Matthias Kranz, Eckehard Steinbach, Stefan Diewald, Andreas Möller, Luis Roalter (Editors)

ADVANCES IN MEDIA TECHNOLOGY

SMART THINGS

January 16, 2012

ISSN 2191-8015

Technische Universität München
Institute for Media Technology/
Distributed Multimodal Information Processing Group

MOBILE INTERACTION AND MOBILE SERVICES

Our everyday life is increasingly pervaded by modern information and communication technologies. Miniaturization, reduced energy consumption, increased computer power, and many more are driving forces behind these developments. So-called 'smart things' can be applied everywhere – in offices, private homes, cars, or even integrated in clothing.

In the course of the seminar, selected examples of intelligent objects ('smart things') from research and development were investigated and summarized thematically. Underlying technologies that enable intelligent objects, as well as examples for the realization in different scenarios were discussed. The seminar focused on state-of-the art research, but also mentions commercial systems that implement the concepts of smart objects.

Each of the single chapters addresses a specific topic and presents fundamental research trends and developments. This report is targeted at electrical engineers, computer scientists and anyone interested in ubiquitous computing, smart objects and related applications.

The seminar has jointly been organized by the Institute for Media Technology and the Distributed Multimodal Information Processing Group at Technische Universität München.

This report contains the following scientific seminar theses:

1. Situated Door Displays and how to interact with them
2. Accessories in the Car
3. Containers in the House
4. Smart Furniture
5. Smart Kitchen and Refrigerator
6. Wearables & Clothing
7. Assistance for Ambient Assisted Living

The website with the electronic version of the proceedings and additional material and resources can be found at `http://www.lmt.ei.tum.de/courses/hsmt/hsmt.2011_WS.html`

We thank all students for the great work and their participation!

Munich, January 2012

Prof. Dr. Matthias Kranz
Prof. Dr.-Ing. Eckehard Steinbach
Stefan Diewald
Andreas Möller
Luis Roalter
(Editors)

TABLE OF CONTENTS

Situated Door Displays and how to interact with them

Barbara Schmid
barbara.elisabeth.schmid@mytum.de

January 16, 2012

Abstract

The number of public displays is rapidly increasing due to their decreasing prices and the advantages of their dynamic behavior. If the displayed content depends on aspects like the time or the location, these displays are called situated displays.

This paper discusses two fields of application for situated displays. One field of application is the displaying of information about a room in combination with room reservation management. The other one is an improvement of simple door plates by offering interaction with a visitor. There are different techniques for interaction with situated displays, some of which will be illustrated. These include the usage of touchscreens, a mobile phone's camera and its Bluetooth capability.

1 Introduction

Nowadays, displays can be seen everywhere. They are in public places, inside or outside of shops, at bus or train stations or in traffic [1]. There they are used for advertisement, entertainment and for the distribution of information. Companies or shops, for instance, advertise their newest products or their latest offers. Cities inform about upcoming events like concerts or exhibitions. In order to catch attention, videos and sounds are used along with texts and images.

Moreover, some of these displays are able to interact with the users. With touchscreens, cameras or sensors, which detect motion or the location of the user, displays attract more attention. In addition, people may be able to download interesting contents, for example, an URL for an advertised product.

Situated displays are a subsection of public displays. Although situated displays are also located where various people can see them, they present different content. It depends on the time, the location of the display and on the changes of the environment, for instance, the current weather [2]. Therefore, information for situated displays has to be tailored to the interests of possible users.

2 Situated door displays

Situated door displays are the digital alternative to conventional doorplates. On the one hand, digital door displays have the disadvantage that they are more expensive than doorplates. However, in recent years the prices for displays are decreasing and so this disadvantage is loosing significance. On the other hand, displays have the advantage of a dynamic behavior, which simplifies the distribution of new and the change of present content. For content management, many displays offer a web interface in addition to physical interaction with the local interface. Depending on their application, displays can grant users different access rights. Some displays allow only the owner to create content; others offer visitors the possibility to leave a notice or upload an item. There is not just one static content but many elements, which are displayed in a presentation. This content can be a picture, text, sound, website, and video. Another advantage of a display is the possibility to interact with it. The most simple way to interact is with a touchscreen, as it is convenient to use and there is no need for any other device. The user just has to navigate on it by touching it with his fingers like most people are used to on their smartphones. Other forms of interaction are controlling a display or exchanging content with it by using a mobile phone.

In the following, the paper will illustrate two fields of application for situated door displays. Room reservation displays are the first application area. They provide information about reservations of a room and enable to make reservations. The WMCSA 2004 conference signage [3][4] and the RoomWizard [5] are examples in this field. The second field of application is as an improvement of a simple door display, which will be illustrated at the example of the Hermes [6][7][8][9] and the OutCast [10] system.

2.1 Room reservation displays

Meeting rooms usually have a doorplate with the name and the room number written on it. Lecture halls, however, often have, besides the name and the room number, a timetable with the weekly lectures. If somebody wants to use a room, he has to go to the person in charge to book it. The person in charge makes the reservation by writing it in a reservation book or saving it in the computer. It is therefore difficult to check whether a room is available or not. A look into the room reveals only if it is currently available, but not for how long it remains. To get this information, it is necessary to go to the person in charge during office hours. Just using an available room can lead to a collision with a person who reserved it. Another problem arises from unused room reservations. In order to cancel a room, the person in charge has to be informed. This is time-consuming so that people tend to ignore it and as a consequence, rooms are not used efficiently. A Room reservation display like the WMCSA conference signage and RoomWizard is able to solve this problem.

2.1.1 WMCSA 2004 conference signage

The WMCSA 2004 conference signage [3][4] is a room reservation display which was tested at the Workshop on Mobile Computing Systems and Applications. For that purpose, four displays (see Fig. 1(a)) were installed at each entrance to the meeting room. The displays provided information about talks and other activities in this or nearby rooms. The information displayed included images, videos, RSS feeds, and web pages. At a given time, the system also displayed navigation symbols to lead the visitors to refreshments.

The WMCSA system has a scheduler that shows content like navigational arrows at the right time. Thereto, the author of content is able to add specifications to each item. These specifications determine when the content should be displayed, for how long and which displays should show it. The scheduler tries to create a time line that best matches all specifications. The time line is then sent to every display via a local network in order to synchronize all displays.

2.1.2 RoomWizard

RoomWizard [5] is a situated display that helps to manage reservations. Similarly to the WMCSA conference signage, it is installed outside of rooms in order to provide information about their availability.

The RoomWizard display (see Fig. 1(b)) is a touchscreen with a size of 8 inches. It displays a time line with slots that indicate when the room is reserved and when it is available. If the room is, for example, currently reserved, the block is highlighted in red. Below that time line, further information about the present time-slot are given. The further information include the duration of the current time-slot and the meeting host. If the room is currently available, the term “free” is displayed instead of the meeting host. The meeting host or “free” is written in a large font size so that persons are able to read it, if they are not directly in front of the display or are just walking by. Additionally, below the meeting host the meeting purpose is displayed. Finally, light strips are installed at each side of the display. These light strips indicate an available room with a green color and a reserved room with the color red. Owing to the installation at both sides of RoomWizard, the light strips enable users to check availability from some distance.

In order to check the availability or make a reservation, RoomWizard offers two techniques. The first one is interacting with the local interface shown on the display, when there is the spontaneous need of a room. The second technique is via a remote interface of a web browser. The remote interface also displays the time line with all reservations. A reservation can be made with both interfaces by clicking on a free time-slot. After choosing a time-slot, the duration, a meeting host and a meeting purpose have to be entered. If several RoomWizards are connected in a network, users are able to search easily for an available room or book all of them.

A study [5] revealed the usefulness of RoomWizard. The system supports users, for instance, in negotiating the usage of rooms. If there is a collision in room usage, the person who reserved the room has more confidence to claim it due to the information on the display. Moreover, users cancel unneeded reservations more often owing to the convenient possibility to cancel the room on their own without having to contact the person in charge. As a consequence, rooms managed with RoomWizard are used more efficiently.

2.2 Office door displays

Office door plates are often glass plates with a paper behind it. The paper contains the number of the room and the owner of the office, but it does not provide information about the owner’s whereabouts in case he is not in his office. Some owners leave a sticky note or some other notice to indicate when they are coming back. If there is no such note and a visitor does not have the mobile phone number to call the owner, he has to try it another time.

(a) WMCSA 2004 conference signage display. Source: [3]

(b) RoomWizard display. Source: [5]

(c) OutCast display. Source: [10]

Figure 1: Figure (a) and (b) show room reservation displays, Figure (c) an office door display

A situated display instead of a door plate solves these problems. Besides the room number and the name of the owner, a display is able to show information about the owner or gives the opportunity to leave a message. On the one hand, the owner can leave a note himself without using a sticky note. On the other hand, a visitor is able to indicate that he could not reach the office owner. Furthermore, a visitor is able to look up the owner's phone number on the display.

OutCast and the Hermes display are two representatives of this application area of situated displays.

2.2.1 OutCast

The OutCast system [10] is a flat-panel monitor with a touchscreen (see Fig. 1(c)). The owner of a cubicle is able to display information in form of, for example, texts, images and photographs via a web browser that runs on the display. The display is used to provide colleagues and visitors information about the owner himself, his work, his current location, and his favorite web pages. It is also possible to share the calendar and leave text messages. The content is displayed in a presentation until a visitor interacts with the OutCast system. Visitors are able to scroll through the uploaded content or leave a message.

An evaluation [10] of the system revealed that visitors primarily used two functions. These are the calendar and the information of the owner's location. Contrary to this, users did not like to leave messages. In the evaluation, testers considered this function to be unreliable and rather used sticky notes.

2.2.2 Hermes

Another office door display is the Hermes system. The first development [6][7] started with PDA-sized displays. The displays were mounted inside a metal case to prevent them from being stolen (see Fig. 2(a)). Hermes enables the owner to create content like a text or a graphic via the Hermes web page, by sending a SMS or interacting with the display itself. The owner has to authenticate himself with a hardware device or a password to leave a permanent message. Visitors, however, are able to leave a notice by scribbling on the display. The scribbling hides behind the original message of the owner so that other visitors cannot read it. The owner is able to view the messages via the web page, email, or directly at the display.

In case the owner leaves his office for a short period, for example for lunch, he is able to leave a temporary message. Thereto, the owner can select a message from a predefined list on the display. The selected notice will be displayed on top of all other messages until the display is touched again. Besides, the Hermes web page allows the owner to define the list of temporary messages.

The major problems of the Hermes Doorplate Display are the limited size of the display and the missing authentication for setting temporary messages.

The improved successor, the Hermes Photo Display [8][9], is a 7-inch Philips Smart Display (see Fig. 2(b)). Additionally, it has the ability to display pictures sent by email or MMS. Thereto, the user sends the picture to the Hermes system and defines the location of the display in the subject header of the message. The system then chooses a few of the saved pictures and shows them on the screen. Another new feature, which was added to the old system, is the display of vCards of registered users.

The enhanced version of the Hermes Photo Display includes a “next page”-button. By touching this button, a user is able to navigate through all pictures. If no user is around, the system automatically changes the displayed pictures every 60 seconds. Moreover, this version can communicate via Bluetooth. Visitors can download or upload pictures and vCards with their mobile devices. Thereto, the Hermes system scans for Bluetooth phones and lists all found devices. The user then chooses his phone and the selected content is transferred. If the user wants to download something, he has to acknowledge the transfer.

(a) The Hermes Doorplate Display, a scribbled graphic and the web interface. Source: [7]

(b) The Hermes Photo Display. Source: [8]

Figure 2: The Hermes system

2.3 Navigation with door displays

With the Hermes Photo Display as a basis, features for locating the owner of a display and navigating visitors to certain rooms were made.

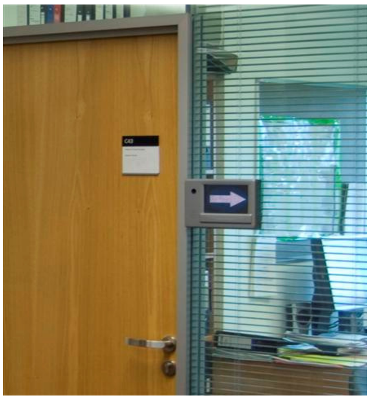
In order to update the owner’s current location on the display, the Hermes team makes use of Google Latitude along with a mobile device [11]. Visitors, who stand in front of the display, are able to see the owner’s current location on a map. In case the user wants more privacy, he can select how often the map is updated or turn off the location feature. For instance, the function should not reveal where the owner lives.

Another useful application is helping a visitor to find an office. Visitors often do not know, where a specific office is. Therefore, they usually follow the signage or ask people the way. The usability of GPS is limited due to the many floors buildings usually have. The accuracy of the GPS height measurement is insufficient for determining on which floor a person is. The Hermes Photo Display together with a Bluetooth-capable phone and a camera mounted onto the display is able to solve that problem [12][13][14].

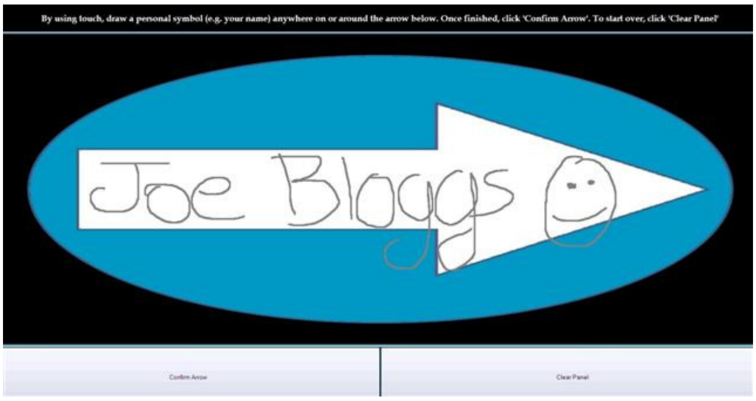
There is a Personal Locator at the entrance, which displays all staff members equipped with a Hermes Photo Display. A visitor can choose the desired person and a route to the office will be calculated. Besides, the user is able to view a 2D map or a three-dimensional fly-through in order to get an overview of his route. If the visitor wants to have these maps, he can download them. The designated route is automatically broadcast to every Hermes Photo Display. The displays then use their cameras to recognize the approaching user. If the visitor nears, the screen shows an arrow pointing in the right direction (see Fig. 3(a)). This arrow can be personalized in order to support multiple wayfinding tasks at the same time. In case the visitor went in the wrong direction, his phone vibrates and tells him with the help of the haptic feedback about his mistake. After the visitor reaches his destination, the displays delete the navigational arrows and show their usual content.

Some display owners do not want their display to show arrows at a given time or at all. Therefore they are able to set their preferences. Similar to that, a visitor can decide which map he wants to view. The 2D map is a JPG that highlights the route to the target as well as some landmarks with dots. The 3D map provides videos with big signs to mark important points of the route. Both maps can be downloaded and viewed with a mobile device to support wayfinding with the Hermes Photo Display.

An evaluation [13] showed the positive feedback of the users. The system successfully helps visitors to find their way to the offices. The owners of the offices like the ability to control the usage of their display [14]. Some make their displays fully accessible and others restrict it, because they want their message not to be occluded. Therefore, a new feature is to make the arrows semi-transparent (see Fig. 3(b)). This way, a visitor is supported by many arrows and the messages of the owner can be read at the same time. A future improvement for a visitor could be to specify how much time or how many displays are left to reach the target.



(a) The Hermes Doorplate Display screening an arrow for navigation. Source: [13]



(b) Semi-transparent arrow plus message on a Hermes Photo Display. Source: [13]

Figure 3: The Hermes Photo Display navigation

2.4 Overview of the introduced situated door displays

The introduced situated door displays vary in their functionality. A feature comparison is given in Table 1.

Functionality	WMCSA signage	RoomWizard	OutCast	Hermes
information about room/owner	X	X	X	X
content-scheduler	X	X	-	-
web interface	X	X	X	X
two-way interaction	-	X	X	X
all content predefined by person in charge	X	-	-	-
visitor can leave a message/make a reservation	-	X	X	X
visitors able to create further content (e.g. images)	-	-	-	X
touchscreen	-	X	X	X
equipped with camera	-	-	-	X
light strips to indicate availability	-	X	-	-
interaction with mobile phone	-	-	-	X
Bluetooth capability	-	-	-	X
downloadable content	-	-	-	X
location of owner	-	-	X	X
navigational support	-	-	-	X

Table 1: Overview of functionalities of the introduced situated door displays

3 Interaction with situated door displays

The most common interaction with displays takes place with touchscreens. A touchscreen displays content and a user touches it to initiate an action like showing the next page. Another interaction device is a mobile phone [15][16][17]. It offers different ways for interaction as an input as well as an output device. Some displays can be controlled with a mobile phone as a pointing device, others output additional or private information on the phone's screen. Furthermore, a mobile phone is able to send SMS, MMS, emails, and provides internet access. In addition, it offers audio and haptic feedback by ringing and vibrating. Phones are also able to download and upload content. Finally, the phones' camera offers an additional way to interact with a display. Despite the many advantages, mobile phones have the disadvantage of a limited screen size. The screen is too small to show exactly the same information as a situated display. Therefore, downloadable content has to be adapted to the screen size of a mobile phone.

An easy way to download content is the usage of the Bluetooth protocol [15]. Almost every mobile phone offers Bluetooth and, opposed to SMS or MMS, it is free of charge. If a mobile phone activates Bluetooth, a display scanning for Bluetooth signals in the immediate vicinity is able to detect it. The display then lists the names of all found devices. In case a user wants to share something with a situated display, he has to pair with it. Pairing is the process of establishing a permanent connection. In order to pair with a display, the user has to exchange a PIN with it. Some systems also demand that a mobile phone has to install an additional software. It enables the mobile phone, for example, to recognize a tag in a photograph of the display. After pairing and installing, the user is able to up- and download information.

3.1 Interaction with the Hermes Photo Display

The Hermes Photo Display (see section 2.2.2) offers many interaction possibilities. Besides the use of a touch-screen, SMS, MMS, and email, it provides Bluetooth functionality. Bluetooth enables visitors to exchange pictures or vCards. If a user wants to exchange something, he is able to choose between two interaction techniques: the asynchronous and the synchronous interaction [8][9].

The asynchronous interaction calls for a pairing in order to exchange information. After that, the user has to touch the display twice in order to choose an item and his phone from the scanning list. Therefore, only few users can exchange content with the display at the same time.

Contrary to this, the synchronous interaction enables several users to exchange information, because they do not have to touch the display. Similar to the asynchronous interaction, the user also has to pair with the Hermes Photo Display. However, while pairing, a Java application will be downloaded and installed on the mobile phone. Three possible methods for direct interaction with the display by using the phone were proposed. The first method enables the user to scroll with his phone through the pictures. In order to distinguish between the several users, each of them has his own allocated color with which the currently selected content is highlighted. The second method is similar to the first one but it shows the content as thumbnails on the mobile phone. The third method shows a number of items and associated Ids on the situated display. The user can enter an Id with the keypad of his phone to retrieve the selected content. The drawback of the synchronous interaction is that the user has to download an application to perform an exchange.

3.2 Snap and Grab

Snap and Grab [15] is an interaction technique that uses the camera of the mobile phone. The user takes a photograph of a displayed item that he wants to have and sends it by Bluetooth OBEX push to the display. The photograph holds a visual tag that the display server extracts and identifies. It scans for an image associated to the tag and if the server finds a match, it tries to send the media content back to the mobile phone. Besides pictures, Snap and Grab enables to exchange audio files, texts, HTML files, vCards, or calendar entries.

Snap and Grab has the advantage that the display does not need to scan for Bluetooth devices. It already knows its communication partner, since the mobile phone initiates the transfer with the request. Moreover, the usage of visual tags in the screened photos offers an exchange of content without the need to download an application.

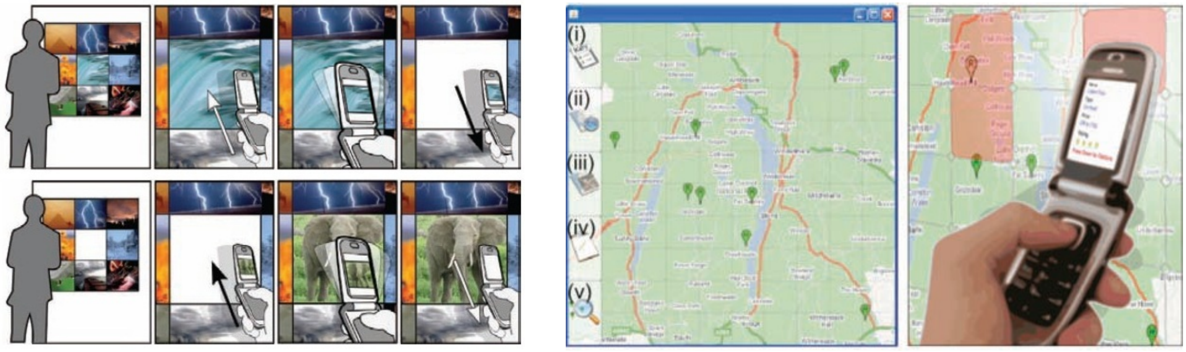
3.3 Touch and Interact

Another interaction technique for a mobile phone and a situated display is called Touch and Interact [16][17]. The Touch and Interact process is initiated when the user touches the screen with his mobile phone to pair the devices. A condition for interaction is that the phone has to be able to read NFC-tags (Near Field Communication) in order to locate the touched point. These NFC-tags have the advantage that they are low priced, robust, and that their read-range allows them to be mounted on the back of a display. The tags are approximately 40 mm by 40 mm large and are aligned in a matrix to represent areas on the display. Each NFC-tag saves its position in the matrix which can be read out by the mobile phone. The phone sends this information to the server, which initiates the action on the display.

Robert Hardy et *al*. [16][17] illustrate different techniques to use Touch and Interact. In order to pick up a picture, the user has to touch it on the display and after a transfer, the picture is saved on the mobile phone. The other way round, the user selects a picture on the phone and drops it on an empty space on the display (see Fig. 4(a)). Furthermore, the user is able to switch positions of pictures on the display, if he transfers it on the phone and releases it on an empty space. To select a certain area of the display, the user has to choose the associated tags. If the user, for instance, wants to select just one field, he has to move the phone within the read-range of the tag and select it with a predefined button. In case the user keeps on pressing the button while moving the phone, he is able to select more than one tag. Finally, the phone is able to provide haptic or audio feedback, for instance, to indicate a successful selection of a pin.

A possible application to this technique is the interaction with a displayed map (see Fig. 4(b)). The user is able to zoom into the map and pan in it to have a closer look at places of interest. By pointing to a special area, it will be enlarged either directly where he pointed or nearby, so the phone does not occlude it. There are pins in the map that indicate events, restaurants and hotels. If the user selects a pin, additional information to the pin is displayed on the mobile phone. By iterating over the pins or selecting one from a displayed list, the user is able to choose a pin that is close to another. Moreover, a side menu is used to enable the displaying of a map key, a view mode, a satellite view, a categorization of the pins, and the building of a downloadable itinerary.

An evaluation [16] about the selection of multiple targets revealed that hovering caused some problems. Phones tend to read a nearby tag because users do not know where the NCF-reader on their phone is mounted. In combination with some other problems, Touch and Interact was rated behind the simple finger interaction with a touchscreen. However, Touch and Interact was even better rated than finger interaction, while evaluating the down- and upload of pictures. Owing to the need to look onto the phone screen in order to check the content, Touch and Interact is more convenient to use than finger interaction because the phone screen is always visible. Contrary to this, finger interaction demands alternately looking onto the phone and the display.



(a) Picking up and dropping a picture by using Touch and Interact. Source: [16]

(b) Navigating on a map with Touch and Interact. Source: [16]

Figure 4: Touch and Interact

4 Conclusions

Summing up, this paper presents an overview of situated door displays and their functionality. It revealed that a situated display is helpful for room management or as an information channel for an office owner. Efforts in the management of rooms are reduced and communication between an office owner and his visitors is improved.

The exemplified interaction techniques support the user in getting the desired information. By using a mobile device, new ways of interaction are emerging. Especially the usage of the mobile phone's camera and the Bluetooth capability are promising developments.

