From Philosophy and Mental-Models to Semantic Desktop research: Theoretical Overview

Danish Nadeem
(Institute of Cognitive Science, University Of Osnabrück, Germany
dnadeem@uos.de)

Leo Sauermann
(Knowledge Management Lab, DFKI GmbH, Kaiserslautern, Germany
sauermann@dfki.uni-kl.de)

Abstract: This paper examines issues on Philosophy of Artificial Intelligence (AI), Cognitive Science and Mental Models. The paper provides a philosophical grounding for the researchers in Personal Information Management (PIM). An overview is given on various philosophical aspects of computer-based activities. Discussions on the theories relevant to understand the goals for the Semantic Desktop community are elicited. Philosophical theories are not immediately transparent to the programmers, but the ideas discussed here are intended to emphasize a theoretical foundation, with respect to Semantic Desktop long term goals. The goal of this paper is to examine the theories of Philosophy and to provide a conceptual idea to design user-intuitive Semantic Desktops. The paper tries to induce scientific curiosity among the Semantic Desktop researchers as well as to develop the future Semantic Desktops to realize *Weak AI*.

Key Words: mental model, knowledge management, semantic desktop
Category: H, H.1.0, H.1.2, H.5.0

1 The Semantic Desktop idea

In [Sauermann et al.2005] Sauermann gives the possible definition of a Semantic Desktop:

> *A Semantic Desktop*[1] *is a device in which an individual stores all her digital information like documents, multimedia and messages. These are interpreted as Semantic Web resources, each is identified by a Uniform Resource Identifier (URI) and all data is accessible and queryable as RDF graph. Resources from the web can be stored and authored content can be shared with others. Ontologies allow the user to express personal Mental Models and form the semantic glue interconnecting information and systems. Applications respect this store, read and communicate via ontologies and Semantic Web protocols. The Semantic Desktop is an enlarged supplement to the user's memory.*

[1] http://semanticdesktop.org

Semantic Desktop is a research approach to provide Personal Information Management [Boardman2004] to the user in an elegant way. It is a challenging issue for Semantic Desktop community to develop a computer application that recognizes the Mental Model of its user and maps Mental Model to the desktop - integrating (or substituting) all other applications [Heim2006]. The theories of AI and Cognitive Science should provide an insight to tackle this challenge and provide a theoretical understanding of design methods to be adopted to develop a user-oriented Semantic Desktop framework. There have been several prototypes that aim towards the goal of Semantic Desktop such as Gnowsis [Sauermann et al.2005], Haystack [D.Quan et al.2003], IRIS [Adam Cheyer2005]. The goal of this paper is to elicit holistic view of Semantic Desktop research from philosophical point of view. The philosophical theories are significant to any applied research towards Artificial Intelligence (AI). Research in Semantic Desktop is a novel attempt to address the issues of AI. Thus, the following section mainly discusses philosophy and theories of Cognitive Science to induce scientific curiosity among the Semantic Desktop researchers.

2 Philosophy, AI and Cognitive Science

The main philosophy behind Artificial Intelligence is based on the question *Can machines think*? Although the question itself doesn't clearly define what is implied by *think*. Within the AI community there has always been a debate *whether* it is possible or not to build intelligent thinking machines which are as good as human in terms of decision making, problem solving, conscious thinking to the extent of making creative discovery or showing sophisticated behavior like understanding the concept of *emotional love*. According to Dietrich [Dietrich2002], the most important of the *whether* problems lie at the intersection of theories of the semantic *content of thought* and the nature of computation. Human thinking is the manipulation of contentful thoughts, involved in cognitive processes as making inferences, recognizing patterns, planning and executing activities. During such processes our thoughts are manipulated to refer to the various things and concepts in our real world. The *content of thought* would possibly mean an expression or summary in our mind about a particular concept. But when this view is translated to computers a real hard problem emerges, because machine cognition is generally based on an algorithmic manipulation and computation of well defined data structures. The role of philosophical problems come to a play at this moment, thoughts have contents or internal states, now the question is when computers do addition of 1 to 2, how internal states are actually denoted to the number 1 or 2 ? Cognitive Science raises many of such interesting questions that are worthy of investigation by Philosophers. For example, if a computer infers *Fido will chase the cats* from the given facts *Dogs chase the cats* and *Fido is a dog*, do any of its internal states refer to dogs, cats, fido and the act of chasing.

> *If computations are radically different from thoughts in that they cannot have semantic content, then it is unlikely that computers can think* [Dietrich2002].

