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Analysis Process in Problem Solving Based on Mental Model

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Abstract:
Problem solving process to discover the correct sequence ways that lead to a solution. Scientists identified four steps in problem solving. This process that requires practical experience and mental capabilities. This article is an attempt to study mind's response encountering problems and the way they are analysed to be solved، based on mental model and perception. Therefore an analysis cylce in the form of conceptual model is recommended. Regarding the symplification of the perception process, the analysis cycle is expanded to different levels and various mental models resulted from the cycle. Then by studying model of critique, uncovering, comparison, and adaptation (CECA) and conforming it to the analysis cylce according to their things in common, we will present a model for solving the problems.

Keywords: *Analysis, problem solving, mental model, feature selection, feature extraction.*

1. Introduction

Through the past, scientists believed that there is a conventional solution for any problem so that once having a certain goal; all the issues can be solved using common algorithms, functionalities, and modeling. Yet some np-hard kind of problems have been cited with quite different structure and dimension considered to be complicated and vague having so many influential input and parameters and no explicit relationship between their elements which do not have a certain goal and there is no clear practical solution for them. It seems that a more appropriate solution can be recommended to solve these problems based on cognitive paradigm founded on overcoming complexity. For this purpose, the way human mind confronts such problems and the way it analyzes can be highly inspiring.

The most important way human communicate with their environment is their five senses. To recognize the world around, received data via five senses should be processed in the form of problem solving. So that after receiving data from the environment, analyze process will be applied on mentioned data to determine an approach in different stages in order to transit from current state to desired state. These stages include uncovering features, understanding relationships, and generating certain mental structures. A cognitive model can be proposed to percept and analyze the environment through surveying the way human mind works and understanding its organizing principles in analysis method and problem solving. Now it can be pointed that agents with human-like capacities can be generated as this model can be applied on agents.

There are four main steps in problem solving: uncovering and understanding the issue, selecting solution, implementing the solution, receiving feedback and modifying data (G. Dennis Beecroft, Grace L. Duffy, and John W. Moran, 2003) which all take place through a determined mental process. Thus, an approach can be cited to find out the analysis method in these steps of problem solving. In uncovering step, environmental stimuli received through human interacting with the world around should be considered as data for the first step of getting aware of problem existence through cognition process. Here, awareness of these stimuli begins with attention via intelligent observation on the whole received data. It holds that in the first level of surveying the problem, data analysis occurs in the form of focusing on more prominent stimuli through division of whole received into smaller components to be processed easier.

To have a better understanding, Herbert Simon's rationality (Herbert A. Simon, 2010) rule can be expressed saying that human mind does not have required capabilities to recognize the world directly. Therefore, confronting environment, it builds a pattern from outside reality (mental model) and applies the process on that so cognition and analysis will be done based on this mental model. Considering that problem solving process is one of the most complicated parts of thinking and also mental model is a description of thinking process in recognizing the world around, it would be perceived that there should be a relationship between problem solving process and mental model. In this paper, it is tried to survey analysis method in understanding the issues in order to solve them based on mental model to find out what processes are happening while facing a problem to be solved. This way, the relationship between perception and mental models can be revealed considering that human mind is solving problems through processing received data

which has been done in the first step by perceptual process. Information sent by sense organs to the brain, are separate, different, and meaningless. They shape as an integrated whole during perceptual process. In order to understand noticed information, analysis process is organized and interpreted through breaking the whole into the elements and their relationships among based on its mental models. In this paper, different steps of analysis including data analysis, feature analysis through selection and fusion to extract feature, analysis of features' relationships and structures, and ultimately organizing and interpreting information during perceptual processes and generating mental model are supposed to be studied. These steps contain uncovering and understanding the issue which by surveying CECA model in the step of selecting solution based on recognizing relationships, a method is allocated for problem solving and then it will be implemented.