References

[1] Müller, J., Alt, F., Michelis, D., Schmidt, A.: Requirements and design space for interactive public displays. In: Proceedings of the international conference on Multimedia, ACM (2010) 1285–1294 1

[2] O'Hara, K., Perry, M., Churchill, E., Russell, D.: Introduction to public and situated displays. Public and situated displays: social and interactional aspects of shared display technologies **2** (2003) 1

[3] Storz, O., Friday, A., Davies, N., Finney, J., Sas, C., Sheridan, J.: Public ubiquitous computing systems: Lessons from the e-campus display deployments. Pervasive Computing, IEEE **5**(3) (2006) 40–47 2, 2.1.1, 1(a)

[4] Storz, O., Friday, A., Davies, N.: Supporting content scheduling on situated public displays. Computers & Graphics **30**(5) (2006) 681–691 2, 2.1.1

[5] O'Hara, K., Perry, M., Lewis, S.: Social coordination around a situated display appliance. In: Proceedings of the SIGCHI conference on Human factors in computing systems, ACM (2003) 65–72 2, 2.1.2, 1(b)

[6] Cheverst, K., Dix, A., Fitton, D., Friday, A., Rouncefield, M.: Exploring the utility of remote messaging and situated office door displays. Human-Computer Interaction with Mobile Devices and Services (2003) 336–341 2, 2.2.2

[7] Dix, A., Cheverst, K., Fitton, D., Friday, A.: The auditability of public space-approaching security through social visibility. (2004) 2, 2.2.2, 2(a)

[8] Cheverst, K., Dix, A., Fitton, D., Kray, C., Rouncefield, M., Saslis-Lagoudakis, G., Sheridan, J.: Exploring mobile phone interaction with situated displays. In: PERMID Workshop, Pervasive. Volume 5. (2005) 2, 2.2.2, 2(b), 3.1

[9] Cheverst, K., Dix, A., Fitton, D., Kray, C., Rouncefield, M., Sas, C., Saslis-Lagoudakis, G., Sheridan, J.: Exploring bluetooth based mobile phone interaction with the hermes photo display. In: Proceedings of the 7th international conference on Human computer interaction with mobile devices & services, ACM (2005) 47–54 2, 2.2.2, 3.1

[10] McCarthy, J., Costa, T., Liongosari, E.: Unicast, outcast & groupcast: Three steps toward ubiquitous, peripheral displays. In: Ubicomp 2001: Ubiquitous Computing, Springer (2001) 332–345 2, 1(c), 2.2.1

[11] Whittaker, P.: The Implementation of Google Latitude within the Hermes Door Display System. Bachelor's thesis, Computing Department, Lancaster University, Lancaster, UK (2011) 2.3

[12] Kray, C., Cheverst, K., Harrison, M., Hamhoum, F., Muller, J.: Towards a location model for indoor navigation support through public displays and mobile devices. MIRW 2008 (2008) 2.3

[13] Taher, F., Cheverst, K., Harding, M., Fitton, D.: Formative studies for dynamic wayfinding support with in-building situated displays and mobile devices. In: Proceedings of the 8th International Conference on Mobile and Ubiquitous Multimedia, ACM (2009) 5 2.3, 3(a), 3(b)

[14] Kray, C., Cheverst, K., Fitton, D., Sas, C., Patterson, J., Rouncefield, M., Stahl, C.: Sharing control of dispersed situated displays between nomadic and residential users. In: Proceedings of the 8th Conference on Human-Computer interaction with Mobile Devices and Services, ACM (2006) 61–68 2.3

[15] Maunder, A., Marsden, G., Harper, R.: Creating and sharing multi-media packages using large situated public displays and mobile phones. In: Proceedings of the 9th international conference on Human computer interaction with mobile devices and services, ACM (2007) 222–225 3, 3.2

[16] Hardy, R., Rukzio, E.: Touch & interact: touch-based interaction of mobile phones with displays. In: Proceedings of the 10th international conference on Human computer interaction with mobile devices and services, ACM (2008) 245–254 3, 3.3, 4(a), 4(b)

[17] Hardy, R., Rukzio, E., Wagner, M., Paolucci, M.: Exploring expressive nfc-based mobile phone interaction with large dynamic displays. In: Near Field Communication, 2009. NFC'09. First International Workshop on, IEEE (2009) 36–41 3, 3.3

Smart Things - Accessories in the Car

Markus Gulden
markus.gulden@mytum

January 16, 2012

Abstract

In the last years, we could observe the expansion of mobile devices like smartphones or tablet computers into nearly any area of our daily life, except in the automotive domain. To keep up with this trend, car manufacturers try to integrate such smart accessories into their cars, too. In this paper, we present different approaches including the implementation and point out appearing difficulties respective usability and safety.

1 Introduction

A permanent advance of mobile computing and social media makes daily life easier and more exciting. As a result of the expansion of 3rd generation's mobile networks, cheaper and more powerful hardware, nomadic devices like smartphones and tablet computers with their innovative and rapid developed services become more and more an essential part of our everyday environment.

To keep up with this trend, automotive manufacturers like BMW, Ford or Toyota also aim at integrating more and more services and interactive entertainment into their cars, to provide customers with an experience similar to their homelike devices. The greatest problem here is that automotive manufacturers have five year development cycles while smartphones are replaced after 2-3 years [1] and the apps on the devices have cycles of a few months. Thus, once a manufacturer brings a new car to market, the integrated services and electronics are already obsolete. As a result, business trends tend to integrate modular devices into cars to face this issue.

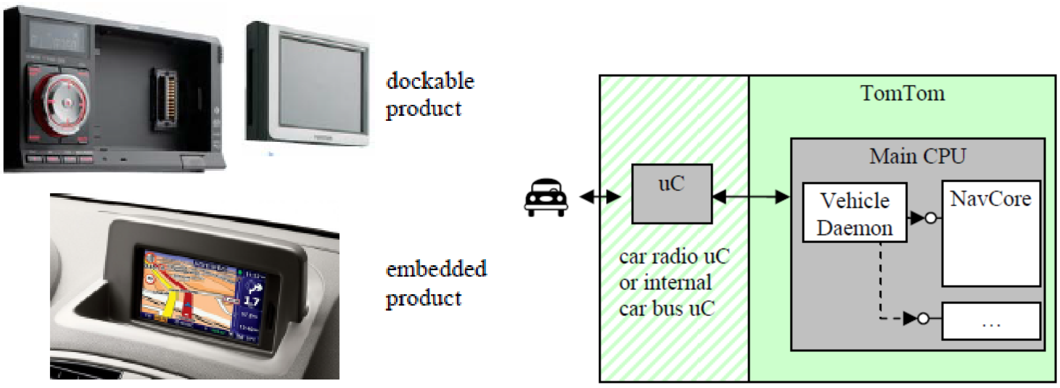
In this paper, activities in this domain will be abstracted, different approaches in view of devices and their interfaces will be pointed out and some products will be presented which are actually available on the market. The paper is structured as follows. After defining "Smart Cars" and showing up different approaches to get smart devices into the car, we will present some ways for physical connection, data interfaces and architectural integration. We then will point out methods to grant usability and safe user-device-interaction and finally close by viewing actual and future functionalities.

2 Different Approaches to Smart Cars

"Smart Cars" in its original context means a vehicle that "aims at assisting its driver with easier driving, less workload and less chance of getting injured" [2]. In our context, "Smart Car" means the modular integration of a device, which brings entertainment and information services into the car. Generally all solutions have a modular architecture, i. e. the device is decoupled from the car, which necessitates some kind of standardized interfaces.

2.1 Integration of Modular Device by Manufacturer

TomTom, which mainly develops Personal Navigation Devices (PND), has development cycles of six months [3]. To integrate these short cycles with the longer five year cycles of car manufacturers, they developed a modular architecture with managed interfaces. This affords the integration of PNDs with one core module into cars of different manufacturers. By doing so, TomTom is able to enhance the core functionalities of an already integrated device without touching the interfaces connecting the device to the car electronics. This enhancement is carried out in the NavCore-modul (see Figure 1(b)), which also contains the graphical user interface and is common to all products. In contrast the VehicleDaemon, which handles the communication between NavCore and the vehicle, is very specific to the car manufacturer. The communication between VehicleDaemon and NavCore is processed by so called "managed interfaces".



(a) Commercially available TomTom products (b) TomTom architecture

Figure 1: The TomTom way from [3]

2.2 Smartphone Integration

A different approach for creating a “Smart Car” is to integrate a smartphone. There are different approaches which connect smartphones over wired or wireless hardware interfaces. Smartphones offer their applications as services to the In-Vehicle Infotainment (IVI) which has to present the GUI and take inputs from the user.

Bose et al. present their solution called “MirrorLink” (former Terminal mode), where they propose the integration of a smartphone over WLAN, Bluetooth or USB [1]. The smartphone offers its functionalities as services, which are consumed by the IVI and presented to the user, so that all functionalities originate from the smartphone. The IVI is responsible for human-machine-interaction. “MirrorLink” requires IP-based connections, uses Universal Plug and Play (UPnP) for service discovery and initiation and an extended Virtual Network Computing (VNC) protocol for user interaction and graphical display. Specialties of “MirrorLink” are the multi-client profiles and the security concept which allows controlling display contents by safety rules, e. g. the driver cannot watch DVD movies while driving, but the other users at the back seats can.

Another solution is presented by Sonnenberg [4]. This solution is also based on IP communication, but it uses the communication framework Devices Profile for Web Services (DPWS). DPWS offers methods for device and service discovery and secure communication. Furthermore, the device services can dynamically generate style less GUIs in HTML, which can be mapped to widgets in a special style by the IVI (see Figure 2). In this way, the user does not only have a manufacturer specific look and feel, but in addition safety is guaranteed by letting the IVI control the presentation of the application.

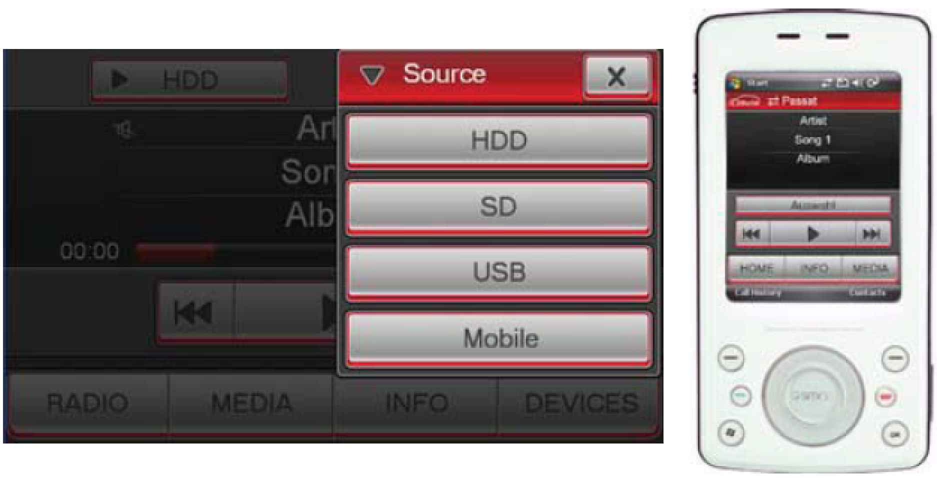


Figure 2: DPWS-solution: Car HMI and smartphone interface from [5]

2.3 Embedded Computer Integration into Vehicle

Finally one approach to "Smart Cars" is the integration of an embedded computer with an adequate software platform, which allows the rapid development and integration of - also 3rd party - apps.

In cooperation with Microsoft, Ford invented the "Ford Sync" platform, a Windows CE operating system running on an embedded PC [6]. The first functionalities were the connecting of phones and music players with the car sound system, so that users could phone or play music from there iPod, Microsoft Zune or other MTP enabled music players. Further functionalities were developed by Ford, e. g. services for traffic, directions and information.

Another solution is AutoLINQ[1] by Continental. AutoLINQ is an Android-based, open, "end-to-end" infotainment platform. It enables users to access their car in different situations, at home on a web interface or on their mobile phone to retrieve car-context-information, but especially from inside the car via the IVI. Actual functionalities are navigation, social networking, communication like email and phone, access to global media and 3rd party apps. At the moment, Continental offers the alpha version of an open SDK[2] which contains a vehicle API, an emulator, a vehicle simulator and guidelines for Human-Machine-Interfaces-(HMI)-development for in-vehicle-context.

Another solution started with the Open Source project MeeGo[3] founded by Nokia and Intel and later hosted by The Linux Foundation. MeeGo was designed to provide a Linux-based software platform for mobile devices, also including a version for IVI systems. The MeeGo IVI platform shall enable internet and multimedia contents to be accessed and offer features like text-to-speech, speech recognition and different multimedia applications like video player, music player and photo viewer [7]. There is a complete software stack (see Figure 3) available, apps can be made available on application stores like Nokia's Ovi Store [4] or Intel's AppUp Center [5].

MeeGo IVIs have not been integrated by manufacturers yet, but users can install a MeeGo image on different Intel IVIs[6]. At the moment, MeeGo is being integrated into the Open Source project TIZEN[7] which is also hosted by The Linux Foundation and also aims to develop a Linux-based platform for different device categories, but in contrast to MeeGo applications shall be based on HTML5.

MeeGo is also compliant with the GENIVI Alliance[8] which was founded to provide an open source development platform for IVI systems. Charter members are amongst others BWM, Intel, ARM and PSA Peugeot Citroen.

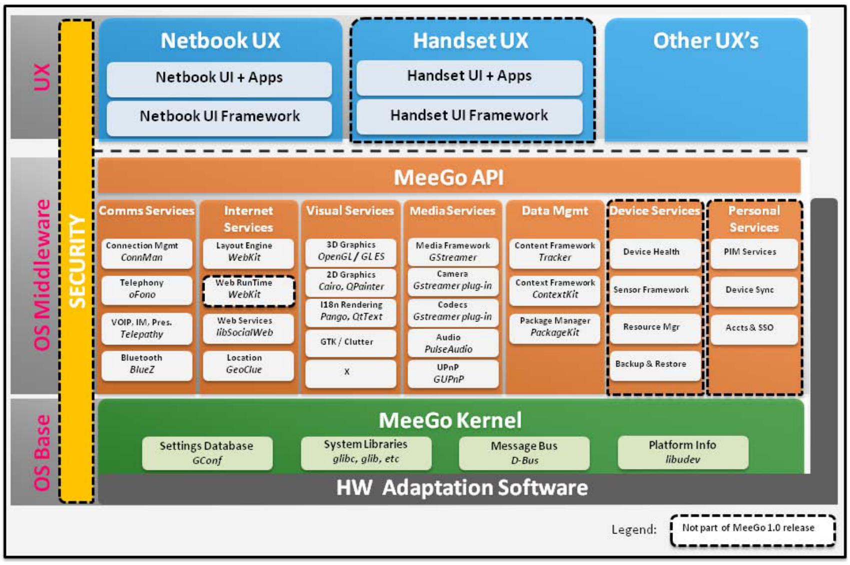


Figure 3: MeeGo reference architecture from [7]

[1] http://www.autolinq.de/
[2] http://www.autolinq.de/developers_overview.aspx, Accessed on January-05-2012
[3] http://www.meego.com
[4] http://store.ovi.com
[5] http://www.appup.com
[6] https://meego.com/devices/in-vehicle/in-vehicle-faq#q1, accessed on January-04-2012
[7] http://www.tizen.org
[8] http://www.genivi.org

3 Car-Device-Interfaces

As soon as a nomadic device is integrated (see Section 2.2), it needs a connection to the car's IVI. First of all, a physical connection is needed, second a software interface by which the device's application can communicate with the IVI.

3.1 Physical Connections

Different physical connections are possible, depending on the particular requirements of the application and on which content is to be transmitted [8]. Supported by nomadic devices and also by newer generation cars are

- Universal Serial Bus (USB),
- Mobile High-definition Link (MHL),
- High-Definition Multimedia Interface (HDMI) and
- Audio Line-In/Line-Out

as wired connections and

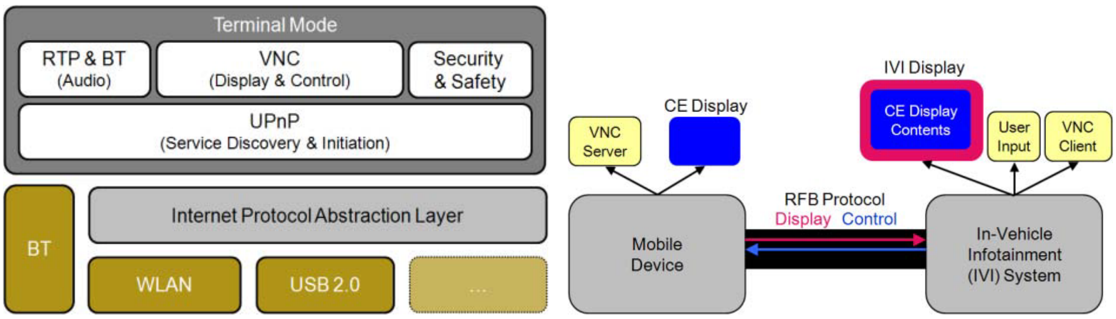
- Wireless Local Area Network (WLAN) and
- Bluetooth

as wireless connections. While MHL, HDMI and Audio Line-In/Line-Out are only adequate for their specific kind of content, namely audio and video, USB, WLAN and Bluetooth are able to transport higher application protocols. As can be seen in Section 3.2, interfaces might be based on an IP protocol, therefore it is important for USB and WLAN to support IP.

3.2 Data Protocols

When integrating nomadic devices, the selection of protocols depends on the type of the solution. Since the format of the data which have to be transferred is not known at the design time, the interface should be generic to be suitable for future applications.

MirrorLink uses the IP-based UPnP for data transportation (see Figure 4(a)). As the IVI only works as a terminal, display data and control inputs are transported via the VNC protocol. Since VNC is based on the remote frame buffer (RFB) protocol which works on the frame buffer level, it is platform-independent. In addition to its normal display, the nomadic device has to offer a VNC server which communicates with the VNC client of the IVI system (see Figure 4(b)).



(a) Terminal Mode Component Stack (b) Remote UI and Control over VNC

Figure 4: MirrorLink architecture from [1]

Even the solution by Sonnenberg is IP-based, the IVI system does not serve as a terminal, but as a complete client which consumes services supplied by the mobile device over the Devices Profile for Web Services (DPWS) (see Figure 5) [4]. DPWS offers mechanisms for device and service discovery, and interfaces can be described and generated even dynamically. The application on the mobile device provides its GUI as plain HTML elements, the client on the IVI maps them to controls in a usable and manufacturer specific style. By doing so, the IVI can control the layout of the GUI and grant a safe usage of the device, even in the manufactures "Look and Feel" (see Figure 2).

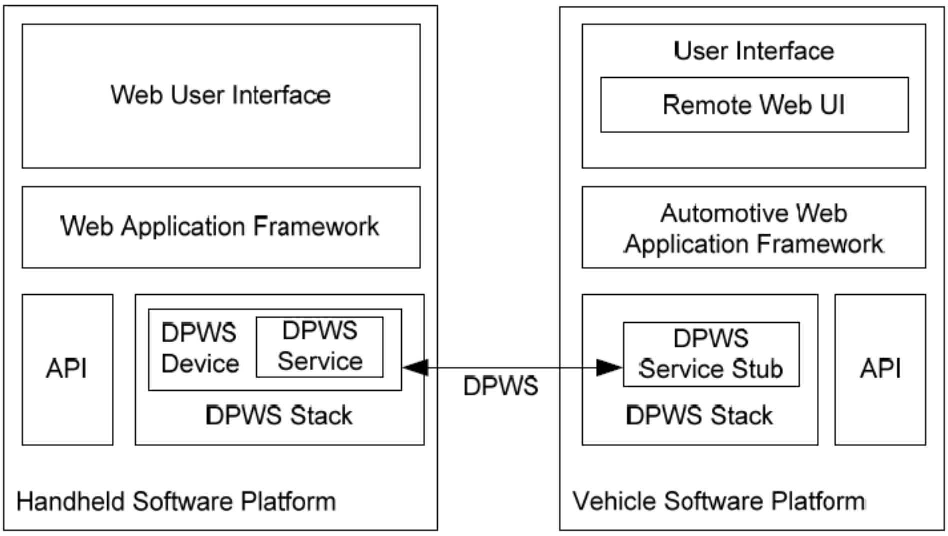


Figure 5: Service and user interface exchange from [4]

3.3 Different Ways to get Access to Car Context

Normally, nomadic devices themselves can capture context data e. g. from GPS or acceleration sensors. But in some situations it might be useful to get data about the vehicle context like outer temperature, an exact speed or fuel consumption. Therefore, the device needs to have access on interfaces for pulling data from the car.

Kranz et al. present three ways for researchers to get access to vehicle data without the need for restricted manufacturer knowledge [9]. Combining these three ways can give quite broad cognition of the vehicle context. First, the OBDII and EOBD diagnostic interfaces provide information about basic data, like engine load and speed or temperature of the engine coolant. The second way, called general purpose data interface, by avoiding the manufacturer's electronic data board network measures the respective state by itself and provides the data to different consumers like HMI interfaces or V2X infrastructure. Finally, Kranz et al. can also read from the CAN bus due to open knowledge about the CAN matrix of their research vehicle.

For granting access to car context for any mobile device, Sonneberg proposes the introduction of standardized APIs in the vehicle [4].

4 User-Device-Interaction, Usability and Safety

As presented in Section 2.2, integrating mobile devices into cars is a cheap way to always have the newest services and functionalities. Besides the interface issue, integrating the device in a useable and safe way might be the greatest challenge. As mobile devices originally are not made for being used in a car, some points concerning mounting, user interfaces and interaction have to be considered.

4.1 Mounting Position

The presented approaches propose either a fixed integration of a PND or an embedded device (see Sections 2.1, 2.3), or the coupling of a mobile device which is controlled over the fixed integrated IVI.

4.2 HMI-Design

The HMI of devices mentioned in approaches Sections 2.1 and 2.3 are designed specifically for being in a car. In contrast, mobile devices and their GUIs are normally not practicable for handling while driving. Even if the user operates the device over the IVI and not over the mobile display, normal graphical controls might be too small, animations might distract the driver or the menu guidance of an application could be too complicated that concentrating on the system could distract the driver from his primary task, i. e. driving the car.

For that reason, different guidelines have been developed for the usable and safe design of HMI. The European Commission has established the "European Statement of Principles on Human Machine Interface for In-Vehicle Information and Communication Systems" (ESoP) [10] which provides 43 design principles with practical examples and cross references to standards and norms. Since 2001, the ESoP is accepted by the "Association of European Vehicle Manufacturers" (ACEA). The actual version from 2006 is also valid for later integrated systems and integrated mobile devices. It contains design goals, principles for installation, information presentation, interaction with displays and controls, system behavior, information about the system and recommendation on influencing use [11].

Different solutions distinguish how the UI is integrated in the IVI. The Cameleon Reference Framework [12] is fitting to classify different types of integration. The Framework proposes four levels of abstraction which are *Tasks and Concepts* (T&C), *abstract user interface* (AUI), *concrete user interface* (CUI) and *final user interface* (FUI) (see Figure 6). Transformations from the T&C level down to the FUI level have to be processed by the IVI, controlled by manufacturer specific rules. While T&C and AUI are on an abstract level, CUI is modally dependent and FUI platform-dependent.

MirrorLink [1] displays contents in form of raster graphics [13]. Therefore, de Melo et al. propose a way, how applications can supply their capabilities and interaction possibilities in an abstract manner [14]. They adopt the four levels of abstraction of the Cameleon Reference Framework, and improve this approach by dropping transformation 1 and introducing an UML based description of the T&C model. Transformation rules are divided into three categories, for the modality of human-machine interaction, for layout and design aspects and for user customations. These rules make it possible to generate various FUIs from the abstract description for different systems.

A similar solution is proposed by Hildisch at al., they use the Web Ontology Language for Web Services (OWL-S)[9] instead of UML description [15].

The DPWS-solution by Sonnenberg is again an example which provides the FUI by a markup language, namely HTML. The UI is sent from the device to the IVI and there interpreted considering the manufacturer specific style [4].

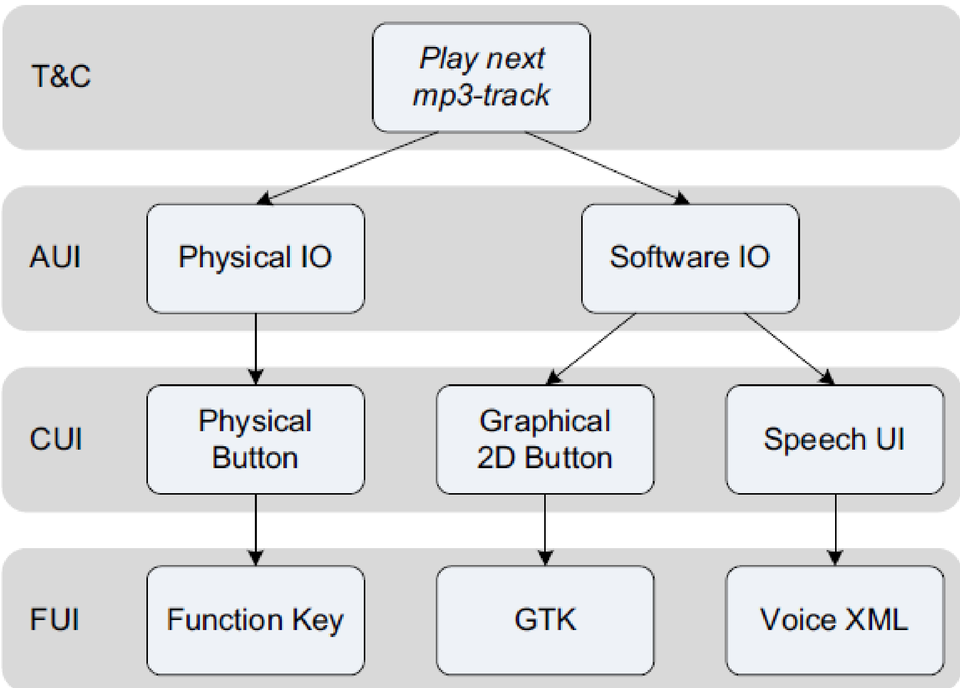


Figure 6: Abstraction levels according to the Cameleon reference framework taking an example from [13]

[9] http://www.w3.org/Submission/OWL-S/

5 Actual and Future Functionalities

As already mentioned in the introduction, drivers and passengers are expecting more and more the integration of similar services which they see on their mobile devices. For automotive manufacturers, the integration of these services is a key differentiator of their vehicles.

