State-of-the-Art Survey

LNAI 3864

Yang Cai
Julio Abascal (Eds.)

Ambient Intelligence in Everyday Life

Foreword by Emile Aarts

Springer

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Library of Congress Control Number: 2006931064

CR Subject Classification (1998): I.2, H.5, H.4, C.2, D.2

LNCS Sublibrary: SL 7 – Artificial Intelligence

ISSN 0302-9743
ISBN-10 3-540-37785-9 Springer Berlin Heidelberg New York
ISBN-13 978-3-540-37785-6 Springer Berlin Heidelberg New York

Springer is a part of Springer Science+Business Media

springer.com

Printed in Germany

Typesetting: Camera-ready by author, data conversion by Scientific Publishing Services, Chennai, India
Printed on acid-free paper SPIN: 11825890 06/3142 5 4 3 2 1 0

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Edited by J. G. Carbonell and J. Siekmann

Subseries of Lecture Notes in Computer Science

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An ordinary summer night in Donostia-San Sebastian, Spain, where Ambient Intelligence for Everyday Life Workshop was held on July 21-22, 2005.

Foreword

Back in 1997, on the occasion of the 50th anniversary of the Association of Computing Machinery, computer scientists from all over the world were asked for their opinion about the next 50 years of computing. Although rooted in many different disciplines, the scientists' reactions were strikingly consistent in the sense that they all envisioned a world consisting of distributed computing devices that would surround people in a non-obtrusive way. As one of the first paradigms following this vision, Marc Weiser's Ubiquitous Computing was aimed at a novel computing infrastructure that would replace the current mobile computing infrastructure by interconnected, transparent, and embedded devices that would facilitate ubiquitous access to any source of information at any place, any point in time and by any person. Such a world could be conceived by a huge distributed network consisting of thousands of interconnected embedded systems surrounding the user and satisfying his or her needs for information, communication, navigation, and entertainment.

Ambient Intelligence (AmI), introduced in the late 1990s as a novel paradigm for digital systems for the years 2010-2020, builds on the early ideas of Weiser by taking the embedding and integration one step further. This disruptive improvement may be conceived by embedding computational intelligence into the networked environment and moving the user into the foreground by supporting him or her with intuitive and natural interaction concepts. According to the definition, ambient intelligence refers to smart electronic environments that are sensitive and responsive to the presence of people. Since its introduction, this vision has grown mature, having become quite influential in the development of new concepts for information processing as well as combining multidisciplinary fields including electrical engineering, computer science, industrial design, user interfaces and cognitive sciences.

The AmI paradigm provides a basis for new models of technological innovation within a multidimensional society. The essential enabling factor of the AmI vision is provided by the fact that current technological developments indeed enable the large-scale integration of electronics into the environment, thus enabling the actors, i.e., people and objects to interact with their environment in a seamless, trustworthy and natural manner. In addition, the past years reveal a growing interest in the role of information and communication technology to support peoples' lives, not only for the purpose of increased productivity, but also for the purpose of self-expression, health-care, leisure, and creativity. A major issue in this respect is given by the growing awareness that novel products such as devices and services should meet elementary user requirements, i.e., usefulness and simplicity. Hence, it is generally believed that novel technologies should not increase functional complexity, but should merely contribute to the development of *easy to use* and *simple to experience* products. Obviously, this statement has a broad endorsement by a wide community of both designers and engineers, but reality reveals that it is hard to achieve in practice, and that novel approaches, as may be provided by the AmI vision, are needed to make it work.

All these new socio-economic developments open up major opportunities for making money in markets that exploit ambient intelligent technology, thus providing the necessary economical foundation for the development of ambient intelligence. The developments in ambient intelligence obtained during its relative short existence reveal that the vision is rapidly gaining traction, and that some of the early ideas following from this vision are growing mature. Examples are the use of context-aware services in mobile phones exploiting RFID tags and personalized media players that apply user profiles and collaborative filtering techniques to recommend and exchange digital information. No matter how smart and technologically advanced these examples may be, they cannot be regarded as the major and the most convincing breakthroughs in ambient intelligence that are needed to lead to full acceptance of the new paradigm.

