Advanced Intelligent Environments

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Victor Callagan · Achilles D. Kameas
Editors

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Springer

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ISBN 978-0-387-76484-9 e-ISBN 978-0-387-76485-6
DOI 10.1007/978-0-387-76485-6
Springer Dordrecht Heidelberg London New York

Library of Congress Control Number: 2008944170

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

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Introduction

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This book highlights recent trends and important issues contributing to the realization of the ambient intelligence vision, where physical space becomes augmented with computation, communication, and digital content, thus transcending the limits of direct human perception. The focus is placed on advanced inhabitable intelligent environments including mechanisms, architectures, design issues, applications, evaluation, and tools.

The book is based on a selected subset of papers from the IET International Conference on intelligent environments (IE 07) held in Ulm, Germany. This conference has been the third in the highly successful intelligent environments (IE) conference series where the first conference (IE 05) took place in Colchester, UK, in June 2005 and the second conference took place in Athens, Greece, in July 2006. In April 2007, the conference series was awarded the Knowledge Network Award by the Institution of Engineering and Technology (IET) as the conference series was perceived to be emerging as the strongest international multi-disciplinary conference in the field. The conference brings together the contributions of different intelligent environments disciplines to form a unique international forum that will help to create new research directions in the intelligent environments area while breaking down barriers between the different disciplines. In addition, the conference provides a leading edge forum for researchers from industry and academia from across the world to present their latest research and to discuss future directions in the area of intelligent environments.

The IE 07 conference programme featured 91 papers from more than 23 different countries representing the 6 continents. Of these nine were invited for publication in this book along with a paper by an invited speaker, i.e. a total of 10 papers. All conference papers were extended and revised before they were submitted as book chapters. Each chapter has subsequently been reviewed by at least two reviewers and further improved on the basis of their comments.

We would like to thank all those who contributed to and helped us in preparing the book. In particular we would like to express our gratitude to the following reviewers for their valuable comments and criticism on the submitted drafts of the book chapters: Elisabeth André, Hakan Duman, Hans Dybkjær, Kjell Elenius, Michael Gardner, Franz Hauck, Sumi Helal, Anne Holohan, Sajid Hussain, Rosa Iglesias, Nicos Komninos, Antonio Lopez, Michael McTear, Anton Nijholt, Angelica Reyes, Albrecht Schmidt, Abdulmotaleb El Saddik, and Roger Whitaker. We are also grateful to Kseniya Zablostkaya and Sergey Zablotskiy at the Institute of Information Technology at the University of Ulm for her support in editing the book.

In the following we give an overview of the book contents by providing excerpts of the chapter abstracts. Very roughly we may divide the chapters into the following categories although many chapters address aspects from more than one category and all chapters deal with intelligent environment aspects.

- Pervasive computing (Chapters 1–3);
- Human–computer interaction (Chapters 4–6);
- Context awareness (Chapters 7–8);
- Architecture (Chapters 9–11).

Pervasive computing: Chapters 1–3 deal with issues in the area of pervasive computing.

In Chapter 1 Helal et al. present an assistive environment for health-care and well-being services to elderly people (Helal et al., 2009). The demand for senior-oriented devices and services will significantly increase in the near future. Assistive environments provide support and compensate for age-related impairments. Pervasive computing environments, such as smart homes, bundle assistive technologies and specially designed architectural and home furnishing elements. However, to be commercially viable, a system should allow the technology to be easily utilized and be introduced in a plug-and-play fashion. As an example for assistive environments, the authors present a residential home for elderly people.

Johnson explores in Chapter 2 consumer experience architecture as a practice and a methodology for developing products and services so that they fit intuitively into the lives of consumers (Johnson, 2009). He draws on recent experiences at Intel, where this framework has directly been applied to the development of personal technology devices. The chapter dismantles the consumer experience architecture into its essential components, exploring real-world examples and illustrations. The reader is challenged to expand current development practices by looking towards science fiction or other cultural inputs as possible laboratories or inspirations for future designs.

