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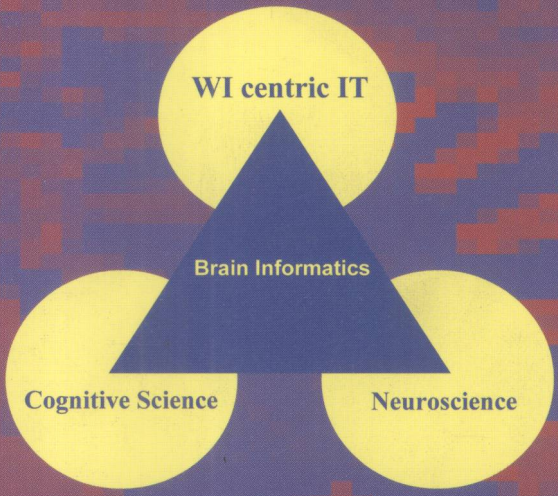
Ning Zhong Jiming Liu
Yiyu Yao Jinglong Wu
Shengfu Lu Kuncheng Li (Eds.)

Web Intelligence Meets Brain Informatics

**First WICI International Workshop, WImBI 2006
Beijing, China, December 2006
Revised Selected and Invited Papers**



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Revised Selected and Invited Papers

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Preface

All the chapters in this volume are invited contributions following a successful international workshop, namely, The First WICI International Workshop on Web Intelligence meets Brain Informatics (WImBI 2006) held in Beijing, China, December 15–16, 2006. The WICI (International WIC Institute, www.iwici.org/) is an international open educational research organization of the Web Intelligence Consortium (WIC, www.wi-consortium.org/). The institute is affiliated with Beijing University of Technology (BJUT).

The workshop explores a new perspective of Web Intelligence (WI) research from the viewpoint of Brain Informatics (BI). BI is a new interdisciplinary field studying human information processing mechanisms from both macro and micro points of view by cooperatively using experimental cognitive neuroscience and advanced WI-centric information technology. The new instrumentation (fMRI etc.) and advanced information technology are causing an impending revolution in Web Intelligence and brain sciences. This revolution is bi-directional: a new understanding and discovery of human intelligence models in brain sciences will yield a new generation of WI research and development; and WI-based technologies will provide a new powerful platform for brain sciences. The synergy between WI with BI will yield profound advances in our analysis and understanding of the natures of data, knowledge, intelligence, and wisdom, as well as their relationship, organization, and creation process. Fundamentals and implementational issues of WI will be studied as a central topic and in a unique way. It will fundamentally change the nature of information technology in general and artificial intelligence in particular, leading towards human-level WI.

In summary, the main features of the WImBI 2006 workshop and the book include:

- This workshop was the first in the field to focus on the interplay between (a) intelligent technologies, especially in the context of WI and (b) studies on human intelligence as explored in neuroscience, cognitive psychology, and brain science instrumentation.
- The participants of this workshop were by invitation only. All the invited attendees are presently world leaders in their respective areas, and can be expected to build a strong synergy and momentum for the "WI meets BI" research in the near future.
- The book, as a volume in the Springer LNCS/LNAI state-of-the-art survey, will be a milestone publication, with research visions and blueprints, for computer scientists and practitioners at large in this exciting interdisciplinary area. All the post-workshop, full-length papers were carefully reviewed and selected for inclusion.

WImBI 2006 had a very exciting program (www.wi-consortium.org/) with a number of features, ranging from technical sessions, keynote/invited talks,

demos/posters, and social programs. Many thanks go to the distinguished keynote speakers, Tomaso Poggio of MIT and Deyi Li of NSFC. We wish to express our gratitude to all members of the Workshop Organizing Committee and the International Advisory Board for their instrumental and unfailing support.

WImBI 2006 could not have taken place without the great team effort of the Local Organizing Committee and the support of Beijing University of Technology. Our special thanks go to Boyuan Fan and Zhenyang Lu (Organizing Chairs), Chunnian Liu, Baocai Yin, and Xunming Ji (Organizing Vice-Chairs) for their enormous efforts in planning and arranging the logistics of the workshop from registration/payment handling, venue preparation, accommodation booking, to banquet/social program organization. We would like to thank Shuai Huang, Jiajin Huang, Jia Hu, and Juzhen Dong, of the conference support team at the International WIC Institute (WICI), the Knowledge Information Systems Laboratory, Maebashi Institute of Technology, and Web Intelligence Laboratory, Inc. for their dedication and hard work.

