

# A Conceptual Model for Ontology-based Mental Model

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**Abstract:** Utilizing mental models by different fields leads to generation of various definitions for this concept. In this paper, these field's significant definitions for mental models will be presented and their key concepts in each field will be analysed. By using regarded features of mental models definitions, ontology will be presented. In the ontology, the main fundamental concepts and their relations have been presented and analysed and then presented in the proposed model. Thirteen basic characteristics have been used to describe the proposed model's functionality. In addition to, types of memory will be analysed and relations between them and presented model will be studied and then illustrated in a conceptual model. The aim of proposed model is to design cognitive agent that thought human-like.

**Keywords:** Cognition, Memory, Mental Models, Modelling, Ontology.

## I. INTRODUCTION

Von Eckardt, in his book what is Cognitive Science [1], expounds that cognition is the set of all mental abilities and processes related to knowledge: attention, memory and working memory, judgment and evaluation, reasoning and computation, problem solving and decision making, comprehension and production of language, etc. Human cognition is conscious and unconscious, concrete or abstract, as well as intuitive (like knowledge of a language) and conceptual (like a model of a language). Cognitive processes use existing knowledge and generate new knowledge. "Cognition" is a word that dates back to the 15th century when it means "thinking and awareness" [2].

Regarding the primary source of cognition presented two different view can be derived from the work of scientists who are presented as follows: 1- precognition (before experience) that the origin of a priori cognition is "mind" or "reason" and do not have experience, and validation of experience-based independent confirmation of mind, 2- post cognition (later on experience) that posterior cognition is gained based on observation and experience, which their distinction has led to rise of two different and distinct philosophical schools called 1- Rationalism, 2- Empiricism. In epistemology, rationalism is the view that "regards reason as the chief source and test of knowledge" [3] or "any view appealing to reason as a source of knowledge or justification" [4]. Empiricism is a theory, that states that knowledge comes only or primarily from sensory experience [5]. The Rationalist believes we come to knowledge a priori – through the use of logic – and is thus independent of sensory experience and the Empiricist essentially believes that knowledge is based on or derived directly from experience [6]. Reality is just in the mind but in Empiricism the mind is considered as a mirror reflecting the reality of outside world. But mind is not only reflecting realities but also builds a part of them.

Mind does not have necessary capacities to analyse and recognize the complexities of the world around, hence; it builds a pattern out of states of this world. The principle of bounded rationality [is] the capacity of the human mind for formulating and solving complex problems is very small compared with the size of the problems whose solution is required for objectively rational behaviour in the real world — or even for a reasonable approximation to such objective rationality [7]. For this reason, mind work indirectly to this way that making model of existent word and then process it. What stands in mind from the world is a model of the outside reality which is a framework for thinking that named mental model and it is "An explanation of someone's thought process about how something works in the real world. It is a representation of the surrounding world, the relationships between its various parts and a person's intuitive perception about their own acts and their consequences. Our mental models help shape our behaviour and define our approach to solving problems (akin to a personal algorithm) and carrying out tasks" [8].

Mental model is thinking process in human being resulting in a set of actions and can specify reactions in different circumstances. Mental model as framework to thinking is a series of complex processes which have been interwoven. Complex phenomena can be always represented simple through eliminating some details. Although during this process some effective parameters in the main phenomena might be ignored, but these simplifying results in a better understanding of concepts [9]. According to that people use cognitive representations in order to characterize, understand, reason and predict the surrounding world and a class of these representations are called mental models [10], by analysed and study its details, it can be claimed that thinking method in human being has been modelled. According to business dictionary

