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A MODEL FOR HUMAN COGNITION

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Abstract

Natural Language is an important characteristic of humans that distinguishes them from other living beings. Communication between individuals could be in the form of spoken and/or written languages, facial and other bodily gestures and signs. Hence, it is important to express and be understood and also understand and respond to the others. In this work, firstly the study of internal functioning of the brain is done which include the detailed insight of how semantic knowledge is represented in the brain, which parts of the brain are mainly involved in language processing and language understanding and cognitive architectures called ACT-R6 and SOAR which is based on the above processes are also studied. Some parts of brain deal with some specific tasks in language processing. To understand it we have gone through various models like model of the memorization process, model of comprehension, model of language processing and cognitive model of brain. On the basis of these models, we have design a model for Natural Language Understanding and Generation process. The working of ACT-R6 is implemented on an application of computations of Family Relations.

Keywords: Brain, memorization model, comprehension model, language processing model, cognitive model, natural language understanding, natural language generation.

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1. Introduction

The nervous system is your body's decision and communication center. The central nervous system (CNS) is made of the brain and the spinal cord and the peripheral nervous system (PNS)

are made of nerves. Together they control every part of your daily life from breathing and blinking to helping you memorize facts for a test. Nerves reach from your brain to your face, ears, eyes, nose, and spinal cord and from the spinal cord to the rest of your body. Sensory nerves gather information from the environment and send that information to the spinal cord, which then sends the message to the brain. The brain then makes sense of that message and fires off response. Motor neurons deliver the instructions from the brain to the rest of your body. The spinal cord, made of a bundle of nerves running up and down the spine, is similar to super highway, speeding messages to and from the brain at every second (http://serendip.brynmawr.edu).

1.1 Human Brain

The human brain is the center of the human nervous system. It has the same general structure as that of other mammals, but is over three times larger than the brain of a typical mammal with an equivalent body size (Johanson, 1996). Especially expanded are the frontal lobes, which are associated with executive functions such as self-control, planning, reasoning, and abstract thought. The portion of the brain devoted to vision, the occipital lobe, is also greatly enlarged in human beings. The brain monitors and regulates the body's actions and reactions. It continuously receives sensory information, and rapidly analyzes this data and then responds accordingly by controlling bodily actions and functions. The brainstem controls breathing, heart rate, and other autonomic processes that are independent of conscious brain functions. The neocortex is the center of higher-order thinking, learning, and memory. The cerebellum is responsible for the body's balance, posture, and the coordination of movement. As

shown in Figure 1, the brain is made of three main parts: the forebrain, midbrain, and hindbrain. The forebrain consists of the cerebrum, thalamus, and hypothalamus (part of the limbic system). The midbrain consists of the tectum and tegmentum. The hindbrain is made of the cerebellum, pons and medulla. Often the midbrain, pons and medulla are referred to together as the brainstem (http://serendip.brynmawr.edu).

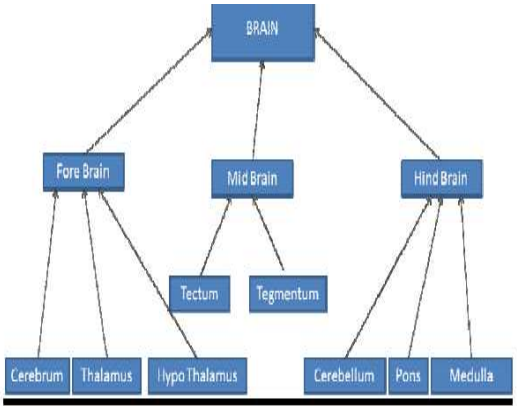

Figure 1: Parts of the brain

1.2 Natural Language Processing

Natural language processing (NLP) is a field of computer science and linguistics concerned with the interactions between computers and human (natural) languages (Charniak, 1984). In theory, natural language processing is a very attractive method of human–computer interaction. Natural language understanding is sometimes referred to as an AI-complete problem because it seems to require extensive knowledge about the outside world and the ability to manipulate it. Natural Language Processing (NLP) is the computerized approach to analyzing text that is based on both a set of theories and a set of technologies and, being a very active area of research and development, there is not a single agreed-upon definition that would satisfy everyone, but there are some aspects, which would be part of any knowledgeable person's definition. Natural Language Processing is a theoretically motivated range of computational techniques for

analyzing and representing naturally occurring texts at one or more levels of linguistic analysis for the purpose of achieving human-like language processing for a range of tasks or applications.

