Towards a Human Centered Infrastructure for KNX enabled Intelligent Environments

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Abstract. Recent projects in the field of Ambient Intelligence (AmI) concentrate on technical aspects to integrate evolving ubicomp techniques into so called smart rooms and smart houses. The concept of context awareness is utilized to create what is called intelligence in such scenarios and the representation of user information on system level in general takes place within a general context model. While technologically impressive, a lack of portability to practical applications can be observed for the majority of such research projects. The tremendous dependency on special and expensive hardware limits the scope of application and prevents Ambient Intelligence for the masses. Additionally the technology centered view accompanied by an (implicit) data driven and non-active user model carries along different usability concerns. As a result the user turns out to be a foreign object on system level, which is excluded from the system's communication layer and – ignoring the user's skills – is merely handled as an obstacle in a technology centered system.

In this paper we present a case study featuring a novel approach to the integration of humans into AmI environments to prepare the ground for a user centric – thus user friendly – infrastructure for smart devices. The key aspect of the concept which we call human centered AmI is a dynamic and active user model which creates a virtual doppelganger of the user on software level. Mapping the user's capabilities and skills to system level, human services integrate seamlessly into the KNX enabled intelligent environment, allowing for transparent human computer interaction. Moreover, it also widens the scope of existing hardware and software components. In particular, the functionality of KNX devices in practical scenarios is complemented by human services and the presented approach.

The concept of human centered AmI is put into effect within the perception-oriented intelligent environment FINCA. This smart conference room is based on standard hardware components and, on sensor level, focuses on visual and acoustic data. In consequence our concept is easily transferable between related scenarios putatively exhibiting different hardware settings.

1 Introduction

Today the availability of more and more cheap and powerful computing devices together with their substantially and continuously shrinking size allow for realization of ubiquitous and disappearing computing. Intelligent environments integrate such technologies to silently serve the user in everyday situations and create what is called *Ambient Intelligence* (AmI) [1]: A supporting, omnipresent environmental intelligence, centered around the user.

In the past years tremendous progress was made by a variety of research projects in the field of AmI, defining the vision of intelligent environmental functionality from the viewpoint of the user. As a prominent example so-called *Smart Houses* left the laboratory state and now allow for practical application in realistic scenarios. Various actuators and sensors are integrated into the private home using ubicomp techniques, aiming for different application areas, e.g., enhancing the living rooms or conference rooms . Key aspect in such scenarios is the realization of context awareness at a global scale.

Being technologically impressive the transfer of recent findings to consumer relevant, real life applications is obstructed by tremendous and cost-intensive hardware dependencies. A multitude of sensors and actuators must be deployed to provide intelligent functionality. We call this gap between environmental intelligence or complete dysfunction of the AmI environment the *all-or-nothing dilemma*. In consequence conventional concepts in the field of AmI prevent a piecewise build up of environment on hardware level but force a complete all-or-nothing hardware setup. However for market relevance and, in particular, for open environments and uncontrolled conditions, a technological basis capable of being extended by time is indispensable. The KNX technology [2] can build such a hardware basis but will not be able to bridge the conceptual gap for AmI applications for the masses. In order to solve obstructing dependencies and to provide intelligent Human Computer Interaction (HCI), intelligent functionality w.r.t. user orientation demands for a global concept to dynamically integrate and couple hardware based and software services.

In [3] we presented an approach for an infrastructure for Ambient Intelligence environments which is centered around the user. In this paper we focus on practical aspects of this new concept of human centered AmI for it's implementation in real-world scenarios, namely smart environments. Especially the role of KNX devices for carrying the proposed concept from vision to practical application is considered. It is this practical issue that allow for the realization of close-to-market solutions beyond laboratory prototypes.

The discussion of this paper is organized as follows. In section 2 the new concept of human centered AmI in contrast to traditional approaches is reviewed. Subsequently in section 3 the realization of human centered AmI within an practical oriented scenario is presented and the application of KNX technology to the presented concept is discussed afterwards. The paper closes with a summary.

2 The Concept of User in AmI

By definition the agile user in everyday situations is identified as the fundamental aspect of Ambient Intelligence and is served by numerous computer based systems, thereby improving his experience. However, the center of focus in the multitude of practical oriented projects in this field can be identified in managing a versatile hardware zoo which provides smart functionality. On technical level, exemplary, two prominent projects, the Gator Tech Smart House [4] and the inHaus Duisburg [5] realize Ambient Intelligence at a large scale. Within realistic domicile scenarios, a multitude of sensors and actuators is integrated to create an AmI environment solving diverse problems of hardware-integration. Certainly, these aspects of hardware integration prepare the ground for every AmI environment. Context awareness, as being the key aspect to differ smart automation processes from intelligent environmental behavior, is realized by a dynamic, integral context model. The user as part of the context as well as his relation to environmental objects is implicitly modeled within this passive and data based concept of context.