model is Graphical, mathematical (symbolic), physical, or verbal representation or simplified version of a concept, phenomenon, relationship, structure, system, or an aspect of the real world. The objectives of a model include (1) facilitating understanding by eliminating unnecessary components, (2) to aid in decision making by simulating 'what if' scenarios, (3) to explain, control, and predict events on the basis of past observations. Since most objects and phenomenon are very complicated (have numerous parts) and much too complex (parts have dense interconnections) to be comprehended in their entirety, a model contains only those features that are of primary importance to the model maker's purpose [11]. Model is an abstract of reality and the key relationships between the components of the phenomenon which shows up an overview of reality and reaches only those details which impacts the process of activities where as a kind of abstraction of reality is applied in model. To achieve this purpose extract basic details of concept of mental model and designed model as ontology. To be able to model the thinking process in human, the thing which thinking is getting shape should be mapped on the agents called mental models in form of a primary model and an evolutionary one and base on can be created thinking process from perception to reasoning and ultimately designing on intelligent cognitive agents. This paper tries to convert thinking process from a mental pattern to an objective pattern. By studying mental model and its effecting details can be implemented thinking in computing and artificial agents just like human so that agents could be replaced with human in doing tasks. Regarding to the workspace, agents can be divided into four categories: reactive agents [12], reflective agents [13], logic agents [14], and cognitive agents [15]. If the agents within a complex and dynamic environment are process-based, they will be as accountable as how much the circumstances goes based on the process that agents have predicted. If not, agents will be disabled to do their tasks. If mental model and thinking method of could be transferred from human on the agent, then agents can be designed that running and implementing them in complex and dynamic environments have higher capacities. To achieve this objective, mental models and their related definitions should be explained. There are definitions of mental models in different areas that each contains different concepts. Surveying these concepts and relations among them, details containing the structure of human thinking in forming mental model can be described and ontology of mental models can be achieved.

Thinking process from sensing, interpret and represent of word need to space for storing information, so thinking and memory are inextricably linked and this process cannot occur in a vacuum; it relies on the long-term memory base and a temporary mental workspace [16], this paper adopts a memory-based approach to explore the relationship between memory types to create mental models and analysed that each detail of mental model perform in which section of memory.

In the following sections, at first different mental models concepts will be expressed and some of definitions will get

presented and after that, efficient components within them will be explained and consequently, and ultimately the proposed model will be offered and described according to the presented ontology, then will be discussed and analysed relations between proposed concept and designed ontology and type of memory and based on a model will be created.

## II. MENTAL MODEL CONCEPTS

Based on applications and needs, each definition focuses on different concepts as mental models. So representing a common concept of mental models seems to be difficult. Having a conceptual model that representing concept and relation between them can efficiently help solving relative problems of mental models that is dynamic and clear explain does not exist for it then by giving information about it can be helping to understand.

### A. Mental Models Definitions

According to Russell & Norvig [17], where they make the distinction between acting rationally and being rational, and define AI as the study of the former, with the advancement of artificial intelligence, researchers have been always trying to find differences between thinking in machines and humans. Thinking is a process which by a new mental representation appears through conversion of information and the interaction between mental qualities, judgment, abstraction, reasoning, and problem-solving [18]. According to thinking process, a model called mental model has come to be from human thinking method and different definitions have been presented in respect of distinct requirements in various areas. In this section, mental model definitions in different areas are mentioned and their concepts are studied and compared with each other.

Definition 1: The Scottish psychologist Kenneth Craik [19] was the first person to propose the term "Mental Models" and believed that the mind constructs "small-scale models" of reality that it uses to anticipate events, to reason, and to underlie explanation.

Definition 2: Mental models can also be defined as 'frameworks' or meaning structures for "describing the interrelationship between activities, objects and abstract items of knowledge in a person's mind, and can also involve prediction of future events" [20].

Definition 3: mental models provide a framework for the interpretation of ideas and activities; assist in restructuring existing information and aid in the inculcation of new information [21].

Definition 4: Like pictures in Wittgenstein's (1922) "picture" theory of the meaning of language, mental models have a structure that corresponds to the structure of what they represent. They are accordingly akin to architects' models of buildings, to molecular biologists' models of complex molecules, and to physicists' diagrams of particle interactions. [22].

Definition 5: "Mental models are representations in the mind of real or imaginary situations. The model theory accounts for deductive, inductive, and abductive

reasoning. For deduction, it postulates that individuals use the meanings of propositions and general knowledge to construct mental models of the possibilities consistent with the premises" [23].

Definition 6: Mental models are personal, internal representations of external reality that people use to interact with the world around them. They are constructed by individuals based on their unique life experiences, perceptions, and understandings of the world [24].

