Editorial
Recent Advances in Cognitive Informatics

COGNITIVE informatics is a new discipline that studies the natural intelligence and internal information processing mechanisms of the brain, as well as processes involved in perception and cognition. This editorial explores the domain of cognitive informatics and its interdisciplinary nature. Foundations of cognitive informatics, particularly the brain versus the mind, and the acquired life functions versus the inherited ones, are elucidated. The coverage of this special issue and recent advances in cognitive informatics are reviewed. This editorial demonstrates that the investigation into cognitive informatics is encouraging and results in fundamental discoveries toward the development of next generation information and software technologies, as well as new architectures of computing systems.

I. INTRODUCTION

The development of classical and contemporary informatics, the cross fertilization between computer science, systems science, cybernetics, computer/software engineering, cognitive science, and neuropsychology, has led to an entire range of extremely interesting new research field known as *cognitive informatics* (CI) [1]–[5]. CI is a transdisciplinary study of cognitive and information sciences that investigates the internal information processing mechanisms and processes of natural intelligence, i.e., the human brain and mind.

CI is a cutting-edge and profound interdisciplinary research area that tackles the fundamental problems of modern informatics, systems science, computation, computer/software engineering, artificial intelligence, cognitive science, neuropsychology, and life sciences. Almost all of the hard problems yet to be solved in the above areas share a common root in the understanding of mechanisms of natural intelligence and cognitive processes of the brain.

In many disciplines of human knowledge, almost all of the hard problems yet to be solved share a common root in the understanding of the mechanisms of natural intelligence and the cognitive processes of the brain. Therefore, CI is a discipline that forges links between a number of natural science and life science disciplines with informatics and computing science.

The fundamental methodology of CI is bidirectional and comparative. In one direction, CI uses informatics and computing techniques to investigate cognitive science problems, such as memory, learning, and reasoning. In the other direction, CI uses cognitive theories to investigate problems in informatics, computing, and software engineering. CI focuses on the nature of information processing in the brain, such as information acquisition, representation, memory, retrieval, generation, and communication. Via an interdisciplinary approach and with the

support of modern information and neuroscience technologies, mechanisms of the brain and the mind will be explored in CI systematically.

Significant problems yet to be addressed in CI include the architectures of the brain, mechanisms of the natural intelligence, perceptual and cognitive processes, mental phenomena, and personality. It is particularly interested in computing and software engineering to explain the mechanisms and processes of memory, learning, and reasoning. It is expected that any breakthrough in CI will be profoundly significant toward the development of next generation technologies in informatics, computing, software, and cognitive sciences.

II. STRUCTURE OF THIS SPECIAL ISSUE

The theme of this special issue of IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS (PART C) is "Cognitive Mechanisms of the Brain and Autonomic Computing." This special issue includes selected best papers from the *Second IEEE International Conference on Cognitive Informatics (ICCI'03)*, which explores an interdisciplinary area between computing/information sciences and cognitive/neural sciences, and focuses on the natural information processing mechanisms and cognitive processes of the brain. Nine papers have been selected from recognized researchers in the transdisciplinary field of CI.

Yingxu Wang, Ying Wang, Shushma Patel, and Dilip Patel present an integrated framework on "A Layered Reference Model of the Brain (LRMB)." The LRMB model explains the functional mechanisms and cognitive processes of the natural intelligence. LRMB elicits the core and recurrent cognitive processes from a huge variety of life functions, which may shed light on the study of the fundamental mechanisms and interactions of complicated mental processes, particularly the relationships and interactions between the inherited and the acquired life functions, as well as those of the subconscious and conscious cognitive processes.

John Bickle proposes an approach of "Ruthless Reductionism in Recent Neuroscience" to CI on the basis of an extended keynote speech [3]. He observed that CI has a stated interest in keeping track of developments within neurosciences concerning a wide range of cognitive phenomena. Therefore, cognitive informaticists should not only focus on cognitive neuroscience and neuropsychology, but also attend to molecular and cellular cognition. The latter employs a "ruthlessly reductive" methodology that continues to elucidate the mechanisms of cognition and consciousness.