1.3 Cognitive Science

Cognitive science is a scientific study of the mind with special emphasis on the use and acquisition of knowledge and information. It is the interdisciplinary scientific study of minds as information processors. It includes research on how information is processed (in faculties such as perception, language, reasoning, and emotion), represented, and transformed in a (human or other animal) nervous system or machine (e.g. computer). Cognitive science consists of multiple research disciplines, including psychology, artificial intelligence, philosophy, neuroscience[1], linguistics[2], sociology, and education (Paul, 2008). It spans many levels of analysis, from low-level learning and decision mechanisms to high-level logic and planning; from neural circuitry to modular brain organization (Longuet-Higgins, 1973). Cognitive science is a large field, and covers a wide array of topics on cognition. However, it should be recognized that cognitive science is not equally concerned with every topic that might bear on the nature and operation of the mind or intelligence. Social and cultural factors, emotion, consciousness, animal cognition, comparative and evolutionary approaches are frequently de-emphasized or excluded outright, often based on key philosophical conflicts. Cognition is the scientific term for "the process of the mind" i.e. how humans perceive, remember, learn and think about information. Usage of the term varies in different disciplines; for example in psychology and cognitive science, it usually refers to an information processing view of an individual's psychological functions.

[1]Neuroscience- The study of the brain and nervous system, including molecular neuroscience, cellular neuroscience, cognitive neuroscience, psychophysics, computational modeling and diseases of the nervous system.

[2] Linguistics- The study of the nature, structure, and variation of language, including phonetics, phonology, morphology, syntax, semantics, sociolinguistics, and pragmatics.

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2. Cognitive Modeling of Human Brain

In cognitive modeling of human brain, we study different models like model of memorization, model of comprehension, model of language processing, and cognitive model of brain. On the basis of these models, we have design a model for Natural Language Understanding and Generation process.

2.1 Model of Memorization

Model of memorization formally represents a cognitive model of the memory and provides a cognitive model revealed by the physiological structure of the human brain. In figure 2, it shows how memories are formed (encoding), how are memories retained (storage), how memories are recalled (retrieval). Encoding is an active process which requires selective attention to the material to be encoded. Memories may then be affected by the amount or type of attention devoted to the task of encoding the material. In storage process memory theories use a computer-based, or information processing, model.

The most accepted model states that there are three stages of memory storage and one more for memory retrieving: Sensory store retains the sensory image for only a small part of a second, just long enough to develop a perception. This is stored in the Sensory Buffer Memory (SBM). Action Buffer Memory (ABM) which is used as a buffer when recovering information. Short Term Memory (STM) lasts about 20 to 30 seconds when we do not consider rehearsal of the information. On the contrary, if rehearsal is used then short term memory will last as long as the rehearsal continues.

Short term memory is also limited in terms of the number of items it can hold. Its capacity is about 7 items but can be increased by chunking, that is, by combining similar material into units**.** Long Term Memory (LTM) has been suggested to be permanent. However, even though no information is forgotten, we might lose the means of retrieving it.

In retrieval process, memory retrieval is not a random process. Once a request is generated the appropriate searching and finding processes take place. This process is triggered according to the organization structures of the LTM, while the requested information is provided via the Action Buffer Memory (Han, 2008).

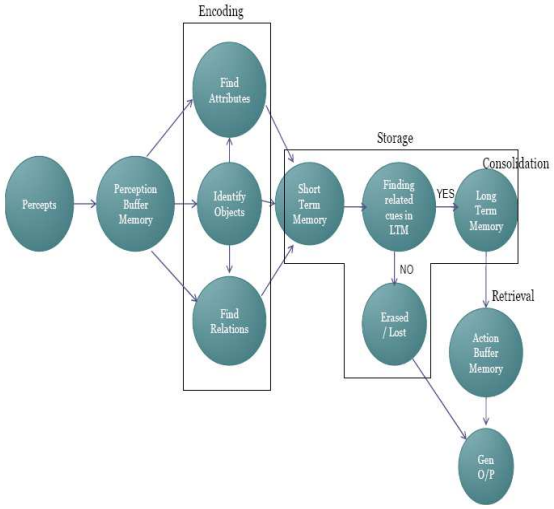

Figure 2: Model of memorization

[Source: Han S., Moka, LLC (2008)]

2.2 Model of Comprehension Process

Comprehension is the action or capability of understanding. In cognitive informatics, comprehension is classified as a higher cognitive process of the brain at the higher cognitive layer that searches relations between a given object or attribute and other objects (O), attributes (A), and relations (R) in the long-term memory, and establishes an OAR model for the object or attribute by connecting it to appropriate clusters of the memory (http://ieeexplore.ieee.org/Xplore/login.jsp). As shown in figure 3, the first step to comprehend a given real entity or concept, the brain searches the corresponding virtual entity and its relations to objects in the abstract layer. Depending on the results of

the search for relations, the next step can be different. The ideal search result is that adequate relations have been found. In this case, comprehension is almost reached. The other possible result is that a partial comprehension or incomprehension is obtained when a partial OAR model is built, or a very low level of comprehension is reached.

