THE CARING ENVIRONMENT

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Abstract. The implementation and possibilities of an ambient, pervasive, ubiquitous and unobtrusive user interface indicating the wellbeing of the person cared for is introduced. Subsequently, the options to extend the user interface for the purpose of communication between informal caregiver and cared for person is discussed.

Keywords: Ambient Assisted Living, Behaviour Pattern Recognition, Pervasive User Interfaces, User Involved Design Process, Informal Caregivers, Older Adults, Elderly, Assisted Persons, Demographic Burden

1 Introduction

A vast body of the research in the field of Ambient Assisted Living (AAL) focuses on improving the quality of life for the inhabitants of smart homes. In the light of the evolving demographic change in Europe and other countries, one aim of AAL is to enable people to live longer independently at home [1] [2]. Contrary to those approaches concentrating on the assisted person (AP) (e.g. mother in need of care) situated in a smart environment, the focus of the system introduced in this paper is on relieving the burden of the informal caregiver (IC) (e.g. the daughter) by means of technology and social design. Such a system addresses the circumstance, that ICs, which often do not belong to the younger generation, are an important pillar in elderly care [3,4,5,6,7]. In Austria, Pochobradsky et al. was able to show that a significant part of the care is provided by ICs and that about 66 % of them feel overburdened with their caring tasks at some point in time [8].

The challenge in the project RelaxedCare[1] is to develop a system based on social awareness technology, applying an "user inspired innovation process" (UIIP) [9] as development process with the aim to reduce the burden of caregiving and thereby enhancing the quality of care and bonding between IC and AP. A particular focus is put on the kind of information presence and the implicit user interaction on different kinds of user interfaces (UI) for the IC. To gain user acceptance and a high degree of usability, we aim to provide the IC a pervasive, ubiquitous, low barrier object as UI that becomes part of his living environment. The source of the information presented on the UI will be primarily data derived from pattern recognition processes going on in the APs home. Hence, we combine methods of ubiquitous computing, ambient intelligence and pattern recognition. Mark Weiser, describes in [10] ubiquitous computing as "the method of enhancing computer use by making many computers available throughout the physical environment, but making them effectively invisible to the user." In this paper we share preliminary results from the UIIP, described in the chapter Methodology, present the technological approach derived, and discuss the challenges and ideas encountered with the development of the User Interfaces for the first prototype, called "object like UI". The emerging design ideas are presented and discussed in the Results and Discussion, respectively. In order to provide a better understanding of the most important concepts of the project, the system architecture as well as the technical environment, in which the UI is embedded, are described next. System architecture: As the central point of interest, the IC shall be enabled at any time to find out at a glance about the wellbeing of his AP without much efforts. At home or at the office, the IC resorts to objects like e.g. an intelligent lamp or a picture frame, which are indicating the wellbeing of his AP, as depicted in **Fig. 1**. Those objects are ubiquitous and pervasive, providing the IC the wellbeing status at a glance without having to overcome barriers as e.g. actively using an object, dialing the phone, or enter PIN codes or passwords to unlock smart devices and computers or opening a webpage. If preferred by the IC, one can also utilize a smartphone application, which could come in handy when being on the way. The displayed wellbeing status is derived by sophisticated pattern recognition algorithms, processed on a workstation, which is located at the AP's flat. Various sensors installed at the home of the AP are the basis for the applied pattern recognition algorithms. Personalization and customization is of importance, since wellbeing is a very individual composition of physical, psychological and social perceptions. Additionally to the compound overall wellbeing state, the social state and the physical activity state could be shown to the IC on the smartphone application.

