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Discovering the Capacity of Human Memory

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Abstract. Despite the fact that the number of neurons in the human brain has been identified in cognitive and neural sciences, the magnitude of human memory capacity is still unknown. This paper reports the discovery of the memory capacity of the human brain, which is on the order of 10^{8432} bits. A cognitive model of the brain is created, which shows that human memory and knowledge are represented by relations, i.e., connections of synapses between neurons, rather than by the neurons themselves as the traditional container metaphor described. The determination of the magnitude of human memory capacity is not only theoretically significant in cognitive science, but also practically useful to unveil the human potential, as well as the gap between the natural and machine intelligence.

Key words: brain, cognitive informatics, cognitive model, knowledge representation, memory capacity, neuropsychology, OAR model, software engineering.

1. Introduction

What is the memory capacity of human brains? This is a fundamental question of cognitive science, neuropsychology, and cognitive informatics. The number of neurons in an adult brain has been identified to be on the order of 100 billion (10^{11}), and each neuron is connected to a large number of other neurons via several hundreds to a few thousands synapses (Marieb, 1992; Smith, 1993; Pinel, 1997; Sternberg, 1998; Rosenzmeig *et al.*, 1999). 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.

It is commonly understood that memory is the foundation of any natural intelligence. Cognitive scientists believe that the elementary function and mechanism of the brain are quite simple; however, the magnitude of the neural networks and their concurrent behaviors are extremely powerful as a whole (Turing, 1936; Rabin and Scott, 1959; Kotulak, 1997; Leahey, 1997; Gabrieli, 1998; Matlin, 1998; Payne and Wenger, 1998; Harnish, 2002). Comparing the human brain and those of other animals, the magnitude of the human memory shows a significant difference. Therefore, to accurately determine the magnitude of human memory capacity is not only theoretically significant in cognitive science, but also practically useful to unveil the human potential. It is also helpful to perceive the status and limitations of current memory and computing technologies in computer science and artificial intelligence.

This paper explores the magnitude of human memory capacity based on a cognitive model of the brain and a set of mathematical and computational algorithms. Section 2 introduces the cognitive model of human memory. Section 3 establishes a mathematical model of memory capacity of the brain, and gives an initial estimation of the magnitude of human memory capacity. Section 4 develops a computational solution for calculating the memory capacity of the brain, which is obtained to be on the order of 10^{8432} bits. Section 5 provides additional mathematical evaluation on the estimation of the memory capacity of the brain. Section 6 explains the physical and physiological meanings of this discovery. Section 7 draws conclusions based on the finding and discusses its impact and applications in cognitive science, neuropsychology, cognitive informatics, and computing science.

2. The Cognitive Model of Human Memory

The human memory includes the sensory buffer memory, the short-term memory, the long-term memory (LTM) (Baddeley, 1990; Smith, 1993; Squire *et al.*, 1993; Sternberg, 1998; Rosenzmeig *et al.*, 1999), and the action buffer memory (Wang *et al.*, 2002; Wang and Wang, 2002). Among these memories, the LTM is the permanent memory that human beings rely on for storing acquired information such as facts, knowledge, and skills. Although cognitive science, neurophysiology, and neuropsychology have so far not been able to determine what the magnitude of the LTM capacity is, it is believed empirically that the LTM is for all intents and purposes (Smith, 1993; Rosenzmeig *et al.*, 1999; Harnish, 2002).

Model 1: The functional model of LTM can be described as a set of *hierarchical neural clusters* with partially connected *neurons* via *synapses*.

The LTM model can be illustrated as shown in Figure 1. Conventionally, LTM is perceived as static and fixed in an adult brain (James, 1890; Baddelay, 1990; Smith, 1993; Sternberg, 1998; Rosenzmeig *et al.*, 1999). This was based on the observation that the capacity of adult brains has already reached a stable state and would not grow continuously. However, latest discoveries in neuroscience and cognitive informatics indicate that LTM is dynamically reconfiguring, particularly at the lower levels of the neural clusters (Squire

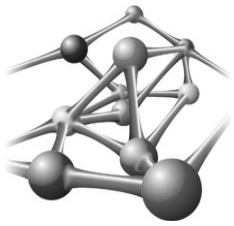

Figure 1. LTM: Hierarchical and partially connected neural clusters. The long-term memory (LTM) is dynamic and partially interconnected neural networks, where a connection between a pair of neurons by a synapse represents a *relation* between two cognitive objects.