These problems are addressed in AI and Cognitive Science as *the problem of mental content or representational content.* Dietrich further identified that the second set of whether-possible problems of AI surrounds *the nature of rationality.* He claims humans constantly evaluate ways of achieving goals and rank them according to various measures such as the probability of success, efficiency and consequences. They evaluate the goals themselves and constantly gauge the relevance of one piece of information to another, the relevance of one goal to another and the relevance of evidence to achieving a goal. Humans are often successful in such evaluation however computers are not, thus human level rationality are not obtainable in an intelligent machine. The third set of whether-possible problems of AI are the issues of addressing the reasoning powers of human mind. In 1931, Kurt Gödel demonstrated by his famous *incompleteness theorem*[2] that within any given branch of mathematics, there would always be some propositions that cannot be proven for true or false using rules and axioms. Gödel proved that all *consistent* (i.e. there is no contradiction in a statement and its negation is also true), logical systems are *incomplete* (in the sense that every statement in the language of Number Theory cannot be either proved or disproved). The logical problems surrounding the self-reference and the incompleteness of certain axiomatic systems (logical systems) seem to be a barrier in building an intelligent machine.

Gödel's Theorem has been used to argue that a computer can never be as smart as a human being because the extent of its knowledge is limited by a fixed set of axioms, whereas people can discover unexpected truths. Philosophers made AI conceivable by considering the ideas that the mind is in some ways like a machine, that it operates on knowledge encoded in some internal language and that thought can be used to help arrive at the right actions to take [Russell and Norvig2003]. Even though Philosophy existed a long before computers came into existence, there has always been a question of how minds work, how do human minds work and can non-human have minds? These are real hard problems that often resulted in heated debates among the Philosophers, AI researchers, Cognitive Scientists. Many have now chosen a computational perspective, because of the various tools being available to study the intelligent behavior in detail. At current state of research, AI is still in its infancy to exhibit the higher-level human cognitive abilities and thought processes in computers. The AI research is actively viewed with respect to two schools of thought to achieve machine intelligence. They are termed as *Strong AI* and *Weak AI* by John Searle [R.Searle1980]:

[2] http://mathworld.wolfram.com/GoedelsIncompletenessTheorem.html

– **Strong AI** is the belief that artificial intelligence can truly reason and solve problems, strong AI supposes that it is possible for machines to become sapient, or self-aware, but may or may not exhibit human-like thought processes. As Searle claimed:

> *..according to strong AI, the computer is not merely a tool in the study of the mind; rather, the appropriately programmed computer really is a mind.*

– **Weak AI** refers to the use of software to study or accomplish specific problem solving or reasoning tasks that do not encompass the full range of human cognitive abilities, unlike strong AI, a weak AI does not achieve self-awareness or demonstrate a wide range of human-level cognitive abilities, and is merely an (arguably) intelligent, more specific problem-solver. The current softwares are Expert systems that are used commonly for specific purposes. For example, there are expert systems that can diagnose human illnesses, make financial forecasts, and schedule routes for delivery vehicles. Some expert systems are designed to take the place of human experts in specific knowledge domains, while others are designed to support them. Expert systems and also the Chess program are a part of Weak AIs.

In the following sections an outline is given about the research in Mental Models and its practical relevance to Semantic Desktop is examined.

3 Mental Models

Mental Models have been studied by cognitive scientists as part of efforts to understand how humans know, perceive, make decisions, and construct behavior in a variety of environments. From the Vannevar Bush ideas of how human mind operates *As we may think* [V.Bush1968] to the Xanadu Project by Ted Nelson, Philosophers have always been interested in *how we think about the things in our world and how it is represented in our minds*? The term *Mental Model* was first mentioned by Craik in his 1943 book, *The Nature of Explanation* [Craik1943]. It said that humans make use of internal models of external reality, which enable them to better understand and react to situations in their environment. In his view people operate on mental representations to simulate real world behavior and produce predictions. In other words this implies humans are not just physically situated in its environment, but they also have their own internal model of it, which allows them to deal with that external reality of world.
After Craik, literatures on Mental Model appeared in three theoretical approaches, viz. Johnson-Laird's (1983) [Johnson-Laird1983] theory of Mental Models, a collection of work on Mental Models of natural phenomena and devices by Genter and Stevens (1983) [Gentner and Stevens1983], and Paivio's (1986)

