Cognitive information models

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Abstract. This article describes cognitive information models. The cognitive information model is compared to the information model and the intellectual model. Formal description of the models is provided. Cognitive information processing system and its subsystems are described. It is shown that cognitive information models are the result of synthesis of cognitive science and information science. It is shown that cognitive information model complements information and intellectual model in the whole complex of outside world cognition.
[Tsvetkov V.Y. **Cognitive information models.** *Life Sci J* 2014;11(4):468-471] (ISSN:1097-8135). http://www.lifesciencesite.com. 68

Keywords: model, cognitive science, information models, cognitive models, intellectual models, first-order tasks, tasks of the second kind.

Introduction

Currently, in a number of sciences (artificial intelligence, education, computers science, management, etc.) the areas that use cognitive science methods are developed intensively [1]. Cognitive science is the science "about thinking", or a science that "studies and models the principles of organization and operation of natural and artificial intelligence systems". The Latin root cognito («co» - together and «gnoscere» - know) means cognition of a certain system or system image [2]. Reverse process occurs as well - enrichment of cognitive science using methods of sciences interacting with it. Therefore, contemporary cognitive science is an interdisciplinary area that covers the following: artificial intelligence, psychology, linguistics, anthropology, neurosciences and education. Cognitive science relies on five basic notions: knowledge representation, speech-and-language, learning, thinking and perception [3].

Methods

The method is in clarifying cognitive concepts in relation to computer sciences, comparison of information and intellectual models and development of the cognitive information model concept on this basis. The method involves the analysis of obtaining a cognitive information model based on the use of cognitive information processing system.

Main part

There are concepts like cognitive processes and technology, cognitive analysis [4].

Cognitive technologies are technologies for cognition that use data about cognition processes, learning, communication, information processing by humans and animals, for characterization of neurosciences, for the theory of self-organization, computer information technologies, mathematical modeling elements of perception, and several other scientific areas [7].

Cognitive analysis is an analysis based on a consistent structuring of information and models based on cognitive methods.

Interaction of cognitive science and computer science resulted in information approach in cognitive science.

Information approach in cognitive science is the kind of cognitive approach that uses tools of computer science, information models, information units and information technology. The feature of the information approach in cognitive science is formalization of cognitive processes in terms of the processes of information interaction, in terms of information models, in terms of information units. This ensures accuracy and specificity of theoretical descriptions and makes it easy to verify models. At the same time, the requirement of modeling formalization in some cases makes it obligatory to simplify models and avoid describing complex phenomena. In addition, the information approach ignores features of the human psyche.

Common but not the only variant of information approach is symbolic approach that understands the human cognitive system as handling discrete pieces of information, i.e., characters. A newer trend is connectionism (from English "connection") that describes a cognitive system as a network of interconnected elements. A still newer trend is handling information semantics [5], and semantic information units [6].

Information approach in psychology closely interacts with research in artificial intelligence and neurosciences. However, unlike artificial intelligence, its basis is in experimental method, and unlike

neurosciences, it is not mandatory that the introduced elements of a cognitive system correspond to the physiological substrate [7]. Information approach is an important part of the cognitive approach, but these two approaches should not be considered identical [8].

This permits to speak of a difference between information models [9], cognitive information models and intellectual models [10].

Information model (Im) is a targeted formalized representation of an existing object, or collection of objects, of reality using a system of interconnected, identifiable, informatively defined parameters, reflecting not only basic properties of simulation objects but also the most important connections and relationships between them and the environment [9].

$$Im=F(A, Cn, Re) \quad (1)$$

A means identifiable, information-defined parameters; Cn means substantial connections; and Re - substantial relationships.

Information model provides a formalized representation of used data and their interrelations. Information model is a generalized manifold concept. For one object, depending on the choice of the consideration aspect, several information models may be built.

Intellectual model (Int) is a targeted formalized representation of reality with the use of a system of interrelated parameters, descriptions of connections and relationships, system of interrelated inference rules and the mechanism of adaptation to changing environment.

$$Int=F(A, Cn, Re, Pr, Am) \quad (2)$$

A means identifiable, information-defined parameters; Cn means substantial connection; Re means substantial relationships; Pr means inference rules (production); and Am means mechanism of adaptation to changing environment.

Cognitive information model (Cim) is a targeted formalized representation of an existing object, or collection of objects, of reality using a system of interconnected, identifiable, fully and partially defined parameters of information that reflects the most significant connections and relationships, and incorporates interaction mechanism between the subject and the object

$$Cim =F(AI, ANI, Cn, Re, SOm) \quad (3)$$

AI means identifiable, information-defined parameters; ANI means identifiable, non information-defined parameters; Cn means substantial connections; Re means substantial relationship; and SOm means the interaction mechanism between the subject and the object.

The cognitive information model (3) takes an intermediate position between an information model (1) and an intellectual model (2). It includes non information-defined parameters, i.e., poorly structured information. The cognitive information model includes the interaction mechanism between the subject and the object, which is an imperfect analogue of inference rule and the mechanism of adaptation to the environment in an intellectual model. Cognitive information model includes a human-centric part and a part focused on computer processing.

The common between the three models is the use of information units [6], as the basis for building any model.

The cognitive information model includes a subject, system and interface levels of description. The subject level of description is related to subject area of model application. This description level is independent of the research object. It describes the environment and the information situation [11].

The system description level is associated with the research object as a complex system. It is primarily defined by characteristics of research object characteristics.

The interface level of description is associated with the mechanism of interaction between the subject and the object. It substantially depends on the language used for description [12]. This level largely determines the results of using the cognitive information model. However, this feature results in subjectivity of this approach, unlike using intelligent models [13].

