing methods may be of two kinds: (a) those which focus on comparing the quantity under analysis with its immediate neighborhood and (b) those which analyze the totality of the collected data.

Group (a) includes methods which analyze a specified lag or window. In the former case, the data are analyzed in their original order, while in the latter they are changed in order. These methods are based on a comparison with the neighboring values and use, for instance, the mean, the weighted moving mean, or the median. Group (b) includes methods employing regression or data clustering. The method of loess – local regression could be classified as belonging to either group.

In the first group of methods (a) a frequent solution is to combine a few of techniques into a single procedure. This is supposed to bring about a situation in which further smoothing does not introduce changes into the collected data.

A strategy of this kind is resmoothing, in which two approaches may be adopted: either 1) smoothing is continued up to the moment when after a subsequent smoothing the curve does not change or 2) a specified number of smoothing cycles is performed, but this involves changing the window size. Two such procedures, 4253H and 3R2H were discussed in (Pyle, 1999). A method which should also be included in the first group (a) is the PVM (peak – valley – mean) method.

Binning, which belongs to group (a) is a method of smoothing (also data cleaning) residing in the creation of bins and the ascription of data to these bins. The data collected in the respective bins are compared to one another within each bin and unified via one of a few methods, for example, via the replacement with the mean value, the replacement with the median, or the replacement with the boundary value.

A significant parameter of smoothing via binning is the selection of the size of bins to be transformed. Since comparing is performed only within the closest data collected in a single bin, binning is a kind of local smoothing of the data.

As was already mentioned above, the second important group of smoothing methods (b) are the techniques employing all the available data. Among others, this includes the methods of regression and of data clustering.

Fig.7 represents the smoothing of the laboratory data attribute (ultimate compressive strength) of greensand in the function of moisture content. The data may be smoothed via adjusting the function to the measured data.

Regression means the adjustment of the best curve to the distribution of two attributes, so that one of these attributes could serve for the prediction of the other attribute. In multilinear regression the function is adjusted to the data collected in the space which is more than two-dimensional.

An example of smoothing with the use of data clustering techniques was discussed in (Kochanski, 2006). In the data which is grouped the outliers may easily be detected and either smoothed or removed from the set. This procedure makes possible defining the range of variability of the data under analysis.

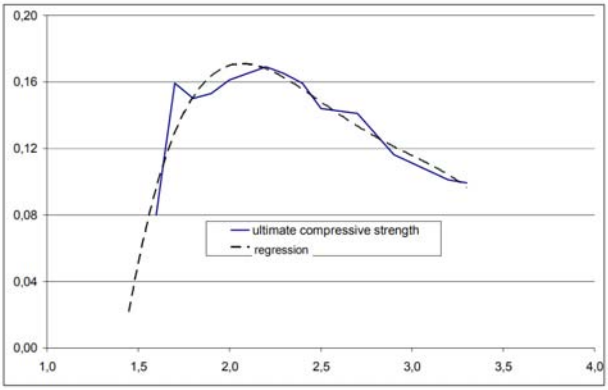


Figure 7. The regression method applied to the industrial data: the ultimate compressive strength of greensand in the function of moisture content (the authors' own research).

In the case of industrial data the issue of smoothing should be treated with an appropriate care. The removal or smoothing of an outlier may determine the model's capability for predicting hazards, break-downs or product defects. The industrial data often contain quantities which result from the process parameter synergy. The quantity which may undergo smoothing is, for instance, the daily or monthly furnace charge for the prediction of the trend in its consumption, but not the form moisture content for the prediction of the appearance of porosity.

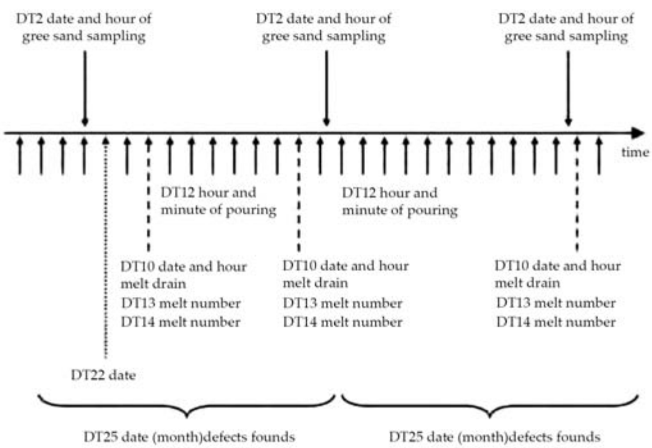


Figure 8. Measurements performed with different frequency and encompassing different time periods: from a measurement encompassing 1 minute to a mea-

surement encompassing the data from an entire month; (the data are collected in different places: DTxx – a symbol for the process technical documentation) (Research report, 2005).

In manufacture processes, when different operations are performed in different places and records are collected in separate forms, a frequent situation is the impossibility of integrating the separate cases into a single database. The absence of a single key makes data integration impossible. (Research report, 2005) discusses data integration with the use of aggregation. Data aggregation (represented as parentheses) and data location on the time axis, which makes possible further integration, are diagrammed in Fig. 8.

Generalization in data preparation is an operation which is aimed at reducing the number of the values that an individual attribute may take. In particular, it converts a continuous quantity into an attribute which takes the value of one of the specified ranges. The replacement of a continuous quantity with a smaller number of labeled ranges makes easier grasping the nature of the correlation found in the course of data exploration. Generalization applies to two terms: discretization and notional hierarchy.

Discretization is a method which makes possible splitting the whole range of attribute variation into a specified number of subregions. Discretization methods in the two main classifications are characterized in terms of the direction in which they are performed or in terms of whether or not in feature division they employ information contained in the features other than the one under discretization. In the first case, we talk about bottom-up or top-down methods. In the second case, we distinguish between supervised and unsupervised methods.

The notional hierarchy for a single feature makes possible reducing the number of the data via grouping and the replacement of a numerical quantity, for instance the percentage of carbon in the chemical composition of an alloy, with a higher-order notion, that is, *a low-carbonic* and *a high-carbonic alloy*. This leads to a partial loss of information but, in turn, thanks to the application of this method it may be easier to provide an interpretation and in the end this interpratation may become more comprehensible.

There are many commonly used methods of data normalization (Pyle, 1999; Larose, 2008). The effect of performing the operation of normalization may be a change in the variable range and/or a change in the variable distribution. Some data mining tools, for example artificial neural networks, require normalized quantities. Ready-made commercial codes have special modules which normalize the entered data. When we perform data analysis, we should take into consideration the method which has been employed in normalization. This method may have a significant influence on the developed model and the accuracy of its predictions (Cannataro, 2008; Ginoris et al., 2007; Al Shalabi et al., 2006).

The following are the main reasons for performing normalization:

- a transformation of the ranges of all attributes into a single range makes possible the elimination of the influence of the feature magnitude (their order 10, 100, 1000) on the developed model. In this way we can avoid revaluing features with high values,
- a transformation of the data into a dimensionless form and the consequent achievement of commensurability of a few features makes possible calculating the case distance, for instance with the use of the Euclid metric,
- a nonlinear transformation makes possible relieving the frequency congestion and uniformly distributing the relevant cases in the range of features,
- a nonlinear transformation makes it possible to take into consideration the outliers,
- data transformation makes possible a comparison of the results from different tests (Liang & Kasabov, 2003).

The following may be listed as the most popular normalization methods:

- min-max normalization – it resides, in the most general form, in the linear transformation of the variable range in such a way that the current minimum takes the value 0 (zero), while the current maximum takes the value 1 (one). This kind of normalization comes in many variants, which differ from one another, among others, with respect to the new ranges, for instance (-1,1); (-0,5, 0,5);
- standarization – it resides in such a transformation in which the new feature has the expectation mean value which equals zero and the variance which equals one. The most frequently used standardization is the Z-score standardization, which is calculated according to the following formula (2):

$$Z = \frac{x - \mu}{\sigma} \tag{2}$$

where: x – feature under standarization, μ – mean value, σ – standard population deviation;

- decimal normalization, in which the decimal separator is moved to the place in which the following equation (3) is satisfied:

$$X^1 = \frac{X}{10^j} \tag{3}$$

where: j is the smallest integer value, for which *Max* ($|X^1|$) < 1.

A weakness of the normalization methods discussed above is that they cannot cope with extreme data or with the outliers retained in the set under analysis. A solution to this problem is a linear – nonlinear normalization, for example the soft-max normalization or a nonlinear normalization, for example the logarithmic one (Bonebakker, 2007).

As was mentioned above, the nonlinear normalization makes it possible to include into the modeling data set extreme data or even outliers, as well as to change the distribution of the variable under transformation. The logarithmic transformation equations given in (4a,b) and the tangent transformation equation in (5) were employed in (Olichwier, 2011):

$$X_i' = w \cdot \lg(c + X_i) \tag{4a}$$

$$X_i' = w \cdot \lg(1 + cX_i) \tag{4b}$$

where: w, c - coefficients

$$X_i' = \frac{1}{2}[\tanh(k \cdot (\frac{X_i - \mu}{\sigma}) + 1] \tag{5}$$

where: k - coefficient, μ – mean value, σ – standard population deviation.

The use of the logarithmic transformation made it possible to locally spread the distributions of the selected parameters. The original skew parameter distribution after the transformation approached the normal distribution. One effect of the transformation in question was a visible increase in the prediction quality of the resulting model.

The data in the databases which are under preparation for mining may be collected in many places and recorded in separate sets. As a result of integrating different data sources it is possible to perform their transformation, for instance in the domain of a single manufacture process.

The data represented by two or more features may be replaced with a different attribute. A classical example of this is the replacement of the two dates defining the beginning and the end of an operation, which were originally recorded in two different places, with a single value defining the duration of the operation, for instance the day and the hour of molding, as well as the day and the hour of the mold assembly are replaced with the mold drying time. A deep knowledge of the data makes possible using mathematical transformations which are more complex than a mere difference. As a consequence, new, semantically justified feature combinations are created. An example of this was discussed in (Kochanski, 2000).

The knowledge of the properties of the algorithm employed in data mining is a different kind of reason behind the creation of new attributes. In the case of algorithms capable only of the division which is parallel to the data space axis (for instance in the case of the majority of decision trees) it is possible to replace the attributes pertaining to features characterized with linear dependence with a new attribute which is the ratio of the former attributes (Witten & Frank, 2005).

It is possible to perform any other transformations of attributes which do not have any mathematical justification but which follow from the general world knowledge: the names of the days of the week may be replaced with the dates, the names of the elements may be replaced with their atomic numbers, etc.

The last encountered way of creating attributes is the replacement of two attributes with a new attribute which is their product. A new attribute created in this way may have no counterpart in reality.

The common use of accommodation suggests that it should be considered as one of the issues of data transformation. What is used in data mining are databases which have been created without any consideration for their future specific application, that is, the application with the use of selected tools or algorithms. In effect, it is often the case that the collected data format does not fit the requirements of the tool used for mining, especially in a commercial code. The popular ARFF (attribute - relation file format) makes use only of the data recorded in a nominal or interval scale. The knowledge gathered in the data recorded in a ratio scale will be lost as a result of being recorded in the ARFF format.

The calculation spreadsheet Excel, which is popular and which is most frequently used for gathering the industrial data, may also be the cause of data distortion. Depending upon the format of the cell in which the registered quantity is recorded, the conversion of files into the txt format (which is required by a part of data mining programs) may result in the loss of modeling quality. This is a consequence of the fact that a defined cell contains the whole number which was recorded in it but what is saved in file conversion is only that part of this number which is displayed (Fig.9).

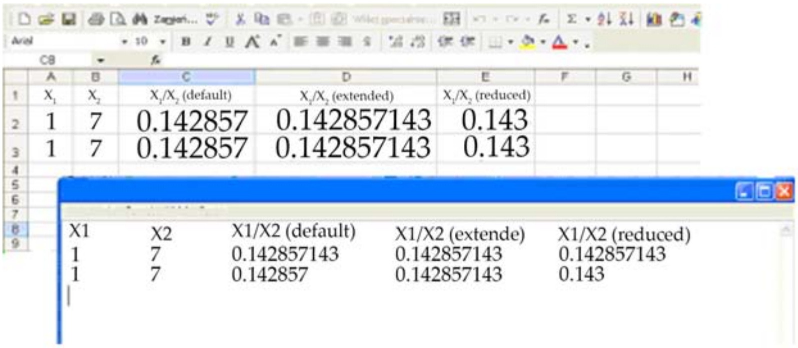


Figure 9. Data conversion – the conversion of a file from the xls to the txt format brings about a partial loss of information (the authors' own work).

Data Reduction

At the introductory stage of data preparation this task is limited to a single operation – attribute selection – and it is directly connected with the expert opinion and experience pertaining to the data under analysis. It is only as a result of a specialist analysis (for example, of brainstorming) that one can remove from the set of collected data those attributes which without question do not have any influence on the features under modeling.

The aim of the main stage data reduction techniques is a significant decrease in the data representation, which at the same time preserves the features of the basic data set. Reduced data mining makes then possible obtaining models and analyses which are identical (or nearly identical) to the analyses performed for the basic data.

Data reduction includes five operations, which are represented in Fig. 10:

- attribute selection – this resides in reducing the data set by eliminating from it the attributes which are redundant or have little significance for the phenomenon under modeling;
- dimension reduction – this resides in transforming the data with the aim of arriving at a reduced representation of the basic data;

- numerosity reduction – this is aimed at reducing the data set via eliminating the recurring or very similar cases;
- discretization – this resides in transforming a continuous variable into a limited and specified number of ranges;
- aggregation – this resides in summing up the data, most frequently in the function of time, for instance from a longer time period encompassing not just the period of a single shift but e.g. the period of a whole month.

The collected industrial database set may contain tens or even hundreds of attributes. Many of these attributes may be insignificant for the current analysis. It is frequently the case that integrated industrial databases contain redundant records, which is a consequence of the specific way in which the data is collected and stored in a single factory in multiple places. Keeping insignificant records in a database which is to be used for modeling may lead not only to – often a significant – teaching time increase but also to developing a poor quality model. Of course, at the introductory stage, a specialist in a given area may identify the group of attributes which are relevant for further modeling, but this may be very time-consuming, especially given that the nature of the phenomenon under analysis is not fully known. Removing the significant attributes or keeping the insignificant ones may make it very difficult, or even impossible, to develop an accurate model for the collected data.

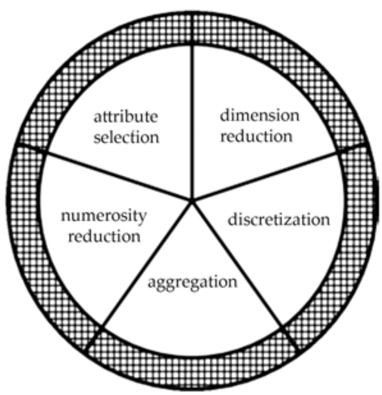


Figure 10. The operations performed in the data reduction task (with the introductory stage represented as the squared area and the main stage represented as the white area).

At the main stage, attribute selection is performed without any essential analysis of the data under modeling, but only with the help of selection algorithms. This is supposed to lead to defining the intrinsic (or effective) dimensionality of the collected data set (Fukunaga, 1990) The algorithms in question are classified as either *filters* or *wrappers*, depending on whether they are employed as the operation preceding the modeling proper (filters) or as the operation which is performed alternately with the modeling (wrappers).

Attribute selection is performed for four reasons: (a) to reduce the dimensionality of the attribute space, (b) to accelerate the learning algorithms, (c) to increase the classification quality, and (d) to facilitate the analysis of the obtained modeling results (Liu et al., 2003). According to the same authors, it may – in particular circumstances – increase the grouping accuracy.

Dimensionality reduction is the process of creating new attributes via a transformation of the current ones. The result of dimensionality reduction is that the current inventory of attributes $X\{x_1,x_2,\dots,x_n\}$ is replaced with a new one $Y\{y_1,y_2,\dots,y_m\}$ in accordance with the following equation (6):

$$Y = F(x_1, x_2, \dots, x_n) \tag{6}$$

where F() is a mapping function and m < n. In the specific case $Y_1 = a_1x_1 + a_2x_2$, where a_1 and a_2 are coefficients (Liu & Motoda, 1998). The same approach, which takes into consideration in its definition the internal dimensionality, may be found in (Van der Maaten et al., 2009). The collected data are located on or in the neighborhood of a multidimensional curve. This curve is characterized with m attributes of the internal dimensionality, but is placed in the n-dimensional space. The reduction frees the data from the excessive dimensionality, which is important since it is sometimes the case that m<<n.

The operation of dimensionality reduction may be performed either by itself or after attribute selection. The latter takes place when the attribute selection operation has still left a considerable number of attributes used for modeling. The difference between dimensionality reduction and attribute selection resides in the fact that dimensionality reduction may lead to a partial loss of the information contained in the data. However, this often leads to the increase in the quality of the obtained model. A disadvantage of dimensionality reduction is the fact that it makes more difficult the interpretation of the obtained results. This results from the impossibility of naming the new (created) attributes. In some publications attribute selection and dimensionality reduction are combined into a single task of data dimensionality reduction[1] (Chizi & Maimon, 2005; Fu & Wang, 2003; Villalba & Cunningham, 2007). However, because of the differences in the methods, means, and aims, the two operations should be considered as distinct. Discretization, in its broadest sense, transforms the data of one kind into the data of another kind. In the literature, this is discussed as the replacement of the quantitative data with the qualitative data or of the continuous data with the discrete data. The latter approach is the approach pertaining to the most frequent cases of discretization. It should be remembered, however, that such an approach narrows down the understanding of the notion of discretization. This is the case since both the continuous and the discrete data are numerical data. The pouring temperature, the charge weight, the percent element content, etc. are continuous data, while the number of melts or the number of the produced casts are discrete data. However, all the above-mentioned examples of quantities are numbers. Discretization makes possible the replacement of a numerical quantity, for instance, the ultimate tensile strength in MPa with the strength characterized verbally as high, medium, or low. In common practice ten methods of discretization method classification are used. These have been put forward and characterized in (Liu et al., 2002; Yang et al., 2005). A number of published works focus on a comparison of discretization methods which takes into account the influence of the selected method on different aspects of further modeling, for instance, decision trees. These comparisons most frequently analyze three parameters upon which data preparation – discretization exerts influence:

- the time needed for developing the model,
- the accuracy of the developed model,
- the comprehensibility of the model.

Comparative analyses are conducted on synthetic data, which are generated in accordance with a specified pattern (Ismail & Ciesielski, 2003; Boullé, 2006), on the widely known data sets, such as Glass, Hepatitis, Iris, Pima, Wine, etc. (Shi & Fu 2005, Boullé, 2006; Ekbal, 2006; Wu QX et al., 2006; Jin et al., 2009; Mitov et al., 2009), and on production data (Perzyk, 2005).

As has been widely demonstrated, the number of cases recorded in the database is decisive with respect to the modeling time. However, no matter what the size of the data set is, this time is negligibly short in comparison with the time devoted to data preparation. Because of that, as well as because of a small size, in comparison, for instance, with the business data sets, numerosity reduction is not usually performed in industrial data sets. The operation of aggregation was first discussed in connection with the discussion of the data transformation task. The difference between these two operations does not reside in the method employed, since the methods are the same, but in the aims with which aggregation is performed. Aggregation performed as a data reduction operation may be treated, in its essence, as the creation of a new attribute, which is the sum of other attributes, a consequence of this being a reduction in the number of events, that is, numerosity reduction.

THE APPLICATION OF THE SELECTED OPERATIONS OF THE INDUSTRIAL DATA PREPARATION METHODOLOGY

For the last twenty years, many articles have been published which discuss the results of research on ductile cast iron ADI. These works discuss the results of research conducted with the aim of investigating the influence of the parameters of the casting process, as well as of the heat treatment of the ductile iron casts on their various properties. These properties include, on the one hand, the widely investigated ultimate tensile strength, elongation, and hardness, and, on the other, also properties which are less widely discussed, such as graphite size, impact, or austenite fraction. The results discussed in the articles contain large numbers of data from laboratory tests and from industrial studies. The data set collected for the present work contains 1468 cases coming both from the journal-published data and from the authors' own research. They are characterized via 27 inputs, such as: the chemical composition (characterized with reference to 14 elements), the structure as cast (characterized in terms of 7 parameters), the features as cast (characterized in terms of 2 parameters), the heat treatment parameters (characterized in terms of 4 parameters), as well as via 11 outputs: the cast structure after heat treatment, characterized in terms of the retained austenite fraction and the cast features (characterized in terms of 10 parameters). 13 inputs were selected from the set, 9 of them characterizing the melt chemical composition and 4 characterizing the heat treatment parameters. Also, 2 outputs were selected – the mechanical properties after treatment – the ultimate tensile strength and the elongation. The set obtained in this way, which contained 922 cases, was prepared as far as data cleaning is concerned, in accordance with the methodology discussed above.

Prior to preparation, the set contained only 34,8 % of completely full records, containing all the inputs and outputs. The set contained a whole range of cases in which outliers were suspected. For the whole population of the data set under preparation outliers and high leverage points were defined. This made possible defining influentials, that is, the points exhibiting a high value for Cook's distance.

In Fig 11, which represents the elongation distribution in the function of the ultimate tensile strength, selected cases were marked (a single color represents a single data source).

The location of these cases in the diagram would not make it possible to unequivocally identify them as outliers. However, when this is combined with an analysis of the cases with a similar chemical composition and heat treatment parameters, the relevant cases may be identified as such.

Fig. 12 below represents the generated correlation matrix of the collected data. The high level of the absent data in the database is visible, among others, in the form of the empty values of the correlation coefficient – for instance, the database contains no case of a simultaneous appearance of both *Al contents* and *participation of graphite nodules*.

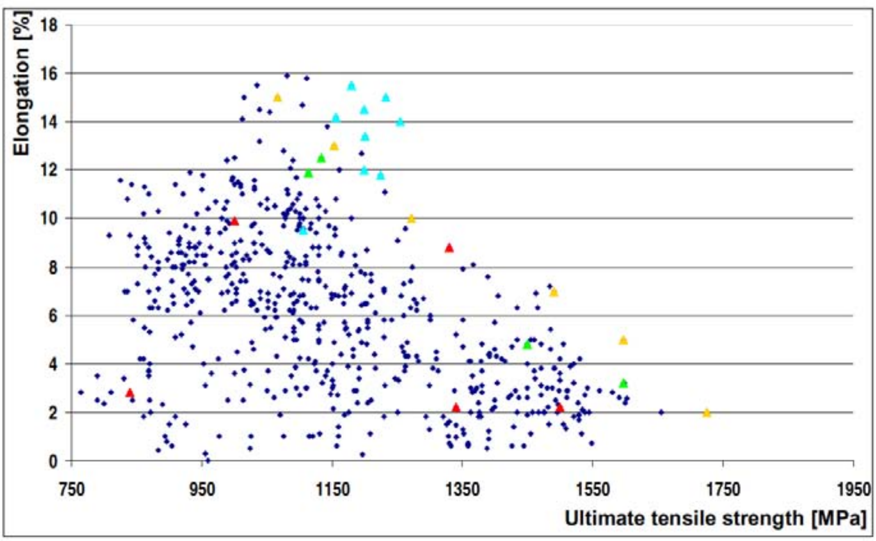


Figure 11. The elongation distribution in the function of the ultimate tensile strength. The colored pints represent cases identified as outliers (the authors' own work)].

With the use of the methodology discussed above, the database was filled in, which resulted in a significant decrease in the percentage of the absent data for the particular inputs and outputs. The degree of the absent data was between 0,5 and 28,1% for inputs and 26,9% for the UTS and 30,6% for the elongation.

The result of filling in the missing data was that the degree of the absent data for inputs was reduced to the value from 0,5 to 12,8%, and for strength and elongation to, respectively, 1,3% and 0,8%. Fig. 13 represents the proportion of the number of records in the particular output ranges "before" and "after" this replacement operation.

Importantly, we can observe a significant increase in the variability range for both dependent variables, that is, for elongation from the level of 0÷15% to the level of 0÷27,5%, and for strength from the level of 585÷1725MPa to the level of 406÷1725MPa, despite the fact that the percentage of the records in the respective ranges remained at a similar level for the data both "before" and "after" the filling operation.

Similar changes occurred for the majority of independent variables – inputs. In this way, via an increase in the learning data set, the reliability of the model was also increased. Also, the range of the practical applications of the taught ANN model was increased, via an increase in the variability range of the parameters under analysis.

The data which was prepared in the way discussed above were then used as the learning set for an artificial neural network (ANN). Basing on the earlier research [4], two data sets were created which characterized the influence of the melt chemical composition and the heat treatment parameters (Tab. 1) of ductile cast iron ADI alloys on the listed mechanical properties.

The study employed a network of the MLP type, with one hidden layer and with the number of neurons hidden in that layer equaling the number of inputs. For each of the two cases, 10 learning sessions were run and the learning selected for further analysis was the one with the smallest mean square error.

A qualitative analysis of the taught model demonstrated that the prediction quality obtained for the almost twice as numerous learning data set obtained after the absent data replacement was comparable, which is witnessed by a comparable quantitative proportion of errors obtained on the learning data set for both cases (Fig. 14).