For that reason, there could be seen a lot of activities in this area. BMW rolled out its service framework called "ConnectedDrive"[10] which contains information and entertainment services. In line with this, it is also possible to connect an iPhone which makes it possible to use iPhone apps like Facebook, Twitter or web radio via the IVI [16]. As well for its brand MINI, BMW offers the "MINI Connected" app which enables the presentation of different iPhone apps via the car display [17].

Equally, Toyota offers its Entune[11] which is compatible with Apple, Android and Blackberry smartphones. An app, installed on the smartphones, enables the user to access services like the Bing search engine, OpenTable, web radios or additional information services like weather, traffic or fuel prices via the car IVI.

Nevertheless, these services are still not so in common because they are expensive. For enabling the smartphone integration, one has to buy extra equipment like display, board computer and even interfaces like USB[12] [13] at BWM and MINI. At Toyota, one has to pay monthly charges for the services, starting from $5 to $15[14]. BMW also asks for an annual fee between EUR 175 and EUR 250, EUR 160 incur for data traffic additionally [18].

In addition, services and functionalities are quite "static". All offered apps like Facebook, search engine or news feeds have to be integrated by the manufacturer, there is no possibility yet to install 3rd party apps by oneself.

When these difficulties will be overcome, a similar trend will be possible like for the traditional smartphones: It will be possible to use this already available quantity of apps in the car, and everybody will be able to afford it to integrate a smartphone in his car.

6 Conclusions

At the moment, we can observe an expansion of mobile services and consumer electronics into the automotive domain. Today, there is still a gap between the long development cycles in the automotive and the short cycles in the consumer area, for what there are different approaches which aim at a modular integration of devices into cars. After presenting the different approaches, this paper pointed out the common physical interfaces and different software interfaces which enable controlling mobile devices over the car's IVI. To face the requirements regarding an adequate, safe and manufacturer style conform HMI, some ways for an abstract and dynamic realization were examined. Last but not least, some actual functionalities were presented and a forecast for future functionalities was made.

References

[1] Bose, R., Brakensiek, J., Park, K.Y.: Terminal mode: transforming mobile devices into automotive application platforms. In: Proceedings of the 2nd International Conference on Automotive User Interfaces and Interactive Vehicular Applications. AutomotiveUI '10, New York, NY, USA, ACM (2010) 148 – 155 1, 2.2, 4, 4.2

[2] Sun, J., Wu, Z.h., Pan, G.: Context-aware smart car: from model to prototype. Journal of Zhejiang University - Science A **10** (2009) 1049 – 1059 2

[3] Slegers, W.J.: Building automotive product lines around managed interfaces. In: Proceedings of the 13th International Software Product Line Conference. SPLC '09, Pittsburgh, PA, USA, Carnegie Mellon University (2009) 257 – 264 2.1, 1

[4] Sonnenberg, J.: Service and user interface transfer from nomadic devices to car infotainment systems. In: Proceedings of the 2nd International Conference on Automotive User Interfaces and Interactive Vehicular Applications. AutomotiveUI '10, New York, NY, USA, ACM (2010) 162 – 165 2.2, 3.2, 5, 3.3, 4.2

[5] Sonnenberg, J.: A distributed in-vehicle service architecture using dynamically created web Services. In: 14th International Symposium on Consumer Electronics (ISCE), 2010 IEEE. (June 2010) 1 – 5 2

[10] http://www.bmw.de/connecteddrive
[11] http://www.toyota.com/entune/
[12] http://www.bmw.de/de/de/general/configurations_center/configurator.html
[13] http://www.mini.de/configurator/
[14] http://www.toyota.com/entune/what-is-entune/entune-account.html, accessed on January-08-2012

[6] Ghangurde, M.: Ford SYNC and Microsoft Windows Embedded Automotive Make Digital Lifestyle a Reality on the Road. SAE International Journal of Passenger Cars - Electronic and Electrical Systems **3**(2) (2010) 99 – 105 2.3

[7] Haddad, I.: Introduction to the MeeGo software platform. Linux J. **2010** (October 2010) 2.3, 3

[8] Diewald, S., Möller, A., Roalter, L., Kranz, M.: Mobile Device Integration and Interaction in the Automotive Domain. In: AutoNUI: Automotive Natural User Interfaces Workshop at the 3rd International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI 2011). (November - December 2011) 3.1

[9] Kranz, M., Weber, E., Frank, K., Galceran, D.H.: Open vehicular data interfaces for in-car context inference. In: Proceedings of the 1st International Conference on Automotive User Interfaces and Interactive Vehicular Applications. AutomotiveUI '09, New York, NY, USA, ACM (2009) 57 – 62 3.3

[10] The Commission of the European Communities: Comission Recommendation of 22 December 2006 on safe and efficient in-vehicle information and communication systems: update of the European Statement of Principles on human machine interface. http://www.umich.edu/~driving/documents/EU_guidelines_2007.pdf 4.2

[11] Weimper, A.: Neue EU Regelungen für Safety und Driver Distraction. Technical report, Harman International (2008) 4.2

[12] Calvary, G., Coutaz, J., Thevenin, D., Limbourg, Q., Bouillon, L., Vanderdonckt, J.: A Unifying Reference Framework for multi-target user interfaces. Interacting with Computers **15**(3) (2003) 289 – 308 Computer-Aided Design of User Interface. 4.2

[13] Hüger, F.: User interface transfer for driver information systems: a survey and an improved approach. Technical report, Volkswagen AG Group Research (2011) 4.2, 6

[14] de Melo, G., Honold, F., Weber, M., Poguntke, M., Berton, A.: Towards a flexible UI model for automotive human-machine interaction. In: Proceedings of the 1st International Conference on Automotive User Interfaces and Interactive Vehicular Applications. AutomotiveUI '09, New York, NY, USA, ACM (2009) 47 – 50 4.2

[15] Hildisch, A., Steurer, J., Stolle, R.: HMI generation for plug-in services from semantic descriptions. In: Proceedings of the 4th International Workshop on Software Engineering for Automotive Systems. SEAS '07, Washington, DC, USA, IEEE Computer Society (2007) 4 – 10 4.2

[16] BMW Group: BMW offers new interface for extended iPhone connectivity. The special option Apps. https://www.press.bmwgroup.com/pressclub/p/pcgl/pressDetail.html?outputChannelId=6&id=T0097916EN&left_menu_item=node__2369 (February 2011) [Online; accessed 08-January-2012]. 5

[17] BMW Group: MINI Connected. https://www.press.bmwgroup.com/pressclub/p/pcgl/pressDetail.html?outputChannelId=6&id=T0105773EN&left_menu_item=node__2369 (April 2011) [Online; accessed 08-January-2012]. 5

[18] BMW Group: Widerrufsbelehrung und gesetzliche Informationen. http://www.bmw.de/de/de/owners/connecteddrive/2010/applications/information.html (2010) [Online; accessed 08-January-2012]. 5

Smart Things - Containers in the House

Andreas Iani
ianiandreas@mytum.de

January 16, 2012

Abstract

We are living in an era full of technological innovations but "Smart Things" have not found their way in our daily lives yet. In this paper, I give a comprising overview on "Smart Things" and discuss if these objects can alleviate our everyday life.

1 Introduction

In the past years, significant advances in information technology, such as the miniaturization of microprocessors and other electrical components, reduction of power consumptions, alternative power sources and more powerful wireless communication have been achieved. These advances allow the development of "Smart Things", physical objects with specialized embedded hardware that can be attached to an object. "Smart Things" are unobtrusively made smart such that humans can use the object naturally without perceiving the technology and also computers can gain useful informations from these objects. Typically, the technology of a Smart Thing includes sensors, microcontroller and wireless communication capabilities [1]

2 musicBottles

In this section, the composition and function of the musicBottle [2] is discussed. These musicBottles are not only restricted for liquid content, they also can save digital informations and interact with their environment. Although the task is not complex, it could be useful.

2.1 Concept

The Tangible Media Group from the MIT Media Laboratory invented a new intelligent item after they were inspired of Mark Weiser's vision of Ubiquitous Computing. He proposes a world in which computational services can be natural and also invisible integrated into our physical environment [3]. Their search, for a suitable item, converged on ubiquitous glass bottles. Because bottles have been part of human culture, serving practical and aesthetic functions. They decided to use glass bottles and equip them with a minimal interface.
The basic task of bottles is to store content inside, and to access it through removal of the lid. In addition to this, bottles offer a number of other interactions such as shaking and pouring. More sophisticated gestures like these suffer from a greater complexity since they can often be interpreted in different ways. For instance, someone might shake a bottle in order to mix its contents, or simply to see how much is inside. Since there goal was to create an intuitive interface that could be used by anyone, they opted for a minimal design that would implement only the basic affordance of bottles.
Although a bottle interface(a bottle augmented with digital informations) based only on simple operations is too restrictive to support a variety of functions for experts, this constraint can be an advantage for providing additional values, such as aesthetic pleasure and emotional richness. They explored this idea through the creation of their musicBottles installation, described in the next section.

2.2 Installation

In the musicBottles installation, each bottle contents a voice or instument in a musical piece: The model, of the Tangible Media Group, for interaction could be represented as multiple synchronized audio streams running in parallel. If a particular bottle gets manipulated (Fig. 1(a)), causes a audio track to be played or possibly muted. The installation consists of set of bottles filled with different kinds of music, and a table in which center the bottles

(a) Three musicBottles.

(b) Triangular table.

Figure 1: The musicBottles installation and close-up of jazz bottles on the central "stage" area of the triangular table. Just there the musicBottles can be activated by removing the cork. The activation is accompanied by color kinetic lights installed in the table [2].

are wirelessly sensed. The triangular table (Fig. 1(b)) houses three Color Kinetics lights, and the center area acts as a rear-projection surface for the display of dynamic light compositions that accompany the music. Placing a bottle in the middle produces a colored visual aura under the bottle as feedback that the bottle is recognized by the computer. If the bottle is opened while on the center of the table, the matching music track is played accompanied by dynamic colored lightning.
The bottles interface incorporates wireless sensing technology. Sensing the manipulation of the bottles is made possible through the use of small electromagnetic resonator tags placed around the opening of each bottle, and pieces of ferrite embedded in the corks.The resonant frequencies of the tags are detected by using a tag reader board and sent to the computer via the serial port. A master control program on the computer is responsible for interpreting the tag reader data and generating the appropriate sound and light output.

2.3 Related work

Another Smart Thing, that is comparable to the musicBottles, is Slurp [4], a tangible interface for locative media interactions in a ubiquitous computing environment. Slurp allows for the extraction of digital media from physical objects and the selection of an appropriate display device to access it from. It contains the digital information rather than working as a physicalized hyperlink. So Slurp could be used similarly to a USB drive but is not bound to a PC or Laptop. Based on the affordances of an eyedropper, Slurp provides haptic and visual feedback while extracting and injecting pointers to digital media between physical objects and displays.

2.4 Conclusions

Although the interaction with the musicBottle is very simple, the use of the bottle is still limited to a special area. But the extension of the area is no big task and than the possibilities expand. I can imagine, that medicine bottles can track a patient's taking patterns. Also the user could be reminded via short message or email to take his medicine, so he will not forget it. Furthermore the family doctor could get the information from the medicine bottles and warn his patient if he takes to high doses.
Summing up, even though the musicBottles have an easy task, they already can entertain us and with the described future extensions they could help us in our daily lives.

3 Smart Cups

The Mediacup [5] project provides insights into the augmentation of artefacts with sensing, processing, and communication capabilities, and into the provision of an open infrastructure for information exchange among artefacts. One of the artefacts studied is the Mediacup, an ordinary coffee cup invisibly augmented with computing and context-awareness. The Mediacup and other computeraugmented everyday artefacts are connected through a network infrastructure supporting loosely-coupled spatially-defined communication.

3.1 The MediaCup

The objective of the hardware development was to augment an ordinary coffee cup with sensing capabilities, processing power, and communication. The design challenge was to provide these additional features without changing the basic properties (shape, size, and weight) of the cup noticeably and without compromising everyday use (ensuring robustness, and maintenance-free use) [5].

3.2 The Cognitive Cup

The Cognitive Cup[6] is based on the MediaCup but goes a bit farther but according to the definition, of Cognitive Objects [7], includes additional skills to fit the needs of humans and robots.To the basic constituents, described in the next paragraph, the Cognitive Cup helps robots to track its location and orientation by infared LEDs built into the seam. This is very important for robots, because the handling of a cup is really different if the cup is empty. Than there is no restriction how the robot grabs the cup. But in case that the cup is full the robot is just allowed to grab the cup in a way, that no content is spilled. Furthermore the Cognitive Cup communicates wirelessly with its environment via RFID (for identicication) and ZigBee (for real-time sensor value transmission) [6].

3.3 Development

The implemantation of the MediaCup, is the result of a number of design iterations. The hardware comprises sensors for temperature and acceleration, a microcontroller, an infrared diode for communication, and a standard Lithium battery. To track movement, atwo-axis acceleration sensor is integrated, which can measure both dynamic and static acceleration. For temperature sensing the cup has a Semiconductor chip measuring from $-55\,^{\circ}\mathrm{C}$ to $+125\,^{\circ}\mathrm{C}$. With the Lithium battery, the MediaCup can be powered for approximately 2-3 weeks. Sensor readings are taken every 50ms for acceleration, and every 3 seconds for temperature. The raw sensor data is processed on the MediaCup, applying heuristics to obtain cues regarding handling and situation of the coffee cup. Acceleration sensor data is mapped to three distinct cues: cup is stationary, drinking out of the cup, and fiddling around with the cup. Temperature data is mapped to the cues: filled up, cooled off, and actual temperature. [8]
In the MediaCup environment, transceivers already present in desktop and laptop computers can be used to receive cup IDs and cues, which are cummunicated every 15 seconds. Also an overhead transceiver infrastructure was added to the office environment to connect MediaCups and to track their location.

Figure 2: Evolution of the MediaCup prototypes. The first versions (left, middle) served for data collection. The MediaCup (right) with all the hardware in the rubber base [8].

In Fig. 2 you can see the evolution of the MediaCup prototypes. Obviously you can see, that the first two version were not ready for day-to-day use but served for data collection. The big difference to the third prototype, is that the hardware mounted in the rubber base of the cup, allowing the removal, so that the cup can be dishwashed [9].

3.4 Applications

Additional to the obvious tasks tasks temperature measurement, fluid status and movement detection, the MediaCup can be used for a colleague awareness application system. If every employee has a MediaCup, his location in the office could be tracked and shared in a web portal, so everybody knows where to find the colleague he needs.
Furthermore the MediaCup can exchange informations with other Smart Objects based on his own state, e.g. when the cup detects that it is empty, he sends a order to the coffee maker. Also it is thinkable that a worker takes his cup with him home, the next day when he comes back to work and draws nearer to the office, his cup gets tracked and establishes to boot the computer. So the worker is able to start his work immediately without any delay.
The Cognitive Cup allows a robot to identify every cup by the RFID tags implemented. Furthermore the surface of the Cognitive Cup is rougher than a normal porcelain mug in order to facilitate grasping by a robot hand. So you can see, that the Cognitive Cup is optimized to meet the requirements of humans and robots.

3.5 Conclusions

Although a cup is a part of our daily life for many years it is interesting to see how scientists try to get all possible informations, by augmenting it, for the users. In the future the use of robots, to aid people in the daily life, will increase and the necessity of smart objects will rise in the same dimensions.

4 Strata Drawer

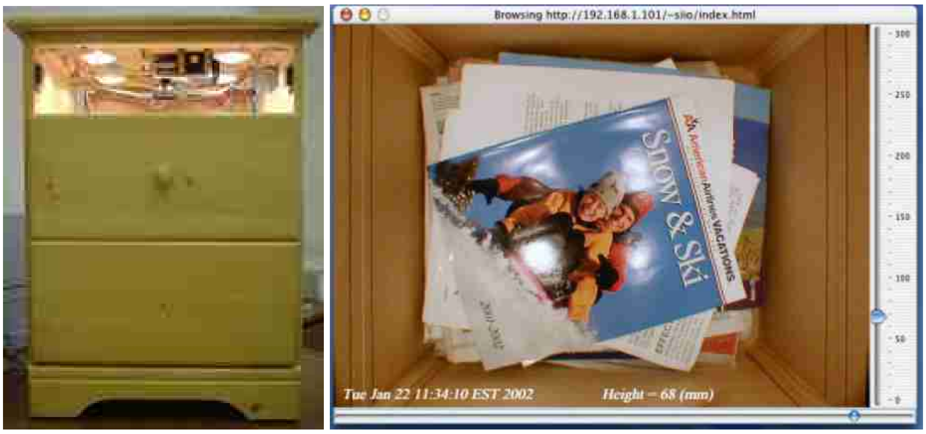


Figure 3: The Strata Drawer has a digital camera and a laser diode that is used to measure the height of the contents (left). The browser with time and height sliders to browse through the stack of objects that are in the drawer (right). [10]

The Strata Drawer is a prototype from the Digital Decor [10] project. Digital Decor is furniture, appliances, and other small objects commonly found in homes and offices that have been augmented with computational power to extend usefulness. As such, Digital Decor is a physical manifestation of the ubiquitous, pervasive, and invisible computer in which the familiar, everyday object is imbued with additional capabilities through a single, simple application. Till now they have investigated two possible functionalities for Digital Decor. Objects which keep track of their own contents, smart storage, and objects that support informal, lightweight communication. The Strata Drawer is augmented to keep track of his contents and his composition is described in the next paragraph.

4.1 Installation

A picture of the Strata Drawer is shown in Fig. 3, it is a camera-enhanced cabinet used for storage. It has a single deep drawer with a reed switch, halogen lamps and electronic circuits. It is also equipped with a digital camera and a laser diode to measure the height of the content inside the drawer. All devices are connected to a computer, which is running a picture-taking program and a WWW server to upload the pictures. The camera is mounted facing downward to take a picture whenever the computer detects, that the drawer is closed, and the halogen lights are on. After the picture is taken, the lamps shut down and the laser measures the height of the content inside the drawer. The picture and the height information is transferred to the computer and uploaded to the WWW server with a timestamp.

The user is able to navigate through the browser by time and depth sliders to find the wanted content. Because the pictures are on the WWW server, browsing can be done by anyone with access to the Internet, which is one major advantage of a strata drawer.

4.2 Application

After getting a good vision how the Strata Drawer is built we can discuss if this augmentation is actually useful. I think it can be very useful for office workers, which tend to pile up documents on their desk. Because they think, that they require them someday in the future. The Strata Drawer could help them store the documents in the drawer and also accelerate the access to them. If the worker just needs an information e.g. a customer ID, which normally is on the front page of a file, he can get it from the web browser and does not even have to open the drawer for it. When someone is searching a specific file you normally have an idea when you put the document on your stack. But when the stack on your table gets higher and higher, you lose your overview and the search gets very difficult. With the aid of the smart storing unit, you can search the file with the timestamp information on the web and get a good feeling where the file is located. You open the drawer, have a quick search in the region of interest and you get access to the file significantly faster than without the Strata Drawer.

4.3 Related work

Although we just discussed the use of camera-enhanced drawers, it is thinkable to use the Strata Drawer wherever we use drawer cabinets. For example, it can be used in a home to store clothing, and to keep a stack of shirts, pants, and underwear. Another possibility is shown in the HomeBox [11] project. The HomeBox is a set of drawers designed as a WWW content creation tool for people in developing countries. Users can arrange the contents of the drawers and create their own WWW page e.g. for selling self made products all over the world.
Whereas Peek-A-Drawer [12] is a pair of networked drawer chests to provide communication between distant family members. Especially it is intended to support lightweight communication between grandparents and grandchildren. For older people the task to deal with a computer is impossible even though the new generation is grown up with computers and multi media products. With Peek-A-Drawer both sides have an easy two-way communication channel to keep in touch.

5 Cooperative Containers

Ubiquitous computing is giving rise to applications that interact closely with activity in the real world. In contrast Cooperative Artefacts [13] are able to cooperatively assess their situation in the world, without need for supporting infrastructure in the environment. The Cooperative Artefact concept is based on embedded domain knowledge, perceptual intelligence, and rule-based inference in movable artefacts. The concept is demonstrated with design and implementation of augmented chemical containers that are able to detect and alert potentially hazardous situations concerning their storage. But it is also conceivable to have Cooperative Containers in every house to assure the right location of the things.

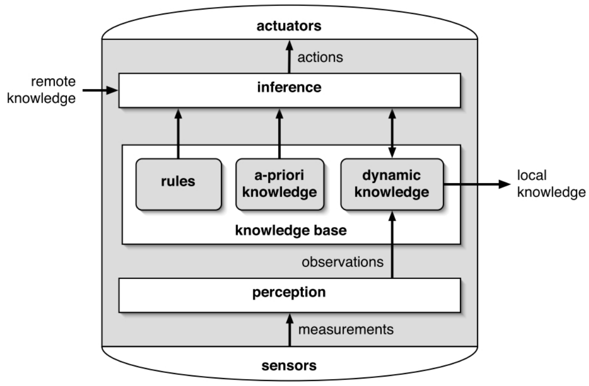
5.1 Concept

Many ubiquitous computing systems and applications rely on knowledge about activity and changes in their physical environment, which they use as context for adaptation of their behaviour [14]. How systems acquire, maintain, and react to models of their changing environment has become one of the central research challenges in the field. Approaches to address this challenge are generally based on instrumentation of locations, user devices, and physical artefacts.
Complementary system intelligence such as perception, reasoning and decision-making is allocated in backend infrastructure or user devices. This means, only those tasks that could not be provided as easily by external devices are embedded with the artefacts, whereas all other tasks are allocated to the environment which can generally be assumed to be more resourceful. However, this makes artefacts reliant on supporting infrastructure, and ties applications to instrumented environments.
So the need of Smart Things that must not rely on any external infrastructure is clear. An example which shows this requirement implemented are chemical containers designed as Cooperative Artefacts. Cooperative Artefacts model their situation on the basis of domain knowledge, observation of the world, and sharing of knowledge with other artefacts. World knowledge associated with artefacts thus becomes integral with the artefact itself and no external infrastructure is required to assess situations in a physical environment. The next section describes the composition of the chemical containers.

5.2 Installation

In Fig. 4(b) the composition for Cooperative Artefacts is shown. The architecture is independent of any particular implementation platform and comprises the following components:

(a) Prototype of a chemical container [13].



(b) Architecture of a Cooperative Artefact [14].

Figure 4: Composition of a Cooperative Artefact. A chemical container with two device modules 4(a) and the architecture of it 4(b).

- **Sensors:** The device contains two sensors: a range sensor for measuring the distance between containers and an infrared light sensor for detecting if the container is located in an approved area.
- **Perception:** The perception component mediates between sensors and knowledge base. It translates ultrasonic distance estimates and IR readings into proximity and location facts, which are added or modified whenever sensor readings change.
- **Knowledge base:** A query/reply protocol is implemented over the wireless link to give artefacts access to knowledge of other artefacts.
- **Inference:** The inference component processes the knowledge of an artefact as well as knowledge provided by other artefacts to infer further knowledge, and to infer actions for the artefact to take in the world.
- **Actuators:** The device includes an LED to visually alert users of potential safety hazards.

A prototype of a chemical container is shown in Fig. 4(a). It is based on two embedded device modules, one is used for sensing and perception of proximity and the other contains the core of the artefact (e.g. knowledge base, inference engine). The function of the artifact is described in the next section.

5.3 Applications

The task of the chemical container is to detect and alert potentially hazardous situations concerning their storage. As we can see in Fig. 4(b) the knowledge base consists of three parts, the dynamic and a-priori knowledge and the rules. The chemical container rules are:

1. A hazard occurs if a chemical is stored outside an approved area for too long.
2. A hazard occurs if incompatible chemicals are stored too close together.
3. A hazard occurs if the total amount of a chemical substance, stored in a collection of neighboring containers, exceeds a pre-defined critical mass.