As the success of the AmI paradigm relies heavily on the social acceptance of the newly proposed ambient technology, we need to look at the human factors' side of the vision in order to study the relation between AmI technology and people's behavior. This would reveal the true added value of ambient intelligence in everyday life. In view of this, the present special LNAI volume on *Ambient Intelligence in Everyday Life* can be considered a timely document that provides an important contribution to the dissemination of the AmI vision. The editors have succeeded in bringing together a quite interesting and inspiring collection of research contributions reporting on the progress of ambient intelligence within various domains. Divided in three parts, i.e., "Human Centered Computing," "Ambient Interfaces," and "Architectures in Ambient Intelligence," the volume presents a fine collection of papers emphasizing the multi-disciplinary character of the investigations not only from the point of view of the various scientific fields involved, but also from an application point of view. To the best of my knowledge, this is the first book that presents achievements and findings of AmI research covering the full spectrum of societally relevant applications, ranging from learning, leisure, and trust, all the way to well-being, healthcare and support for elderly and disabled persons. These make the volume truly unique, and in more than one respect, a truly valuable source of information that may be considered a landmark in the progress of ambient intelligence. Congratulations to all those who have contributed!

Eindhoven, November 2005

Emile Aarts
Vice President of Philips Research

Preface

As sensors and antennas are embeddable in things around us, a new era of physical Internet begins. The revolution is brought by economies of scale and millions of consumers. Today, a music birthday card may have more computing power than a mainframe computer a few decades ago. However, we still don't know how to sense human feelings electronically. Perhaps we need to go back to the drawing board and rethink our daily life.

In this volume, we focus on the cognitive aspects of ambient intelligence. In a broad sense, ambient intelligence is *perceptual interaction*, which involves sensory fusion, common sense, insight, anticipation, esthetics and emotion that we normally take for granted. We interact with the world through the windows of our senses: sight, sound, smell, taste and touch, which not only describe the nature of physical reality, but also connect us to it emotionally. Our knowledge is composed by the fusion of multidimensional information sources: shape, color, time, distance, direction, balance, speed, force, similarity, likelihood, intent and truth. Ambient intelligence is not only a perception, but also an interaction. We not only acquire information, but also construct and share information.

Common sense has been an immense challenge to ambient intelligence. For over 20 years, with over a 20-million-dollar investment, Douglas Lenat and his colleagues have been developing Cyc, a project that aims to create a reusable general knowledge base for intelligent assistants. Cyc essentially looks for a representation model of human consensual knowledge that can construct a *semantic web* where meaning is made explicit, allowing computers to process intelligently. One remarkable extension of the knowledge formalism in Cyc is the ability to handle default reasoning. In many cases, ambient intelligence operates at a default level or below perceptual thresholds. Default reasoning is generally common sense itself.

Empathic computing, or human-centric computing has been a rapidly growing area because we want an intelligent system to know the "who, what, when, and where" as it encounters different situations. In this volume, Maja Pantic reviews the-state-of-the-art face interfaces, especially in the facial emotion detection area. Furthermore, empathic computing systems such as eWatch and wearable sensor networks are explored for transforming multimodal signals into recognizable patterns. As information appliances enter our daily life, sensor-rich computing is necessary to interpret the data.

Innovative ambient interfaces are also presented in this volume, which includes co-creation in ambient narrative, hyper-reality, a pre-communication system and an ambient browser. As sound interfaces are gaining momentum because of their ambient nature, in this volume, we include papers about whistling to a mobile robot, online music search by tapping, and user-specific acoustic phased arrays.

Finally, ambient infrastructures are presented to seamlessly connect the dots between homes, offices and individuals, including a middleware structure, interfaces for elderly people at home, a smart wheelchair, and online collaborators.

The volume of work comes from the Workshop of Ambient Intelligence in Everyday Life that was held at the Miramar Congress Center, a historical building in Donostia-San Sebastian, Spain, July 21-22, 2005. The idea of organizing this small workshop was inspired by Norbert Wiener's vision about scientific communication. In his book on Cybernetics 50 years ago, he said, "the idea has been to get together a group of modest size, not exceeding some twenty in number of workers in various related fields, and to hold them together for two successive days in all-day series of informal papers, discussions, and meals together, until they have had the opportunity to thresh out their differences and to make progress in thinking along the same lines." Although the workshop was proven successful in the exchange of the different opinions, not every participant thought along the same lines about how to define ambient intelligence. This indeed reflects the nature of this dynamic field.

