Studies in Computational Intelligence, Volume 323

Editor-in-Chief
Prof. Janusz Kacprzyk
Systems Research Institute
Polish Academy of Sciences
ul. Newelska 6
01-447 Warsaw
Poland
E-mail: kacprzyk@ibspan.waw.pl

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Advances in Cognitive Informatics and Cognitive Computing, 2010
ISBN 978-3-642-16082-0

Yingxu Wang, Du Zhang, and Witold Kinsner (Eds.)

Advances in Cognitive Informatics and Cognitive Computing

Springer

Yingxu Wang
Dept. of Electrical and
Computer Engineering
Schulich Schools of Engineering
University of Calgary
2500 University Drive, NW
Calgary, Alberta, T2N 1N4
Canada
E-mail: yingxu@ucalgary.ca

Witold Kinsner
Dept. of Electrical and
Computer Engineering
University of Manitoba
Winnipeg, Manitoba, R3T 5V6
Canada
E-mail: kinsner@ee.umanitoba.ca

Du Zhang
Department of Computer Science
California State University
Sacramento, CA 95819-6021
USA
E-mail: zhangd@ecs.csus.edu

ISBN 978-3-642-16082-0 e-ISBN 978-3-642-16083-7

DOI 10.1007/978-3-642-16083-7

Studies in Computational Intelligence ISSN 1860-949X

Library of Congress Control Number: 2010938247

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Typeset & *Cover Design:* Scientific Publishing Services Pvt. Ltd., Chennai, India.

Printed on acid-free paper

9 8 7 6 5 4 3 2 1

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Preface

Cognitive Informatics (CI) is a transdisciplinary enquiry of computer science, information science, cognitive science, and intelligence science that investigates into the internal information processing mechanisms and processes of the brain and natural intelligence, as well as their engineering applications in cognitive computing. CI has been initiated by Yingxu Wang and his colleagues in 2002. In CI it is perceived that information theories have gone through three-generation evolvement known as those of classic information theory, modern information theory, and cognitive information theories. The latest advances and engineering applications of CI have led to the emergence of cognitive computing and the development of cognitive computers that reason and learn.

Cognitive Computing (CC) is an emerging paradigm of intelligent computing methodologies and systems based on cognitive informatics that implements computational intelligence by autonomous inferences and perceptions mimicking the mechanisms of the brain. As proposed by Yingxu Wang and his colleagues, CC is emerged and developed based on the transdisciplinary research in cognitive informatics, abstract intelligence, and denotational mathematics since the inauguration of the 1st IEEE International Conference on Cognitive Informatics (ICCI 2002).

A wide range of applications of CI and CC have been identified and developed in intelligence science, cognitive science, knowledge science, abstract intelligence, computational intelligence, intelligent information processing, and software engineering. CI focuses on the nature of information processing in the brain, such as information acquisition, representation, memory, retrieval, creation, and communication. Through the interdisciplinary approach and with the support of modern information and neuroscience technologies, mechanisms of the brain and the mind may be systematically explored within the framework of CI.

This book entitled *Advances in Cognitive Informatics and Cognitive Computing* presents some of the latest advances in cognitive informatics and cognitive computing. The book includes 14 chapters based on selected and refined papers from the IEEE 7th International Conference on Cognitive Informatics (ICCI 2008) held at Stanford University as well as new contributions as highlighted below.

Chapter 1, **Advances in the Fields of Cognitive Informatics and Cognitive Computing**, by Yingxu Wang, Du Zhang, and Witold Kinsner, presents an overview of the book and its theoretical, transdisciplinary, and historical backgrounds. This chapter explores the cutting-edge field of cognitive informatics (CI) and its applications in cognitive computing. CI is a transdisciplinary study of cognitive and information sciences, which investigates the internal information processing mechanisms and processes of the natural intelligence – human brains

and minds – and their engineering applications in computational intelligence. The 7th IEEE International Conference on Cognitive Informatics (ICCI 2008) has been organized at Stanford University during August 14-16, 2008. The ICCI 2008 program covers a wide spectrum of subjects that contribute to cognitive informatics and cognitive computing. This chapter highlights the latest advances in cognitive informatics and cognitive computing presented in ICCI 2008. The theoretical framework and applications of CI and cognitive computing are described. A set of selected papers from ICCI 2008 is introduced.