Definition 7: Mental models are psychological representations of real, hypothetical, or imaginary situations. They were first postulated by the American philosopher Charles Sanders Peirce, who postulated (1896) that reasoning is a process by which a human "examines the state of things asserted in the premises, forms a diagram of that state of things, perceives in the parts of the diagram relations not explicitly mentioned in the premises, satisfies itself by mental experiments upon the diagram that these relations would always subsist, or at least would do so in a certain proportion of cases, and concludes their necessary, or probable, truth" [25].

Definition 8: "The image of the world around us, which we carry in our head, is just a model. Nobody in his head imagines all the world, government or country. He has only selected concepts, and relationships between them, and uses those to represent the real system"[26].

Definition 9: "In psychology, the term mental model is sometimes used to refer to mental representations or mental simulation generally". At other times it is used to refer to mental models and reasoning and to the mental model theory of reasoning developed by Philip Johnson-Laird and Ruth M.J. Byrne [27].

Definition 10: "In interacting with the environment, with others, and with the artifacts of technology, people form internal, mental models of themselves and of the things with which they are interacting. These models provide predictive and explanatory power for understanding the interaction" [28].

"How are mental models constructed?

One notion is that analogies or metaphors function as tools of thoughts which help structure unfamiliar domain (Gentner and Gentner, 1983)

Example: (Analogies) Flowing waters simulates the flow of electricity and any other liquid substances.

Example: (Metaphor) More is up/good is up I'm feeling up. That boosted my spirits Get up. Wake up. She rises early He's at the peak of health I am on top of the situation. He is under my power my income rose last year".

Definition 11: "Mental models are representations of reality that people use to understand specific phenomena. They represent deeply ingrained assumptions or generalizations that influence how we understand the world and how we take action. These deeply held internal images of how the world works are developed overtime through the process of socialization, including education, experience and interaction with others. Mental models are very often hidden and we are not consciously aware of our mental models or the effects they have on our behaviour. Once created, they become fixed and reinforced in the

mind, becoming difficult to change. The function of mental models is to 'mediate reality for our minds and help us categorize and organize an endless stream of information we take every day" [29].

Definition 12: "although people do not always behave congruently with what they say (espoused theories), they do behave congruently with their mental models" [30].

Definition 13: "Mental models are deeply ingrained assumptions, generalizations, or even pictures or images that influence how we understand the worlds and how we take action. Very often, we are not consciously aware of our mental models or the effect they have on our behaviour" [31].

Definition 14: " the task of theory consist in constructing an image of the external word that exist purely internally and must be our guiding star in thought and experiment ;that is in completing, as it were, the thinking process and carrying out globally what on a small scale occurs within us whenever we form an idea. All our ideas and concepts are only internal pictures" [32].

Definition 15: "appropriate mental models, or representations, of the knowledge being acquired. The next step is learning to use the available mental models to solve problems" [33].

Definition 16: "Humans constantly construct mental models of reality, which include their assumptions, beliefs, experiences, and biases about the world. In fact, humans construct mental models of reality often without an awareness of it. In decision making, mental models include an individual's perception of a situation, variables in the system, alternative solutions, decision premises, and biases" [34].

Definition 17: "Mental models give you a deep understanding of people's motivations and thought-processes, along with the emotional and philosophical landscape in which they are operating" [35].

Definition 18: "To create a mental model, you talk to people about what they're doing, look for patterns, and organize those patterns from the bottom up into a model"[35].

### III.MEMOTY DEFENITION AND TYPES

In psychology, memory is a process in which information is encoded, stored, and retrieved. Encoding allows information from the outside world to reach the five senses in the forms of chemical and physical stimuli. In first stage the information must be changed so that it may be put into the encoding process. Storage is the second memory stage or process. This entails that information is maintained over periods of time. Finally the third process is the retrieval of information that has been stored. Such information must be located and returned to the consciousness. Some retrieval attempts may be effortless due to the type of information, and other attempts to remember stored information may be more demanding for various reasons [36]. From information processing perspective there are three main stages in the formation and retrieval of memory [37]:

a) Encoding or registration: receiving, processing and

combining of received information.

- b) Storage: creation of a permanent record of the encoded information.
- c) Retrieval, recall or recollection: calling back the stored information in response to some cue for use in a process or activity.