We are deeply in debt to all the authors and reviewers who contributed to this special volume. Without their effective support and commitment, there wouldn't be this meaningful product at all. We thank Emile Aarts from Philips Research for the Foreword. Special thanks to local workshop organizers Elena Lazkano and Basilio Sierra, the Program Committee, and all of those who were involved in the refereeing process, and all of those who helped to convene this successful workshop. We acknowledge those who have supported the research in ambient intelligence for the past years: Counselor Paul op den Brouw and Attaché Roger Kleinenberg for Science and Technology of the Royal Netherlands Embassy in Washington, DC, Program Managers Pierre-Louis Xech and Marco Combetto from Microsoft Research, Cambridge, Program Managers Karen Moe, Steven Smith, Horace Mitchell, Kai Dee Chu, Yongxiang Hu and Bin Lin from NASA, and President Karen Wolk Feinstein and Senior Program Officer Nancy Zionts from Jewish Healthcare Foundation, and colleagues from Carnegie Mellon University: Pareedp Khosla, Mel Seigel, David Kaufer, Michael Reiter, Don McGillen, Bill Eddy, Howard Watlar, Daniel Siewiorek and Raj Rajkummar.

This project was in part sponsored by grants from the University of the Basque Country-Euskal Herriko Unibertsitatea, Kutxa, Universidad del Pais Vasco, Gipuzkoako Feru Aldundia Diputacion Foral de Gipuzkoa, Robotiker, Ikerlan, NASA ESTO-AIST Program, NASA LaRC C&I Initiative and ARO.

Yang Cai and Julio Abascal
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Part III: Architectures in Ambient Intelligence

Common Sense Reasoning – From Cyc to Intelligent Assistant

Kathy Panton, Cynthia Matuszek, Douglas Lenat, Dave Schneider, Michael Witbrock, Nick Siegel, and Blake Shepard

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Abstract. Semi-formally represented knowledge, such as the use of standardized keywords, is a traditional and valuable mechanism for helping people to access information. Extending that mechanism to include formally represented knowledge (based on a shared ontology) presents a more effective way of sharing large bodies of knowledge between groups; reasoning systems that draw on that knowledge are the logical counterparts to tools that perform well on a single, rigidly defined task. The underlying philosophy of the Cyc Project is that software will never reach its full potential until it can react flexibly to a variety of challenges. Furthermore, systems should not only handle tasks automatically, but also actively anticipate the need to perform them. A system that rests on a large, general-purpose knowledge base can potentially manage tasks that require world knowledge, or "common sense" – the knowledge that every person assumes his neighbors also possess. Until that knowledge is fully represented and integrated, tools will continue to be, at best, *idiots savants*. Accordingly, this paper will in part present progress made in the overall Cyc Project during its twenty-year lifespan – its vision, its achievements thus far, and the work that remains to be done. We will also describe how these capabilities can be brought together into a useful ambient assistant application.

Ultimately, intelligent software assistants should dramatically reduce the time and cognitive effort spent on infrastructure tasks. Software assistants should be *ambient systems* – a user works within an environment in which agents are actively trying to classify the user's activities, predict useful subtasks and expected future tasks, and, proactively, perform those tasks or at least the sub-tasks that can be performed automatically. This in turn requires a variety of necessary technologies (including script and plan recognition, abductive reasoning, integration of external knowledge sources, facilitating appropriate knowledge entry and hypothesis formation), which must be integrated into the Cyc reasoning system and Knowledge Base to be fully effective.

1 The Evolution of Cyc

1.1 Beginnings of the Cyc Project

In the early 1970s, rule-based expert systems such as MYCIN [18] and DENDRAL [3] were AI's major success story. MYCIN acted as an assistant in the diagnosis of

Y. Cai and J. Abascal (Eds.): Ambient Intelligence in Everyday Life, LNAI 3864, pp. 1 – 31, 2006.

blood infections, while DENDRAL's expertise was in chemical analysis. These applications used rules to solve problems within circumscribed domains. Expert systems represented a major step forward in AI technology and are used today to address problems as diverse as camera lens design and cargo placement [5], but their limitations quickly became obvious. Lenat and Guha [10] provide several examples of the *brittleness* displayed by expert systems. Two will suffice here:

> An expert system authorizes a car loan to someone who stated, on his application, that he'd worked at the same job for twenty years. A good risk? Perhaps, but the individual also stated he was 18 years old.
>
> A skin disease diagnosis program is told about a "patient" that is a 1969 Chevrolet:
>
> ***Program:*** Are there spots on the body?
> ***User:*** Yes.
> ***Program:*** What color spots?
> ***User:*** Reddish-brown.
> ***Program:*** Are there more spots on the trunk than elsewhere?
> ***User:*** No.
> ***Program:*** The patient has measles.

