Ambient Intelligence and Smart Environments: A State of the Art

Juan Carlos Augusto, Hideyuki Nakashima, Hamid Aghajan

1 Introduction

Advances in the miniaturization of electronics is allowing computing devices with various capabilities and interfaces to become part of our daily life. Sensors, actuators, and processing units can now be purchased at very affordable prices. This technology can be networked and used with the coordination of highly intelligent software to understand the events and relevant context of a specific environment and to take sensible decisions in real-time or *a posteriori*.

AmI is aligned with the concept of the *"disappearing computer"* [23, 24, 22]:

> *"The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it."*

It is particularly interesting to contrast this time in history when accomplishing Weiser's aims sounds plausible with the situation five decades ago when computers had the size of a room and the idea of a computer being camouflaged with any environment was an unimaginable notion. Today different appliances have successfully become integrated to our daily life surroundings to such an extent that we use them without consciously thinking about them. Computing devices have transitioned in this past half a century from big mainframes to small chips that can be embedded in a variety of places. This has allowed various industries to silently distribute computing devices all around us, often without us even noticing, both in public spaces and in our more private surroundings. Now washing machines, heating systems and even toys come equipped with some capability for autonomous decision making. Auto-

Juan Carlos Augusto
University of Ulster, UK

Hideyuki Nakashima
Future University Hakodate, Japan

Hamid Aghajan
Stanford University, USA

H. Nakashima et al. (eds.), *Handbook of Ambient Intelligence and Smart Environments*,
DOI 10.1007/978-0-387-93808-0_1,

motive industry has become increasingly interested in embedding sensing mechanisms that allow the car to make decisions for a safer and less expensive journey, and as a result cars now have dozens of sensor and actuator systems that make decisions on behalf of or to assist the driver. Public spaces have become increasingly occupied with tracking devices which enable a range of applications such as sensing shoplifted object and crowd behavior monitoring in a shopping mall.

Whether it is our home anticipating when the lights should be turned on and off, when to wake us up or order our favorite food from the supermarket, a transport station facilitating commuting, or a hospital room helping to care for a patient, there are strong reasons to believe that our lives are going to be transformed in the next decades by the introduction of a wide range of devices which will equip many diverse environments with computing power.

These computing devices will have to be coordinated by intelligent systems that integrate the resources available to provide an "intelligent environment". This confluence of topics has led to the introduction of the area of "Ambient Intelligence" (AmI):

> *"a digital environment that proactively, but sensibly, supports people in their daily lives."* [7]

Ambient Intelligence started to be used as a term to describe this type of developments about a decade ago (see for example [25, 1, 16, 3]) and it has now been adopted as a term to refer to a multidisciplinary area which embraces a variety of pre-existing fields of computer science as well as engineering, see Figure 1. Given the diversity of potential applications this relationship naturally extends to other areas of science like education, health and social care, entertainment, sports, transportation, etc.

Whilst AmI nourishes from all those areas, it should not be confused with any of those in particular. Networks, sensors, human-computer interfaces, pervasive computing and Artificial Intelligence (here we also include robotics and multi-agent systems) are all relevant but none of them conceptually fully covers AmI. It is AmI which brings together all these resources as well as many other areas to provide flexible and intelligent services to users acting in their environments.

By Ambient Intelligence we refer to the mechanisms that rule the behavior of the environment: The definition of Ambient Intelligence given above includes the need for a "sensible" system, and this means a system with intelligence. The definition reflects an analogy with how a trained assistant, e.g. a nurse, typically behaves. The assistant will help when needed but will restrain to intervene except when necessary. Being sensible demands recognizing the user, learning or knowing her/his preferences, and the capability to exhibit empathy with or react to the user's mood and the prevailing situation, i.e., it implicitly requires for the system to be sensitive. We reserve here the term *"Smart Environments"* (see for example [12]) to emphasize the physical infrastructure (sensors, actuators and networks) that supports the system.

An important aspect of AmI has to do with interactivity. On the one hand there is a motivation to reduce *explicit* human-computer interaction (HCI) as the sys-

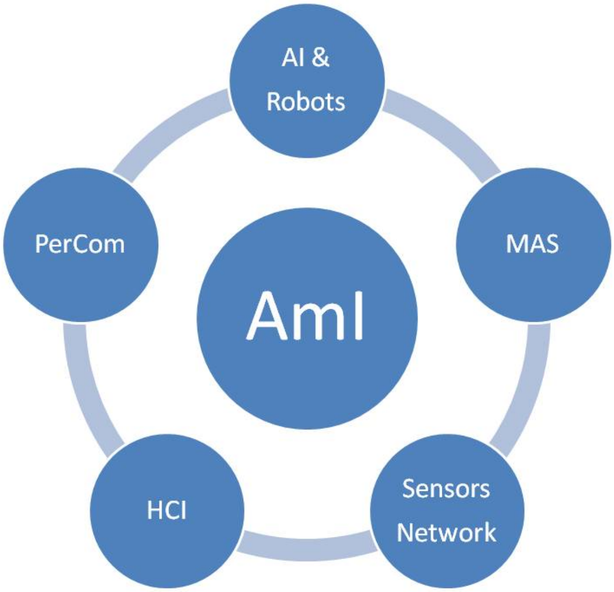

Fig. 1 Relationship between AmI and several scientific areas.

tem is supposed to use its intelligence to infer the situations and user needs from the observed activities, as if a passive human assistant were observing the activities unfold with the expectation to help when (and only if) required. Systems are expected to provide situation-aware information (I-want-here-now) through natural interfaces[18]. On the other hand, a diversity of users may need or voluntarily seek direct interaction with the system to indicate preferences, needs, etc. HCI has been an important area of computer science since the inception of computing as an area of study and development. Today, with so many gadgets incorporating computing power of some sort, HCI continues to thrive as an important AmI topic.

It is also worthwhile to note that the concept of AmI is closely related to the "service science"[21] in the sense that the objective is to offer proper services to users. It may not be of interest to a user what kind of sensors are embedded in the environment or what type of middleware architecture is deployed to connect them. Only the services given to the user matter to them. Therefore, the main thrust of research in AmI should be integration of existing technologies rather than development of each elemental device.

Within the notion of the service science, it is important to consider the implications of user evaluation in a "service-evaluation-research" loop (Figure 2). As part of their investigation, AmI researchers should assess efforts to setting up working intelligent environments in which users conduct their normal activities. As the system is distributed in the environment, users only notice services they receive. The researchers then observe the interaction and (re-)evaluate the system. The result of the evaluation may lead to identifying new services, new viewpoints or even new evaluation criteria. Then all of the findings can be fed back to new research and development.

This Handbook is organized in several thematic parts. Each of these parts provides a state of the art in research and development related to the specific sub-areas contributing to the development of the broader subject of this volume. Section 2 focuses on the infrastructure and how sensors (including vision as a high-level way of capturing information from an environment) are networked and utilized in a few application settings. Section 3 considers the technology that can be built over a networked sensing infrastructure to make resources widely available in an unobtrusive way. Section 4 gathers contributions on the interaction between humans and artificial systems. Section 5 focuses on developments that aim to make artificial system more rational. This is complemented with section 6 focused on Multi-Agent Systems (MAS). While an area with its own development architecture, these system contribute to the resources an artificial system can use to understand different situations and to decide intelligently. The volume provides in section 7 a wide range of applications as well as consideration of the impact this technology can have in our lives (safety, privacy, etc.). Section 9 provides insight into some of the recent major projects developed around the world.

