Chapter 2
The Cognitive Process of Comprehension: A Formal Description

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ABSTRACT

Comprehension is an ability to understand the meaning of a concept or an action. Comprehension is an important intelligent power of abstract thought and reasoning of humans or intelligent systems. It is highly curious to explore the internal process of comprehension in the brain and to explain its basic mechanisms in cognitive informatics and computational intelligence. This paper presents a formal model of the cognitive process of comprehension. The mechanism and process of comprehension are systematically explained with its conceptual, mathematical, and process models based on the Layered Reference Model of the Brain (LRMB) and the Object-Attribute-Relation (OAR) model for internal knowledge representation. Contemporary denotational mathematics such as concept algebra and Real-Time Process Algebra (RTPA) are adopted in order to formally describe the comprehension process and its interaction with other cognitive processes of the brain.

INTRODUCTION

Despite of several-decade advances in computer science and artificial intelligence (AI), computers are still passive machines (Wilson & Keil, 2001; Wang, 2002a, 2009b). However, human beings are much active and intelligent in problem solving and decision-making, although they are not good at memory and retrieving of information. In general, computers can store a huge amount of data efficiently; while human beings make sense of or comprehend them in order to make them useful for the society and everyday lives.

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Cognitive Informatics (CI) is a new and interdisciplinary research area that studies how information is processed and represented by human brain and how this knowledge can be applied in computing and information sciences (Wang, 2002a, 2003, 2007b; Wang, Kinsner, & Zhang, 2009; Wang et al., 2009). Cognitive informatics treats the natural world as a triple $<I, E, M>$ where I is information, E energy, and M matter. *Information* is used to model the abstract world, whereas *energy* and *matter* are used to model the physical world. A Layered Reference Model of the Brain (LRMB) is developed in (Wang et al., 2006) that identified 43 cognitive processes at seven layers known as the sensation, memory, perception, action, meta-cognitive, meta-inference, and higher cognitive layers from the bottom up.

In cognitive informatics, cognitive science, AI, and computational intelligence, comprehension is identified as an ability to understand something, which indicates an intelligent power of abstract thought and reasoning of humans or intelligent systems. It is curious to explore the internal process of comprehension in the brain and to explain its basic mechanisms, because comprehension is one of the fundamental processes of brain at the higher cognitive layer according to LRMB. Two denotational mathematical means known as concept algebra (Wang, 2008c) and Real-Time Process Algebra (RTPA) (Wang, 2002b, 2007a) will be introduced in order to formally deal with the modeling of the highly abstract cognitive entity and process of comprehension and other cognitive processes.

This paper attempts to build a formal model for the fundamental cognitive process of comprehension. The mechanism and process of comprehension are systematically explained with its conceptual, mathematical, and process models. The paper discusses the conceptual model of comprehension in cognitive informatics and cognitive psychology based on the computational, functional, and cognitive models of the brain developed in (Wang & Wang, 2007). The Object-Attribute-Relation (OAR) model for internal knowledge representation (Wang, 2007c) and concept algebra are introduced, which forms a foundation for explaining the cognitive mechanisms of comprehension. The mathematical model of comprehension is developed based on OAR and concept algebra. Then, comprehension as a cognitive process is conceptually elaborated and formally modeled in RTPA, which provides a rigorous description of the comprehension process and its interaction with other cognitive processes of the brain.

THE CONCEPTUAL MODEL OF COMPREHENSION

The linguistic meaning of *comprehension* is an ability to understand the meaning of a concept or an action based on the intelligent power of abstract thought and reasoning. The basic unit of comprehension is a concept (Wallas, 1926; Hurley, 1997; Ganter & Wille, 1999; Wang, 2008c). Therefore, large scope comprehension at sentence and article levels may be analyzed and synthesized by concept-level comprehensions from the top down or the bottom up.

Concepts, Semantics, and Comprehension

The conceptual mode of comprehension to a given concept can be described by the analysis of the intension and extension of the concept and its relations to the entire knowledge of a person in term of an OAR model.

Definition 1. A *concept* is a basic cognitive unit to identify and/or model a real-world concrete entity and a perceived-world abstract subject.

A *concept* in linguistics is a noun or noun-phrase that serves as the subject of a *to-be* statement (Hurley, 1997; Ganter & Wille, 1999; Wang,