By considering and incorporating the results of the requirements engineering and by following the paradigm of creating a system that is easy to set up, easy to be personalized and open for further extensions and adaptations, we developed the system architecture presented in **Fig. 2**. Therefore it was decided to use the HOMER middleware platform on both sides and to provide a logical connection and configuration possibility via a cloud service. The HOMe Event Recognition System (HOMER) integrates local sensors (using standard of different off the shelf networks) and performs pre-

[1] http://www.RelaxedCare.eu

processing. HOMER is made available as open platform based on an Apache Karaf OSGi framework and encapsulates its functionalities in terms of OSGi bundles which enables a high modularity [11]. Within this project, it is the first time that two individual instances of HOMER communicate with each other over RabbitMQ[2]. This is a message broker based on the Advanced Message Queuing Protocol (AMQP), used as a common platform for sending and receiving messages. The novelty of using the OwnCloud server in between improves reliability of the overall system and simplifies software maintenance.

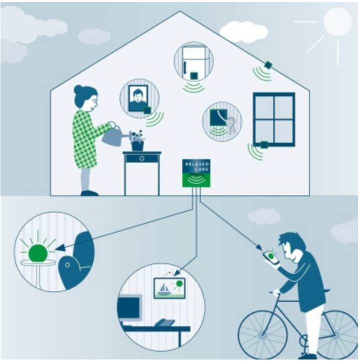

Fig. 1. Basic framework of concept for RC.

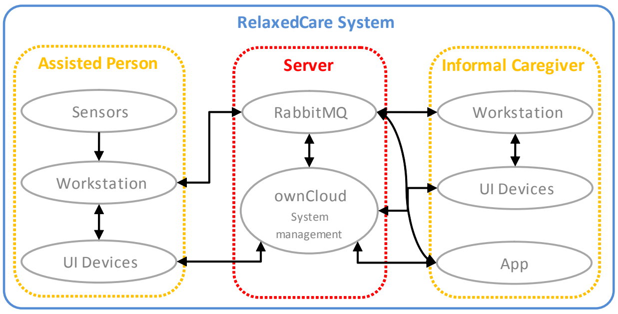

Fig. 2. System architecture of the system.

2 Methodology

Involving the end-users throughout the project lifecycle is of utmost importance to develop an accepted, user-orientated and beneficial prototype [12]. In the RC project therefore the UIIP is applied from the very beginning. The RC project is also committed to user-centred design/development (UCD) and the ISO 9241 (Ergonomics of human-system interaction). Especially the part ISO 9241-210 come to the fore: The international standard provides requirements and recommendations for human-centred design principles and activities throughout the life cycle of computer-based interactive systems. It is intended to be used by those managing design processes, and is concerned with ways in which both hardware and software components of interactive systems can enhance human-system interaction [13].
Before first designs for the UI were developed, the requirements were determined.
The requirements engineering phase of the project was designed as a not standardized qualitative research study [14]. The study design was a comparative study of seven methods of qualitative social research and design research methods: 1. Assumption

2 http://www.rabbitmq.com/features.html

personas, 2. Questionnaire, 3. Show and tell, 4. Focus group-interview, 5. Cultural probes, 6. Design-workshop, and 7. Contextual inquiry.

While the assumption personas were constructed in cooperation with all partners of the project, mainly to find a common perception of the target group, the questionnaire and the design workshop were conducted in Austria only. The other methods, show and tell, focus group interview, cultural probes and the contextual inquiry were executed in Austria and Switzerland. As all test subjects were native German speakers, additional complications by conducting the methods in different languages were avoided. From the basic requirements, the system architecture and the first design proposals for the UI were derived. After narrowing the number of choices, the 3 most promising design proposals were created as mock-ups and story boards based on scenarios defined in the requirements were drawn. The mock-ups and storyboards were the foundation for an informal usability testing in Switzerland. 17 test subjects participated. The demographics and further information is given in **Table 1**. It should be clarified that it has been an underestimated challenge to recruit couples consisting of IC and AP. Hence for this test, ICs and APs are not represented as couples. Furthermore, the test subjects are not a sub-group of the test persons involved in the initial requirements acquisition.

