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Yang Cai (Ed.)

Ambient Intelligence for Scientific Discovery

Foundations, Theories, and Systems

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The Museum of Modern Art is perhaps one of the most interesting landmarks in Vienna, where SIGCHI 2004 Workshop of "Ambient Intelligence for Scientific Discovery" was held. The building is covered by walls and ceiling composed of thick slabs of dark basalt stone cut at intervals by narrow vertical slits, accentuating the monolithic effect of the entire volume.

Preface

For half a century, computer scientists have been working on systems for discovering lawful patterns in letters, numbers, words and images. The research has expanded into the computational study of the process of scientific discovery, producing such well-known AI programs as BACON and DENDRAL. However, *autonomous* discovery systems have been rarely used in the real world. While many factors have contributed to this, the most chronic difficulties seem always to fall into two categories: (1) the representation of the prior knowledge that people bring to their tasks, and (2) the awareness of new context.

Many difficult scientific discovery tasks can only be solved in *interactive* ways, by combining intelligent computing techniques with intuitive and adaptive user interfaces. It is inevitable that human intelligence is used in scientific discovery systems. For example, the human eyes can capture complex patterns and relationships, along with detecting the exceptional cases in a data set. The human brain can easily manipulate perceptions (shape, color, balance, time, distance, direction, speed, force, similarity, likelihood, intent and well-being) to make decisions. This process consists of *perception* and *communication* and it is often ubiquitous and autonomous. We refer to this kind of intelligence as ambient intelligence (AmI).

Ambient intelligence is about human interaction with information in a way that permits humans to spot interesting signs in massive data sources – building tools that capitalize on human strengths and compensate for human weaknesses to enhance and extend discovery capabilities. For example, people are much better than machines at detecting patterns in a visual scene, while machines are better at manipulating streams of numbers.

Scientific discovery is a process of creative perception and communication. With growing data streams and the complexity of discovery tasks, we see a demand for integrating novel digital media and communications (e.g., body media, capsule cameras, WiFi, etc.) and opportunities for ambient intelligence to use interaction methods that are usually taken for granted, such as perception, insight and analogy. We want to search for solutions to interesting questions such as: How do we significantly reduce information while maintaining meaning? How do we extract patterns from massive and growing data resources?

This volume represents the outcome of the SIGCHI Workshop on "Ambient Intelligence for Scientific Discovery," held in Vienna, on April 25, 2004. The chapters in this volume were selected from the revised papers submitted to the workshop and contributions from leading researchers in this area. The objective of this volume is to present a state-of-the-art survey of studies in ambient intelligence for scientific discovery, including novel ideas, insightful findings and ambient intelligence systems across multiple disciplines and applications. The volume is published for graduate students, senior undergraduate students, researchers and professionals. Therefore, extended references are provided in each chapter.

The contents in this volume are organized into three tracks: Part I, New Paradigms in Scientific Discovery; Part II, Ambient Cognition; and Part III, Ambient Intelligence Systems. Many chapters share common features such as interaction, vision, language, and biomedicine, which reflects the interdisciplinary nature of this volume.

I. New Paradigms in Scientific Discovery. Processing massive data has been a bottleneck to modern sciences. In Chap. 1, "Science at the Speed of Thought," Devaney et al. describe a virtual laboratory that is designed to accelerate scientific exploration and discovery by minimizing the time between the generation of a scientific hypothesis and the test of that idea, and thereby enabling science at the speed of thought. In Chap. 2, "Computational Biology and Language," Ganapathiraju et al. present a breakthrough approach that enables exploitation of an analogy between natural language and speech processing techniques in computational biology. In Chap. 3, "Interactive Comprehensible Data Mining," Pryke and Beale present their interactive data mining system that helps users gain insight from the dynamically created virtual data space. In Chap. 4, "Scientific Discovery Within Data Streams," Cowell et al. present the architecture of a next-generation analytical environment for scientific discovery within continuous, time-varying data streams.