The fact base of a chemical container consist of domain and observational knowledge. In the domain knowledge the nearly static variables (e.g. content, mass) are defined. The observational knowledge interacts with other artefacts to trace the location and the proximity to other containers.
With these rules and facts, the chemical container is able to detect critical situations. In the prototype version of the chemical container, the LED is switched on, if at least one of the rules can be triggered. But that is not sufficient enough, because the situations can occur in different environments (e.g.plants, transit) and there is not always someone present to act when the LED flashes. Furthermore it is thinkable that a loud noise is played or a message is send to a control PC to warn the people, before a dangerous situation is developing.

5.4 Conclusions

Although the chemical containers are not directly usable in our homes, the idea of proper storage is quite interesting. Every package where, perishable food is stored, for example, could be equipped with a device and trigger an alert when the storage situation changes. Then you can react immediately and restore proper conditions for your goods. Because the containers are aware of their own content, the user is always up-to-date of his inventory and the develop of the next shopping list is uncomplicated.
It is also thinkable, that the history of the storage is stored and that customers can access these informations before they buy something. This would facilitate the purchase for salesman and customers, because they could be sure, that the product was properly stored.

6 Conclusions

In this paper I have presented some "Smart Things" that could make the everyday life more easy and that the connection of all things, especially in the household, is on the rise.
Because the field of research is quite a new one, there is not "One" true definition for "Smart Things". Digital Decor, Cognitive Objects and Cooperative artefacts are all smart and expand the usability of normal objects. The most important aspects, that "Smart Things" enforce in our everyday life, are:

- The usability and convenience of the object should not be deteriorated.
- The user has to accept the benefit by using a "Smart Thing".

Only then we can profit from the new invented things, that we will find in our homes soon.

References

[1] Strohbach, M.: A dispersed systems framework for application development based on smart objects. In: First Year Report for PhD Assessment. (May 2003) 1

[2] Ishii, H., Mazalek, A., Lee, J.: Bottles as a minimal interface to access digital information. In: Extended Abstracts of Conference on Human Factors in Computing Systems, Seattle, Washington, USA, ACM Press (March 31 - April 5, 2001 2001) pp.187–188 2, 1

[3] Weiser, M.: The computer for the 21st century. In: Scientific American. Number 265 (3) (1991) pp. 94–104 2.1

[4] Zigelbaum, J., Kumpf, A., Vazquez, A., Ishii, H.: Slurp : Tangibility , spatiality , and an eyedropper. CHI 08 extended abstracts on Human factors in computing systems (2008) 2565–2574 2.3

[5] Beigl, M., Gellersen, H.W., Schmidt, A.: Mediacups: experience with design and use of computer-augmented everyday artefacts. In: Computer Networks, Volume 35, Karlsruhe, Germany, Elsevier (March 2001 2001) pp. 401–409 3, 3.1

[6] Kranz, M., Möller, A., Roalter, L.: Robots, objects, humans: Towards seamless interaction in intelligent environments. In: 1st International Conference on Pervasive and Embedded Computing and Communication Systems (PECCS 2011), Algarve, Portugal (March 2011) pp. 163–172 3.2

[7] Möller, A., Roalter, L., Kranz, M.: Cognitive objects for human-computer interaction and human-robot interaction. In: 6th ACM/IEEE International Conference on Human-Robot Interaction (HRI2011). (2011) pp. 207–208 3.2

[8] Gellersen, H., Beigl, M., Krull, H.: The mediacup: Awareness technology embedded in an everyday object. In: Handheld and Ubiquitous Computing, Springer (1999) pp. 308–310 3.3, 2

[9] Gellersen, H.W., Schmidt, A., Beigl, M.: Adding some smartness to devices and everyday things. In: Proceedings of the Third IEEE Workshop on Mobile Computing Systems and Applications (WMCSA'00), Washington, DC, USA, IEEE Computer Society (2000) 3– 3.3

[10] Siio, I., Rowan, J., Mima, N., Mynatt, E.: Digital decor: Augmented everyday things. In: Graphics Interface. Volume 11., Lausanne, Swizerland, Citeseer (March 2011 2003) pp. 155–166 3, 4

[11] Piper, a.B., Hwang, Young, R.E.: The homebox: a web content creation tool for the developing world. In: CHI '01 extended abstracts on Human factors in computing systems. CHI EA '01, New York, NY, USA, ACM (2001) pp 145–146 4.3

[12] Siio, I., Rowan, J., Mynatt, E.: Finding objects in strata drawer. In: CHI'03 extended abstracts on Human factors in computing systems, ACM (2003) pp. 982–983 4.3

[13] Strohbach, M., Gellersen, H., Kortuem, G., Kray, C.: Cooperative artefacts: Assessing real world situations with embedded technology. UbiComp 2004: Ubiquitous Computing (2004) pp. 250–267 5, 4(a)

[14] Strohbach, M., G., K., Gellersen, H.: Cooperative artefacts - a framework for embedding knowledge in real world objects. In: Workshop on Smart Object Systems. (2005) 5.1, 4(b)

Smart Furniture

Lorenz Maximilian Heitzer
Loro@mytum.de

January 16, 2012

Abstract

The development of smart furniture and other intelligent products is supported by technological advancement, that leads to ever smaller and yet more capable electrical devices. It is very tempting to augment everyday objects with technology to provide support and comfort. At a certain point the smart objects are only restricted by the physical boundaries of their chassis. Enabling the communication between pieces of smart furniture, sensors or other devices is the logical step that unlocks the potential of this technology. Services of middlewares will be required to deal with the heterogeneity of the devices and applications. The communication between smart objects leads to the creation of intelligent environments, with the potential to vastly improve human life and possibly provide a solution for an underestimated social problem - the aging population.

1 Introduction

Everyone, interested in the matter or not, has remarked the developments in electrical engineering. If someone wanted to call another person en route 20 years ago, he had to find a public telephone booth and pay with a phone card or coins. In our days smartphones provide mobile internet access, photography and many other features. The further advancement of technology regarding processing power, miniaturization and wireless sensor networks leads to countless possibilities regarding the enhancement of our environment. So if mobile phones can be „smart " , the conception and creation of smart furniture is obvious. But the development doesn't stop here. Whole rooms can be enhanced and modified to create an intelligent environment, which contains several communicating smart furniture objects, or intelligent products in general.

Because of the wide variety of possible designs, it is important to discuss the requirements for a product to be smart. The following chapter contains a differentiation of multiple levels of intelligence. In Chapter 3 the concept of a middleware is analysed, while Chapter 4 presents application scenarios for smart furniture and intelligent environments.

2 Properties of Smart Furniture

2.1 Levels of Intelligence

Certain requirements must be fulfilled to proceed from simple augmentation to intelligent products. The paper [1] proposes an interesting approach to this problem by visualising different aspects in a 3 dimensional coordinate system. In the following the 3 sub-items of the upper branch in Figure 1 are further investigated and enhanced when necessary.

2.2 Information Handling

The ability to handle information is a very basic prerequisite.

An object, e.g. an armchair with a pressure pad, recognizing a sitting person, is meeting this requirement. But it is definitely far from being smart. As the chair can only track information, it is not able to inter- or react or influence its own status.

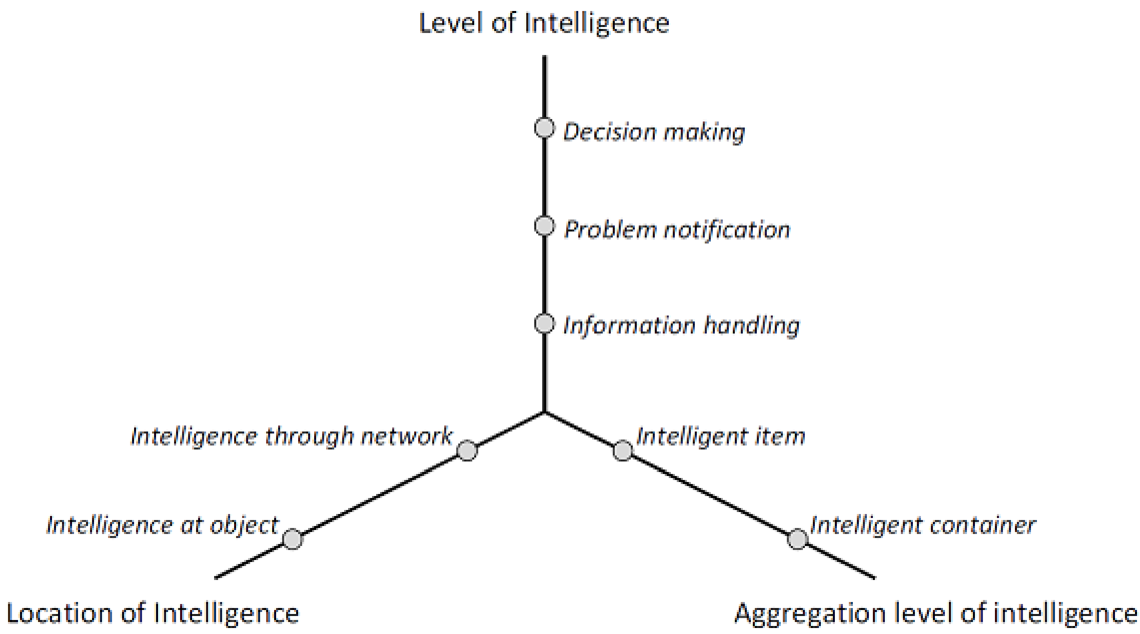


Figure 1: Classification system for intelligent objects from [1]

2.3 Problem Notification

This level implies the ability to sense and a basic level of context awareness. An object with these abilities has a limited form of context awareness in accordance with [2]. It is nevertheless still limited to its own physical boundaries.

The integration of a position sensor into the afore mentioned armchair would enable the knowledge background for a warning signal if the chair is about to fall over. These features are sufficient to reach this level.

2.4 Decision Making

The ability to decide of it's own accord is a very huge step compared to the previous one. Proper decisions require the capability to sense, reason and, at last, act. But the smart furniture is still limited to its own body.

The armchair could be enhanced with actuators in its backrest and an embedded computer. This way the armchair could slightly change the shape of its backrest to properly support the sitting persons back and spine.

2.5 Communication

Until now intelligent products are still limited to their own physical body, but the ability to communicate offers a lot more opportunities for augmentations and is an important step for the development of intelligent environments.

Integrating a touchscreen into one armrest and enabling the armchair to control a TV would increase its usefulness significantly. It would be able to switch on the TV automatically if a person sits down and render a separate remote control obsolete. This basic example shows the importance of the ability to communicate and interact with other objects.

To further explore this route, the former example is expanded with another piece of smart furniture. A bed with an integrated pressure pad and an embedded computer could decide that, after being occupied for a certain amount of time, the user can be considered asleep. This new user status could be shared with the armchair in the living room. If the user forgot to turn off the TV before going to bed, his chair could resolve to do so, in order to save energy.

The service of a middleware is required to support the communication between pieces of Smart Furniture and sensors, hence the following section will provide basic information about these programs.

3 Middleware

There is an urgent need for a moderating software between the various intelligent objects as depicted in the previous chapter. The amount of different protocols and solutions stands in relation to the virtually limitless possibilities to enhance human life with smart furniture. Since companies often have difficulties to agree on common standards in software or hardware developments, it's easy to predict that a highly flexible middleware will be a crucial factor for the commercial future of intelligent environments.

Based on [2], [3] and [4] the next section provides an overview of desired features and design variations. Additionally the functions of ROS are discussed as an example for the different topics.

3.1 Organization

The basic organization of provided services can be either centralized oder decentralized.
A centralized organization model assumes a stationary environment with only a few mobile devices, thus being a location centric approach. A capable computer with a high availability is required to fulfill the role of a central management and coordination device. Having such a contact point simplifies application development and programming since information and data is reliably distributed throughout the whole network. But the dependence on one single device contains obvious disadvantages, namely high traffic and malfunctions of mentioned computer.

The decentralized approach, also called peer-to-peer, assumes a dynamically formed collection of smart objects. It is based on a people-centric, or in the case of ROS a robot-centric, viewpoint. Flexibility and robustness are gained by the independence from a central coordinating computer. But increased management difficulty likely paired with a decreased efficiency are the aftermath of decentralization.

ROS utilizes the peer-to-peer topology since its original development started with robots in mind, thus favoring independence from a central computer. The Cognitive Office presented in [4] and [5] works with ROS combined with central data servers. An intelligent environment or a piece of smart furniture can be viewed as an immobile robot, explaining the connection between robot and smart environment technologies.

3.2 Communication and Interaction

One of the most important responsibilities of middleware is to enable the communication between heterogeneous applications and devices. Only then can sensor data or status updates be shared within the intelligent environment. This feature also includes means for service detection and mediation.

Interoperability is the keyword in this particular topic. One way to achieve this is to provide a set of protocols, whose messages are encoded in a predefined way. Devices based on this protocols can, without any difficulties, communicate and interact. While this solution surely has a disadvantage in terms of flexibility, its effectiveness increases with the level of standardization.
Another way is a dynamic approach that includes the change of protocols at runtime by the middleware. While this definitely brings increased flexibility and adaptability it is also prone to errors.

The coupling between communicating partners is also an important part. There can be either a „tight " coupling between the communicating devices or a „loose " one. The first one describes a direct communication which requires a stable connection for a certain amount of time. Also the requesting device or application needs a mean to discover a proper partner. This is a common approach in service-based communication systems or if an application needs an immediate information.
A loose coupling stands for an indirect way of communication, to the effect that the provider of data and the client in need of said data do not have to be aware of each other. Event-based data exchange works with publish-subscribe abstraction. Data consumers subscribe to a certain topic and get notified if a data provider published information related to this topic.

ROS uses XML-RPC to support a predefined set of languages. It is however, according to [3], easy to upgrade ROS' messaging scheme. Since both communication systems have their uses in an intelligent environment, both are supported by ROS, as highlighted in [4].
After acquiring basic knowledge about middlewares and their impact on the communication between smart furniture, sensors and other intelligent products, the last section now presents the concept of intelligent environments and their possible application scenarios.

4 Intelligent Environment

Communicating intelligent objects may finally create an intelligent environment, or ambient intelligence as [6] calls it. Taking the abilities of smart objects described in previous chapters into account, a development focused on creating a smart environment opens interesting new possibilities.

4.1 Additional Features of Intelligent Environments

Since the abilities to reason and decide are already integrated, features like recognition, learning and prediction become available.
User recognition and predictions require a sufficient database as a foundation. Recognizing user activities allows to remark changes in behavior or problems. Thus the smart furniture can provide help if, and only if, needed and does not hinder or annoy the user by being overzealous. On the basis of stored data concerning user behavior it is possible for the smart environment to anticipate and, by acting in time, to properly assist a person.

According to [6], the MavHome Smart Home project was able to reduce daily interactions by 76%.

4.2 Security Concerns

The theoretical possibilities of smart environments or ambient intelligence in living environments sound very promising, but there's also a drawback. As more and more people experience online social networks and gain an understanding of the value of personal data, the users develop an increased sensitivity concerning this particular topic. This results in the skepticism, or even rejection of wearable sensors and supervision per video cameras, as highlighted in [7] and [8]. Not long ago credit card related information was stolen from Sony thus enraging the customers and causing the stock value to drop significantly. An unsettling discovery was made in December 2011 concerning a software from a company called CarrierIQ, hidden in modern smartphones and transmitting data. Ambient intelligence in a living environment needs to monitor, evaluate and remember the users activities and preferences to be able to perform cognitive abilities on a high level and therein lies the problem. Smart environment works with highly personal data to be the most efficient and supportive. It's acceptance from the customer depends highly on the safety of the users personal data. This issue is further addressed in [6].

4.3 Application Scenarios

There are a lot of practical application scenarios for smart furniture and intelligent environments. Support in the office like in [5] is one of them. Providing support and comfort in smart homes as shown in [6], or simplifying manufacturing purposes as discussed in [1] are other possible scenarios easy to imagine. Saving energy is also a very interesting and actual topic. A smart home could easily observe the times of day when nobody is at home and turn down the heating. Since it can predict the time the first user returns home, it would also be capable of switching the heating on again early enough.
Another application scenario is however of special interest. The Statistisches Bundesamt released an outlook regarding the population development in the Federal Republic of Germany until 2060. Figure 2 shows that the percentage of citizens older than 79 years will rise from 5% to 14%. In absolute numbers this means a rise from 4 Million to 9 Million people.

As our formal health care system is already costly and problematic, this outlook is unsettling. But ambient intelligence could help in this matter, because elderly people would be able to stay in their own homes and remain relatively independent. The smart home application for eldercare in [7] seems very promising. A corner point of this eldercare program is the monitoring of one persons activity level. It is customary that after an injury or any other event that causes a decline in health and overall activity older people can hardly recover. Thus they won't be able to reach their former level of activity and autonomy. By continuously monitoring the overall activity level,

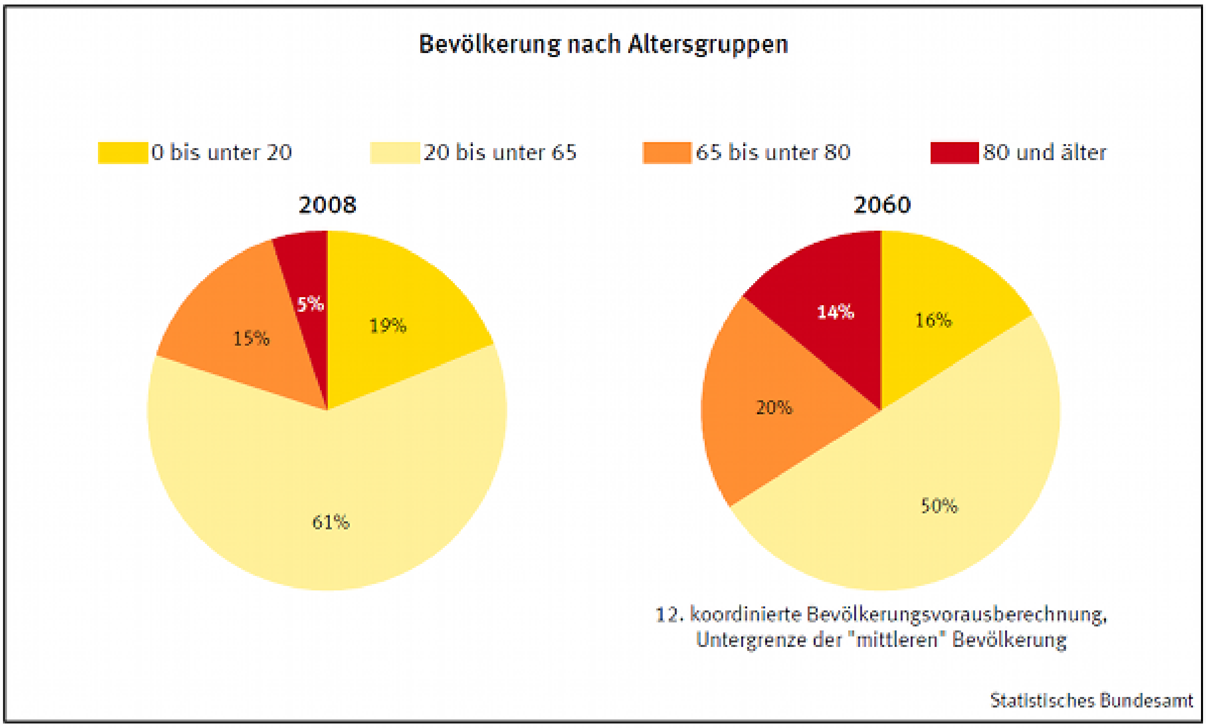


Figure 2: Age distribution of the population in the Federal Republic of Germany by 2060 from [9]

it's possible to early detect health problems and counter them effectively. In the architecture shown in Figure 3 the bed sensor is the most sophisticated furniture. It detects a persons presence in bed, its pulse, respiration and bed restlessness and transmits multiple event based on these measurements. The stove is also augmented and tracks his temperature in combination with movement in the kitchen, thus being able to generate an alarm event if unattended. To the senior citizens contentment the video sensors only track peoples silhouettes and a security system prevents any unauthorized access to personal data. Events are distributed in a publish/subscribe manner and state machine implementations combine timers with single or multiple sensor events.

The further development of smart furniture and smart environments could definitely improve the life of older people. Via activity tracking and user related motion pattern analysis, like in [8] and [7], combined with other features mentioned in [6], it will be possible for older citizens to retain their independence for a much longer time, while still receiving medical care whenever needed. The result will be a much more cost effective health care system.

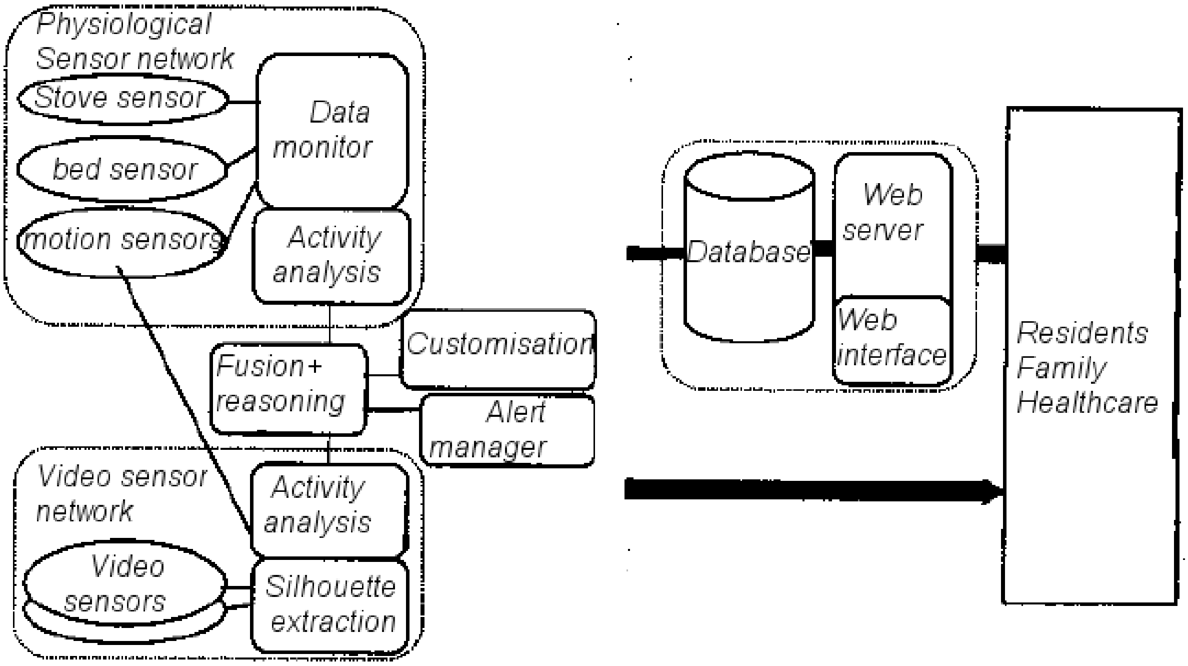


Figure 3: Sensor network architecture presented in [7]

5 Conclusion

Looking back on this examination, the prediction that smart furniture and even whole intelligent environments will step by step become part of our everyday life isn't a difficult one. Possible improvements of everyones daily routine provided by sensing, reasoning and then acting smart objects or help and support concerning special requests like enabling elderly persons in need for medical care to keep their independent life in their own home make the further development of smart furniture a worthwhile and profitable project for both developers, as there will surely be a vast demand for their products, and future users. Seeing that every smart object is restricted to its body, the crucial problem in creating an intelligent environment is the communication between smart furniture and sensors or other devices. The services of a capable middleware are therefore essential. There remains nevertheless one point which could be able to limit the theoretically limitless possibilities to enhance environments with smart objects and furniture, namely the question of personal user data security.

References

[1] Gerben G. Meyer, Kary Främling, J.H.: Intelligent products: a survey. Computers in Industry **60**(3) (2009) 137–148 2.1, 1, 4.3

[2] Gregor Schiele, Marcus Handte, C.B.: Pervasive computing middleware. In Hideyuki Nakashimai, Hamid Aghajan, J.C.A., ed.: Handbook of Ambient Intelligence and Smart Environments. Springer Science+Business Media (2010) 201–227 2.3, 3

[3] Quigley, M., Conley, K., Gerkey, B.P., Faust, J., Foote, T., Leibs, J., Wheeler, R., Ng, A.Y.: Ros: an open-source robot operating system. In: ICRA Workshop on Open Source Software. (2009) 3, 3.2

[4] Kranz, M., Möller, A., Roalter, L.: A middleware for intelligent environments and the internet of things. In Yu, Z., Liscano, R., Chen, G., Zhang, D., Zhou, X., eds.: Ubiquitous Intelligence and Computing. Volume 6406 of Lecture Notes in Computer Science. Springer Berlin / Heidelberg (2010) 267–281 3, 3.1, 3.2

[5] Kranz, M., Möller, A., Roalter, L.: Robots, objects, humans: Towards seamless interaction in intelligent environments. In: 1st International Conference on Pervasive and Embedded Computing and Communication Systems (PECCS 2011), Algarve, Portugal (March 2011) 163–172 3.1, 4.3

[6] Diane J. Cook, Juan C. Augusto, V.R.J.: Ambient intelligence: Technologies, applications, and opportunities. Pervasive and Mobile Computing **5**(4) (2009) 277–298 4, 4.1, 4.2, 4.3, 4.3

[7] Skubic, M., Alexander, G., Popescu, M., Rantz, M., Keller, J.: A smart home application to eldercare: Current status and lessons learned. Technol. Health Care **17** (August 2009) 183–201 4.2, 4.3, 3

[8] Rashidi, P., Cook, D.J., Holder, L.B., Edgecombe, M.S.: Discovering Activities to Recognize and Track in a Smart Environment. IEEE Transactions on Knowledge and Data Engineering **23** (2011) 527–539 4.2, 4.3

[9] Statistisches Bundesamt: Pressekonferenz Bevölkerungsentwicklung in Deutschland bis 2060 (November 2009) 2

The Kitchen and Refrigerator

Duc Hanh Bui Tran
DucHanhBuiTran@mytum.de

January 16, 2012

Abstract

In the last twenty years the number of people with obesity and overweight has increased immensely in industrialised countries. Many research groups are developing smart applications that support users to have a healthier nutrition. This paper gives an overview of smart kitchens and refrigerator with a focus on enabling better nutrition and eating habits of individuals.