Table 1. Demographic of test subjects

Participant	Age	Gender	Situation in life	Occupation	(Former) job title	Focus group or inter-
IC-1	66	F	Married, care of parents and friends	Pensioner	Nurse	Fg
IC-2	65	F	Married, care of parents in law	Pensioner	Waitress	Fg
IC-3	51	M	Married, care of parents and friends	Employed	Computer scientist	Fg
IC-4	44	M	Married, care of parents	Employed	House husband	Fg
IC-5	50	M	Married, care of parents	Employed	Graphic designer	I
IC-6	67	W	Married, care of mother	Part time job	Interpreter	I
IC-7	46	W	Married, care of mother	Employed	Commercial clerk	I
IC-8	55	W	Divorced, care of father	Employed	Nurse	I
AP-1	73	W	Widowed, living alone	Pensioner, free lancer	Teacher	Fg
AP-2	77	M	Married, living with wife	Pensioner	Engineer	Fg

AP-3	90	M	Widowed, living alone	Pensioner	Banker	Fg
AP-4	80	M	Widowed, living alone	Pensioner	-	Fg
AP-5	76	W	Widowed, living alone	Pensioner	-	I
AP-6	87	M	Widowed, living alone	Pensioner	Engineer	I
AP-7	91	W	Widowed, living alone	Pensioner	Teacher	I
AP-8	75	W	Widowed, living alone	Employed	Teacher, alternative practitioner	I
AP-9	78	M	Widowed, living with wife	Pensioner	Social worker	I

Since the number of test subjects is too small for applying quantitative methods in the analysis of the recorded answers, they were listed, grouped and interpreted by the conductor of the test. Although concerns regarding intellectual property rights does not allow the disclosure of the designs, some of the results are of interest to researchers working in the same domain.

The interpretation of the answers provides the hint, that the aspect of communication is more important than anticipated in the requirements engineering phase. Additionally, the answers suggest that the utilization of the telephone is a competition for RC. The message of the informal usability test led to a redesign of the UI. The current status of the design is described in the next chapter as a result of the UIIP.

The resulting prototype 1 (two iterations are planned in the lifetime of the project) is going to be tested within the next months by about 10 test subjects in Austria and about 15 test subjects in Switzerland. Lessons learned from these usability lab-tests will be implemented in prototype 2. This prototype will be part of the field-trials, where the system as a whole is tested in real life settings over a longer period of time.

3 Results

The shape of the object-like UI was chosen to be cubic to be aesthetically neutral. The cube is of semi-transparent plastic, being illuminated from within. The device contains several colour LED stripes connected to a controller. By being able to control each LED separately, 3 independent light areas were defined. Several turns of LED stripes are mounted into the core object. The light emitted from that core area and diffused at the walls of the cube indicates the colour coded wellbeing. Similar to a traffic light, 3 different levels of wellbeing are possible. Colours were selected to resemble green and amber. Instead of red a shade of pink/purple was selected to avoid associations as “red equals danger.” The second light area, located in the lid of the cube, is dedicated for the indication of low barrier 1-bit communication. It is turned on only when a message from the remote person was received. Dedicated LED strips are also on the top and bottom edges of the cube. The light beam of the bottom stripes is oriented almost parallel to the flat surface the cube can be placed on (e.g. table) while the strips in the top edges beam upwards vertically. These particular light stripes enable the cube to be utilized as ambient light more efficiently.

Relying exclusively on coloured light as output modality could be challenging in rooms flooded with daylight or in very bright rooms in general. Furthermore it could also be a barrier providing only a single mode of information. Although all LED stripes consume about 50 W in energy, colours appear to be pale when the object is exposed to bare sunlight. Therefore it is recommended to appeal to more than one sense and the cube is equipped with a loud speaker. All levels of wellbeing are assigned to a defined LED colour and to a sound file. The volume and nature of the sound files correspond to such used for meditation. **Table 2** shows the association between LED colour and sound file. Furthermore it lists the short sound clips (< 10 s) played in intervals of several minutes when a message is received and the state of the table top fountain. It is located in the centre of the cube's lid and can be detached if desired. In general, the metaphor of a table top fountain and the level of wellbeing seems to be almost self-explanatory, once the user is familiar with the goals of RC.