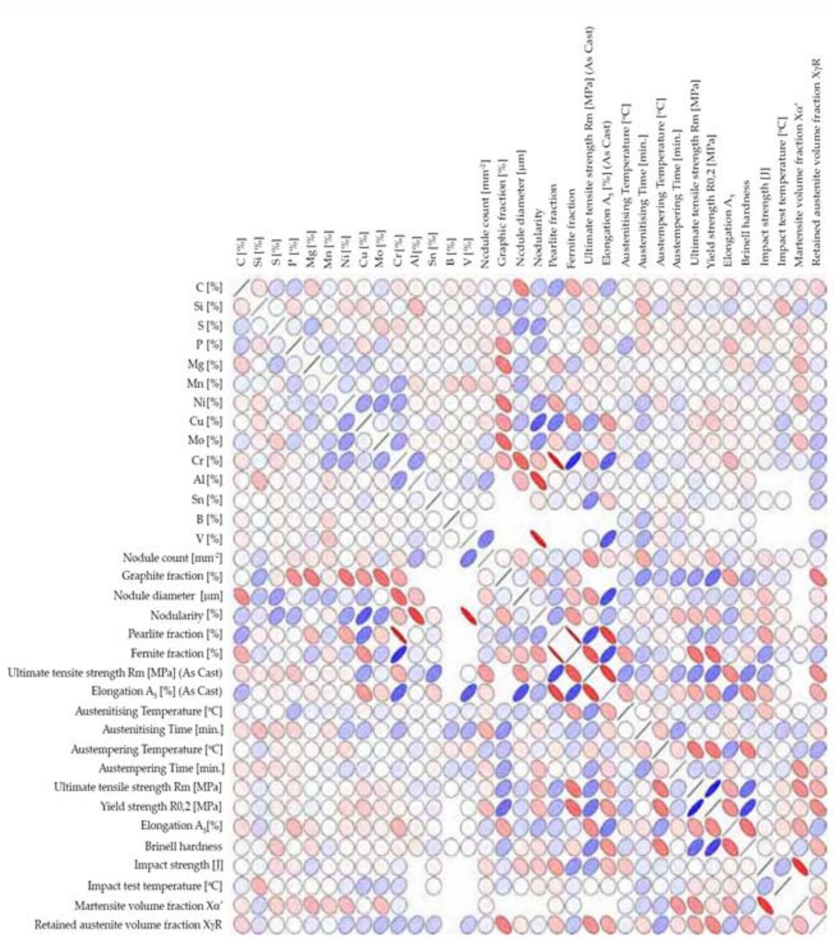
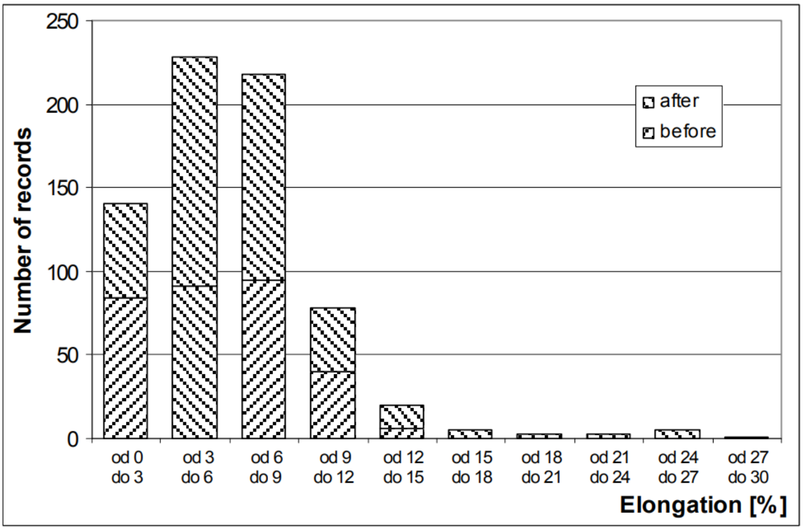
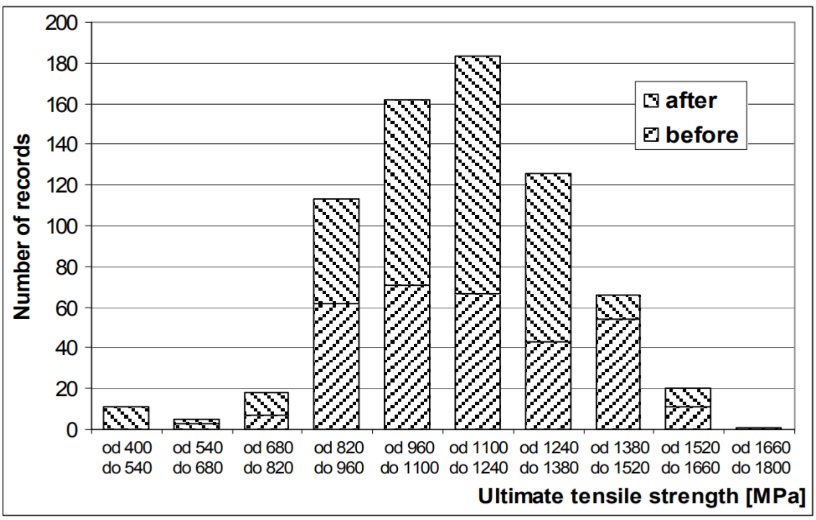


Figure 12. The input and output correlation matrix. The blue color represents the positive correlation while the red color represents the negative one; the deformation size correlation, of the circle (ellipsoidality) and the color saturation indicate the correlation strength (Murdoch & Chow, 1996).

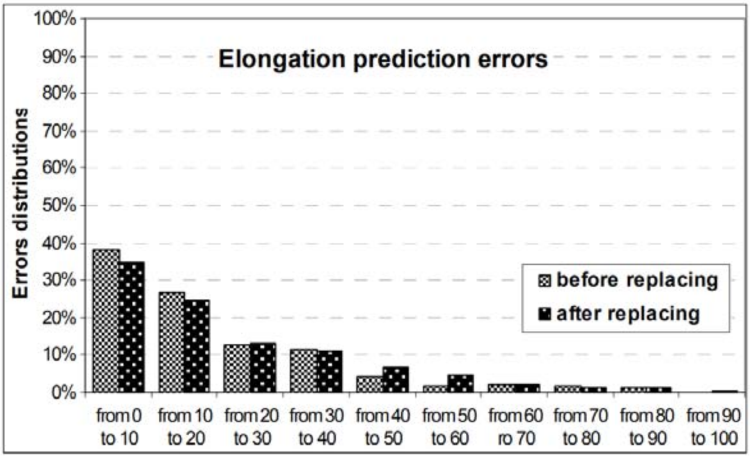


(a)

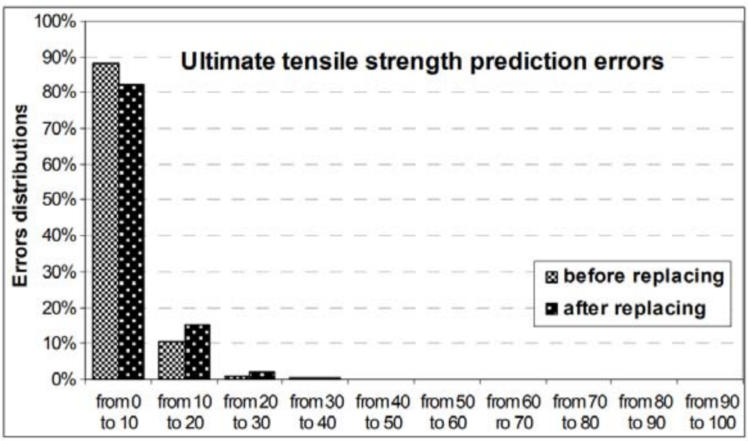


(b)

Figure 13. The proportions of the numbers of records in the specified ranges of the output variables a) elongation [%], b) ultimate tensile strength [MPa] before and after replacing the missing and empty values.



(a)



(b)

Figure 14. Output prediction error distribution a) elongation [%], b) ultimate tensile strength [MPa].

A further confirmation of this comes from a comparative analysis of the real results and the ANN answers which was based on correlation graphs and a modified version of the correlation graph, taking into account the variable distribution density (Fig. 15 and 16). In all cases under analysis we can observe that the ANN model shows a tendency to overestimate the minima and to underestimate the maxima. This weakness of ANNs was discussed in (Kozlowski, 2009).

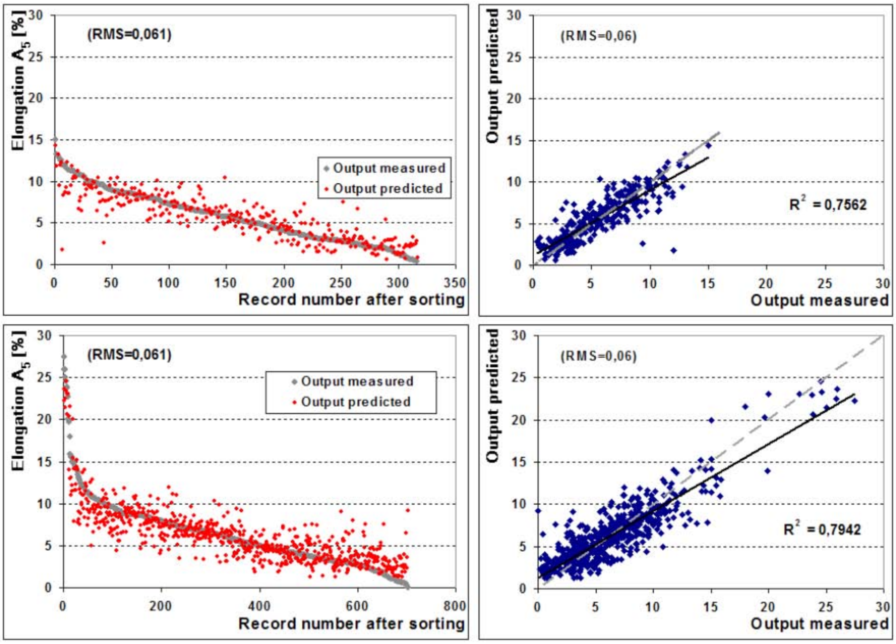


Figure 15. The distribution of the real results and the predictions of the elongation variable for a) the data set without replacement; b) the data set after replacement.

The analyzed cases suggest that an ANN model taught on a data set after absent data replacement exhibits similar and at the same high values of the model prediction quality, that is, of the mean square error, as well as of the coefficient of determination R^2. In the case of predicting A_5, the more accurate model was the ANN model based on the data set after replacement (for R_m the opposite was the case). However, the most important observable advantage following from data replacement and from the modeling with the use of the data set after replacement is the fact that the ANN model increased its prediction range with respect to the extreme output values (in spite of a few deviations and errors in their predictions). This is extremely important from the perspective of the practical model application, since it is the extreme values which are frequently the most desired (for instance, obtaining the maximum value R_m with, simultaneously, the highest possible A_5), and, unfortunately, the sources – for objective reasons – usually do not spell out the complete data, for which these values were obtained. In spite of the small number of records characterizing the extreme outputs, an ANN model was successfully developed which can make predictions in the whole possible range of dependent variables. This may suggest that the absent data was replaced with appropriate values, reflecting the obtaining general tendencies and correlations. It should also be noted that the biggest prediction errors occur for the low values of the parameters under analysis (e.g.: for A_5 within the range 0÷1%), which may be directly connected with the inaccuracy and the noise in the measurement (e.g.: with a premature break of a tensile specimen resulting from discontinuity or non-metallic inclusions).The application of the proposed methodology makes possible a successful inclusion into data sets of the pieces of information coming from different sources, including also uncertain data.An increase in the number of cases in the data set used for modeling results in the model accuracy increase, at the same time significantly widening the practical application range of the taught ANN model, via a significant increase, sometimes even doubling, of the variability range of the parameters under analysis.Multiple works suggested that ANN models should not be used for predicting results which are beyond the learning data range. The methodology proposed above makes possible the absent data replacement and therefore, the increase of the database size. This, in turn, makes possible developing models with a significantly wider applicability range.

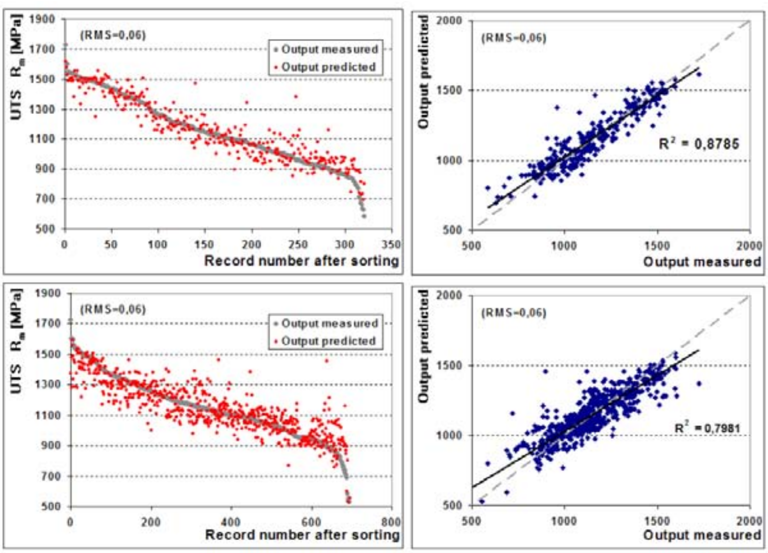


Figure 16. The distribution of the real results and the predictions of the UTS (ultimate tensile strength) variable for a) the data set without replacement; b) the data set after replacement.

CONCLUSION

The proposed methodology makes possible the full use of imperfect data coming from various sources. Appropriate preparation of the data for modeling via, for instance, absent data replacement makes it possible to widen, directly and indirectly, the parameter variability range and to increase the set size. Models developed on such sets are high-quality models and their prediction accuracy can be more satisfactory.

The consequent wider applicability range of the model and its stronger reliability, in combination with its higher accuracy, open a way to a deeper and wider analysis of the phenomenon or process under analysis.

NOTES

1Data Dimensionality Reduction DDR, Dimension Reduction Techniques DRT

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SECTION 4:

CLINICAL NEUROSCIENCE

CHAPTER 13

Neuroscience, Unconscious processes: Clinical Applications

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ABSTRACT

This article reviews selected neuroscience and psychoanalytic writings about respective concepts regarding unconscious processes. Two objectives are pursued. The first is the modification of an apparent dualistic view of the psychoanalytic, dynamic unconscious described by Freud and the implicit, automated unconscious described by neuroscientists into a unified unconscious process concept. Secondly, to examine the functional, structural theory of Freud and to connect it to neuroscience findings via neurodevelopment and the concomitant development of speech and language, an exclusive communicative capacity of the human species. The goal is to illustrate the application of the objectives into clinical settings.

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Keywords: Genome, Neuroscience, The Unconscious, Structural Theory, Clinical Applications

INTRODUCTION

The literature of neuroscience and psychology contains a vast amount of findings and information derived from scientific investigations, clinical studies, and theoretical hypotheses which clinicians evaluate and assimilate. Patients present with their unique, integrated physical and psychological pathologies expressed through their behavior and individual personalities. In modern molecular biology and genetics the genome is the entirety of an organism's hereditary information. The constituents of the genome are represented in the receptor mechanisms of the cells of the central nervous system (CNS), autonomic nervous system (ANS), and peripheral nervous system (PNS). The cell membranes of the nervous systems are candidate genes intrinsically involved in the differentiation, development, and functioning of all biological organ systems. Neurons develop and make connections not only within the CNS, ANS, and PNS but within every organ system of the body. The differentiation of organ systems is determined by tissue specific genes in proximity to other specific genes interacting with each other to a greater or lesser degree. The process is guided by subtle intrinsic action potentials of cell membranes in synchronization with functional neural circuits. Edelman [1] states that, "the development of individuals is constrained by genes and inheritance and from early life on is epigenetic. Neurons extend the branching process in many directions generating extensive variability in the connective patterns of neural circuits. Neurons that fire together, wire together in the developing individual which persists throughout each individual's lifetime." Elemental potential for change lies within the genome itself. According to the Encode Project [2], "It is not just the gene but the network that makes the gene dynamic… transcription factors—special genes that can simultaneously activate or silence thousands of genes and are wired together in hierarchal fashion…" Edelman [3] states that, "the brain is an example of a self-organizing system." Groups of neurons function together based on an individual's motor, mental, and trans-organ system activities and are disposed into maps in the brain that connect and overlap. Along with simultaneous input from the neural activity of the sense organs, there occurs a hierarchal synchronization of maps into a, "global mapping" of various maps. Global mapping activity of the brain cortex includes, of course, connections with the emotional centers of the brain, the so-called hedonic centers. The formatting of mental concepts is the product of the brain categorizing its own activities by way of memory processes and perceptions both internal [including fantasy] and external. Damasio [4] described a somatic marker hypothesis which consists of bodily sensations that is in juxtaposition to the brain's capacity to image events. He posits an image space in which disposional memories are reconstituted in recall held in neuron assemblies called, "conversion zones." Conversion zones are hypothesized to represent cortical, and subcortical regional centers of the brain [hedonic centers] involved in the act of perceiving and responding to brain images and external objects. Damasio [5] states, "emotions also effect the modes of operation of numerous brain circuits; the variety of emotional responses is both responsible for profound changes in both the body landscape and the brain landscape."

The collection of these changes constitute the substrate for the neural patterns which eventually becomes feelings and emotions. Emotions persistently influence higher level thought processes. Speech and language is the pathway to higher thinking and allows for open ended formation of concepts. It pertains to a capacity for metaphor, symbolism, abstraction, and creativity. Edelman [6] states that, "The fundamental mental triad of higher brain function is composed of perceptual categorization, memory, and learning… it involves continual motor activity and repeated rehearsal in different contexts." Kandel [7] identifies the merger of psychology and neuroscience as cognitive neuroscience.

The two subordinates of cognition are learning and memory. He holds the view that, "alteration in gene expression induced by learning indicates that a major consequence of such alteration is the growth of synaptic connections and the changes in patterns of neural connections." Hyman [8] describes the neurobiology of clinical addictions which he believes might serve as a model for the plasticity of the brain in connection with emotional pleasure factors. His model involves the transcription of ribonucleic acid (RNA) over a period of several months. These patterns develop as well in cadence with the development of speech and language that is central to bring about higher order thinking involving open ended thought processes and distinctive thinking capabilities. The purview of understanding higher level thinking belongs to the realm of psychology and psychoanalysis. I will turn now to my first objective, "the unconscious" a term which seems to imply a selfcontained entity.

THE UNCONSCIOUS PROCESS OF NEURAL CIRCUITS AND NEUROPSYCHOLOGY

Regina Palley [9] states that, “the bridge between the neuroscience of emotion and psychoanalysis is that both center on unconscious mechanisms. Neuroscience asserts that emotion is processed independently of conscious awareness; not the dynamic unconscious of Freud but in a biographical unconscious governed by the rules and constraints of neural circuits and neuropsychology.” She believes that the findings of neuroscience reveals that non-verbal communication between mother and infant, as is illustrated by attachment (mother-infant feedback loop in which mother and infant regulate each other) regulates minds and bodies between individuals. Westin [10] asserts that, “the concept of ‘the unconscious’ has outlived its usefulness because there are many different kinds of unconscious processes that serve different functions (many of which have neuroanatomical substrates). Cognitive scientists today recognize at least two systems, one conscious (called explicit) and the other unconscious (called implicit). An example of implicit memory is procedural memory of how to ride a bicycle, throw a ball or play a musical instrument. Another kind of implicit memory involves associative memory the formation of associations that guides mental processes and behavior outside of consciousness.” Researchers have studied a multitude of unconscious processes which serve many functions, ranging from sensation and perception to memory, decision making, emotion, and motivation. Westin argues that such a large set of processes should not be lumped together and be called, “the unconscious”, as if they all do the same thing, serve the same function or operate under the same principles. We should instead speak of unconscious processes. An example of unconscious factors determining behavior is a post-hypnotic suggestion. The posthypnotic subject, at a predetermined signal by the hypnotist, gets up, walks to the sink, pours himself a glass of water and drinks it all outside of his awareness that he was told to do it while in a hypnotic state, It demonstrates how a thought can bring about a complex motor activity. Freud himself believed that slips of the tongue were a simple way to illustrate unconscious mental conflict. My own observation is that nearly everyone becomes an instantaneous, transitory Freudian when exposed to a slip of the tongue that has a sexual connotation. There are different degrees of participation of unconscious processes along with neurodevelopment as each individual experiences mental activity in connection with perceived external events and situations. In my view, neurodevelopment is based on the dynamic genome with candidate genes represented in cell membranes of the nervous systems throughout human functioning. That is, the CNS, ANS, and PNS are expressed in transorgan responses. In basic fight or flight responses mediated through neurotransmitters there is no quibbling about alternative views or interpretations of memories implicit, explicit, hormonal releases (i.e. cortisol), unconscious or conscious mental activity. Networks of neuronal activity are at play with the connecting line being that of epigenetically determined neural membrane responses acting synchronously. Clinically, the syndrome of Post Traumatic Stress Disorder serves as an example of imagery interlaced with different organ systems; somatic symptoms, both motor and autonomic, and with changes in behavior. An acute episode may be triggered by various sensory stimuli such as visual, auditory, olfactory, and others that may have been associated with the experienced trauma. “The neurons that fire together, wire together,” as Edelman has stated and can be properly extended throughout life experiences. The neurons that wire together include those circuits linked to emotional, affective centers in the brain. These links are widely believed to be involved with the evolutionary imperatives, so-called instinctual drives related to survival (aggression) and propagation (sexual) of the human species. Unique for the human species is the development of speech and language in conjunction with social and cultural influences. Unconscious processes are inherent in neurodevelopment in the context of interactions with primary family figures and interpersonal relationships throughout life as individual human dramas unfold. At this point I will take up the second objective of this article which is to connect Freud’s Structural Theory with neuroscience.

THE STRUCTURAL THEORY AND NEUROSCIENCE

Fisher [11] cites Freud who stated, “The poets and philosophers before me discovered the unconscious; what I discovered was the scientific method by which the unconscious mind can be studied.” He was referring to the method of free association that is still practiced today. Psychoanalysis is not only a therapeutic modality but remains a productive research modality that has generated the most comprehensive understanding of human emotions, thinking, and behavior, neuroscience notwithstanding. In his hallmark book, The Interpretation of Dreams, Freud worked out many of the mental mechanisms involved in dream work such as displacement, condensation of mental images, and considerations of the representativeness of mental images. He distinguished between primary process thinking and secondary process thinking which has relevance in clinical psychiatry today. Arieti [11] refers to von Domarus who described primary process thinking in which a schizophrenic may form a delusion based on identification of predicates to form a conclusion. For example, Subject A, who has white hair and a white mustache, might think, “I am a man with white hair and mustache. Albert Schweizer (Subject B) has white hair and a white mustache. Therefore, I am Albert Schweizer.” Logical or Aristotelian secondary process cognition, in contrast, rejects that type of identification because, logically, if Subject A and Subject B are different, they cannot be the same. The law of identity says that A is always A, never B. At the other end of the thinking spectrum, Kandel [12,13] states, “Because primary process is freer and hyper associative, it is thought to facilitate the emergence of creativity that promotes new combinations and permutation of ideas— the equivalent of an Aha! moment where the full focus of secondary processes thinking is required for the working through, the elaboration of creative insight... like much of our cognitive and affective life, even our decision making is partially unconscious suggests that unconscious mental processes are necessary for creative thinking as well.”

Neurodevelopment is grounded in the dynamic genome expressed in motor and glandular outlets. The lines of connection are candidate genes in membranes of neurons branching out in trans-organ coordination. Evolutionary imperatives of survival (aggressive instinct) and propagation of species (sexual instinct) develop in conjunction with motor, sensory, and mental interplay, including phantasy.

The long period of infantile dependency on parents/caregivers necessarily incorporates those figures in the neuropsychological development of individuals. Freud first conceived of a topical model of the mind: unconscious, pre-conscious, and conscious. When it became apparent that mental defense mechanisms, monitored by a pleasure-unpleasure continuum, were themselves partially unconscious, he abandoned the topical theory in favor of the structural theory. The structural theory is a functional entity comprised of Id, Ego, and Superego working in unison each containing varying degrees of conscious and unconscious dimensions. Brenner [14] emphasized the monitoring of sexual and aggressive drive derivatives according to the pleasure-unpleasure spectrum. He maintains that the mind is in continuous intrinsic conflict and attempts to resolve conflicts by compromise formation in thought and somatic action. He argues that each thought, perception, mental representation has unconscious and conscious participation of Id, Ego, and Superego in varying proportions. I would add, in a neurophysiological vein, that all thoughts and actions are grounded in parallel neurological networks via intercellular and trans-organ communication. The connecting mechanisms are propagated by the candidate gene receptors on nerve cell membranes of the CNS, ANS, and PNS. Neural networks underlie cognition, perception, memories and phantasies with obligatory simultaneous activity of the neural circuitry of emotional centers located in the midbrain particularly the thalamus, cingulate gyrus, and amygdale nucleus with their neural projections to the cerebral cortex. According to the structural theory, unconscious and conscious processes are merged in varying proportions which determine the outcome of thoughts, feelings, emotions and actions. I will leave it to those who disagree to explain why unconscious processes alone should be exempt from dynamic neuropsychological processes. Now that my two objectives have been set forth I will turn to the goal of illustrating the application of the discussed objectives to the clinical venue.

CLINICAL MANIFESTATIONS OF UNCONSCIOUS PROCESSES

In the current dominance of biological psychiatry expressed in psychopharmacology, the clinical psychiatrist routinely makes medication appointments which last conventionally for 20 - 30 minutes. It is instructive to trace back to the model used in the development of neuroleptic agents. Snyder [15] states, “Both amphetamines and apomorphines produce in rats stereotyped sniffing, licking and gnawing.