[Paivio1986] dual coding approach for classification of mental representations. The Johnson-Laird volume proposed Mental Models as a way of describing the process which humans go through to solve deductive reasoning problems. His theory included the use of a set of diagrams to describe the various combinations of premises and possible conclusions [Johnson-Laird1983]. Johnson-Laird proposed three types of mental representations: (1) Propositional representations: which are pieces of information resembling natural language. (2) Mental Models: which are structural analogies of the world. (3) Mental imagery: which are perceptual correlates of models from a particular point of view. Another book appeared in the same year by Gentner and Stevens. They proposed that Mental Models provide humans with information on how physical systems work. This approach could be generalized to a number of situations that humans face, including the behavior of objects according to laws of physics [Gentner and Stevens1983].
The fundamental philosophical issue addressed within the context of Mental Model is that *things are not the way it is represented in our thoughts*, for instance, thoughts about computer are not computer itself, rather probably a conceptualization of the features of computer. The question is then how the abstract thoughts manage to represent the things in such a way, even though there are missing information. More interestingly, our thoughts are not always restricted to represent existing things, but there are things that cannot possibly exist (rectangular basketball), things that do no exist (unicorn), things which are not perceivable (limit of universe). How all these representations are possible without the things existing itself or the way it exist. Human thoughts have *semantic content*, which is missing in computers. For instance, when a number is added to itself it is twice the number, this is general principle for computation which an algorithm computes for computers, but for humans we have more intuitive information processing mechanism and deeper understanding, humans can rank the worth of computation based on thought content. According to Dietrich [Dietrich2002], when a computer does addition there occurs a cascade of causal processes which implements an algorithm that in turn, if followed exactly guarantees that two numbers will be added. We can make an analogy to wonder why computers and its processing is different than humans, lets take a coffee machine example. A coffee machine doesn't know at all about the type of coffee, nor does it represent coffee and also it has no knowledge about the coffee it is preparing. It is given rather a configuration to use different ingredients to produce specific coffee types. Can we encode semantic content to improving this situation in an intelligent machine? If yes, then we can hypothesize of thinking computer or at least attempting towards a human type information processing rather than simple procedural computations without any thought content involved.

> *One way out of this dilemma is to attempt to develop a philosophical theory of mental content that clearly explains how thoughts get the content*

> *that they do. Then we could just check to see whether computations could get content in the same way. If they can, then AI is on firm ground, if they cannot then AI is without hope [Dietrich2002].*

According to Dietrich comment, the nature of semantics are viewed on two perspectives namely: (1) *world-mind relations*: It saw semantics as essentially associated with the truth, causation and getting along in the world. (2) *mind-mind relations*: It saw semantics as essentially associated with being able to draw certain inferences, construct plans and in general determine how one thought and representation relates to another.

The two views mentioned above are necessary to understand and develop the theory of representational content. Within the Semantic Desktop framework a computer can be causally connected to the environment and its representations can be implemented. Semantic Desktop could be a proxy to user's world view to represent and relate concepts a person keeps in her mind. Although a thought content would still remain a problem for computers to comprehend.

The Semantic Desktop is a relatively new research approach motivated to tackle the challenges for Personal Information Management to help the users making sense of their ever increasing personal information. Cognitive Science research perspectives help to develop a theoretical base here, thus the Mental Model would surely become the vocabulary for Semantic Desktop community for representing complex and ever changing world of information. Also for the Human-Computer Interaction (HCI) practitioners a Mental Model provides a set of beliefs about system functionality. Human interactions with system is based on these beliefs [Norman1990].

Usability issues of Semantic Desktop is also tightly connected to the user's Mental Model. But it is quite challenging to meet the needs of an expert as well as a novice users' Mental Model, further discussion explains the reason. A design of Semantic Desktop should be consistent with person's natural Mental Model about the concepts, ideas and everyday objects encountered in environment. For instance, the way people organize their paper-work while doing a specific task like writing a thesis or working on a project should be reflected in Semantic Desktop, all the relevant objects should be related and tagged in a sensible way to efficiently organize the work. Semantic Desktop should provide an interface to model the physical paper-way of organizing with which a user is most familiar in daily activities.

Many existing systems put too many demands on the users that use them, users are often required to adjust the way a system works. A system with inaccurate Mental Model leads to frustration and inconvenience. Moreover with an increasing demand for usability in technology products and the people's dependence on computers, we have to expect the non-experts interacting with the system for Personal Information Management. Such user could be lacking technical exper-

tise and tolerance. The role of technology products such as Semantic Desktop must accommodate the needs of the users of future generation who are more diverse, less technical, very explorative and quite impatient [Gribbons1999]. The system designer bores the responsibility of capturing user's expectations and hypothesize more about user-adaptiveness to deliver intuitive and predictable system consistent with the user's Mental Model.

4 Realizing Theories in Semantic Desktop

This section describes how Mental Models described in [Section 3] could be realized as design methods for Semantic Desktop development. Semantic Desktop should be designed to help users build productive Mental Models of system functionalities. As argued in this paper, the usability issues of Semantic Desktop are closely connected with user's Mental Model. A user should be informed through interfaces in a such a way so that she could exploit the maximum benefit of Semantic Desktop goals. There have been excellent efforts to address the issues of Mental Models [Davidson et al.1999, Sasse1997] to have a better understanding of user-interaction with the systems. According to McDaniel [McDaniel2003] Mental Models are the conceptual representation within the person's mind that helps her to understand the world [Kurtz2003]. Mental Models may be (1) An Image, (2) A script, (3) A set of related Mental Models, (4) A controlled vocabulary, or (5) A set of assumptions.