Chapter 2, **The Design of a Symbiotic Agent for Recognizing Real Space in Ubiquitous Environments,** is presented by Shigeru Fujita, Kenji Sugawara, and Claude Moulin. The growth of ubiquitous computing and Web services is expected to make everyday life of people more convenient, and it is also expected to make the society safer and more active. However, the problems of the Internet age such as the digital divide, network criminals and the insecurity of privacy prevent many people from seeing the benefits of the Internet. To solve the problems, we have been studying a methodology which aims at developing a cognitive agent which supports the social activities of a person based on a symbiotic relationship between the person and the agent. The symbiotic relationship means that the person and the agent are tightly coupled in a ubiquitous environment and keep their partnership to support each other, according to Licklider's symbiosis. In this chapter, we propose a concept of a symbiotic agent and an agent model to design and implement functions defined in the symbiotic agent. To realize the concept, we have implemented an agent platform to run multi-agent systems consisting of primitive agents using Steel Bank Common Lisp running on Linux and MacOS.

Chapter 3, **Adaptive Evaluation of Complex Dynamical Systems Using Low-Dimensional Neural Architectures,** by Ivo Bukovsky and Jiri Bila, studies a new methodology of adaptive monitoring and evaluation of complicated dynamic data. The major objectives are monitoring and evaluation of both instantaneous and long-term attributes of complex dynamic behavior, such as of chaotic systems and real-world dynamical systems. In the sense of monitoring, the methodology introduces a novel approach to quantification and visualization of cognitively observed system behavior in a real time without further processing of these observations. In the sense of evaluation, the methodology opens new possibilities for consequent qualitative and quantitative processing of cognitively monitored system behavior. Techniques and enhancements are introduced to improve the stability of low-dimensional neural architectures and to improve their capability in approximating nonlinear dynamical systems that behave complex in high-dimensional state space. Low-dimensional dynamic quadratic neural units enhanced as forced dynamic oscillators are introduced to improve the approximation quality of higher dimensional systems. However, the introduced methodology can be universally used for adaptive evaluation of dynamic behavior variability also with other neural architectures and adaptive models, and it can be used for theoretical chaotic systems as well as for real-world dynamical systems. Simulation results on applications to deterministic, however, highly chaotic time series are shown to explain the new methodology and to demonstrate its capability

in sensitive and instantaneous detections of changing behavior, and these detections serve for monitoring and evaluating the level of determinism (predictability) in complex signals. The applications of the proposed methodology are shown with real-world data and further discussions.

Chapter 4, **Intelligent Adaptation and the Nature of Software Changes,** by Paolo Rocchi, presents a variety of internal and external entities requiring managers to update software programs in a business. Organizational measures frequently are not in line with the needs, and software maintenance still makes a hot problem in companies and institutions. There are numerous studies related to software evolution processes, but the original ideas of software evolution do not seem completely clear. There are contradictory opinions on the argument, some deem a software update as an accident or an occasional disturb, others consider software maintenance as a systematic phase of software implementation. The intention of this chapter is to scrutinize the root-causes of software evolutions so that one can be fully conscious of the nature of software changes and can handle practical countermeasures in more appropriate manners. In a preliminary stage the author develops two broad, referential notions: the human intelligence and the information system, and the author attempts to see how both of them contribute to the successful adaptation of work organizations. Then, programs are significantly involved in the adaptation process just seen contributing to the continuous evolution of companies and organizations. Finally the author provides viable suggestions for the management of software development and maintenance which are deduced from the preliminary theoretical frame.

Chapter 5, **The Reactive-Causal Cognitive Agent Architecture,** by Ali Orhan Aydın and Mehmet Ali Orgun, studies a general agent architecture to simulate human-like intelligence. The design philosophy behind the architecture is driven by a combination of Maslow's theories of needs and Dennett's intentional notion. Furthermore, to explain motives of intelligent agents, the authors adopt Alderfer's theory of needs which revises the ideas of Maslow. Intelligent agents are considered as entities driven by unsatisfied needs, and in order to satisfy those needs they act intentionally. Based on these ideas, the authors present a three tiered cognitive agent architecture to mimic any aspect of human intelligence. The active layer enables an agent to continuously observe internal and external conditions and act accordingly. The deliberative layer provides the means for learning, planning, conflict resolution with other agents, and dispatching tasks to the components in the reactive layer. The causal layer oversees the high-level decision-making and emotion generation processes.