Continuing the paper in the second section, definition of analysis in different fields is surveyed and different levels of analysis are studied. Afterwards, definitions of feature selection and extraction are presented in the third section. Then in the fourth section, the process of analysis is surveyed as feature selection and extraction and a perceptual model is proposed based on its relationship with perception and mental model. Subsequently a comparison is done between proposed model and CECA model in the fifth section and at last, based on a cognitive approach- a model will be presented in the method of problem solving through adaption of the proposed model.

2. Definition of Analysis & Level of Analysis in Cognitive Science

To have a better understanding of analysis process in this section, different definitions are going to be surveyed in different fields. Since studying a special phenomenon in different levels can bring a deeper understanding, levels of analysis are presented due to David Marr.

2.1. Definition of Analysis

1. Analysis is the process of breaking a complex topic or substance into smaller parts in order to gain a better understanding of it (Michael Beaney, 2012).
2. Analysis refers to the ability to break down material into its component parts so that its organizational structure may be understood. This may include the identification of the parts, analysis of the relationship between parts, and recognition of the organizational principles involved (Norman Herr, 2008).
3. Analysis is the process of breaking down a something into its parts to learn what they do and how they relate to one another (Your Dictionary definition and usage example, 2015).
4. a separating or breaking up of any whole into its parts, esp. with an examination of these parts to find out their nature, proportion, function, interrelationship, etc. (Your Dictionary definition and usage example, 2015).
5. Analysis is a higher CP of the brain at the higher cognitive layer that divides a physical or abstract object into its constitute parts in order to examine or determine their relationship deductively (Ying Wang, Shushma Patel, and Dilip Patel, 2006).
6. A systematic examination and evaluation of data or information, by breaking it into its component parts to uncover their interrelationships. Opposite of synthesis (http://www.businessdictionary.com/definition/analysis.html).
7. An examination of data and facts to uncover and understand cause-effect relationships, thus providing basis for problem solving and decision making (http://www.businessdictionary.com/definition/analysis.html).
8. The division of a physical or abstract whole into its constituent parts to examine or determine their relationship or compare value synthesis (http://dictionary.reference.com/browse/analysis).
9. This process as a method of studying the nature of something or of determining its essential features and their relationships (http://dictionary.reference.com/browse/analysis).

2.2. Level of Analysis in Cognitive Science

According to David Marr, information processing systems must be understood at three distinct yet complementary levels of analysis - an analysis at one level alone is not sufficient (José Luis Bermúdez, 2010).

A. Computational

The computational level of analysis identifies what the information processing system does (e.g.: what problems does it solve or overcome) and similarly, why does it do these things.

B. Algorithmic/representational

The algorithmic/representational level of analysis identifies how the information processing system performs its computations, specifically, what representations are used and what processes are employed to build and manipulate the representations.

C. Physical/implementation

The physical level of analysis identifies how the information processing system is physically realized (in the case of biological vision, what neural structures and neuronal activities implement the visual system).

3. Feature Selection & Extraction

The output of sensors is some raw signals in need of processing to be understood. For this purpose, feature selection out of more prominent stimuli is done and feature extraction is performed through fusion of features and acknowledging a relationship between them based on the stored knowledge in the memory which generates patterns to specify data. In this section, definitions of feature selection and extraction are going to be studied in order to survey analysis method of received data in the form of these two actions.

2.1. Feature Selection

Feature selection approaches try to find a subset of the original variables (also called features or attributes). There are three strategies; filter (e.g. information gain) and wrapper (e.g. search guided by accuracy) approaches, and embedded (features are selected to add or be removed while building the model based on the prediction errors (https:// en.wikipedia.org/ wiki/ Dimensionality_reduction).

Feature selection, also known as variable selection, attribute selection or variable subset selection, is the process of selecting a subset of relevant features (variables, predictors) for use in model construction. Feature selection techniques are used for three reasons:

Simplification of models to make them easier to interpret by researchers/users, (Gareth James; Daniela Witten; Trevor Hastie; Robert Tibshirani, 2013) Shorter training times, Enhanced generalization by reducing over fitting (Bermingham, Mairead L.; Pong-Wong, Ricardo; Spiliopoulou, Athina; Hayward, Caroline; Rudan, Igor; Campbell, Harry; Wright, Alan F.; Wilson, James F.; Agakov, Felix; Navarro, Pau; Haley, Chris S., 2015) (formally, reduction of variance (Gareth James; Daniela Witten; Trevor Hastie; Robert Tibshirani, 2013)).