1 Introduction

A well-balanced nutrition has always been an important factor for a long-term health [1]. Especially for people with a chronic illness, like heart disease, diabetes, high blood pressure or obesity, it is even more important to have a strict diet control. According to the OECD's[1] book "Health at a Glance 2011" there is a rapid increase of diabetes in every part of the world [2]. One reason for that increase is our unhealthy lifestyle. Beside genetic predisposition, overweight and physical inactivity are major risk factors for type 2 diabetes, which is largely preventable. But unfortunately in the past twenty years there is also a rise in overweight and obesity in the OECD countries. Obesity does not only increase the risk for type 2 diabetes but also many other diseases, such as hypertension, asthma, cardiovascular diseases, high cholesterol, arthritis and even some forms of cancer [2].

Thus it is reasonable to develop systems that support people to have a healthier eating habit. In this paper we concentrate on research related to smart kitchens and kitchen utilities helping to improve an individual's eating habit. The following chapter discusses various methods for ingredient detection and also their properties. The third chapter describes different smart applications in the kitchen for dietary control based on the methods, which are presented in the second chapter. Conclusion is given in chapter four.

2 Detection of Ingredients and their Properties

One of the main tasks for developing a smart kitchen, smart refrigerator or even smart kitchenware for improving your eating habits, is to find a way to identify all the various ingredients. The identification of the food ingredient alone is clearly not enough. Thus, another task is the determination of the properties, such as the weight or the amount of carbohydrates and fat content. Even the cooking method can be determined, which also plays an important role in healthy cooking [3].

To accomplish these tasks, there are various approaches using different kind of sensors. In the first following subsection, diverse sensors for the identification of food ingredients are presented. Subsection 2.2 briefly describes sensors that determine the properties of an ingredient.

2.1 Methods for Identifying Ingredients

Three different kind of approaches for identifying ingredient will be presented in this chapter. The first one uses acceleration sensor and transducer. The second one uses microphones. And the last one is based on Radio Frequency Identification technology.

Acceleration Sensor and Transducer Kranz et al. [4] present an approach to determine the type of food during the meal preparation by using an acceleration sensor, load cells and a force/torque transducer.

[1] Organisation for Economic Co-operation and Development

An common wooden cutting board has been equipped with four load cells and an acceleration sensor. The weight gives only little information on the food type. But the change of the load distribution, perceived by the load cells, provides more meaningful data. With help of an acceleration sensor, the cutting board is now able to detect small movements while cutting the ingredient. Every ingredient has a specific movement pattern, so it is possible to identify the food. The data which are retrieved from the acceleration sensor also give a lot information about the type of food. The second smart device is a Chef's knife which has been equipped with a force/torque transducer. The sensor was placed very closely to the handle to retain the comfortable grip of the knife. The transducer provides six different measurements. For each of the three axes force and torque are measured. The force, which arises while cutting, has a specific signature depending on what you are cutting. This enables the classifier to distinguish different kind of ingredient.

The two top diagrams of Figure 1 show data from cutting a carrot (top, left) and a kohlrabi (top, right) on the smart cutting board. And in the bottom diagrams the result from using the Chef's knife with the force/torque transducer while cutting a banana (bottom, left) and a carrot (bottom, right) is shown.

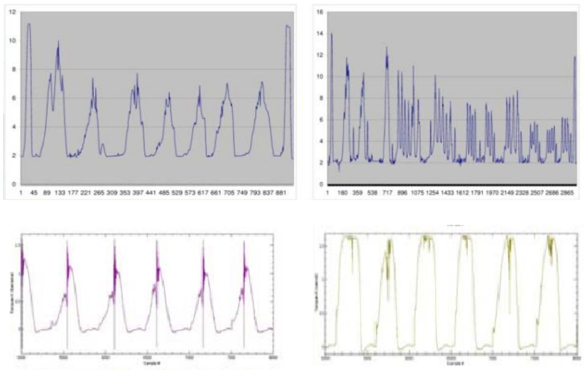


Figure 1: Data from cutting a carrot (top, left) and a kohlrabi (top, right) on cutting board. Data from cutting a banana (bottom, left) and a carrot (bottom, right) with the smart knife [4]

Audio Sensor Another approach for ingredient detection is using microphones because they can be embedded into a lot of objects. In [5] a microphone has been placed approximately 30cm above the cutting board. First of all the audio signal has to be preprocessed by using the Hamming-window. The signal is separated into frames. A feature extraction is applied on each frame. The feature contours contain information for example about energy, amplitude, pitch, Harmonics-to-Noise Ratio and bandwidth. Due to around seven thousand features a feature selection algorithm is used to reduce the amount to 250. The classificator was able to achieve 85.5% accuracy on the food classification and the corresponding confusion matrix is listed in Table 1. There are many other positions for the microphone.

Amft et al. [6] for example suggest to place it in the inner ear. A discrimination of food products is now possible by analyzing the chewing sound. The bone-conducted sounds, which are produced during the masticatory process, are transmitted to the microphone in the inner ear through the mandibular bones. A requirement for the analysis of the masticated food type is the identification of chewing segments in a continuous sound signal. They propose two different methods. The first one uses the intensity of audio signal. By placing the microphone in the inner ear the chewing sound amplitude peaks are much higher than background music or a normal conversation. But unfortunately this method easily mixes up loud speech with chewing sounds because loud speech can produce very similar amplitude peaks to chewing signals. The second method (Chewing Sound - Speech Classifier) can separate this two classes by using audio features, like frequency centroid, spectral roll-off point, fluctuation of spectrum, band energy ratio and six cepstral coefficients. The audio signal will be divided in short segments and for each segment they perform a feature extraction. Afterwards a trained classifier is applied on those extracted features. After the eating recognition, for which they could achieve up to 99% accuracy, they distinguish the food type by dividing the audio signal in segments and using the same procedure as in the chewing segment identification. The food type recognition for single bites was only around 66% to 86%. But by applying a majority decision on the whole chewing cycle the recognition rate could be increased by 15% to 20%. A majority decision is possible because during a chewing cycle the food type does not change. The confusion matrix for the chewing cycles is shown in Table 2.

a	*b*	*c*	*d*	*e*	*f*	*g*	← *classified as*
31	0	0	3	5	0	1	*a* = *Apple cut*
0	41	0	0	0	0	1	*b* = *Carrot cut*
1	0	42	0	0	0	0	*c* = *Carrot peel*
4	1	0	24	0	2	3	*d* = *Kohlrabi cut*
3	1	0	2	23	1	1	*e* = *Kohlrabi peel*
1	0	0	0	0	46	1	*f* = *Leek cut*
4	3	0	1	0	0	23	*g* = *Pepper cut*

Table 1: Confusion matrix for cutting and peeling [5]

a	*b*	*c*	*d*	← *classified as*
156	12	1	10	*a* = *Chips*
24	198	1	22	*b* = *Apple*
0	0	74	0	*c* = *Pasta*
4	21	0	127	*d* = *Lettuce*

Table 2: Confusion matrix for chewing cycles [6]

RFID Another possibility to identify food ingredient is the use of Radio Frequency Identification technology. In [7], [8] and [9] they use RFID tags on food products or food containers. By reading out the RFID tags over radio frequency using a RFID reader the ingredient can easily be determined.

2.2 Methods for determining properties of ingredients

This chapter introduces three methods for determining properties of ingredients. The first one is to use RFID. The second method uses temperature sensor and the last one uses weight sensor.

RFID RFID can not only be used for the ingredient identification but also to determine properties of ingredients by storing all kind of food information such as calorie, fat percentage, protein, carbohydrate and so on, inside a database. To get the needed nutritional information we just have to look up the tag-id in the food database which is indexed by RFID codes [8], [7].

Temperature Sensor Another useful information for a healthy cooking is the temperature. To retrieve this information you can use temperature sensors. Gellersen et al. [10] integrated a DS1621 Dallas Semiconductor chip in the rubber base of their Media Cup for temperature measurements. This enables measurement of temperatures between -55 to +125Â°C. Kranz et al. [11] also augmented the socket of their coffee cup with a temperature sensor.

Weight sensor It is not only important to know about the nutritional properties of food but also the amount of the ingredient. Embedding weight sensors into surfaces such as tables, stoves and cabinets, it is possible to retrieve the weight of ingredients. But furthermore you can also determine the position of ingredients and derive context information [8], [12],[13].

3 Fields of Application

This chapter describes various research and scenarios with focus on intelligent kitchen applications which improve healthier nutrition. In general a meal preparation can be divided in three steps. These three steps are represented in Figure 2 and in each of these steps you can already influence the eating habit of an individual. Here the applications are categorized into these three steps. For each step this paper describes scenarios from different research groups. Most of them use the methods presented in Chapter 2 for the ingredient and properties identification.

Figure 2: Steps for preparing a meal

3.1 Foodstuff Management

The foodstuff management contains the action before cooking. For example, knowing how much and what food you have at home or what food does need to be replenished. And also to give advice in the selection of healthy recipes. The first application, which will be presented in this paper, is a smart shopping list. The next application refers smart refrigerators, since every household has a refrigerator in the kitchen.

3.1.1 Shopping List

Mankoff et al. [14] suggest a system that could generate a healthier shopping list by using the information from former shopping receipt data. The system consists of three stages. In the first stage the receipts are scanned in and passed onto the Optical Character Recognition(OCR). The OCR parses the results into a list of foods, prices and quantities. Afterwards the list will be sent to the database. The database contains general data of nutrition, profiles of the users, their shopping habits and dietary reference intakes(DRI). Depending on personal profile of weight, age, gender and specific health requirements a customized DRI for the user will be calculated. The inferencing system takes the food list produced by the OCR program and informations from the database. The food items from the old shopping receipt will only be replaced if the food, which is a substitute for the original, has at least twenty percent more of the missing nutrient than the original food item. After that the inferencing system weighs alternatives with less fat and more overall daily nutrient more highly. A new shopping list with the best alternatives will be generated. The printed shopping list provides users with the opportunity to give feedback to the system. But this function is not implemented yet in the research of Mankoff [14]. For a better understanding the system flow is shown in Figure 3.

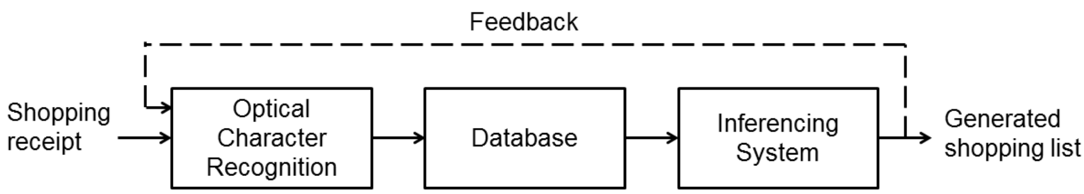


Figure 3: Application flow for Mankoff's shopping list system

Other research groups also suggest generating a shopping list. But they create the recommended shopping list by retrieving information about the food stocking from the fridge [7] [15]. Figure 4 shows the implementation of generating a shopping list from Gu and Wang based on a smart fridge. The content processor needs the information of the user and the raw food item, which is the available food that is currently in the fridge. The user information expresses the patient's record or their eating habits. If the content processor has all this information, it can create a well-balanced shopping list with their food ontology construction mechanism and weight adjusting algorithm [7]. More functions and the architecture of this smart refrigerator system will be described in the next chapter.

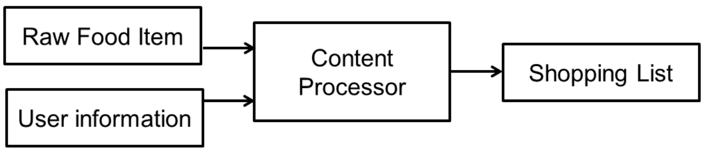


Figure 4: Steps for generating a shopping list [7]

3.1.2 Smart Refrigerator

By equipping the refrigerator with RFID readers Gu et al. [7] could monitor the current food in the refrigerator, which is needed for creating a shopping list. Furthermore they could also analyze the relationships between different kind of foods. An overall architecture of the whole system from Gu et al. [7] is shown in Figure 5. The system consists of three following parts: Health Center, Shopping Center/Community and Household. The household system, shown in Figure 6 includes a mobile client, a household server and a smart refrigerator. The smart refrigerator is equipped with RFID readers for monitoring the stock of the fridge. So it can provide informtion about the content(Raw Food Item) of the refrigerator to the content processor for the shopping list, which was mentioned in the previous chapter. With the mobile client the user can set a threshold of the food stock. If food items are about to run out the household server will inform the user. With the help of RFID tags the system can easily provide users detailed information, such as nutrition, weight, durability and so on, about each food item. From remote database in Health Center the content processor gets the patient's records so it can analyze the health condition of the user and adjust the food amount. The smart refrigerator can also make recommendations on recipes. The recipe recommendation is based on the ingredients that are currently in the refrigerator and also take into account the users health condition. Furthermore all the residents in the community are able to share their recipes with each others via the internet.

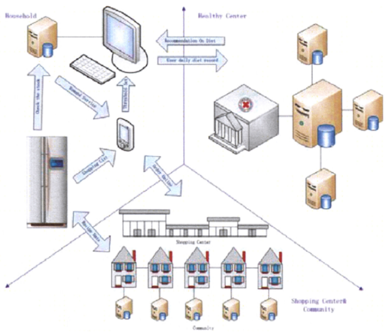


Figure 5: System for Home-healthcare [7]

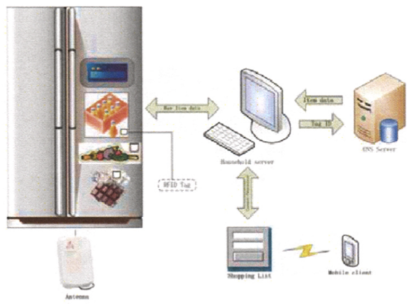


Figure 6: Architecture of content-aware fridge [7]

Luo et al. [12] developed a smart fridge with focus on healthy nutritional habits as well. Besides the functions of generating a shopping list, recipe recommendation and display nutritional information, they suggest a multimedia cooking demonstration and a body mass index (BMI) calculator for the user.

Huang et al. [16] propose a Context-Aware Personal Diet Suggestion System (CPDSS) that helps users to have a healthier eating habit. Unlike the earlier presented food recommendation systems, this one does not only base on food stock and user information (for example: weight, height, age, medical report and allergic food), but also on the activity of daily living (ADL). For the inference of ADLs the deployed sensors in our home can be used. For example for jogging or walking a mobile or a wearable device can record the activity level. Their diet suggestion system is executed on a RFID-equipped smart refrigerator. Due to an integration platform the fridge can interconnect with other components such as a dietitian or other devices. A system overview is shown in Figure 7.

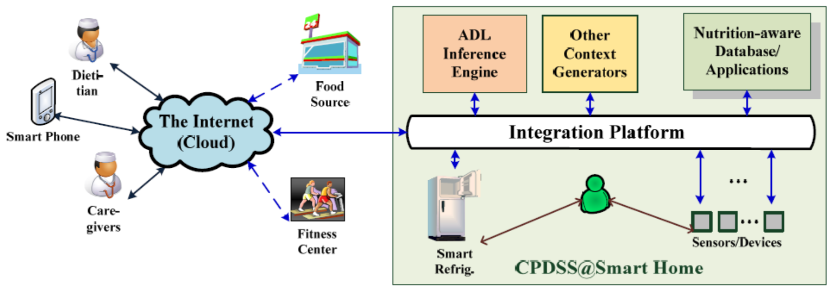


Figure 7: System Overview [16]

3.2 Assistance while Cooking

3.2.1 Smart Kitchen

Chen et al. [17] describe a smart kitchen scenario. Their smart kitchen consists of a smart fridge, stove, counter and a cabinet. Except for the stove all the other three kitchen appliances are augmented with sensor surface consisting of RFID antennas/readers and weight sensors. They assume that all food ingredients are stored in containers. Each container has RFID tags, which include nutritional information. Now with help of the sensor surface they can detect, identify and track the ingredients between cabinet, fridge and counter. The stove can detect the cooking temperature, duration and style by having a variety of sensors. With all those sensor information the kitchen can provide feedback about healthy cooking alternatives to the user through LCD display and speaker.

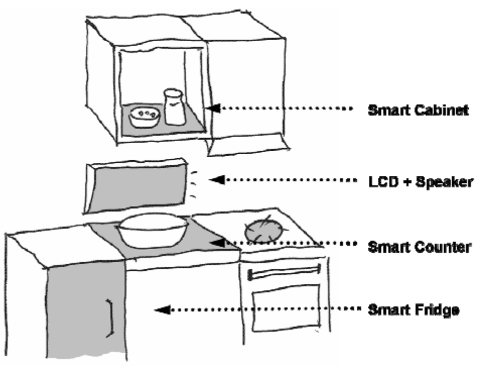


Figure 8: Smart Kitchen [17]

3.2.2 Nutrition-Aware Cooking

Another concept that provide support to the user during cooking is from Chen et al. [18]. Their system gives real-time feedback to increase the user's awareness of nutrition while cooking. The system includes two modules: a nutrition tracker and a countertop display. The nutrition tracker can detect in real-time cooking action that may change the meal's nutrition during cooking by deploying weight sensors under the stove and the kitchen counter. They use a camera above the counter for filtering out noise from the the weight-sensing surface. For the ingredient identification during user studies they use the Wizard of Oz method. Their system brings some limitation with it. For example it cannot recognize concurrent actions and the ingredient has to be inside containers on cutting boards. The real-time feedback is given by the countertop display. They present three different displays: the Nutritional Facts Display, the Calorie Display(shown in Figure 9) and the Calorie and Nutritional Balance Display.

The Nutritional Facts Display shows basic nutritional content of the most recently used container of food and a mapping of detected ingredient, which are presented by small rectangles. The user could not interpret the basic nutritional content value to determine how healthy the cooking was. Furthermore the final meal calories were not shown because the display only presents information for the last used container. The mapping from the nutritional information to the ingredients on the counter were too confusing. The second display(Calorie Display) however shows many improvements to the the Nutritional Facts Display. They reduce the nutritional details to only calorie information and for each ingredient the calories are now shown. Furthermore they display recommended calories, whose calculation is based on profiles of family members who are attending the meal. Containers are now displayed by rectangles, whose size reflects the real container's size. The colors of the rectangles change with the number of calories. The more calories the more darker the color is. The Calorie and Nutritional Balance Display does not only show the recommended calories but also provides a recommendation on nutritional-balance information, such as grains, vegetables, meat, beans and also oils.

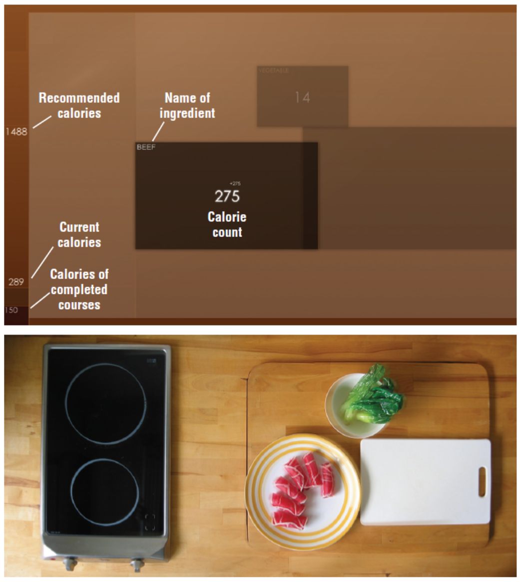


Figure 9: Calorie Display [18]

3.3 Control of Food Intake

After the preparation of dishes the eating can commence. Even here there are various approaches to improve the eating habits of individuals, such as dietary monitoring. Two approaches will be presented here.

Already mentioned in Chapter 2.1, Amft et al.[6] suggest using a microphone in the inner ear. With this approach they wanted to achieve an automatic monitoring of the user's eating habit and thus to improve the user's eating habit.

The second one is a dining table augmented with two layers of sensor surfaces(a weighing surface and a RFID surface) to track food movement paths, introduced by Chang et al. [8]. They divide the dining table in 3x3 cells in order to recognize multiple concurrent person-object interaction. As shown in the left picture of Figure 10, each of the cells have a weighing sensor and a RFID antenna. Each cell may contain only one table object as illustrated in the middle picture of Figure 10. They assume that the food items are in containers, which are correctly labeled by RFID tags. And furthermore each participant has their own containers(plate, cup). The system can now recognize high level behaviors, such as eating-food,pour-tea and transferring-food (to a personal container), by interpreting information from the sensors. To evaluate the system they performed two scenarios. The first one is an afternoon tea and the second one a Chinese-style dinner. Both of them have multiple table participants who are continuously and concurrently eating, drinking and transferring food. At a typical Chinese-style dinner (right picture in Figure 10) family members are sitting around the table and each of them has their own rice bowl. In the middle of the table are the main dishes. First the Participants transfer the food from the main dishes to their personal plate/bowl and then eat from there. In the two scenarios they could reach around 80% recognition accuracy. A future function would be a just-in-time persuasive feedback for encouraging healthier dining behaviors. For example a diabetes patient could receive a notification if they already reached their recommended daily consumption.

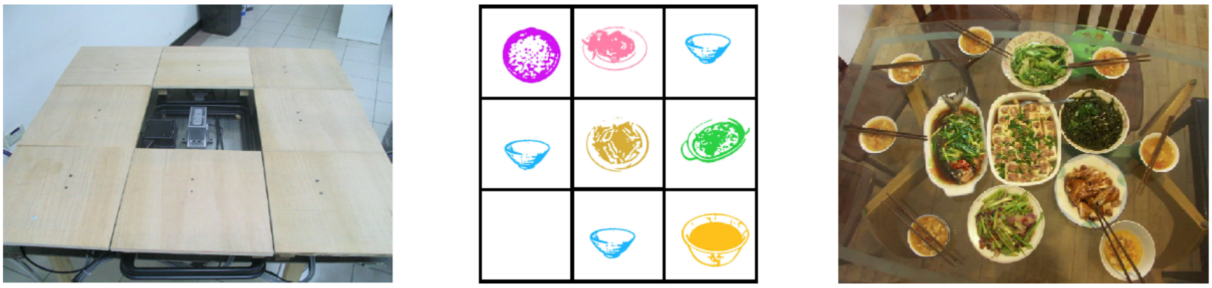


Figure 10: Diet-aware dining table; left picture: Embedded RFID and weighing table surfaces; middle picture: Showing the placements of table objects ; rigt picutre: Typical Chinese dining table setting [8]

3.4 Discussion

All the applications and scenarios presented in this paper provide the user great support for a healthier lifestyle.But there also problems which are left unsolved.

The inconvenience of scanning every single receipt in the case of the shopping list from Mankoff et al. [14] would be too large for the user. There also exist the problem of the efficiency of the recognition. Not all items can be recognized by their system. For example things brought in a bakery will not all be listed in the receipt explicitly.

The problem concerning RFID based systems is the current feasibility. Those systems all assume that food items are tagged correctly. So there has to be an agreement about tagging all food items between consumer and producer. That would generate more work for the producer which would imply higher prices for the user. Self made food is also problematic because of the lack of a corresponding RFID tag.

Another aspect should also be mentioned. In some cases the user has to adapt in order to interact correctly with the system. Hence this could make the user behave unnaturally. For example the system for Nutrition-Aware Cooking Chen et al. [18] introduces, allows the user to add only one ingredient at a time during cooking. Another example for unnatural behavior is the dining table, which does not allow the user to put his arm on the table during the meal because of the weight sensors. The dining table has also a flaw concerning the identification of complex dishes where the ingredients differ too much in their properties, for example the value of calories. The assumption about eating the same amount of different things of a dish is not viable in reality. A person who likes to eat meat rather than vegetables will probably not eat the same amount of both things of a dish. Hence the actual amount of consumed food will not mirror the value the system calculates. And also the dietary monitoring systems of Amft [6] does not suit the natural behavior of a person because if you are eating a meal you do not always eat the ingredient seperately. For example a bite from a burger contains at the same time meat, bread, cheese and salad. In this case the dietary monitoring system will have troubles to identify the food.