These drugs produce fighting among male rats and enhance rope climbing behavior in mice. All of these effects are antagonized by neuroleptics in proportion to their dopamine blocking properties.” Pharmaceutical companies then do toxicology studies, next pre-clinical trials, and then clinical trials to determine efficacy before submitting to the Federal Drug Administration for approval. It’s hard to reach an understanding of human behavior and higher level thinking derived from a rat model. Perusal in the Physician’s Desk Reference of the mechanism of action of neuroleptic medications show that they are essentially unknown in spite of all the technical investigations conducted by neuroscientists. The range of side effects, however, is well known and reflects a trans-organ response. In general, the specificity of the nervous system and other biological findings do not provide a comprehensive understanding of human behavior and higher level thinking. Clark [16] stated that Einstein was asked, “Do you believe that absolutely everything can be expressed scientifically”, “Yes,” he replied, it would be possible, but it would make no sense. "It would be description without meaning—as if you described a Beethoven symphony as a variation of wave pressure."

Freud [17] stated in regard to his theory of dreams, "but if you ask me how much of dream interpretation has been accepted by outsiders—by the many psychiatrists and therapists who warm their pot of soup at our fire (incidentally without being very grateful for our hospitality)… The reply finds little cause for satisfaction." He might say the same for his psychoanalytic findings today. Nonetheless, they turn up in modern clinical practice albeit indirectly. I have discussed above how the structural theory relates to neurobiological facts. Along the way of its development psychology and biological psychiatry has spun off a considerable amount of psychobabble and analogous biobabble. Over the past half-century behavior therapy and cognitive therapy have been widespread. It is risky, however, to ignore the origin of things so these latter treatment techniques have undergone necessary modifications. A combination technique known as cognitive behavior therapy (CBT) has emerged followed by dialectic-behavior therapy (DBT) whereby the, "talking cure" is brought in. Next appeared transference focused psychotherapy (TFP) which necessarily must involve countertransference phenomenon as well. Mentalization based therapy (MBT) has a more psychodynamic approach dealing with emotions and feelings. Schema focused therapy (SFT) seems to be a composite of several therapies. The foregoing therapies have obvious roots in the psychoanalytic literature. In the course of clinical treatment the clinician frequently encounters the psychoanalytic concept of "resistance" to treatment manifested by lack of adherence to medication regimens, treatment protocols, a pattern of late or missed appointments, breach of so-called contracts for treatment, etc. Dependency/independency issues of control may interfere with proscribed treatment. Every psychiatric and psychosocial assessment of the presenting illness is traced back to the patient's individual's personal history of earlier life experiences. Attention is paid to the individual's interpersonal relationships, traumatic events, and the influence of early family caretakers. Gabbard [18] states, "A basic premise of psychodynamic thinking is that internal object relations etched in neural networks from early childhood development tend to repeat themselves again and again in adult relationships." The fundamental psychoanalytic discovery that conflicts of the past continue to influence present behavior and the capacity to resolve mental conflicts by verbalizing them is extant.

CONCLUSION

In a Darwinian sense, the facts and findings of neuroscience and the concepts of psychoanalysis will be validated by their durability and serviceability. Both will survive and will be determining factors in humankind's vicissitudinous pathway into the future. In addition to treating acute clinical presentations clinicians are faced with the need for chronic maintenance therapy and management. This will inevitably involve the personality of the patients/clients that requires an integrated biological and psychological foundation. An operational familiarity with psychoanalytic premises, tenets, and postulates would, therefore, be of benefit to providers in the clinical encounter.

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CHAPTER 14

Validating New Technologies to Treat Depression, Pain and The Feeling of Sentient Beings: A Reply to "Neuroscience for The Soul"

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ABSTRACT

The primary assumption of Neuroscience is that all experiences are strongly correlated with or caused by the specifics of brain structures and their particular dynamics. The profound experiences attributed to the "sensed presence" and their cultural anthropomorphisms such as deities and gods

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are persistent reports in human populations that are frequently associated with permanent changes in behavior, reduced depression and alleviation of pain. The majority of traditional clinical observations and modern imaging techniques have emphasized the central role of right temporal lobe structures and their directly related networks. The experimental simulation of sensed presences which can result in attributions to spiritual, deity-based or mystical sources within the clinical laboratory by the application of physiologically-patterned magnetic fields across the temporal lobes through our God Helmet requires the same precision of technology that is essential for synthesizing molecular treatments for modifying anomalous behavior, depression and pain. Despite the clinical utility of these simulated conditions within Neuroscience and Medicine, misinformation concerning the bases and efficacy of this new technology persist. Here we present detailed technical clarifications and rebuttals to refute these misconceptions. A Hegelian approach to this delay of development and impedance provides a context through which the ultimate synthesis and application of this technology may be accommodated in the near future.

Keywords: Sensed Presence, Physiologically Patterned Magnetic Fields, Temporal Lobes, Neurotheology, Religiosity, Spiritual Experiences, Hippocampal Formation, s-LORETA, Imaging, The God Helmet

INTRODUCTION

Hegel's observation that a novel discovery or idea, a thesis, is followed by an antithesis that then results in a synthesis has been conspicuous within the progress of human knowledge [1] . There is balance when new knowledge appears within the traditional aggregate of assumptions but only if the antithesis is as valid as the thesis. In the history of Medicine and Neuroscience, there have been multiple examples where a new and valid idea is delayed or suppressed from development through systematic replication by the general scientific community due to persistently vocal misrepresentations and fallacious arguments by antagonists whose interests are based upon agendas or maintenance of the status quo rather than data-based criteria. As a result, the potential benefits from these new discoveries for the human population have been delayed or denied. The most recent perturbation concerns the validity and efficacy of specific temporally patterned, weak magnetic fields applied across the temporal lobes to produce fundamental experiences such as the "sensed presence" (the feeling of a "Sentient Being") as well as their capacity to reduce depression and pain.

Neuroscience is predicated on the assumption that all experiences are so strongly correlated with brain activity and structure that they can be considered causes of both public and private behaviors. These are behaviors that can be observed or measured by others or observed ("measured") only by the experients. The latter are traditionally labeled as thoughts and ideas. The recent documentation of the Default Mode Network [2] [3] that includes the anterior cingulate, posterior cingulate, posterior temporal-parietal lateral region and related structures as well as other highly predictable networks for specific types of cognitive operations, has indicated that the traditionally obscure domain of "thinking, beliefs, and exotic experiences" is caused by brain activity. Consequently they are measureable. If they are measureable then the responses to experimental manipulation can be discerned, categorized and simulated.If all experiences are caused by specific complexities of brain activity then affecting this activity must potentially modify any specific class of behaviors. The consequence of brain injuries, whereby local damage or loss of neurons disinhibits neuronal clusters in other regions which actually cause the emergent behavior, is well known. The discernment of subtle more complex changes requires more precise instrumentation. Since the implementation of imaging technology such as fMRI (functional Magnetic Resonance Imaging), SPECT (Single Positron Emission Computerized Tomography), PET (Positron Emission Tomography), quantitative electroencephalographic (QEEG) and s-LORETA (standardized Low Resolution Electromagnetic Tomography) the data have clearly shown that routine operations such as presenting different stimulus patterns through different sensory modalities produce predictable and reliable alterations in activations of networks within the human cerebral volume as well as very predictable private and public behaviors.

As indicated by Johannes Mueller during the late 19th century, human awareness was effectively a reflection of "the states of the nerves" rather than the direct isomorphic representation to stimuli impinging upon the senses. Elementary neuroanatomy indicates that there are at least six transformations, represented as synapses that occur between the impingement of photons upon rods and cones and the experience of a gestalt image at the level of the cerebral cortical networks. As aptly shown by Van Essen and Drury [4] , the information contained within the action potentials from what appears to be a singular retinal image is deconstructed upon arrival within the caudal cerebral cortices into multiple components that include position, color, motion, shape, and meaning. These fractal components are then reintegrated into the perceptions that are experienced as a "whole" or gestalt.

As a result inexplicable phenomena such as palinopsia [5] are no longer mysterious but represent the integration of additional information into the aggregate before it is manifested as experience. The source of the extraneous patterns of neuronal activity that could become integrated into the final gestalt that constitutes the perception is usually ascribed to endogenous anomalous networks. They can also be the source of "illusions" or hallucinations. However the occurrence of this "re-integrative process" at the cerebral cortical level suggests that other stimuli such as electromagnetic fields applied externally from sources that penetrate the cerebral volume could also be integrated into the final experience.

The experimental and medical capacity to modify all brain activity and hence experiences has the potential to open new domains for treatment and explanation. One of the most powerful and persistent experiences (which are correlated with the activity within the caudal cerebral space) and beliefs (which are strongly correlated with the prefrontal regions associated with the organization of experiences) involves phenomena that are described as "sentient". They are experienced as occupying a larger space and longer time than the individual experient. This Sentience is considered personal and strongly emotional [6] . The Sentience or its anthropomorphic attributions (the Sentient Being) is perceived as intricately related to the person's sense of self as well as the persistence of this sense of self after the demise of the brain and body.

In clinical settings the concern about death and the disruptive consternation associated with the demise of the person is often a major pre-occupation. Some philosophers and early 20th century clinicians [7] had suggested that thanatophobia, that is the fear of death, was the source of all anxieties. Anxiety is defined operationally as the anticipation of an aversive stimulus such as the unknown following dissolution of the self. Unbridled anxiety results in difficulties with adaptation and can significantly reduce the patient's capacity to achieve the universal goals of clinical normality. They are the ability to live relatively free of distress, the capacity to love and to be productive, and the ability to develop the person's own unique potential.

The concepts of Sentient Beings (the anthropomorphic attribution of the sensed presence) whose temporal duration is indefinite and who occupy all of space imply cognitively that there is no finality. If a person can be perceived to be a subset or identity with this "non-finality" then anxiety does not occur because there is no end. If belief concerning a Sentient Being is acquired by cultural learning or following a personal experience then the personal anxiety can be reduced. Like other forms of negative reinforcement, any response that is associated with the removal of a negative stimulus will be repeated. The cognitive operation for reducing this potentially devastating existential anxiety is remarkably simple. It is usually reflected in some statement such as “I am child of X” or “I believe in X” where X is the cultural name for the Sentient Being. If personal anxiety is reduced, the probability of displaying these verbal behaviors both as thoughts and speech are more likely to occur again [8] . Subsequent reduction of depression and re-integration of the person’s cognitive structure with purpose and productivity, without medication, following these conversions have been remarkably ubiquitous both historically and cross-culturally.

The clinical and experimental capacities to directly affect the cerebral processes that are central to the experience of a Sentient Being or a Sensed Presence creates the potential to implement this technology for amelioration of distress experienced by patients who are terminal, who are engaging in protracted and unresolved grieving, or who are experiencing incapacitating existential anxiety. For the last 30 years we [9] - [11] have been developing a technology to accommodate these persistent human conditions that could be employed by the clinician to improve the quality of life. The technology is based upon the basic principles of Neuroscience. If all experiences are produced by specific brain activity and structure then the simulation of these patterns of activity within the cerebral volume should produce these experiences.

The emergence of a domain of research which has been most frequently labeled as “neurotheology” [12] is a logical extrapolation of the premise that all experiences are produced by brain function. However because the subject matter, that is the beliefs about the validity and sources of the subject matter (theological entities) are subject to testing and potential refutation, one would expect frustrative aggression to be displayed by strong believers when the validity of their beliefs is challenged. In this context the scalar quantity is more critical than the vector. In other words it is not the type of belief, theism or atheism; it is the magnitude of that belief that would be expected to produce the greatest frustrative aggression and opposition towards the idea. Although the arguments of antithesis are consistent with Hegel’s interpretation, arguments based upon affect and agenda rather than facts and data do not often contribute to the productive synthesis that allows beneficial application to Science and Medicine.

THE DISCOVERY

Like many discoveries the elicitation of the sensed presence by physiologically-patterned, weak magnetic fields was based upon an intuitive challenge. The left hemispheric processes were associated with the sense of self [13] , mediated primarily through linguistic operations. The sagacious insights of Durkheim [14] reflected in his 19th century book, Suicide, indicate how the sense of self and its integrity is influenced by language and culture. From this perspective the proclivity for human beings within a culture to fight or to die to maintain their language and culture is not only predictable but very likely strongly determined. This approach also indicates that the sense of self is intricately interwoven not only with the process of language operations within brain functions but also with the idiosyncratic details of the language's syntax and semantics.

The obvious question is: what analogous experience is associated with right hemispheric processes? The prescient and perspicacious 19th century neurologist Hughlings Jackson [15] had inferred, on the bases of observing many patients before and during temporal lobe seizures, the transience of a "parasitic" consciousness that was experienced as "the other". Many other researchers such as Julian Jaynes [16] as well as Suedfeld and Mocellin [17] have emphasized the importance of "the sensed presence" that can be produced by specific environmental factors or altered states. When we applied physiologically-patterned fields across the temporal lobes such that there was a slight gradient from the right (higher) to the left side a sensed presence was frequently reported [18] . However like the natural or spontaneous occurrences of the sensed presence there were concurrent environmental conditions required to enhance the probability that the experience would be reported. After all, the sensed presence or its attribution to a Sentient Being is not a frequent or routine experience for most human beings.

There were several conditions required to produce the effect. First, physiologically-patterned magnetic fields were essential. By "physiologically-patterned" we mean those with temporal shapes and characteristics that imitate or simulate the electromagnetic changes of single neurons or aggregates of neurons within the cerebrum. Second, the person must sit blindfolded within a dark acoustic chamber or room. We reasoned that without the passive stimulation from background sounds and sights the neurons that would typically be involved with responding to these stimuli would then have the capacity to be recruited into the patterns induced by the experimental fields penetrating through the cerebrum. Consequently, the intensities of the applied fields were not required to be excessive. We assumed that the energy associated with the patterned magnetic field within the cerebral volume was the primary basis of the mechanism rather than frank current induction most typically defined by Faraday's law. Within the cerebral space the effective intensity ranges were found to be between 100 nanoTesla and 5 microTesla. This magnitude is a million times less intense than that employed for TMS or transcranial magnetic stimulation [19] that operates through current induction within focal areas. The two mechanisms are quite distinct but can produce similar effects. To differentiate the two methods we have sometimes referred to our technology as "Transcerebral Magnetic Stimulation (TCMS)".

The third component was the manner in which the magnetic fields were generated. Function generators which produce temporally symmetrically sine waves and square waves were not effective or minimally effective. Instead the computer software-generated magnetic fields developed by Professor Stanley A. Koren required point durations that when integrated over time produced the physiologically-patterned fields [20] . Point durations of 3 ms were more effective than either <2 ms or >4 ms. This meant that great care was required to ensure the pattern was not distorted. This is analogous to ensuring the structure of a molecule in neuropharmacology. If a component, even a single chlorine or amine group, is altered or deleted many molecules no longer function within the brain in the same manner. Fourth, the total duration for exposure was about 30 min. Briefer exposure durations were less effective. Fifth, it was optimal, except for film crews who were documenting the phenomenon, for volunteers to be "blind", that is not aware, of whether or not they were receiving actual fields or no fields (sham condition).

The standard protocol is to explain to the person that relaxation during the exposure without cognitive direction is optimal. Talking in order to communicate the experiences (through a lapel microphone to the experimenters) might interfere with the phenomenon but the person is free to do so if he or she wishes. Each subject is told that the experiences are subtle and that he or she should behave as a passive observer rather than actively intending. Two patterns of fields produce the most frequent numbers of sensed presences. The first is a 30 min exposure to a frequency modulated (decelerating) pattern with 3 ms point durations such that the range shifts between 26 Hz and 8 Hz once every 2 s continuously. This has been also called "the Thomas pulse".

At the end of the 30 min sequence the person responds to a questionnaire containing 20 items that refer to the typical experiences a person might perceive during the exposure. The details of the items have been published elsewhere [21] . The questionnaire is completed in dim light while the person is still wearing the Koren Helmet ("the God Helmet") that generates the fields across the temporal lobes and is sitting in the comfortable chair. The person is then blindfolded again. For another 30 min a second pattern (accelerating frequency modulated pattern) is presented with equal intensity across both hemispheres for ~1 s every 3 s or 4 s while the person sits in the darkness in the acoustic chamber. At the end of the 30 min the same questions are answered again. The particular mark-space ratio of 1 s every 4 s was derived from the results of experiments involving weak electrical currents that showed a stimulation once every 4 s resulted in analgesia. The presentation of two patterns allowed each person to serve as his or her own control with respect to the differential effects of the fields. Previous experiments [22] have shown that the reversal of the order of presentation of the two types of fields is associated with minimal reports of a sensed presence. We consider the critical nature of the order similar to many pharmacological phenomena. For example if lithium chloride is injected into rats 4 hrs before injections of 30 mg per kg of pilocarpine, clear limbic seizures with overt convulsions emerge within about 30 min. If the injection order of the two compounds is reversed, neither seizures nor convulsions occur [23] .

Based upon the results of the questionnaire the experiences associated with the first 30 min, when a continuous 3 ms point duration, frequency modulated (decelerating) pattern with slightly higher intensity is applied over the right hemisphere are more negative and tend to be lateralized or at least attributed to the left side of the body. If fear is to be reported it occurs during this interval. During the second 30 min, the theme of the report is usually more relaxing tranquil and peaceful. Frequently (although not always) the sensed presence is more likely to occur or is more intense during this segment. What we have learned over the last 30 years is that people who have experienced negative or untoward effects from consuming morphine also reported that exposures to these magnetic fields were unpleasant. Even in the popular literature reports of mystical experiences are not always positive. In fact about 10% of near-death experiences, the prototype for positive sensed presence phenomena, are extremely aversive [24] .

In recent years the person wears an EEG cap under the helmet which allows continuous real-time monitoring of the person's QEEG for later analyses by s-LORETA. The helmet is a modified snowmobile head piece within which four pairs of solenoids (275-0232 Radio Shack reed relays, 5 VDC, 250 ohms; nominal current 20 mA) are embedded in the sides at the level of the temporal lobes. The circuit is connected such that at any given time a solenoid on the left and right side of the helmet is activated; consequently the magnetic field is generated through the space occupied by the participant's cerebrum. The particular field pattern is rotated to each of the four pairs of solenoids every 0.5 s such that a complete cycle is completed every 2 s. Because of the orientation of the applied field, the low strengths, and the nature of EEG filtering there are no induction artifacts. They can be produced by increasing the applied field strength. When they are present, they are obvious.

The different types of experiences associated with the sensed presence have been described elsewhere [25] - [27] . Factor analyses have revealed a gender structural difference to the items that are correlated with the sensed presence. Although there are always individual signatures, the general pattern of the themes associated with our protocol are consistent when they occur. Reference to a "presence" is reported about 80% of the time. The patterns of experiences are also frequently induced when volunteers are exposed to similar patterns but generated by different equipment that was designed by the second author. They have been called the Shiva and Shakti series.

In the clinical setting the efficacy of a component of the protocol has been demonstrated and replicated. Baker-Price and her colleagues [28] [29] exposed patients who had sustained closed head injuries and were experiencing pain and depression that were refractory to anti-depressant medication. Patients were exposed to the burst-firing pattern (the second pattern in the standard protocol) for one hour once per week for 6 weeks. In both series of clinical trials the patients who were exposed to the burst-firing transcerebral magnetic fields reported significant reduction in depression that was verified by psychometric data. There was also reduction of pain that was so conspicuous that some patients requested their own devices for their personal use. Patients exposed to sham field conditions either did not report this improvement or did not complete the trials. Dropouts from clinical trials where voluntary participation is the only motivation are often indicative of failure for the desired effect to occur.

That the fields were indeed affecting nociceptive thresholds and not produced as an artifact of the procedure or placebo was indicated by comparable reductions in pain thresholds displayed by rodents [30] . Rats exposed for 30 min after a baseline nociceptive threshold measurement to the burst-firing magnetic fields displayed marked elevations of threshold (analgesia) that was comparable to a single injection of 4 mg/kg of morphine sulfate. The analgesia from the magnetic field exposure was still apparent 30 min after the termination of the field exposure when the third threshold measure was taken [31] . The effect was evident over three successive days of treatments. The physiologically-patterned induced magnetic field analgesia could also be blocked by the mu-receptor antagonist naloxone which indicated that the field was mediating its effect through the same or similar receptor-coupled chemical pathways as morphine [32] .

Martin and his colleagues [33] showed that rats that had sustained brain injuries, secondary to experimentally induced limbic seizures, responded to the positive effects of 30 min exposures per day for 3 days. The brain-injured rats also showed a permanent shift in their nociceptive thresholds. Over three successive days the baseline threshold for nociception for these rats returned to that of normal rats that had never sustained brain injuries. This type of long-term change would be consistent with the persistence of the diminished pain and depression that was reported by our patients after they were exposed to our standard treatment. Their symptoms had not been responsive to tricyclic and SSRI antidepressants. Many volunteers who have experienced a powerful sensed presence during exposure to our magnetic field protocols later reported there were persistent changes in their beliefs and world views that were still manifest years after the single 60 min exposure.

RESPONDING TO THE ANTITHESIS ARGUMENTS: THE TERMINOLOGY

There have been a significant number of online misunderstandings and misrepresentations of our research and approaches concerning “neurotheology”. Our major goal has been to develop technologies that will aid in the patient’s or client’s personal development within the domains that have often been reserved for Sentient Beings and the ultimate meaning for the sense of self and its dissolution or demise. Aaen-Stockdale’s magazine article [34] is one example of the proliferation of multiple errors. According to Aaen-Stockdale “As far as I can tell, Persinger’s theory is based on the literature on religiosity in temporal lobe epileptics; a literature that I argue … is both flawed and outdated”.

He refers to an experiment by Booth and Persinger [35] that reported the measurements of discrete shifts within the theta band of QEEG between the frontal and parietal regions of the right hemisphere and the experience of the sensed presence. This experiment did not involve temporal lobe epileptics nor did the effect require the reference to or the presence of complex partial epilepsy. The results of the experiment, that have been replicated many times, involved the sensed presence, which is an experience. It is not religiosity, which relates primarily to shifts in behavioral patterns ("personality") and beliefs. The distinctions between experiences and beliefs are important because they involve different networks of cerebral activity and imply different strategies for intervention.

The literature concerning temporal lobe epileptics and religiosity to which Aaen-Stockdale referred involved the classic studies by Dewhurst and Beard [36] , Slater and Beard [37] and Bear [38] . There have been multiple case studies where the sensed presence or the feeling of someone standing nearby was associated with a right temporal lobe anomaly such as a space-occupying lesion. In our clinical practice these cases are occasionally evident during routine EEG following neuropsychological assessments. Persinger and Tiller [39] described a woman who reported a frequent right-sided presence preceded by the sensation of "an electric shock" through either her right hand or both hands, icy coldness, and vibrations moving through her body.

The presence was considered profound and was associated with paroxysmal 4 - 5 Hz activity over the temporal lobes. In the original case [40] that initiated the first author's interest in the phenomenon almost 40 years ago a seasoned transcendental meditation instructor reported a profound presence of god that suddenly appeared beside her in the laboratory towards the end of a routine 20 min meditation. The very meaningful experience was concurrent with conspicuous spike and slow wave activity for about 10 to 20 s over the right (T4) temporal region. The fundamental themes from these types of clinical observations have been replicated by direct electrical stimulation of deep (mesiobasal) and cortical temporal lobe structures by Kubie [41] , Williams [42] , Halgren [43] , Stevens et al. [44] , Bancaud et al. [45] , Gloor [46] and Mahl et al. [47] .

These were classic studies whose relevance and validity are still clear today. In fact Picard [48] identified an activation source within the right dorsal mid-insula (where it converges with the temporal stem) during intense feelings of meaningfulness and bliss. The association is not specific to patients. Persinger and Makarec [49] completed factor analyses of responses to a questionnaire whose construct validity for temporal lobe functions [50] had been verified. They found that the feeling of a “spontaneous presence” loaded on the same factor as a history of transient episodes of enhanced verbal meaningfulness associated with “cosmic” attribution. Even with strip chart EEG profiles the correlation between increases in relative right temporal lobe theta activity, Vingiano’s hemispheric quotient, and a history of reported sensed presences [51] was apparent. As the technologies for direct measurement of behavior and brain function have become more precise, the intricate relationships between the sensed presence and its various manifestations in a person’s personality and experiences have been verified. Urgesi et al. [52] reported that modifications of neural activity in the temporoparietal area could induce changes within the “spiritual brain” that leads to self-transcendence. Within the brains of individuals diagnosed as “schizophrenics”, according to Taber et al. [53] , the process could promote misattributions and religious delusions.

The more recent MRI imaging studies have consistently confirmed the clinical observations by Dewhurst and Beard [36] that sudden religious conversions are related to alterations in the right hemispheric cerebral circuitry often found in complex partial epileptic seizures. Wuerfel et al. [54] measured an inverse relationship between religiosity and right hippocampal volumes in patients with refractory epilepsy. Significantly greater hippocampal atrophy was also reported by Owen et al. [55] in older, non-epileptic adults who had reported life-changing religious experiences. In fact Chan et al. [56] have suggested that hyperreligiosity, visual hallucinations, and cross-modal experiences may be a syndrome relatively specific to right temporal lobe atrophy. Because the process contributing to the atrophy or reduced hippocampal volume would facilitate the electrical lability of the right temporal lobe intermittent intercalation between the two hemispheres and experience of the right hemispheric equivalent (the sense of presence or Sentient Being) of the left hemispheric sense of self would occur more frequently. As predicted by our hypothesis such cerebral organizations are the central bases for these experiences spontaneously and can be simulated or evoked within the laboratory when the appropriate intracerebral electromagnetic patterns are simulated.