According to Goumopoulos et al. (Chapter 3) artifacts will have a dual self in the forthcoming Ambient Intelligence environments: artifacts are objects with physical properties and they have a digital counterpart accessible through a network (Goumopoulos et al., 2009). An important characteristic may be the merging of physical and digital space (i.e. tangible objects and physical environments are acquiring a digital representation), still, people's interaction with their environment will not cease to be goal-oriented and task-centric. However, ubiquitous computing technology will allow people to carry out new tasks, as well as old tasks in new and better ways.

Human–computer interaction: Chapters 4–6 deal with issues in the area of human–computer interaction in intelligent environments.

In Chapter 4 Jacquet et al. propose a ubiquitous information system providing personalized information to mobile users, such as in airports and train stations (Jacquet et al., 2009). The goal is to perform a selection among the set of available information items, so as to present, in a multimodal way, only those relevant to people located at proximity. A device will provide information to a user only if one of its output modalities is compatible with one of the user's input modalities. The proposed agent architecture is based on an alternative to traditional software architecture models for human–computer interaction.

The trend in affective computing currently aims towards providing simpler and more natural interfaces for human–computer interaction. The computer should be able to adapt its interaction policies to the user's emotional status. Scherer et al. investigate in Chapter 5 the performance of an automatic emotion recognizer using biologically motivated features (Scherer et al., 2009). Single classifiers using only one type of features and multi-classifier systems utilizing all three types are examined using two classifier fusion techniques. The performance is compared with earlier work as well as with human recognition performance. Using simple fusion techniques could improve the performance significantly.

In Chapter 6 Willis et al. investigate the nature of spatial knowledge acquisition in an environmental setting (Willis et al., 2009). The authors use a task where the participants have learnt the environment using spatial assistance, either from a map or from a mobile map. Results of an empirical experiment which evaluated participants spatial knowledge acquisition for orientation and distance estimation tasks in a large-scale urban environmental setting are outlined. The experiments showed that mobile map participants performed worse in distance estimation tasks than map participants, especially for complex routes.

Context awareness: Chapters 7–8 deal with context awareness in intelligent environments.

In Chapter 7 Hussain and Islam present a genetic algorithm to generate balanced and energy-efficient data aggregation spanning trees for wireless sensor networks (Hussain and Islam, 2009). These networks are commonly used in various ubiquitous and pervasive applications. Due to limited power resources, the energy-efficient communication protocols and intelligent data dissemination techniques are needed. Otherwise, the energy resources will deplete drastically and the network monitoring will be severely limited. In a data aggregation environment, the gathered data are highly correlated and each node is capable of aggregating any incoming messages to a single message and reduce data redundancy.

The objective of the research described by Jakkula et al. in Chapter 8 is to identify temporal relations among daily activities in a smart home to enhance prediction and decision-making with these discovered relations, and to detect anomalies (Jakkula et al., 2009). The authors hypothesize that machine learning algorithms can be designed to automatically learn models of resident behavior in a smart home. When these are incorporated with temporal information, the results can be used to detect anomalies. This hypothesis is validated using empirical studies based on the data collected from real resident and virtual resident data.

Architecture: Chapters 9–11 address architectural issues, both in terms of computer architecture (middleware) and bulidings and structures.

Service-oriented architecture, addressed by Yang et al. in Chapter 9, has established itself as a prevailing software engineering practice in recent years and extends to the domain of pervasive computing (Yang et al., 2009). The proposed solution for building fault-resilient pervasive computing systems consists of two parts: First, the virtual sensor framework improves the availability of basic component services. Second, an architecture for performing service composition can efficiently model, monitor and re-plan this process. To create a comprehensive solution, these two parts have to work hand in hand during the entire life cycle of pervasive services.

Chapter 10 by Dale et al. describes a system of parametric-networked urbanism that explores the integration of adaptive spaces according to cultural, social and economic dynamics (Dale et al., 2009). The goal of the research was to explore new forms of urbanism corresponding to criteria of parametric design and further the development of a proposal about the London area. Embedded with self-learning behavioral and responsive systems, the project allows for an intelligent choreography of soft programmatic spaces to create new leisure experiences, negotiating the changing effects of time, weather, programmatic, and crowd dynamical inputs, extending parametric processes to drive urban performance.