Witold Kinsner develops a new approach to "Characterizing Chaos Through Lyapunov Metrics." He suggests that signal processing and recognition are a common cognitive activity in science, engineering, medicine, biology, and many other areas.

In order to quantitatively process chaotic signals, he proposes a measure of chaos using Lyapunov metrics. He studies the characterizing strange attractors by the divergence and folding of trajectories, and the largest local and global Lyapunov exponents by rescaling and renormalization. A number of algorithms are described for calculating Lyapunov exponents for characterizing chaotic signals.

Violaine Prince and Mathieu Lafourcade present a study on "Mixing Semantic Networks and Conceptual Vectors Application to Hyperonymy." They focus on a key issue in natural language processing known as lexical semantics. A convergent approach with conceptual knowledge representation and ontology is adopted. A conceptual vector model is proposed that demonstrates how hyperonymy, an ontological representation of the *is-a* relation, is established in the vector-based semantics. This leads to a *cooperation* process between semantic networks and conceptual vectors.

Yingxu Wang works "On the Informatics Laws and Deductive Semantics of Software." It is widely conceived that software as an artifact of human creativity is not constrained by the laws and principles discovered in the physical world. This paper explains that software is a type of instructive and behavioral information and it is asserted that software obeys the laws of informatics. Further, a comprehensive set of 19 informatics laws and the deductive semantics of software have been established, which extended the knowledge on the fundamental laws and properties of software, where the conventional product metaphor could not explain.

Nicolas Bredeche, Zhongzhi Shi, and Jean-Daniel Zucker present "Perceptual Learning and Abstraction in Machine Learning: An Application to Autonomous Robotics." Perceptual learning, in compliment to cognitive learning, is considered as an essential part of a living system. The authors argue that biologically inspired perceptual learning mechanisms could be used to build efficient low-level abstraction operators that deal with real world data. An application on perceptual learning inspired metaoperators is presented to perform an abstraction of autonomic robot visual perception. This work enables robots to learn how to identify objects in its environment.

Natalia López, Ismael Rodríguez, and Fernando Rubio's paper is on "Defining and Testing Metaadaptable Agents." It is found that it is not a trivial task to find the optimal intelligent mechanism. A method that adapts the intelligence of a multiagent system via genetics is proposed. This results in a technology known as a meta-adaptable system. An illustration of such a metaadaptable system is fully implemented, which can be extended to deal with more complicated situations such as multiple mobile agents based systems.

Witold Kinsner, Vincent Cheung, Kevin Cannons, Joseph Pear, and Toby Martin present a work on "Signal Classification Through Multifractal Analysis and Complex Domain Neural Networks." In order to analyze a wide variety of signals such as the stochastic, self-affine, and nonstationary signals, a classifying system with mutifractal and domain neural networks is implemented. The significance of this work is that it considers a measured behavior and discovers a minimum number of classes representing the behavior, without *a priori* knowledge of those classes.

Yingxu Wang and Ying Wang's paper explores "Cognitive Informatics Models of the Brain." This paper develops logical and cognitive models of the brain by using CI and formal methodologies. The cognitive model of the brain consists of the thinking engine, memory architectures, and sensory and action buffer mechanisms. On the basis of the cognitive model, human behaviors and consciousness, particularly the inherited and acquired life functions and their interactions, can be explained. This work also lays a foundation for computer simulation of the natural intelligent behaviors and cognitive processes.

III. CONCLUSION

CI has been recognized as a new frontier that studies internal information processing mechanisms and processes of the brain, and their applications in autonomic computing and the IT industry. This editorial has provided perspectives on CI and described the coverage of this special issue on CI. The guest editors expect that readers of the IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS will benefit from the papers presented in this special issue.