Through this vision, a subset of main variables of the problem called features or attributes is generated to enable separation of problem samples accurately. This method tries to reduce data dimensions through selecting a subset of primary features.

2.2. Feature Extraction

Feature extraction transforms the data in the high-dimensional space to a space of fewer dimensions. The data transformation may be linear, as in principal component analysis (PCA), but many nonlinear dimensionality reduction techniques also exist (Samet, H., 2006) (C. Ding, X. He, H. Zha, H.D. Simon, 2002).

Feature extraction is a process which in significant and prominent features are specified through applying some operations on data. In this case, the goal is to find a mapping of current features space to a space with fewer dimensions which in the least information waste (considering the separable criteria of classes) is generated. This method maps a multi-dimension space into a space with fewer dimensions. Actually, dimensions are deducted through fusion of available feature values so these features have all (or a great part of) existing information in primary features (Isabelle Guyon, Masoud Nikravesh, Steve Gunn, Lotfi A. Zadeh, 2006).

4. Analysis

A great volume of data and several variables are respectively received via communications and five senses which recognition and awareness over them is a problem human is always confronting. Perception takes place in the first step of human interaction with their environment to achieve cognition. As through the action of attention, mind focuses on stimulus or particular stimuli of the environment under some factors including size, intensity, frequency, difference, movement, change, and refreshment so that other data will not be considered to be influential. Based on this, information is received as a whole which in some of data has higher significance and all received data can be considered as the first step of problem solving to recognize that. Analysis is done as breaking this receives whole into smaller and simpler components to perceive the nature of that. Since whole is considered as a set of objects, their features and relationships, thus analysis is initially done through selecting features or the same variables determining data dimension. Hence, a subset of features is selected in the form of a model of current situation (Isabelle Tapiero, 2014) shaping a primary mental model which generates a pattern of the world around and diminishes the reality with high data dimensions into a model in mind with fewer such dimensions. In the next step, regarding to the stored knowledge in long-term memory and comparing with that, a relationship among features is extracted based on deduction and based on that, features fusion can be done. Therefore, the operation of feature extraction is done through their fusion in order to reduce variables to present a simpler model. This fusion is also done based on existing schemas, experiences, and knowledge within the mind. Relationships are defined for features, and afterwards, they are represented as a chain of reality existence, feature, and relationship. The output of this step of analysis is a call for long-term memory, breaking relationships, and fetching them which is assigned to features. In this regard, features are combined and interpretation and conceptualization based on former experience and knowledge produce a mental model of a higher level which in information is conceptualized and perceiving the problem occurs based on that. The steps of analysis can be considered as division, separating, specification, selection, and comparison which are as generating distinction among important features with the least important ones, organizing them, and relating them subsequently. Based on aforementioned explanations, a model for cycle of analysis has been proposed in figure 1.