4 Conclusion

This paper gives an overview about systems which support users for a better eating habit, focusing on the kitchen and refrigerator. The presented approaches are all excellent but they are not marketable yet. One reason lies in the inability to realize the applications in that form. For example the RFID tag problem which is mentionend in the discussion section. Another reason is the effort the user has to undertake in order to use the system. The last reason is the unnatural change in the user's behavior to operate the system.

One possibility to solve some of the problems could be the combination of the presented applications and scenarios. For example in the Nutrition-Aware Cooking scenario,the augmented knife or the cutting board could be used for the ingredient indentification instead of the Wizard of Oz Method. Furthermore the dietary monitoring system with the inner ear microphone could get information about the recommended recipe for dinner by communicating with the smart fridge. With information about used ingredient for cooking the systen could restrict the number of possible ingredients beforehand. So they could improve their food identification during chewing.

As can be seen, the pervasive computing plays an important role for future intelligent applications and it will most probably be used in everyday household.

References

[1] Rosenberg, I.: Nutrition Research: An Investment in the Nation's Health. Nutrition Reviews **54**(1) (1996) 5–6 1

[2] OECD(2011): Health at a Glance 2011: OECD Indicators, OECD Publishing. http://dx.doi.org/10.1787/health_glance-2011-en. 1

[3] Nursal, B., Yücecan, S.: Vitamin C losses in some Frozen Vegetables due to various Cooking Methods. Food/Nahrung **44**(6) (2000) 451–453 2

[4] Kranz, M., Schmidt, A., Maldonado, A., Rusu, R., Beetz, M., Hörnler, B., Rigoll, G.: Context-Aware Kitchen Utilities. In: Proceedings of the 1st International Conference on Tangible and embedded Interaction, ACM (2007) 213–214 2.1, 1

[5] Kranz, M., Schmidt, A., Rusu, R., Maldonado, A., Beetz, M., Hornler, B., Rigoll, G.: Sensing Technologies and the Player-Middleware for Context-Awareness in Kitchen Environments. In: Networked Sensing Systems, 2007. INSS'07. Fourth International Conference on, IEEE (2007) 179–186 2.1, 1

[6] Amft, O., Stäger, M., Lukowicz, P., Tröster, G.: Analysis of Chewing Sounds for Dietary Monitoring. UbiComp 2005: Ubiquitous Computing **3660** 2.1, 2, 3.3, 3.4

[7] Gu, H., Wang, D.: A Content-aware Fridge Based on RFID in Smart Home for Home-Healthcare. In: Advanced Communication Technology, 2009. ICACT 2009. 11th International Conference on. Volume 2., IEEE (2009) 987–990 2.1, 2.2, 3.1.1, 4, 3.1.2, 5, 6

[8] Chang, K., Liu, S., Chu, H., Hsu, J., Chen, C., Lin, T., Chen, C., Huang, P.: The Diet-Aware Dining Table: Observing Dietary Behaviors over a Tabletop Surface. Pervasive Computing **3968** (2006) 366–382 2.1, 2.2, 2.2, 3.3, 10

[9] Chen, Y., Hsieh, M., Wang, C., Lee, H.: RFID-Based Intelligent Systems for Home-Healthcare. In: Consumer Electronics, 2007. ICCE 2007. Digest of Technical Papers. International Conference on, IEEE (2007) 1–2 2.1

[10] Gellersen, H., Beigl, M., Krull, H.: The MediaCup: Awareness Technology embedded in an Everyday Object. In: Handheld and Ubiquitous Computing. Volume 1707., Springer (1999) 308–310 2.2

[11] Kranz, M., Möller, A., Roalter, L.: Robots, Objects, Humans: Towards Seamless Interaction in Intelligent Environments. In: 1st International Conference on Pervasive and Embedded Computing and Communication Systems, SciTePress (2011) 163–172 2.2

[12] Luo, S., Jin, J., Li, J.: A Smart Fridge with an Ability to Enhance Health and Enable Better Nutrition. International Journal of Multimedia and Ubiquitous Engineering **4**(2) (2009) 69–79 2.2, 3.1.2

[13] Schmidt, A., Strohbach, M., Van Laerhoven, K., Friday, A., Gellersen, H.: Context Acquisition Based on Load Sensing. UbiComp 2002: Ubiquitous Computing **2498** (2002) 161–192 2.2

[14] Mankoff, J., Hsieh, G., Hung, H., Lee, S., Nitao, E.: Using Low-Cost Sensing to Support Nutritional Awareness. In: UbiComp 2002: Ubiquitous Computing. Volume 2498., Springer (2002) 371–378 3.1.1, 3.4

[15] Li, B., Hathaipontaluk, P., Luo, S.: Intelligent Oven in Smart Home Environment. In: Research Challenges in Computer Science, 2009. ICRCCS'09. International Conference on, IEEE (2009) 247–250 3.1.1

[16] Huang, Y., Lu, C., Yang, T., Fu, L., Wang, C.: Context-Aware Personal Diet Suggestion System. Aging Friendly Technology for Health and Independence **6159** (2010) 76–84 3.1.2, 7

[17] Chen, J., Chang, K., Chi, P., Chu, H.: A Smart Kitchen to Promote Healthy Cooking (2006) 3.2.1, 8

[18] Chen, J., Chi, P., Chu, H., Chen, C., Huang, P.: A Smart Kitchen for Nutrition-Aware Cooking. Pervasive Computing, IEEE **9**(4) (2010) 58–65 3.2.2, 9, 3.4

Smart Things: Wearables & Clothing

Jürgen Gepperth
juergen.gepperth@mytum.de

January 16, 2012

Abstract

While technology and digital processing of data has affected our daily life in many aspects, data processing and applications embedded in our wearables and clothing are still rare to be found in the real world. On the one hand, wearability, application scenarios and realization are still complicated topics. On the other hand a lot of potential exists in using recent progress in wearable devices in combination with sensors and actors placed in clothing. This paper gives an overview over the state of the art in "Smart Wearables and Clothing" - such as "Wearable Computing" and "Smart Textiles" - and describes common problems as well as approaches to deal with them.

1 Introduction

As part of a fast changing digital world we are confronted with countless information day by day. Embedded systems, computers and other devices are developed to assist and help us to access and process these information. In this context we can imagine a situation in the supermarket. If a product has no ingredient information printed on it, we may use our smartphone to look it up in the internet by scanning the bar code. But would it not be nice to have the information directly displayed in a "Head-Up Display" (HUD) by just holding the product? Therefore we imagine a RFID-system in our watch that scans the product. Our mobile phone, that is wireless connected to the watch, is automatically looking up the information about the product in the internet and transfers the data wireless to our glasses ,our HUD, that presents the information. The second scenario is easier to use, faster and less obtrusive, since the user can see the ingredients without actively looking it up.

“The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.” is the well known statement of Mark Weiser’s “The Computer for the Twenty-First Century” [1].

As part of this idea "Smart Wearables and Clothing" describes the concept of integrating smart and assisting systems, that do not interrupt or disturb us at our activities, in our daily wardrobe and accessories. Technologies like "Wireless Body Area Networks", high performance integrated circuits (IC) and electronic fibres, attached to clothing and wearables, make it possible to collect data from distributed body sensors. Once collected, the data about health condition, movement or the environment can be used to recognize emergencies, activities, social interactions or performance improvements. Combined with actors, optical feedback or other sensing related systems, the technology is capable of notifying, warning and interact with the user.

Nevertheless, smart wearables and clothing are still not very common nowadays. Even with the opportunity of using wireless connections, advanced processing units and improved communication capabilities, modern systems have to deal with several challenges. Placement is limited due to normal movement of the user and the rigidity of components. Energy sources have to be worn in addition or be integrated in wearables or clothing. In order to survive harsh environments or the cleaning process, special materials and constructions for in-woven applications are demanded. Algorithms have to recognize and interpret the activities of the user in order to perform the desired feedback. In addition the functionality has to be available at all times without requiring too much attention of the bearer. And above all, human comfort has to be considered in order to achieve acceptance of the users.

Therefore the aim of this paper is to present recent research and concepts that implement smart wearables and clothing and give an overview about application scenarios and challenges.

2 Smart Things: Wearable & Clothing

2.1 Definition

The first question that arises is: What are "smart wearables" and "smart clothes"?

Since "smart" is a highly relative expression and is used very differently from several authors, we have to define what "smart" means in context of this paper.

"Smart wearables" and "Smart clothing" are both part of "Wearable computing" [2], describing the idea of embedding "computers into anything that we normally use to cover or accessorise our bodies" [2].

For "wearable computing" a set of three criteria was proposed by Steve Mann, a pioneer in the field of wearable computing [2]. He proposed the Eudaemonic-criterion, the Existential-criterion and the Ephemeral criterion. The first describes the components of the system to be part of the bearer. The second postulates the system to be in the users domain, meaning that the system is controlled by the user and not another entity. The third describes the system to be sufficiently fast, so that delays are very small or non-existent. [2]

"Smart clothes" or "Smart textiles", as a part of "Wearable computing", have been defined differently over the years [3]. "Smart" in conjunction with textiles can, for example, range from dirt repellent features to integrated Mp3-Players or electronics, providing advanced communication systems, health monitoring or other assisting systems. Recently the European Committee for Standardization (CEN) has released a definition for "smart textiles" consisting of several levels of "smart" [4]. Therefore the author refers to a level of "smart" used by Van Langenhove, considering "a textile to be smart when it has the capability to measure and/or react" [5].

Based on these definitions we focus on the progress of "smart wearables and clothing" as part of the domain "wearable computing", meaning the integration of electronic components, computers and algorithms in normal wearables and clothing to assist the bearer in his daily life by sensing and reacting. On the basis of the "Operational constancy"-criteria [2], this task should be achieved while being available at all times of usage.

2.2 Applications

The application scenarios of wearable computing are exciting and versatile. Clothes that recognize heart attacks and assist in emergencies, lightening that changes with the mood or a watch that recognizes gestures are only a few of the many possibilities one can think of. Applications for smart wearables and clothing were categorized by several institutions and authors in different ways. As there exists no consistent categorization, the author is using a classification similar to Lucy E. Dunne [6], director of the "Wearable Technology Lab" of the University of Minnesota. Therefore the applications are separated into three categories: "Sensing and data analysis", "Interfaces" and "Functionality and Aesthetics".

2.2.1 Sensing and data analysis

A system that is capable of assisting the bearer depends on input, which can be provided by sensors distributed over the body or in special locations. A temperature sensor, for example, that is positioned on the outside of a jacket can collect data about the ambient temperature. Since this data is not of greater value without interpretation, the data has to be processed or analysed, for example, by a central processing unit integrated in the back of the jacket. If the temperature drops below a configured value the jacket could, for example, heat up integrated heating pads to provide the user with more comfort. The user has not to pay any attention to this process. Pervasive sensing and data analysis is a active research field, that result in applications for healthcare, sports and gaming, and context aware computing.

For example in health monitoring, data are obtained by built-in shirt sensors or straps that are measuring the electrical activity of the heart (electrocardiography; ECG), respiratory activity, oxygen saturation and skin temperature. Two examples are the Chronious project [7] and the Healthwear project [8]. The patient can be monitored continuously and data can be accessed remotely by clinical personal. Data about health status, past condition and emergency alerts enable telemedicine, observation of chronic diseases and preventive care [3]. In addition, collected data could be used for clinical studies or for optimization of treatment concepts.

Another common utilization of sensing and data analysis can be seen in the sport and gaming industry. By using data analysis athletes are able to improve their training or technique. Most of the existing systems are part of researches or are used by professionals. They are expensive and therefore not widespread. One example for research can be given by Holleczek et *al*. [9, 10] who is researching snowboarding assistance systems. This includes movement recognition, positioning, analysis and feedback. Therefore sensor data are obtained by gyroscopes, gps-modules, accelerometers and pressure insoles. The analysis is done by a central processing unit, which is capable of recognizing different turns and movements as well as the users speed and positioning. However, feedback for the rider is planned, but not implemented yet. A corresponding feedback system is researched by Spelmezan et *al*. [11]. By adding vibrotactile actors in different places of the body, they showed that tactile feedback could be used to support users during learning new activities or to improve their skills. In their study snowboarders received tactile feedback in relevant body parts as instructions. Users of the system "perceived and correctly classified our tactile instruction patterns" [11].

In contradiction to the named examples exists a widespread exception for smart wearables in sports. The Nike+ system uses acceleration sensors and GPS modules, which are placed in the shoe respectively in the sportswatch/-band or mobile device (iPhone/iPod) to collect running and tracking information, including speed and position data. They can be used to monitor the personal performance, evaluate improvements, adapt music frequency while running or compare with others via the internet. According to Nike there are recently five million runners using the system. [1]

An important field of research in wearable technology is context aware computing. It describes the idea of computer technology adapting automatically to the situation by analysing the available sensor and data input [2]. Recognizing the users movements, physiological condition and even emotional state enables the device to recognize activities (activity recognition) and tailor its functionality to the situation. Activity recognition can be performed with data from various sources. This includes input from movements of all kind, physiological signals, environmental properties, accessing of nearby data sources or other inputs. For sports, activity recognition is necessary to determine the performance of different actions. The mentioned snowboarder performs different turns, that have to be recognized as such in order to analyse the performance of each turn and deliver a applicable feedback.

Part of the movement based activity recognition is focussing on the eyes of the user. Bulling et *al*. [12, 13], for example, are using eye movement data, recorded with electrooculography (EOG), to determine the users activity. EOG uses the electric potential field of the eye to track its movement. The method can be realised by five electrodes which are, for example, placed in ordinary safety goggles [12]. Bulling et *al*. were able to obtain an average accuracy of 76.1 percent for an example set of five activity classes in a office environment.

Recent conferences like the "International Symposium on Wearable Computers" (ISWC 2010/2011) indicate a new approach by using "Smartphones as Wearables" [2] [14]. Smartphones are seen as an opportunity for smart wearables, especially in activity recognition [15]. They possess open standards for connectivity, like Bluetooth or WiFi, high performance and easier ways to implement software (so called apps). Above all, modern smartphones come with plenty of sensors like GPS, acceleration, microphone and light intensity that can be used to acquire data in addition or solely. Smartphones can access nearby data sources like Wifi and Bluetooth and collect data of the users behaviour and movement. This leads to a pool of collected data that can be used to infer relations, activities and upcoming tasks.

In this context Do and Gatica-Perez [16] proposed a probabilistic relational model to analyse social networks through Bluetooth proximity data. The obtained data of 40 people over a period of one year were used to measure social interaction and infer their purpose, for example, the difference between a work related interaction or a family related one, without the users noticing the proceeding.

In addition to sensors and fast processing units, smartphones are able to communicate with external sources like servers that can provide storage as well as processing or classification services, like for example the ActiServ project [17] that is using classifiers based on fuzzy inference and a back-end server technology. Only few initial movement data are used to set up a basic activity profile. Subsequently new data are evaluated and compared by the server with old data sets in order to improve the activity recognition. The advantage of this system is a higher accuracy over time and adaptation of the system to the users habits. In contrast to this approach Muehlbauer et *al*. [15] showed that it is possible to implement activity recognition user independent. By using a smartphone placed in a commercial arm holster they were able to identify 35 different upper-body exercises among seven users with an accuracy up to 85,1 percent. User independent recognition could be used to provide users with out-of-the-box applications that support, for example, the personal workout. This advantage is especially relevant for commercial usage [15].

2.2.2 Interfaces

In the chapter above we have seen application scenarios which collect data, analyse the user and probably give feedback to the bearer. In order to provide the user with control features or information, interfaces have to be introduced. Common interfaces like keyboards, screens and touchscreens are only applicable for situations where the user is able to draw attention to the device [2, 6]. To ensure that the bearer is barely distracted, novel techniques

[1] Nike, Inc.; FY 2012 Q1 Earnings Release Conference Call Transcript; September 2011; http://investors.nikeinc.com/Theme/Nike/files/doc_financials/2012Q1.pdf (December 2011)

[2] "Table of Contents"; 15th Annual International Symposium on Wearable Computers; http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5959606 (December 2011)

for interaction have to be applied [6]. These approaches include gesture control, haptic signalisation, auditory communication and embedded visual feedback.

One way to implement an interface is to use gesture recognition and haptic signalisation. Physical movement is analysed in order to determine the commands of the user and vibrotactile actors are used to provide information to the user. For example Pasquero et *al*. [18] developed a sensor wristwatch that is connected to a mobile device via Bluetooth for eyes-free gesture control. Gesture control features were implemented to mute the phone, set different ringing profiles or activate feedback features. Their work also included experiments to determine a useful rate for tactual acquired numerical data. In order to determine the number of new e-mails, for example, the user has to perform a gesture that triggers a feedback. Subsequent vibrotactile actors, integrated in the watch, deliver the number of new mails in form of pulses (numerical data). A similar approach for gesture control is used by Lee et *al*. [19]. They improved the predecessor "Gesture Watch" by Kim et *al*. [20] - that is basically a likewise setup as the one by Pasquero *al*. - by adding a push-to-gesture feature. A recognized gesture triggers a confirm request in form of a haptic feedback to avoid unintended activation.

Control features can not only be implemented by arm gesture control, but also through other motions like foot movement. Higuchi and Nojima proposed a "Shoe-shaped i/o interface" [21] that is using foot movement in order to control a projected image on the floor. They showed that an according system could be implemented as guitar-assistance device or for the entertainment industry.

A more natural approach for interfaces are auditory systems. Using speech as input and output has the advantage, that there is no need to learn it separately like special movement patterns, since speech is the normal way for humans to communicate. It provides the user with hands-free control features and information retrieval. In addition, microphones and speakers are very small and inexpensive [22]. A corresponding research for voice recognition in mobile devices was, for example, performed by Lee and Grice [22] in cooperation with Samsung Electronics Co., Ltd., Korea. They investigated design and development criteria for voice-based applications on a mobile device and implemented a prototype for "Palm OS". Speech recognition and interpretation has also been introduced by the software "Siri", which is currently implemented on the "iPhone 4S"[3]. It is based on research from several universities and institutes over several decades and was founded by the "Defense Advanced Research Projects Agency" (DARPA) via SRI International Artificial Intelligence Center [4]. The software is able to interpret speech commands using a back-end-server, that analyses the request and triggers the functionality on the device.

Interfaces in the sense of smart wearables can also be realised as visual based systems. "Head-Mounted Displays" (HMD), "Eyetaps" or "Virtual Retinal Displays" (VRD) provide information and data displayed in the field of view. The information are either projected onto the real image, like in a "Head-Up Display" (HUD), or they are part of a generated image, like in some HMDs. [2]

Concepts and implementation of HUDs, HMDs, Eyetaps and VRDs are already existing in military, automotive and medical applications. Eyetaps, in comparison to the other technologies, have the advantage, that the original scene, available to the eye, is also available to the processing unit. This enables the device to process the same scene as perceived by the user, which is input for the processing unit [2] and enables the device for context aware computing. Recent development also indicates contact lenses as possibility to establish a HUD.

At the University of Washington in Seattle new steps towards a contact lens HUD were recently taken as Pandey et *al*. [23] were able to integrate a remote supplied micro-LED into a contact lens. It is based on the work of Ho et *al*. [24] who developed a process to integrate electronic interconnects into a contact lens. The LED is powered by far-field energy harvesting using "Radio Frequency" (RF) antenna design and a harvesting IC. Although the setup only includes one LED, "contact lenses could be used as a platform on which to build a display" [23]. The research also showed that the LED on this design can be lit up over a distance of 10 cm, without exceeding biological radiation safety criteria. In future designs they hope to achieve more LED pixels and "operating distances over several tens of centimetres" [23].

2.2.3 Functionality and Aesthetics

While most of the research is concentrating on the integration of utilities in smart wearables and clothing, concepts of functionality and aesthetics are often unattended. Changes of the clothes attributes, like colour, shape or lightening, as a reaction to the environment could have "significant implications" for design and aesthetics but is yet "relatively under-investigated" [6]. Examples for adaptive design concepts were introduced by Berzowska and Coetho [25], who implemented memory functionality in combination with lightening and other features into clothing to enrich social interaction. "The Intimate Memory shirt and skirt" [25], for example, recognizes physical intimacy through pressure sensors and a microphone, which subsequently leads to an optical feedback in form of LED enlightening. Over time the illumination fades, indicating the time elapsed since the last intimacy moment.

[3] Apple Homepage: Siri Information; http://www.apple.com/iphone/features/siri.html (December 2011)
[4] SRI International Homepage: Siri Information; http://sri.com/about/siri.html (December 2011)

In context to this example one can easily think of further application scenarios, such as clothing and wearables adapting to mood by observing the galvanic skin response or motorcycle clothing that automatically illuminates in the near of the bike as useful functionality.

2.3 Challenges and Concepts

As seen in the previous chapters, smart wearables and clothes have exiting application scenarios and concepts. But in order to provide usability, several general challenges have to be solved. Sensors and actors need to be placed carefully in order to achieve the desired functionality, not only to avoid constraints or movement limitations, but also to ensure that sensors and actors can work properly. If interaction is part of the design, the developer has to consider novel techniques that are unobtrusive, do not draw too much attention and are natural to the user or at least easy to learn. Besides that, electronic components need energy sources to work. Embedding these sources in mobile environments like wearables and clothing is still one of the most limiting factors [6]. Even with high concentrated batteries, low power circuits, solar fibres or other energy harvesting techniques, its space requirements, energy output and energy distribution are often unfavourable. And above all there is a need for users acceptance, as technical realisation might be antagonistic to human comfort. Social and physical well-being of the user is therefore sometimes omitted [6]. This chapter gives an overview about key problems of smart wearables and clothing while presenting current concepts and researches that address these issues. As commercial realisation is not part of this work, large scale manufacturing will not be discussed. Here the author also refers to a similar structure as L. Dunne [6], including a discussion about "Placement and Integration", "Interaction", "Energy Sources" and "User acceptance".

2.3.1 Placement and Integration

The placement and integration of wearable technology is still an active field of research. Many considerations have to be made in order to preserve functionality of the electronic devices without interfering in the movement or the comfort of the bearer. For the purpose of fulfilling the functionality, the electronic components have to be connected either by wiring or wireless. Wiring can be achieved by laminating or weaving conductive fibres into clothing. Disadvantages of solid wiring normally include limitation of movement through rigidity [26], insulation requirements or the problem of interconnecting distributed sensors over several garments [3]. To address the problem of rigidity and insulation, Zysset et *al*. [26] introduced a method to integrate electronic functionality into the yarn level of textiles. The resulting electronic bus structure was realised with a commercial weaving machine. Advantage of this technique is the maintenance of flexibility while offering the possibility to interconnect components in a piece of clothing. "Wireless Body Area Networks" (WBAN), that were first introduced by Zimmermann et *al*. [27], connect several components by using electric field properties of the human body. In this way a wireless (body area) network of distributed sensors, actors and processing units can be established. Therefore the problems of solid wiring become obsolete. However, there exists the disadvantage that these components also have to possess access to energy sources to work, which will be discussed in one of the next chapters.

The human body is very flexible and offers only few places on the surface for rigid structures like printed circuits boards, processing units or other related devices. Therefore the placement of rigid structures has been investigated by Gemperle et *al*. [28], who studied the movement of the body in order to determine spots with little dynamic that offer space for electronics, which is, for example, the upper arm. Especially processing units, which require a lot of space and are normally rigid, have to be placed in corresponding places in order to avoid movement limitations or cracking of the device.

Another aspect is the functionality of the system, which has also to be considered during the integration process. Sensors and actors often require mechanical coupling or skin contact in order to provide useful functionality [6]. For example an electro-dermal sensor that is used to determine galvanic skin response has to have skin contact for measuring, or a vibrotactile actor, that is placed in the shirt to extend call notifications, only delivers vibration to the bearer if the mechanical coupling is sufficient [6]. In addition, certain factors have to be considered for the usability in the daily life: Clothes are often folded in the wardrobe and need to be washable in the washing machine. For this reason the electronics should either be removable or possess a certain bendability and robustness.

2.3.2 Interaction

Interaction with electronic devices is traditionally performed via keyboard, touchscreen or similar input methods. The result of the interaction is usually displayed on a screen. This concept originated from times of static Human-Computer-Interaction (HCI) where the user was expected to devote his full attention to the device in a constant environment. [2]

In mobile HCI, however, the requirements are shifted. The user has to adapt his attention to different environments and might not be able to devote too much attention to the device [19, 6]. But even today, the majority of mobile platforms, like smartphones, are using the already mentioned type of interaction. In regard to "smart" wearables and clothing, as defined before, this concept is not sufficient. New concepts of HCI have to be applied in order to reduce the amount of attention the bearer has to pay, including a natural or at least easy to learn input method. Mobile HCI could be based on body movement, like gesture control using the arm [19, 20, 18] or other body parts, like the feet [21]. Disadvantage of this approach is that the user has to learn most of the gestures and movements in order to control the device properly. For tactile feedback, the meaning has to be interpreted correctly by the bearer to obtain the correct information. For auditory interfaces, like speech recognition, we have to notice, that they suffer from noise and differences in human speech behaviour [22]. Solutions are based on learning mechanisms or back-end server architectures, which analyse the data remotely. For example the software "Siri", which is installed on the "iPhone 4S" uses these techniques. Besides that, recent progress in eye movement recognition has led to research regarding eye movement as a possibility to interact with mobile devices [29].

