Chapter 30
On a Novel Cognitive Knowledge Base (CKB) for Cognitive Robots and Machine Learning

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ABSTRACT

A cognitive knowledge base (CKB) is a novel structure of intelligent knowledge base that represents and manipulates knowledge as a dynamic concept network mimicking human knowledge processing. The essence of CKB is the denotational mathematical model of formal concept that is dynamically associated to other concepts in a CKB beyond conventional rule-based or ontology-based knowledge bases. This paper presents a formal CKB and autonomous knowledge manipulation system based on recent advances in neuroinformatics, concept algebra, semantic algebra, and cognitive computing. An item knowledge in CKB is represented by a formal concept, while the entire knowledge base is embodied by a dynamic concept network. The CKB system is manipulated by algorithms of knowledge acquisition and retrieval on the basis of concept algebra. CKB serves as a kernel of cognitive learning engines for cognitive robots and machine learning systems. CKB plays a central role not only in explaining the mechanisms of human knowledge acquisition and learning, but also in the development of cognitive robots, cognitive learning engines, and knowledge-based systems.

1. INTRODUCTION

The hierarchy of human knowledge is categorized at the levels of *data, information, knowledge,* and *intelligence*. Knowledge bases and databases are significantly different in both theories and manipulation mechanisms in cognitive informatics and cognitive computing (Hayes-Roth et al., 1983; Debenham, 1989; Krishna, 1992; Miller, 1995; Bender, 1996; Ullman & Widom, 1997; Fellbaum, 1998; Pojman, 2003; Brewster et al., 2004; Leone et al., 2006; Wang, 2008a, 2009b, 2010b, 2012a, 2013b, 2014g, 2015;

Hu et al., 2010). According to basic studies in cognitive science and neurophysiology (Hampton, 1997; Pojman, 2003; Leone et al., 2006; Wang, 2003, 2012b, 2013a, 2014c; Wang & Wang, 2006; Wang & Fariello, 2012), the foundations of human knowledge in long-term memory can be represented by an object-attribute-relation model (Wang, 2007a) based on the synaptic structure of human memory, which represents the hierarchical and dynamic neural clusters of knowledge retained in memory as well as the logical model of knowledge bases.

Conventional technologies for knowledge base modeling and manipulations can be classified into three categories known as *linguistic knowledge bases* (Crystal, 1987; Debenham, 1989; Miller, 1995; Pullman, 1997; Fellbaum, 1998; Liddy, 2001; Wang & Berwick, 2012, 2014), *expert knowledge bases* (Hayes-Roth et al., 1983; Bender, 1996; Wang, 2009c, 2012c), and *ontology* (Smith & Medin, 1981; Gruber, 1993; Miller, 1995; Cocchiarella, 1996; Brewster et al., 2004; Tiberino et al., 2005; Leone et al., 2006; Sanchez, 2010; Wang, 2008a, 2015a; Wang et al., 2011). Typical linguistic knowledge bases are lexical databases such as WordNet and ConceptNet (Miller, 1995; Fellbaum, 1998; Berners-Lee, 2001; Liu & Singh, 2004). Expert knowledge bases are represented by various logical rule-based systems (Hayes-Roth et al., 1983; Bender, 1996) and fuzzy rule-based systems (Zadeh, 1965, 2004; Surmann, 2000; Wang, 2014d, 2014e, 2015c). Ontology treats a small-scale knowledge as a set of words and their relations in a certain domain (Gruber, 1993; Tiberino et al., 2005; Leone et al., 2006; Sanchez, 2010; Wang et al., 2011). It is recognized that main problems of conventional methodologies for knowledge bases are man-made rather than machine built, the lack of rigorous and adequate operations on acquired knowledge, inflexible for learnt knowledge synergy, and the weak transformability among different knowledge bases (Wang, 2015a; Wang et al., 2011).

In order to solve the aforementioned problems in knowledge base theory and methodologies, a novel *cognitive knowledge base* (CKB) is introduced as a formal knowledge base built on the basis of concept algebra for knowledge representation and manipulations mimicking human knowledge processing mechanisms as reveled in cognitive informatics, neuroinformatics, and cognitive linguistics. The CKB theories and technologies for knowledge acquisitions and manipulations deal with a set of fundamental problems in knowledge representation, machine learning, cognitive computing, and cognitive robots (Chang et al., 2006; Debenham, 1989; Wang, 2009a, 2009d, 2010a, 2014a, 2014b, 2015b; Wang & Berwick, 2012, 2013; Wang et al., 2009). CKB is demanded in cognitive robotics, machine learning, knowledge-based systems, and cognitive computers in general, as well as in the development of the cognitive learning engine in particular. CKB is a central component for machine learning via autonomous knowledge acquisition and manipulation, because the general form of learning is a knowledge acquisition process according to the latest studies in cognitive science, brain science, and neuroinformatics (Wilson & Keil, 2001; Debenham, 1989; Pullman, 1997; Evan & Green, 2006; Wang, 2003, 2009a, 2009d).

This paper presents a formal CKB and autonomous knowledge manipulation system that represents and manipulates knowledge as a dynamic concept network based on concept algebra. The formal structure model of CKB is presented by formal concept for item knowledge and dynamic concept network for the entire knowledge base in Section 2. The mechanisms of knowledge manipulations are embodied by algorithms of knowledge acquisition and retrieval on the basis of the logical structure of CKB in Sections 3 and 4, respectively. The CKB system as the kernel of a cognitive learning engine for cognitive robots and machine learning systems is formally described by a set of algorithms specified in real-time process algebra (RTPA). CKB plays a central role not only in explaining the mechanisms of human knowledge acquisition and learning, but also in the development of cognitive robots, cognitive learning engines, and knowledge-based systems.

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