Pantelidou introduces in Chapter 11 the concept of the totality of space, defining it as a corporation's bounded spaces and the connections between them (Pantelidou, 2009). This concept expresses itself in the evolution of banking in the twentieth century. The chapter argues the importance of revealing and understanding the characteristics of the totality of space, which are inherent to the banking industry's spatial thought, thus allowing architects to bring the knowledge of their field and participate in a design/planning process of directing its possible future forms.

We believe that jointly this collection of chapters provides a good picture of how far we are today within the AmI vision and of the important challenges ahead. On this background we hope that computer scientists, engineers, architects and others who work in the broad area of intelligent environments, no matter if from an academic or industrial perspective, may benefit from the book and find it useful to their own work. Graduate students and Ph.D. students focusing on AmI-related topics may also find the book interesting and profit from reading it.

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Chapter 1

ASSISTIVE ENVIRONMENTS FOR SUCCESSFUL AGING

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Abstract With nearly 80 million baby boomers in the United States just reaching their sixties, the demand for senior-oriented devices and services will explode in the coming years. Managing the increasing health-care costs for such a population requires developing technologies that will allow seniors to maintain active, independent lifestyles. Pervasive computing environments, such as smart homes, bundle assistive technologies and specially designed architectural and home furnishing elements provide health-care and well-being services to its residents. However, for such environments to be commercially viable, we require a system that allows technology to be easily utilized and included as it enters the market place. Also we require new technology to be introduced in a plug-and-play fashion, and applications that are developed by programmers, not system integrators. The Gator Tech Smart House, a full-size, free-standing residential home located in the Oak Hammock Retirement Community in Gainesville, Florida, is an example of this kind of assistive environment. It uses the Atlas sensor network platform, an enabling technology that combines a hardware platform and software middleware, making the Gator Tech Smart House a truly programmable pervasive computing space.

Keywords: Assistive technology; Sensor networks; Ubiquitous service composition; Pervasive computing; Sensor platform.

1. Introduction

Research groups in both academia and industry have developed prototype systems to demonstrate the benefits of pervasive computing in various

W. Minker et al. (eds.), *Advanced Intelligent Environments*,

DOI 10.1007/978-0-387-76485-6_1,

application domains. These projects have typically focused on basic system integration-interconnecting sensors, actuators, computers, and other devices in the environment. Unfortunately, many first-generation pervasive computing systems lack the ability to evolve as new technologies emerge or as an application domain matures. Integrating numerous heterogeneous elements is mostly a manual, ad hoc process. Inserting a new element requires researching its characteristics and operation, determining how to configure and integrate it, and tedious and repeated testing to avoid causing conflicts or indeterminate behavior in the overall system. The environments are also closed, limiting development or extension to the original implementers.

To address this limitation, the University of Florida's Mobile and Pervasive Computing Laboratory is developing programmable pervasive spaces in which a smart space exists as both a runtime environment and a software library (Helal, 2005). Service discovery and gateway protocols automatically integrate system components using generic middleware that maintains a service definition for each sensor, actuator, and device in the space. Programmers assemble services into composite applications, which third parties can easily implement or extend.

The use of service-oriented programmable spaces is broadening the traditional programmer model. Our approach enables domain experts – for example, health professionals such as psychiatrists or gastroenterologists – to develop and deploy powerful new applications for users.

In collaboration with the university's College of Public Health and Health Professions, and with federal funding as well as donations and gifts, we have created a programmable space specifically designed for the elderly and dis-

Figure 1. Front view of the Gator Tech Smart House.

abled. The Gator Tech Smart House (GTSH), shown in Figure 1, located in the Oak Hammock Retirement Community in Gainesville, Florida, is the culmination of more than 6 years of research in pervasive and mobile computing. The project's goal is to create assistive environments that can provide special services to the residents to compensate for cognitive, mobility, and other age-related impairments (Helal et al., 2005).

2. Assistive Services in the Gator Tech Smart House

Figure 2 shows most of the "hot spots" that are currently active or under development in the Gator Tech Smart House. An interactive 3D model (GTSH, 2007) provides a virtual tour of the house with up-to-date descriptions of the technologies arranged by name and location. This section will describe several of the major services and features provided in this assistive environment.