We now switch the viewpoint from the technical aspects, turning towards the characteristics of the user, his persona, abilities and skills. In fact the user is the integral part of every AmI environment, predominantly and actively determining the state of the context. In consequence, his characteristics must be first and foremost taken into account within the context modeling process. Conventional approaches in the field of AmI model the user within a passive, integral context model. In contrast in this approach the user is modeled separately allowing to take into account his special characteristics in the modeling process.

Moreover in practical oriented, complex AmI scenarios the user is confronted with ubiquitous systems he might not see, with intelligent functionality he might even not be aware of. This novel situation in Human Computer Interaction raises further usability concerns for AmI environments, beyond the technical scope of hardware integration.

2.1 Human Skills and a Proactive User Model

In our approach of human centered AmI which is briefly summarized here [1] the central component of the context model is an autonomous and active software agent representing the user on system level. In contrast to conventional approaches which implicitly model the user within a global and integral context model, this concept of a *virtual doppelganger* separates the user from an integral context model. However, the relationship between the overall environment context components is tight. The respective mutual interferences are illustrated in figure 1. But the separation of the user model enriches its potential, allowing to map the user's behavior and, moreover, the user's skills to the model, the realization of which we will call *human services*. In consequence the user and

[1] For a more thorough discussion of the concept of human centered AmI based on human services cf. [3]

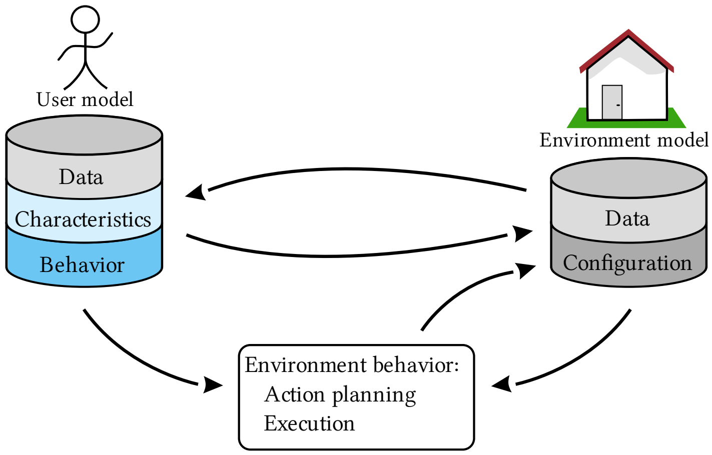

Fig. 1. There is a close relation between user and context model. The state of the environment directly influences the role of the user and, vice versa, the user implicitly determines the current state of the environment (taken from [3]).

his characteristics are integrated on system level the motivation of which is to overcome the aforementioned all-or-nothing dilemma and allow for system wide intelligent, adaptive and user-guiding HCI.

The concept and the realization of human services is inspired by the the UPnP technology [6] which is the de facto standard for service discovery, description and control in the field of consumer electronics. Numerous hardware devices and software applications implement the defined interfaces . Software agents and gateways allow to refit this technology to existing but innately incompatible devices to dynamically deploy functionality. Similarly, the human user brings in a variety of high level skills into the AmI environment but, up to this point, a solution for integration of those is not existent. The concept of human services proposes a *human control point*, offering his capabilities as software services. This allows for dynamic coupling of off-the-shelf hardware devices, based on KNX [2], UPnP [6] or OSGi [7] technology, just to mention some examples of putative underlying technologies.

On level of function, human services can be divided into two categories. First, communication services implement HCI interfaces which, while dynamically adopting to the user, realize a system wide intelligent communication channel between user and his environment. In consequence messages to the user are delivered dependent on available output devices, selecting appropriate modalities and language. As a prominent example a text message can be read to the (blind) user, visually presented or even suppressed if the user gives a talk and the message is of minor urgency. The second category of human services provides the user's skills as environmental functionality, making use of communication services itself. Exemplary a door-open-service is offered by the user which can be coupled with conventional services, e.g., controlling light conditions. This service can be demanded by different software or hardware components of the AmI environment.

Following an object oriented approach, decisions on service offering and withdrawal are taken by the proactive user model, depending on knowledge about the user, his current activity and global context information.