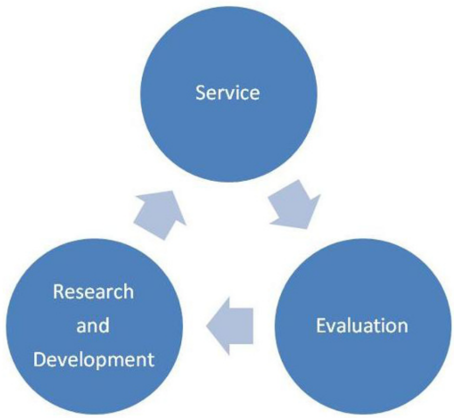

Fig. 2 The loop of R&D, service, and evaluation.

2 Sensors, Vision, and Networks

The focus of this thematic part is on the role vision and sensor networks play in acquiring information from the environment and events for responsive and reactive applications. As illustrated in Figure 3, these networks can offer a variety of inferences from the event and human activities of interest [5]. The information is then transferred to high-level reasoning modules for knowledge accumulation in applications involving behavior monitoring, or for reacting to the situation in applications based on ambient intelligence and smart environments. Another type of interaction between vision and higher-level application context may involve visualization of events or human actions which can take the form of video distribution or avatar-based visual communication [4]. In both kinds of interfaces, two-way communication between the vision and data processing modules on the one hand, and high-level reasoning and visualization modules on the other hand can enable effective information acquisition by guiding vision to the features of interest, and validating the vision output based on prior knowledge, context, and accumulated behavior models.

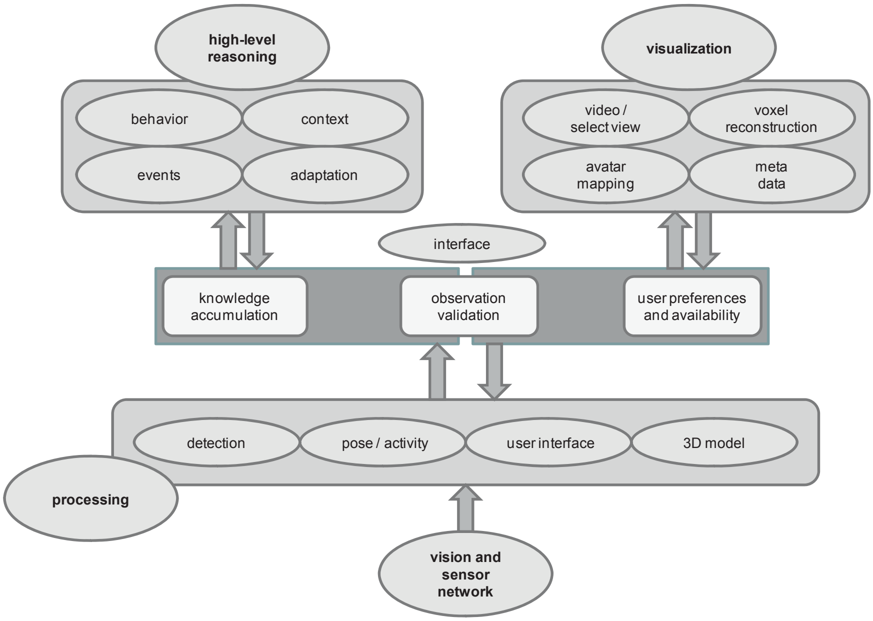

Fig. 3 The role of vision and sensor networks in interaction with high-level reasoning and visualization.

In this section the contributing authors offer an overview of the latest trends in algorithm and application development based on visual and sensory inputs.

1. A Survey of Distributed Computer Vision Algorithms

   Recent years have seen great advances in computer vision research dealing with large numbers of cameras. However, many multi-camera computer vision algorithms assume that the information from all cameras is communicated in a lossless fashion to a central processor that solves the problem. This assumption is unrealistic for emerging wireless camera networks, which may contain processors with limited capability, antennas with limited power, and batteries with limited life. In this chapter, an overview of algorithms that solve computer vision problems in a distributed manner is presented, and their implementation on a visual sensor network is discussed. Methods for topology estimation, camera calibration, and visual tracking are introduced as case studies.

2. Vision-based People Tracking

   Human pose tracking is a key enabling technology for myriad applications, such as the analysis of human activities for perceptive environments and novel man-machine interfaces. Nevertheless, despite years of research, 3D human pose tracking remains a challenging problem. Pose estimation and tracking is currently possible in constrained environments with multiple cameras and under limited occlusion and scene clutter. Monocular 3D pose tracking in unconstrained natural scenes is much more difficult, but recent results are promising. This chapter provides an introduction to the principal elements of an approach to people tracking in terms of Bayesian filtering. It discusses likelihood functions which characterize the consistency between a hypothetical 3D pose and image measurements, including image appearance and image gradients. To help constrain pose estimation solutions, common prior models over plausible 3D poses and motions are considered. Toward this end, due to the high dimensionality of human pose, dimensionality reduction techniques are often employed as means of constraining the inferred poses to lie on a manifold spanned by training examples. Since the underlying problems are non-linear and result in non-Gaussian posterior distributions, online inference is achieved with particle filters or direct optimization. The chapter also discusses discriminative methods for static pose estimation, which are found helpful for initialization and transient failure recovery.

3. Locomotion Activities in Smart Environments

   One sub-area in the context of ambient intelligence concerns the support of moving objects, i.e. to monitor the course of events while an object crosses a smart environment and to intervene if the environment should provide assistance. For this purpose, the smart environment has to employ methods of knowledge representation and spatio-temporal reasoning. This enables the support of such diverse tasks as way-finding, spatial search, and collaborative spatial work. A number of case studies are introduced and examined in this chapter to demonstrate how smart environments can effectively make use of the information about the movement of people. A specific focus lies in the research question as to which minimal information suffices the need of the smart environment to deal with approximate motion information in a robust and efficient way, and under realistic conditions. The study indicates that a thorough analysis of the task at hand can enable the smart environment to achieve results using a minimum of sensory information.

4. Tracking in Urban Environments using Sensor Networks based on Audio-Video Fusion

   Recent advances in sensor networks, micro-scale, and embedded vision technologies are enabling the vision of ambient intelligence and smart environments. Environments will react in an attentive, adaptive and active way to the presence and activities of humans and other objects in order to provide intelligent and smart services. Heterogeneous sensor networks with embedded vision, acoustic, and other sensor modalities offer a pivotal technology solution for realizing such systems. Networks with multiple sensing modalities are gaining popularity in different fields because they can support multiple applications that may require diverse resources.
   This chapter discusses a heterogeneous network consisting of audio and video sensors for multimodal tracking in an urban environment. If a moving target emits sound, then both audio and video sensors can be utilized for tracking. Audio and video can complement each other, and improve the performance of the other modality through data fusion. Multimodal tracking can also provide cues for the other available modalities for actuation. An approach for multimodal target tracking in urban environments is demonstrated, utilizing a network of mote class devices equipped with microphone arrays as audio sensors and embedded PCs equipped with web cameras as video sensors.

5. Multi-Camera Vision for Surveillance

   In this chapter, a variety of visual surveillance systems are surveyed. Visual surveillance methods are classified according to the criteria which distinguish between systems intended to acquire detailed information on a small number of subjects, systems designed to track as many subjects as possible, and systems designed to acquire trajectories of subjects and to recognize scenes in specific environments. These systems are also classified based on camera types and situations.

3 Mobile and Pervasive Computing

This thematic part focuses on physical aspects of mobility and pervasiveness of devices, as well as systems that support mobility of them. Logical mobility such as mobile agents is treated in section 6 and contextual issues are treated in section 4.

Middleware architecture plays an important role here since the connection between devices are not fixed. We need a flexible and light-weight operating system not only for connecting sensors and actuators, but for providing seamless connection from devices to users (Figure 4). For context-aware computation, some of the context information such as location, time, temperature, etc. must be handed over to application software modules in some predefined format. To accomplish this, data conversion and even data fusion from many different devices must be handled by the middleware.

