International Journal of Cognitive Informatics and Natural Intelligence
Volume 12 • Issue 1 • January-March 2018

Cognitive Informatics:
Towards Cognitive Machine Learning and Autonomous Knowledge Manipulation

Yingxu Wang, University of Calgary, Calgary, Canada
Newton Howard, University of Oxford, Oxford, UK
Janusz Kacprzyk, Polish Academy of Sciences, Warsaw, Poland
Ophir Frieder, Georgetown University, Washington, DC, USA
Phillip Sheu, University of California, Irvine, CA, USA
Rodolfo A. Fiorini, Politecnico di Milano University, Milano, Italy
Marina Gavrilova, University of Calgary, Calgary, Canada
Shushma Patel, London South Bank University, London, UK
Jun Peng, Chongqing University of Science and Technology, Chongqing, China
Bernard Widrow, Stanford University, Stanford, CA, USA

ABSTRACT

Cognitive Informatics (CI) is a contemporary field of basic studies on the brain, computational intelligence theories and underpinning denotational mathematics. Its applications include cognitive systems, cognitive computing, cognitive machine learning and cognitive robotics. IEEE ICCI*CC'17 on Cognitive Informatics and Cognitive Computing was focused on the theme of neurocomputation, cognitive machine learning and brain-inspired systems. This paper reports the plenary panel (Part I) at IEEE ICCI*CC'17 held at Oxford University. The summary is contributed by invited keynote speakers and distinguished panelists who are part of the world's renowned scholars in the transdisciplinary field of CI and cognitive computing.

KEYWORDS

Applications, Artificial Intelligence, Brain-Inspired Systems, Cognitive Computers, Cognitive Engineering, Cognitive Informatics, Cognitive Robotics, Cognitive Systems, Computational Intelligence, Deep Learning, Deep Reasoning, Denotational Mathematics, Knowledge Learning

1. INTRODUCTION

Cognitive Informatics (CI) is a transdisciplinary enquiry of the internal information processing processes of the brain and abstract intelligence towards applications in cognitive computing and cognitive engineering (Wang, 2002, 2003, 2007a, 2009a, 2009b, 2009c, 2011b, 2012e, 2013c, 2015a, 2016a, 2017a; Wang et al., 2009, 2010, 2016; Howard et al., 2017). CI is a contemporary field spanning across computer science, information science, cognitive science, brain science, neuroscience, intelligence science, knowledge science, robotics, cognitive linguistics, cognitive philosophy, and

DOI: 10.4018/IJCINI.2018010101

cognitive engineering. Cognitive Computing (CC) is a novel paradigm of intelligent computing platforms of cognitive methodologies and systems based on CI, which embodying computational intelligence by cognitive and autonomous systems mimicking the mechanisms of the brain (Wang, 2002, 2007a; Wang et al., 2002, 2007a, 2009a, 2009b, 2016a, 2017a).

The IEEE series of *International Conferences on Cognitive Informatics and Cognitive Computing* (ICCI*CC) has been established since 2002 (Wang, 2002; Wang et al, 2002). Since its inception, the ICCI*CC series has been growing steadily in its size, scope, and depth. It has attracted worldwide researchers from academia, government agencies, and industry practitioners. The IEEE ICCI*CC series provides a main forum for the exchange and cross-fertilization of ideas in the new research field of CI toward revealing the cognitive mechanisms and processes of human information processing and the approaches to mimic them in cognitive computing. A wide range of breakthroughs have been recognized and a wide range of applications has been developed in CI and CC in the last decade. The representative paradigms and technologies developed in cognitive informatics include cognitive computers, abstract intelligence, cognitive learning engines, cognitive knowledge bases, denotational mathematics and applied cognitive systems.

CI studies the cognitive objects represented in the brain in the categories of data, information, knowledge and intelligence by a hierarchical structure (Berkeley, 1954; Turing, 1950; Shannon, 1948; von Neumann, 1958; McCulloch, 1965; Debenham, 1989; Wang, 2009a, 2014a, 2015f). The relationship between the four categories of cognitive objects in the hierarchical framework of human cognition is illustrated in Figure 1 (Wang, 2016b). It is perceived that data are acquired raw information which are usually a quantitative abstraction of external entities and their relations. Information is meaningful data or an interpretation of data. Knowledge is consumed information related to existing knowledge in the brain. Intelligence is a collection of cognitive abilities of humans or cognitive systems that transforms information into behaviors (Wang, 2012c). Rigorous models and mathematical manipulations on intelligence, knowledge, information and data are formally described in (Wang, 2015f).

Fundamental theories of CI cover the Matter-Energy-Information-Intelligence (MEII) model (Wang, 2015g), 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) (Wang, 2009a, 2012c), Neuroinformatics (Wang, 2013a; Wang and Fariello, 2012), Denotational Mathematics (Wang, 2008, 2009d, 2012a,b), Cognitive Linguistics (Wang & Berwick, 2012, 2013), the Spike Frequency Modulation (SFM) Theory of neural signaling (Wang, 2016h), the Neural Circuit Theories (Wang, 2017; Wang and Fariello, 2012), and cognitive systems (Wang et al., 2017). Recent studies on LRMB in CI reveal an entire set of cognitive functions of the brain and their cognitive

Figure 1. The hierarchical framework of cognitive objects in CI