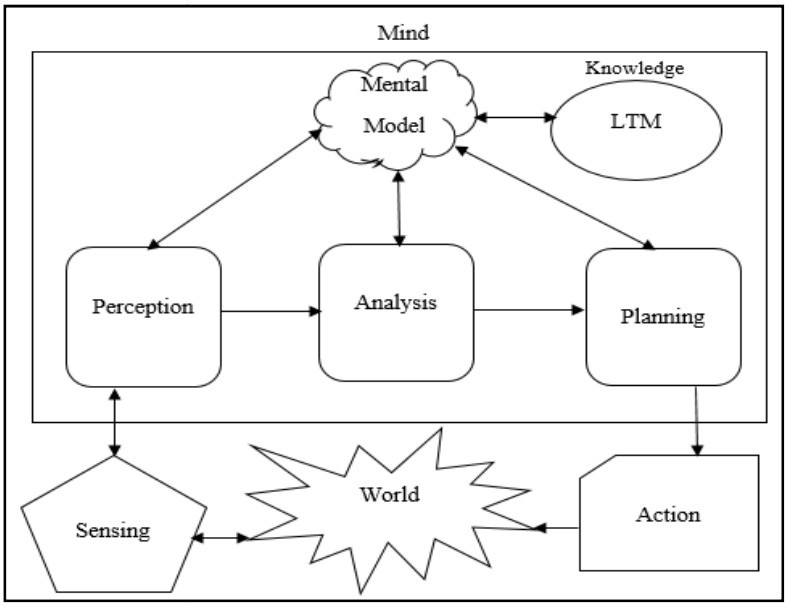

Figure 1: Cycle of Analysis

Previous studies on perception (Somayeh Mohammadi, Touraj Banirostam, 2015) shows that this complex process in done through different steps that each can be considered in a separate level to be better understood. So a perceptual formula is considered in three levels of sensing perception, logical perception, and meaning perception (Somayeh Mohammadi, Touraj Banirostam, 2015) has been illustrated in figure 2.

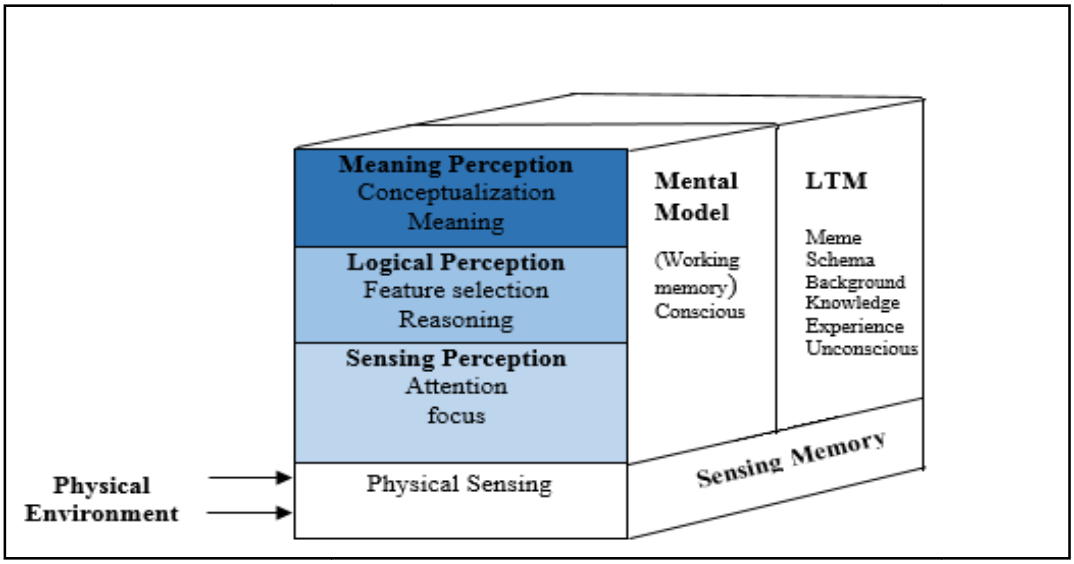

Figure 2: Meta Model of Perception

Since analysis process occurs after perception, and in order to simplification and better understanding, analysis also can be considered in relationship with different layers of perception in different steps. Regarding this point that focus and attention are done in sensing perception layer which can lead to behavior generation at once as a kind of action and reaction, the level of analysis taking place in this step can be called simple analysis including separation, distinction, and specification. Since mental models can be addressed as the result of perception, so a relationship is coming up between mental model and perception after analysis. In the first level of analysis, mental model is generated as a cognitive map. Afterwards, analysis process is done as feature selection and a primary mental model is shaped based on selected features so that this second phase can be called selection analysis. Comparing these features in terms of similarity, difference, and proximity leads to generation of logical perception layer. Regarding to former experiences and knowledge, some relationships can be pointed among mentioned features to be combined in order to feature extraction. The output of this step is a high level mental model which in conceptualization takes place and based on this action, perception occurs semantically. So the third phase of analysis -breaking relationships and allocating them- can be considered as relational analysis. This process has been demonstrated as a developed model of analysis in figure 3.