The primary limit of Aaen-Stockdale’s argument is he states that we have assumed that religious experiences are epileptic events. This is not correct. We have reiterated that many of the experiences reported by individuals who report intense religious experiences involving a Sensed Presence or a Sentient Being are similar to the experiences reported by individuals who have been diagnosed with complex partial epilepsy with a focus within the temporal lobe. The experiences during the specific, limited interval of the ictal display must be differentiated from the interictal behaviors that often emerge subsequent to the multiple ictal events. Like the prototype of "kindling" the gradual changes in synaptic re-organization within limbic structures (particularly the dentate gyrus) results in permanent alterations in behaviors. The latter are more associated with what Bear [38] labeled as the "temporal lobe personality". These characteristics include hyper-religiosity, a sense of the personal (of being "selected" for a purpose), widening of affect, cognitive viscosity, circumlocution of cognitive processes, and a compulsion to proselytize about the universal significance of the (religious) experience. We have found this pattern of behavior can occur following energetic conversion to either theism or atheism. Both are often associated with a tireless and often aggressive compulsion to proselytize for "the good of Humankind".

In the first author's original hypothesis [57] from 1983 the term "microseizure" was employed as a metaphor to indicate the cerebral bases for the sensed presence and that it could interact with the substrates that determine the strength of endorsement of god experiences and beliefs in different cultures. The attributes of the deities reflect the expectations of the cultural beliefs and the reinforcement histories of the individuals. That the degrees or proportions of belief in a god, the average importance of that god and religiosity are related to cerebral function has been shown by Kanazawa [58] who correlated indices of these propensities with the general level of intellectual functioning within approximately 192 nations and regions. There were strong inverse correlations between the three belief variables and intelligence. He concluded that "national IQ alone accounts for more than 70% of the variance in the mean importance of God across nations".

That does not prove that belief in religious content involves diminished intellectual level. However it does indicate that what has been considered ephemeral or beyond scientific explanation, such religiosity, can be related to a measure such as intelligence that has been shown to have strong cerebral determinants. As reviewed by Fingelkurts et al. [59] the discipline of Neuroscience can now ask if the human brain is "hardwired to produce God" or is the brain "hardwired to perceive God". There is no requirement for pejorative inferences or conclusions. More recent direct measurements by Kanai et al. [60] have shown that even cognitive styles between liberals and conservatives with respect to political attitudes are discernable by differing MRI-measurable volumes of grey matter. They found that greater liberalism was associated with increased proportions of grey matter in the anterior cingulate while conservatism was associated with increased volume of the right amygdala.

The initial concept [57] of the "microseizure" was based upon normal behavior. Perhaps a more accurate term would have been paroxysmal discharge or pattern. For example, the depth recording of the limbic system of human beings during dreaming or rapid eye movement shows transient patterns that would be considered microseizures if they occurred over the cerebral cortices during the day. Having assessed more than 1000 patients who sustained a closed head injury from concussive impacts, without loss of consciousness, over the last 35 years the first author has noted that the occurrence of transient paroxysmal activity for about 10 to 20 s over the right temporal lobe is almost always associated with a concomitant experience of a sensed presence. The person is not "epileptic". The experience and the unique EEG signature may never occur again.

Clinical neurology indicates that even when patients are diagnosed as complex partial epileptics with a focus in the temporal lobes overt anomalous displays can occur without discernable electroencephalographic patterns. This would be consistent with the seminal observation of Goldensohn [61] who implanted electrodes within the cerebrum of epileptic patients and compared the activity with those from the classical international 10 - 20 sensor array. The electrodes embedded within the cerebral cortices were separated by about 2 mm; ~4 to 6 cm usually separates surface sensors. He found that paroxysmal activity was frequently measured from the embedded electrodes while no activity was evident from surface EEG measurements. In addition he found that shared paroxysmal activity within a critical density of the 2 mm electrode arrays was required before a representation was detected by the surface indicators. Goldensohn attributed the "microseizures" to labile activity of cerebral cortical columns which in the human brain are about 0.5 to 1 millimeter in diameter. When a critical number of these cortical columns were activated the clinical indicators were then discernable.

The concept of a continuum has been central to our approach. We have employed the term "temporal lobe continuum" to refer to the range of labilities (lower thresholds or greater "sensitivities") in the activities of the temporal lobes. Based upon questionnaire studies, the normal population is distributed along this continuum. The idea is similar to that developed by Richards and his colleagues [62] for individuals who have sustained closed head injuries from primarily concussive events. They have applied the term "epileptic spectrum disorder". This continuum concept is representative of the human population. The frequency (incidence) and intensity of spontaneous sensed presences as well as the cultural-specific anthropomorphism (Sentient Beings) also exhibit what appears to be a Gaussian-like distribution. Some sub-populations may report the experience of the propinquity of spiritual entities several times per day [63] .

Direct measurements within human limbic structures have shown a clear neurodynamic bases for this continuum. Babb et al. [64] implanted (stereoencephalography) arrays of electrodes within the cerebra of epileptic patients and quantitatively assessed the proportion of coherent activity between the electrodes. During background conditions about 7% of the electrode activity was coherent. During the "altered states" or what Hughlings Jackson would have likely called "dreamy" states when the "parasitic" consciousness of "another" would have been discerned, the coherence was 14%. When the coherence achieved levels of about 36% overt symptoms, such as clinical seizures and loss of consciousness, were reflected in the surface electroencephalographic activity. The cell signaling network underlying epileptic behavior, as reviewed by Bozzi et al. [65] , involves many of the same pathways that are influenced by the specific patterns of magnetic fields by which we induce the sensed presence and produce long-term improvements in depression and reduction in pain.

RESPONDING TO THE ANTITHESIS ARGUMENTS: SPECIFIC APPLICATIONS

Anecdotal accounts are precarious arguments for either support or refutation of a concept or a hypothesis. A more reliable source of support or refutation is based upon large groups of individuals such that the major source of variance for human behavior (individual differences) can be accommodated. Aaen-Stockdale states "Atheist-in-Chief Richard Dawkins was subjected (sic) to the God Helmet as part of a 2005 BBC Horizon documentary ("God on the Brain"). Afterwards Dawkins said: "It pretty much felt as if I was in total darkness, with a helmet on my head and pleasantly relaxed". Not exactly a road to Damascus experience, but Dawkins is of course, a damned skeptic (sic) and Persinger simply argued that he wasn't temporal-lobey enough". Although the statement may have been intended to portray a pique post-hoc rationalization, ignoring the temporal lobe dynamics of a person who is being exposed to the physiologically-patterned magnetic fields would be analogous to stating that a drug has no valid effects or is simply a placebo because a subset of patients do not express the receptor subtypes required to sequester the drug in order to mediate its effects.

We were the researchers who measured Dr. Dawkins directly (rather than being dependent upon second hand accounts). Dawkins did report significant experiences that are a component of the continuum that leads to a sensed presence within the experimental setting. He reported a mild dizziness, twitching in his legs, and a twitchy feeling in his breathing. These are the first types of experiences that are the antecedents to a profound sensed presence. Dawkins reported these experiences despite the fact that was required to sit for more than an hour while being exposed to hot lights and sounds while the BBC director adjusted conditions for filming. The first author wrote in his notes during the filming that the subject (Dr. Dawkins) was becoming increasing agitated from the protracted delays and discussions. In addition the original plan for the experiment was to directly compare Dr. Dawkin's experiences with those of the Archbishop of Canterbury who decided not to participate.

We know antecedent noisy and sensory overloading conditions before the exposure to the protocol is counterproductive to producing the state that allows the interaction with the applied transcerebral magnetic fields and is associated with the report of a sensed presence. Our actual protocol involves the subject sitting within the darkened chamber shortly after completing the consent forms and beginning the experiment within about 10 min once the scalp sensors and helmet are applied. Although now we employ the QEEG cap system so that the data can be transformed into s-LORETA images to discern where in the cerebrum the frequency-specific activities were changing during the experience of the sensed presence, the initial 3-channel (Grass Model 79) monitoring was to discern the arousal level of the subject. We had learned that if the person enters light sleep (Stage II) where prefrontal spindles emerge or if the person is too activated (dominant beta activity with little posterior alpha rhythms) the optimal interaction with the applied transcerebral fields does not occur as indicated by the subjective experiences and even the discernable alterations (by the older strip chart EEG technologies) over the right temporal regions.

For every negative anecdotal experience, there is a very positive anecdotal experience. This is consistent with Hegelian process. The televised case of one of our experiments involving an undergraduate female university volunteer for an episode of Morgan Freeman's Through the Worm Hole is an example. The subject reported the classic richness of the experiences associated with the sensed presence, out of body experience and the lateralization of the visual experiences to the side of the body that was dependent upon the major source of asymmetry of the applied field. Within a week we received a telephone call from one of the pioneers of deep surgical stimulation, Dr. Vernon Mark, who indicated he was struck by the profound similarity of what his patients had reported during surgical stimulation and the report of the subject in the Worm Hole episode during the application of external, weak transcerebral weak magnetic fields.

Like the continuum of temporal lobe lability or Roberts' epileptic spectrum disorder [62] there is a range of responses to the 60 min of exposure to the transcerebral stimulation of our standard protocol. One classic example was the young diabetic woman who experienced a sensed presence. When she attempted to discern the location of it, the presence appeared to move to the other side. We have since shown that when people intend the network pattern of brain activity change and consequently the vectorial characteristics of the interaction with the applied field changes. The woman felt a profound sense of peace and tranquility. When we stopped the field application, without her knowledge, the sensed presence faded away and she began to cry. She reported she felt as if she had lost a sense of closeness with a Sentient Being.

For any discovery to be sufficiently generalized to have utility for clinical treatment or intervention, the results cannot be anecdotal. The exit questionnaire data indicated that approximately 80% of the more than 500 subjects who have been exposed over the last 30 years to the appropriately patterned magnetic fields report "yes" to the item that they experienced a sensed presence. Post-session interviews indicated how the person explained or attributed the source of the presence. They varied as a function of his or her culture and beliefs. We have been impressed by the profundity and "realness" of the induced experiences. Even though all of the subjects know they are sitting in a chamber involved with an experiment it is not unusual for the person to attribute the experience to a deceased relative, a spiritual icon, or to a mystical source. Of the approximately 40 atheists we have tested, most of them reported both a sensed presence and an out of body experience. Like Michael Shermer, the editor of Skeptic, who was exposed to our standard protocol they attribute the experiences to their brains rather than to external mystical sources or culturally religious deities.

RESPONDING TO THE ANTITHESIS ARGUMENTS: THE ISSUES OF REPLICATION, CONFOUNDING VARIABLES AND CONSTRUCT VALIDITY

Replication and the capacity for the average clinician or scientist to reproduce a phenomenon or effect is the cornerstone of Medicine and Science. Replication often reflects both the generalizability of the phenomena between places as well as the ease of reproducing the equipment that produces the phenomena. In the history of Science and Medicine there have been instances where the technology was so complicated or intricate, such as Leeuwenhoek's lens for the first microscope, that decades passed before others developed comparable technical capacities. Sometimes the idiosyncratic characteristics of the technology that created the effect may change over time inadvertently because of altered manufacturing and the phenomenon no longer appears. This has occurred many times in the chemical industry. For example after the manufacturing and synthesis techniques for coal tar derivatives such as dicyanin-A changed between the first and second World Wars, the diagnostic potentials for solutions of these compounds were no longer evident.

According to Aaen-Stockdale, "unfortunately the only published attempt failed to evoke a 'sensed presence'. Using a kit and code borrowed from Persinger himself Granqvist and his colleagues could not reproduce the effects". What is not stated objectively is that Granqvist and colleagues [66] did not reproduce the effects because they did not reproduce the procedures. As reiterated by Persinger and Koren [67] the Granqvist group borrowed a prototype of another device that was not the helmet. They had told us they required a device they could use to discern if weak magnetic fields could affect profiles from Positron Emission Tomography. In addition they employed a computer and software that distorted the patterned field. The failure to elicit the effect would be analogous to changing the molecular structure of a ligand or a specific drug and then being surprised that the modification did not produce the same effect as the original ligand or drug. When the actual scores for the exit questionnaire reported by Granqvist's experimental and control groups were compared to the groups exposed to our sham field treatments, there was no statistically significant differences. In other words different populations tested by different experimenters with almost antithetic approaches to the phenomena displayed comparable experience scores following sham-field conditions. In most clinical trials this would be considered strong evidence that the treatment was not appropriately applied or elicited.

Although innovation and modification of a technique for the local requirements of the clinician or scientist support the generalized nature of a treatment, there is still a tacit assumption that the original protocol and construction of equipment will be followed. If replications don't occur when other equipment is applied the information becomes very useful for isolating the effective components of the equipment and procedure that produced the effect. For example French et al. [68] applied the "Goldwave" auditor editor to produce a wave-file version of one of our electromagnetic patterns. He asked the subjects to discern if they could detect the field or could sense a presence. They did not. Normally this would suggest that the appropriate equipment was not applied rather than dismissing the validity of the phenomenon. The second author had also employed the Goldwave procedure during the first draft of signal production. This method was not effective. The Murphy signals for the Shakti and Shiva equipment only became effective after a proprietary method was added. The validation of their efficacy and comparable impact with the Complex Software applied through the Koren Helmet was then demonstrated by quantitative electroencephalography by Tsang et al. [69]. Actual replications employ the equipment and measurements that are consistent with a phenomenon. If a clinical trial was intended to discern the efficacy of a new anti-depressant drug, measuring the patient's height and weight may not be revealing. Yet when Gendle et al. [70] tested the second author's 8-coil Shakti system to test subjective emotional experiences they used psychometric measures that were both non-specific and peripheral to the spontaneous experiences reported by hundreds of participants that were recorded in on-line monitoring protocols for years. These types of responses by other researchers are consistent with and predicted by Hegel's approach to discovery.

Double-blind studies for human subjects are considered important when cognitive structure is a significant variable in the outcome of an effect. Double blind studies are less required for drugs like strychnine where the expectations of the person have minimal effect on the outcome. In all of our major experiments involving the experimental induction of the sensed presence [e.g., 71], the procedures were double blind despite the insistent claims by Granqvist and their proliferation by Aaen-Stockdale [34] . By double blind we mean that the person was: 1) recruited to be in a "relaxation study"; 2) told they may or may not be exposed to a magnetic field (a requirement of the guidelines for the ethical treatment of subjects since the Nuremberg and Helsinki agreements), and; 3) exposed to different patterns of fields that elicited different degrees of producing sensed presences.

The experimenters, who were usually fourth year thesis students or graduate students, may have been aware of which subjects received the field or non-field once the volunteers were secured in the acoustic chamber, but they (the experimenters) did not know what type of field was being applied or whether it was a presence-induc- ing field or a "comparator field". That was known by the first author or another graduate student who was never present during the experiments. This is a standard procedure for controlling for placebo effects during drug trials. Even though we have repeated these facts multiple times, Granqvist et al. [71] and Aaen-Stockdale [34] , as predicted by Hegel's concepts, do not incorporate the corrections into their discourse.

Although one could argue that our laboratory was known for studying the sensed presence, the fact that the subject did not know if he or she was receiving a field or what type of field was being received minimizes this confounding variable. Most of the subjects had completed a temporal lobe sensitivity and belief inventory (the Personal Philosophy Inventory or PPI) between one month and 10 months before the experiment. The long latency since the administration of the questionnaire would not have been sufficient to influence the immediate experiences during the experiment. Administration of the questionnaire was a component of the agreement with ethics board that if subjects said yes to question 113 "I have had an epileptic seizure" they would not be exposed to any of the magnetic fields.

Granqvist et al. [66] and French et al. [68] claimed they did not replicate the effects. Yet they did not manipulate the variables or attempt further replications through modifications of the parameters of their equipment. This is an established practice by in most laboratories because of idiosyncratic local factors and site-specific organizations of equipment that affect outcome. Instead both groups of researchers attributed the elicitation of the sensed presence by application of transcerebral magnetic fields to suggestibility. However neither group of researchers actually measured suggestibility. This characteristic was the first co-measurement completed in our original sensed presence studies. As reviewed by St-Pierre and her colleagues [71] we directly measured suggestibility for each individual subject by a clinical interactive scale developed by Spiegel and Spiegel [72] rather than infer this construct by secondary inferences from questionnaires as did Granqvist [66] and French [68] . Quantitative analyses indicated that when suggestibility was first covaried before the primary analyses of variance the effectiveness of specific magnetic field exposures to be associated with the report of sensed presences did not change significantly. Post hoc rationalization by enthusiastic explanations does not replace empirical and direct measurement.

It is important to emphasize the difference between primary effects and the potential role of placebo effects adding to or subtracting from a phenomenon. There is no doubt that the weak magnetic fields that elicit the sensed presence and reduce depression and relieve pain in human volunteers and patients also produce significant behavioral effects in non-human subjects which are presumably not prone to placebo responding. In addition to the powerful, duration dependent, “dose-dependent”, and pattern-specific analgesic effects demonstrated for rats [31] , planarian [73] , and inferred from the behaviours of human subjects [74] while being exposed to these magnetic fields in our laboratories, comparable changes have been reported and replicated by many other research groups. Similar changes as well as receptor and pharmacological mechanisms have been shown for decades by Alex Thomas [75] and his colleagues. A thorough review of the dozens of experiments involving these fields was published by del Seppia and her colleagues [76] . During the year 2016 a commercial headphone device will be released (Nervana) that generates magnetic fields and sounds to produce analgesia. The manufacturer’s claims are the effects are so potent that the user must accommodate at least 30 min of post exposure rest to ensure the effects have dissipated.

There have been replications of our original Koren Helmet effects by other researchers. For example, Tinoca et al. [77] , a Brazilian research team, demonstrated a partial replication of differential emotive dimensions of verbal reports [78] when their custom-constructed device was applied over the temporal lobes. More than 20 years ago the remarkable innovative researcher Dr. Chris Montoya, a prior stem cell researcher from the University of Cambridge UK, utilized a custom-constructed helmet that synchronized pulsed light with similarly patterned magnetic fields. Powerful effects, that did not require questionnaires to be discerned, were induced within a population of 100 young adults from Williams Lake British Columbia. However, 10 years after the experiments were completed his current university’s ethics committee prohibited him from publishing this research, coupled this censorship to his maintained employment, and argued that the paper’s publication could impact other grants and scholarships from the Canadian Tri-Council. As predicted by Hegel, even the occurrence of results that are consistent with a thesis can be ignored or suppressed during the phases of antithesis. A further decade later he is now currently re-attempting to have this research published.

Construct validity has been considered by many scientists the quintessential indicator of the veridicality of a hypothesis. Construct validity suggests that one is measuring what is supposed to be measured. Our basic hypothesis is that the sensed presence is the right hemispheric equivalent to the left hemispheric sense of self. The two stages of the exposure protocol were designed to first activate the right hemisphere such that when the second field, which is applied more homogenously occurs the initial activation can more easily intercalate with left hemispheric processes. As a result the person becomes transiently aware of the right hemispheric equivalent of the sense of self. This is the sensed presence. The labeling and correlative imagery is a function of cultural expectations. The details and images of the "memories" of these experiences are determined by the active and passive (primarily left prefrontal) encoding at the time of the experiences. Most of the "details of the memory" a person reconstructs through right prefrontal activations days later are dominated by the images and details of the verbal labels that were applied to the experiences rather than the evoked experiences themselves.

Recently Saroka and Persinger [79] applied s-LORETA technology to discern the level of coherence between the left and right hemispheres during the protocol. The groups that reported a sensed presence differed from those who did not. The only statistically significant interhemispheric coherence occurred between the left and right temporal lobes as predicted by the hypothesis. There was increased coherence within the 10 to 13 Hz band for those subjects who would ultimately report a sensed presence that began about 5 min after the initiation of the first field and continued for about 15 min. About five min after the initiation of the alpha coherence between sensors T3 and T4 an increase in coherence for the gamma range (30 to 40 Hz) occurred between the more caudal temporal regions at T5 and T6. s-LORETA confirmed that during the latter state there was a marked and conspicuous increase in current densities associated with gamma range power within the right prefrontal region and anterior portions of the temporal pole. These results were considered consistent with the concept that the sensed presence, when it occurs, is associated with enhanced intercalation between the left and right temporal lobes during which time the person becomes "aware" of the right hemispheric sense of self, i.e., the presence.

RESPONDING TO THE ANTITHESIS ARGUMENTS: IMPORTANCE OF MECHANISMS AND THEORY

When mesmerism was the primary means of producing analgesia for surgery before the development of modern pharmacology, the consensus was there no viable mechanism. Therefore it could not be effective. During the 19th

century James Braid witnessed the powerful effect of this procedure during a popular demonstration. Shortly thereafter he demonstrated the same phenomena to his medical colleagues. He explained this "new discovery" according to the accepted mechanisms of the day and called it another name: "hypnotism". By changing the name and offering a palatable mechanism that was consensual to the scientific peers of his day, a powerful phenomenon that had been denied since the French Academy of Science had dismissed it and its originator became legitimate.

The designation of a domain of heterogeneous phenomena with multiple and different mechanisms by a single word such as magnetism does not imply all phenomena within the domain are equal or the same. One of Edison 's researchers placed his head for a few minutes within a strong magnetic field during the early part of the 20th century and concluded there was no effect of magnetic fields upon the brain or thinking. However strong magnetic fields when appropriately applied produce significant alterations in organ states as well as their biomolecular substrates. Applied optimally they become the bases for MRI. When focused specifically the fields become the technology of Transcranial Magnetic Stimulation. Dismissing all potentially significant phenomena due to exposure to weak, physiologically-patterned magnetic fields by placing a static refrigerator magnet over the head because there was no subjective experience is analogous to asking the patient to drink dihydrous (mono) oxide and upon observing no effects concluding therefore all chemicals have no effect. The statement ignores the myriad nuances of temporal patterns that can resonate and interact with the matter that composes the brain and consequently the experiences generated by it.

The argument by Aaen-Stockdale that the weak magnetic fields cannot penetrate the skull (and hence the cerebral volume) was based upon belief rather than upon evidence. Complete penetrability of the same fields and point durations employed in the protocol through thicknesses (wood) more than twice that of the human skull was shown experimentally by Persinger and Saroka [80] . The field strengths were reduced by only about a third when sheet metal (for duct systems) was used as a simulated skull. The importance of measurement rather than speculation or "sensibility" cannot be over emphasized. Subtle energies can evoke powerful effects that are mediated from the basic units of matter to the complex organizations from which consciousness emerges. Chapellier and Matta [81] have also expressed this approach: "medium stimulation by adequate magnetic fields can modulate this phase shift in a therapeutic direction".

The recent demonstration by the punctilious experiments by Buckner and her colleagues [82] clearly demonstrated that the sensed presence fields with specific point durations of 3 ms presented for 30 min altered the T-type calcium channels in plasma membranes of cells in culture. It has been known for more than a decade that only 30 min of intractable paroxysmal activity within the limbic structure in rats can produce permanent shifts in calcium channels within hippocampal neurons from L-type to T-type [83] which encourage burst-firing and interictal behaviors. Burst-firing patterns are fundamental to many critical phenomena within brain space including long term potentiation (the major substrate to the formations of "memories"), kindling, and the synaptic reorganization that produces the interictal environment [84] that supports the changes in personality described by Bear [38] . The coupling between T-type calcium channels to potassium channels in membranes of neurons that control dopamine release [85] , the strong correlates to both addiction and subjective meaningfulness, suggests that the precise identification and synthesis of the molecular mechanisms for the ecstatic states of religious experiences and Dostoevsky-type rapture, and the physiologically-patterned magnetic field induction of these experiences [79] depend only upon the precision of the appropriate technology.

The other major argument is that only intense, Tesla-level magnetic fields can evoke changes in neuronal activity. From a faradic perspective, which is based upon mechanical induction of changes from the current produced from alterations in electric fields with respect to the resistivity of interstitial fluids, large field strengths are required to affect cell metabolism. The human cerebrum generates about 20 Joules per second (Watts) due the utilization of glucose to maintain the integrity of the cells and their processes. On the other hand the primary correlates of thinking and thought involve much less energy that has the potential to be influenced by much smaller quantities of energy [86] [87] . Metaphorically one can employ two methods to open a door. One can kick the door open with brute force. Or, one can open the door through a lock with a key. The latter requires understanding the pattern of the interaction and the match between the key and the lock. This is the same metaphor employed by the 19th century physician Paul Ehrlich to describe the precision and small quantities of energy associated with the binding of the ligand to the receptor.

The action potential, the presumed basis of experiences that are determined by the patterns of those potentials, involves about 10^{-20} J [86] . The critical mass of neurons distributed through the cerebral cortices that are associated with "awareness" of experiences or a perception has been estimated to be in the order of 10^7 [87] - [89] . Consequently if each of these neurons were generating a median 10 action potentials per second (10 Hz) the total energy would associated with "cognition" would be $\sim 10^{-12}$ J. This quantity is more than a trillion times less energy than that required to maintain the integrity of the cellular metabolism. The energy from the temporally patterned magnetic field applied within the cerebral volume of about 10^{-3} m^3 can be estimated by the product of the volume and the magnetic field strength (1 μT^2) divided by 2 μ (magnetic permeability) where μ is $4\ \pi \cdot 10^{-7}$ $N \cdot A^{-2}$. The result is 10^{-9} to 10^{-10} J which is a factor of 100 to 1000 more than required to accommodate the energy associated with the aggregate of action potentials.

The marked discrepancy between mechanically based and electromagnetic based energies is important to understand. If a 1 gm candy was dropped from a distance of 1 m onto a table the force would be in the order of a milliNewton. The energy applied through the upper veneer of the table would be in the order of microJoules. As a force the effect is negligible. However if the energy were electromagnetic and exhibited a wavelength within the visible range, it would be sufficient to produce a sensation of light in the dark-adapted eyes ($\sim 10^{-17}$ Joules) of every human being on this planet. The quality of the pattern is also critical. A person can experience the sensation of loudness by sound pressure fluctuations of only a few milliPascals. However there are no reliable accounts of people "hearing" the atmosphere whose quasi-static pressure is a billion times (101 kPa) more intense. The fact that the human cerebrum can respond to different stimuli whose quantities of application can differ by orders of magnitude reiterates the versatility of the organ. Persinger and Saroka [90] compared the proportions of experiences and intracerebral consequences from the classical studies of surgical stimulation and exposures to the protocol that generates the sensed presence. Our analyses concurred with the impression of Vernon Mark of the remarkable similarity of the experiences despite the differences of method: current induction with imbedded electrodes vs. externally applied temporally patterned magnetic fields. There were specific differences that reflected the application geometry or the population. What was more critical was the calculated numbers of neurons that would have been activated by both methods. Employing the actual values of the electrical parameters for the surgical stimulation reported by the surgeons we found that numbers of neurons that would have been influenced were the same order of magnitude as the numbers of neurons that could be affected by the energy from our applied magnetic fields.

