The OAR Model of Neural Informatics for Internal Knowledge Representation in the Brain

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ABSTRACT

The cognitive models of information representation are fundamental research areas in cognitive informatics, which attempts to reveal the mechanisms and potential of the brain in learning and knowledge representation. Because memory is the foundation of all forms of natural intelligence, a generic model of memory, particularly the long-term memory, may explain the fundamental mechanism of internal information representation and the forms of learning results. This article presents the Object-Attribute-Relation (OAR) model to formally represent the structures of internal information and knowledge acquired and learned in the brain. The neural informatics model of human memory is introduced with particular focus on the long-term memory. Then, the OAR model that explains the mechanisms of internal knowledge and information representation in the brain is formally described, and the physical and physiological meanings of this model are explained. Based on the OAR model, knowledge structures and learning mechanisms are rigorously explained. Further, the magnitude of human memory capacity is rigorously estimated on the basis of OAR, by which the memory capacity is derived to be in the order of $10^{432}$ bits.

Keywords: AI; cognitive informatics; cognitive models of the brain; intelligence science; internal information representation; knowledge engineering; knowledge representation; learning mechanisms; memory architecture; memory capacity; natural intelligence; neural informatics; OAR model; software engineering

INTRODUCTION

Cognitive models of internal information and knowledge presentation in human brains are fundamental issues in cognitive informatics, neuropsychology, cognitive science, computing, software engineering, and knowledge engineering. It is identified that the number of neurons in an adult brain is in the order of 100 billion ($10^{11}$), and each neuron is connected to a large number of other neurons via several hundred to a few thousand synapses (Marieb, 1992; Pinel, 1997; Rosenzweig, Leiman, & Breedlove, 1999; Smith, 1993; Sternberg, 1998). However, the magnitude of memory capacity of human brains is still a mystery. This is mainly because the estimation of this factor is highly dependent on suitable cognitive and mathematical models of the brain, particularly how information and
knowledge are represented and stored in the memory.

It is commonly understood that memory is the foundation of all forms of natural intelligence. Although the magnitude of the neural networks and their concurrent behaviors are extremely powerful as a whole, the elementary function and mechanism of the brain are quite simple (Gabrieli, 1998; Harnish, 2002; Kotulak, 1997; Leahy, 1997; Matlin, 1998; Payne & Wenger, 1998; Turing, 1936). This view can be formally stated in the following theorem and explained in the mathematical models of human memory developed throughout this article.

- **Theorem 1:** The quantitative advantage of human brain states that the magnitude of the memory capacity of the brain is tremendously larger than that of the closest species; the qualitative advantage of human brain states that the possession of the abstract layer of memory and the abstract reasoning capacity makes human brain profoundly powerful on the basis of the quantitative advantage.

This article presents the OAR model to formally represent the structures of internal information and knowledge acquired and learned in the brain. The neural informatics model of human memory is introduced, and particular focus is put on the long-term memory and action buffer memory. Then, the OAR model that explains the mechanisms of internal knowledge and information representation in the brain is rigorously explained. Based on the OAR model, knowledge structures and learning mechanisms are rigorously explained. Further, the magnitude of human memory capacity is estimated on the basis of OAR, by which the memory capacity is rigorously derived.

**Neural Informatics Models of Memory**

The human memory encompasses the sensory buffer memory, the short-term memory, the long-term memory (Baddeley, 1990; Rosenzweig et al., 1999; Smith, 1993; Squire, Knowlton, & Musen, 1993; Sternberg, 1998), and the action buffer memory (Wang & Wang, 2006; Wang, Wang, Patel, & Patel, 2006). Among these memories, the Long-Term Memory (LTM) is the permanent memory that human beings rely on for storing acquired information such as facts, knowledge, experiences, and part of skills and behaviors. For the latter, the main parts of skills and behaviors are stored in the action-buffer memory as logically modeled by Wang and Wang (2006), which is interconnected with the motor servo muscles.

An important theory of NeI pertains to the architecture of the memories in the brain as described next.

- **Definition 2:** The Cognitive Models of Memory (CMM) state that the architecture of human memory is parallel configured by the Sensory Buffer Memory (SBM), Short-Term Memory (STM), Long-Term Memory, and Action-Buffer Memory (ABM), that is:

\[
\text{CMM} \triangleq \text{SBM} \parallel \text{STM} \parallel \text{LTM} \parallel \text{ABM} \quad (1)
\]

where the ABM is newly identified by Wang and Wang (2006).
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