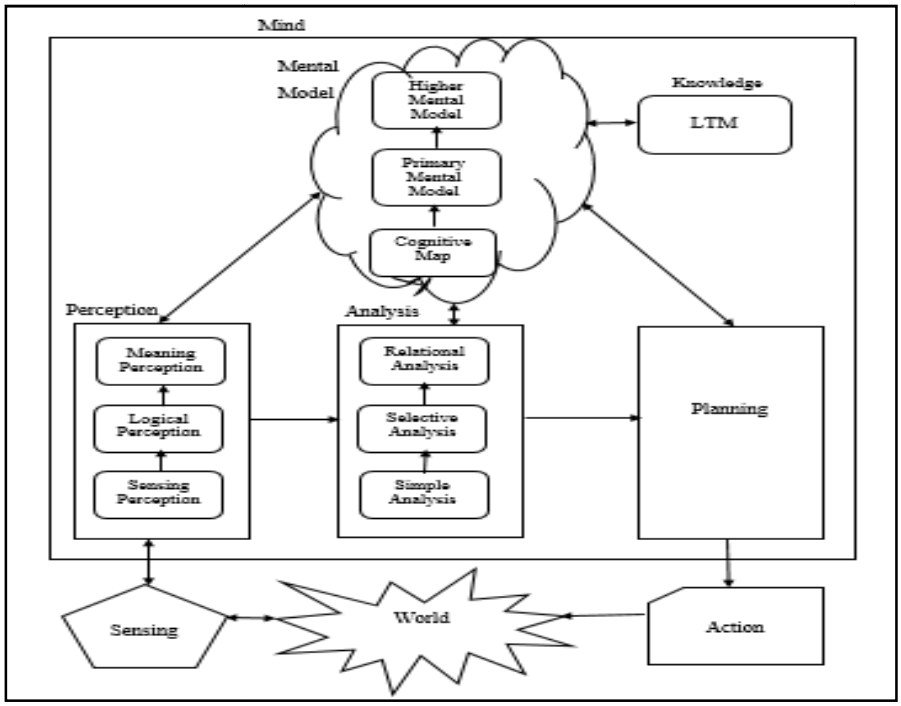

Figure 3: Development of Analysis

5. Compare the Proposed Model with CECA Model

CECA model or model of critique, uncovering, comparison, and adaptation has been presented by Brayant (2004) citing human key actions in selecting a solution out of available ones. This model presents a simple representation of estimating situation and process. Information requirements are also fixed in critique phase. For this purpose, some questions are noticed in respect of sensitive and key dimensions of mental model's goals which using these questions, required data can be specified. Consequently, information that should be provided in sensor level is determined which is called directed telescope. This telescope is used in uncovering phase and is in charge of active and passive data gathering from the environment. Criteria of environmental input sensors filtering depend on conceptual model. Gathered information is used to generate and update situation model. In comparison phase, situation model is compared with conceptual model. This comparison is to determine invalid or incompatible dimensions of conceptual model with current situation model. Based on the differences between situation and conceptual model, conceptual model needs some modifications depending on decision maker's point of view to find the appropriate response to incompatibility of these two models. This process takes place in adaptation phase. If the difference is not significant, incompatibility will be ignored or tools and methods to reach the solution will be changed so it can be said that most of assumptions related to concept model are wrong and solution should be changed. This model has been shown in figure 4.