Handling security also turns into a different issue due to mobility, since traditional methods that assume fixed configuration may not be applicable.

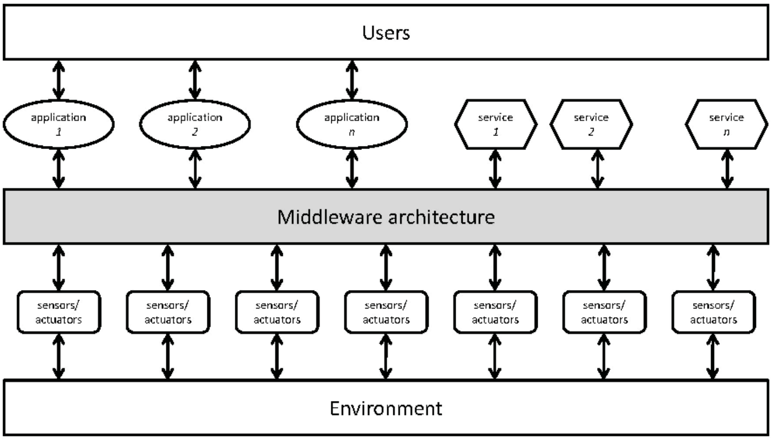

Fig. 4 AmI architecture with the middleware.

This thematic part consists of the following chapters:

1. Collaboration Support for Mobile Users in Ubiquitous Environments

   Collaboration among people happens ubiquitously. User mobility and seamless access to artifacts and devices are natural parts of collaboration. This chapter will first discuss some core characteristics of collaboration, addressing issues connected with the physical embodiment of resources, informal collaboration, and changes in context, considering that the context of any collaboration includes physical as well as social elements. Discussing these characteristics it focuses on the intersection between the research fields of Computer Supported Cooperative Work (CSCW) and Ambient Intelligence (AmI) and ubiquitous computing. A brief overview of technology supporting ubiquitous collaboration is provided. The last part of the chapter focuses on current research activities at

Ubicollab, including development of a platform for design of ubiquitous applications to support cooperation among distributed users.

2. Pervasive Computing Middleware

   Pervasive computing envisions seamless application support for user tasks. In most scenarios, these applications are executed on sets of networked computers that are integrated invisibly into everyday objects. Due to user mobility the resulting systems are dynamic. As a consequence, applications need to cope with ever-changing execution environments and vastly different user context. Without further support, the development of such applications is a complex and error prone task. Middleware systems can help to reduce the resulting complexity by providing a set of supportive services. This chapter discusses such middleware systems and their services. To do that, the chapter first presents a number of design considerations that have a significant impact on the middleware and service design. Thereafter, it discusses the three main functionalities of pervasive computing middleware. These functionalities provide support for (1) spontaneous remote interaction, (2) context management, and (3) application adaptation. To enable the analysis of a broad range of existing systems, the chapter introduces subcategories, compares their advantages and disadvantages, and classifies approaches accordingly.

3. Case Study of Middleware Infrastructure for Ambient Intelligence Environments

   A variety of application services in ambient intelligence environments can be realized at reduced cost by encapsulating complex issues in middleware infrastructures that are shared by the applications. Since these attractive services are typically quite complicated, their development is not easy for average programmers. High level abstractions offered by middleware infrastructures make it possible to hide the complexities in ambient intelligence environments. This chapter first discusses several potential future services in ambient intelligence environments, and how high level abstractions offered by middleware infrastructures facilitate their development. Then, it illustrates the effectiveness of the high level abstractions through several case studies of middleware designs. Finally, the chapter describes a number of important design issues for the future development of middleware infrastructures.

4. Collaborative Context Recognition for Mobile Devices

   This chapter investigates collaborative methods for context awareness with mobile devices. Interpretation of context often has to rely on unreliable sensor information that is noisy, conflicting, or simply missing. To limit the search space of possible interpretations it is useful to have reasonable default conditions. The chapter proposes to obtain the defaults from other people (or their devices). In a way, mobile devices would then mimic humans: observe other people and see how they behave in unfamiliar situations. For instance, if everyone else keeps quiet in a concert, perhaps we should keep quiet too. If everyone has switched their phone to "silent" mode, maybe ours should be set to the same – automatically. The chapter discusses experiments suggesting that such collaboration not only provides useful first guesses for context analysis, but also improves the recognition accuracy over single-node algorithms. Through short-range links, mobile devices can query each other's context information and then jointly (and individually) arrive at a shared interpretation of the situation. The chapter describes possible methods for using the shared context data and outlines some potential application areas as well as the potential risks of the approach.

5. Security Issues in Ubiquitous Computing

   With ubiquitous computing, everyday objects become networked computing devices. What new security risks does this revolution introduce? Small devices such as RFID tags severely constrain the gate count and the energy budget: how can we build secure protocols on such a foundation? At the next level up, devices with greater resources such as cell phones and A/V components still need to be paired up securely so as to be able to give orders to each other: how can this be done, especially over radio links where you can never be sure of the origin of a message? Going up another level, how can you defend your privacy if wearing networked devices makes you trackable everywhere you go? And finally, how can we reconcile security with usability? This last point is probably one of the most pressing challenges facing designers of ubiquitous systems today.

6. Pervasive Systems in Health Care

   As the computer disappears in the environments surrounding our activities, the objects therein are transformed to artifacts, that is, they are augmented with Information and Communication Technology (ICT) components (i.e. sensors, actuators, processor, memory, wireless communication modules) and can receive, store, process and transmit information. Artifacts may be totally new objects or improved versions of existing objects, which by using the ambient technology, allow people to carry out novel or traditional tasks in unobtrusive and effective ways.

   This chapter surveys the application of pervasive systems in supporting activities with health significance. Furthermore an abstract architecture of pervasive health care systems is presented. Then, as an example of a model architecture, the chapter describes and analyzes the HEARTS system, a pervasive system architecture that integrates a number of technologies to enable and support patients with congestive heart failure.

4 Human-centered Interfaces

The area of smart environment design is the confluence of a multitude of disciplines involving sensor fusion, human-computer interfaces, networking and pervasive computing, and actuation and response services. Developed upon the premise of a user-centric data extraction and decision making paradigm, many smart environment applications support interactivity based on interpretation of the gesture, region of interest, and interactions of the user with the surrounding environment components [6]. Thanks to the proliferation of inexpensive sensors such as cameras, as well as embedded processors, unprecedented potentials exist for realizing novel real-time applications such as immersive human-computer interfaces for virtual reality, gaming, teleconferencing, smart presentations, and gesture-based control, as well as other human-centric applications such as patient monitoring and assistive technologies.

Integration of multiple sensors in a distributed human-centric interface embodies new research and development opportunities in algorithm design methods based on collaborative sensing and processing, data fusion, event interpretation, context extraction, and generation of behavior models.

while the notion of human centricity finds many interpretations, its true meaning goes beyond any of the individual aspects that have been discussed in the literature. It truly refers to a new paradigm in developing and utilizing technology to serve its user in whatever form and flavor that best offers the intended experience of the application of interest by the user. In the new paradigm, privacy management, ease of use, unobtrusive design, and customized system can each be part of the definition of a human-centric interface. However, these factors are not regarded as rigid requirements when the essence of human centricity is considered, meaning different levels of each factor and relative priorities between them need to be derived from the context and objective of the application. In other words, for example the same vision sensing mechanism that may be perceived as intrusive when used in surveillance applications can be employed in a human-centric paradigm to improve the quality of life of patients and the elderly by timely detection of abnormal events or accidents.

Chapters in this thematic part offer an overview of the studies and methodologies of human-centric interface design for applications in smart environments.