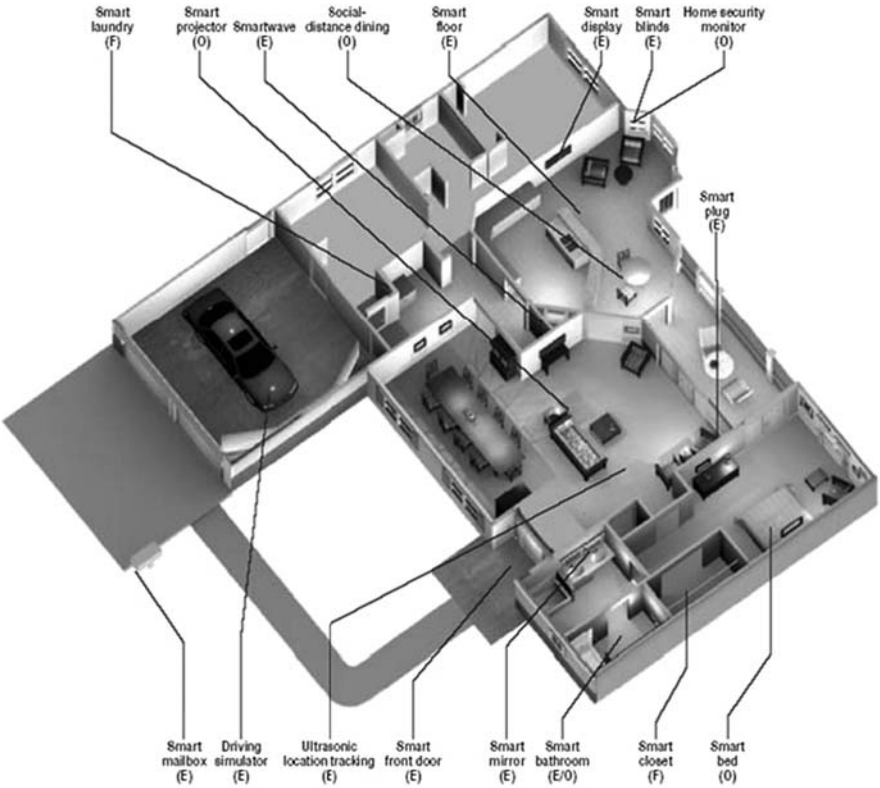

Figure 2. Gator Tech Smart House floorplan. The project features numerous existing (E), ongoing (O), and future (F) "hot spots" located throughout the premises.

2.1 Entry Assistant

The front door area of the Gator Tech Smart Houses makes use of several devices and services that together comprise the entry assistant. A radio-frequency identification (RFID) system built into the wall of the entranceway recognizes residents as they approach the house by means of passive RFID tags attached to their key rings. Two devices, an electronic deadbolt and an automatic door opener (Figure 3), work together to allow the residents access to the house and to secure the premises when the door is closed.

Figure 3. Entry assistant front door, with electronic deadbolt (*left*) and door opener (*right*).

The doorbell of the house connects to the smart space. This allows the Gator Tech Smart House to easily adapt the notification system to the needs of its residents. For example, a visual indicator such as a flashing light can be provided to a resident with a hearing impairment. The doorbell also triggers the door view service – a small video camera built into the peephole of the door. The video is automatically transmitted to the monitor nearest the resident in the house. Access to the house can be granted with a voice command or the resident may provide the visitor with audio or text messages using the speakers or LCD display built into the entranceway.

While the entry assistant provides several smart services for the resident, an important note for this and our other applications is that the "dumb" functionality of devices is never removed. The automatic door opener we chose is free swinging, meaning the door can be opened or closed by hand. The electronic deadbolt, while containing an internal motor for automatic control, also has a normal key interface outside and knob inside. Residents are not forced to do things the “new” way.

2.2 Location Tracking and Activity Monitoring

Location tracking is a fundamental service in a pervasive computing environment such as a smart house. The location of residents in the house can trigger or halt certain applications, affect various notification systems in the environment, and can be used to ascertain data about the health of the residents in terms of daily activity or detecting falls.

