Basic Theories for Neuroinformatics and Neurocomputing

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ABSTRACT

A fundamental challenge for almost all scientific disciplines is to explain how natural intelligence is generated by physiological organs and what the logical model of the brain is beyond its neural architectures. According to cognitive informatics and abstract intelligence, the exploration of the brain is a complicated recursive problem where contemporary denotational mathematics is needed to efficiently deal with it. Cognitive psychology and medical science were used to explain that the brain works in a certain way based on empirical observations on related activities in usually overlapped brain areas. However, the lack of precise models and rigorous causality in brain studies has dissatisfied the formal expectations of researchers in computational intelligence and mathematics, because a computer, the logical counterpart of the brain, might not be explained in such a vague and empirical approach without the support of formal models and rigorous means.

In order to formally explain the architectures and functions of the brain, as well as their intricate relations and interactions, systematic models of the brain are sought for revealing the principles and mechanisms of the brain at the neural, physiological, cognitive, and logical levels. Cognitive and brain informatics investigate into the brain via not only inductive syntheses through these four cognitive levels from the bottom up in order to form theories based on empirical observations, but also deductive analyses from the top down in order to explain various functional and behavioral instances according to the abstract intelligence theory.

This keynote lecture presents systematic models of the brain from the facets of cognitive informatics, abstract intelligence, brain Informatics, neuroinformatics, and cognitive psychology. A logical model of the brain is introduced that maps the cognitive functions of the brain onto its neural and physiological architectures. This work leads to a coherent abstract intelligence theory based on both denotational mathematical models and cognitive psychology observations, which rigorously explains the underpinning principles and mechanisms of the brain. On the basis of the abstract intelligence theories and the logical models of the brain, a comprehensive set of cognitive behaviors as identified in the Layered Reference Model of the Brain (LRMB) such as perception, inference and learning can be rigorously explained and simulated.

The logical model of the brain and the abstract intelligence theory of natural intelligence will enable the development of cognitive computers that perceive, think and learn. The functional and theoretical difference between cognitive computers and classic computers are that the latter are data processors based on Boolean algebra and its logical counterparts; while the former are knowledge processors based on contemporary denotational mathematics. A wide range of applications of cognitive computers have been developing in ICIC [http://www.ucalgary.ca/icic/] and my laboratory such as, inter alia, cognitive robots, cognitive learning engines, cognitive Internet, cognitive agents, cognitive search engines, cognitive translators, cognitive control systems, and cognitive automobiles.

Keywords: Cognitive informatics, cognitive computing, abstract intelligence, denotational mathematics, cognitive computers, knowledge processors, inference engines, learning engines, perception engines, computational intelligence, applications

ABOUT THE KEYNOTE SPEAKER

Yingxu Wang is professor of cognitive informatics and software science, President of International Institute of Cognitive Informatics and Cognitive Computing (ICIC, www.ucalgary.ca/icic/), Director of Laboratory for Cognitive Informatics and Cognitive Computing, and a Fellow of Denotational Mathematics and Software Science at the University of Calgary. He is a Fellow of WIF (UK), a Fellow of ICIC, a P.Eng of Canada, and a Senior Member of IEEE and ACM. He received a PhD in Software Engineering from the Nottingham Trent University, UK, and a BSc in Electrical Engineering from Shanghai Tiedao University. He has industrial experience since 1972 and has been a full professor since 1994. He was a visiting professor on sabbatical leaves at Oxford University (1995), Stanford University (2008), University of California, Berkeley (2008), and MIT (2012), respectively. He is the
founder and steering committee chair of the annual IEEE International Conference on Cognitive Informatics and Cognitive Computing (ICCI*CC). He is founding Editor-in-Chief of International Journal of Cognitive Informatics and Natural Intelligence (IJCINI), founding Editor-in-Chief of International Journal of Software Science and Computational Intelligence (IJSSCI), Associate Editor of IEEE Trans. on System, Man, and Cybernetics - Systems, and Editor-in-Chief of Journal of Advanced Mathematics and Applications.

Dr. Wang is the initiator of a few cutting-edge research fields such as cognitive informatics (CI, the theoretical framework of CI, neuroinformatics, the logical model of the brain (LMB), the lay referenced model of the brain (LRMB), the cognitive model of brain informatics (CMBI), the mathematical model of consciousness, and the cognitive learning engine (CLE)); abstract intelligence; cognitive computing (such as cognitive computers, cognitive robots, cognitive agents, and the cognitive Internet); denotational mathematics (i.e., concept algebra, inference algebra, semantic algebra, behavioral process algebra, system algebra, granular algebra, and visual semantic algebra); software science (on unified mathematical models and laws of software, cognitive complexity of software, automatic code generators, the coordinative work organization theory, and built-in tests (BITs)); basic studies in cognitive linguistics (such as the cognitive linguistic framework of languages, semantic algebra, formal semantics of languages, deductive grammar of English, and the cognitive complexity of text comprehension). He has published over 130 peer reviewed journal papers, 220 peer reviewed conference papers, and 18 books in cognitive informatics, cognitive computing, software science, denotational mathematics, and computational intelligence. He is the recipient of dozens international awards on academic leadership, outstanding contributions, research achievement, best papers, and teaching in the last three decades.

REFERENCES