2.3.3 Energy Sources

One of the most limiting factors for wearable technology is the energy availability in mobile applications. Depending on the scenario there exist different possibilities to supply the components with energy. Energy storages, like batteries, can be worn in addition or integrated into the garment. Solar fibres can be woven into clothing or the needed energy is harvested, for example, due to movement. [3]

Since the availability of the "smart feature" has to be accessible at all times of usage, sources need to be designed for at least one "application period". For example wearing a shirt for one day indicates at least one day of power supply. The designer also has to consider integration aspects. Wireless sensors in a WBAN also require distributed energy sources since every sensor has to be supplied. Batteries provide high energy concentration on small space but have to be worn in addition. They need to be recharged or changed periodically [3], yet recharging may require additional loading circuitry. However, even small batteries need space, have to be removed for laundry and are normally stiff [6], which is a part of placement problematic, as described above. Storing energy can also be realised by capacitors. For textile applications soft capacitor fibres have been researched by Gu et *al*. [30]. They presented a novel soft capacitor fibre, composed of conductive plastic with higher capacitance than a similar coaxial cable, while being flexible and lightweight. Another concept to obtain energy is by "harvesting". Similar to a dynamo on a bike the system uses the movement of the user to extract energy, which is subsequently used directly or stored by, for example, capacitors. Orecchini et *al*. [31] implemented an active RFID tag integrated into a shoe, which was supplied by harvesting energy with a piezoelectric element. The element was placed into the heel of the shoe in order to harvest energy on foot strikes. The system provided a loading circuit with enough energy to transmit data over the RFID tag. Moreover, energy supply can potentially be provided by solar power. Current research in solar cell fibres indicate a potential usage as in-woven energy source [32]. Wang and Liu [33] investigated solar clothing in regard to placement and material. They showed that flexible solar cells can be positioned at the body without reducing the wearing comfort. As this technique is dependent on light intensity, the greatest shortcoming is energy availability during the nights or indoors. Storing the energy from the day results in batteries or other storages, that were considered before. Improvements to this approach can be done by increasing the photoelectric conversion rate and further investigation of embedded storage technologies like the soft capacitor fibres mentioned before [33].

2.3.4 User Acceptance

A critical barrier for smart wearables and clothing is the acceptance of the user. Accessories and clothing should not only be comfortable and functional, but also integrate into the users natural appearance. They are a reflection on the users wish to express theirself and are also a social representation [6]. Comfort in regard to textiles can be achieved by conductive and functional fibres [33]. As rigid components require an elaborated placement [28], the functionality of the device should be tailored to support the user without interfering too much with his activities and interaction must be intuitive and easy to learn. Another part of the functionality is the handling of the wearables and clothing in the daily life. Removing all electronic components of the clothing prior to washing is impractical and leads to displeasure of the user. The same can be imagined, if the user has to change batteries or reload his wearable technology repeatedly [6]. Last but not least, the design of wearables and clothing is also relevant, as it has impact on the users identity. Wearables and clothes are perceived as part of the person and not as an external entity [6]. Therefore the design requirements are linked with fashion trends and can not be ignored by the developer.

3 Conclusions

In this seminar paper we have shown the diversity of application scenarios and existing challenges for smart wearables and clothing. Therefore, we had to define what "smart" means in this context and present recent research as well as basic information and problems. Opportunities for wearable technology exist by using advanced materials, new interfaces, better algorithms and modern devices.

Conductive, capacitive and solar fibres, that are woven into the yarn level of textiles can be used to interconnect components and generate or store energy, while being still flexible, comfortable and lightweight. WBANs can be used to connect sensors, actors and other components across the whole body, assuming they have access to energy sources. New interfaces like gesture control, tactile feedback, speech recognition or HUDs can provide the user with control features and information. In order to perform an applicable action, algorithms have to determine the users activities and needs. Since smartphones posses fast processing units and communication features, it can be observed that they are used more often to achieve this task. They can be seen as "smart wearables" in a wider sense and could potentially be powerful tools in combination with sensors and actors embedded in clothing.

Challenges for wearable technology include integration issues for processing units, sensors, actors and wiring as well as the issues of energy supply, functionality and user acceptance. They are forming key barriers for the development and are persistent attendants on the way to true usability.

Once these problems are solved, there is no doubt that smart wearables and clothing will enrich our daily life in many facets.

References

[1] Weiser, M.: The computer for the 21st century,. Scientific American 256(3): 66-75 (1991) 1

[2] Posland, S.: Ubiquitous Computing - Smart Devices, Environments and Interactions. Wiley (2009) 2.1, 2.2.1, 2.2.2, 2.3.2

[3] Van Langenhove, L.: Smart textiles for medicine and healthcare: materials, systems and applications. CRC Press (2007) 2.1, 2.2.1, 2.3.1, 2.3.3

[4] Committee for Textiles, N....A.: Textiles and textile products - smart textiles - definitions, categorisation, applications and standardization needs; cen/tr 16298:2011. Technical report, European Committee for Standardization (2011) 2.1

[5] Van Langenhove, L., Hertleer, C., Schwarz, A.: Smart textiles: An overview. Intelligent Textiles and Clothing for Ballistic and NBC Protection (2012) 119–136 2.1

[6] Dunne, L.: Smart clothing in practice: Key design barriers to commercialization. Fashion Practice - The Journal of Design Creative Process & the Fashion Industr **2**(1) (May 2010) 41–66 2.2, 2.2.2, 2.2.3, 2.3, 2.3.1, 2.3.2, 2.3.3, 2.3.4

[7] Rosso, R., Munaro, G., Salvetti, O., Colantonio, S., Ciancitto, F.: Chronious: An open, ubiquitous and adaptive chronic disease management platform for chronic obstructive pulmonary disease (copd), chronic kidney disease (ckd) and renal insufficiency. In: Proc. Annual Int Engineering in Medicine and Biology Society (EMBC) Conf. of the IEEE. (2010) 6850–6853 2.2.1

[8] Paradiso, R., Alonso, A., Cianflone, D., Milsis, A., Vavouras, T., Malliopoulos, C.: Remote health monitoring with wearable non-invasive mobile system: The healthwear project. In: Proc. 30th Annual Int. Conf. of the IEEE Engineering in Medicine and Biology Society EMBS 2008. (2008) 1699–1702 2.2.1

[9] Holleczek, T., Zysset, C., Arnrich, B., Roggen, D., Troster, G.: Towards an interactive snowboarding assistance system. In: Proc. Int. Symp. Wearable Computers ISWC ’09. (2009) 147–148 2.2.1

[10] Holleczek, T., Schoch, J., Arnrich, B., Troster, G.: Recognizing turns and other snowboarding activities with a gyroscope. In: Proc. Int Wearable Computers (ISWC) Symp. (2010) 2.2.1

[11] Spelmezan, D., Jacobs, M., Hilgers, A., Borchers, J.: Tactile motion instructions for physical activities. In: Proceedings of the 27th international conference on Human factors in computing systems. CHI ’09, New York, NY, USA, ACM (2009) 2243–2252 2.2.1

[12] Bulling, A., Roggen, D., Troester, G.: What’s in the eyes for context-awareness? Pervasive Computing, IEEE **10**(2) (2011) 48–57 2.2.1

[13] Bulling, A., Ward, J.A., Gellersen, H., Troester, G.: Eye movement analysis for activity recognition using electrooculography. Pattern Analysis and Machine Intelligence, IEEE Transactions on **33**(4) (2011) 741–753 2.2.1

[14] Smailagic, A., Kenn, H.: Pervasive computing, ieee. Issue: 4 **10**(4) (2011) 96–100 2.2.1

[15] Muehlbauer, M., Bahle, G., Lukowicz, P.: What can an arm holster worn smart phone do for activity recognition? In: Proc. 15th Annual Int Wearable Computers (ISWC) Symp. (2011) 79–82 2.2.1

[16] Do, T.M.T., Gatica-Perez, D.: Groupus: Smartphone proximity data and human interaction type mining. In: Proc. 15th Annual Int Wearable Computers (ISWC) Symp. (2011) 21–28 2.2.1

[17] Berchtold, M., Budde, M., Gordon, D., Schmidtke, H.R., Beigl, M.: Actiserv: Activity recognition service for mobile phones. In: Proc. Int Wearable Computers (ISWC) Symp. (2010) 2.2.1

[18] Pasquero, J., Stobbe, S.J., Stonehouse, N.: A haptic wristwatch for eyes-free interactions. In: Proceedings of the 2011 annual conference on Human factors in computing systems. CHI '11, New York, NY, USA, ACM (2011) 3257–3266 2.2.2, 2.3.2

[19] Lee, S.C., Li, B., Starner, T.: Airtouch: Synchronizing in-air hand gesture and on-body tactile feedback to augment mobile gesture interaction. In: Proc. 15th Annual Int Wearable Computers (ISWC) Symp. (2011) 3–10 2.2.2, 2.3.2

[20] Kim, J., He, J., Lyons, K., Starner, T.: The gesture watch: A wireless contact-free gesture based wrist interface. In: Proc. 11th IEEE Int Wearable Computers Symp. (2007) 15–22 2.2.2, 2.3.2

[21] Higuchi, H., Nojima, T.: Shoe-shaped i/o interface. In: Adjunct proceedings of the 23nd annual ACM symposium on User interface software and technology. UIST '10, New York, NY, USA, ACM (2010) 423–424 2.2.2, 2.3.2

[22] Lee, K.B., Grice, R.A.: The design and development of user interfaces for voice application in mobile devices. In: Proc. IEEE Int. Professional Communication Conf. (2006) 308–320 2.2.2, 2.3.2

[23] Pandey, J., Liao, Y.T., Lingley, A., Mirjalili, R., Parviz, B., Otis, B.: A fully integrated rf-powered contact lens with a single element display. Biomedical Circuits and Systems, IEEE Transactions on **4**(6) (2010) 454–461 2.2.2

[24] Ho, H., Saeedi, E., Kim, S.S., Shen, T.T., Parviz, B.A.: Contact lens with integrated inorganic semiconductor devices. In: Proc. IEEE 21st Int. Conf. Micro Electro Mechanical Systems MEMS 2008. (2008) 403–406 2.2.2

[25] Berzowska, J., Coelho, M.: Memory-rich clothing. In: CHI '06 extended abstracts on Human factors in computing systems. CHI EA '06, New York, NY, USA, ACM (2006) 275–278 2.2.3

[26] Zysset, C., Cherenack, K., Kinkeldei, T., Troster, G.: Weaving integrated circuits into textiles. In: Proc. Int Wearable Computers (ISWC) Symp. (2010) 1–8 2.3.1

[27] Zimmerman, T.G., Smith, J.R., Paradiso, J.A., Allport, D., Gershenfeld, N.: Applying electric field sensing to human-computer interfaces. In: Proceedings of the SIGCHI conference on Human factors in computing systems. CHI '95, New York, NY, USA, ACM Press/Addison-Wesley Publishing Co. (1995) 280–287 2.3.1

[28] Gemperle, F., Kasabach, C., Stivoric, J., Bauer, M., Martin, R.: Design for wearability. In: Proc. Digest of Papers Wearable Computers Second Int. Symp. (1998) 116–122 2.3.1, 2.3.4

[29] Bulling, A., Gellersen, H.: Toward mobile eye-based human-computer interaction. Pervasive Computing, IEEE **9**(4) (2010) 8–12 2.3.2

[30] Gu, J.F., Gorgutsa, S., Skorobogatiy, M.: Soft capacitor fibers using conductive polymers for electronic textiles. Smart Materials and Structures **19**(11) (2010) 115006 2.3.3

[31] Orecchini, G., Yang, L., Tentzeris, M.M., Roselli, L.: Wearable battery-free active paper-printed rfid tag with human-energy scavenger. In: Proc. IEEE MTT-S Int. Microwave Symp. Digest (MTT). (2011) 2.3.3

[32] Zou, D., Wang, D., Chu, Z., Lv, Z., Fan, X.: Fiber-shaped flexible solar cells. Coordination Chemistry Reviews **254**(9-10) (2010) 1169 – 1178 2.3.3

[33] Wang, X., Liu, Z.: Development of comfort solar clothing. Advanced Materials Research **113** (2010) 698–701 2.3.3, 2.3.4

].

Smart Things - Assistance for Ambient Assisted Living

Matthias Kaufmann
matthias.kaufmann@mytum.de

January 16, 2012

Abstract

Ambient assisted living (AAL) is a possible solution for the social challenge of the increasing number of elderly caused by the demographic change, the lack of qualified nursing staff, exploding health care costs and a changing society. This paper gives an overview on assistance solutions for AAL. The systems will be differentiated by several aspects, like sensor and actuator type, rule-based or context-aware decision processes, energy consumption and communication type and is analysed from different points of view. Existing living labs give feedback about real life, human beings, and acceptance of and problems with these systems. The hardware for such systems will be described from the bottom up starting with a tabular overview of sensors and actuators and will be continued by several hardware platforms. On top of these platforms the middleware – a very important component including the core logic – combines different hardware platforms hiding complexity as well as drivers and offers one abstraction layer for programming, interaction, and user interfaces. In addition to technical problems, also human, cultural, ethical and social aspects are important. Finally, several scenarios for different rooms and situations are shown to demonstrate the potential of assistance for AAL.

1 Introduction and Motivation

This paper gives an overview of assistance systems for ambient assisted living (AAL) in the context of *Smart Things*.

"The general goal of ambient assisted living solutions is to apply ambient intelligence technology to enable people with specific demands, e.g. handicapped or elderly, to live in their preferred environment longer" [1]. "This includes increasing their autonomy, enhancing their security, and preventing isolation by staying socially connected" [2]. Besides the necessary technical components like sensors, actuators, hardware platform, or middleware and the wired or wireless communication infrastructure, assistance for AAL aims in particular at the assistance scenarios and use cases for elderly or handicapped people. Therefore, the whole issue of AAL and the resulting assistance scenarios are much more than the sum of mere technical components. Thus, different objects can be regarded as *Smart Thing* in the context of the *Internet of Things*. In addition, AAL is related to the topics of *Pervasive Computing* and *Ubiquitous Computing* and hence they have a lot in common, e.g. the basic technical concepts, but they vary in scenarios, target groups and especially in the requirements.

According to the *World Population Prospects, the 2010 Revision* of the United Nations, Department of Economic and Social Affairs, Population Division, Population Estimates and Projections Section[1] the demographic change will cause more and more people in the generation of 65+. Figure 1 shows the development of the demographic change during the years 1960, 2010 and 2060. While the increase of elderly people happens all over the world, this development is especially rapidly in the so called *more developed regions* that comprise Europe, Northern America, Australia/New Zealand and Japan. In addition to the increase of the 65+ population, "structural [...] and social trends tend towards [...] single households, which have dramatic effects on public and private health care, emergency medical services, and the individuals themselves" [1]. Moreover, a lack of qualified nursing staff becomes obvious. Having these developments in mind, AAL is a possible solution for this issues. People can stay in their well known environment while, for example, tele health care [3] can reduce the necessary number of qualified nursing staff and reduce costs.

Discussing assistance for AAL, one has to keep in mind that this ongoing research topic is multidisciplinary: "The challenges of facilitating independent living at home with integrated sets of methods and technologies require a holistic and interdisciplinary approach, including experts from the domains of medical science, architecture, design, robotics, computer science, electrical engineering, human-computer interaction and the housing industry" [4].

[1] http://esa.un.org/unpd/wpp; last visited: 27.12.2011, 16:51

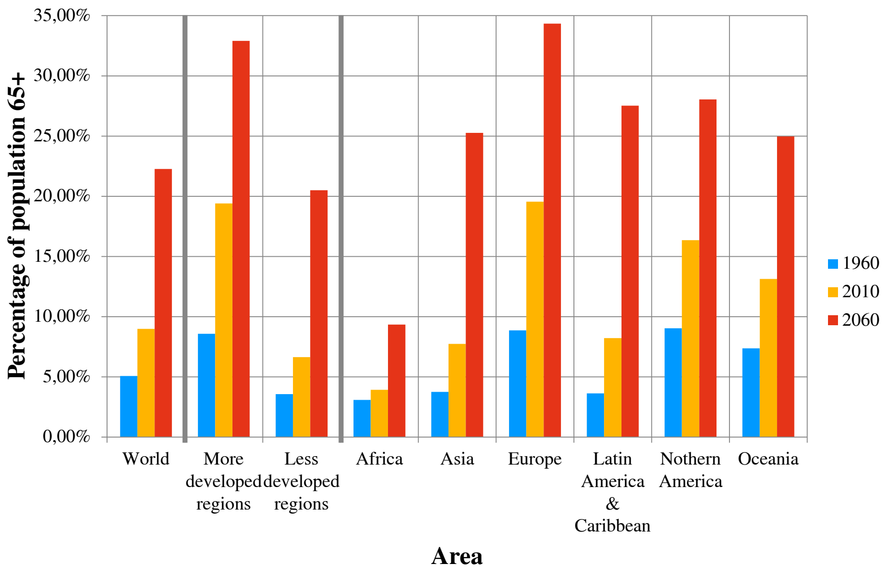


Figure 1: Development of the share of the 65+ population over the years 1960, 2010 and 2060: The development is shown for the whole world, more developed regions (comprise Europe, Northern America, Australia/New Zealand and Japan), less developed regions (comprise all regions of Africa, Asia [excluding Japan], Latin America and the Caribbean plus Melanesia, Micronesia and Polynesia), and the different continents. The figure uses data of the World Population Prospects, the 2010 Revision of the United Nations, Department of Economic and Social Affairs, Population Division, Population Estimates and Projections Section

The paper is organized as follows: Section 2 describes related work with a variety of system differentiations and existing living labs. In section 3 the necessary hardware including sensors, actuators, hardware platforms, middleware and different robotic systems is described. In section 4 human, cultural, ethical and social aspects concerning AAL are discussed. Section 5 will show different scenarios. In section 6 a conclusion and an outlook are given.

2 Related Work

This section takes a closer look at work related to the topic of AAL and describes the basics and technical background. It starts with a variety of system differentiations, has a look at several existing living labs and ends on modularity, interoperability, and standards.

2.1 System Differentiation

As shown in [1] and in figure 2, the entire domain of home care systems can be split into three parts: *Emergency Assistance*, *Autonomy Enhancement*, and *Comfort*. Depending on the aim of the system and the target group, different parts or combinations take center stage. While *Smart Living* or *Smart Home* concepts mostly focus on *Comfort*, AAL puts *Autonomy Enhancement* and especially *Emergency Assistance* into the focus [2].

Besides active parts like sensors, actuators, or the core logic, also passive aspects like architecture and the design of the system are considered. “A carefully chosen and aware combination of both passive and active systems significantly enhances the ability of environments to holistically address geriatric challenges” [4]. Within the field of active systems an additional differentiation between reactive and proactive systems can be made. While the former can only *re-act* after sensing the environment or receiving new information (e.g. calling ambulance after person felt), the latter have (heuristic) algorithms to forecast situations and can *pro-act* before these situations happens (e.g. advising person to sit down and call a doctor when detecting weak blood pressure and shaky movement) [5].

Context-awareness “enables the system to recognize some mid-term or long-term trends and short-term deviations from the usual daily routine. Through enhanced self-awareness[,][...] context-awareness [and identification of intuition] the systems are able to adapt themselves to changing situations (e.g., changing capabilities of the users). Thus, they can render their services at a new level of experience and enhance the quality of service” [1].

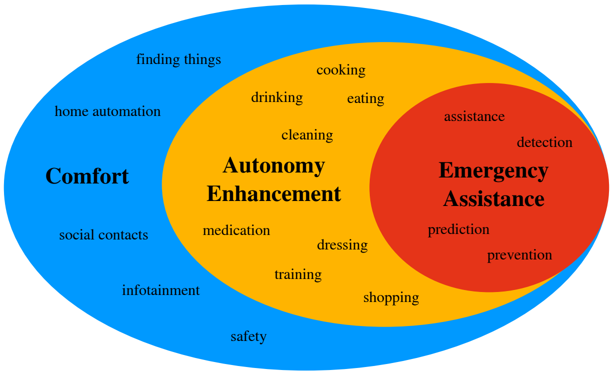


Figure 2: Home care system domain: While smart living concepts focus mostly on comfort, AAL solutions put autonomy enhancement and especially emergency assistance into the focus. Figure adapted from [1]

Comparing context-awareness with rule based decisions it becomes obvious that "context-awareness requires more than the mere connection of inputs and outputs, and more application scenarios do require more specialized middleware" [6]. Nevertheless, context-awareness has already found its way to the *Player* middleware [7] and different kitchen utilities [8].

AAL can also be perceived as a robotic system. The range starts with humanoid robots and goes via mobile and smart items to immobile robots – often called "ImmoBots" – installed into equipment and furnishings. The acceptance of the different robotics is mainly a question of culture: While especially Japanese people accept humanoid robots, the European elderly suspect them and prefer immobile solutions. Different robotic systems and cultural aspects are discussed in more detail in section 3.4 and 4.

Thinking about the installation of ambient assisted equipments in apartments and houses, there are two fundamental approaches: AAL can be integrated into the planing, simulation and construction phase of new constructed apartments and houses or it needs to be installed later on into already existing homes. The second one is more complex as people are already living there and existing furniture has to be considered as well. There has been a lot of research on different solutions of integrating AAL into existing environments like *Service Cores*, *Service Walls*, and *Service Rooms* [3] [5] [9] [4], which are discussed in more detail in section 3.4.

Besides the middleware including the logic and therefore the artificial intelligence, hardware platforms and user interfaces, many different sensors and actuators are needed for AAL solutions. Distributed devices need to communicate wired or wireless with each other using client-server networks, peer-to-peer communication or a mixture of both. Using wireless communication, sensors and actuators can be installed more easily as no wire is needed, but the reliability of data transmission needs to be ensured. [10] compares different wireless communication standards such as WiFi, ZigBee and a proprietary device having the power consumption in mind. In addition to external power supply and batteries, energy harvesting can be used to be more independent in placing sensors. Energy harvesting, e.g. EnOcean[2], uses the environmental factors like pressure, light or temperature change to generate energy. This becomes very interesting when one thinks about sensors not installed in the environment but placed directly on people, like blood glucose measurement devices.

Finally, different points of view need to be considered: The system should be easy to use, understandable and helpful for the *end user*. *Professional users* like nursing staff and doctors need the possibility to exchange data easily and comfortably and to customize the behaviour of the system. The *technical point of view* has reliability, standardized components and interfaces as well as expandability in mind.

2.2 Living Labs

To test intelligent environments for private applications, different demonstrators – so called *Living Labs* – exist. The idea of these labs is to have a real environment to bring research and innovation together, to demonstrate different scenarios, and to have a showcase for potential customers and companies. One drawback of living labs is the fact, that they focus more on new houses and environments rather than on the possibility of upgrading existing homes with AAL.

One example is *House_n*[3] of the Massachusetts Institute of Technology which is a research and demonstration platform for all topics concerning houses of the future. Besides AAL in general, this includes also an open source build alliance, context-sensitive measurement of physical activity, and PlaceLab to only list a couple of

[2]http://www.enocean.com/en/energy-harvesting-wireless; last visited: 30.12.2011, 15:21

[3]http://architecture.mit.edu/house_n; last visited: 30.12.2011, 17:27

projects. "House_n research is focused on how the design of the home and its related technologies, products, and services should evolve to better meet the opportunities and challenges of the future"[4]. With *PlaceLab*, "a highly instrumented apartment-scale shared research facility where new technologies and design concepts can be tested and evaluated in the context of everyday living. [...] [Its idea is] to systematically test and evaluate strategies and technologies for the home in a natural setting with volunteer occupants."[5]. Other examples are the *Aware Home*[6] of the Georgia Institute of Technology and the Philips *ExperienceLab*[7]. The Toyota *Dream House PAPI*[8] focuses more on prefabricating houses and the Fraunhofer *inHaus Zentrum*[9] contains two houses: The *inHaus1*[10] is an renovated house concentrating on energy saving assistance systems in private houses, the *inHaus2*[11] on intelligent room and building systems (Smart Buildings).

2.3 Modularity and Interoperability

The idea of *Integration of Everything* in AAL and the related topics *Smart Things* and *Internet of Things* necessitate to co-operate with different companies' interfaces and components.

Therefore, modularity is an important factor: Having modules enabling a specific functionality, these modules can be modelled, pre-installed, and updated by the manufacturer but also configured easily by end-users. Modularity can also parallelize system development – including visualization, simulation, information flow, and even physical space [4] – to reduce time as well as costs [3].

