Developing Ambient Intelligence Applications for the Assisted Living of the Elderly

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Abstract:
Ambient Assisted Living is a research area which has emerged to assist individuals in performing their everyday activities with the help of ambient intelligence technology. To accomplish this, technological aspects such as context acquisition, device integration, networking, and social aspects such as accessibility, usability, privacy, and others, play an important role. These aspects become crucial when assisting the elderly, because they present very specific and demanding requirements. In this paper, we present work in some application scenarios conducted within our research group, focused on supporting the elderly. The implementation of these scenarios is possible through the use of our proposed technological infrastructure consisting of hardware and software platforms.

1 Introduction

The ubiquitous computing vision [11] describes an augmented world full of intelligent devices that comprises a fine grained distributed network. Ambient intelligence (AmI) goes further by studying how to allow environments to be sensitive, adaptive, and responsive to the presence of people, in order to support them in their day to day experiences [2]. We focus our research in the ambient assisted living (AAL) domain, and specially in how they support the elderly. The main reason is their physical and mental declination that comes with the natural aging process. We are interested in how AmI can come up with new alternatives and innovative tools to improve their lifestyle by helping them to maintain certain degree of independence.

The rest of the paper is organized as follows. In section 2 we talk about the motivation of our work and explain why the support for the elders is a good case study for AmI. Next, in section 3 we discuss some of the related work. In section 4, we present our technological infrastructure, which comprises both a physical and a software platform. Then, in section 5, we discuss the cases of study implemented with our contributions, talking in section 6 about the lessons learned. We conclude in section 7 and outline the future work.

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2 Motivation

Augmented spaces are particularly helpful for the elders, and, as average life expectancy increases worldwide with an aging population constantly growing [10], we can expect a greater demand for services and applications oriented toward assisting them. These demands include providing services for those who suffer from various illnesses (both mental and physical) such as: diabetes, arthritis, senile dementia, Alzheimer, heart-related diseases among many others. The emergence of new types of mobile and embedded computing devices, developments in wireless networking, smart sensors, and others, gives us the tools and methods to come up with innovative applications to better assist users, and therefore, improve their lifestyle.

We believe that support for the elderly through AAL infrastructures is the most naturally appropriate. Not just because of its evident social impact, but because of the characteristics of its special requirements. We summarize this by analysing the characteristics shown by a traditional AmI system, according to Weber, *et al.* [7]:

- *Invisible.* Since there is the need to track and automatically identify the users of an augmented space, they are required to wear a digital tag that can take the form of a watch, a purse, glasses, be embedded in clothes, and others.

- *Mobile.* As users move around their homes, or nursing rooms, they need to carry with them some of the computation or sensing needed to support their activities.

- *Context-aware.* This requirement becomes really important for the elder because some systems usually rely on personal context such as blood pressure, sugar levels, and others. Context in such situations should be acquired, derived, and communicated in fast, reliable and opportune ways.

- *Anticipatory.* For instance, if the elder user has suffered a fall, the system must proactively alert the nursing home personnel without requiring the user's request.

- *Natural communication with users.* This requirement is specially important with the elderly. This kind of user presents interaction problems with traditional mechanisms such as mouse, keyboard, text on screens, etc. A new approach must be taken when displaying data, selecting between options, and requesting input data. Possible approaches could be the use of voice commands and visual components. This is a topic of active research (for instance, see [6]). Also, additional research is needed to accomplish proper usability.

- *Natural interaction.* AmI systems should interact with the user by the means of everyday items and devices the users are used to.

- *Adaptive.* Systems must be designed to be able to resolve abnormal or exceptional situations autonomously (if possible), and be prepared to support other scenarios the user could need to incorporate or change after time.

Additionally, elders hosted in a nursing home are used to stay in well known and confined spaces, for instance, their bedrooms, a game area, a TV room, and so on. In such cases, the augmentation of their spaces can, therefore, be carefully planned. Detractors of AAL usually mention privacy as a major concern. Sometimes the elderly must be constantly monitored, their activities have to be tracked and usually video taped. So, there is an interesting trade-off in providing adequate support but without disregarding important privacy issues. We acknowledge this but it remained out of the scope of the present work.

3 Related Work

AlarmNET [13] is an AAL system designed to provide assistance through a smart healthcare environment. It specifically targets assisted-living residents and others whom may benefit from continuous remote healthcare monitoring. Similarly to this work, our platform offers a number of different services to support the elder, while we also offer a sensorial infrastructure, we provide other services and tools such as physical actuators, an augmented reality framework, and others, that allow the implementation of many different application scenarios.

