

Chapter 8

A Computational Simulation of the Cognitive Process of Children Knowledge Acquisition and Memory Development

Jeff Bancroft

University of Calgary, Canada

Yingxu Wang

University of Calgary, Canada

ABSTRACT

The cognitive mechanisms of knowledge representation, memory establishment, and learning are fundamental issues in understanding the brain. A basic approach to studying these mental processes is to observe and simulate how knowledge is memorized by little children. This paper presents a simulation tool for knowledge acquisition and memory development for young children of two to five years old. The cognitive mechanisms of memory, the mathematical model of concepts and knowledge, and the fundamental elements of internal knowledge representation are explored. The cognitive processes of children's memory and knowledge development are described based on concept algebra and the object-attribute-relation (OAR) model. The design of the simulation tool for children's knowledge acquisition and memory development is presented with the graphical representor of memory and the dynamic concept network of knowledge. Applications of the simulation tool are described by case studies on children's knowledge acquisition about family members, relatives, and transportation. This work is a part of the development of cognitive computers that mimic human knowledge processing and autonomous learning.

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1. INTRODUCTION

With the ever increasing storage capacity of new electronic devices, some individuals may suggest that we no longer need to learn how the brain stores information because we will soon be able to have all the information we need in personal computers. While the storage space on a computer tends to double every eighteen to twenty four months, this assumption is completely false. Researches in neural science, biopsychology, and cognitive informatics have discovered that the average human brain possesses approximately 10^{11} neurons and each neuron has an average of 10^3 synaptic connections (Pinel, 1997; Gabrieli, 1998; Sternberg, 1998; Matlin, 1998; Wang, 2009b; Wang & Wang, 2006). The observation on the generally unchanging number of neurons over the life span of an adult leads researchers to believe that information in the brain is stored as relationships between neurons via the creation of synaptic connections (Gabrieli, 1998; Wilson & Keil, 2001; Wang & Wang, 2006). Based on these factors, Wang and his colleagues find that the maximum capacity of human memory, i.e., the possible number of synaptic connections among neurons in the brain, is up to $10^{8,432}$ bits based on a rigorous mathematical model (Wang et al., 2003).

The current size of a desktop computer with dual terabyte drives holds close to 10^{12} bits of information. When we compare how miniscule the amount of information the desktop computer can hold and that of the human brain, we quickly realize how impressive the brain is. We must also consider the accessibility of that information, how quickly we can sort through the information to recall specific knowledge, and how humans are still much better at understanding patterns than a computer. When all of these observations are taken into account, we not only see that the idea of the computer being better than the brain as ridiculous, but it also demands that the brain be studied so that the current computers may be improved and the future generation of cognitive computers may be developed.

All around the globe and throughout history, many people such as Plato, Socrates, and Chuang Tsui have wondered about the cognitive ability of the human mind (Tsui, 400BC; Wang, 2003). This desire for answers led to the development of fields of study such as philosophy, psychology, life science, and knowledge engineering. A new field of enquiry, cognitive informatics, was initiated by Wang and his colleagues in 2002, which establishes a trans-disciplinary study on cognitive science, computer science, information science, cybernetics, and life science (Wang, 2002, 2003, 2007b; Wang et al., 2009). Cognitive informatics investigates natural intelligence, i.e., how the brain acquires, processes, interprets, expresses, and utilizes information, its applications in cognitive computing, and the denotational mathematical means for both natural and computational intelligence (Wang, 2003).

It is recognized that studies about human knowledge acquisition, memory development, and internal knowledge representation can be enriched by observations on mechanisms of young children learning and memory development. Findings in this approach may improve the understanding about human memory and knowledge representation. Based on this study, a computational simulation of the cognitive process of children knowledge acquisition and memory development is designed and implemented. The project reported in this paper uses the theories of the formal concept model of memory to model the growing understanding of a small child. A child of eighteen months should have a vocabulary of three to twenty words and be able to comprehend approximately fifty words. A child of twenty-four months should have a vocabulary of approximately two hundred words (Grizzle & Simms, 2005). This project helps to demonstrate the growth and complexity of the growing amount of information a child knows in order to empirically simulate the relational memory theories (Baddeley, 1990; Squire et al., 1993; Wang, 2009b; Hu et al., 2010) and the mathematical model of formal concepts as the basic unit of human knowledge (Wang, 2008a, 2009a, 2009b).

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