Formal RTPA Models for a Set of Meta-Cognitive Processes of the Brain

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ABSTRACT

The cognitive processes modeled at the metacognitive level of the layered reference mode of the brain (LRMB) encompass those of object identification, abstraction, concept establishment, search, categorization, comparison, memorization, qualification, quantification, and selection. It is recognized that all higher layer cognitive processes of the brain rely on the metacognitive processes. Each of this set of fundamental cognitive processes is formally described by a mathematical model and a process model. Real-time process algebra (RTPA) is adopted as a denotational mathematical means for rigorous modeling and describing the metacognitive processes. All cognitive models and processes are explained on the basis of the object-attribute-relation (OAR) model for internal information and knowledge representation and manipulation.

Keywords: abstraction; brain model; categorization; cognitive processes; computational intelligence; comparison; concept algebra; concept establishment; denotational mathematics; LRMB; mathematical model; object identification; OAR; process model; qualification; quantification; RTPA

INTRODUCTION

A layered reference model of the brain (LRMB) is developed in order to investigate the fundamental mechanisms of the brain as well as natural and computational intelligence (Wang, 2007c; Wang, Wang, Patel, & Patel, 2006). LRMB reveals that the brain is functioning with 39 fundamental cognitive processes in seven layers known as the sensation, memory, perception, action, metacognition, meta-inference, and higher cognition layers from the bottom up. The metacognitive-process layer as modeled in LRMB is one of the crucial layers of the brain because almost all higher layer cognitive processes rely on it (Gray, 1994; Matlin, 1998; Pinel, 1997; Reisberg, 2001; Smith, 1993; Wang, 2007c; Wang et al.; Westen, 1999; Wilson & Keil, 2001).

Definition 1. A meta-cognitive function of the brain is a fundamental and elementary life function of the brain that is commonly used to support the higher layer cognitive life functions.
The metacognitive functions at Layer 5 of LRMB encompass the basic cognitive life functions of object identification, abstraction, concept establishment, search, categorization, comparison, memorization, qualification, quantification, and selection, as described in Figure 1.

The modeling of LRMB is a part of the development of the theoretical framework of cognitive informatics (Wang, 2002a, 2003a, 2006a, 2007c; Wang et al., 2006). The methodologies and denotational mathematics (Wang, 2007d, in press) adopted in this article are concept algebra (Wang, 2008c) and real-time process algebra (RTPA; Wang, 2002b, 2003b, 2007d, 2008d). The former is used to denote the mathematical model and algebraic operations of concept as the basic unit of thinking and inferences. The latter is adopted as the mathematical means for rigorously modeling and describing cognitive processes as a series of dynamic actions and behaviors.

This article presents a set of formal descriptions of the eight metacognitive processes at Layer 5 as shown in Figure 1. Two of the ten metacognition processes, that is, the cognitive processes of abstraction and memorization, have been presented in Wang (2007a) and Wang (2007b), respectively. In the following sections, the mathematical model of each metaprocess will be created, and its cognitive process will be rigorously described in RTPA. All cognitive models and processes are explained on the basis of the object-attribute-relation (OAR) model (Wang, 2007c; Wang, Liu, & Wang, 2003; Wang & Wang, 2006) for internal information and knowledge representation.

**THE COGNITIVE PROCESS OF OBJECT IDENTIFICATION**

According to LRMB, object identification is a cognitive process of the brain at the metacognition layer that identifies an object by relating it to a concept or comprehends a concept by known meanings. An object and its attributes as well as relations can be defined as follows.

**Definition 2.** An object \( o \) is a representation of an entity in the real world and/or a concept in the abstract world.

**Definition 3.** An attribute \( a \) is a subconcept that is used to characterize the properties of a given concept by more specific or precise concepts in the abstract hierarchy.

**Definition 4.** A relation \( r \) is an association or interrelationship between any pair of objects, an object and an attribute, an attribute and an object, and/or attributes.

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*Figure 1. Cognitive processes at the metacognition layer of LRMB*