CONCLUSION

We have both written different texts [91] [92] regarding the neuroscientific bases for the powerful subjective behaviors that have been labeled “religious”, spiritual, deities-related, or mystical experiences. These patterns of responses are predictable by the contemporary principles of brain function, particularly the properties within the right temporal lobe and the various intrinsic neuronal networks that strongly affect this region. The experimental simulation of the general class of experiences by applying weak, appropriately and physiologically-patterned magnetic fields across the temporal lobes has been replicated within and between laboratories. As predicted by Hegel’s concept of challenges to contemporary knowledge the responses to the implications of this approach and technology have been characterized by derision, superficial arguments, or failure to apply the same methods of investigative persistence that are standard in other areas of endeavor. The final stage of the Hegelian process will be the synthesis of the opposing views that is likely to involve the integration of “neurotheology” with the “Rosetta stone” that ultimately allows the translation of electromagnetic energies to more well known particulate processes that define molecular pathways.

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Erratum to "Is Alzheimer's Disease an Adaptability Disorder? What Role Does Happiness Have in Treatment, Management and Prevention" [World Journal of Neuroscience 5 (2015) 180-188]

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ABSTRACT

A case presentation indicating the importance of "happiness" in childhood causing memory block until the patent presented with probable mixed vascular and neurodegenerative memory loss at 60 years of age is presented to highlight the role of emotional factors in causing the disease. The question of whether Alzheimer's disease is an adaptability disorder

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is raised, given the patient blocked out her memory of her childhood experience. The importance of "happiness" as a treatment goal raises issues of advocacy and Guardianship as well as capacity, which is addressed by actual case reference and court action in defense of the patient's rights to have their wishes respected and observed. Functional mental capacity assessment, using the Functional Mental State Measure (FMSM) gives a greater indication of neuronal reserve than standard cognitive testing, as it helps to unravel the dilemma associated with pure cognitive assessment in Alzheimer's Disease as well as vascular dementia patients and patients who, despite retained and intact functional capacity and ability to express their wishes, i.e. "best interest", are "wrongly" placed under Guardianship. A General Systems approach, which recognizes functional interaction as optimal and withdrawal or inadequate and/or inappropriate response as not, provides further understanding of the relationship between emotional factors, memory and neurodegenerative (Alzheimer's) disease.

Keywords: Alzheimer's Disease, Vascular Dementia, "Happiness as a Goal, Cause and in Management", Functional Mental Capacity, Memory, Cognitive Development, Advocacy, Behavior, General Systems Theory

AIM

To raise the question of happiness in prevention of Alzheimer's Disease and to guide patient management.

INTRODUCTION

Since the Nun study [1] , linguistic ability (as an index of cognitive performance) at base-line has been the focus of attention in terms of development of Alzheimer's Disease though terms of happiness used is found to be associated with longevity [2] . The Scottish tracking study shows that perceived health manifests with less memory impairment and disability in old age [3] . Different factors determine functional reserve including cognitive reserve [4] or neuronal plasticity and vascular factors as well as neuronal regeneration. This indicates that functional reserve which declines with time and which defines aging [5] is determined by initial reserve capacity or brain capacity [4] , and by degradation rate over time, though an individual's decline rate may vary depending on the social stressors they encounter. These include nutritional environment, in terms of physical health and mental stimulation as brain "food", and the effects of parental nurturing and socioeconomic factors that may impact to determine physical and mental health and wellbeing, even in old age [6] .

The eco-social environment [7] is an important consideration in terms of holistic care and disease prevention. Epigenetic factors and/or familial factors may also play a part in memory development [8] [9] , as was suggested in 1982 they do in hypertension development [10] . In terms of General Systems Theory [10] cellular and behavioral responses are directed to maintain the constancy of the external milieu [10] . When escape cannot occur, the organism is forced to adapt [11] . Maladaptive responses are either inappropriate and/or inadequate. In an interactive human situation this may apply either to the giver or receiver, or to both. It may present as a behavioral or memory disorder, whereas adequate and appropriate responses to environmental changes, challenges or stressors, to which the organism, or person, with or without aid, responds results in functional interaction and happiness. This is an ideal outcome. Cellular, including genomic, epigenetic, transcriptional, metabolic sub- cellular and cellular mechanisms may be affected or be involved in a reinforcing way, either as a result of the behavioural response or in response to emotion that triggers it.

Study of epigenetic factors as a science has burgeoned since 1990. Various factors have been looked at. Emotional factors may play a part in determining reserve capacity or determine activity of neuronal mechanisms that affect memory, as stress can affect memory or concentration. Chemical drivers or immune responses may be at the core of this [12] , or, altered responses of metabolic pathways that remove unwanted memory or limit formation of "good" memory or any of the above may determine the final common pathway, which presents as a neurodegenerative process. Whether this is an adaptive phenomenon to either recall "happy" memories or to forget unhappy ones, remains to be determined.

Memory dysfunction in old age may be a mixed disease, due to vascular insufficiency or neurodegenerative effects. Common to both of these may be the effect of emotional "state" or stability. The following case report suggests that this view is an important one that needs to be considered, timing of which may also be critical to determining outcome.

Case History

JF 60 y, married, presented with profound short-term memory loss of several months duration. She expressed that she "has always had 'block-out' memory that helped her to cope with orphanage life from four and a half years of age", which she described as "horrible, frightening, bullying, belting by the nuns—they were brutal. Not all of them". "The more smacks you get the better you'll be. I was as frightened as the children being taunted". "This has all come up to me recently. I have never spoken about it to this extent, (because of) fear, very much so..."

Results

Normotensive and not diabetic. There was no obvious periodontal disease present [13] , though she did mouth breathe [14] . The Folstein Mini-Mental State test score was 21/30 in May, 24/30 on retesting in September that improved with an acetylcholinesterase inhibitor (AChEI) or anti-cholinesterase to MMSE 27/30, with loss of short-term word recall, but feeling better.

The patient's finger nails, Figure 1, shows "nail band width" widening (N estimate < 2 mm), the nail bed shows terminal recession in an irregular manner and a splinter haemorrhage is noted in the middle finger nail at the proximal edge of the nail band that suggest microvascular involvement in agreement with the micro infarcts seen on brain MRI, Figure 2. Carotid Doppler showed mild plaque. Temporal lobe atrophy, bilateral, was found on MRI, Figure 3.

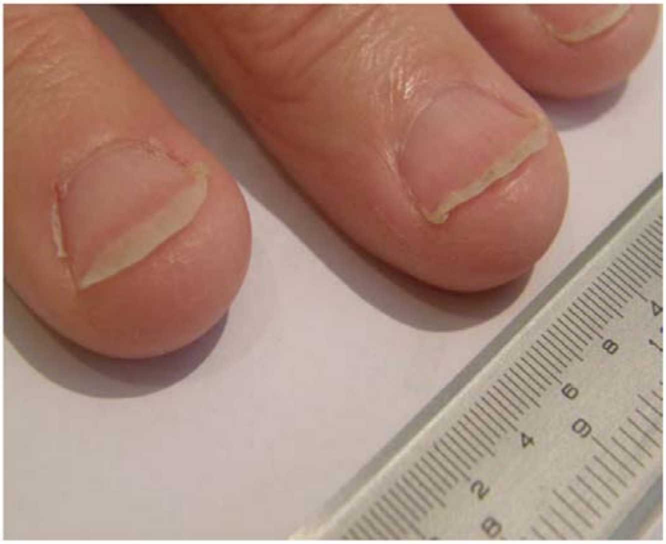

Figure 1. The patient's finger nails show nail band width is widened, the nail bed shows terminal recession in an irregular manner. A pale, receding, splinter

hemorrhage is discernible in the middle finger nail bed at the proximal edge of the nail band to the left of centre (lateral side) in line with the 4.4 ruler marking.

Figure 2. MRI showing micro-infarction in the left subcortical region.

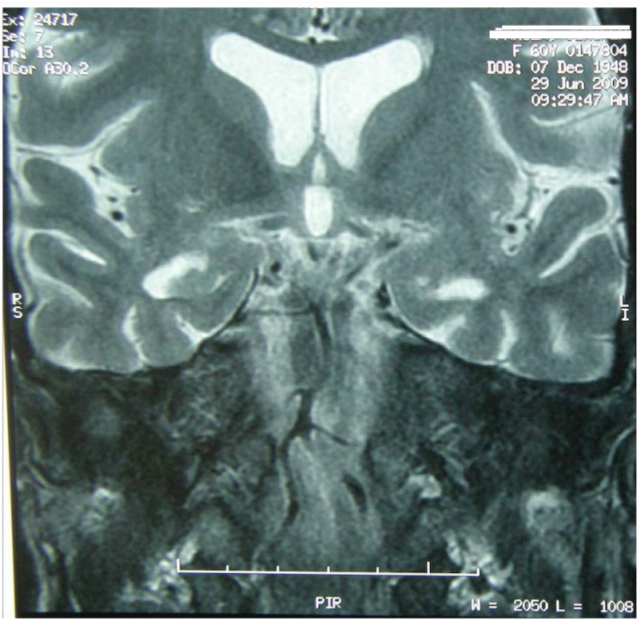

Figure 3. Temporal lobe view of the brain.

Discussion

The patient presented with loss of short term recall which she attributed to "blocking" the memories of an unhappy childhood when from the age of four she was placed in a convent where fear inducing anti-bedwetting codes was used which terrified her.

If happiness provides the best milieu for growth and development and learning, then unhappiness may impair this and lead to neurodegenerative and or dementing illness.

The adage "use it or lose it" may occur due to "emotional state" and explain the idea that depression or emotional withdrawal is also associated with cognitive impairment and memory loss while mental stimulation helps to retain it. It is also possible that memory or recall differs in older age. Fernandes showed that when objects were presented to older subjects in a meaningful or recognizable context for them to recall, their results improved and the memory differences between young and older subjects disappeared. It made no difference to recall in the younger group as to whether material presented was in abstract form or in a way that was personal, or familiar and contextual [15] . This raises questions as to the effect of meaning or whether emotional ties influence recall in older age, and whether deep seated connections influence recall in older persons that are not required in younger persons. Similarly, one needs to ask, "is Alzheimer's an adaptability disorder" [16] that impairs memory development even in the young due to "blocking" that leads to temporal lobe atrophy, amyloid deposition and tangles, by removing contextual recall as well as the event, i.e. by removing the emotional component? If so, it behoves us to look as early as childhood, and during fetal development in utero, to determine whether unhappy memories that are blocked leads to temporal lobe atrophy and short-term memory loss, a significant feature of Alzheimer's Disease and whether happy experiences do not [16].

Was Alzheimer's Disease present in this patient? The nail findings and micro-infarctions seen in the subcortical region are more indicative of a vascular picture [5] [17] . However, the response to treatment with an acetylcholinesterase inhibitor, which was tested by Mini-mental Sate examination, could have been spuriously affected and change notwithstanding medical treatment or showed a response expected of a neurodegenerative process rather than a vascular one. In addition to localized subcortical micro infarction, bilateral temporal lobe atrophy, on Brain MRI, was reported. Whichever condition predominates, the patient's report on presentation led to the question, “Is Alzheimer’s disease an adaptability disorder?” [16] . Could emotional impact and the response to it determine intellectual development, functioning and reserve and cause loss even of short-term recall in later life?

Early life effects are becoming increasingly recognized as a factor in later onset of disease [18] [19] and aging [9] . These could also determine intellectual development, functioning and reserve and cause loss, even of short-term recall, in later life, either through neuronal or vascular epigenetic developmental pathways that result in neurodegenerative or vascular insufficiency disease [8] [10] [13] .

Biological (cellular, physiological and social) stress related environmental factors are recognizable and modifiable and therefore can be used in the prevention and treatment of disease. The recent Nobel Prize in Medicine was awarded to Elizabeth Blackburn and Colleagues who in collaborative studies showed that women exposed to stress have altered telomerase activity and shorter telomeres—in other words age faster [20] , indicate that stress is an important factor in determining lifelong patterns of aging and or disease.

Wellness may therefore carry an adaptive advantage, whether this is physical, mental or emotional. Dementia syndromes focus on cognition and there is evidence that cognitive challenges may alter the course of the disease in animals experimentally placed in more environmentally stimulating conditions [21] , whereas even in humans withdrawal has adverse cognitive function effects associated with changes in brain structure [22] .

The focus of cognitive input has left the field of emotion free of challenge and purpose in terms of capacity and cause of memory loss. In this case report, the suggestion raised is that childhood memories do impact on memory, then and later, and suggests that unhappy memory results in memory block, which happened in this patient, that manifests in later adulthood with Alzheimer’s disease. No family history of Alzheimer’s disease was able to be obtained other than of siblings not known to have symptoms of disease, all of whom attended the boarding school, were also orphaned but each had different challenges and responded to their situation differently. Mrs. JF was also accosted by her holiday host to the extent that she threatened she would jump out of the window to avoid anything from happening.

Although anecdotal and unable to be scientifically proven by this case report alone, the suggestion is nevertheless an interesting one, as emotion and fond memories may be protective and ought to be encouraged. Feeling good about oneself and one’s past helps one to develop an ethical awareness as well as cognitively, producing an interaction of effects that are adaptive and beneficial and which permit more space for random access memory as well as storage of memory and memory recovery, and at a cellular level regeneration and plasticity.

Response to the same situation could also result in schizophrenic syndromes as a result of withdrawal from a seemingly insensitive and rather crass world as perceived by the sufferer, whose condition is an adaptation, by withdrawing from the world completely. Similarly depression is, in the writer's view, the result of an "egocentric" world view [23] or of comparison. Having a negative self perception leads to blaming others, from which manipulation results [23] . On the other hand, feelings of unhappiness or happiness are a reflective state that flows from actual incidents. These may have impinged on the person's rights, with feelings of having been violated, that one feels one cannot do anything about. This leads to feeling alienated and without hope, which is why faith is so important for recovery from and overcoming such challenges. Parenting skills come into this as they determine who feels assured and who does not [24] . Clearly, orphaned children and fostered children were not included in that debate [24] . These issues indicate the importance of maintaining an optimal external environment according General Systems Theory [10] , which states that inadequate or inappropriate responses lead to disorder or disease and occur, whereas appropriate and adequate response have evolutionary significance [10] [14] . These clearly relate to an individual and to behaviour [7] [10] [22] [24] [25] [28] , and to both the giver and receiver in any situation. Happiness reflects an optimal eco-social [7] [14] situation.

If happiness is a factor in later memory function, and emotional stability is conducive to memory function, prevention may be possible through ensuring greater adaptability, increased reserve capacity and by proactively removing the factors that impinge on memory function throughout growth and development and into old age, as in each period factors may increase or reduce susceptibility to or from memory loss and disease. Ensuring a person's rights and encouraging happiness, whether to live in one's own home instead of being placed are challenges modern medicine now has to regard as intrinsic to patient wellness and quality of life [25] [26] .

Emotional factors may not only play a significant role during development and prenatally [9] . Emotion may be the last facet of humanity that remains within each of us, which is why it is first to develop and lasts, to the last gasp [27] , until death do us part. Knowingly, emotional response affects how we regard people and their wishes [28] . Do we need to have cognitive function to be managed according to our wishes [22] ? Or are emotional responses sufficient reason to have regard to our wishes, that were made known when we are able to cognitively give expression to them [21] ? We respond with fear to people who show anger, but to those who are affectionate and friendly we respond with reciprocal warmth, understanding and love. Why does it not occur to us to respond to a person’s state of happiness in the same way. Is it because it does not directly affect us? It ought to. Compassion is a virtue which defines humanity. It needs to be present in us to recognize that even those who cannot voice their opinion in cognitive terms, do still appreciate to be comforted and loved, and understood in terms that they find comforting and meaningful, i.e. according to their wishes, which is the cornerstone that defines “best interest” [25] .

This issue has obvious significance for Guardianship and respect of rights of the individual under Guardianship, such as where they wish to be cared for, funds permitting that this can be arranged, if their request is to be cared for in their own home [23] [25] [26] . Asking the patient is an essential component of capacity assessment [29] -[31] and goal setting [25] [26] [32] . Using the Functional Mental State Measure (FMSM) [29] -[31] to assess mental capacity one obtains the person’s own rating performance, which is compared to a health professional’s assessment, using a simple, 1-7 rating score, based on the Functional Independence Measure (FIM) score [33] . The concordance or discordance of the scores is an indicator of capacity, which can also be an indicator of the need for treatment [29] [30] .

The advantage of a functional mental capacity assessment is that it tests what the patient can do in terms of activities of daily living and their recognition of the need for any help personally or in domestic tasks or community activities such as shopping, and by asking questions as to where they wish to live, who with them or they with whom, and whether they would like a pet, and can take their medication or call for help if required and under what circumstances, and whether they need help to carry out activities or to appoint a power of Attorney or advocate. Capacity assessment tests their belief as to what they can do or think they can do. Mental capacity is demonstrated by how accurately they assess that. It has personal relevance, which adds meaning and therefore interest to take part in the assessment. Cognitive testing, on the other hand, is abstract and measures what the person cannot do. The advantage of a functional mental capacity assessment over cognitive assessment is not recognized enough nor followed through. Cognitive assessment, including neuropsychological assessments which do not test functional capacity, but which are requested by "stakeholders", whether family members or appointed Guardians, or Tribunals and Courts [23] [25] [34] -[39] and often detect impairment are used to restrict a person's choice and Rights. The FMSM was developed to address this [25] [29] .

HAPPINESS AND ADVOCACY

Doctors must advocate for their patients' rights, even when they have capacity to choose. Legislative provision ensures that doctors who advocate to ensure their patient's rights are to be exonerated. It is therefore surprising that even though Legislative provision existed [Medical Treatment Act 1988], in Myers v Medical Practitioner's Board [VCSA 2007], it was ruled against Myers who advocated for his patient's right to go home from hospital once her condition was deemed palliative. It was her choice and for her part, her only option, to return home, with carer support, under the care of Dr. Myers, who was the only doctor she trusted, and to her husband. Given that unfortunate Court decision and the wrong it represents [22] [36] , it is not surprising that the Australian Council of Health Care [ACHC] standards, in 2013, put in place requirements that patient rights be respected or hospitals who do not would lose their accreditation [40] [41] .

This indicated an acceptance of standards that supported the view of the two senior Supreme Court judges who, on the basis that "findings of misconduct against a doctor are of some significance" granted leave to Appeal as the decisions below indicated "error and", in their view, "wrong, were the decision to stand" [36] . The ACHC standard and guidelines [40] showed that the profession [41] and public [42] accepted what the Chief Justice did not, but which the Appeal Court Judges who granted leave did [36] , as did the expert witnesses who testified before the Tribunal. They described Myers, as "a leader in the field", "his intentions are pure, whereas I (the other specialist) acted with expediency to save my own backside at the expense of the patient's happiness" and "Dr. Myers goes beyond the call of duty for his patients". The Tribunal failed to take notice and sided with the Medical Board. In hindsight, and given the ACHC standards recently proposed [40] [41] , it is clear that the Supreme Court of Appeal Judges, including the Chief Justice, M Warren, who decided the matter, also erred, though reference to the Medical Treatment Act 1988, which the Chief Justice chose to ignore, at the time, already indicated their "error and wrong" [23] [36] . Similarly, the High Court judges, Hayne J. and Crennan J., in failing to grant special leave to Appeal the remaining 10/53 allegations, all ten of which were prefaced on there being Elder Abuse, they, in my view, spawned this singular opportunity to prevent, or at least warn against committing, Elder Abuse in Australia.

As time would have it, the ACHC requirement [40] and call for inclusion to upgrade current practice [41] would show a correction was needed, and prove my view and actions, as veritable and correct, as Buchanan J. and Nettle J., in granting leave to appeal the Medical Board's, Tribunal's, Master of the Supreme Court's and Kaye, J., Supreme Court's decision, had done [36] . It was also against the Legislative provision as contained in the Medical Treatment Act 1988, the relevant Law in this case, which gives recognition to the patient's wishes and exonerates the doctor who advocates for his patient's rights to refuse treatment. Had her wish to go home, which was known to all at the time, been granted and her rights upheld, prior to the Tribunal decision that she be discharged home, as deemed palliative, it would have extended her period at home and her happiness. Keeping her there led to withdrawal, her refusal to eat, development of a leg ulcer and feelings of unhappiness. She desired familiar surroundings, proximity to her husband and his affection in their own home, where carers, she had employed to care for her, were to cook and clean, so that she and her husband could continue to live there together, as was their wish, to continue in their marriage of more than fifty years.

The President of the Medical Board, Dr. Joanna Flynn stated that "discharging the patient to a nursing home was acceptable". As it was against the patient's wish, that view cannot be upheld. It is a view that caused the patient's unhappiness and which is in conflict with the Medical Treatment Act 1988, Law and Human Rights. The Supreme Court of Appeal decision is likewise a violation of Human Rights [43] . Both decisions are at odds with the ethical practice standards that have been upgraded and reflect the advised current standards of practice that now pertain [40] . Dr. Myers' advocacy for his patients was noted by his peers and experts, to be, "beyond the call of duty", "ensuring his patient's happiness", some four-teen years before these newly recognized standards pertained, that "he is a leader in the field" who was ahead of his time. His advocacy and management is even more laudable, as it was in the face of opposition to his patient's wishes by a third party who complained to the Medical Board as she did not want her mother in law to go home, for selfish reasons. Indeed, in the preamble to the said Act, the Medical Treatment Act 1988 acknowledgement is made to the difficult circumstances doctors who advocate for their patients, may find themselves in. Persistence and endurance and the Tribunal's contemporaneous decision on the basis of the carer's testimony that the patient only trusted Dr. Myers, ensured the patient and her husband got their wish to being together in their own home, and her happiness, in achieving their wish and goal.

It is important to note that the legal/judicial system does have some components that turn for the good, as their Honours Buchanan J. and Nettle J. showed. On 01 April, 2005 (authenticated 15 April 2005), their Honors granted Myers (the applicant) leave to Appeal the Supreme Court findings [2004] VSC 532, VSCA No. 2005/7516, the Medical Board's [2003] MPBV 12 and the Victorian Civil and Administrative Tribunal [2004] VCAT 1358 (VCAT Reference No. B95/2003) decision and findings in respect of the Medical Board's findings. Even though 43 allegations had been dismissed already, in their consideration, based on the ten allegations (10/53) remaining, the case was still clearly worthy of an Appeal. They stated, "A finding of professional misconduct against a medical practitioner is one of some importance. Accordingly we think that there is a risk of substantial injustice being caused to the applicant if the decision is to stand although wrong. We are also of the opinion that there are tenable grounds available to the applicant with respect of correctness of the decision below". (A) Their Honours' succinctly worded decision was the only fair and unbiased decision, in toto, in this case, as in making it they both (i) took the patient's wishes into account (ii) noted error below and (iii) wrong were the decision to stand, and (iv) tenable argument, as their Honours' rightfully and correctly recognized that all of the ten remaining allegations were premised on Elder Abuse. Twenty nine (29) allegations were dismissed by the Medical Board and a further fourteen (14) were dismissed by the Tribunal. The barrister who acted for the Medical Board and appeared before the Medical Board admitted that the allegations resulted from their combined effort and were not only of the daughter in law's making. (v) Their Honours' joint, unanimous and objective decision, which would have ensured the patients' happiness by serving their best interest, was also in line with the relevant legislation, the Medical Treatment Act 1988 that upholds the Rights of patients and which exonerates doctors who advocate for their patients, and which acknowledges that doing so occurs in circumstances that are difficult. (vi) Their Honors' decision upheld what is now promoted as the best standard of practice. (vii) (a) Their Honor's regard to "risk of substantial injustice being caused to the applicant if the decision is to stand although wrong" requires veneration. (b) Their Honor's clarity of vision and understanding of the total fabric of Law also foresaw "the substantial injustice" that has now repeatedly occurred in every Tribunal and Court proceeding in any and all matters involving the Medical Board and Dr Myers, all of which have been prejudicial against Dr Myers and in favor of the Medical Board, admittedly, to date. (c) There has also been wider injustice by adverse publicity by a Press that denied Dr Myers the Right of reply to address the mockery of justice as described in (vii) (b). (d) Injustice is compounded within the Law by a judicial system that has regard to decisions and case law, and which quotes such decisions, to which no external quality review or objective and prospective "Evaluation of Decisions" has been applied, to determine whether the decision and findings bear witness to what has been recorded and transcribed and whether such conclusions can be drawn, and the effect of such decisions as to determine "risk" that their Honors Buchanan J. and Nettle J. were wise to and raised, which clearly needs and need to be addressed [39] . (B) In direct contrast to their Honours' awareness shown, and relevance of the Medical Treatment Act 1988, as above, the Medical Practitioner's Act 1994 (MPA), that was renamed as the Australian Health Professions Registration Act (AHPRA) 2010, on which the Medical Board based their decision and still do, as did the Courts and Tribunal, is characterised by the following: (a) The AHPRA (MPA) Act does not even take the patient's views into account, (b) has no contextual reference built into it, and therefore does not have an inbuilt ethical standard to refer to [23] , such that (c) its use opens further opportunity of abuse by (i) vexatious third parties, and (ii) by the Medical Board itself and (iii) concurring jurisdictions, namely the Tribunal and courts, including even the High Court with regard to seeking special leave to Appeal, which abrogated its essential function of acting independently of the courts below, as occurred in this case, (d) at the expense of ensuring an outcome that would ensure the patient's happiness and goals [26] , i.e. according the patient's wishes, which equates with in their "best interest" [25] [26] .