To be prepared for future requirements, a NFC-reader is implemented at one side of the cube. Thus, users bringing NFC tags (preferably attached to other objects of their liking) in the vicinity of the reader can prompt predefined actions.

By implementing a passive infrared motion detector (orientation parallel to the floor), the cube is able to react to body movement. Depending on sensitivity selected, the sensor can detect motion within a range of several meters, or just detect the hand almost touching the surface of the cube at the location. Hence the information of the motion detector can be used as an input signal similar to that of a switch (e.g. to acknowledge a received message), or it can be used as a further sensor of a smart home installation.

Table 2. Attribution of light and sound characteristics in the UI.

Wellbeing status	LED colour emitted	Sound file	Table top fountain
Above average	Green(ish)	Vivid creek	on
Average	Amber(ish)	Calm river	on
Below average	Purple(ish)	Thunder and rain	off
Message received	Wellbeing core area: unchanged Message area: White/blue LED animation	Gongs of meditation bowls	no change

All modules are controlled by an energy efficient, credit card sized, single board, Linux based microcomputer (MC) called "RaspberryPi Model B Revision 2", which has been successfully employed by other research groups before [15,16,17,18]. However the MC is connected via Ethernet to a router, it is feasible to resort to WLAN if required. At the AAL-Forum 2014, modules from all contributing technical partners (sensors, HOMER, UI) were connected for the first time and the overall RC system was running during the exhibition.

4 Discussion

The object-like UI as described in the previous chapter is poor in aesthetics but rich in potential functionality and shall serve as platform for end-user tests and as stepping stone for further developments. In order to avoid preferring a fancy design of the UI because it matches the interior design of one test subject, however not the others, the poor shape of the object has been selected intentionally. It is considered to be "neutral" in shape and equally fitting in most apartments. Inquiring end users in tests for their preferred design will show, whether it is advisable to aim for a "one fits all" design approach, or to new requirements, such as the design has to be configurable. This would open the door for designs that are easy to exchange. The UI could be designed as socket, in which to plug third party design objects (e.g. vases or bowls come into mind). Pursuing the idea of configurability leads to possibilities again comparable to the smartphone market: instead of downloading ring tones for the object, soundscapes could be downloaded and exchanged by users. Perhaps even the manufacturers of furniture would offer soundscapes matching the interior design. This becomes the more important the more devices are to be utilized in one apartment. The technical system architecture does not limit the number of objects within the household. Having several objects operating at home (e.g. in the living room, the kitchen, etc.) and perhaps an additional one at the office (maybe in the size of "Picco" [19]) helps the ubiquity and pervasiveness, which is otherwise hard to achieve with an object confined to one space.

Another challenging question is how to address the desire of end users for improving communication. After all, the aim of RC is not to substitute human contact by technical means. On the contrary, social awareness design of technology should improve the quality of time spent together. Even for end users not familiar with instant messengers (WhatsApp, IRC, etc.) the telephone is in competition with the RC system. Since advancing the telephone is not in the scope of this project, offering communication has to be performed in other ways. In fact, RC can offer several layers of communication. By being able to get objective data about the wellbeing, the IC has the reassurance that the AP was indeed as active as usual - meaning the AP does not only say "I am fine" out of politeness, or because of not wanting to bother the stressed IC. A further advantage of the RC system as envisioned now is the option of having a visual and acoustical means to output a message. While the degrees of freedom for LED stripe pattern combinations and animations are as plentiful as the use of different sounds, the key element is considered to be low barrier communication. It means that the major advantage over the phone or written text messages is the option to avoid lengthy authentication procedures (e.g. entering password or PIN). Sending a signal to the remote person should be almost as effortless and spontaneous as checking the wellbeing of the remote person at a glance.