1. Human-centered Computing

   Human-centered Computing (HCC) is a set of methodologies that applies to any field that uses computers, in any form, in applications in which humans directly interact with devices or systems that use computer technologies. This chapter offers an overview of HCC from different perspectives. It describes the three main areas of HCC: content production, analysis, and interaction. In addition, the chapter identifies the core characteristics of HCC, provides example applications and investigates the deployment of the existing systems into real world conditions. Finally, a research agenda for HCC is proposed for future development.

2. End-User Customization of Intelligent Environments

   This chapter describes a methodology that enables non-technical occupants of intelligent environments to translate conceptual ideas for the functionality of networked environments and appliances into concrete designs. It builds on a technique called “programming by example” which was first proposed by David Canfield Smith (Stanford University) in the mid-seventies and, later, continued by Henry Lieberman (MIT) in the nineties. The chapter shows how this approach, which has hitherto been applied only to single computing platforms, was extended to allow non-technical people to program distributed computing platforms of the type that make up intelligent environments. In order to achieve this vision the chapter introduces a number of novel concepts and methodologies, in particular a new networked service aggregation model (the deconstructed appliance model), a representation for virtual appliances (meta-appliances/applications), an ontology to support decomposition (dComp) and a tool for programming coordinated behavior in rule-based network artifacts (Pervasive Interactive Programming). Finally, the chapter reports on a user evaluation of this methodology, which demonstrates that users find the methods both simple and enjoyable to use.

3. Intelligent Interfaces to Empower People with Disabilities

   Smart environments are essential for the well-being of people with severe paralysis. Intelligent interfaces can immensely improve their daily lives by allowing them to communicate and participate in the information society, for example, by browsing the web, posting messages, or emailing friends. People with motion impairments often prefer camera-based interfaces, because these are customizable, comfortable, and do not require user-borne accessories that could draw attention to their disability. This chapter presents smart environments that enable users to communicate with the computer via inexpensive video cameras. The video input is processed in real time so that users can work effectively with assistive software for text entry, web browsing, image editing, and animation. Because motion abilities differ from person to person and may change due to a progressive disease, the solution offers a number of environments from which the user may choose. Each environment addresses a different special need. Users may also create their own smart environments that understand their gestures.

4. Visual Attention, Speaking Activity, and Group Conversational Analysis in Multi-Sensor Environments

   One of the most challenging domains in multi-sensor environments is the automatic analysis of multi-party conversations from sensor data. While spoken language constitutes a strong communicative channel, nonverbal communication is also fundamental, has been substantially documented in social psychol-

ogy and cognition, and is opening new computational problems in smart spaces equipped with microphones and cameras.
This chapter discusses the role of two nonverbal cues for analysis of group conversations, namely visual attention and speaking activity. The chapter reviews techniques for the extraction of such cues from real conversations - summarizing novel approaches based on contextual and audio-visual integration - and discusses their use in emerging applications on face-to-face and remote conversation enhancement and in the recognition of social behavior.

5. Using Multimodal Sensing for Human Activity Modeling in the Real World

   This chapter describes experiences from a five-year investigation on the design and deployment of a wearable system for automatically sensing, inferring, and logging a variety of human physical activity. The chapter highlights some of the key findings resulting from the deployment of a working system in three-week and three-month real world field trials, which are framed in terms of system usability, adaptability, and credibility.

6. Recognizing Facial Expressions Automatically from Video

   Facial expressions are the face changes in response to a person's internal emotional states, intentions, or social communications. Computer recognition of facial expressions has many important applications such as intelligent human-computer interaction, computer animation, and awareness systems. This chapter introduces recent advances in computer recognition of facial expressions. It first describes the problem space, which includes multiple dimensions: level of description, static versus dynamic expression, facial feature extraction and representation, expression subspace learning, facial expression recognition, posed versus spontaneous expression, expression intensity, controlled versus uncontrolled data acquisition, correlation with bodily expression, and databases. Meanwhile, the state of the art of facial expression recognition is also surveyed from different aspects. In the second part, the chapter proposes an approach to recognizing facial expressions using discriminative local statistical features. Particularly, Local Binary Patterns are investigated for facial representation. Finally, the current status, open problems, and research directions are discussed.

7. Sharing Content and Experiences in Smart Environments

   This chapter discusses the possibilities and challenges arising from the growing amount of content that can be accessed on-line anywhere, including being carried around in mobile devices or even being embedded in our environment. The chapter focuses on consumer contents such as music, pictures, video clips, streaming content and games, which people may create, carry around and share with others. The content may be enjoyed alone or together with others via mobile devices or appliances in the environment. Mobility allows novel content delivery mechanisms based on the identified context. Current and future application potentials, the issues relating to user expectations, the concept of experience as opposed to simple content, and the options for experience sharing are discussed. The chapter will review interaction solutions that exploit the environment to provide a synergetic interface for content management and rendering. User-driven design is emphasized: The user acts not only as content consumer but also as content producer and co-designer when setting up shared content environments. Technological and other challenges arising from these issues will be presented.

8. User Interfaces and HCI for Ambient Intelligence and Smart Environments

   This chapter aims to present a systematic structure of the field of User Interfaces, as it applies to Ambient Intelligence and Smart Environments. It starts with the machine side (i.e., the hardware in use) and the human side (i.e., conceptual models, human issues in interaction), then proceeds to sections about designing and evaluating UIs, and ends with some case studies.

9. Multimodal Dialogue for Ambient Intelligence and Smart Environments

   One goal of Ambient Intelligence and Smart Environments is to make it possible for users to interact naturally with their environment, for example, using speech and/or gestures to switch on the TV or turn off a lamp. This goal can be addressed by setting up a specialized dialogue system that interacts with the user and his environment. On the one hand, this system must process the data provided by a diversity of sensors placed in the environment (e.g., microphones, cameras, and presence detectors), which capture information from the user. The dialogue system may need to employ several dialogue management strategies, user models and contextual information to interact with the user and the environment. The interaction may be initiated by the user or by the system if the latter is designed to be proactive. The dialogue system must then decide on the proper actions to be performed in response to the data captured from the user and the status of the environment. This chapter discusses several issues regarding the implementation of this kind of systems, focusing on context awareness, handling of multimodal input, dialogue management, response generation and evaluation.

5 Artificial Intelligence and Robotics

Artificial Intelligence and Robotics are well established areas of research which have witnessed good progress in the past few decades. Yet it is recognized they have not reached their full potential and much work needs to be done in these areas to develop methods for practical AmI and SmE applications. From expert systems to multi-agents there has been significant work and lessons learned.

The arrival of the topic of AmI which calls for new computing methods to deliver services in the expected way (see [9] and [20]) and the deployment of AmI concepts over Smart Environments which are characterized by a network of interconnected devices each with limited capability presents both a new opportunity and a new challenge. The opportunity lies in that now AI has another opportunity to get closer to people, to improve the way they live. Now the focus has shifted from justifying the need of AI/robots to support humankind in missions where it is not possible/desirable to involve humans (e.g., going to an inhospitable planet like Mars, entering a building in flames or in danger of collapse, or deactivating a bomb) to more humble and close to people services. Now systems can measure their intelligence in simpler (still enormously challenging) tasks like helping drivers to find their way round a city, helping tourists to make the most of a visit to the museum, making vulnerable people feel safer by notifying carers when their health or safety seems compromised. All this is very healthy for AI because it allows to demonstrate its usefulness for practical applications and to enable it to reach out to outside the lab and deal with the uncertainties of everyday life in the real world. The challenge lies in the complexity that is part of any element of real applications. Systems developed under this concept should be intelligent to detect the situations that matter, and to react to them appropriately and reliably. Relevant to the development of AI systems that can make an environment truly intelligent is the need for such an environment to be able to: (a) learn habits, preferences and needs of the occupants, (b) correctly diagnose situations, (c) be aware of where and when the events of interest occur, (d) integrate mobile elements like robots, and (e) provide a structured way to analyze, decide and react over that environment. The chapters in this thematic part provide a step forward in addressing these issues.