#### B. Types of Human Memories

There are 3 basic recall types [38]:

- **Sensory Memory:** Sensory memory holds sensory information for less than one second after an item is perceived. The ability to look at an item and remember what it looked like with just a split second of observation, or memorization, is the example of sensory memory. It is out of cognitive control and is an automatic response. With very short presentations, participants often report that they seem to "see" more than they can actually report. The first experiments exploring this form of sensory memory were conducted by [39] using the "partial report paradigm"
- **Short-term or Working Memory:** Short-term memory allows recall for a period of several seconds to a minute without rehearsal. Its capacity is also very limited: George A. Miller (1956), when working at Bell Laboratories, conducted experiments showing that the store of short-term memory was  $7 \pm 2$  items (the title of his famous paper, "The magical number  $7 \pm 2$ ") [40]. Most of the information that gets into sensory memory is forgotten, but information that we turn our attention to, with the goal of remembering it, may pass into short-term memory. Short-term memory (STM) is the place where small amounts of information can be temporarily kept for more than a few seconds but usually for less than one minute. Information in short-term memory is not stored permanently but rather becomes available for us to process, and the processes that we use to make sense of, modify, interpret, and store information in STM are known as working memory [41]. Working memory is the system that is responsible for the transient holding and processing of new and already stored information, an important process for reasoning, comprehension, learning and memory updating. Working memory is generally used synonymously with short term memory, but the two concepts are distinct and should be distinguished from one another. Working memory is a theoretical framework that refers to structures and processes used for temporarily storing and manipulating information. Short-term memory in general refers to the short-term storage of information, and does not entail the manipulation or organization of material held in memory [42]. Baddeley and Hitch (1974) developed a model of short-term memory which they called working memory (see fig 1).



Figure1. The Working Memory Model (Baddeley and Hitch, 1974)

- **Long-term Memory:** The storage in sensory memory and short-term memory generally has a strictly limited capacity and duration, which means that information, is not retained indefinitely. By contrast, long-term memory can store much larger quantities of information for potentially unlimited duration (sometimes a whole life span). Its capacity is immeasurably large [37].

#### IV. ONTOLOGY OF MENTAL MODELS

In this paper, mental model consider as a complex phenomenon and for understanding each part of it, presented ontology for it that set of words of different concepts that specified existence of reality. Ontology is a description (like a formal specification of a program) of the concepts and relationships that can formally exist for an agent or a community of agents. This definition is consistent with the usage of ontology as set of concept definitions, but more general. And it is different senses of the word than its use in philosophy [43]. Various concept of components is to be effective on mental model formation. These main concepts can be used for representing ontology.

To connect these concepts regarding to the definitions, ontology can be considered which contains the way these relations are set among them. Based on the mentioned definitions of mental models, these main concepts will be achieved: perception, memory, reasoning, experience, background knowledge, planning, schemas, memes, judgment, optimization, evaluation, conceptualization, adaption and learning. According to functions of each of the concepts can divided into two categories of memory and cognitive activities. Memes, schema, background knowledge and experience are to be in the category of memory activities.

A meme is "an idea, behavior, or style that spreads from person to person within a culture." A meme acts as a unit for carrying cultural ideas, symbols, or practices that can be transmitted from one mind to another through writing, speech, gestures, rituals, or other imitable phenomena with a mimicked theme [44].

In psychology and cognitive science, a schema (plural schemata or schemas) describes an organized pattern of thought or behavior that organizes categories of information and the relationships among them[45].

Adaptation, planning, reasoning, judgment, perception, learning, optimization, evaluation, and conceptualization are counted to be in cognitive activities. These two categories are in relationship with each other. A part of ontology includes functionalities applied on each component. In the first and thirteenth definition, understanding surrounding world has been considered as perception in the proposed model and mental models have been noticed as a result of perceptions. In second definition has been presented that relation between activities, objects and abstract items with knowledge of person that has been considering background knowledge. In third definition has been pointed to optimization. In the fourth, fifth, and Seventh ones, assistance in complex problem solving emphasizes on reasoning aspect in mental