II. Ambient Cognition. Understanding how people sense, understand and use images and words in everyday work and life can eventually help us design more effective discovery systems. In Chap. 5, Leyton reviews his theory of "Shape as Memory Storage", addressing shape description over time. Leyton's theory has been used in more than 40 fields, such as radiology, metrology, computer vision, chemical engineering, geology, computer-aided design, anatomy, botany, forensic science, software engineering, architecture, linguistics, mechanical engineering, computer graphics, art, semiotics, archaeology, and anthropology, etc. In Chap. 6, Hubona and Shirah investigate how various spatial depth cues, such as motion, stereoscopic vision, shadows and scene background, are utilized to promote the perceptual discovery and interpretation of the presented imagery in 3D scientific visualization. In Chap. 7, "Textual Genre Analysis and Identification," Kaufer et al. present a knowledge-based approach for encoding a large library of English strings used to capture textual impressions and report on a study of a popular textual genre – the technology review. The expert system incorporates contextual information, e.g., culture, emotion, context, and purpose, etc., which is different from many prevailing methods such as machine learning or statistics. In Chap. 8, "Cognitive Artifacts in Complex Work," Jones and Nemeth use acute care and scientific ethnographic field studies to show how cognitive artifacts can be used to grasp the nature of cognitive work in uncertain, complex, technical work settings. This front-end research is aimed at optimizing distributed cognitive work.

III. Ambient Intelligence Systems. Ubiquitous sensors and communication technologies not only can assist scientific discovery, but can also catalyze new sciences. In Chap. 9, "Multi-modal Interaction in Biomedicine," Zudilova and Sloot investigate the practical deployment of virtual reality systems in the medical environment. They explore the multi-modal interaction of virtual reality and desktop computers in Virtual Radiology Explorer. In Chap. 10, "Continuous Body Monitoring," Farringdon and Nashold describe a personal and continuous body monitor that is one of the few examples of ambient intelligence devices commercially available today. This also brings challenges to sciences: for example, how do we extract the interesting patterns from a continuous body monitor? From this example we can see how the research scope has been extended from laboratories to homes and in vivo. In Chap. 11, "Ambient Diagnosis," Cai et al. explore *Ambient Diagnosis* that is based on traditional Chinese medicine (TCM). The case study shows how to map the visual features on the tongue into a vector of numbers. In Chap. 12, Tanz et al. describe methods for location mapping in a wireless local area network (WLAN) and applications in social sciences. The system cmuSKY developed by the authors has become a public online resource for scientific discovery. In Chap. 13, "Behavior-Based Indoor Navigation," Abascal et al. present a method for motor fusion using ambient information from the environment. Indoor robotic navigation has been an active subject because of applications in assisted-living, such as smart wheelchair control, guidance for the visually impaired, or indoor assistance of the elderly. Finally, in Chap. 14, "Ambient Intelligence Through Agile Agents," O'Hare et al. explore agile agents as a key enabler for the realization of the ambient intelligence vision.

We are deeply indebted to all the authors who contributed papers to this volume; without this depth of support and commitment there would have been no meaningful product at all. We acknowledge the members of the program committee, all those involved in the refereeing process, the workshop organizers, and all those in the community who helped to convene a successful workshop. Special thanks go to Judith Klein-Seetharaman, Peter Jones, William Eddy, David Kaufer, Yongxiang Hu, Bin Lin, and Vijayalaxmi Manoharan for their contributions to the workshop and this volume. Thanks to the external reviewers Howard Choset, Lori Levin, Susan Fussell, and Tony Adriaansen for their comments on the manuscripts. Thanks to Teri Mick for assisting the volume editing and Sarah Nashold for assisting the book design. This project is in part sponsored by NASA grant NAG-1-03024 and National Academy of Sciences (NAS) grant T-37.

Pittsburgh, October 2004 Yang Cai

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