Though the low barrier comes at a cost: sending messages with high information density is not as barrier free as limiting the message to a single signal. Therefore, the meaning of the signal, which is either active or absent, must be predefined. Since it is only one signal, having relatively neutral visual-acoustical output in the current implementation, the meaning described to the signal should be defined by the end users themselves. Potentially, the idea of taking advantage of ambiguity in designing tools for communication opens new directions to think in respect to the situation in care [20,21,22]. The publication of Nardi et al. [23] examining the utilization of instant messaging, especially the process (termed “outeraction” in relation to “interaction”) of how people connect and how they use the instant messaging to manage communication can certainly initiate new thoughts on what a low barrier UI, that is not to replace the telephone or WhatsApp, could offer users with less affinity to new technology. Another aspect granting the aim of low barrier communication with new value for users is the option to employ technology to foster emotional bonding, or to reduce the burden of loneliness. While this is no novel research domain [24, 25, 26, 27, 28, 29] the application of these approaches is rarely applied to the situation of informal caregiving. Obvious implementations for the technological infrastructure available in the UI presented here are the exchange of light colour, sound or music and motion. Assuming that the UI can be used as ambient light, its ability to communicate with the ambient light at the remote person’s place, enables the exchange of the light colour settings to the remote device without problem. The beauty in this approach is that the couple could not only share favourite colours, they can also communicate by light in a very unobtrusive manner (also in an secret way, only they are enable to decode). This means, there is no time pressure to react to changes of the light, because it is unclear whether the recipient is focused on his intelligent ambient light. On the other hand, once a colour changes, it automatically means that the remote person is right now next to its ambient light. Thinkable is also, that certain habits can be derived from changes in light by the remote person, for example when preparing for going to sleep, the light is set to a red sundown colour, the recipient of that colour change knows, that the remote person has left the area of attention and loans for the bed. Similar to the direct and indirect information exchange by light from the previous example, the exchange of music could be accomplished. The intelligent ambient light could be informed what music is streamed in the home network of the remote person, and plays the same song locally. It can not be stressed enough, that the important characteristic of the idea is to provide unobtrusive exchange of information/music. As one consequence, the music playing possibly in high volume at the remote partner, is meant to be played in low volume locally - just to perceive such subtle information as “remote person at home”, or “remote partner is likely to be in good mood judging by the genre of music she is listening to.” Besides the unobtrusiveness, the low barrier principles are featured. In this example with music, no person has to undertake any additional effort to get the added value of sharing more than just the direct, conventional communication.

When using the integrated motion detector of the object to detect moving persons up to a few meters, sharing the information of a present and active remote partner can be derived, even without the need to resort to a smart home. Triggering of the motion detector could lead to changes in the ambient light colours of the remote cube. The more activity, the deeper the colours, and with inactivity the colours of the remote ambient light fade away. The list of functionality, especially in the domain of emotional/ambient communication, could be extended further. As always, the end user will make the verdict on what to elaborate.

5 Conclusion

The aim of the RC project is to let the IC unobtrusively take advantage of the smart environment the AP is living in and thereby use technology to reduce the burden of caring at least a bit. Instead of realising the proposed system architecture, in which only the wellbeing status of the AP was to be indicated in a pervasive, ubiquitous ambient and unobtrusive manner to the IC, the UIIP has led to an evolved system architecture. In that, sensors/the smart home can be applied at both sides, at the AP and also at the IC. However, the most distinct request of the end users during the requirements engineering phase and in an informal usability test with 8 ICs and 9 APs was to improve the possibilities of communication with the pervasive object like UI. At the same time, end users saw the telephone as main competition, rendering the value for themselves as very limited. The improvements within the prototype 2 development phase will focus on a platform offering various options for communication and communication concepts, such as 1-bit communication, ambient communication, emotional communication and the concept of ambiguity as part of improved communication. The design and implementation of the introduced object like UI is considered a stepping stone between the end user based requirements, an informal usability test and a future usability test dedicated to the object like UI itself. Results of the test will lead to an improved prototype of the UI, which will be part of the field trials of the overall system. With this process, we are confident to be able to cover the input of end users and to achieve a prototype, that provides added value for the IC and AP.

When informal caregivers perceive (at least sometimes) their role of being an informal caregiver as relaxed as walking through the woods due to the right level of ubiquitous information, the project RC has achieved its goal.

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