This goal and outcome can be expressed in General Systems terms, as having restored her eco-social [7] situation, in her own home, and constancy of the milieu extérieur [10] as she wanted it, in which she, together with her husband, could now thrive. Her wish, expressed to Dr Myers was that he ensure her return home, "even, if for only a day". Though that day was foreshortened to 15/24 h, by the arrangements the hospital social worker had put in place to cover the hospital's concept of "duty of care", rather than "duty to care" [26] , she achieved her goal to live in happiness in her own home with her husband and invite whomever she wanted to be there, while being cared for according to their own choice.

Documentation of Happiness, as a Goal and for the Record

Unjust and unfair are decisions in regard to appropriate management that fail to take into account contemporaneous reports of "happiness" by the patients themselves or about them by those caring for them at the time [23] . Failure to assess later complaints in that context, promotes maladjusted behavior in notifiers [23] , does not protect the public, is not in the patient's interest [42] , and does not ensure medical services of a high standard or at all [23] [42] .

Documentation of the patient's own admission of happiness as well as their own contemporaneous documentation and expressions describing their own happiness [23] [25] [26] [28] , above all, reflects correct professional standards of ethical medical practice and management [2] [25] -[29] [35] [37] [44] [45] .

Contemporaneous documentation by a professional and independent third party serves to counter claims "of unhappiness", that psychiatrically disturbed or manipulative patients may claim, either in their own personal settings, in medico-legal claims or clinical settings [23] . The required standard of assessing "happiness" must be contemporaneous. Similarly, anything that provokes levels of unhappiness is to be noted at the time. They ought to be considered as abusive if they cause unhappiness to be voiced, noted or expressed, and where those factors, despite warning, or knowingly related to a person's unhappiness, are continued [23] .

Assessment of this patient using the Functional Mental State Measurement (FMSM), as described above, [29] -[31] , indicated that she retained capacity with good concordance of her own assessment and the examiner's and assessing her answers to lifestyle questions and personal choice with her husband's knowledge of them, and they concurred. She was able to recall her "unhappiness" and to reclaim her "happiness" now.

CONCLUSION

Ensuring a person's wishes are fulfilled, which is their "best interest" [23] [25] [26] [32] [44] [45] , also referred to as social and psychological wellbeing [46] , and which ensures their happiness, and which offsets disease [2] [7] , offers new avenues of reflection and action that may prevent later development of Alzheimer's Disease. This approach may also serve as a useful standard to guide management of Elder persons, with and without Alzheimer's Disease, and who retain capacity. It may also be applied to the management of egocentric or maladjusted and or manipulative psychiatric patients. Thus, "happiness" may serve as the basis on which to formulate balanced assessments of different psycho-social situations in the patient's best interest, relevant goal setting [23] [25] [26] [28] and audits [32] . By doing so, we can understand the factors involved and that prevent and or delay mental illness and memory loss occurrence [1] -[4] [6] [9] [10] [15] [23] , and assess treatment by obtaining direct answers and responses from patients [23] [28] [29] , provided they are genuine and are not being manipulative [23] .

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CHAPTER 16

How Neuroscience Relates to Hearing Aid Amplification

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ABSTRACT

Hearing aids are used to improve sound audibility for people with hearing loss, but the ability to make use of the amplified signal, especially in the presence of competing noise, can vary across people. Here we review how neuroscientists, clinicians, and engineers are using various types of physiological information to improve the design and use of hearing aids.

INTRODUCTION

Despite advances in hearing aid signal processing over the last few decades and careful verification using recommended clinical practices, successful use of amplification continues to vary widely. This is particularly true in

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background noise, where approximately 60% of hearing aid users are satisfied with their performance in noisy environments [1]. Dissatisfaction can lead to undesirable consequences, such as discontinued hearing aid use, cognitive decline, and poor quality of life [2, 3].Many factors can contribute to aided speech understanding in noisy environments, including device centered (e.g., directional microphones, signal processing, and gain settings) and patient centered variables (e.g., age, attention, motivation, and biology). Although many contributors to hearing aid outcomes are known (e.g., audibility, age, duration of hearing loss, etc.), a large portion of the variance in outcomes remains unexplained. Even less is known about the influence interacting variables can have on performance. To help advance the field and spawn new scientific perspectives, Souza and Tremblay [4] put forth a simple framework for thinking about the possible sources in hearing aid performance variability. Their review included descriptions of emerging technology that could be used to quantify the acoustic content of the amplified signal and its relation to perception. For example, new technological advances (e.g., probe microphone recordings using real speech) were making it possible to explore the relationship between amplified speech signals, at the level of an individual's ear, and the perception of those same signals. Electrophysiological recordings of amplified signals were also being introduced as a potential tool for assessing the neural detection of amplified sound. The emphasis of the framework was on signal audibility and the ear-to-brain upstream processes associated with speech understanding. Since that time, many new directions of research have emerged, as has an appreciation of the cognitive resources involved when listening to amplified sounds. We therefore revisit this framework when highlighting some of the advances that have taken place since the original Souza and Tremblay [4] article (e.g., SNR, listening effort, and the importance of outcome measures) and emphasize the growing contribution of neuroscience (Figure 1).

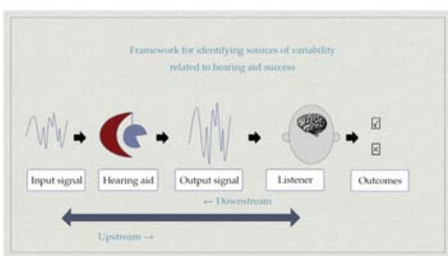


Figure 1. Framework for identifying sources of variability related to hearing aid success.

UPSTREAM, DOWNSTREAM, AND INTEGRATED STAGES

A typical example highlighting the interaction between upstream and downstream contributions to performance outcomes is that involving the cocktail party. The cocktail party effect is the phenomenon of a listener being able to attend to a particular stimulus while filtering out a variety of competing stimuli, similar to partygoer focusing on a single conversation in a noisy room [5, 6]. The ability of a particular individual to "tune into" a single voice and "tune out" all that is coming out of their hearing aid is also an example of how variables specific to the individual can also contribute to performance outcomes.

When described as a series of upstream events that could take place in someone's everyday life, the *input signal* refers to the acoustic properties of the incoming signal and/or the context in which the signal is presented. It could consist of a single or multiple talkers; it could be an auditory announcement projected overhead from a loudspeaker at the airport, or it could be a teacher giving homework instructions to children in a classroom. It has long been known that the ability to understand speech can vary in different types of listening environments because the signal-to-noise ratio (SNR) can vary from −2 dB, when in the presence of background noise outside the home, to +9 dB SNR, a level found inside urban homes [7]. Support for the idea that environmental SNR may influence a person's ability to make good use of their hearing aids comes from research showing that listeners are more dissatisfied and receive less benefit with their aids in noise than in quiet environments (e.g., [1, 8, 9]). From of a large-scale survey, two of the top three reasons for nonadoption of aids were that aids did not perform well in noise (48%) and/or that they picked up background sounds (45%; [10]). And of the people who did try aids, nearly half of them returned their aids due to lack of perceived benefit in noise or amplification of background noise. It is therefore not surprising that traditional hearing aid research has focused on hearing aid engineering in attempt to improve signal processing in challenging listening situations, so that optimal and audible signals can promote effective real-world hearing.

The next stage emphasizes the contribution ofthe *hearing aid* and how it modifies the acoustic signal (e.g., compression, gain and advanced signal processing algorithms). Examples include the study of real-world effectiveness of directional microphone and digital noise reduction features in hearing aids (e.g., [11, 12]). Amplification of background noise is one of the most significant consumer-based complaints associated with hearing aids, and directional hearing aids can improve the SNR of speech occurring in a noisy background (e.g., [13, 14]). However, these findings in the laboratory may not translate to perceived benefit in the real world. When participants were given a four-week take-home trial, omnidirectional microphones were preferred over directional microphones [15]. Over the past several decades, few advances in hearing aid technology have been shown to result in improved outcomes (e.g., [9, 16]). Thus, attempts at enhancing the quality of the signal do not guarantee improved perception. It suggests that something, in addition to signal audibility and clarity, contributes to performance variability.

What is received by the individual's auditory system is not the signal entering the hearing aid but rather a modified signal leaving the hearing aid and entering the ear canal. Therefore, quantification of the signal at the *output of the hearing aid* is an important and necessary step to understanding the biological processing of amplified sound. Although simple measures of the hearing aid output (e.g., gain for a given input level) in a coupler (i.e., simulated ear canal) have been captured for decades, current best practice guidelines highlight the importance of measuring hearing aid function in the listener's own ear canal. Individual differences in ear canal volume and resonance and how the hearing aid is coupled to an individual's ear can lead to significant differences in ear canal output levels [17]. Furthermore, as hearing aid analysis systems become more sophisticated, we are able to document the hearing aid response to more complex input signals such as speech or even speech and noise [18], which provides greater ecological validity than simple pure tone sweeps. In addition, hearing aid features can alter other acoustic properties of a speech signal. For example, several researchers have evaluated the effects of compression parameters on temporal envelope or the slow fluctuations in a speech signal [19–23], spectral contrast or consonant vowel ratio [20, 24–26], bandwidth [24], effective compression ratio [23, 24, 27], dynamic range [27], and audibility [24, 27, 28]. For example, as the number of compression channels increases, spectral differences between vowel formants decrease [26], the level of consonants compared to the level of vowels increases [29], and dynamic range decreases [27]. Similarly, as compression time constants get shorter, the temporal envelope will reduce/smear [20, 21, 23] and the effective compression ratio will increase [27]. A stronger compression ratio has been linked to greater temporal envelope changes [21, 23]. Linear amplification may also create acoustic changes, such as changes in spectral contrast if the high frequencies have much more gain than the low frequencies (e.g., [24]). The acoustic changes caused by compression processing have been linked to perceptual changes in many cases [19–22, 24, 26, 30]. In general, altering compression settings (e.g., time constants or compression ratio) modifies the acoustics of the signal and the perceptual effects can be detrimental. For this reason, an emerging area of interest is to examine how frequency compression hearing aid technology affects the neural representation and perception of sound [31].

Characteristics of the *listener* (e.g., biology) can also contribute to a person's listening experience. Starting with bottom-up processing, one approach in neuroscience has been to model the auditory-nerve discharge patterns in normal and damaged ears in response to speech sounds so that this information can be translated into new hearing aid signal processing [32, 33]. The impact of cochlear dead regions on the fitting of hearing aids is another example of how biological information can influence hearing aid fitting [34]. Further upstream, Willott [49] established how aging and peripheral hearing loss affects sound transmission, including temporal processing, at higher levels in the brain. For this reason, brainstem and cortical evoked potentials are currently being used to quantify the neural representation of sound onset, offset and even speech envelope, in children and adults wearing hearing aids, to assist clinicians with hearing aid fitting [36–39]. When evoked by different speech sounds at suprathreshold levels, patterns of cortical activity (e.g., P1-N1-P2—also called acoustic change responses (ACC)) are highly repeatable in individuals and can be used to distinguish some sounds that are different from one another [4, 37]. Despite this ability, we and others have since shown that P1-N1-P2 evoked responses do not reliably reflect hearing aid gain, even when different types of hearing aids (analog and digital) and their parameters (e.g., gain and frequency response) are manipulated [40–45]. What is more, the signal levels of phones when repeatedly presented in isolation to evoke cortical evoked potentials are not the same as hearing aid output levels when phonemes are presented in running speech context [46]. These examples are provided because they reinforce the importance of examining the output of the hearing aid. Neural activity is modulated by both endogenous and exogenous factors and, in this example, the P1-N1-P2 complex was driven by the signal-to-noise ratio (SNR) of the amplified signal. Figure 2 shows the significant effect hearing aid amplification had on SNR when Billings et al. [43] presented a 1000 Hz tone through a hearing aid. Hearing aids are not designed to process steady-state tones, but results are similar even when naturally produced speech syllables were used [37]. Acoustic waveforms, recorded in-the-canal, are shown (unaided = left;

aided=right). The output of the hearing aid, as measured at the 1000 Hz centered 1/3 octave band, was approximately equivalent at 73 and 74 dB SPL for unaided and aided conditions. Noise levels in that same 1/3 octave band, however, approximated 26 dB in the unaided condition and 54 dB SPL in the aided condition. Thus SNRs in the unaided and aided conditions, measured at the output of the hearing aid, were very different, and time-locked evoked brain activity shown in Figure 3 was influenced more by SNR than absolute signal level. Most of these SNR studies have been conducted in normal hearing listeners and thus the noise was audible, something unlikely to occur at some frequencies if a person has a hearing loss. Nevertheless, noise is always present in an amplified signal and contributors may range from amplified ambient noise to circuit noise generated by the hearing aid. It is therefore important to consider the effects of noise, among the many other modifications introduced by hearing aid processing (e.g., compression) on evoked brain activity. This is especially important because commercially available evoked potential systems are being used to estimate aided hearing sensitivity in young children [47].

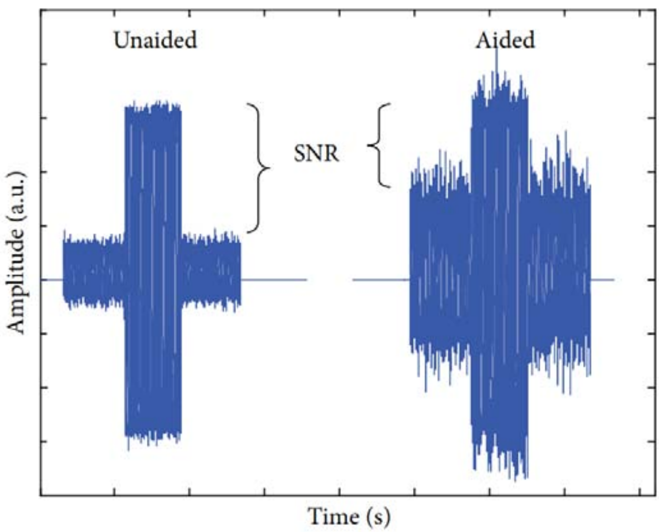
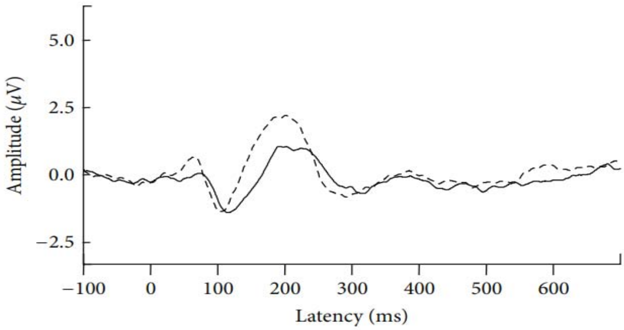


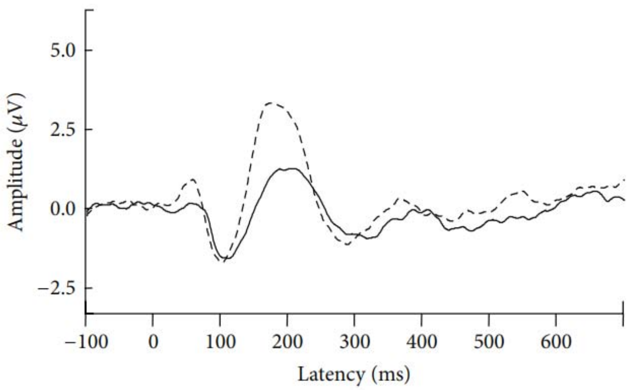
Figure 2. Time waveforms of in-the-canal acoustic recordings for one individual. The unaided (left) and aided (right) conditions are shown together. Signal output as measured at the 1000 Hz centered 1/3 octave band was approximately equivalent at 73 and 74 dB SPL for the unaided and aided conditions. However, noise levels in the same 1/3 octave band were approximately 26 and 54 dB SPL, demonstrating the significant change in SNR.



	Input signal	Gain	Output signal	Output noise	SNR
- - - Unaided	40	—	44.0	26.4	17.6
—— Aided	40	0	43.5	31.9	11.6

*Input and output values are in dB SPL

(a)



	Input signal	Gain	Output signal	Output noise	SNR
- - - Unaided	60	—	64.4	26.6	37.8
—— Aided	60	20	66.7	47.0	19.7

*Input and output values are in dB SPL

(b)

Figure 3. Two examples showing grand mean CAEPs recorded with similar mean output signal levels. Panels: (a) 40 dB input signals and (b) 60 dB input signals show unaided and aided grand mean waveforms evoked with corre-

sponding in-the-canal acoustic measures. Despite similar input and output signal levels, unaided and aided brain responses are quite different. Aided responses are smaller than unaided responses, perhaps because the SNRs are poorer in the aided condition.

What remains unclear is how neural networks process different SNRs, facilitate the suppression of unwanted competing signals (e.g., noise), and process simultaneous streams of information when people with hearing loss wear hearing aids. Individual listening abilities have been attributed to variability involving motivation, selective attention, stream segregation, and multimodal interactions, as well as many other cognitive contributions [48]. It can be mediated by the biological consequences of aging and duration of hearing loss, as well as the peripheral and central effects of peripheral pathology (for reviews see [44, 49]). Despite the obvious importance of this stage and the plethora of papers published each year on the topics of selective attention, auditory streaming, object formation, and spatial hearing, the inclusion of people with hearing loss and who wear hearing aids remains relatively slim.

Over a decade ago, a working group that included scientists from academia and industry gathered and discussed the need to include central factors when considering hearing aid use [50] and since then there has been increased awareness about including measures of cognition, listening effort, and other top-down functions when discussing rehabilitation involving hearing aid fitting [51]. However, finding universally agreed upon definitions and methods to quantify cognitive function remains a challenge. Several self-report questionnaires and other subjective measures have evolved to measure listening effort, for example, but there are also concerns that self-report measures do not always correlate with objective measures [52, 53]. For this reason, new explorations involving objective measures are underway.

There have been tremendous advances in technology that permit noninvasive objective assessments of sensory and cognitive function. With this information it might become possible to harness cognitive resources in ways that have been previously unexplored. For example, it might become possible to use brain measures to guide manufacturer designs. Knowing how the auditory system responds to gain, noise reduction, and/or compression circuitry could influence future generations of biologically motivated changes in hearing aid design. The influence of brain responses is especially important with current advances in hearing aid design featuring binaural processing, which involve algorithms making decisions based on cues received from both hearing aids. Returning to the example of listening effort, pupillometry [54], an objective measure of pupil dilation, and even skin conductance (EMG activity; [55]) are being explored as an objective method for quantifying listening effort and cognitive load. Other approaches include the use of EEG and other neuropsychological correlates of auditive processing for the purpose of setting a hearing device by detecting listening effort [56]. In fact, there already exist a number of existing patents for this purpose by hearing aid manufacturers such as Siemens, Widex, and Oticon, to name a few. These new advances in neuroscience make it clear that multidisciplinary efforts that combine neuroscience and engineering and are verified using clinical trials are innovative directions in hearing aid science. Taking this point one step further, biological codes have been used to innervate motion of artificial limbs/prostheses, and it might someday be possible to design a hearing prosthesis that includes neuromachine interface systems driven by a person's listening effort or attention [57–59]. Over the last decade, engineers and neuroscientists have worked together to translate brain-computer-interface systems from the laboratory for widespread clinical use, including hearing loss [60]. Most recently, eye gaze is being used as a means of steering directional amplification. The visually guided hearing aid (VGHA) combines an eye tracker and an acoustic beam-forming microphone array that work together to tune in the sounds your eyes are directed to while minimizing others [61]. The VGHA is a lab-based prototype whose components connect via computers and other equipment, but a goal is to turn it into a wearable device. But, once again, the successful application of future BCI/VGHA devices will likely require interdisciplinary efforts, described within our framework, given that successful use of amplification involves more than signal processing and engineering.

If a goal of hearing aid research is to enhance and empower a person's listening experience while using hearing aids, then a critical metric within this framework is the outcome measure. Quantifying a person's listening experience using a hearing aid as being positive [✓] or negative [✗] might seem straight forward, but decades of research on the topic of outcome measures show this is not the case. Research aimed at modeling and predicting hearing aid outcome [9, 62] shows that there are multiple variables that influence various hearing aid outcomes. A person's age, their expectations, and the point in time in which they are queried can all influence the outcome measure. The type of outcome measure, self-report or otherwise, can also affect results. It is for this reason that a combination of measures (e.g., objective measures of speech-understanding performance;

self-report measures of hearing aid usage; and self-report measures of hearing aid benefit and satisfaction) is used to characterize communication-related hearing aid outcome. Expanding our knowledge about the biological influences on speech understanding in noise can inspire the development of new outcome measures that are more sensitive to a listener's perception and to clinical interventions. For example, measuring participation in communication may assess a listener's use of their auditory reception on a deeper level than current outcomes asking how well speech is understood in various environments [63], which could be a promising new development in aided self-report outcomes.

PUTTING IT ALL TOGETHER

Many factors can contribute to aided speech understanding in noisy environments, including device centered (e.g., directional microphones, signal processing, and gain settings) and patient centered variables (e.g., age, attention, motivation, and biology). The framework (Figure 1) proposed by Souza and Tremblay [4] provides a context for discussing the multiple stages involved in the perception of amplified sounds. What is more, it illustrates how research aimed at exploring one variable in isolation (e.g., neural mechanisms underlying auditory streaming) falls short of understanding the many interactive stages that are involved in auditory streaming in a person who wears a hearing aid. It can be argued that it is necessary to first understand how normal hearing ear-brain systems stream, but it can also be argued that interventions based on normal hearing studies are limited in their generalizability to hearing aid users.

A person's self-report or aided performance on an outcome measure can be attributed to many different variables illustrated in Figure 1. Each variable (e.g., input signal) could vary in different ways. One listener might describe themselves as performing well [✓] when the input *signal* is a single speaker in moderate noise conditions, provided they are paying *attention* to the speaker while using a hearing aid that makes use of a *directional microphone*. This same listener might struggle [✗] if this single speaker is a lecturer in the front of a large classroom who paces back and forth across the stage and intermittently speaks into a microphone. In this example, changes in the quality and direction of a single source of input may be enough to negatively affect a person's use of sound upstream because of a reduced neural capacity to follow sounds when they change in location and in space. This framework and these examples are overly simplistic, but they are used to emphasize the complexity and multiple interactions that contribute to overall performance variability. We also argue that it is overly simplistic for clinicians and scientists to assume that explanations of performance variability rest solely one stage/variable. For this reason, interdisciplinary research that considers the contribution of neuroscience as an important stage along the continuum is encouraged.

The experiments highlighted here serve as examples to show how far, and multidisciplinary, hearing aid research has come. Since the original publication of Souza and Tremblay [4], advances have been made on the clinical front as shown through the many studies aimed at using neural detection measures to assist with hearing aid fitting. And it is through neuroengineering that that next generation of hearing prostheses will likely come.

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CHAPTER 17

Social Cognition Through the Lens of Cognitive and Clinical Neuroscience

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ABSTRACT

Social cognition refers to a set of processes, ranging from perception to decision-making, underlying the ability to decode others' intentions and behaviors to plan actions fitting with social and moral, besides individual and economic considerations. Its centrality in everyday life reflects the neural complexity of social processing and the ubiquity of social cognitive deficits in different pathological conditions. Social cognitive processes can be clustered in three domains associated with (a) perceptual processing of social information such as faces and emotional expressions (social perception), (b) grasping others' cognitive or affective states (social understanding), and (c) planning behaviors taking into consideration others', in addition to one's

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own, goals (social decision-making). We review these domains from the lens of cognitive neuroscience, i.e., in terms of the brain areas mediating the role of such processes in the ability to make sense of others' behavior and plan socially appropriate actions. The increasing evidence on the "social brain" obtained from healthy young individuals nowadays constitutes the baseline for detecting changes in social cognitive skills associated with physiological aging or pathological conditions.

In the latter case, impairments in one or more of the abovementioned domains represent a prominent concern, or even a core facet, of neurological (e.g., acquired brain injury or neurodegenerative diseases), psychiatric (e.g., schizophrenia), and developmental (e.g., autism) disorders. To pave the way for the other papers of this issue, addressing the social cognitive deficits associated with severe acquired brain injury, we will briefly discuss the available evidence on the status of social cognition in normal aging and its breakdown in neurodegenerative disorders. Although the assessment and treatment of such impairments is a relatively novel sector in neurorehabilitation, the evidence summarized here strongly suggests that the development of remediation procedures for social cognitive skills will represent a future field of translational research in clinical neuroscience.

MAKING SENSE OF OTHERS' BEHAVIOR WITH SOCIAL COGNITION

Social cognition refers to a set of neurocognitive processes underlying the individuals' ability to "*make sense of others' behavior*" as a crucial prerequisite of social interaction [1]. Such a complex ability entails a variety of skills, ranging from decoding social information (e.g., faces and emotional expressions) and drawing inferences on others' mental or affective states to making decisions consistent with social norms and others' welfare.

Social abilities emerge as early as 14 months [2], also in nonhuman species [3], and remain crucial for the lifespan [4]. Their centrality in everyday life is clearly shown by those conditions in which a social cognitive impairment results in a variety of adverse outcomes, e.g., mental [5] and physical [6] deficits, functional disability [7], unemployment [5], and more generally poor quality of life [8]. The last edition of the American Psychiatric Association's Diagnostic and Statistical Manual for Mental Disorders (DSM-5) has indeed introduced social cognition as one of the six main factors of neurocognitive functioning, impaired in different pathological conditions.