In the first example, the system failed to notice what was likely to have been a simple typo; perhaps the applicant meant that he had been at his current job for two years, or 20 months. Rules encoded in that system might nevertheless conclude that someone employed by the same company for 20 years is a very good credit risk, resulting in an easy loan approval. The system breaks down because it cannot detect what, to humans, are very obvious contradictions. These errors can have effects far more dire than in the car loan case. For example, a medical transcriptionist accidentally transposing a patient's weight and age in a patient record could lead to that patient being prescribed medications at dangerously incorrect dosage levels.

The second example illustrates that expert systems work only within the domain for which they were explicitly engineered; this software cannot correctly diagnose rust spots on a car. Furthermore, the system is unable to use its knowledge about skin infections to do things like recommend treatment or explain to users how long the disease might last and what other symptoms the patient may be experiencing. In short, this software contains many handcrafted rules that encode useful information about skin diseases, but this knowledge is isolated and opaque: it is useless when applied to an object outside its domain, and cannot be reused across similar or related problems.

Expert systems have no understanding of what they are for, or the extent of their own knowledge. But their brittleness is mainly due to a lack of *common sense*. This is the general knowledge that allows us to get by in the real world, and to flexibly understand and react to novel situations. We remember and use (though usually not consciously) heuristics such as "Water makes things wet"; "Wet metal may rust"; "No two objects can occupy the same space at the same time"; and "Inanimate objects don't get diseases".

The driving force behind the Cyc Project was the realization that almost all software programs would benefit from the application of common sense. Expert systems would gain protection against user error or intentional fraud; the consistency of data in spreadsheets could be checked automatically; information-retrieval systems and word processors could exhibit more useful behaviors based on an understanding of the user's goals at any given point. The greatest impediment to the achievement of AI was the inability of programs to accumulate, apply, and reuse general knowledge.

Lenat began the Cyc Project in 1984, at the Microelectronics and Computer Technology Corporation in Austin, Texas, with the goal of building a single intelligent agent. This agent would be equipped not just with static facts, but also with heuristics and other problem-solving methods that would allow it to act as a substrate, an almost invisible performance-boosting layer, underlying a variety of software applications. The Cyc Project was initially envisioned as a series of ten-year, two-to-ten-person-century efforts, in (1) knowledge base and ontology building, or "pump priming"; (2) natural language understanding and interactive dialogue; and (3) automated discovery.

1.2 Representing Knowledge

Three preliminary research questions presented themselves: How much does a system need to know in order to be useful? What kinds of knowledge are necessary? How should this knowledge be represented?

1.2.1 Amount of Knowledge

The "annoying, inelegant, but apparently true" answer to the first question was that vast amounts of commonsense knowledge, representing human consensus reality, would need to be encoded to produce a general AI system (Lenat and Guha 1990) [10]. In order to mimic human reasoning, Cyc would require background knowledge regarding science, society and culture, climate and weather, money and financial systems, health care, history, politics, and many other domains of human experience. The Cyc Project team expected to encode at least a million facts spanning these and many other topic areas.

1.2.2 Kinds of Knowledge

Lenat and his team understood that the "pump priming" information was not specific facts (e.g. "President Lincoln was assassinated"), but rather the "white space" – the unstated knowledge which the writer of such sentences assumes the reader already knows, such as the fact that being President requires one to be alive.

In order to truly comprehend a sentence such as "President Abraham Lincoln was assassinated", and be able to make inferences about its likely consequences, a person must have already learned many facts about the world. Someone unable to answer the following questions cannot be said to have fully understood the example sentence:

What is a President?
Was Lincoln President two months after he was assassinated?
Was Lincoln alive 300 years before he was assassinated?