1. Learning Situation Models in Smart Spaces

   Smart Spaces enhance user capabilities and comfort by providing new services and automated service execution based on sensed user activity. Though, when becoming really "smart", such spaces should not only provide some service automation, but further learn and adapt their behavior during use. This chapter motivates and investigates learning of situation models in a smart space, covering knowledge acquisition from observation as well as evolving situation models during use. An integral framework for acquiring and evolving different layers of a situation model is detailed. Different learning methods are presented as part of this framework: role detection per entity, unsupervised extraction of situations from multimodal data, supervised learning of situation representations, and the evolution of a predetermined situation model with feedback. The situation model serves as frame and support for the different methods, permitting to stay in an intuitive declarative framework. An implementation of the whole framework for a smart home environment is described, and the results of several evaluations are depicted.

2. Smart Monitoring for Physical Infrastructures

   Condition monitoring of physical infrastructures such as power and railway networks is an important prerequisite for optimizing operations and maintenance. Today, various sensor systems are in place but generally lack integration for assessing conditions more precisely. This is a typical challenge faced by context-aware ambient intelligence systems, which tackle it using formal knowledge representation and reasoning. This chapter adopts the knowledge-based approach for infrastructure monitoring: Description Logic-based ontologies are used for developing declarative, extensible and machine-workable models of symptoms, faults, and conditions. A novel approach for reasoning over distributed knowledge bases of context information is introduced. Finally, a case study on European railway monitoring demonstrates the feasibility and potential of the proposed approach.

3. Spatio-Temporal Reasoning and Context Awareness

   An important aspect of ambient intelligence in smart environments is the ability to classify complex human behavior and to react to it in a context-specific way. For example, a heating system can detect if a human is present in the room, but for it to react appropriately and adjust the temperature to a comfortable level, it needs to consider a wider context: someone watching TV, for example, might require a warmer room than somebody engaged in exercise, whereas someone entering to simply look for a book may be leaving the room shortly. The classification of complex human behavior requires an advanced form of spatio-temporal reasoning, since such classification is often dependent on where or when the behavior occurs. For example, someone walking around a triangle repeatedly, stopping at various points along the route, would look odd unless it occurred in a kitchen, with the triangle being the space between the fridge, sink, and stove. Even in this space, a recurring pattern of behavior has to be interpreted in different ways, depending on the time interval it occurs in – cooking a large meal in the middle of the night would still be unusual. This chapter looks at some of the major conceptual and methodological challenges around spatio-temporal reasoning and context awareness and methods of approaching them.

4. From Autonomous Robots to Artificial Ecosystems

   In recent years, the new paradigm of ubiquitous robotics attracted many researchers worldwide for its tremendous implications: mobile robots are moving entities within smart environments, where they coexist and cooperate with a plethora of distributed and smart nodes that can be assigned with a certain amount of computational resources and a certain degree of autonomy. This chapter is organized in three main parts: the first part surveys the state-of-the-art, pointing out analogies and correspondences between different approaches; the second part describes a real-world scenario: the setup of a robot team for autonomous transportation and surveillance within an intelligent building; and the third part introduces the artificial ecosystem framework as a case study to investigate how ubiquitous robotics can be exploited for the deployment of robotic applications in complex real world scenarios.

5. Behavior Modeling for Detection, Identification, Prediction, and Reaction in AI Systems Solutions

   Behavior modeling automation is a requirement in today's application development in AI, and the need to fuse data from a large number of sensors demands such automation in the operations to observe, fuse and interpret the data. Applications in abnormal behavior detection, ambient intelligence, and intelligent decision making are a few of the unlimited applications of human intelligence automation. A generalized software approach to implement these solutions is presented in this chapter to break the artificial intelligence behavior modeling problem into four distinct intelligence functions to describe and implement using the distinct subsystems of: Detection, Identification, Prediction, and Reaction (DIPR). These subsystems also allow complete fusion of all sensor features into the intelligent use as a result. Behaviors can be modeled as sequences of classified features, fused with intelligence rules, and events into time and space. Multiple features are extracted with low-level classifiers in time and space in the "Detection" subsystem. The temporal (feature,space) matrix is used by the "Identification" subsystem to combine with low-level simple rules to form intelligent states (symbols). The "Prediction" subsystem concatenates symbols over time/space to form spatial-temporal sequences. These sequences are classified into behaviors and then passed through an inferred predicted behavior outcome module. The final stage is the "Reaction" subsystem for an action producing intelligent solution. The DIPR system is shown to be overlaid onto a number of different distributed networks and a number of pre-engineered application models are presented to demonstrate the applications of the system.

6 Multi-Agents

Studies of intelligent agents are roughly divided into three categories: (1) those trying to design a human-like intelligent agents, (2) those trying to implement (semi-) intelligent autonomous software modules, and (3) those emphasizing on the coordination or collaboration among many agents (multi-agents). Agents in the latter two types are extremely useful in AmI.

To provide useful functionality in the environments, we have to implement some autonomously functioning software into devices embedded in the environment. Agent technologies are useful in creating such functions. Moreover, to make those devices collaborate with each other and to make them function in unity, we need multi-agent technologies.

1. Multi-Agent Social Simulation

   The difficulty in the introduction of a new IT system is in the uncertainty of its effect in the society. The benefit of any IT systems appears when it is implemented deeply into the society and impacts social activities in a large scope. Social simulation, especially, multi-agent simulation will provide an important tool to evaluate how the IT system may change the behavior of the society. This chapter discusses the capabilities of multi-agent systems in social simulations, and provides some examples of multi-agent simulations that evaluate new IT methodologies.

2. Multi-Agent Strategic Modeling in a Specific Environment

   One of the tasks in ambient intelligence is to deduce the behavior of agents in the environment. Here we present an algorithm for multi-agent strategic modeling applied in a robotic soccer domain. The algorithm transforms a multi-agent action sequence into a set of strategic action descriptions in a graphical and symbolic form. Moreover, graphic and symbolic strategic action descriptions are enriched with corresponding symbolic rules at different levels of abstraction. The domain independent method was evaluated on the RoboCup Soccer Server Internet League data, using hierarchically ordered domain knowledge.

3. Learning Activity Models for Multiple Agents in a Smart Space

   Intelligent environment research has resulted in many useful tools such as activity recognition, prediction, and automation. However, most of these techniques have been applied in the context of a single resident. A current looming issue for intelligent environment systems is performing these same techniques when multiple residents are present in the environment. This chapter investigates the problem of attributing sensor events to individuals in a multi-resident intelligent environment. Specifically, a naive Bayesian classifier and a hidden Markov model are used to identify the resident responsible for a sensor event. Results of experimental validation in a real intelligent workplace testbed are presented and the unique issues that arise in addressing this challenging problem are discussed.

4. Mobile Agents

   Mobile agent technology has been promoted as an emerging technology that makes it much easier to design, implement, and maintain distributed systems, including cloud computing and sensor networks. It provides an infrastructure not only for executing autonomous agents but also for migrating them between computers. This chapter discusses the potential uses of mobile agents in distributed systems, lists their potential advantages and disadvantages, and describes technologies for executing, migrating, and implementing mobile agents. The chapter presents several practical and potential applications of mobile agents in distributed systems and smart environments.

