Chapter 4
Cognitive Computing:
Methodologies for Neural Computing and Semantic Computing in Brain-Inspired Systems

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ABSTRACT

Cognitive Computing (CC) is a contemporary field of studies on intelligent computing methodologies and brain-inspired mechanisms of cognitive systems, cognitive machine learning and cognitive robotics. The IEEE conference ICCI*CC'17 on Cognitive Informatics and Cognitive Computing was focused on the theme of neurocomputation, cognitive machine learning and brain-inspired systems. This article reports the plenary panel (Part II) in IEEE ICCI*CC'17 at Oxford University. The summary is contributed by distinguished panelists who are part of the world's renowned scholars in the transdisciplinary field of cognitive computing.

1. INTRODUCTION

Cognitive Computing (CC) is a novel paradigm of intelligent computing platforms and methodologies for developing cognitive and autonomous systems mimicking the mechanisms of the brain (Wang, 2002, 2003, 2007a, 2009a-c, 2011b, 2012e, 2013c, 2015a, 2016a, 2017a; Wang et al., 2009, 2010, 2016; Howard et al., 2017). CC emerged from transdisciplinary studies in both natural intelligence in cognitive/brain sciences (Anderson, 1983; Sternberg, 1998; Reisberg, 2001; Wilson & Keil, 2001; Wang, 2002, 2007a; Wang et al., 2002, 2007a, 2009a, 2009b, 2016a, 2017a) and artificial intelligence in computer science (Bender, 1996; Poole et al., 1997; Zadeh, 1999, 2016; Widrow, 2015; Widrow et al., 2015; Wang, 2010a, 2016c). Formal models are sought for revealing the principles and mechanisms of the brain. This leads to the theory of abstract intelligence (αI) (Wang, 2009a, 2012c) that investigates into the brain via not only inductive syntheses of theories and principles of intelligence science through mathematical engineering, but also deductive analyses of architectural and behavioral instances of natural and artificial intelligent systems through cognitive engineering. The key methodology suitable for dealing with the nature of αI is mathematical engineering, which is an emerging discipline of contemporary engineering that studies the formal structural models and functions of complex abstract and mental objects as well as their systematic and rigorous manipulations (Wang, 2015a; Wang et al., 2017a).

Fundamental theories of CC cover the *Layered Reference Model of the Brain* (LRMB) (Wang et al., 2006), the *Object-Attribute-Relation* (OAR) model of internal information and knowledge representation (Wang, 2007c), the *Cognitive Functional Model of the Brain* (CFMB) (Wang & Wang, 2006), *Abstract Intelligence* (αI), *Neuroinformatics* (Wang, 2013a; Wang & Fariello, 2012), *Denotational Mathematics* (Wang, 2008, 2009d, 2012a, 2012b), *Cognitive Linguistics* (Wang and Berwick, 2012, 2013), the *Spike Frequency Modulation (SFM) Theory* of neural signaling (Wang, 2016h), the *Neural Circuit Theories* (Wang and Fariello, 2012), and *cognitive systems* (Wang et al., 2017). Recent studies on LRMB reveal an entire set of cognitive functions of the brain and their cognitive processes, which explain the cognitive mechanisms and processes of the natural intelligence with 52 cognitive processes at seven layers known as the sensation, action, memory, perception, cognitive, inference, and intelligence layers (Wang et al., 2006).

IEEE ICCI*CC'17 on Cognitive Informatics and Cognitive Computing has been held at Oxford University during July 26-28, 2017 (Howard et al., 2017). This paper is a summary of the position statements of invited panellists presented in the *Plenary Panel* of IEEE ICCI*CC 2017 *on Neurocomputation, Cognitive Machine Learning and Brain-Inspired System* (Part II). It is noteworthy that the individual statements and opinions included in this paper may not necessarily be shared by all panellists.

2. THE THEORETICAL FRAMEWORK OF BRAIN AND INTELLIGENCE SCIENCES FOR COGNITIVE COMPUTING

It it recognized that the brain may be explained by a hierarchically reductive structure at the logical, cognitive, physiological and neurological levels from the bottom up, which form the studies known as abstract intelligence, cognitive informatics, brain informatics, and neuroinformatics. The theoretical framework of brain science and intelligence science can be described as shown in Figure 1 according to cognitive informatics studies (Wang, 2007a, 2008, 2009a, 2011b, 2012c/e, 2015b/d, 2016a, 2017a). The synergy of multidisciplinary studies at all levels leads to the theory of cognitive computing for explaining

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