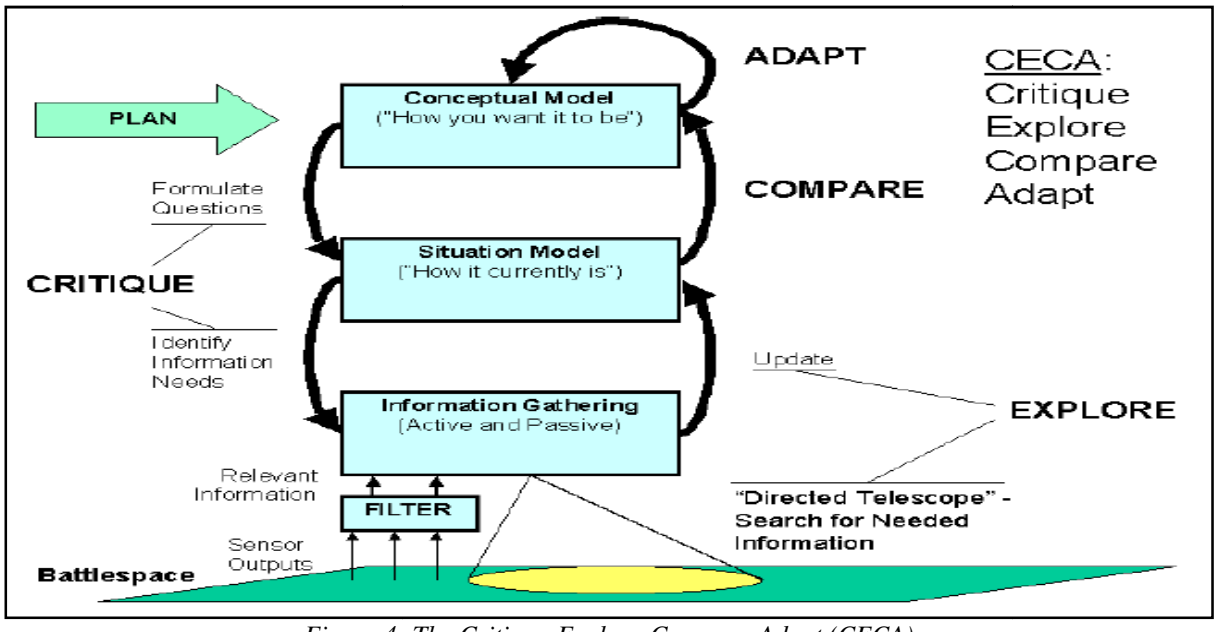

Figure 4: The Critique-Explore-Compare-Adapt (CECA)

Due to how different parts of CECA model works, uncovering phase can be considered to be the same as human perception process. A primary mental model is generated out of data based on analysis by gathered and filtered information which is equal to situation model in CECA. After that, analysis as breaking relationships and relating them to features of former experiences and knowledge leads to generating a high level mental model which also can be noticed as concept model in CECA. Critique identity required information and formulated questions phase is the one which is studied based on definitions and analysis method having the same function. It is based on problem solving process including finding effective solutions or compatible with the problem that occurs after the step of uncovering and perceiving the issue. On this section, solution analysis method which ultimately results in selecting one of them is going to be surveyed. So that after uncovering the issue taking place after perception in problem solving, is generated as a model of current situation based on selecting mental model's feature. Understanding the issue occurs through specifying data and perceiving the relationship among them and the structures based on former experiences and knowledge and schema takes place as generating a high level mental model. Considering CECA adapted model on cycle of analysis, if the difference between situation model and mental model was insignificant and generally two models were similar, adaptation would occur and mental model could be considered as the basis of decision-making and solution. But in case of difference between mental model and situation model, progressive chain would be made and mental model would be updated and a new solution would be generated. Hence CECA adaptation model on analysis cycle has been presented in figure 5.