We are very grateful to the WImBI 2006 corporate sponsors: State Administration of Foreign Experts Affairs, National Natural Science Foundation of China, Web Intelligence Consortium, Beijing University of Technology, Xuanwu Hospital/Capital University of Medical Sciences, Maebashi Institute of Technology, Web Intelligence Laboratory, Inc., and Springer *Lecture Notes in Computer Science* for their generous support. Last but not least, we thank Alfred Hofmann of Springer for his help in coordinating the publication of this special volume in an emerging and interdisciplinary research area.

September 2007

Ning Zhong
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Table of Contents

Introduction

Synergy of Web Intelligence and Brain Informatics

Cognitive Science, Neuroscience, and Brain Informatics

Web Intelligence Applications

Web Intelligence Meets Brain Informatics

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Abstract. In this chapter, we outline a vision of Web Intelligence (WI) research from the viewpoint of Brain Informatics (BI), a new interdisciplinary field that systematically studies the mechanisms of human information processing from both the macro and micro viewpoints by combining experimental cognitive neuroscience with advanced information technology. BI studies human brain from the viewpoint of informatics (i.e., human brain is an information processing system) and uses informatics (i.e., WI centric information technology) to support brain science study. Advances in instrumentation, e.g., based on fMRI and information technologies offer more opportunities for research in both Web intelligence and brain sciences. Further understanding of human intelligence through brain sciences fosters innovative Web intelligence research and development. WI portal techniques provide a powerful new platform for brain sciences. The synergy between WI and BI advances our ways of analyzing and understanding of data, knowledge, intelligence, and wisdom, as well as their interrelationships, organizations, and creation processes. Web intelligence is becoming a central field that revolutionizes information technologies and artificial intelligence to achieve human-level Web intelligence.

1 Introduction

The term "Web Intelligence (WI)" was first introduced in 2000 [88]. As a new field of study, it presents excellent opportunities and challenges for the research and development of new generations of Web-based information processing technology, as well as for exploiting Web-based advanced applications [38,91,93]. In a previous paper [76], we discussed several perspectives of WI research:

> WI may be viewed as applying results from existing disciplines (e.g., Artificial Intelligence (AI) and Information Technology (IT)) to a totally new domain - the World Wide Web (the Web for short); WI may be considered as an enhancement or an extension of AI and IT; WI introduces new problems and challenges to the established disciplines.

N. Zhong et al. (Eds.): WImBI 2006, LNAI 4845, pp. 1–31, 2007.

WI has been recognized gradually as a new research field on studying intelligence on the Web and intelligence for the Web.

Although WI related topics have been investigated separately in several existing disciplines, such as AI, Cognitive Science, and Neuroscience, there is a lack of a unified framework so that intelligence can be systematically studied for developing *human-level* Web intelligence. Brain Informatics (BI) is an emerging interdisciplinary field to systematically investigate human information processing mechanisms from both macro and micro points of view, by cooperatively using experimental, computational, cognitive neuroscience, and advanced WI centric information technology. It attempts to understand human intelligence in depth, towards a holistic view at a long-term, global vision to understand the principles and mechanisms of human information processing system (HIPS). The main objective of this chapter is to outline such a unified framework by examining what happens when *WI meets BI*. This leads to a new brain informatics perspective of WI research.

As more detailed blueprints and issues of WI are being evolved and specified [38,76,93,100], it becomes evident that one of the fundamental goals of WI research is to understand and develop wisdom Web based intelligent systems. Such systems integrate all human-level capabilities such as real-time response, robustness, autonomous interaction with their environment, communication in natural language, commonsense reasoning, planning, learning, discovery and creativity.

Turing gave the first scientific discussion of human-level machine intelligence [71]. Newell and Simon pioneered studies on programming computers for general intelligence [46]. McCarthy argued that reaching human-level AI requires programs that deal with the commonsense informative situation, in which the phenomena to be taken into account in achieving a goal are not fixed in advance [42]. Laird and Lent argued that interactive computer games are the killer application for human-level AI research, because they can provide the environments for research on the right kinds of problems that lead to the type of incremental and integrative research needed to achieve human-level AI [28].

In this chapter, we argue that human-level intelligence may be achieved by the combination of WI and BI. While the Web and the Web-based intelligent systems provide the necessary infrastructure for supporting BI research, as well as testbeds and applications of BI, BI research provides foundations to WI research. The rest of the paper is organized as follows. Section 2 details a new perspective of WI research. Section 3 examines how studies in two of the most fundamental WI related research areas, namely Autonomy Oriented Computing (AOC) and Granular Computing (GrC), interplay with those in BI. Section 4 describes several high-impact *WI meets BI* research topics. Finally, Section 5 gives concluding remarks.

2 A Brain Informatics Perspective of WI Research

There are urgent needs and great benefits of combining WI and BI research. Fundamental issues in both fields need to be investigated and integrated systematically in order to materialize those benefits.