YINGXU WANG, *Guest Editor*
Theoretical and Empirical Software Eng. Res. Center
Department of Electrical and Computer Engineering
University of Calgary
Calgary, AB T2N 1N4, Canada

WITOLD KINSNER, *Guest Editor*
Department of Electrical and Computer Engineering
University of Manitoba
Winnipeg, MB R3T 5V6, Canada

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Yingxu Wang (M'97–SM'04) received the B.S. degree in electrical engineering from Shanghai Tiedao University, Shanghai, China, in 1983, and the Ph.D. degree in software engineering from Nottingham Trent University, Nottingham, U.K., in 1997.

Since 1994, he has been a Full Professor at Lanzhou Tiedao University, Lanzhou, China. In 1995, he was a Visiting Professor in the Computing Laboratory, Oxford University, U.K. He is currently a Full Professor of Cognitive Informatics and Software Engineering and the Director of Theoretical and Empirical Software Engineering Research Center (TESERC), University of Calgary, Calgary, AB, Canada, since 2000. He has accomplished a number of EU, Canadian, and industry-funded research projects as Principal Investigator and/or Coordinator, and has published over 260 papers and six books in software engineering and cognitive informatics.

Dr. Wang is a Fellow of WIF, a Senior Member of IEEE with the Societies of Computer, SMC, and Communications, and a member of ACM, ISO/IEC JTC1, and the Canadian Advisory Committee (CAC) for ISO. He is the founder and Steering Committee Chair of the Annual IEEE International Conference on Cognitive Informatics (ICCI). He is the Editor-in-Chief of the *International Journal of Cognitive Informatics and Natural Intelligence* (IJCI&NI), Editor-in-Chief of the World Scientific Book Series on Cognitive Informatics, and Editor of the CRC Book Series in Software Engineering. He was the Chairman of the Computer Chapter of IEEE Sweden during 1999–2000. He has served on numerous editorial boards and program committees, and as guest editors for a number of academic journals. He has won dozens of Research Achievement, Best Paper, and Teaching Awards in the last 25 years, particularly the IBC 21st Century Award for Achievement in recognition of outstanding contribution in the field of Cognitive Informatics and Software Science. He is a Professional Engineer of Canada.

Witold Kinsner (S'72–M'73–SM'88) received the Ph.D. degree in electrical engineering from McMaster University, Hamilton, ON, Canada, in 1974.

He was an Assistant Professor in electrical engineering at McMaster University and the McGill University. He is currently a Professor and Associate Head at the Department of Electrical and Computer Engineering, University of Manitoba, Winnipeg, MB, Canada. He is also Affiliate Professor at the Institute of Industrial Mathematical Sciences and Adjunct Scientist at the Telecommunications Research Laboratories, Winnipeg. He is a cofounder of the first Microelectronics Centre in Canada and was its Director of Research from 1979 to 1987. He has also designed configurable self-synchronizing CMOS memories at the ASIC Division, National Semiconductor, Santa Clara, CA. He has been involved in research on algorithms and software/hardware computing engines for real-time multimedia, using wavelets, fractals, chaos, emergent computation, genetic algorithms, rough sets, fuzzy logic, and neural networks. Applications included signal and data compression, signal enhancement, classification, segmentation, and feature extraction in various areas such as real-time speech compression for multimedia, wideband audio compression, aerial and space ortho image compression, biomedical signal classification, severe weather classification from volumetric radar data, radio and power-line transient classification, image/video enhancement, and modeling of complex processes such as dielectric discharges. He has also spent many years in VLSI design (configurable high-speed CMOS memories, as well as magnetic bubble memories) and computer-aided engineering of electronic circuits (routing and placement for VLSI, and field-programmable gate arrays). He has authored and coauthored over 500 publications in the above areas.

Dr. Kinsner is a member of the Association of Computing Machinery, the Mathematical and Computer Modelling Society, and Sigma Xi, and a life member of the Radio Amateurs of Canada.