The Gator Tech Smart House supports a variety of location tracking technologies. The original technology used, carried over from our in-lab prototype house, is an ultrasonic tag-based system. Each resident is given a pair of transceivers to wear, and transmissions between these devices and transceivers in the ceiling are able to triangulate each resident.

While there are several benefits to such a system, such as the ease of multi-resident tracking, and the ability to detect the direction each resident is facing, the major drawback to this system is that it requires active participation by the residents: for the house to locate them, they must remember to put on the transceivers, ensure that the batteries are charged, etc.

The primary location tracking system used in the Gator Tech Smart House is the smart floor (Kaddourah et al., 2005). The flooring for the entire house consists of residential-grade raised platform. Each platform is approximately one square foot, and underneath each we installed a force sensor (Figure 4). Unlike the ultrasonic tag method, the smart floor requires no attention from the residents, and unlike some other unencumbered tracking systems, there are no cameras that invade the residents’ privacy. This allows for constant but inoffensive monitoring throughout the day and night, even in areas such as the bathroom. Figure 5 shows an example of this tracking.

Applications that make use of the smart floor service include the house’s notification system. Alerts can be sent to the video or audio device nearest the resident. The entertainment system makes use of location information by following the resident throughout the house, turning off the television in one room and turning it on in another. More importantly, the activity monitor is able to record a resident’s typical amount of movement in a day. If a significant decrease in activity is detected, the house is able to automatically notify caregivers.

Currently we are working to further improve our location tracking system. We are investigating the use of vibration sensors located at certain points in the house to replace the full coverage of force sensors. While this would be more expensive in terms of device cost, the time necessary to deploy the solution is significantly less, allowing for a packaged solution. Additionally, it would

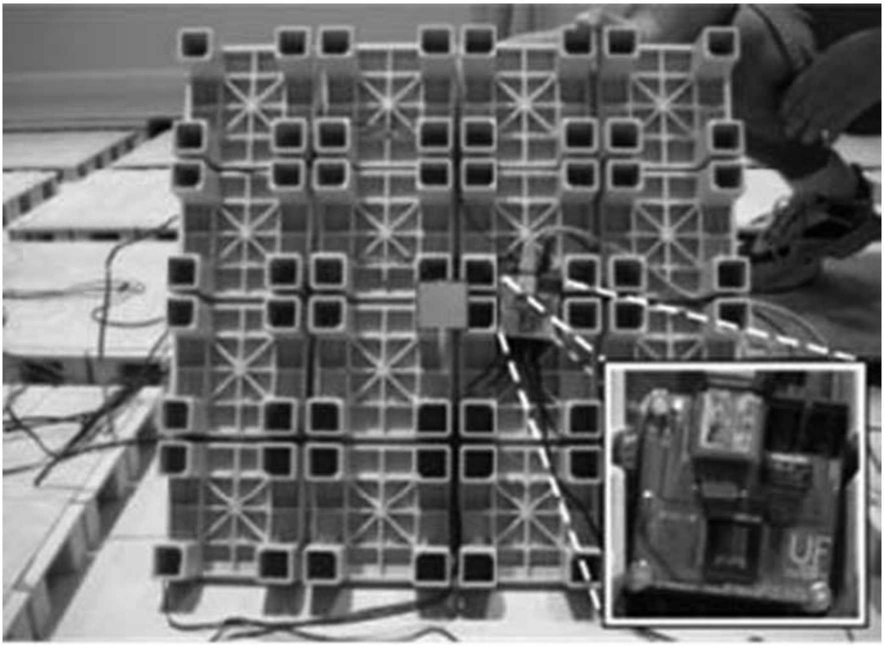

Figure 4. Tile of the smart floor.

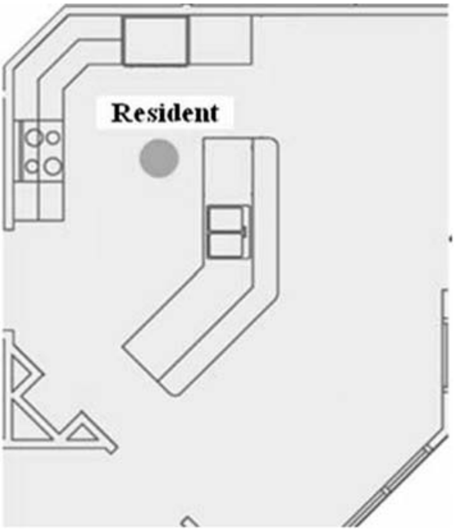

Figure 5. Visual location tracking application.

allow smart floor technology to be installed in any home, not just those with raised flooring.