2.2 Human Centered AmI

The dynamic and active user model, utilizing the concept of human services, enhances conventional approaches in the field of AmI. The user is integrated into environment on system level, taking the central role within the overall context model. Hence, we call this concept Human Centered AmI offers a way out of the proposed all-or-nothing dilemma and enables intelligent HCI. The different aspects of the concept – the context model's components, the virtual doppelganger, the integration of human services in strategy planning – are illustrated in figure 2.

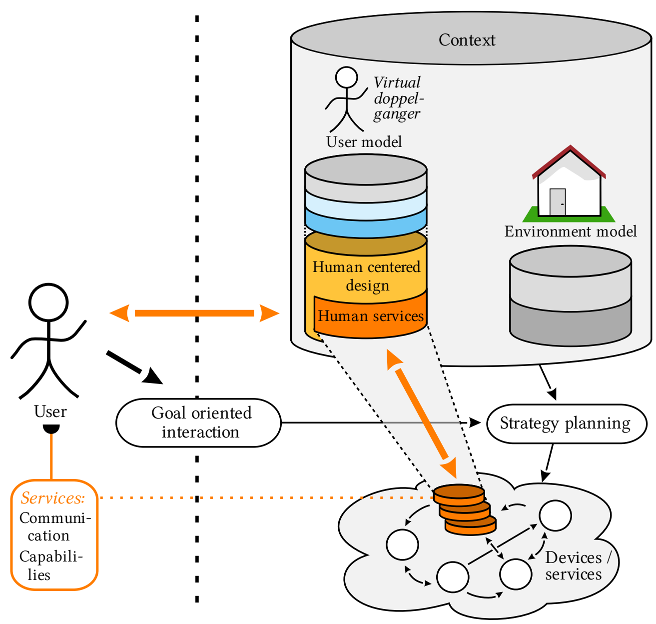

Fig. 2. Human services allow for the integration of the user's capabilities into the strategy planning process of intelligent environments and are the key feature of Human Centered AmI. On the left hand side the real user is shown, on the right his virtual doppelganger. The integration of the user model into the system is accomplished at service level. The role of the user shifts from being the trigger of system activities to an active component within the overall system. The user model thereby controls the intelligent communication between the user and his virtual doppelganger (adopted from [3]).

Fig. 3. Overview of the FINCA (left) and inside view of the smart conference room.

This process of user integration follows the paradigm of service orientation. Hence, an implementation of our approach using standard service oriented software frameworks is feasible. We propose this concept for building smart, extensible and user centric spaces on basis of standard technologies.

3 From Vision to Application

Directed towards the user, the focus of Ambient Intelligence lies on usability in general, context awareness and HCI to be major aspects of interest in this field. In concordance, we proposed the concept of Human Centered AmI. Furthermore AmI clearly defines the target audience – the (general) mobile user in everyday situations – which sets tight constraints w.r.t. hardware deployment. Hence, for practical relevance of research findings, evaluation and discussion has to be conducted w.r.t. this background. In the following we will present an AmI environment, designed to meet these constraints. We will refer to a case study on usability in this environment, analyzing the concept of Human Centered AmI to, finally, return to the hardware level discussing aspects relevance in practice.

3.1 The FINCA: A Perception Oriented Intelligent Environment

The FINCA, a Flexible, Intelligent eNvironment with Computational Augmentation [8] provides the context for the work presented in this paper. Aiming at the development of techniques for sophisticated and natural HCI, sensor data related to human perception are processed using statistical pattern recognition techniques. In this project a Smart House has been build, consisting of basically two areas: A smart conference room equipped with numerous sensors (e.g. cameras, microphones and light switches) and actuators (e.g. light and sun-blind control units). Furthermore a lab-space exists, serving different scientific research projects. An overview of the FINCA building and the conference room is shown in figure 3.

To serve as a practical oriented scenario for AmI applications and to assure transferability of findings to different (real life) scenarios, only standard, off-the-shelf hardware components have been chosen for the set-up of environment. In particular KNX technology [2], providing the standard for home and building control, is used for numerous tasks within the FINCA. Furthermore the OSGi technology [7] serves as service oriented framework for the FINCA. On top, numerous software applications implement gateways between different communication systems and transparently provide unified software services across technologies. In example, only through services provided by the OSGi framework, a 3D-gesture-detection service, running on a remote computer, demands and receives camera images via network and accordingly controls light units which feature the KNX technology.