CenceMe, is a personal sensing system that enables users to share their activities through the Web, particularly through the use of social networks [4]. The CenceMe system can identify the status of a user in terms of his activity, disposition, habits, and surroundings. While our infrastructure also includes a behavioral analysis service that can be used to infer if a user is seated, walking, or if he has fallen, we are taking this further by offering a complete solution for applications that use that information to enable further support for AAL scenarios.

4 Technological Infrastructure

Before presenting and discussing the different scenarios we have explored to support the elders, we have to talk about our technological infrastructure. We have designed and implemented a platform featuring basic services and tools to allow the easy composition of hardware and software functionality.

4.1 Services

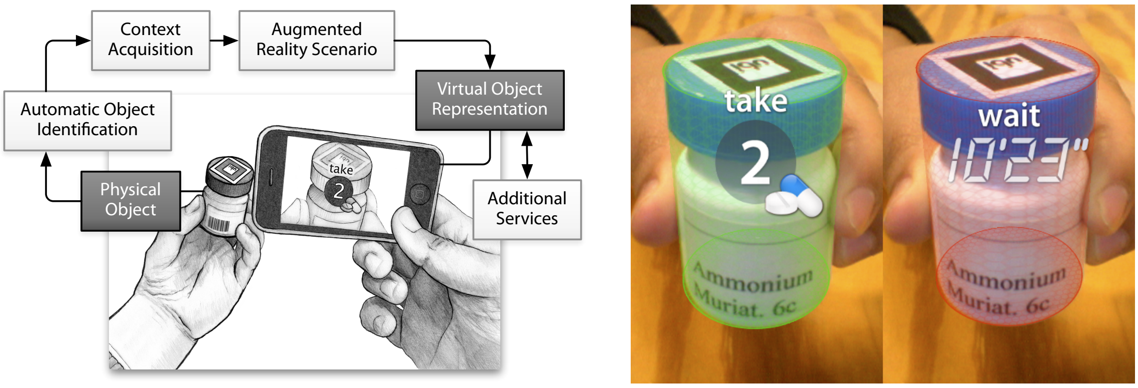
A service in our platform consists of a RESTful [5] Web service which exposes its functionality by describing what common interfaces it implements, and that notifies its availability by registering in the environment's discovery mechanism. Once they are registered, a developer can create compositions by defining which services are involved and the application flow between them. The composition files are sent to one of the execution engines available in the environment, which are in charge of handling the requests and data involved on the execution of the described functionality. The developer can alternatively use our platform framework to directly interact with the discovery and description mechanisms to handle its own composition implementation.

We have implemented a working prototype of our platform that includes server, desktop, and mobile versions of the execution engine. To conduct our cases of study, we also implemented the next basic services:

- *Indoor geo-localization.* Used to estimate the user's position based on the signal's intensity of surrounding Wi-Fi access points.
- *Sensing.* Provides a high-level abstraction to acquire readings from WSNs deployed in the environment, and a mechanism to communicate derived context in near-real-time.
- *Auto-identification.* Provides an abstraction to receive and communicate RFID readings. It is used to identify objects and users in the environment.
- *Video widgets.* A visual component to be embedded in other Web pages or systems, while currently not implemented, it is designed to be used in conjunction with image processing techniques to offer video-based behavioral analysis.
- *Voice commands.* Used to detect an user's command by the analyzing sound within the human voice range coming form a network of WSN nodes with open microphones. Reliability was its most important design requirement (see [8] for in-depth details).
- *Actuators.* Allows to perform a physical reaction in the environment. We provide support for motors, lights, and speech synthesis. The implementation of these services is generic so developers can easily adapt them to other devices.
- *User-inputs.* Allows the users to interact with the environment by means of buttons, sliders, touch events, rotators, and others. They are event-based so any interested interface is notified in near-real-time.

4.2 Tools

Along with the design and implementation of the services in the platform, we have a couple of tools built on top of our infrastructure to better support the development of AAL applications for the elderly. The most important one is a sentient visor toolkit that can be used to develop applications that allow the interaction of users with augmented objects in a very natural way.