7 Applications

This thematic part overviews the application areas of Ambient Intelligence and Smart Environments (AISE). One of the important aspects of many concepts developed in AISE is their closeness to the society. While other areas of computer science impact everyday life in our society, AISE provides a framework in which information technologies are applied to the real world situations in a systemic and often multi-disciplinary fashion to enhance our lives. It is worth noting that even subjects in computer science not covered in this handbook, for example, the Internet, language processing and search engines are nevertheless related to AISE because they are part of the intelligence or smartness of the environments we live or work in. We do not cover them here because if we did, this handbook would have been a handbook of the whole computer science!

The list of topics covered in this part is not an exhaustive enumeration of applications based on AISE, but a selected set of representative topics from various application fields. The subjects are roughly ordered from applications for supporting an individual to providing services to a large number of people.

1. Ambient Human-to-Human Communication

   The traditional telephone and video conference systems are examples of a terminal-centered interaction scenario where the user is either holding the terminal in the hand or seated in front of it. The terminal centricity guides the interaction to take the form of an on/off session which starts by making a call and ends by terminating the call. A terminal-centered communication session has the same social characteristics as a formal face-to-face meeting. When people are physically together there is a larger variety of interaction modes available which may be characterized by different ranges of social or interpersonal distances beyond the face-to-face meeting mode. The model for the ambient communication technology is the natural interaction between people who are physically present. In this chapter we give a general overview of various topics related to ambient communication. A detailed description of the architecture and essential components of a voice-based ambient telephone system is provided as an example.

2. Smart Environments for Occupancy Sensing and Services

   This chapter discusses recent developments in occupancy sensing and applications related to sensing the location of users and physical objects and occupation in smart environments, mainly houses, offices, and urban spaces. The sensory equipment widely used for sensing are presented, as well as different tools and algorithms used to process, present, and apply the information. The focus is on different detecting devices, data mining, and statistical techniques that have been utilized in pervasive computing applications. Examples that utilize occupancy information to enable services for ordinary or professional users are studied.

3. Smart Offices and Smart Decision Rooms

   Decision making is one of the noblest activities of the human being. Most of times, decisions are made involving several persons (group decision making) in specific spaces (e.g. meeting rooms). On the other hand many scenarios (e.g. increased business opportunities, intense competition in the business community) demand fast decision making to achieve success. Smart offices and decision rooms contribute to reducing the decision cycle, and offer connectivity wherever the users are, aggregating the knowledge and information sources.
   This chapter provides a survey of smart offices and intelligent meeting rooms, considering the hardware and software perspectives. It presents the Smart Decision Room, a project platform created to provide support to meeting room participants, assisting them in the argumentation and decision making processes, while combining the rational and emotional aspects.

4. Smart Classroom: Bringing Pervasive Computing into Distance Learning

   The Smart Classroom project aims to build a real-time interactive classroom with tele-education experience by bringing pervasive computing technologies into traditional distance learning. This chapter presents the current state of the project which includes four key technologies: 1) a Smart Classroom, which embeds multiple sensors and actuators (e.g. location sensor, RFID, microphone array) to enhance the conventional classroom-based learning environment; 2) key multimodal interface technologies and context-aware applications, which merge speech, handwriting, gestures, location tracking, direct manipulation, large projected touch-sensitive displays, and laser pointer tracking, providing enhanced interaction experience for teachers and students; 3) a dedicated software called “SameView”, which uses a hybrid application-layer multicast protocol and adaptive content delivery scheme, providing a rich set of functions for teachers, local students and large-scale remote students to carry out real-time, collaborative distance learning experience; 4) a software infrastructure based on multi-agent architecture called Smart Platform, which integrates, coordinates and manages all the distributed collaborative modules in the smart environment, supporting various data transmission modes in terms of different quality of service (QoS) levels. The smart classroom system has been demonstrated as a prototype system in Tsinghua University.

5. Ambient Intelligence in the City

   This chapters aims to address deficits in the way ambient intelligence conceives of and designs for urban environments. It begins with an overview of issues surrounding ambient intelligence in the city, followed by critical voices and examples of alternative ambient intelligence systems. The text argues for the inclusion of pervasive sensing issues into urban planning, in particular to negotiate between private and public interests.

6. The Advancement of World Digital Cities

   This chapter reviews the advances in several worldwide activities on regional information spaces empowered by new technologies in sensors, information terminals, broadband networks and wireless networks. In the US and Canada, a large number of community networks supported by grass-root activities appeared in the early 1990s. In Europe, more than one hundred digital cities have been tried, often supported by local or central governments and the EU in the name of local digitalization. Asian countries have actively adopted the latest information technologies as a part of national initiatives. In the past 15 years since the first stage of digital cities, the development of the original digital cities has leveled off or stabilized. In spite of that, by looking back at the trajectory of the development of digital cities, it is clear that digital environments in cities have often benefited from the previous activities on various regional information technology spaces.

8 Societal Implications and Impact

It is well known within the community that the areas covered in this volume can potentially have profound impacts in our society. On the one hand they can provide unprecedented support for the society to enter a true modern digital era where computers everywhere silently assist us. On the other hand, this can also prove to be a technical minefield where many problems arise as a result of attempting to offer the intended services [13, 15, 2, 10]. User-oriented design, privacy preservation, personalization and social intelligence are some of the fundamental concepts the area has to approach efficiently in order to encourage acceptance from the masses. Failing to do well in those aspects will most certainly cause the users to feel overwhelmed and distrustful of the technology that is entering their daily lives in a disruptive way. The chapters in this thematic part address some of these important user-related issues, namely how to achieve truly unobtrusive systems, give privacy issues a well deserved relevance, personalize systems to a user, and consider social interaction as an essential element of design.

1. Human Factors Consideration for the Design of Collaborative Machine Assistants

   The basic idea of ambient intelligence is to connect and integrate technological devices into our environment such that the technology itself disappears from sight and only the user interface remains. Representative technologies used in ambient intelligent environments are collaborative machine assistants (CMAs), for example, in the form of a virtual agent or robot. Designing effective CMAs requires attention to the user interaction making it critical to consider user characteristics (e.g., age, knowledge), technology characteristics (e.g., perceived usefulness, ease of use), and relational characteristics (e.g., voluntariness, attraction) during the design. We propose a framework for understanding the user variables that influence the acceptance of CMAs. Our goal is to provide designers with heuristic tools to be used during the design process to increase user acceptance of such technology.

2. Privacy Sensitive Surveillance for Assisted Living: A Smart Camera Approach

   Western societies are aging rapidly. An automated 24/7 surveillance to ensure safety of the elderly while respecting privacy becomes a major challenge. At the same time this is a representative of novel and emerging video surveillance applications discovered lately besides the classic surveillance protection applications in airports, government buildings and industrial plants. Three problems of current surveillance systems are identified. A *distributed* and *automated* smart camera based approach is proposed that addresses these problems. The proposed system's goal set is to analyze the real world and reflect all relevant – and only relevant – information live in an integrated virtual counterpart for visualization. It covers geo referenced person tracking and activity recognition (falling person detection). A prototype system is installed in a home for assisted living running 24/7 for several months now and shows quite promising performance.

3. Data Mining for User Modeling and Personalization in Ubiquitous Spaces

   User modeling has traditionally been concerned with analyzing a user's interaction with a system and developing cognitive models that aid in the design of user interfaces and interaction mechanisms. In recent years, the large amounts of data that can be collected from users of technology in multiple scenarios (web, mobile, etc.) has created additional opportunities for research, not only for traditional data mining applications, but also for creating new user models that lead to personalized interaction and services. The explosion of available user data presents many opportunities and challenges, requiring the development of new algorithms and approaches for data mining, modeling and personalization, particularly considering the importance of the socio-cultural context in which technologies are used. This chapter will present an overview of data mining of ubiquitous data, review user modeling and personalization methods, and discuss how these can be used in ubiquitous spaces not just for designing new interfaces, but also in determining how user models can inform the decisions concerning what services and functionalities are adequate for particular users.