> *We should create these Mental Model descriptions during user analysis to document users' current understanding. Then, during a design phase, we should create the target model to show the Mental Model we want users adopt.* - McDaniel [McDaniel2003]

Many research from the area of Cognitive Science give some generic ideas that human mind is quite flexible, and our learning abilities, memorizing and conceptualization is quite often based on analogy of relationships among the real-world objects. In digital ambience in relevance to HCI we have distributed and different information but they are often connected with multiple relationships, explicitly or implicitly, which means either it is visible from a given information model (explicit) or it could be inferred (implicit). Based on our discussions we identified some of the general features and criteria for Semantic Desktop to support user in making productive Mental Models. They are illustrated as follows.

– **User Expressivity**: The Semantic Desktop should enable the user to express her personal concepts. Users should be allowed to make their real-world concepts in an intuitive way. User tend to categorize their information according to their own sense, thus any strict categorization feature should be avoided. This would support user's information filing behavior.

– **Reducing Cognitive Overload**: The Semantic Desktop is meant to reduce cognitive overload of information. In [Kirsh2000], David Kirsh points out that too often the information falls between the cracks of our classifying scheme and we are faced to go through the challenging process of creating new indices and categories or painfully stretching the old ones. Whenever we create a new category or stretch an old one there is the danger that where we place the information will be forgotten next time we look for it. This is all stressful specially because the less one has system for dealing with invaded information (i.e. information in the form of emails, newsletters etc.) and the more one must make ad-hoc decisions for each incoming piece of information.

  > *The psychological effort of making hard decisions about invaded information is the first cause of cognitive overload* [Kirsh2000]

– **Preserving Association (user context)**: We have known from the vision of Bush [V.Bush1968] that human mind operates by association. With one item in its grasp it quickly moves to the next item suggested by the association of thoughts stored as a web of trails. Semantic Desktop should be able to provide users with necessary priming needed to preserve the context in which a user is currently in and a possible trails to move other related contexts. For example, a user reading a paper might also like to know the authors homepage, other co-authors and related publications.

– **Improving accuracy in Mental Model**: Accuracy of Mental Model is proportional to Usability of the system. On one side we have a user with a "Mental Model" who wants to use the system for a specific task, on the other side there is a computer system which follows user behavior and knows user preference and goals (i.e. the system keeps a user model). The task of Semantic Desktop would be to map the Mental Model to the user model for the person to use the system more effectively. Normally the Mental Models people create of computer systems are inaccurate [Norman1983]. By designing the systems that help people to create a more accurate Mental Model of the system, usability would significantly improve [Norman1983]. This means that if the designer creates the correct design model and communicates the model successfully through the system image. Then users interacting with the system will develop an appropriate user model, which will allow them to interact with the system successfully.

– **Personalization**: Personalization of Semantic Desktop systems would enhance user satisfaction and productivity. Each person has her own mental representation of the concepts from the real-world. Semantic Desktop is a way to express these mental concepts with respect to each user. Users prefer to make their own customization according to their interests, motivation and expertise. By giving the user freedom to personalize their concepts would

support their memory and familiarity. This would encourage the user to use Semantic Desktops in an intuitive way.

Mental Models are meant to simplify the reality. They are promising human factors in consideration of design, but the real difficulty exist in methodology to design system that would help the user to create best Mental Model [Jenny Preece and Carey1994]. Therefore the efforts should be focused on providing an accurate initial Mental Model and capturing user behavior over time. This approach has been taken in PIMO- an Ontology to support initial Mental Model of user, see [Sauermann2006] for details.

5 Conclusions

Cognitive Science gives a better insight to understand Mental Models but to capture and validate users Mental Models poses difficulties. The potential for rewards of improved design and increased usability based on correct Mental Models compensate for the effort, but they are still an open area of challenging research. The ideas discussed in this paper provides a holistic view from the perspective of Philosophy and Cognitive Science theories, which could help in building Semantic Desktop to meet the users requirements. The theories of Mental Models discussed in the paper is an important knowledge needed for any steps in building Semantic Desktop, although not detailed but there is a hint given in this work to emphasize a theoretical foundation as well as practical applications of Mental Model. This has to be kept in mind while designing specification for Semantic Desktop long term goals. In Gnowsis context, we can identify success stories by individual users about their experiences on how Semantic Desktop should ideally work. Comparing their answers would reflect different Mental Models and expectations. This should be used for redesigning prototype to exploit system features and improve usability. We still lack the proper evaluation of the Semantic Desktop systems, specially with the non-expert users to judge how well the systems adopts to user's Mental Model. Moreover, it would be interesting to investigate if Semantic Desktop is an effort realizing *Weak AI*. One such research direction would be to investigate experimentally, how Semantic Desktop systems provide an aid to human memory.

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