(a) *Scenario of application.* **(b)** *Taking medications implementation.*

Figure 1: *The sentient visor tool.*

4.2.1 Sentient Visors

User interaction on AAL is intended to be the most natural possible. Elder users need new approaches that require them neither previous knowledge nor training and information has to be filtered and condensed based on their personal profile and preferences. Following the ambient devices concept [12] we have been working on what we call sentient visors [3] (see Fig. 1(a)). A tablet computer or smartphone can be used as visor. To start the interaction, the user points with it to an object or area of interest. Then the device automatically identifies what is being focused on, captures additional context as required, and then requests a special service in the environment for the AR scenario to be drawn on the screen. The AR scenario is interactive, so the user can touch objects on it. Additional requests to the appropriate data providers will be casted as the application is used.

5 Application Scenarios

We now present some scenarios that we came across during our work with AAL technologies to promote safer and healthier lifestyles for elders. These scenarios have also been very useful for highlighting the benefits o f our proposed platform for developing AmI applications.

You may find some more details at [1] which is the version accepted by the reviewers. Due to a sudden change of formats, we were forced to shorten this paper for publication.

5.1 Taking Medications

Mr. Smith is a senior of advanced age who needs to take many different medications on a daily basis. Sometimes he forgets to take the medications, and maybe worse, he takes the same amount of pills twice or thrice because he just wants to be sure he took it. This situation can lead to adverse, sometimes very serious consequences and it is known to cause many problems worldwide [9]. Mr. Smith is physically impaired, is impossible for him to visit his physician except on certain special occasions. Without frequent visits, the medical examinations are conducted via phone calls and sometimes his physician changes the dose by altering the number of pills to be taken or by setting a different intaking schedule, which makes the problem even worse because Mr. Smith must remember the proper dose of each of the many bottles of pills he takes during the day. Clearly, the object to be augmented was the bottle of pills. We attached a RFID tag to each bottle to later be able to look for the proper pill doses. Two services had to be implemented, one to allow the physician to set the doses, and other to querying the user's prescription, describe the AR scenario to send back to the visor. Thanks to our contributions Mr. Smith now picks a bottle of pills, points to it the visor and then he can know how many pills to take, or if he has to wait (see Fig. 1(b)).

5.2 Intelligent Care Monitoring

Mrs. Jones is a caregiver at a nursing facility. As part of her activities, she must regularly check the residents to look if they require assistance. To avoid her to walk around the many different rooms, they installed a closed circuit camera system for her. Now, when she is in the office she can keep an eye on the residents by watching a monitor that shows all the camera feeds in the building. Sometimes, one of the residents falls and if she is not careful, the elder could spent a long time unattended. Given the fact that during the aging process there is a considerable decline in motor capabilities, older adults become more prone to falls. Also, as Mrs. Jones have many other activities, after some time, the camera feeds are no longer being used for monitoring, but for having a record of what happens inside the building. We supported this scenario by providing each of the residents with wearable sensor nodes, in this way, we are aware of their location (using the indoor geo-localization service) and could infer their behaviour by analyzing the readings of an embedded accelerometer (a special implementation for this scenario). We take advantage as well of the video widgets to build a centralized system so Mrs. Jones can what the videos as usual, and receive opportunely alerts if the elder falls or asks for help (a button in the wearable node).

5.3 Voice-Enabled Assistance

Mr. Brown is a patient who uses an electric-powered wheelchair to move himself around the building. Very often, he requires assistance to open doors or to go to the bathroom. When nobody is around he usually finds himself waiting until a caregiver or another patient assists him. To support this scenario, we are using the geo-localization, voice commands, and actuators services. When Mr. Brown needs to open or close a door, he just needs to say the proper command, if he needs the assistance of a caregiver he can press the button on its wearable node or say another command.

6 Lessons Learned

Working with assisted living systems for supporting the elderly is a very interesting and challenging task; while the research offers a good degree of complexity, the results have an important and quick social impact. When designing the application scenarios, we found many issues that required very well planed privacy management, for instance, the *intelligent care monitoring* scenario, where the activities of the residents of a nursing house are always tracked. We think that, as long as the application is managed locally, privacy of users in such cases is not so crucial. We faced another problem when dealing with the precision of the indoor localization service. We needed a mechanism to get localization at the lowest cost possible (in terms of computation, infrastructure, and price) which led us to base it on Wi-Fi signal strength readings. Wi-Fi based techniques manage to get estimations within an approximate error of 20 meters, we needed a better one and considered a 5 meters error window. The precision we finally got was satisfactorily enough but this resulted particularly difficult on the *voice-enabled assistance* scenario, where the user activates the doors in front of him. Luckily, doors in the nursing room in which we conducted the experimentation were spread in far longer distances than our error window.