4. Experience Research: a Methodology for Developing Human-centered Interfaces

   Ten years of Ambient Intelligence (AmI) research have led to new insights and the understanding that Ambient Intelligence should not be so much about system intelligence and computing but more about social intelligence and innovation. We discuss these novel insights and their resulting impact on the AmI research landscape. We argue that new ways of working are required applying the concept of Experience Research resulting in a true user-centered approach to ambient intelligence. The Experience Research approach is illustrated with a small case study on applying this methodology in the area of Ambient Assisted Living.

9 Selected Research Projects

Another sign of the interest these areas are attracting is the number of projects that have been started in the last decade around the world. The number of such projects have grown exponentially thanks to the realization of governments (predominantly in the north hemisphere) of the strategic importance this problem has for the future development of the most industrialized nations. Both governments and companies have started to invest heavily in addressing different bottlenecks for the future development of the area and in the development of the first generation of system which can increase safety, entertainment, healthy lifestyle habits, and many other services that people can enjoy during work, life at home, and leisure time. This thematic part provides a glance on some of those projects, given space restrictions we can only offer a small number of them but they illustrate a variety of topics (human-centric models of computing, non-traditional ways of interaction, robust middleware, ambient assisted living, efficient and automated light control, and large ubiquitous experiments in Japan and Korea) which have been effectively addressed by large consortia of academic and industrial organizations in a collaborative way.

1. Computers in the Human Interaction Loop

   Computers have become an essential part of modern life, supporting human activities in a multiplicity of ways. Access to the services that computers provide, however, comes at a price: Human attention is bound and directed toward a technical artifact rather than at the human activity or interaction that computing is to serve. In CHIL (Computers in the Human Interaction Loop) Computing we explore an alternative paradigm for computing in a human centered way. Rather than humans attending to computers, we are developing computing services and technologies that attend to humans while they go about their normal activities and attempt to provide implicit support. By analogy to a human butler hovering in the background, computers that attend to human needs implicitly would require a much richer understanding and quite a bit of careful observation of human interaction and activities. This presumes a wide set of perceptual capabilities, allowing to determine who was doing what to whom, where, why and how, based on a multimodal integration of many sensors. It also presumes the ability to derive rich descriptions of human activities and state, so that suitable inferences for the determination of implied need can be made. In this chapter, we present several prototypical CHIL services and their supporting perceptual technologies. We also discuss the evaluation framework under which technological advances are made, and the software architecture by which perceptual components are integrated. Finally, we examine the social impact of CHIL computers; how increasingly social machines can better cooperate with humans and how CHIL computers enhance their effectiveness.

2. Eye-based Direct Interaction for Environmental Control in Heterogeneous Smart Environments

   Eye-based environmental control requires innovative solutions for supporting effective user interaction, for allowing home automation and control, and for making homes more "attentive" to user needs.
   This chapter describes the research efforts within the COGAIN project, where the gaze-based home automation problem is tackled as a whole, exploiting state-of-the-art technologies and trying to integrate interaction modalities that are currently supported and that may be supported in the near future. User-home interaction is sought through an innovative interaction pattern: direct interaction. Integration between the eye tracking interfaces, or other interaction modalities, and the wide variety of equipment that may be present in an intelligent house (appliances and devices) is achieved by the implementation of a Domotic House Gateway that adopts technologies derived from the semantic web to abstract devices and to enable interoperability of different automation subsystems.
   Innovative points can be identified in the wide flexibility of the approach which allows on one hand integration of virtually all home devices having a communication interface, and, on the other hand, direct user interaction paradigms, exploiting the immediacy of command and feedback.

3. Middleware Architecture for Ambient Intelligence in the Networked Home The

   European IST FP6 Amigo project aimed at developing a networked home system enabling the ambient intelligence / pervasive computing vision. Key feature of the Amigo system is effectively integrating and composing heterogeneous devices and services from the four application domains (i.e., personal computing, mobile computing, consumer electronics and home automation) that are met in todayÃÔ home. The design of the supporting interoperability middleware architecture is the focus of this chapter. The Amigo middleware architecture is based on the service-oriented architectural style, hence enabling a networked home system structured around autonomous, loosely coupled services that are able to communicate, compose and evolve in the open, dynamic and heterogeneous home environment. The distinguishing feature of the proposed middleware architecture is that it poses limited technology-specific restrictions: interoperability among heterogeneous services is supported through semantic-based interoperability mechanisms that are key elements of the Amigo architecture.

4. The PERSONA Service Platform for Ambient Assisted Living Spaces

   An European project started in January 2007 in the field of Ambient Assisted Living, PERSONA strives for the development of sustainable and affordable solutions for the independent living of senior citizens. AAL Services with focus on social integration, assistance in daily activities, safety and security, and mobility should be developed based on an open scalable technological platform. This chapter summarizes the conceptual design of this service platform for AAL spaces that is being finalized in the end of the second year after project start. It introduces a physical and a logical architecture for AAL spaces at an abstract level along with a set of more concrete functional components that are identified as part of the platform. The abstract physical architecture treats an AAL space as a dynamic ensemble of networked nodes and the interoperability framework abstracts all functionality not leading to context, input, or output events (or the direct processing of such events) as service. Hence, the proposed architecture is service oriented. A last topic treated in this chapter concerns the PERSONA solution for binding ultra-thin devices through a Sensor Abstraction and Integration Layer.

5. ALADIN - a Magic Lamp for the Elderly?

   The overall aim of ALADIN, an EU-funded research project in the realm of Ambient Assisted Living (AAL), is to extend our knowledge about the impact of lighting on the well-being and comfort of older people and translate this into a cost-effective open solution. The development approach is underpinned by an ambient intelligence framework which focuses on user experience and emphasizes activity support. The adaptive lighting system developed in ALADIN consists of an intelligent open-loop control, which can adapt various light parameters in response to the psycho-physiological data it receives. For adaptive control, simulated annealing and genetic algorithms have been developed.
   In the lab tests that were carried out to determine the psycho-physiological target values for activation and relaxation, skin conductance response emerged as the most appropriate target value with heart rate as the second best candidate. Tests with different light parameters (color temperature, intensity, distribution) showed a clear impact on older adults both in terms of activation and relaxation. The technical architecture and hardware prerequisites (sensor device, lighting installation) as well as the different software applications are described. Finally, the preliminary results of the extensive field trials conducted in twelve private households are discussed. The user feedback provides the basis for future application scenarios and exploitation plans of the Consortium partners.

6. Japanese Ubiquitous Network Project: Ubila

   From 2003 to March 2008, Ubila , a part of the “u-Japan” project, was a pioneering national ubiquitous network R&D project in Japan. Its objective was to develop core technologies to realize ambient environments with the cooperation of networks, middleware and information processing technologies. The Ubila project has demonstrated various activities. Every year, its research outputs were demonstrated at exhibitions and also periodically demonstrations were also conducted at smart spaces for guests. the Ubila project has released two service prototype videos that reflect its R&D directions. the Ubila project marked a unique and important step toward the advent of the ambient world.

7. Ubiquitous Korea Project

   In 2006 Korean government planed to construct u-Korea until 2015. Although the plan has not been executed exactly, the government has established several huge national projects for constructing u-Korea. In this chapter we introduce four major projects related with ubiquitous computing technology which has been conducted by Korean government.

10 Perspectives of the Area

When we look back to the research in intelligent systems, we can see the general direction moving from the individual to the group, and from closed systems to open systems. When the research area of Artificial Intelligence was first established, the dominating concept was "the physical symbol system hypothesis" which postulates that the essence of intelligence is captured by and only by symbol processing[19]. As a natural consequence, an intelligent system was modeled as an input-compute-output, or recognize-compute-act system (Figure 5).