A partial OAR model is a sub OAR model, where no sufficient relations have been found. The comprehension process starts with identifying of an input object .The object in this case is a virtual entity or concept. For instance, when you are reading a text you may come across with a word or term of which the meaning is not obvious. Then you may attempt to comprehend the meaning of the term. Another example can be that if you look at a picture you may not understand what it denotes or the meaning of some part of it may not be clear for you. In the above examples the input objects can be a word, concept, formula, shape, picture, and the like. When the object has been identified, the brain searches for possible relations between existing objects in LTM and the input object from external world. The brain looks for relations at the image layer and then the abstract layer respectively. Once a connection with existing objects is found, the next step is to find related attributes and relations to build an OAR model for the object under comprehension. If the problem domain is familiar to be understood, it is more likely that more related objects exist in LTM. After these steps, the brain checks if the result of searching is adequate for building an OAR model for the object. If the findings are sufficient then the brain builds an OAR model for the given object. When the model is built it needs to be connected with a cluster. The brain classifies the OAR model and connects it to the most appropriate cluster in LTM. Only after this step, comprehension is achieved. However, if the findings are not adequate after the search, the brain builds a partial OAR model with limited information and requires further actions to obtain additional information from external resource. For example, if you could not recall or do not know the meaning of a given word by your existing knowledge, you may look for it in a dictionary or encyclopedia. The search from external resources may be a

repetitive process. For instance, if one cannot find the meaning of the word in the dictionary, then someone may be asked for its meaning. After searching several times in external resources, the brain checks again whether findings are adequate. If so, steps will be repeated otherwise, it is regarded as incomprehension has been achieved at this given moment, but still the results are remembered in LTM (Wang, 2002).

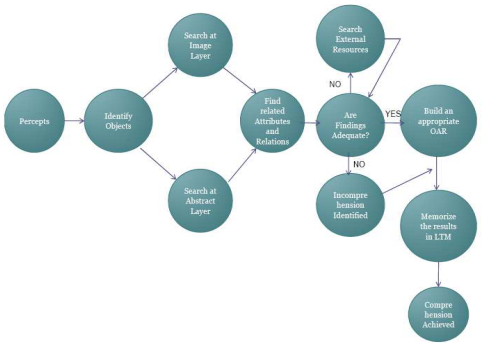

Figure 3: The model of Comprehension

[Source: Wang Y., Davrondjon G. (2003)]

2.3 Language Processing Model of Brain

In language processing model of brain, we will concentrate on the ways how a human brain can process English and other human natural languages because taken in general sense the ability to speak English or other human languages is only serious distinguishing feature that rises humans over the rest of the world making a human an intellectual being (Borzenko, 2008). As shown in figure 4, when we see something or hear something, our sensors get activated, and tend to capture the input symbols, visual or auditory. These symbols are then passed on to the brain. Now the brain gets activated and all the objects perceived by the sensor get stored into the Perceptual Buffer Memory (PBM). It is a kind of buffer which stores all the percepts, which is called as a percept sequence. It is an input oriented temporary memory and a set of queues corresponding to each of the sensors of the brain i.e. visual sensor and auditory sensor.

The capacity of PBM is quite small. When new information arrives, the old one in the queue should either be moved into STM or replaced by the new one. Perception Interface acts as an interface for both perception buffer memory and action buffer memory. In perception interface, thought process can occur and matching takes place in the STM and LTM and if best match can found, object get stored in the ABM (Action Buffer Memory). It is an output oriented temporary memory and its functional model is a set of parallel queues. The ABM now initiates an output action, that can be generated either through speech/write