Chapter 6, **Applying Strategies to Recommend Groupware Tools according to Cognitive Characteristics of a Team,** by Gabriela N. Aranda, Aurora Vizcaíno, Alejandra Cechich, and Mario Piattini presents the global software development (GSD) process. It is found that, despite the economic benefits that globalization may introduce, GSD faces a series of factors that affect communication and challenge its success. In order to improve communication in such environments, the authors focus on techniques from the field of cognitive psychology to define a new approach to groupware tools selection. In this paper the authors present a series of strategies to find the best choice for a given group

of people, taking into account the different combinations of cognitive profiles that can arise in a GSD project, as well as the application of one of these strategies in a case study.

Chapter 7, **An Ontology Modeling Tool,** by Christine W. Chan and Robert Harrison, presents the design and implementation of a software tool for modeling dynamic knowledge to be used in knowledge based systems or the Semantic Web. The tool presented has been developed based on the Inferential Modeling Technique, which is a knowledge modeling technique for representing both static and dynamic knowledge elements of a problem domain. A major deficiency of existing tools is the lack of support for modeling dynamic knowledge. To address this inadequacy, the focus of this work is on dynamic knowledge modeling. A Protégé plug-in, called Dyna, has been developed which supports modeling task behavior using the Task Behavior Language (TBL). Dyna also can create test cases for testing task behavior. Test cases are runnable and can enable verification that the model is working as expected. The dynamic knowledge models are stored in XML and OWL, and can be shared and re-used. The tool is applied for constructing a knowledge model in the petroleum contamination remediation selection domain.

Chapter 8, **Cognitive Approach to Negotiation,** is presented by Alberto de la Encina, Mercedes Hidalgo-Herrero, and Natalia López. It is found that cognitive systems often require abilities to perform negotiations to exchange resources among different entities. Unfortunately, providing a general framework to allow specifying such abilities is not a trivial task. In this chapter the authors present an approach to allow specifying how agents can exchange resources in a multi-agent system. The exchanges are performed taking into account the utility functions of each of the agents. Moreover, the resources available in the system are not restricted to material goods. That is, intangible goods (like information) can also be handled in the environment. In addition to that, the authors also analyze how to infer the utility functions associated to each agent.

Chapter 9, **The Visual Implications of Inspection Time,** by Tyler W. Garaas and Marc Pomplun, presents the quest to define human intelligence, which has led researchers down a large range of paths. One such path has been the search for a single, basic psychometric measure that can be used to account for a large portion of the variance in human mental ability. Inspection Time (IT) has emerged at the forefront of these efforts and can be shown to account for approximately 25% of the variance in psychometric tests of intelligence (e.g., IQ). In this study, the authors attempt to gain an insight into the nature of IT as a psychometric measure by first contrasting individuals that are adept at performing the IT task (those with low ITs) with individuals that are not (those with high ITs) using oculomotor and task-performance measures recorded during two visual tasks. The results of the first experiment show that the current prevailing theory regarding IT, the integration theory, is incapable of accounting for the results found during the visual tasks. This leads us to introduce a novel theory of IT, the watered-tree theory, which places IT as a measure of information propagation. The authors then perform a second experiment to test the opposing predictions of the integration theory and the watered-tree theory and find that the results are in line

with the predictions of the watered-tree theory. A discussion is presented on the implications of the proposed theory and the need for its future validation.

Chapter 10, **Socialware for People with Cognitive Disabilities,** by Fumio Hattori, Kazuhiro Kuwabara, Noriaki Kuwahara, Shinji Abe, and Kiyoshi Yasuda, studies socialware as a multiagent system that supports social activities in the symbiotic society. In this chapter, the authors focused on supporting people with such cognitive disabilities as dementia, aphasia, higher cerebral dysfunction, and senior citizens suffering from cognitive decline. The authors propose general socialware architecture for people with disabilities as multiagent systems that are composed of personal, communication, and community agents. Three experimental systems are introduced: a networked reminiscence system, a walk navigation system using photographs, and a conversation support system for people with aphasia.

Chapter 11, **Cognitive Informatics in Automatic Pattern Understanding and Cognitive Information Systems,** by Lidia Ogiela, presents a new way of pattern interpretation aimed at the automatic semantic categorization and image content understanding. Such an understanding is based on the linguistic theories of pattern classification and is aimed at facilitating the content analysis of some classes of medical and economical patterns. The approach presented in this chapter shows great opportunities for the automatic disease interpretation in some analyzed structures, and for supporting information management using the grammar approach. The interpretation is based on cognitive resonance processes which imitate the psychological processes of understanding registered patterns which take place in the brain of a human being. Cognitive and thinking processes taking place in the human brain have become the basis for defining classes of cognitive categorization systems designed for the in-depth, meaning-based interpretation and analysis of data. This type of an analysis is only possible thanks to applying interpretation and reasoning processes usually taking place in the human brain in a system. In addition, this type of an analysis is made possible by the use of linguistic algorithms for describing, analyzing and interpreting data in computer systems. Algorithms of this type support a meaning-based analysis of data which leads to understanding the semantic content of the analyzed data and to attempts at making forecasts with regard to the analyzed information.