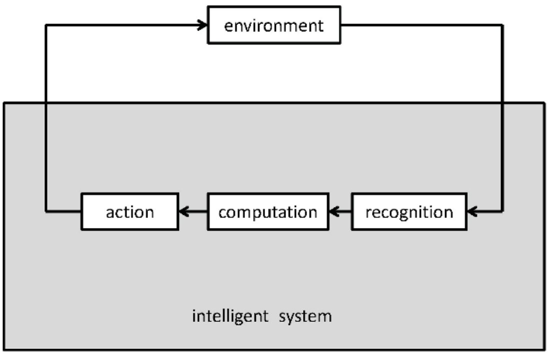

Fig. 5 The old view of intelligence.

As experience was gained in the area, the community began to recognize the importance of the environment. There even exists a viewpoint declaring that only the environment is the key to intelligent behavior: An agent (or any actor in the environment) only demonstrates behavior by picking up an affordance provided by the environment [14]. This view, although regarded by some as extreme, has some alignment with the concept of Ambient Intelligence in emphasizing the various influences and multi-faceted services the environment has to offer to its occupants.

Around the same period, the concept of Autopoiesis which denies a predefined distinction between the system and the environment was proposed [17]. These concepts also match research directions taken on in robotics where sensors and actuators play more important roles than symbolic planning. Brooks [11] even denied the necessity of internal symbolic representation. These new view of intelligence can be formalized as Figure 6 where recognition, computation and action take place in parallel.

The essence of general research direction in Ambient Intelligence, placing more emphasis on the environment than the agents acting in the environment, can be captured along the same direction but in a wider scope. The area is not limited to a single agent, but rather aims to support a team of agents in one environment, or even the society as a whole. This reflects the trend from focusing on the individual towards serving a group.

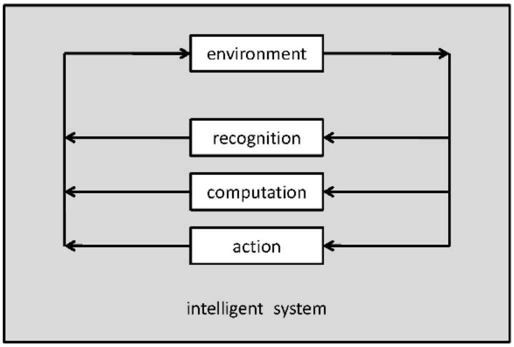

Fig. 6 A new view of intelligence, which includes the environment within the system.

11 Conclusions

This handbook offers a snapshot of the state-of-the-art in Ambient Intelligence and Smart Environments. The various core disciplines participating in the creation of the concepts and applications of AmI and SmE are represented through examples of research and development efforts by leading experts in each field. The domain of potentials is vast with applications in all aspects of life for an individual or a community. The extent of the area overlaps with such diverse groups of disciplines as sensor networks and sociology, and artificial intelligence and communication networks. While this offers ample opportunities for many areas of science and technology to impact the future of AmI and SmE by providing tools from within the focus area of each discipline, truly ground breaking impact is possible through collaboration among researchers from several disciplines. This handbook aims to offer and encourage such opportunities by introducing a representative set of fundamental concepts from the different areas. It is hoped that the presented material will inspire researchers to steer their work towards making novel contributions to this promising area.

The rest of the handbook is divided into 8 thematic parts, each with a collection of contributions from recent studies. We hope you will find the material as exciting and inspiring as we have.

Acknowledgments

We wish to thank Jennifer Evans and Melissa Fearon of Springer for their encouragement and support of this project. We are also grateful to Valerie Schofield and Jennifer Maurer of Springer for their assistance with the production of this handbook. Many thanks go to the contributors of the chapters for the book. Their active and timely cooperation is highly appreciated.

References

[1] Aarts E, Appelo L (1999) Ambient intelligence: thuisomgevingen van de toekomst. IT Monitor (9):7–11
[2] Aarts E, de Ruyter B (2009) New research perspectives on ambient intelligence. Journal on Ambient Intelligence and Smart Environments (JAISE) 1(1):5–14
[3] Aarts E, Harwig R, Schuurmans M (2002) Ambient intelligence. In: The invisible future: the seamless integration of technology into everyday life, McGraw-Hill, pp 235–250
[4] Aghajan Y, Lacroix j, Cui J, van Halteren A, Aghajan H (2009) Home Exercise in a Social Context: Real-Time Experience Sharing using Avatars, Intetain'09
[5] Aghajan H, Cavallaro A (2009) Multi-Camera Networks: Principles and Applications, Academic Press 2009
[6] Aghajan H, Augusto J, Delgado R (2009) Human-centric Interfaces for Ambient Intelligence, Academic Press 2009
[7] Augusto JC (2007) Ambient Intelligence: the Confluence of Ubiquitous/Pervasive Computing and Artificial Intelligence, Springer London, pp 213–234. Intelligent Computing Everywhere
[8] Augusto JC, Nugent CD (eds) (2006) Designing Smart Homes. The Role of Artificial Intelligence. Springer-Verlag
[9] Augusto JC, Nugent CD (2006) Smart homes can be smarter. In: [8], Springer-Verlag, pp 1–15

[10] Böhlen M (2009) Second order ambient intelligence. Journal on Ambient Intelligence and Smart Environments (JAISE) 1(1):63–67

[11] Brooks R (1990) Elephants Don't Play Chess. In: Robotics and Autonomous Systems 6, pp. 3–15

[12] Cook D, Das S (2004) Smart Environments: Technology, Protocols and Applications (Wiley Series on Parallel and Distributed Computing). Wiley-Interscience

[13] Dertouzos M (2001) Human-centered systems. In: The Invisible Future, McGraw-Hill, pp 181–192

[14] Gibson J (1979) The Ecological Approach to Visual Perception. Houghton Mifflin, Boston

[15] Huuskonen P (2007) Run to the hills! ubiquitous computing meltdown. In: Augusto JC, Shapiro D (eds) Advances in Ambient Intelligence, no. 164 in Frontiers in Artificial Intelligence and Applications (FAIA), IOS Press

[16] IST Advisory Group (2001) The European union report, scenarios for ambient intelligence in 2010. URL: `ftp://ftp.cordis.lu/pub/ist/docs/istagscenarios2010.pdf`

[17] Maturana H and Varela F (1980) Autopoiesis and Cognition: The Realization of the Living. D. Reidel Publishing Co., Dordrecht, Holland

[18] Nakashima H (2007) Cyber assist project for ambient intelligence. In: Augusto JC, Shapiro D (eds) Advances in Ambient Intelligence, IOS Press Inc.

[19] Newell A, Simon H (1963), GPS: A Program that Simulates Human Thought. In: Feigenbaum E, Feldman J (eds) Computers and Thought, McGraw-Hill

[20] Ramos C, Dey A, Kameas A (2009) Thematic Issue on Contribution of Artificial Intelligence to AmI. Journal on Ambient Intelligence and Smart Environments (JAISE) 1(3)

[21] Spohrer J, Maglio P, Bailey J, Gruhl D (2007) Steps Toward a Science of Service Systems, IEEE Computer 40(1):71–77

[22] Streitz NA, Kameas A, Mavrommati I (eds) (2007) The Disappearing Computer, Lecture Notes in Computer Science, vol 4500, Springer

[23] Weiser M (1991) The computer for the twenty-first century. Scientific American 165:94–104

[24] Weiser M (1993) Hot topics: Ubiquitous computing. IEEE Computer 26(10):71–72

[25] Zelkha E (1998) The future of information appliances and consumer devices, Palo Alto Ventures, Palo Alto, California