7 Conclusions and Future Work

In this article, we approached the use of ambient intelligence systems in the context of ambient assisted living for supporting the elder. This is a topic that has been pursued recently and it has gained greater importance because of the worldwide increase in average life expectancy [10]. We also presented our hardware and software infrastructure to support this kind of applications and discussed the implementation of a number of scenarios conducted in our research group. We believe our proposals will contribute in improving the lifestyle of the elderly by allowing the rapid construction of prototypes for usability, and application-driven research.

As stated before, the elder users have quite specific requirements, and their relationship with augmented objects and modern interface technologies have yet to be carefully analyzed. We plan to conduct an extensive evaluation of our contributions from two approaches. First, to evaluate the construction of ambient assisted living applications for the elderly with the use of our platform from the perspective of the developers of such applications. Second, to evaluate usability and acceptance of technology of the applications from the perspective of the elderly user. We have successfully tested the implemented applications in our laboratory, the next step is to conduct the usability studies by using our prototypes in the nursing home in which we conducted our analysis.

Acknowledgments

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References

[1] http://usuario.cicese.mx/~jagm/docs/aviles-ant10acc.pdf.

[2] E. Aarts, H. Harwig, and M. Schuurmans. *The invisible future: the seamless integration of technology into everyday life*. McGraw-Hill, Inc., New York, NY, USA, 2002.

[3] Edgardo Avilés-López, Ismael Villanueva-Miranda, J. Antonio García-Macías, and Luis E. Palafox-Maestre. Taking care of our elders through augmented spaces. In *CLIHC'09: Proc. of the Latin-American Conference on Human-Computer Interaction*, Nov 2009.

[4] Andrew T. Campbell, Shane B. Eisenman, Kristf Fodor, Nicholas D. Lane, Hong Lu, Emiliano Miluzzo, Mirco Musolesi, Ronald A. Peterson, and Xiao Zheng. CenceMe: Injecting sensing presence into social network applications using mobile phones. In *MobiHoc'08: Proc. of ACM 9th International Symposium on Mobile Ad Hoc Networking and Computing*, May 2008.

[5] Roy T. Fielding. *Architectural styles and the design of network-based software architectures*. PhD thesis, University of California, Irvine, 2000.

[6] Thomas Kleinberger, Martin Becker, Eric Ras, Andreas Holzinger, and Paul Müller. Ambient intelligence in assisted living: Enable elderly people to handle future interfaces. In *Universal Access in Human-Computer Interaction. Ambient Interaction*, pages 103–112. 2007.

[7] R. Oppermann, R. Rashev, and K. Kinshuk. Adaptability and adaptivity in learning systems. *Knowledge Transfer*, 2:173–179, 1997.

[8] Luis E. Palafox and J. Antonio García-Macias. Wireless sensor networks for voice capture in ubiquitous home environments. In *ISWPC'09: Proc. of the 4th international conference on wireless pervasive computing*, pages 332–336, 2009.

[9] P. A. Routledge, M. S. O'Mahony, and K. W. Woodhouse. Adverse drug reactions in elderly patients. *British journal of clinical pharmacology*, 57(2):121–126, 2004.

[10] United Nations. World population prospects the 2008 revisions. http://www.un.org/esa/population/publications/wpp2008/wpp2008_highlights.pdf.

[11] Mark Weiser and John Seely Brown. The coming age of calm technology. *Beyond Calculation: The Next Fifty Years of Computing*, pages 75–85, 1997.

[12] Craig Wisneski, Hiroshi Ishii, Andrew Dahley, Matthew G. Gorbet, Scott Brave, Brygg Ullmer, and Paul Yarin. Ambient displays: Turning architectural space into an interface between people and digital information. In *CoBuild '98: Proceedings of the First International Workshop on Cooperative Buildings, Integrating Information, Organization, and Architecture*, pages 22–32, London, UK, 1998. Springer-Verlag.

[13] A. Wood, G. Virone, T. Doan, Q. Cao, L. Selavo, Y. Wu, L. Fang, Z. He, S. Lin, and J. Stankovic. ALARM-NET: Wireless sensor networks for assisted-living and residential monitoring. Technical Report CS-2006-11, Department of Computer Science, University of Virginia, 2006.