model; something uses some given statements to reach a conclusion and helps understanding unknown structures based on specified and clear concepts. In the Fifth definition, the focus is on some kind of reasoning in building mental models called inductive. In sixth definition has been pointed to experience. In the eighth, twelfth and fourteenth ones, conceptualization is emphasized so that we model the world in form of concepts in our mind. In Tenth, eleventh, sixteenth definitions point to design schemas and memes since the questions become understandable for us once logic matches with design schemas and memes in the mind. In twelfth, and seventeenth definition indirectly has been speak about judgment and evaluation. In eleventh one learning and experience are studied in the process of forming mental models. In the fifteenth definition, the relation between mental models and knowledge is under attention. Reason is associated with optimization because created result that leads to making new information. In optimization process to making perfect something or fact perform adapting and evaluation act to determining the importance. Planning process required to evaluation for organizing function to achieve goal. Using these concepts and relations among them, mental model ontology can be illustrated as figure 2 based on concepts of definitions.

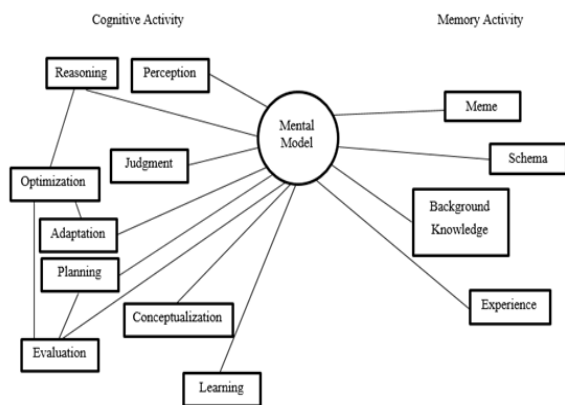


Figure 2- Proposed Ontology for Mental Models

A part of ontology is an operation which is defined on ontological components. According to the definitions of working memory and model provided in figure 1a cycle has been intended in this proposed model the in this cycle information enters sensing memory after attention and focus on it and performed processing as a perception of environment then analysed that information entered memory will be compared and evaluated with previous concepts and performed judgment and new concepts will be reasoned out of them. Current state analysis and its comparison with previous concepts and created a higher level notions. Some kind of optimization occurs in concepts and their relations that cause the alternation of former ontology and updating will be done so that mental model and a newer ontology can be shaped and previous knowledge will also be updated accordingly. Then organized the functions required to achieve to the goal or

act as behaviour. These activities accomplished in working memory that performed needed processing directly achieve to cognitive. These processes compared with previous knowledge, schemas, and memes that stored in long memory to see whether they match with previous concepts. If it is so, they will be stored in memory as schema if be related to series of experience that connect with together as a network and be organized and if belief and culture or social schemas as meme store and if not, will be stored as a new experience. Meme, schema, experience, and background knowledge set in long memory. Based on presented process, this cycle can be also considered as figure 3.

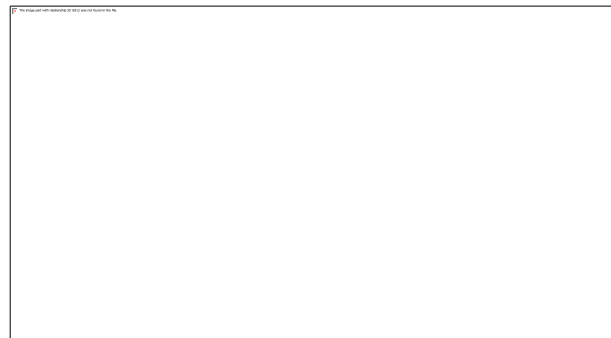


Figure 3- Classification concepts in mental model based on performance

## V. CONCLUSION

Different definitions of mental models presented and their concepts were analyzed and studied. The Thirteen characteristics extracted and the way of their relation in the model was described. Considering the definitions, this can be seen that concepts like communication with the perception, conceptualization, judgment, planning, optimization, evaluation, reasoning, learning, adaptation, meme, schema and experience and background knowledge on mental models formation. In continuing this study, with recognizing different aspects and actions of mental models in memory offered conceptual model. Representing more efficient mental models can lead to design and implementation of structures intelligence cognitive agents and also using such systems can result in producing systems with higher robustness and efficiency.

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