Social cognitive impairments are a prominent concern, or even a core facet, of several neurodegenerative (e.g., behavioral variant of frontotemporal dementia), neuropsychiatric (e.g., schizophrenia, major depressive disorder, and bipolar disorder), and neurodevelopmental (e.g., autism spectrum disorder and attention deficit hyperactivity disorder) conditions, and often occur after acute brain damage (e.g., traumatic brain injury and stroke) [9]. Moreover, such deficits are critical predictors of functional outcomes because they affect the ability to create and maintain interpersonal relationships, thereby removing their benefits in everyday life [7]. In this respect, the rewarding and healthy value of social interaction [10] is shown by growing evidence on the negative consequences of isolation in terms of morbidity and mortality [11–13]. Interestingly, *perceived* social isolation (i.e., loneliness) is a major risk factor for several diseases, including dementia, independent of objective social isolation [14].

In order to pave the way for other articles of this special issue on the social cognitive deficits associated with acquired brain injury, this review aims at providing an overview of the social brain and its main functions. We will pursue this goal by summarizing the main findings obtained within the research field popularly known as "social cognitive neuroscience" [15]. For explanatory purposes, the complexity of social cognition will be addressed in terms of its three main domains, i.e., social perception, social understanding, and decision-making in the social context.

Each of these subjects, representing distinct—although strictly intertwined—sectors of social neuroscience, will be first addressed in terms of cognitive processes and their modulating variables and then with regard to the available *f*MRI evidence on their neural correlates. Since the consequences of brain damage on social cognitive performance might be confounded by aging effects, in the last section we will briefly summarize the main findings of a fast-growing literature concerned with age-related changes in different facets of social cognition.

To complement the evidence on the effects of acquired brain injury presented in other articles of this issue, this section will also review few selected findings from a lively interdisciplinary research sector exploring social cognitive deficits in neurodegenerative disorders. To introduce the potential translational implications of research in social cognitive neuroscience, we conclude by discussing selected examples of social cognitive treatment protocols assessed in previous studies and the available meta-analytic evidence about their effectiveness.

THREE MAIN DOMAINS OF SOCIAL COGNITION

The ability to establish appropriate social interactions entails several distinct processes. First, the social agent must recognize the others as "living persons," via the analysis of complex perceptual information including facial expressions, gestures, postures and body language, and voice, [16]. Once integrated, this information will represent the input for higher-level processes underlying a direct resonance to others' affective states (i.e., "empathy") and/or the interpretation of their observable behaviors in terms of mental states and dispositions (i.e., "mentalizing" or "theory of mind" [17]). By modulating decision-making, the outcome of these processes will likely lead the observer to adapt her/his own social behavior [18]. This framework highlights the three key domains of social cognition which will be discussed in the next sections, i.e., social perception, social understanding, and social decision-making.

Social Perception

A basic prerequisite of social cognition is the ability to distinguish between objects (whose behavior is completely explained by physical forces) and persons (characterized by inner experiences, such as motivations, reasons, and intentions, which make their behavior not completely predictable) (Fiske and Taylor, 2013) [19].

A related question in social cognitive neuroscience is whether social stimuli represent a qualitatively different perceptual category or rather the specificity of their neural processing can be reduced to "low-level" perceptual dimensions such as vividness, salience or familiarity (Fiske & Taylor, 2013). The former hypothesis fits with the centrality of social stimuli in human life, with their different functions being expressed at various levels of complexity: survival for the single individual, communication in dyads, social coordination in groups, and, finally, culture in institutions [20]. The prototypical example, in this respect, is represented by the neural processing of human faces [21], providing multifaceted information on both others' changeable characteristics such as emotions and intentions, and invariant features such as identity. The unique salience of human faces [22] is indeed considered to reflect their predictive power with respect to others' intentions and thus their potential consequence in social terms [23]. In line with this view, different experimental paradigms suggest that faces and objects undergo different styles of cognitive processing, i.e., holistic vs. part-based coding, respectively, with parts being integrated into a whole in upright but not inverted faces [24]. This evidence for the unique status of faces fits with the existence of a dedicated neural circuitry for this category of social stimuli, additionally showing stronger responses to upright than inverted faces [25].

In particular, the eyes represent the most dynamic and informative social stimulus, capturing our attention more than head/body movements and postures [26]. Gaze direction reveals overt attention shifts, and the informative value of another's eye-movement patterns with respect to her/his mental states explains why gaze perception is considered a crucial prerequisite of mentalizing [27]. Alongside gaze, also the emotional expressions produced by the contractions of facial muscles provide crucial social information [28, 29]. In addition to the obvious communicative valence of emotions ("*A radar and rapid response system, constructing and carrying meaning across the flow of experience*" [30]), it is important to stress their adaptive value for appraising experience and preparing to act in response to external stimuli. The popular Ekman and Friesen's (2003) facial action coding scheme (FACS) describes facial expressions as combinations of the action units characterizing different emotions. This model is based on the notion of a set of six basic universal emotions (happiness, anger, sadness, fear, disgust, and surprise) which all humans can express and recognize regardless of sociocultural effects [31]. It is worth mentioning that more recently, a similar proposal has been made for specific social emotions such as shame and embarrassment (Cordaro et al., 2017). On the other hand, available evidence on the role played by cultural rules on the processing of facial expression and interpretation of emotions strengthens an "interactionist perspective" taking into consideration both biological and social/cultural factors [32].

While facial expressions represent the most effective means for emotional communication, the latter can involve also the body [33] and the voice [34]. In the first case, bodily changes are related to the role of emotions in preparing to act in response to external stimuli. If different emotions involve specific patterns of body movement and posture, this information could support emotional decoding based on visuomotor analyses of body language. Evidence based on point-light displays indeed shows high accuracy in relating such a minimal information to the emotion expressed by a moving body [35]. In addition, voices reveal our feelings as well, through nonverbal vocalizations (e.g., laugh) and prosody. However, available evidence suggests that the voice conveys mostly unspecific facets of affective states, such as physiological arousal [36], but no clear cue to specific emotions. On the other hand, the combination of different features could contribute to distinguish emotions in spoken sentences [37], and there is evidence for intersubject reliability in emotional judgments based on vocalizations [38]. Moreover, although most studies have addressed the information provided by face, body, and voice in isolation, the typical co-occurrence of multiple input channels improves emotional decoding (Martinez et al., 2015).

According to the "Feedback hypothesis", faces, voices, and bodies not only express but also influence emotional experiences, because the production of facial expressions, sounds, and postures results in related sensory feedback which in turn modulates the intensity of feelings [39]. The latter would be thus enhanced by the expression of a congruent emotion and decreased either by the inhibition of a congruent emotion or by the expression of an incongruent emotion [40]. This hypothesis suggests a tight relationship between the perceptual and "private" facets of emotional processing, which fits with recent evidence on emotion perception. Several theoretical speculations and empirical investigations on this subject revolve around the notion of "embodied simulation." That is, a mirror-like mechanism [41] is considered to provide a direct link between the first- and third-person experiences and thus access to the meaning of others' actions and emotions [42]. In this perspective, mirroring the others' facial emotional expressions, via the engagement of the corresponding motor circuits and muscular contractions (i.e., mimicry; [43, 44]), underpins a direct and experiential grasp of their meaning [45].

The notion of embodiment, however, has been also proposed to underlie even cognitive phenomena exceeding perception and action. According to the "embodied cognition" framework [46], all cognitive representations and operations would be fundamentally grounded in their physical sensory-motor context [47]. Even our semantic knowledge would be ultimately represented, at the neural level, in the sensory-motor systems underlying our direct experience with the world (Niedenthal, 2007), so that semantic representations of objects or events involve (some of) the brain sensory-motor states associated with their direct experience (Barsalou, 2008). This approach strongly departs from associative network models, considering memory as a web of semantic concepts that describe objects and events [48] in terms of basic units represented by propositions [49]. In the latter framework, any object would be represented in memory by a set of descriptive propositions, interconnected by associative links made through experience. The engagement of an emotion unit would spread activity in this interconnected web [50], thus increasing the accessibility to words and memories associated with the target emotion [51]. In the embodied cognition framework, instead, even the somehow "abstract" facets of emotional processing, such as those representing the affective value of an object brought to memory, involves reactivating the motor programs and feelings associated with its direct sensorimotor experience [52]. The latter would then provide an experiential access to the meaning of concepts, including their affective features.

Neural Correlates of Social Perception

The fast growth of social cognitive neuroscience is providing increasing evidence on the brain networks subserving the different domains previously described, and the available data nowadays allow to fractionate the social brain in distinct sets of areas associated with relatively specific functions. We will focus on the neural processing of visual stimuli, representing the richest source of information in everyday social life as well as in the available literature.

The first nodes of the neural pathways underlying the processing of visual social stimuli involve the occipitotemporal cortex, where distinct brain regions have been associated with a preliminary decomposition of the visual scene into different categories and particularly faces (Occipital Face Area (OFA) in the inferior occipital gyrus and Fusiform Face Area (FFA) in the fusiform gyrus; [53]) and bodies or body-parts (Extrastriate Body Area (EBA) in the lateral occipito-temporal cortex and Fusiform Body Area (FBA) in the fusiform gyrus [54]). The activation of these areas has been interpreted as reflecting a dedicated neural circuitry for faces ("*face-selective hypothesis*" [21]), or a greater expertise in discriminating faces compared with other kinds of stimuli ("*expertise hypothesis*" [55]). The latter hypothesis found support in the FFA activation in participants trained to identify novel artificial objects sharing some typical constraints of faces (i.e., greebles; [56]), but subsequent studies reinterpreted this evidence in terms of subjects coding these stimuli as face-related [57].

While the OFA and EBA appear to underpin the neural representation of parts of faces and bodies, respectively, the FFA and FBA seem to reflect more holistic representations of these stimuli, i.e., processing the configurations of face- and body-parts into wholes [58]. Alongside the proximity of FFA and FBA in the posterior fusiform gyrus, the latter evidence raises the possibility that their functional integration underpins the ability to identify other individuals based on cues from both faces and bodies, particularly when a single cue-type is not sufficient for recognition [54]. This proposal fits with the notion that, among distinct neural pathways originating from these areas, a “ventral” pathway, running along the temporal cortex, underpins the semantic representation of specific concepts, i.e., the *identity* of familiar or unique stimuli. In particular, the polar sectors of the temporal and medial temporal cortex seem to be associated with the processing of unique houses or persons (e.g., the White House or President Obama) [59]. Along this pathway, single-cell recordings during awake-surgery have highlighted, in the human temporal and hippocampal cortex, neurons showing invariant responses to single persons, landmarks, and object [60]. The fact that these neurons are activated by different pictures of a same stimulus and some of them even by letter strings reporting its name strongly suggests their role in coding an abstract representation of specific concepts.

Another neural pathway of social perception involves the posterior portion of the lateral temporal cortex, where a hierarchical organization includes brain areas responding to pure motion (area MT/V5 in the inferior/middle temporal cortex), the typical motion of objects (middle temporal cortex), and biological motion (posterior portion of superior temporal sulcus; pSTS) [61] (Figure 2(a)). The pSTS represents a crucial hub of the brain network of social perception, processing the changeable features of biological stimuli and particularly their action-related motion patterns [62]. Neurophysiological studies have highlighted, in this region, single neurons responding to the observation of movements performed by different biological effectors, including eye-gaze [63]. Some of these neurons respond to complex visual patterns, such as the interaction between effector and objects, or a reaching action but only if the agent’s gaze is directed to the target object [64]. Overall, the available evidence suggests that the pSTS plays a key role in the sensory binding of different features of biological motion, likely generating a superordinate representation of perceived actions [65]. Since pSTS neurons do not discharge during active movements, this region of the monkey brain does not display a “mirror-like” response. However, both neurophysiological data from the monkey [62] and neuroimaging evidence in human subjects [66, 67] suggest that the pSTS sends higher-level perceptual inputs to the frontoparietal mirror system associated with the analysis of the meaning of others’ actions (Figure 2(b)).

The pSTS is also part of another network, including the amygdala and orbitofrontal cortex (Amaral et al., 1992), associated with the processing of the affective value of observed stimuli. The amygdala is a key node of the social brain (Brothers, 1990), in which neuroimaging studies are associated with the emotional facets of social perception, such as the processing of facial expressions (Todorov et al., 2012) and judgments of trustworthiness [68]. This correlational evidence found support in lesional data showing the consequences of its damage, or abnormal functioning, on social cognitive processing [69] and real social interactions [70].

In line with the recent emphasis on the notion of "connectome" [71], diffusion imaging studies have started to address the structural connections underpinning the different facets of social cognition [72]. In the case of face processing, converging evidence shows the involvement of the inferior longitudinal fasciculus (IFL) and inferior frontooccipital fasciculus (IFOF), projecting from the occipital cortex to the anterior temporal and frontal cortex, respectively [73]. Their crucial role in connecting the nodes of the network subserving face processing is shown by studies relating distinct metrics of structural connectivity to face perception skills in normal conditions [74], physiological aging (disruption of the right IFL [75]), and in association with face blindness in developmental prosopoagnosia (disruption of both the right IFL and IFOF [76]). Preliminary evidence additionally shows the involvement of the superior longitudinal fasciculus (SLF), connecting temporal, parietal, and frontal regions [77] and particularly face-responsive portions of the STS with orbitofrontal and inferior frontal cortex ([78, 79].

Social Understanding: Representing Others' Behavior

Since others' behavior is not completely predictable, the success of social interactions depends on the ability to decode their mental and, particularly, intentional states [80]. Interpreting others' behavior in terms of mental states, such as beliefs, desires, intentions, goals, experiences, sensations, and emotions, is thus a critical step for predicting their future actions [81]. This natural disposition to mentalizing entails the development of a "Theory of Mind" (ToM) based on the awareness that people have mental states, information, and motivations that may differ from one's own (Frith and Frith, 2006) [82]. On this assumption, mentalizing performance is typically measured with tasks assessing whether an individual is able to represent mental states, attributes them to oneself vs. other persons, and then, based on such attribution, correctly understands and/or predicts others' behavior [83–85].

Far from being a unique process, mentalizing involves several components and the integration of different facets of social understanding

[86, 87]. Neuroimaging studies are providing increasing knowledge on the neural correlates of such components. A first crucial distinction regards the ability to attribute mental states vs. affective states, i.e., *cold* or *cognitive ToM* vs. *hot or affective ToM*, respectively [88]. Moreover, representing others' thoughts, desires, feelings, and traits, i.e., mentalizing, differs from grasping and automatically sharing affective states, i.e., empathy [89]. On the other hand, these constructs are partially overlapping [90], and an influential model considers cognitive ToM a prerequisite for affective ToM, which additionally requires empathic skills ([91] see Figure 1).

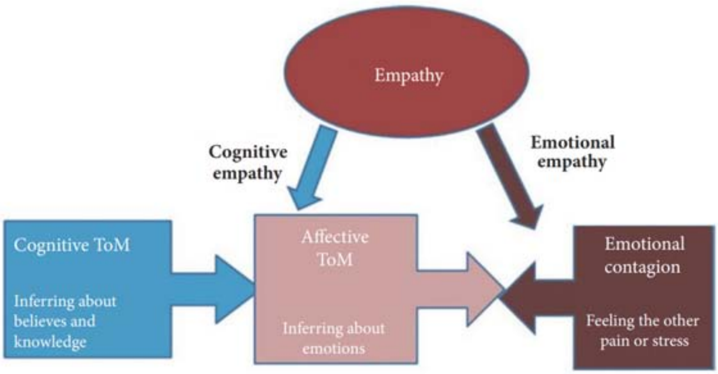
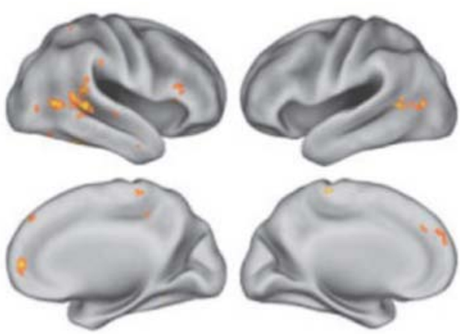
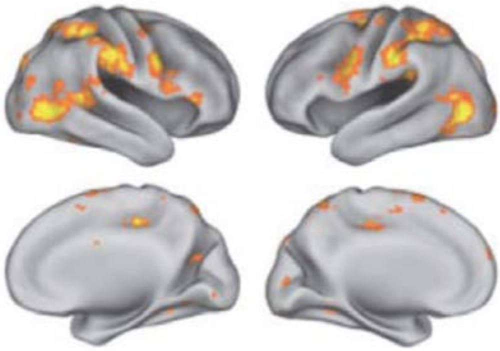


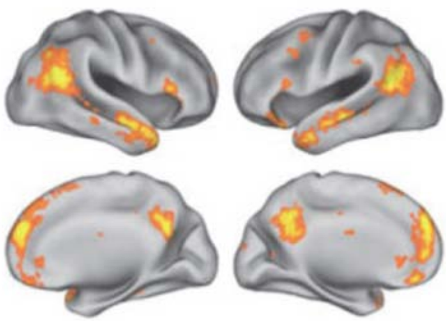
Figure 1. Empathy and mentalizing. The figure depicts Shamay-Tsoori et al.'s [91] model of the relationship between the key processes of social understanding, i.e., empathy and mentalizing. According to the model, cognitive mentalizing is a prerequisite for affective mentalizing, which however interacts with emotional empathy. Reproduced with permission from Shamay-Tsoori, Harari, Aharon-Peretz, and Levckovitz, [91].



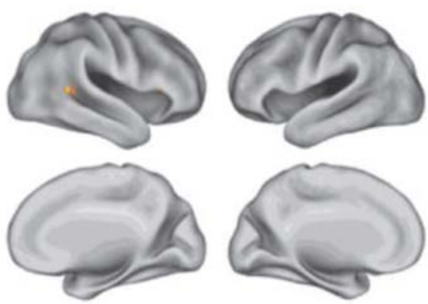
(a) Social perception



(b) Mirror system



(c) Mentalizing system



(d) Social perception and mirroring and mentalizing

Figure 2. Brain networks of social cognition. Meta-analytic evidence for the neural networks underlying social perception (a), action observation (mirror system) (b), and mentalizing (Theory of Mind system) (c). As shown in the bot-

tom sector of the figure, these three networks overlap in the STS, a crucial hub of the social brain providing inputs to both the mirror and mentalizing systems [66]. Reproduced with permission from Yang, Rosenblau, Keifer, and Pelphrey, *An Integrative Neural Model of Social Perception, Action Observation, and Theory of Mind*, Neuroscience and Biobehavioral Reviews, 51 (2015) 263–275, doi:10.1016/j.neubiorev.2015.01.020.

In addition, a dissociation has been proposed between implicit and explicit mentalizing [80]: while the former would be present even in infants, who can ascribe false beliefs to agents from nonverbal behavior [2], explicit mentalizing represents a cognitively demanding sociocultural skill acquired by verbal instructions. Considerable evidence nowadays shows that explicit mentalizing develops slowly in the childhood [87]. Finally, based on computational complexity it is common to distinguish between first and higher-order Theory of Mind processing. First-order ToM, involving the representation of another individual's mental states (inclusive of both its affective and cognitive components) [92], develops between the age of 4 and 5 [93]. Second-order ToM, i.e., mentalizing what someone else is thinking or feeling about a third person's mental states [94], typically develops at the age of 6.

Social perception and in particular emotion decoding are considered to precede mentalizing [85]. The former stage would indeed reflect low-level perceptual processes providing inputs to the higher-level integrative and inferential processes associated with mentalizing [95]. On the other hand, mentalizing can influence social perception via top-down mechanisms mediated by long-term knowledge. This bidirectional relationship represents a core element of the influential Mindreading model [96], in which social perception and mentalizing represent different components of a larger system subserving the ability to perceive and respond appropriately to others' emotions and intentions [97]. This model entails three key perceptual detectors for mental states, gaze, and affective states, alongside a shared attention mechanism supporting the ability to selectively focus on specific stimuli and integrating the outcome of detector-specific basic perceptual processes. On top of this hierarchy, an advanced mentalizing ability allows us to perceive and respond appropriately to others' emotions, beliefs, and behaviors.

The kind of processes underpinning the mentalizing ability is, however, strongly debated (Goldman and Sripada, 2005). According to so-called "Theory-theory", people act as naïve social scientists, developing psychological theories to infer others' mental states [98]. Based on the aforementioned mirroring process, "Simulation theory" rather states that we attribute mental states to others by simulating them in our own mind [45, 99]. A considerable literature, mostly based on neuroimaging data, suggests that different processes, revolving around simulative mechanisms vs. inferential routines, are recruited depending on the type of stimuli (visual vs. verbal) and instructions (implicit vs. explicit) ([66, 100] see [101]).

An alternative to both these approaches is represented by so-called "interaction theory" [102], stressing the role played by embodiment and direct perception when experiencing real social interactions (Froese and Gallagher, 2012). Based on the uniqueness of social interaction, in terms of the richness of incoming information and complexity of the responses, the advocates of this perspective aim to address social cognition from an interactor's point of view [103], also with innovative experimental designs grounded in virtual reality [104, 105], to investigate the mechanisms whereby individuals modulate their actions online [106]. This change of perspective involves shifting from "open-loop" to "closed-loop" scenarios where interactors influence one another dynamically, reciprocally, and continuously [107]. Neuroimaging studies based on this approach have shown that compared with the mere observation of social stimuli, being actively engaged in a social interaction activates a more extensive network of areas associated with perception-action coupling and affective evaluations, promoting motor responses coherent with the social stimulus [107]. These results highlight the potential implications of such an ecological approach not only for studying the neural bases of social cognition in normal individuals, but also for characterizing related disorders in pathological populations and for rehabilitation after brain damage. For example, recent evidence based on human-avatar online interactions shows that apraxics' motor impairments in a social reach-to-grasp task are abolished when patients are asked to interact with a virtual partner rather than performing actions on their own [108].

Neural Correlates of Social Understanding

Distinct research lines, within social cognitive neuroscience, have addressed the neural bases of the ability to understand others' behaviors and decode their intentions and feelings. Most of the related evidence revolves around the mirror and mentalizing brain networks which, based on inputs from the pSTS, appear to underpin distinct levels of the hierarchy of social understanding [66, 109].

The mirror system includes inferior frontal, premotor, and parietal regions which are activated both when performing an action and when observing the same action performed by someone else [41] (Figure 2(b)). This network is considered to underpin a variety of action-related social functions, from action recognition [110] and imitation learning (Vogt et al., 2007) to the context-based decoding of so-called "private goals," e.g., grasping a cup to drink vs. to clean the table (Iacoboni et al., 2005). The mirror system is anatomically and functionally distinct from the mentalizing system, which includes the medial prefrontal cortex (mPFC), temporoparietal junction (TPJ), medial precuneus/posterior cingulate cortex, and temporal poles [86, 111, 112] (Figure 2(c)). This network of areas is typically engaged when others' intentions cannot be automatically derived from visual cues and must thus be inferred in terms of thoughts and beliefs [101, 109].

Therefore, a superordinate dimension eliciting the specific recruitment of the mirror vs. mentalizing systems is represented by the aim to identify, respectively, *how* (executed movements associated with a behavioral state) vs. *why* (beliefs and intentions associated with a mental state) an action is performed [113–115]. The mirror and mentalizing systems seem thus to play complementary roles in processing others' intentions, driven by the presence of, respectively, biological actions vs. abstract information (e.g., observing real scenes vs. reading stories) or implicit vs. explicit instructions (e.g., to passive observe vs. to infer characters' intentions) [101], and by identifying *how* vs. *why* the character is expressing a feeling (i.e., explicit identification vs. attribution [114]).

While the evidence reviewed above involves the attribution of intentions and cognitive states, other research lines have addressed the neural bases of empathy, i.e., grasping others' feelings through their direct resonance in the observer's brain. This process seems to recruit a mirror-like mechanism specific for different kinds of empathic responses, involving the same brain regions associated with their first-person experience rather than the frontoparietal mirror network. This is the main finding of a series of studies which have reported the involvement of (a subset of) the same brain regions when directly experiencing, and when attending in someone else, specific affective or sensory stimulations. Such a mechanism has been described for the direct and vicarious experience of pain (anterior insula and anterior cingulate cortex, i.e., the affective sector of the so-called pain matrix [116, 117]), disgust (anterior insula [118]), tactile sensations (secondary somatosensory cortex SII [119]), and even regret for the outcomes of choices (orbitofrontal cortex and anterior cingulate cortex [120, 121]). In keeping with the notion of "mirroring," these results suggest that the observation, or even the mere awareness [116, 117], of another person in a particular emotional state may automatically activate the neural representation of the same state in the observer. Such representation includes its associated autonomic and somatic responses, neurally associated with the activation of the anterior insula and dorsal anterior cingulate cortex [122, 123], which provides support to the concept of a mirroring, sensorimotor, and nature of empathy [124]. This notion is strengthened by recent evidence on the neurophysiological correlates of facial mimicry, i.e., the unconscious and unintentional automatic response to the facial expressions of others [125]. The simultaneous recording of facial muscular reactivity (via electromyography, EMG) and brain activity (via *f*MRI) highlighted a correlation between spontaneous facial muscle reactions to facial expressions and brain activity in the frontoinsular and inferior parietal "mirror" sectors associated with their motor simulation. Overall, considerable evidence indicates that such a limbic, visceromotor, mirroring system for shared sensory and emotional experience provides the neural framework for emotional insights into other minds.