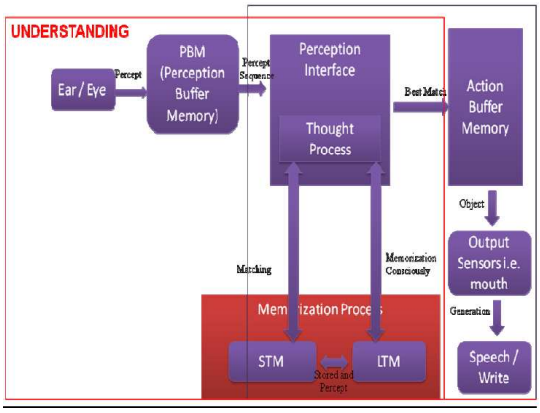

Figure 4: Language processing model of Brain [Source: Borzenko, A. (2008)]

2.4 Cognitive Model of Brain

In cognitive model of brain, there are some fundamental cognitive mechanisms of the brain, such as the architecture of the thinking engine, knowledge representation and establishment in long-term memory, and roles of sleep in long-term memory development (Wang, 2002). The cognitive model of the brain is shown in figure 5; Symbols are classified into two types visual symbols and verbal symbols. Visual symbols related to perception and verbal symbols related with words. Visual symbols related with words goes to the left posterior temporal occipital cortices and generates a visual map for language processing that can act as an interface for both left posterior

temporal occipital cortices and left anterior temporal regions that generates words and in language processing ,it understand both visual mapping and words and generated a response.

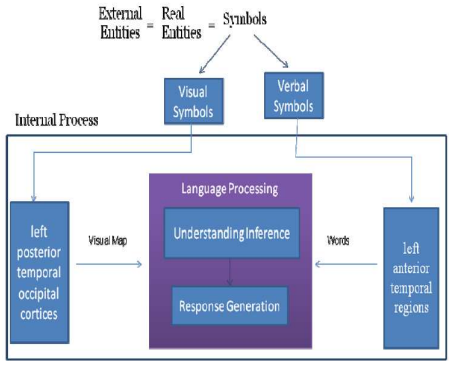

Figure 5: Cognitive model of Brain

[Source: Wang Y., Wang Y. (2002)]

2.5 Natural Language Understanding and Generation Process

Natural Language Generation (NLG) is the natural language processing task of generating natural language from a machine representation system such as a knowledge base or a form. NLG[3] may be viewed as the opposite of natural language understanding. The difference can be put this way: whereas in natural language understanding the system needs to disambiguate the input sentence to produce the machine representation language, in NLG the system needs to make decisions about how to put a concept into words. By studying all the above models we have got an idea to make a model on natural language understanding & generation. As shown in figure 6, when we see something or hear something, our sensors get activated, and tend to capture the input symbols, visual or auditory. These symbols are then passed on to the brain. Now the brain gets activated and all the objects perceived by the sensor get

[3]NLG- is the natural language processing task of generating natural language from a machine representation system such as a knowledge base or a logical form.

stored into the Perceptual Buffer Memory (PBM). It is a kind of buffer which stores all the percepts, which is called as a percept sequence. It is an input oriented temporary memory and a set of queues corresponding to each of the sensors of the brain i.e. visual sensor and auditory sensor. The capacity of PBM is quite small. When new information arrives, the old one in the queue should either be moved into STM or replaced by the new one.

Now brain will filter out the objects which are of its interest and intuitively identify the correlations amongst them. The thought process is bifurcated into Image layer and Abstract layer. The virtual structure of the percept is stored in the image layer and the behavioral aspects like attributes and relations are stored in abstract layer. So these are the two inputs to the working memory, i.e. Short Term Memory (STM).The input percept is now matched with the contents of both the image layer and the abstract layer. The STM is a set of stacks and when the virtual image and its attributes match with contents of the working memory, the Object-Attribute-Relation (OAR) model will be built. The OAR model is a model which represents the relationships amongst the objects and their attributes. The building of OAR model means that comprehension has been achieved. This object (language) will get stored into ABM (Action Buffer Memory). It is an output oriented temporary memory and its functional model is a set of parallel queues. The ABM now initiates an output action which is again symbolic in the form of language token.

If matching fails, the 'percept understanding' needs the intervention of external resources like dictionary or another human and if the hint / help comes from the environment then again the input sensor will get activated and now the same process will become the process of language understanding and if it does not come from the environment, the thought process gets background or temporarily delinked, reaching a dead state.

The memory can be made permanent by a refresh process which involves attention, repetition and associated ideas or concepts i.e. it can be converted into Long Term Memory (LTM).