When using cognitive approach, data from the outside world are perceived by the human through sensory receptors and after that are placed to short-term memory buffer for analysis [8]. The other domain of the memory (long-term memory) stores symbols and semantic connections between them, which are used for explaining new information from short-term memory. Long-term memory stores objects and connections between them, i.e. symbolic images, rather than facts and data. Large volumes of data are constantly recorded into short-term memory, and the subject analyzes the information it receives in order to find out how important it is and how it relates to the images that are stored in the long-term memory.

Cognitive processing of information is performed in three subsystems (Fig. 1). They determine the result of processing, i.e., the cognitive information model.

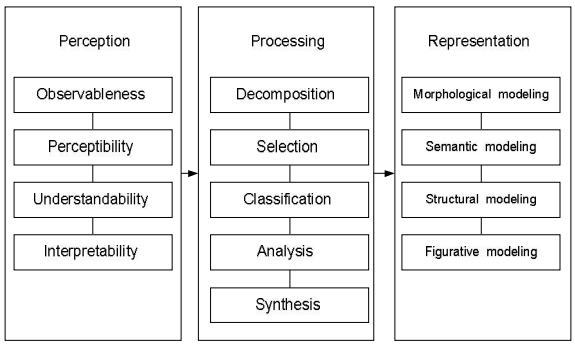

Fig.1. Three subsystems of cognitive information processing

The three subsystems of cognitive information processing can be described as follows. The first subsystem, "perception", analyzes properties of the object being studied. Cognitive factors in it play a defining role. They are represented by a set of corresponding characteristics. If it satisfies certain requirements of the first subsystem, the information is sent to the second subsystem.

The second subsystem, "processing", processes information about the object being studied. In this subsystem cognitive factors are represented weaker than in the first one. In the second subsystem, the algorithmic factor plays the main role. After processing the information should be submitted in a form readable to the human.

The third subsystem, "representation" converts the results of information processing into a user-defined form. In this subsystem, cognitive factors are also important. Each subsystem processes the information from top downwards, and the whole process goes from the left to the right.

In the first and the third subsystems, cognitive factors play the main role. In the second one, the main is the factor of information processing. As a whole, this results in creating a cognitive information model.

When studying an arbitrary object, the human creates its cognitive information model that should meet the basic properties within the analysis properties subsystem. Since visualization is a property of human cognition, there is an analogy between spatial models [14] and cognitive information models. Hence, properties of cognitive models are closely related to information perception as a spatial object.

Readability is the property of a cognitive model that lies in the fact that the human is able to view a set of parameters and relationships within the study, as a whole. If the object is not readable, either the readable part of it is studied, or the analysis is terminated [14].

Perceptibility is the property of cognitive models that lies in the fact that the human can perceive this model as a reflection of objective reality. [14] If the model is not readable or not perceptible, it is usually discarded and not used by the human. Presence of information asymmetry between managers and executives leads to the fact that managers often reject a new model that they cannot understand.

Comprehensibility is the property of cognitive models, lying in the fact that the human can perceive and understand the model by its nature, functions, purpose and intended use. If the model is not comprehensible, it is usually discarded and not used by the human.

Interpretability is the property of a cognitive model, lying in the fact that the subject can interpret the model and its behavior using the means at his disposal. [14] Interpretability depends greatly on researcher's intelligence.

One can continue this series of object of study model properties. In fig. 1, main properties are shown.

Once a cognitive model of the object has been checked for compliance with the basic properties of the first subsystem, it is sent to the second subsystem, i.e., the processing subsystem. Classical processing includes the following steps: decomposition, selection, classification, analysis and synthesis [15].

The third subsystem for cognitive information processing finally forms the cognitive information model. It includes various types of modeling: morphological modeling, semantic modeling, structural modeling, descriptive modeling, etc.

Information model can be called algorithmic, since it makes it possible to process information according to the known algorithms without human intervention. This makes it possible to solve first-order tasks whose scheme looks like

$$K_P \rightarrow K_T \quad (4)$$

whereas KP is the initial state of the object model (problem situation model); Kt is the model of desired state of the object (problem solution model).

The cognitive information model can be called heuristic, since it makes it possible to process information for cases where a direct solution using a single algorithm is impossible.

Such problems recalled problems of the second kind. They have another solution scheme. If the goal cannot be achieved through one solution cycle, the solution for the problem can be decomposed into individual actions and generally presented as a sequence of the following actions:

$$K_P \rightarrow d1(K_P) \rightarrow K_1 \rightarrow d2(K_1) \rightarrow K_2 \rightarrow d3(K_2) \rightarrow K_3 \rightarrow K_T \quad (5)$$

The sequence of action of a cognitive solving system <d1, d2, ..., dn> is the way of solving a second kind problem. Upon completion of each step of the solution, analysis of the solution takes place. Basing on the analysis, the next step is chosen, and so on, until the final solution to the problem is found. This heuristic procedure is based on cognitive processes.

Conclusion

The cognitive information model is a relatively new concept in the computer science. Interaction of information science and cognitive science provides a new step to the development of both.

The use of the cognitive information model extends possibilities to study the outside world. The cognitive information model is efficient for processing cases of poorly structured information, as well as for solving problems of the second kind. The cognitive information model complements information and intellectual model, being a tool for exploring the outside world. The cognitive information model promotes development of intellectual models and research in the area of artificial intelligence.

Acknowledgments

The author expresses his gratitude to the RAS Academician A.S. Sigov and Professor I. V. Solovyov for discussing this article.

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