2.1 What Is Brain Informatics?

Brain Informatics (BI) is an emerging interdisciplinary field to study human information processing mechanism systematically from both macro and micro points of view by cooperatively using experimental, computational, cognitive neuroscience and advanced WI centric information technology. It attempts to understand human intelligence in depth, towards a holistic view at a long-term, global vision to understand the principles and mechanisms of human information processing system (HIPS), with respect to functions from perception to thinking, such as multi-perception, attention, memory, language, computation, heuristic search, reasoning, planning, decision-making, problem-solving, learning, discovery and creativity. BI can be regarded as brain science in WI centric IT age [98,99]. BI is proposing to study human brain from the viewpoint of informatics (i.e., human brain is an information processing system) and use informatics (i.e., WI centric information technology) to support brain science study.

Figure 1 shows the relationship between BI and other brain science related disciplines as well as the WI centric IT. On one hand, although brain sciences have been studied from different disciplines such as cognitive science and neuroscience, BI represents a potentially revolutionary shift in the way that research is undertaken. It attempts to capture new forms of collaborative and interdisciplinary work. In this vision, new kinds of BI methods and global research communities will emerge, through infrastructure on the wisdom Web and knowledge grids that enables high speed and distributed, large-scale analysis and computations, and radically new ways of sharing data/knowledge. On the other hand, some of these lessons in cognitive science and neuroscience are applicable to novel technological developments in BI, yet others may need to be enhanced or transformed in order to manage and account for the complex and possibly more innovative practices of sharing data/knowledge that are made technically possible by the wisdom Web and knowledge grids [37,38,98].

2.2 Key Research Topics of Brain Informatics

In order to study BI systematically and give a global view to answer what is brain informatics, we list several major subtopics in each research area below, which is an extensional description of BI research.

- Thinking centric investigation of HIPS:
  - Human deductive/inductive reasoning mechanism for understanding the principle of human reasoning and problem solving;
  - Human learning mechanism for acquiring personalized student models in an interactive learning process dynamically and naturally.
- Perception centric investigation of HIPS:
  - Human multi-perception mechanism;
  - Auditory, visual and tactile information processing.
- Modeling human brain information processing mechanism:
  - Neuro-mechanism of HIPS;

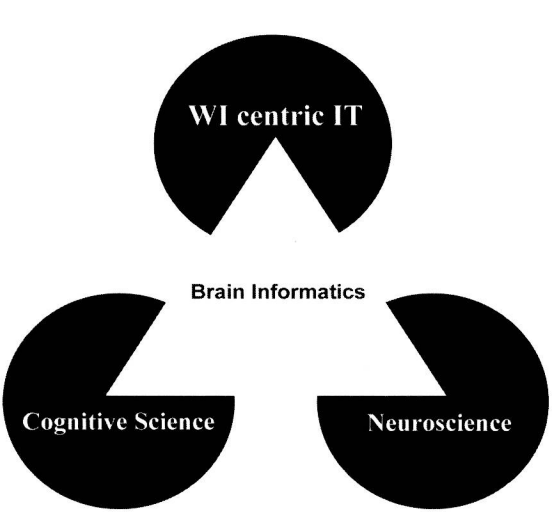

Fig. 1. The relationship between Brain Informatics and other brain science related disciplines as well as the WI centric IT

  - Mathematical models of HIPS;
  - Cognitive and computational models of HIPS.
- Information technologies for management and use of human brain data:
  - Human brain data collection, pre-processing, management, and analysis;
  - Multi-media human brain data mining and reasoning;
  - Databasing the brain and constructing data brain models;
  - Developing brain data grid and brain research support portals.

As a crucial step in understanding human intelligence, we must fully examine the mechanisms in which the human brain operates. The existing results, as reported over the last few decades about human information processing mechanism, are greatly related to progress of measurement and analysis technologies. Various non-invasive brain functional measurements are possible recently, such as fMRI and EEG. If these measurement data are analyzed systematically, the relationship between a state and an activity part will become clear. Furthermore, it is useful to discover more advanced human cognitive models based on such measurement and analysis. New instrumentation and new data analysis methods are causing a revolution in both AI and brain sciences [45,67].

In summary, BI emphasizes on a *systematic* approach for investigating human information processing mechanisms, including measuring, collecting, modeling, transforming, managing, mining, interpreting, and explaining multiple human brain data obtained from various cognitive experiments by using powerful equipments, such as fMRI and EEG. Human brain is regarded as an information processing system. A *systematic* study includes the investigation of human thinking centric mechanisms, the design of cognitive experiments, human brain data management, and human brain data analysis. Multi-aspect analysis in multiple