We are also looking at improving the activity monitoring support by including tracking technology in more than the floor. For example, similar force sensors in the bed can be used to detect when residents are sleeping. Variations in sleep patterns would be of interest to the residents and caregivers.

2.3 SmartWave

The SmartWave (Figure 6) is a collection of devices and services that facilitates meal preparation in the Gator Tech Smart House (Russo et al., 2004). A standard microwave oven was modified to allow computer control of the cooking process. An RFID reader in the cabinet below the microwave allows appropriately tagged frozen meals to be placed in front of the device and recognized by the smart house.

Figure 6. The SmartWave meal preparation assistance system.

The resident will be provided with any necessary instructions to ready the meal for cooking (remove film, stir ingredients, etc.). The SmartWave will set power levels and cooking times automatically. This technology assists a variety of residents, such as those with visual impairments who are unable to read the fine print on the frozen meals. Once the meal is ready, a notification will be sent to the resident, wherever he/she is in the house.

2.4 Real-World Modeling for Remote Monitoring and Intervention

An assistive environment such as the Gator Tech Smart House should provide tools and services that benefit both the residents and the residents' caregivers. In many cases, however, caregivers will be living off-site. Caregivers include the residents' adult sons and daughters, or contracted healthcare providers. In either case, situations will arise where the caregivers will need a remote presence in the house.

To support this remote presence, we developed a number of research projects under the heading self-sensing spaces. A smart house should be able to recognize the devices and services it has available, interpret their status, and generate a model of the space (Figure 7). It should also recognize the residents and their activities, and include a representation of these in the model.

Figure 7. Real-world model of the smart house, provided to remote caregivers.

2.4.1 Smart Plugs. We first broached this issue of allowing the house to recognize installed devices with our smart plug project (El-Zabadani et al., 2005). Smart plugs include an RFID reader behind each electrical wall socket in the house (Figure 8, left). Each electrical device was then given an RFID tag that indicated what the device was and the commands it could be issued (Figure 8, right). This system allows the Gator Tech Smart House to detect devices as they enter or leave the space. A graphical model of the house is updated, providing remote caregivers with an accurate view of the capabilities of the house. In addition to just providing an image of the space, the system also allows remote caregivers to drive operation of devices. For example, if the caregiver notices that temperatures are climbing, they can click on fans to turn them on.

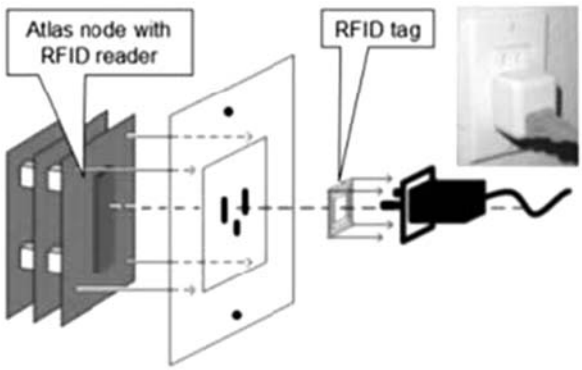

Figure 8. Smart plug deployed behind an electrical socket.

2.4.2 PerVision. While the smart plug system is able to detect active objects, we also require a system to detect passive objects such as furniture. The first iteration of this project, PerVision (El-Zabadani et al., 2006), made use of cameras and RFID to recognize and extract information about passive objects in the environment (Figure 9).

Before a passive object such as a chair or table was brought into the house, it was labeled with an RFID tag identifying certain characteristics about it: shape, volume, bounding box, color hues, etc. RFID readers deployed by the doors would detect items as they enter or leave the space. The PerVision system then used a series of cameras throughout the house to run image recognition techniques to determine the location of these objects as they were deployed and moved throughout the house. The computer vision techniques were assisted by information from the RFID tags and from the smart floor.