Being a platform for high level applications the FINCA is a cooperative house environment supporting users during various activities. Detecting, locating and tracking its communication partners by analysis of visual and acoustic data, the FINCA allows for multimedia scene analysis and natural HCI. In consequence it builds an adequate platform for human centered AmI.

3.2 The Role of Home and Building Control for Successful AmI

So far it has been shown that human centered AmI, in principle, offers a solution for user integration for next generation smart environments. In fact the human centered AmI represents a step beyond existing concepts for user and context modeling in AmI environments. Taking into account the specific characteristics of a human user, the virtual doppelganger and human services potentially allow for high level Ambient Intelligence.

One goal of Ambient Intelligence is to develop general solutions for everyday situations, i.e. solutions that work in practice. Thus technical aspects of concrete realization have to be considered to assure for market relevance. Analyzing typical use-cases of smart environments it becomes obvious, that smartness is directly linked to natural and intuitive, thus intelligent, human computer interaction tasks. Moreover high responsiveness of an environment is a basic necessity for this to achieve. A human user interacting with the intelligent house expects appropriate reactions of the technical system. For example, controlling of light conditions via high level services, e.g., speech and gesture recognition, in practice demands for immediate environmental activity – the light shall actualy be turned on or off.

To allow for the necessary physical reaction at the technical level a complex interaction problem w.r.t. concrete physical devices has to be solved. At this point technologies for smart home and building control come into play by linking the field of electrotechnical installations to AmI. In concrete, the well established KNX technology offers the desired functions for smart actions and automation processes within intelligent environments. Numerous hardware devices, i.e. sensors, actuators and control units, can be explicitly addressed by the environments software framework and dynamically coupled to miscellaneous services.

Different use cases illustrate the flawless collaboration of approved home and building control technologies and the concept of human centered AmI. To pick up the previously mentioned example, controlling lighting conditions can be accomplished by standard switches or, more sophisticated, by multi-functional-control panels, PDAs or smartphones and so forth. But integrated into the concept of human centered AmI the actuators can be controlled by intuitive interaction means, namely using natural modalities like speech and gestures. Even personal preferences of the user can be taken into account for the controlling task. The KNX technology introduces an layer for abstraction, allowing for "soft-wiring" of devices and, in consequence, dynamic coupling w.r.t. intelligent environmental activity. In contrast to hard-wired logical entities of devices, this message based infrastructure bridges the gap between the desired natural interaction and it's grounding to physical actions.

Furthermore, every newly integrated KNX device not only enlarges the functional pool but, coupled to human services can be lifted to new application areas. For example, the actual function of a conventional switch can depend on a pointing-gesture of the user. In consequence the KNX technology can draw benefit from high level AmI functionality and in turn can manifest it's position within the infrastructure of environment. Integration of conventional hardware devices – devices, first and foremost not designed for intuitive HCI – on service level allow for high-level Ambient Intelligence, beyond the domain of home automation applications.

To sum up, it is the concrete installation of electric devices and their integration into a framework for home and building control that represents the basis for responsiveness in AmI environments. Consequently, the KNX infrastructure is, to some extent, the pre-requisite for "AmI for the masses".

4 Summary

One goal of Ambient Intelligence is to develop concrete applications that support the users in their everyday life in an intuitive and natural way. Along this way cost-efficiency and broad availability of hardware are considered as constraints. However to reach the mass-market, AmI approaches must solve the all-or-nothing dilemma, which we identified for conventional AmI applications: If an application relies on specific software and hardware services the overall application is hardly transferable, even to related scenarios. For example, AmI solutions developed for Smart Houses substantially depend on the specific hardware setup and will fail otherwise. Furthermore usability issues arising from the fact that the user is surrounded by a multitude of ubiquitous computing systems need to be solved.

In our work we developed an approach which focuses on the user and, respectively, the user's model on system level. This concept we call human centered Ambient Intelligence. A virtual doppelganger is created which represents the user, his characteristics and behaviour on system level and actively co-determines activities within the software framework. In consequence, the user is transparently integrated into the Service Oriented Architecture, thereby offering his skills as so called human services. A case study on usability showed the effectiveness and acceptance of this concept in practice. Moreover it was argued that the all-or-nothing dilemma, putatively, can be resolved by this concept.

The discussion on home and building control technologies for AmI environments showed the mutual benefit w.r.t. practical application. To be precise, the KNX technology proved to provide a solid infrastructure to realize responsiveness within AmI environments. In return, conventional KNX devices can draw benefit when coupled to other high level services. Consequently the KNX technology can play an important role for Ambient Intelligence in real-world settings.

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