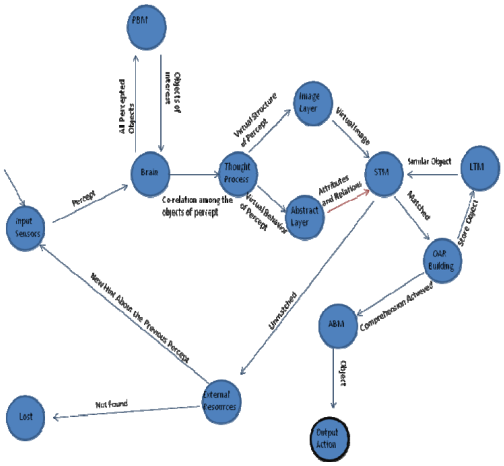

Figure 6 Natural Language Understanding and Generation Process

3. Results for BMC of Family Relations

The following are the results of the brain mapping in computations of family relations

3.1 Main Form Output

Figure 7 acts as an interface in which various options like Project Info, Family Members, Family Relations and Enquiry are shown.

Figure 7: Snapshot of Output

3.2 ProjectInfoPanel Output

Figure 8 shows how a cognitive architecture ACT-R works. There are two kinds of memory modules in ACT-R: Declarative memory and Procedural memory. Declarative memory consisting of facts and procedural memory made of productions in which pattern matching takes place.

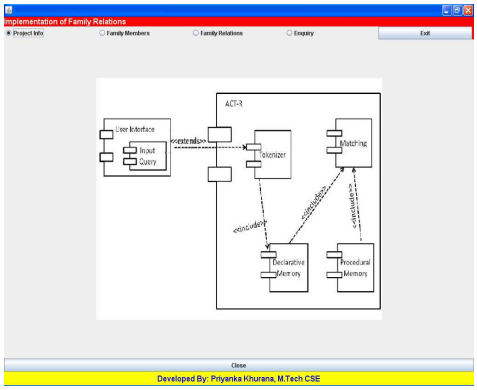

Figure 8: Snapshot of Output

3.3 FamilyPanel Output

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Figure 9 store member names and gender, after adding this it save this information into declarative memory of brain.

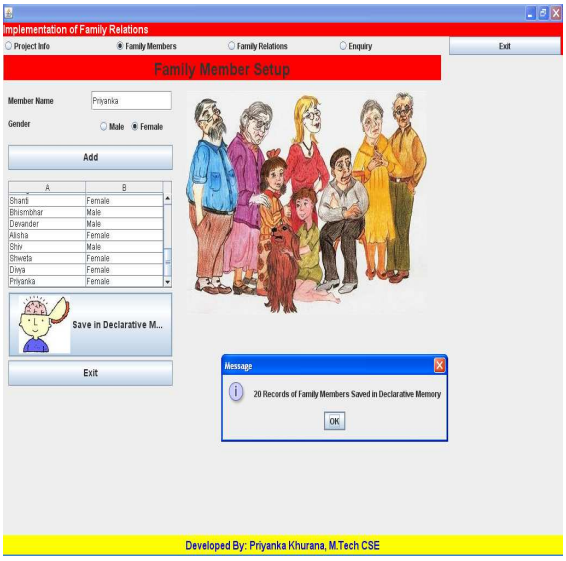

Figure 9: Snapshot of Output

3.4 RelationPanel Output

In Figure 10 relations are added and save into declarative memory of brain.

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Figure 10 Snapshot of Output

3.5 InferencingFrame Output

Figure 11 shows the inferencing of family relations. In this we can select the name of two family members and it can infer the relations between these two with the help of pattern matching process in procedural memory.

Figure 11 Snapshot of Output

4. Conclusion

Language understanding and generation are based upon an individual's memorization capability with specific parts of brain dealing with specific tasks in language processing. To understand this process of human cognition various cognition models relating to memorization and comprehension processes have been studied. On the basis of these models, a model for language understanding and generation process has been proposed and the working of ACT-R6 is implemented on an application of computations of family relations in a typical north Indian family. The working of brain has been simulated by developing various modules like MainForm, ProjectInfoPanel, FamilyPanel, RelationPanel and InferencingFrame. MainForm act as an interface whereas ProjectInfoPanel shows, how a cognitive architecture ACT-R works. FamilyPanel form is used to store member name and gender, after adding this it save this information into declarative memory of brain. In RelationPanel the relations are added and save into declarative memory of brain. After that the InferencingFrame is used to infer the relations between two family members with the help of pattern matching process in procedural memory and shows the results.

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