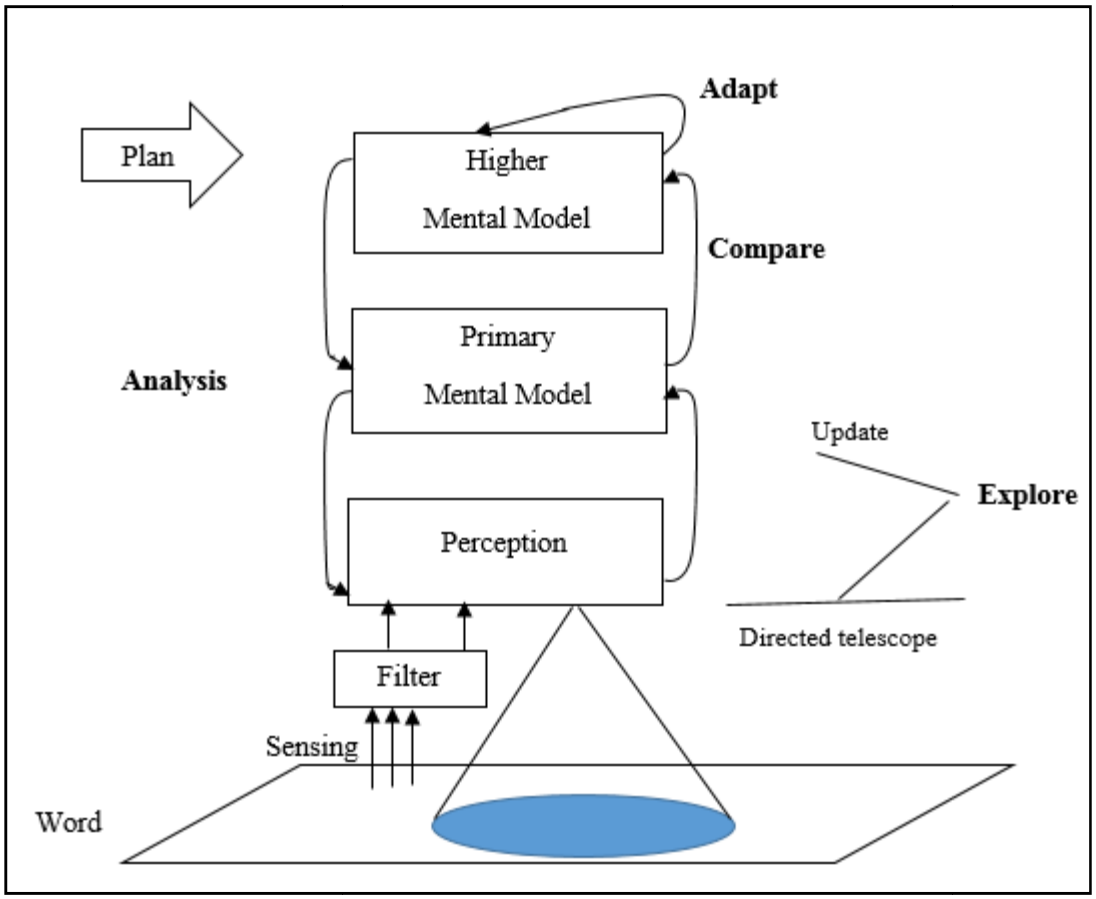

Figure 5: Adapted CECA on Cycle of Analysis Model

Based on the generated mental model as a result of analysis after perception process, different solutions are produced in problem solving. Regarding to adaptation of analysis cycle on CECA model, the appropriate techniques of selecting solutions are surveyed through comparison with conceptual model generated in mind which in case of their similarity, the appropriate approach would be determined for problem solving. Otherwise, based on received data, perception process and building up mental model out of situation in order to uncover and understanding the issue would occur once again and conceptual model should be updated by this new information. Then a comparison will be done between generated mental model which came out of new situation and the updated conceptual model in order to select an appropriate solution.

6. Conclusion

This paper has presented a method in np-hard problem solving and their analysis techniques with cognitive approach based on the function of mind which contains uncovering and perceiving the issue, selecting solution, implementing solution, feedback, and modifying achievements. For this purpose, process of analysis can be considered as breaking received whole to smaller parts, attention and focus on perception. In order to process information, two actions of feature selection and extraction are done which as their result,

mental model is generated making possible to uncover and understand the issue. Cycle of analysis is expanded due to simplification of perception process into different levels which leads to generation of different mental models. Afterwards, CECA model has been studied and adapted on cycle of analysis model to express analysis techniques in selecting solution. This model can be applied on cognitive agents in solving complicated issues.

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