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On Cognitive Computing

Yingxu Wang, University of Calgary, Canada

ABSTRACT

Inspired by the latest development in cognitive informatics and contemporary denotational mathematics, cognitive computing is an emerging paradigm of intelligent computing methodologies and systems, which implements computational intelligence by autonomous inferences and perceptions mimicking the mechanisms of the brain. This article presents a survey on the theoretical framework and architectural techniques of cognitive computing beyond conventional imperative and autonomic computing technologies. Theoretical foundations of cognitive computing are elaborated from the aspects of cognitive informatics, neural informatics, and denotational mathematics. Conceptual models of cognitive computing are explored on the basis of the latest advances in abstract intelligence and computational intelligence. Applications of cognitive computing are described from the aspects of autonomous agent systems and cognitive search engines, which demonstrate how machine and computational intelligence may be generated and implemented by cognitive computing theories and technologies toward autonomous knowledge processing. [Article copies are available for purchase from InfoSci-on-Demand.com]

Keywords: *Autonomous Agent Systems; Autonomous Systems; Cognitive Computing; Cognitive Informatics; Cognitive Search Engines; Computational Intelligence; Denotational Mathematics; Natural Intelligence; Neural Informatics; Soft Computing*

INTRODUCTION

Computing as a discipline in a narrow sense, is an application of computers to solve a given computational problem by imperative instructions; while in a broad sense, it is a process to implement the instructive intelligence by a system that transfers a set of given information or instructions into expected behaviors.

According to theories of cognitive informatics (Wang, 2002a, 2003, 2006, 2007b, 2007c, 2008a, 2009a; Wang et al., 2009b), computing technologies and systems may be classified into the categories of imperative, autonomic, and cognitive from the bottom up. Imperative computing is a traditional and passive technology based on stored-program controlled behaviors for data processing (Turing, 1950; von Neumann, 1946, 1958; Gersting, 1982; Mandrioli and Ghezzi, 1987; Lewis and Papadimitriou, 1998). An autonomic computing is goal-driven and self-decision-driven technologies that do not rely on instructive and procedural information (Kephart and Chess, 2003; IBM, 2006; Wang, 2004, 2007a). Cognitive computing is more intelligent technologies beyond imperative and autonomic computing, which embodies major natural intelligence behaviors of the brain such as thinking, inference, learning, and perceptions.

Definition 1. *Cognitive computing is an emerging paradigm of intelligent computing methodologies and systems that implements computational intelligence by autonomous inferences and perceptions mimicking the mechanisms of the brain.*

Cognitive computing systems are designed for cognitive and perceptive knowledge processing based on contemporary denotational mathematics (Zadeh, 1965; Wang, 2002b, 2007a, 2008b, 2008c, 2008d, 2008e; Wang et al, 2009a), which are centered by the parallel autonomous inference and perception mechanisms of the brain as revealed in the Layered Reference Model of the Brain (LRMB) (Wang et al., 2006). On the basis of cognitive computing, next generation cognitive computers and autonomous intelligent systems that think and feel may be designed and implemented.

This article presents the theoretical framework and architectural techniques of cognitive computing beyond conventional imperative and autonomic computing systems. Theoretical foundations of cognitive computing are elaborated from the aspects of cognitive informatics, neural informatics, and denotational mathematics. Conceptual models of cognitive computing are explored from the latest development in abstract intelligence, intelligent behaviors, and computational intelligence. Applications of cognitive computing are described with an autonomous agent system and a cognitive search engine, which demonstrate how machine and computational intelligence may be generated and implemented by cognitive computing theories and technologies toward autonomous knowledge processing.

THEORETICAL FOUNDATIONS FOR COGNITIVE COMPUTING

Theories and methodologies of cognitive computing are inspired by the latest advances in cognitive informatics and denotational mathematics. This section elaborates the cognitive informatics theories and denotational mathematical structures for cognitive computing.

Cognitive Informatics for Cognitive Computing

The fundamental theories and methodologies underpinning cognitive computing are cognitive informatics (Wang, 2002a, 2003, 2006, 2007b, 2007c, 2008a, 2009a; Wang et al., 2009b). Cognitive informatics is a cutting-edge and multidisciplinary research field that tackles the fundamental problems shared by modern informatics, computation, software engineering, AI, computational intelligence, cybernetics, cognitive science, neuropsychology, medical science, systems science, philosophy, linguistics, economics, management science, and life sciences. The development and the cross fertilization between the aforementioned science and engineering disciplines have led to a whole range of emerging research areas known as cognitive informatics.

Definition 2. *Cognitive informatics is a transdisciplinary enquiry of cognitive, computing, and information sciences, which studies the internal information processing mechanisms and processes of natural intelligence (the brain), the theoretical framework and denotational mathematics of abstract intelligence, and their engineering applications by cognitive computing.*

The architecture of the theoretical framework of cognitive informatics (Wang, 2007b) covers the Information-Matter-Energy (IME) model (Wang, 2003), the Layered Reference Model of the Brain (LRMB) (Wang et al., 2006), the Object-Attribute-Relation (OAR) model of information representation in the brain (Wang, 2007d), the cognitive informatics model of the brain (Wang and Wang, 2006), Natural Intelligence (NI) (Wang, 2002a), Neural Informatics (NeI) (Wang, 2007b), the mechanisms of human perception processes (Wang, 2007e), and cognitive computing (Wang, 2006).