Both mirroring and mentalizing have been associated with structural connections between temporal, parietal, and frontal lobes underpinned by the superior longitudinal fasciculus [72]. The latter has been indeed associated with individual differences in abilities such as emotion recognition [126, 127], empathy [128], and imitation [129]. Other facets of embodied cognition have been ascribed to further limbic tracts, i.e., the uncinate fasciculus linking medial temporal and orbitofrontal cortex [130], involved in socioemotional processing [131], and the anterior thalamic radiation connecting the hypothalamus and limbic structures to prefrontal and anterior cingulate cortex [132], associated with affective processing and emotional regulation [133]. In keeping with their role in face processing, the inferior longitudinal fasciculus (ILF) and inferior frontooccipital fasciculus (IFOF) have been also associated with emotion recognition and empathy skills both in healthy [128, 134] and brain-lesioned [135, 136] individuals. In addition to the SLF, mentalizing seems to be supported also by the cingulum (linking medial prefrontal, posterior cingulate and medial temporal cortex [130]) and arcuate fasciculus (connecting the temporoparietal junction with prefrontal cortex [137]). Mentalizing abilities have been related to the degree of axonal injury in the left cingulum in brain-lesioned children [138] and in the arcuate fasciculus, near the temporoparietal junction, in high-functioning autistic individuals [139]. Strong evidence for this association comes also from direct electrical stimulation during neurosurgery, showing that the virtual disconnection of these tracts results in a marked decrease of mentalizing performance [140, 141].

Social Decision-Making

Understanding others' behaviors in terms of dispositions and intentions is often critical for making appropriate decisions in a variety of social contexts. Most choices are made within direct or indirect social interactions within complex and dynamic environments. They will thus depend either on the choices already made by others (if they are known) or on our prediction of the choices they will make (if concurrent with our own ones) and more generally on the awareness of their consequences for both ourselves and others [142]. From the economic standpoint, studying decisions made in different types of social context, or even within social interactions, is aimed at identifying the optimal choice among the available ones. On the other hand, psychological studies have shown several examples of preferences which seem to reflect prosocial and/or affective considerations even more than economic utilities. Researchers have thus begun to investigate the social and cognitive variables modulating social decision-making using tasks originally developed in distinct research fields within the economic sciences.

One typical example is represented by studies modeling agents' choices with the tools of Game Theory. The latter is based on rigorous models aiming to identify the optimal choice for interacting agents, in different possible situations in which they know the respective outcomes of each possible choice and they can, or cannot, make agreements before choosing. As anticipated, however, real human choices often deviate from the predictions of such models. For instance, classical Game Theory predicts that a group of rational players will make decisions to reach outcomes, known as Nash equilibria [143], from which no player can increase his/her own playoff unilaterally. Still, considerable evidence shows that people introduce psychological and prosocial considerations in their strategies, which appear to be less selfish and more fairness-oriented than predicted by economic models [144]. Typical examples of such prosocial attitude are represented by the usual response patterns observed in three tasks entailing two interacting players, popularly known as Ultimatum, Dictator, and Trust games (Fehr and Fischbacher, 2006).

In the *Ultimatum Game* [145], the proposer is asked how much of a financial endowment she/he is willing to send to an unknown responder. The latter can accept or reject the offer: in the first case, the sum is divided as proposed; in case of rejection, instead, no one receives anything. Against the economic prescription, i.e., to accept any offer as a responder and thus to offer as less as possible as a proposer [146], people usually propose "fair" offers [147] and reject unfair offers [148], although with some cultural differences [149], rejection-rates increase substantially as offers decrease in magnitude. A similar trend is found in the *Dictator game*, although the responder can only accept the proposer's offer.

In the *Trust Game*, two players receive the same initial endowment. Then, the "trustor" player decides how much of this sum to send to a trustee. Both players know that the transferred amount will be multiplied by a factor >1. The trustee must then decide whether to return some of her/his payoff to the trustor. If she/he honors trust, both players end up with a net monetary increase. If instead the trustee keeps the entire amount, the trustor ends up with a loss. In the case of a single interaction (i.e., "one-shot"), a rational and selfish trustee would not be expected to honor the first player's trust. Therefore, the latter should never trust the other player. Against this prediction, instead, in most studies the first player sends some money to the second one, with trust being typically reciprocated [150].

Both in their "one-shot" and iterated versions, these tasks typically highlight the willingness to punish, at own expenses, defectors who will never be met again [144, 151]. Considerable evidence seems indeed to show the role played, in real human interactions, by an *expectation of reciprocity*. The latter is the basis of the "tit-for-tat" strategy, i.e., trusting the partner at the first move and then replicating her/his next moves, in which both informatic simulations and psychological studies highlight as the natural strategy in social interactions (Axelrod and Hamilton, 1981). Importantly, this strategy requires the identification and punishment of defectors, even when this is not directly beneficial to the punisher. Since the simple presence vs. absence of the possibility to punish has been shown to increase vs. reduce cooperation in social interaction [151], this behavior has been called "altruistic punishment" because its costs will benefit individuals other than the punisher. While representing another puzzling behavior for economic theories, real interaction-games have shown that altruistic punishment is a key prerequisite for cooperative behavior to spread in a society [151]. There must exist, then, some incentive to behaviors which are socially advantageous, but individually expensive. A possible incentive for altruistic punishment by single individuals has been found in the strong negative emotions associated with unfairness, defection, and abuse of one's own trust, eliciting a "desire of revenge" [151]. In simpler words, anticipating the pleasure inherent in satisfying such desire would represent the incentive to punishment behaviors which, although irrational in purely economic terms for the single individual, exert prosocial consequences at the society level.

While classical economic models had largely ignored the influence of emotions on decision-making, growing evidence at the crossroad between cognitive neuroscience and economics is showing the effect of affective processing on actual choices [152]. It is now widely acknowledged that decision-making is driven by anticipated outcome-related feelings and particularly by the attempt to experience positive feelings associated with gains and prosociality and to avoid negative feelings such as disappointment for a loss, regret for a foregone outcome, or guilt for the adverse consequences of one's choices for another [153]. The neural bases of these processes constitute the subject of neuroeconomics, a lively research field at the crossroad among neural, psychological, and social sciences.

Neural Correlates of Social Decision-Making

Understanding others' affective and cognitive states and particularly intentions is often a crucial step for different facets of social decision-making. These might include anticipating others' choices in a strategic context, or planning the reaction to another's defection, e.g., an unfair proposal in the Ultimatum Game, or unreciprocated trust in the Trust Game. While the aforementioned psychological studies have highlighted actual behaviors inconsistent with "rational" economic predictions, neuroscientific data suggest that the typical human prosocial attitude might largely reflect motivational drives associated with brain regions underlying affective and hedonic evaluations. This research field is indeed grounded in the notion that the weight of affective drives, largely acknowledged in individual decision-making (e.g., [120, 121, 154, 155]), is even enhanced when making choices in a social context [156, 157].

A fast-growing literature is unveiling a mosaic of brain regions underlying the different facets of this process. First, the activation of the anterior insula in association with the receipt and rejection of unequal offers by another human subject [158] might reflect the negative affective reactions elicited by unfairness. Interestingly, accepting unfair offers reflects in increased activity of the dorsolateral prefrontal cortex, a key node of the executive network associated with cognitive control and response inhibition. The latter evidence has been initially interpreted in terms of the role played by this region in inhibiting the negative affects prompting the rejection of unfair offers [158]. However, against this hypothesis further studies have shown an increase of acceptance rate after its deactivation with transcranial magnetic stimulation (TMS) [159, 160]. The dorsolateral prefrontal cortex might thus underpin the selfish drive to accept every offer, rather than the prosocial aptitude toward altruistic punishment. On the other hand, the fact that punishing defectors reflects in the activation of the ventral striatum [161], the key node of the brain reward network (Schultz et al., 2006), suggests that altruistic punishment might be also stimulated by the rewarding experience implicit in satisfying the desire for revenge against nonreciprocators.

Due to its costs, such behavior requires to weigh economic and hedonic outcomes, a tradeoff involving the ventromedial prefrontal cortex [161]. Overall, the activation of the striatum in association with "tit-for-tat" behaviors and particularly with reciprocated cooperation [162] highlights a neurobiological interpretation of the, economically irrational, tendency to prefer prosocial behaviors over individual gratifications [163]: the subjective utility associated with mutual cooperation would represent a short-term social reward outweighing that resulting from unilateral defection (which, in contrast, might additionally reflect in negative feelings such as shame and guilt).

While these data seem to highlight a natural human disposition to prosocial behavior and sharing of resources, less optimistic evidence comes from studies investigating the neural bases of altruism and charity, i.e., costly behaviors providing benefits only to other people. On the one hand, the activation of the ventral striatal hub of the reward network [164, 165] might suggest that altruistic behavior is rewarding in itself, which could be interpreted as an evidence against the existence of "pure" altruism. Moreover, other studies have shown, in the same subjects, overlapping ventral striatal activations when deciding to donate money while knowing to be observed and when deciding to keep the money while knowing that no one was observing them [166].

These results suggest the opportunity to reframe the theoretical speculations and empirical analyses of the putative human prosocial, or even altruistic, disposition in a broader perspective merging economic, psychological and neuroscientific evidence.

AGE-RELATED CHANGES IN SOCIAL COGNITION

A growing literature on age-related changes in cognitive proficiency reveals that physiological aging entails both losses and gains of functions (Kensinger et al., 2017) [167]. Despite a global decrease of cognitive efficiency, some facets of social cognitive and affective processing remain stable or even improve with age [168], bringing potential benefits to everyday functioning [169].

Such changes involve the interaction of multiple processes, i.e., disruption of functions, resource limitations, and reallocation, as well as compensative mechanisms (Kensinger et al., 2017). In turn, these processes are modulated by a wide range of factors including, among others, individual differences in education [170], level of fluid cognition [171], and resource availability [172]. Within this complex scenario, two variables are considered to provide the strongest contribution to age-related changes in social cognition [173].

The first variable concerns the cooperation vs. competition between automatic and controlled processes. Since aging mainly impacts executive control (von Hippel and Henry 2012), a significant reduction of the ability to inhibit automatic responses can result in socially disinhibited and inappropriate behaviors [174]. The same mechanism appears to facilitate stereotypical thoughts, which are automatically activated in the presence of stereotyped group members, making older adults more inclined to show prejudices than younger adults (von Hippel and Henry 2012).

Secondly, changes in social cognition seem to depend on whether and to what extent tasks rely on novel information processing vs. accumulated experience [175]. Despite a global decrease of cognitive efficiency (in terms of speed processing, memory, complex reasoning, attention, and inhibitory control), as well as physical [176] and perceptual [177] functioning, several studies reported smaller age-related effects in domains related to past experience, including vocabulary and general knowledge [175]. This is a crucial notion, since these skills might contribute to specific facets of social cognitive and affective processing and thus partially compensate the overall cognitive decline.

For instance, although older adults perform worse than young adults on memory recall tasks, even when presented with social and affective stimuli [178], they show equally, or even more, effective emotion regulation skills [171]. While the latter evidence may appear at odds with an executive decline, emotion regulation may require less resources in older than young adults due to the improved procedural knowledge accumulated throughout life [168]. In addition, older adults may allocate a greater proportion of resources to emotion regulation compared to younger adults [179], due both to the possible prioritization of arousing and to self-relevant information (Kensinger et al., 2017), and to age-related motivational changes toward the maximization of the emotional satisfaction in the "here and now" [168].

Overall, these findings highlight the complexity of age-related changes in social cognition, which are deeply intertwined with both the physiological decrease of cognitive functioning and the shifts in life goals. We will briefly review the available evidence on the changes reported in the three domains of social cognition previously described.

Age-Related Changes in Social Perception

Faces represent a crucial source of social signals, and emotion recognition from facial expressions is a critical prerequisite for appropriate interpersonal communication and social functioning [180] (von Hippel and Henry, 2012).

While aging is associated with significantly decreased performance in recognizing negative emotions such as fear, sadness, and anger [180], older adults perform better than younger ones in the case of positive emotions (i.e., happiness and surprise) and disgust. This evidence has been ascribed to the *top-bottom bias*, indicating age-related changes in face-processing strategies: older, compared with younger, adults are more likely to focus on the bottom half of the face (mouth or nose), which provides information concerning the muscular contractions specifically associated with happiness and disgust [181], rather than on the eyes [182]. This pattern might reflect functional and/or structural age-related changes within the face-processing brain network—including the STS, medial PFC and amygdala—associated with eye-gaze perception and decoding [167].

On the other hand, the decline in recognizing negative emotions from faces might be also attributed to the "*age-related positivity effect"* [183], indicating the older adults' tendency to focus more on positive than negative stimuli compared with younger adults. This effect, consistently described also in attention ad memory domains [184], has been linked to age-related changes in emotion regulation mechanisms, helping elders to preserve a better mood [185]. These changes might reflect the fact that, in the elderly, only negative stimuli are associated with the activation of the medial prefrontal cortex (PFC), possibly supporting top-down emotion regulation processes aimed to inhibit negative emotions [186].

Age-Related Changes in Social Understanding

The preservation of functions underlying social understanding, such as emotional sharing and the attribution of cognitive or affective states to others, predicts successful outcomes in aging [187]. In the attempt to disentangle specific changes in the different facets of social understanding, several studies have shown a prominent age-related decline in its *cognitive* components (i.e., mentalizing and social metacognition), with a relative conservation, or even an enhancement, of the *affective* ones (i.e., empathy and compassion) [167, 173, 188]. Also in this case, the former evidence may reflect an overall decline in executive control and fluid intelligence [189], associated with reduced activity of the dorsolateral PFC [167]. Additionally, older adults seem to shift their motivations: according to the *socioemotional selectivity theory* they disengage their focus from future-oriented goals and prioritize social and emotional meaningful activities by selectively allocating more resources on emotional processing and emotion regulation strategies [190]. This view is supported by a study reporting age-related neurostructural changes in 883 healthy individuals. While cortical thickness decreased with age in brain regions related to executive functioning, such as the dorsal ACC alongside the superior and lateral sectors of the PFC, no age affect was found in regions typically engaged in emotion regulation, such as the ventromedial PFC and ventral ACC [191].

Age-Related Changes in Social Decision-Making

Alongside an enhancement of affective processing skills, different facets of social behavior and decision-making, like generativity and prosociality, undergo substantial changes with age.

Generativity, i.e., the tendency to expand the individual focus of concern beyond oneself [192], becomes a prominent challenge in late life, prompting the desire of cooperation between generations and the need for older adults to offer emotional support and mediate conflicts, which are perceived as essential goals for survival (Gurven and Kaplan, 2009). Compared with young people, older adults endorse more generative goals and other-focused problem solving [193]. Moreover, both the feeling of pity and the willingness to help others seem to progressively increase with age [194].

Closely related to social affective skills, also the tendency to prosociality seems to increase in late life [195]. In line with the *socioemotional selectivity theory*, contexts relevant to social and affective goals might motivate older adults, even more than younger ones, to help others, since empathy and/

or compassion represent powerful skills capable of promoting prosocial behaviors [195]. This is the core of "empathic concern" [196], whereby acting to benefit needy others can mitigate the negative emotional arousal induced by experiencing their needs. The enhancement of emotion regulation skills might thus mediate the higher prosociality displayed by older adults, ultimately increasing their well-being, satisfaction and emotional fulfillment [193].

ALTERED SOCIAL COGNITION IN NEURODEGENERATIVE DISEASES

Increasing evidence highlights a variety of social cognitive impairments in different neurological (e.g., neurodegenerative diseases, traumatic brain injuries, and brain tumors) and psychiatric (e.g., mood disorders, autism, and schizophrenia) conditions [197–200]. These alterations are mainly associated with the functional consequences of neuropathological processes or brain lesions affecting regions and networks underlying social cognition skills.

Within the realm of neurodegenerative diseases, pathological changes in social cognition and behavior are a major hallmark of the frontotemporal dementia (FTD) disease spectrum, including the primary progressive aphasias (i.e., semantic, nonfluent, and logopenic variants) [201] and the behavioral variant (bvFTD) [202]. Due to the progressive degeneration of frontobasal and limbic networks associated with the processing of emotional and social cues [203–207], bvFTD represents a prototypical example of the breakdown of social cognition. A marked neurocognitive impairment has been reported, in this disease, in all the domains previously discussed, from emotion recognition and social understanding to judgment involving social dilemmas and violations (Elamin et al., 2013). Despite similar deficits in emotion recognition and social understanding [208, 209], bvFTD and both the semantic and the nonfluent FTD variants have been associated with different patterns of structural damage within a frontoinsular-temporal network which is also known as "social context network" [210]. This model is based on the notion that different social cognitive processes are encapsulated into specific context circumstances, having an intrinsic social meaning. Specific patterns of social cognitive impairment, typical of neurological and psychiatric diseases, might thus arise from selective dysfunctions within a distributed network causing a global impairment in the processing of social context information. This network is considered to include three main hubs with specific functions, i.e., (1) frontal areas, supporting the updating of context cues to make predictions; (2) temporal cortex, underlying the consolidation of value-based learning of contextual associations; (3) insular cortex, managing the convergence between emotional and cognitive states related to the coordination between external and internal milieus and thus facilitating frontotemporal interactions in processing social contexts.

Further cues into the abnormal social brain come from the literature revolving around the FTD-Amyotrophic Lateral Sclerosis (ALS) continuum hypothesis [211]. The growing evidence on the neuropathological, genetic, neuroimaging, and clinical commonalities between the two conditions [212–217] now includes social cognitive deficits, which have been revealed also in ALS patient without dementia [218].Social cognitive impairments have been described also in other neurodegenerative disorders. Although these symptoms are not considered central or typical expressions of these diseases, the impairment can involve one or more of the domains reviewed before. As discussed in the next paragraphs, social perception and social understanding are, to date, the most frequently investigated domains in neurodegenerative disorders.

Altered Social Perception in Neurodegenerative Diseases

With respect to social perception, evidence exists for abnormal visual and/or auditory (i.e., based on prosodic cues) recognition of basic emotions, especially involving negative emotions, in bvFTD [219–222]. Interestingly, emotion recognition from faces discriminates bvFTD from other neurodegenerative, as well as psychiatric, diseases [207]. However, abnormal affective processing and emotion recognition (particularly for negative emotions) have been found also in other disorders (Elamin et al., 2013) [223], such as ALS [126, 224], Parkinson's disease [225], corticobasal syndrome and progressive supranuclear palsy [226], and Huntington's disease [223, 227], as well as Alzheimer's disease (AD) and mild cognitive impairment, particularly when subtle or static emotional stimuli are presented [8, 228].

Altered Social Understanding in Neurodegenerative Diseases

The studies addressing social understanding in neurodegenerative diseases are contributing to unveil a complex scenario, with different disorders reflecting in distinct patterns of functional impairment. Defective mentalizing skills have been reported in bvFTD and AD [229]. However, while in AD this deficit likely reflects a global cognitive breakdown, bvFTD patients display a relatively selective impairment in affective mentalizing [229], likely reflecting their marked difficulties with empathic abilities [230]. In line with the continuum hypothesis, this pattern has been also described in a subset of ASL patients displaying a prominent impairment in the processing of emotional cues (Cerami et al., 2013) [127]. In Parkinson's disease, early mentalizing deficits are accompanied by decreased empathic skills in the later disease stages, reflecting the progression of the pathology from the dorsolateral prefrontal to orbitofrontal circuits (Elamin et al., 2013). In Huntington's disease, the impairment of both cognitive and affective components of social understanding is often associated with the severity of executive decline and motor symptoms [223].

Altered Social Decision-Making in Neurodegenerative Diseases

Abnormal performance in tasks assessing individual decision-making has been described in different neurodegenerative diseases, such as FTD, AD, Parkinson's disease, and Huntington disease (see [231] for a review). Instead, the evidence on social decision-making in neurodegenerative diseases is still limited and mainly related to bvFTD and AD [223]. In particular, bvFTD patients display a significant reduction in the tendency to prosociality [232] and cooperative behavior [233] (O'Callagan et al., 2015). In line with the "social context network" model described above [210], such changes might reflect the damage in frontostriatal areas supporting the generation and update of predictions based on social contextual information.

CONCLUSIONS

The data reviewed here summarize the main results of social cognitive neuroscience in the attempt to unveil the brain networks underlying the humans' automatic disposition to make sense of others' behavior. While most of the initial efforts within this lively research field dealt with the "social brain" in healthy individuals, its most recent developments are concerned with identifying the changes associated with physiological aging or different pathological conditions. A growing literature shows that the multilevel approach of social cognitive neuroscience, connecting seemingly distinct drivers of human behavior such as hormones or prosocial motivations [234], constitutes a platform providing experimental paradigms for targeting specific social cognitive processes, as well as objective metrics for assessing their impairment, or the effectiveness of remediation procedures, in different neuropsychiatric diseases [7].The advancements in parcellating social cognitive processes and their neural bases nowadays allow design interventions based on robust evidence at the level of the construct of interest (e.g., face processing), or of deeper neurobiological mechanisms such as the modulation of amygdala activity by oxytocin (Ebert and Brune, 2017). The complexity of social cognition and its multifaceted nature indeed reflect in the variety of different remediation procedures which have been already proposed to improve social skills and to assess their impact beyond the trained process. Different approaches aim to improve either basic cognitive skills, to increase relational competence via training strategies underlying the analysis of social context and emotional information (i.e., “wide interventions; Peyroux and Frank, 2014), or specific components of social cognition such as emotion recognition [235], mentalizing [236], or empathy (Klimecki et al., 2013) (i.e., “targeted interventions”), particularly in schizophrenia [237] and autism [238, 239]. Meta-analytic results highlight moderate training effects on emotion recognition and mentalizing, with such improvements being transferred to daily social life [240], but also limited success in remediating more complex, higher-order social cognitive functions [241]. Possible explanations for this negative evidence might include the lack of consideration of basic cognitive impairments and of real-world social situations characterized by a basic property of social cognition such as the mutual interdependence between agents. As previously discussed, the potential implications of novels paradigms entailing real or virtual social interactions represent one of the most promising challenges for social neuroscience [106], already supported by positive outcomes in neurological patients [108].More generally, the available evidence suggests that the effectiveness of social cognitive remediation depends on “baseline” skills and that successful programs require adapting management strategies based on individual profiles. A detailed description of social cognitive processes and their neural correlates is thus critical to tailor remediation protocols to target specific brain networks and their associated cognitive functions. By summarizing the extensive available evidence on the neural bases of social cognition, the present review highlights specific domains which should be evaluated in pathological populations, taken into consideration when designing novel tests [242, 243] or rehabilitation procedures [244], and addressed in original studies. As in all areas of empirical research, the quality of the answers depends on the quality of the questions. This is one of the main reasons why the increasing interaction among social and clinical as well as basic and translational research areas represents one of the most exciting developments within cognitive neuroscience.

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Index

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Neuroscience and Computational Intelligence

Neuroscience allows us to better understand how the brain works. This science also provides answers to many important, but also fun questions: do we really use only ten percent of the brain, are brain exercises useful, can we mentally move parts of other people's bodies? Neuroscientists are researching the brain. They rely on knowledge from areas such as biology, physics or electronics. Neuroscience is on the border between brain and mind research. Brain analysis and study is of great importance for understanding and comprehending the ways in which we perceive and perform interactions with the environment and, in particular, in which all ways human experience and human biology are mutually conditioned. It can be said that this is a young science, because it gained momentum only after the Second World War. Some of the devices designed for war purposes were later used in neuroscience. Three hundred years ago, it was assumed that there were some impulses in the brain, but there was no way to measure them. Neuroscience does not deal with psychology; rather, the brain is of interest to researchers from the standpoint of electrophysiology. Neuroscience is a broad field that deals with the scientific study of the nervous system, including structure, functions, history of evolution, development, genetics, biochemistry, physiology, pharmacology, and pathology of the nervous system. It has traditionally been classified in biology. Recent intersections of interests in many scientific fields and disciplines, including cognitive and neuropsychology, computing, statistics, physics and medicine, have led to the expansion of neuroscience tasks, and today include any scientific and systematic, experimental and theoretical research on the central and peripheral nervous systems of biological organisms. The methodologies used by neuroscientists include analysis of biochemical processes and genetic analysis of the dynamics of individual nerve cells and their molecular components, to the visual representation of perceptual and motor processes in the brain. This edition covers different topics from neuroscience and computational intelligence, including semantic and concept modeling, general neuroscience topics, reasoning and knowledge modeling, and topics from clinical neuroscience.

Section 1 focuses on semantic and concept modeling, describing automatic concept extraction in semantic summarization process, a further analysis of taxonomic links in conceptual modelling, a general knowledge representation model of concepts, intelligent information access based on logical semantic binding method, and automatic concept extraction in semantic summarization process.

Section 2 focuses on general neuroscience topics, describing the philosophy and neuroscience movement, the creativity as central to critical reasoning and the facilitative role of moral education, the information infrastructure for cooperative research in neuroscience, and computational intelligence and neuroscience in neurorobotics.

Section 3 focuses on reasoning and knowledge modeling, describing knowledge representation in a proof checker for logic programs, episodic reasoning for vision-based human action recognition, a knowledge representation formalism for semantic business process management, and gaining knowledge from imperfect data.

Section 4 focuses on clinical neuroscience, describing neuroscience and unconscious processes, validating new technologies to treat depression, pain and the feeling of sentient beings, Alzheimer's disease as an adaptability disorder and what role does happiness have in treatment, management and prevention, as well as how neuroscience relates to hearing aid amplification and social cognition through the lens of cognitive and clinical neuroscience.

Jovan obtained his PhD in Computer Science from RMIT University in Melbourne, Australia in 2007. His research interests include big data, business intelligence and predictive analytics, data and information science, information retrieval, XML, web services and service-oriented architectures, and relational and NoSQL database systems. He has published over 30 journal and conference papers and he also serves as a journal and conference reviewer. He is currently working as a Dean and Associate Professor at European University in Skopje, Macedonia.

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