On the other side, interoperability and standards are needed to avoid isolated applications. The AAL congress[12] of the German Federal Ministry of Education and Research and the VDE Association for Electrical, Electronic & Information Technologies has started the *Roadmap AAL Interoperabilität* (engl. roadmap AAL interoperability) where experts should develop concepts for implementing interoperable AAL components and systems [11].

3 Hardware

This section describes the necessary hardware for AAL solutions from the bottom up starting with the sensors and actuators and going via hardware platforms and middleware to entire robotic systems.

3.1 Sensors and Actuators

The basic hardware AAL systems need are sensors and actuators as they are interacting with the environment.

Those can be classified by their intended purpose, standards and degree of virtualization and digitalization. In general, sensors are measuring physical dimensions and converting them into digital signals while actuators are translating digital signals into physical actions.

In the context of AAL, sensors and actuators are interesting in the meaning of which information is provided and which action can be executed. Table 1 gives an overview of different sensors, their use case as well as the type and degree of virtualization as a continuum. Table 2 lists some actuators concerning the same details as the sensor table. Both tables contain only some examples and are without requirement on completeness.

3.2 Hardware Platforms

The hardware platform converts the sensor signals into digital information and relays them to the middleware. In the same manner, the hardware platform receives commands from the middleware and controls the actuators accordingly. There are several existing platforms like *Arduino*[13], *BeagleBoard*[14], and *pandaboard*[15]. Most of them are widespread, cheap and often even the hardware is open source. In addition, there are some specialized home automation systems available like *FS20- /FHT- /HMS-System*, *Moeller XComfort*, *BatiBus*, and *KNX-Standard*.

[4] http://architecture.mit.edu/house_n/intro.html; last visited: 31.12.2011, 12;54
[5] http://architecture.mit.edu/house_n/projects.html; last visited: 31.12.2011, 12:59
[6] http://awarehome.imtc.gatech.edu; last visited: 30.12.2011, 17:30
[7] http://www.research.philips.com/focused/experiencelab.html; last visited: 31.12.2011, 13:06
[8] http://toyotahome-net.com/papi; last visited: 12.12.2011, 13:10
[9] http://www.inhaus.fraunhofer.de/en; last visited 31.12.2011, 15:20
[10] http://www.inhaus.fraunhofer.de/en/discover_inHaus/inHaus1; last visited 31.12.2011, 15:31
[11] http://www.inhaus.fraunhofer.de/en/discover_inHaus/inHaus2; last visited: 31.12.2011, 15:34
[12] http://www.aal-kongress.de; last visited: 31.12.2011, 17:46
[13] http://www.arduino.cc; last visited: 31.12.2011, 19:10
[14] http://beagleboard.org; last visited: 31.12.2011, 19:20
[15] http://pandaboard.org; last visited: 31.12.2011, 19:25

Sensor	Application (example)	Type	Degree of virtualization
Infrared/Ultrasonic Sensor	Movement Detection	Basic Sensor	Physical Sensor
Temperature Sensor	Room Temperature Regulation	Basic Sensor	⇑
Ligthning Sensor	Light Management	Basic Sensor	‖
Smoke/Fire Detector	Emergency System	Basic Sensor	‖
Microphone	Voice Interaction	Basic Sensor	‖
Video Camera	Movement/Activity Detection	Basic Sensor	‖
Glucose Meter	Glucose Level	Health Sensors	‖
Breathing Sensor	Vital Parameter Monitoring	Health Sensor	‖
Pulse Sensor	Vital Parameter Monitoring	Health Sensor	‖
Blood Pressure Sensor	Vital Parameter Monitoring	Health Sensor	‖
Incontinence Detector	Disease Detection	Health Sensor	‖
RFID	Object Detection	Object Sensor	‖
Bar-code	Object Detection	Object Sensor	‖
Toilet Flush Sensor	Toilet Usage Frequency	Environmental Sensor	‖
Fridge Opening Detector	Eating/Drinking Frequency	Environmental Sensor	‖
Hot Plate	Warning System	Environmental Sensor	‖
Intelligent Floor	Emergency Case (Fall)	Higher Complexity Sensor	‖
People Recognition	Social Context	Higher Complexity Sensor	⇓
RSS Feed	Weather Conditions	Higher Complexity Sensor	Digital/Logical Sensor

Table 1: Overview of some sensors, their use case as well as the type and degree of virtualization (continuum)

Actuator	Application (example)	Type	Degree of virtualization
Motor	Automatic Door	Basic Actuator	Physical Actuator
Switch	Device turn-on Procedure	Basic Actuator	⇑
Heating Installation	Temperature Control System	Living Comfort Actuator	‖
Lightning	Light Management	Living Comfort Actuator	‖
Air Moistening	Air Quality	Living Comfort Actuator	‖
Sound Wave Generator	Loudspeaker	Audio Device	‖
Image Generator	Television	Video Device	‖
Alarm System	Automatic Emergency Call	Higher Complexity Actuator	‖
Calendar	Reminder of Medication	Higher Complexity Actuator	‖
Social Network	Facebook, Google+, Twitter	Higher Complexity Actuator	⇓
Task Guide	Guide for Tea Cooking	Higher Complexity Actuator	Digital/Logical Actuator

Table 2: Overview of some actuators, their use case as well as the type and degree of virtualization (continuum)

3.3 Middleware

The basic idea of middleware is to hide the different hardware controls, drivers and communication systems and therefore to offer one common abstraction layer for programming and configuration. For programming it is no longer necessary to know exactly which hardware is used or how the specific hardware is controlled. Instructions and informations are exchanged by a defined abstract layer and are translated by the middleware for the specific purpose [4][6][12]. Figure 3 shows the idea of middleware.

As the middleware contains the central control of the AAL equipment and thus the core logic, programming needs to be done only once while consistent user interfaces can be used. Normally fuzzy logic, ranking of several sensor data and metrics are used to determine the most accurate action. Additionally it needs to take care of data privacy and high priority emergency cases.

There are many existing middleware solutions with different aims like the *i2home* project's "*Universal Control Hub* (UCH)[17] that supports up-to-date prominent communication standards and allows for controlling multiple devices at the same time" [2] and "promotes the concept of pluggable user interfaces, that is, the abstract interface being rendered on a controller" [14]. Another example is "*GAIA* [...] a distributed middleware infrastructure

[16] http://upload.wikimedia.org/wikipedia/commons/2/20/Middleware_Schema.svg; last visited 21.12.2011 19:17

[17] "The Universal Control Hub (UCH) is a gateway based architecture for implementing the Universal Remote Console (URC) framework" [13] specified in in ISO/IEC 24752

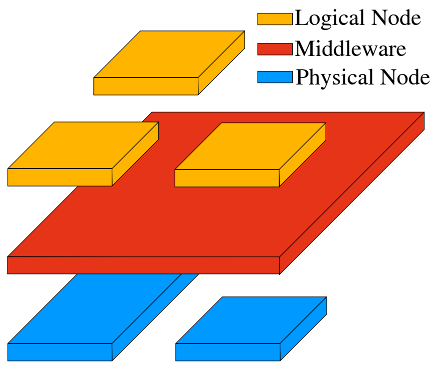


Figure 3: Basic idea of middleware: Hiding different hardware, drivers and communication systems (physical nodes) to offer one common abstraction layer (middleware). On top of the middleware, consistent programming and user interfaces can be used (locigal nodes). Figure adapted from[16]

that coordinates software entities and heterogeneous networked devices contained in a physical space. [...] The main contribution of Gaia is not in the individual services, but indeed, in the interaction of these services" [15]. "MundoCore is a communication middleware specifically designed for the requirements of pervasive computing. To address the high degree of heterogeneity of platforms and networking technologies, it is based on a microkernel design, supports dynamic reconfiguration, and provides a common set of APIs for different programming languages [...] on a wide range of different devices" [16]. The list of published middleware or operating systems for AAL or pervasive computing can be continued with Aura, COBAR, DCOM, JavaRMI, RCSM, and the Robot Operating System (ROS) but will still not be complete. The main problems of most middleware systems are availability, no or limited reuse, missing community support and short life cycles [6]. Therefore, [6] "investigated [...][a] available midddleware especially with a focus on community support, maturity, extent of supported hardware and software and management architecture" [6] build up on the Robot Operating System (ROS). In general, "middleware [should be considered] as an extremely important issue towards deployable and working systems" [3][4].

3.4 Robotics

Using sensors and actuators, hardware platforms, and middleware entire robotic systems with artificiality intelligence can be built. The range of different robotics starts with *Mobile Robots* via *Semi-Mobile Robots* to *Immobile Robots* as mentioned in section 2.1. The acceptance and propagation of different robots is mostly a question of culture. This issue is discussed later on in section 4.

Mobile Robots are mostly built in a humanoid style and can execute many tasks that otherwise would have to be executed by real persons, for example, serving food, cleaning dishes, or even communicating in a natural way. A selection of examples for such humanoid robots are the NEC *PaPeRo* [18], the HITACH *EMIEW*[19] and the *EMIEW 2*[20], the Mitsubishi *wakamaru*[21], and the Panasonic *HOSPI-Rimo*[22] with many different concepts, ideas, target groups and goals. Other mobile robots are built for a specific purpose in a non-humanoid style, like well known vacuum cleaner robots, e.g. the iRobot Corporation's *Roomba*[23].

Semi-Mobile Robots are mobile objects and items with own intelligence offering additional values and services. Many examples of these mobile robots can be found in kitchens, like *sensor-enriched knifes* [8][7], *intelligent spoons* [24] or *augmented cutting boards* [8][7].

So far, mobile robots as well as semi-mobile robots are useful and intelligent but in some way isolated. To obtain more values, services, and a higher degree of overall intelligence, both of them need to be used in smart environment which leads us to the *Immobile Robots (ImmoBots)*. These robotic systems are installed into the environment like, for example, kitchens, beds, bathrooms, or living rooms. They are mostly hidden and thus not noticed immediately. The problem of these ImmoBots is the installation: While constructing new apartments or houses the ImmoBots can be considered, planed and installed from bottom up, the later installation into existing

[18] http://www.nec.co.jp/products/robot/en/index.html; last visited 01.01.2012, 18:44
[19] http://www.hitachi.com/rd/research/robotics/emiew1_01.html; last visited 01.01.2012, 19:00
[20] http://www.hitachi.com/rd/research/robotics/emiew2_01.html; last visited 01.01.2012, 19:05
[21] http://www.mhi.co.jp/en/products/detail/wakamaru.html; last visited 01.01.2012, 19:17
[22] http://panasonic.co.jp/corp/news/official.data/data.dir/en110926-2/en110926-2.html; last visited 01.01.2012, 19:23
[23] http://www.irobot.com; last visited 07.01.2012, 20:11
[24] http://www.media.mit.edu/ci/projects/intelligentspoon.html; last visited 01.01.2012, 19:31

living spaces is more complex, costly and time consuming [9]. In addition, exchanging or updating ImmoBot systems or parts of them can also get more complicated. Therefore, three different ImmoBots, focusing on later integration into existing houses or apartments and "designed as a »compact« alternative to fully networked homes and houses" [3], have been proposed [3][5][9][4]: The *Service Core* "is placed in the middle of a room, house or flat and organizes customized functions as kitchen, bath, and/or sleeping circularly. Customers are free to choose from a pre-defined set of functionalities, smart appliances, sensors and interface systems to equip their Service Core in order to meet their preferences and assist their daily activities" [9]. "Prefabricated *Service Walls* melts usually separated systems as »wall« and »assistive furniture« into one system combining them with mechatronic sub-systems, sensors, actuators and ambient intelligence. [...] The Service Wall has been designed especially for people with mobility complaints and which are not or no longer able to move by themselves from one location to another and thus perform actions as cooking, washing or other daily activities" [5]. The third type is a room-in-room solution called *Service Room* which can be installed within existing buildings. It "is designed for people with severe motor and cognitive disabilities [...][and] has the function of a very compact hospital or care facility deployed at home. [...] Within the constraint of this compact unit a minimum of motion and/or movement is needed to perform daily tasks. Bath appliances, kitchen appliances and resting place are distributed within a compact space thus reducing physical and cognitive stress for patients with highly constraint activities" [9].

4 Human, Cultural, Ethical, and Social Aspects

Besides technical issues, also human, cultural, ethical and social aspects need to be considered, especially when elderly or handicapped people are addressed. All different systems should put the human at the center and concentrate on what is helpful and needed rather than what is technically possible. This would reduce the danger of a technical overkill for elderly.

With elderly or handicapped people as target group, especially the user interfaces need to be considered. As shown in [1], future user interfaces have to fulfill some requirements like adaptivity, natural and anticipatory human-computer interaction, and heterogeneity. Therefore, one needs to focus on usability for elderly people, as most important stakeholders, and late learners [1]. This can, for example, be achieved with pluggable and hence exchangeable user interfaces [14] like the *Universal Control Hub* [13]. In general, user interfaces should be isolated from the rest of the system enabling people to select their preferred interface including custom individualizing. Different types of human-computer interaction should also be taken into account during the development process [3] to reduce the low acceptance of health care assistance solutions [17].

Considering cultural aspects in particular the acceptance of different robotic systems becomes important. European people relate robots to "dull, dirty and dangerous tasks" [4]. Therefore, robotic systems should be invisible and operate in the background. Mobile or humanoid robots are rarely accepted. In contrast, Asian people, especially the Japanese, are used to mobile as well as humanoid robots. These systems are widely accepted and robotics do not need to stay in the background but can operate visible. This includes also direct interaction.

Ethical aspects should not only be considered during usage but already during planing and construction phases. An ethical guideline for AAL has been pronounced and could be used as a check list [18]. The ethical guideline builds on six ethical principles: *Privacy* (control of personal information and protect of own space), *Autonomy* (decision what technology to use), *Integrity and Dignity* (respect of individuals and protect of dignity of human beings), *Reliability* (protection against threat of physical or mental health), *E-Inclusion* (access for all user groups), and *Role of Technology in the Society* (increase of living quality, no harm to anyone) [18].

Another aspect is a social one. Elderly "are becoming passive consumers of the societal services rather than active creators. In so doing, they also lose their self-esteem. [...] A home care system with human participation could help encourage the elderly people to actively participate in group activities as peer participants, and possibly even to use their experiences to help the younger generation [...]" [17]. Therefore, a "so-called »mutual assistance community« to bring services from human side into AAL environments" [17] is proposed. This would prevent "isolation by staying socially connected" [2]. The "longterm vision is to promote an accessible intelligent environment based on open standards and architectures and innovative solutions where everyone can continue to play a role in society" [2].

5 Scenarios

With assistance for AAL not only the rare technical combination of smart things but also the use cases and assistance services are meant. These assistance services are different scenarios in which the artificial intelligence of the AAL solutions uses the information of several sensors, different hardware platforms, the middleware, including the logic core, and several user interfaces and actuators. In the following several scenarios are listed and one example for each is given.

As already mentioned, discussing semi-mobile robots in section 3.4, *Smart Kitchens* often use not only smart environment, but also smart things. One can think about a cooking guide projected onto the kitchen wall showing instructions. Depending on individual information like diabetes, the blood glucose level and the blood pressure a balanced diet and an appropriate recipe can be recommended. Video cameras, microphones, an augmented cutting board and a sensor-enriched knife detect the ingredients which are currently prepared. With the intelligent spoon, also liquids can be detected and measured. The oven and hot plates can automatically be turned off depending on the cooking time and the person can be reminded to look after the food while being busy with other things.

In *Smart Bathrooms* privacy becomes an major factor. Therefore, video cameras will not be accepted and other sensors like microphones are needed. A toilet flush sensor can detect the duration and frequency of toilet usage determining diseases or digestion problems. The absence of a regular usage can also indicate an emergency case. Information, guides and reminders, e.g. to take pills, can be displayed at the bathroom's mirror. Other services focus on comfort like temperature regulation.

In the *Smart Sleeping Room*, the bed can be used to gather a lot of medical and healthcare information. During the night, people will only reside in this small area and sensors can be placed next to, under or even in the bed. Using the mattress, e.g. movement, respiration, pulse, or incontinence can be detected and used for further actions like warnings. Light management, temperature regulation and automatic alarm clocks can enhance the living quality as well.

The *Smart Living Room* is probably the main habitation during daytime. The couch can be equipped with similar sensors like the bed to monitor the health care of the elderly while the television or other projection surfaces will serve as the major interaction device. Besides common remote controls, voice, gesture or other natural human-computer input methods can be used. On the screen, different information, reminders, and guides can be displayed. Using a webcam, microphones and loudspeakers communication with family, friends and professional people like nursing staff and doctors is possible. Using the sensor enriched couch, tele health care can use these data to inform, warn or alarm corresponding persons like doctors.

In addition to these room dependent scenarios, other supporting services are possible. One of them is the *Smart Medicament Blister*: “If medicines are taken irregularly, incorrectly or even not-at-all, physicians and pharmacists speak of a lack of compliance” [2]. This issue can be addressed with weekly blisters for patients. “In such blisters the medicines prescribed by the physician are arranged in solid oral forms and in he correct dosage, presorted for the seven days of the week and for taking four times a day (morning, afternoon, evening, nigh)” [2]. These blister can contain a bar code or RFID tag which promotes digital information about the pills inside. Being at home, the patient can scan the blister using an intelligent medicament cupboard [2] in which the bar-code or RFID tag is scanned. The digital data from the sensor are received by the hardware platform and transported to the central middleware. The system has now information about the type and taking frequency of the new drugs and can receive further information contacting a remote medicine database. In addition to the doctor's and pharmacy's check for side effects, the system can use current information about the individual, its health status, and the diet for a more detailed analysis of possible intolerance. The taking of the pills can be saved into the calendar and the patient can be reminded by alerting service e.g. while watching television. Cameras with object detection and sensors inside the medicine blister can be used to detect the taking of the pills. If the pills are taken irregularly, wrongly or not at all, a warning can be displayed and family, the nursing staff or the doctor can be informed. In emergency cases, where the taken pills are crucial to life, the ambulance can be alerted as well. The scenario of a smart medicament blister shows the potential of assistance for AAL. While pure medicament scanners (e.g. bar-code, RFID, NFC, video based object detection, or text input) can only get information about the medicine itself, the blister contains not only information about the drugs but additionally the individual taking times and frequency. Combining this information with individual and personal data like the blood pressure, the system offers additional services like avoidance of intolerance, an alert service, observation of the taking and emergency services.

6 Conclusion and Outlook

With assistance for AAL the everyday-live of elderly or handicapped people can be improved. The system can assist the people in different situations like daily routines, household, or food preparation. Other use cases are health care monitoring, tele health care and social interaction. Therefore, AAL is a solution to the issue of demographic change, lack of qualified nursing staff, exploding health care costs and a changing society.

Nevertheless, there are still some problems like missing standards and platforms to solve before AAL can be part of the everyday life and of the mass market. While standards for sensors, actuators, and hardware platforms might be useful but not necessary, middleware, logical components, user interfaces, and infrastructure are more critical. In particular, when thinking about emergency cases, tele health care, health data flow to family and friends, or local treatment by nursing staff or doctors, these standards are obligatory. In the future, one or a few middleware solutions as well as data privacy policy and communication standards using the internet for tele health care should establish among developers and accordingly also in the market. For nursing staff and doctors the interaction with local equipment needs to be consistent and programming or influencing the AAL must be easy but request authorization. Designing user interfaces, the limitations of elderly as late learners but most important stake holders must be taken into account.

References

[1] Kleinberger, T., Becker, M., Ras, E., Holzinger, A., Müller, P.: Ambient Intelligence in Assisted Living: Enable Elderly People to Handle Future Interfaces. In: Universal Access in Human-Computer Interaction, Ambient Interaction. Volume 4555 of Lecture Notes in Computer Science. Springer Berlin / Heidelberg (2007) 103–112 1, 1, 2.1, 2.1, 2, 4

[2] Neßelrath, R., Haupert, J., Frey, J., Brandherm, B.: Supporting Persons with Special Needs in Their Daily Life in a Smart Home. In: 7th International Conference on Intelligent Environments (IE), IEEE Computer Society (July 2011) 370–373 1, 2.1, 3.3, 4, 5

[3] Kranz, M., Linner, T., Ellmann, B., Bittner, A., Roalter, L.: Robotic Service Cores for Ambient Assisted Living. In: 4th International Conference on Pervasive Computing Technologies for Healthcare (Pervasive-Health), IEEE Computer Society (March 2010) 1–8 1, 2.1, 2.3, 3.3, 3.4, 4

[4] Linner, T., Kranz, M., Roalter, L., Bock, T.: Robotic and Ubiquitous Technologies for Welfare Habitat. Journal of Habitat Engineering **3**(1) (March 2011) 101–110 1, 2.1, 2.3, 3.3, 3.3, 3.4, 4

[5] Bock, T., Linner, T., Lee, S.Y.: Ambient Integrated Robotics: New Approach for Supporting Elderly People with Integrated Technology in Living Environments. Robotics (ISR), 41st International Symposium on and 6th German Conference on Robotics (ROBOTIK) (June 2010) 1 –4 2.1, 3.4

[6] Roalter, L., Kranz, M., Möller, A.: A Middleware for Intelligent Environments and the Internet of Things. In: Ubiquitous Intelligence and Computing. Volume 6406 of Lecture Notes in Computer Science. Springer Berlin / Heidelberg (2010) 267–281 2.1, 3.3, 3.3

[7] Kranz, M., Schmidt, A., Rusu, R., Maldonado, A., Beetz, M., Hornler, B., Rigoll, G.: Sensing Technologies and the Player-Middleware for Context-Awareness in Kitchen Environments. In: Fourth International Conference on Networked Sensing Systems, IEEE (June 2007) 179–186 2.1, 3.4

[8] Kranz, M., Schmidt, A., Maldonado, A., Rusu, R., Beetz, M., Hörnler, B., Rigoll, G.: Context-Aware Kitchen Utilities. In: Proceedings of the 1st international conference on Tangible and embedded interaction. TEI '07 Proceedings of the 1st international conference on Tangible and embedded interaction, Association for Computing Machinery (2007) 213–214 2.1, 3.4

[9] Linner, T., Kranz, M., Roalter, L., Bock, T.: Compacted and Industrially Customizable Ambient Intelligent Service Units: Typology, Examples and Performance. In: Proceedings of the 2010 Sixth International Conference on Intelligent Environments (IE), IEEE Computer Society (July 2010) 295–300 2.1, 3.4

[10] Figueiredo, C., Gama, O., Pereira, C., Mendes, P., Silva, S., Domingues, L., Hoffmann, K.: Autonomy Suitability of Wireless Modules for Ambient Assisted Living Applications: WiFi, Zigbee, and Proprietary Devices. In: Fourth International Conference on Sensor Technologies and Applications (SENSORCOMM), IEEE Computer Society (July 2010) 169–172 2.1

[11] Sälzer, C.: Ambient Assisted Living - Technik fürs Leben. VDE digital: Das Technologie-Magazin (Januray 2012) 32–33 2.3

[12] Roalter, L., Möller, A., Diewald, S., Kranz, M.: Developing Intelligent Environments: A Development Tool Chain for Creation, Testing and Simulation of Smart and Intelligent Environments. In: 7th International Conference on Intelligent Environments (IE), IEEE Computer Society (July 2011) 214–221 3.3

[13] Zimmermann, G., Vanderheiden, G.: The Universal Control Hub: An Open Platform for Remote User Interfaces in the Digital Home. In: Human-Computer Interaction, Interaction Platforms and Techniques. Volume 4551 of Lecture Notes in Computer Science. Springer Berlin / Heidelberg (2007) 1040–1049 17, 4

[14] Frey, J., Schulz, C., Nesselrath, R., Stein, V., Alexandersson, J.: Towards Pluggable User Interfaces for People with Cognitive Disabilities. In: Proceedings of the 3rd International Conference on Health Informatics (HEALTHINF). (2010) 428–431 3.3, 4

[15] Román, M., Hess, C., Cerqueira, R., Ranganathan, A., Campbell, R., Nahrstedt, K.: GAIA: A Middleware Platform for Active Spaces. SIGMOBILE Mobile Computing and Communications Review **6**(4) (2002) 65–67 3.3

[16] Aitenbichler, E., Kangasharju, J., Muhlhauser, M.: MundoCore: A Light-Weight Infrastructure for Pervasive Computing. Pervasive and Mobile Computing **3**(4) (2007) 332–361 3.3

[17] Sun, H., De Florio, V., Gui, N., Blondia, C.: Promises and Challenges of Ambient Assisted Living Systems. In: Sixth International Conference on Information Technology: New Generations, 2009. ITNG'09, IEEE Computer Society (April 2009) 1201–1207 4

[18] Ikonen, V., Kaasinen, E.: Ethical Assessment in the Design of Ambient Assisted Living. In: Assisted Living Systems - Models, Architectures and Engineering Approaches. Number 07462 in Dagstuhl Seminar Proceedings, Schloss Dagstuhl - Leibniz-Zentrum fuer Informatik, Germany (2008) 4