Chapter 12, **A Visual Cognitive Method Based on Hyper Surface for Data Understanding,** by Qing He, Qing Tan, Xiurong Zhao, and Zhongzhi Shi, studies classification as a fundamental problem in data mining, which has extensive applications in information technology. Data understanding is highly relevant to how to sense and perceive them. However, the existing approaches for classification have been developed mainly based on dividing dataset space, less or no emphasis paid on simulating human or animal visual cognition. This chapter attempts to understand visual classification by using both psychophysical and machine learning techniques. A new Hyper Surface Classification method (HSC) has been studied since 2002. In HSC, a model of hyper surface is obtained by adaptively dividing the sample space and then the hyper surface is directly used to classify large database based on Jordan Curve Theorem in Topology. In this chapter the authors point out that HSC is a data understanding method which

accords with visual cognitive mechanism. Simulation results show that the proposed method is effective on large test data with complex distribution and high density. In particular, the authors show that HSC can deal with high dimensional data and build corresponding visual hyper surface using dimension transposition or ensemble method which accords with visual dimension transposition and multi-dimension cognitive mechanism respectively.

Chapter 13, **Cognitive Prism–More than a Metaphor of Metaphor,** by Tiansi Dong, studies a basic question in the functional model of the mind: with which mechanism a cognitive agent can understand new concepts and propose an answer: the cognitive prism mechanism. This mechanism is rooted in the information process of a neuron. Research results in cognitive psychology and linguistics support that such mechanism is used in concept-understanding in everyday-life. The authors show that this mechanism is used to integrate spatial environments existing at different temporal points and form a spatial concept. Lako's theory in concept understanding can be reformulated in terms of the cognitive prism mechanism. The classic mathematical logic, as well as fuzzy logic, can be understood as the (prism) mapping from language to true or false values. In Chinese medicine, human-body structure is referenced to spatial concepts through certain cognitive prism mechanism. The authors argue that metaphor is not only the mechanism to relate concepts in non-physical domain to physical ones, but also the mechanism to relate concepts within the physical domain. The authors briefly criticize the current theory of joks and propose a novel perspective to the understanding of jokes in term of 'potential tension' of cognitive prism. The authors conclude that equipped with the cognitive prism mechanism and concepts of spatial environment cognitive agents shall understand quite a lot of spatial/non-spatial concepts.

Chapter 14, **System Complexity and its Measures: How Complex is Complex,** by Witold Kinsner, presents that the last few decades of physics, chemistry, biology, computer science, engineering, and social sciences have been marked by major developments of views on cognitive systems, dynamical systems, complex systems, complexity, self-organization, and emergent phenomena that originate from the interactions among the constituent components (agents) and with the environment, without any central authority. How can measures of complexity capture the intuitive sense of pattern, order, structure, regularity, evolution of features, memory, and correlation? This chapter describes several key ideas, including dynamical systems, complex systems, complexity, and quantification of complexity. As there is no single definition of a complex system, its complexity and complexity measures too have many definitions. As a major contribution, this chapter provides a new comprehensive taxonomy of such measures. This chapter also addresses some practical aspects of acquiring the observables properly.

The editors expect that the readers of *Advances in Cognitive Informatics and Cognitive Computing* will benefit from the chapters presented in this book, which represents the latest research and development in cognitive informatics and its applications in cognitive computing, brain informatics, abstract intelligence, computational intelligence, and artificial intelligence.

Acknowledgments

The editors of this book, SCI 323, would like to thank all authors for submitting their interesting work. We are grateful to the reviewers for their great contributions to this book. We would like to express our sincere appreciation to the Editors-in-Chief of SCI, Prof. Janusz Kacprzyk and Senior Editor, Dr. Thomas Ditzinger, for their advice and support. We also thank the editorial staff at Springer for their professional help throughout the publication processes of this book.

May 2010

Yingxu Wang
Du Zhang
Witold Kinsner

IEEE ICCI 2008 Keynote Speakers and Co-chairs at Stanford University

(from right to left: *Jean-Claude Latombe, Lotfi A. Zadeh, Yingxu Wang, Witold Kinsner, and Du Zhang*)

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