Creating Ambient Intelligence: Applications and Design Guidelines for the Home

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ABSTRACT

Ambient intelligence is a vision for the future where technology will blend seamlessly with the environment in order to support human living. As technology continues to develop and mature, this vision is increasingly becoming a real possibility. However, some fundamental questions need to be asked in order to develop solutions that will be appropriated by target users. Firstly, this review will discuss four categories of applications for ambient intelligence solutions. These are emergency treatment, autonomy enhancement, comfort services and integration with the community. Secondly, design guidelines for three aspects of ambient intelligence solutions are discussed – integration into the user's life, eliciting appropriate emotional responses from the user for behavioral change and maintaining the user's privacy and data security.

INTRODUCTION

Ambient Intelligence is a vision for developing environments which assist inhabitants by providing access to information and people in a natural and contextually aware manner. It is characterized as being adaptive, ubiquitous, sensitive, responsive and transparent [2]. The convergence of many different areas of research including ubiquitous computing, multimodal natural user interfaces, artificial intelligent, multi-agent systems, sensor network technologies, low cost sensor hardware, decision support systems, mobile communications and wireless technologies is required for the development of ambient intelligence technologies [4]. As research and development continues in each of these areas, the likelihood of converting the vision of ambient intelligence into reality increases.

The aim of this paper is to provide a starting point for developing ambient intelligence solutions that will become integrated into the lives of its users. The first part discusses various categories for the application of ambient intelligence solutions specifically for home use. Following this, research discussing design guidelines for ambient intelligence solutions is also presented. Different aspects of ambient intelligence designs are discussed such as integrating solutions into the user's life, encouraging changes in the behavior of users, and ensuring their privacy and data security.

APPLICATIONS FOR AMBIENT INTELLIGENCE SOLUTIONS IN THE HOME

The home environment represents a large market for ambient intelligence. This section looks at possible areas of application for ambient intelligence.

Current Technologies for the Home

Becker et. al [1] believe that ambient intelligence will significantly enhance Home Care System (HCS) technology. An evaluation of the current HCS solutions shows that design emphasis is placed on the technology and usability is neglected [1]. Designers provide static and unnatural interfaces that require time to learn and are prone to user errors. Some solutions are body mounted and obtrusive, resulting in low compliance. Current solutions also lack functionality. They use single sensors, lack integration with other solutions and are not contextually-aware which leads to false-positive alerts [1].

It is proposed that by integrating the characteristics of ambient intelligence such as adaptability and sensitivity, with HCS products, more usable solutions can be developed. Figure 1 shows the current categorization of the HCS domain – emergency treatment, autonomy enhancement and comfort services [1]. The scope of ambient intelligence in each of these categories is further explored in the following sections.

Emergency Treatment

Ambient intelligence focused on *emergency treatment* would provide prediction, prevention, detection and assistance to users in case of emergencies. In New Zealand alone, more than 100,000 people, aged 25 – 64, are injured

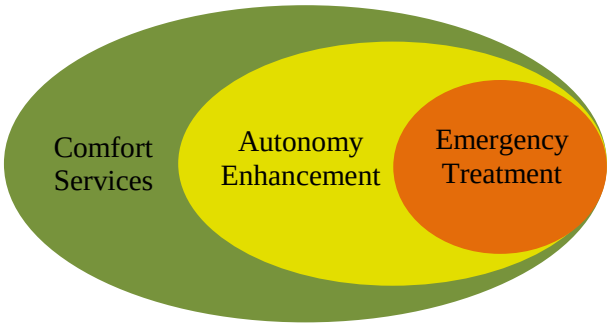

Figure 1. Categories for Ambient Intelligence Solutions [1]

by a fall while at home every year. More than 10% of these are seriously injured and unable to work. In 2010, the social and economic cost of injury caused by falling is estimated to be $1.84billion [8]. In 2011, the number of recorded robbery, theft, unlawful entry with intent to burgle and related offences was 448 per 10,000 people. Only 21.2% of these were resolved [12].

Ambient intelligence solutions could provide an increased sense of security for users [5]. These solutions could monitor the health and wellbeing of inhabitants, leading to emergency response units being alerted quicker. It could also prevent injuries from occurring. Ambient intelligence solutions could detect intruders entering the house [13] and also exert control over who has physical access to the dwelling [5].

The Unattended Autonomous System (UAS) is one such ambient intelligence product specifically designed for the elderly [7]. The UAS system was installed in different configurations in the homes of 18 elderly. The functions that were installed were based on the needs of the individual. They included mobility monitoring, fire detection, wandering detection and prevention, and voice response in the event of these alarms being raised.

Autonomy Enhancement

Ambient intelligence solutions that focus on autonomy enhancement are especially useful to people who are physically or mentally impaired, as well as the elderly [2]. Services would include help with cooking, cleaning, dressing, shopping, eating, drinking and taking medication. An example of a product would be a "smart pillbox" that remembers when users have taken their medication [13].

This category can also be extended to health monitoring and assistance in the home, post treatment in a hospital. It will be beneficial in reducing the amount of hospital care required by increasing the care and monitoring capability of the patient's home [2]. For example, it is estimated that in Germany alone, discharging patients earlier because of the capabilities of a home health monitoring system would save 1.5billion Euros each year [2]. One such product is a head band that measures physiological signals while the user sleeps and sends the data to be analyzed for sleep apnea [13]. This device would mean that users would not need to spend the night in the unfamiliar environment of a sleep lab – an experience which can be daunting for the elderly.

In combination with emergency treatment, autonomy enhancement can encourage ageing-in-place by increasing the amount of time that the elderly can safely and comfortably continuing living independently in their own homes [2]. One of the four "deep needs" of the elderly is *autonomy with anticipated support* [14]. This was also found during the evaluation of the UAS system – the elderly (and their families) were concerned about safety in their own homes but were still reluctant to move into an aged care facility [7]. They wished to stay in their own dwellings because of emotional attachment to their own home and possessions. The elderly feared burglars, power outages and not being able to access help in the event of an emergency. Those with psychogeriatric health conditions are more at risk, for example, when they unwittingly wander out of their homes or forget to turn off the stove [7].

Comfort Services

Comfort Services provided by ambient intelligence solutions would involve logistics assistance, home automation, social contacts, finding things, infotainment and safety. This category might not seem as crucial as emergency treatment or autonomy enhancement but it could encourage the wider acceptance of ambient intelligence solutions [1]. Additionally, one of the four "deep needs" of the elderly comes under this category [14]. *Social touch* is the desire of the elderly to maintain relationships especially deep and meaningful ones rather than many shallow ones. Providing ambient intelligence solutions that allow the elderly to communicate with loved ones that are separated by space or busy schedules would be welcomed.

Specific applications include a networked home environment [2] and dynamic networking (introducing people who are making similar decisions for e.g., commuting to work at the same time) [5]. The UAS system was trialed with the SCOTTY system, a device that allows video calls with care professionals and loved ones. The evaluation found that the system was hardly used by the elderly due to it being difficult to operate. This highlights the need for usability to be considered when designing these solutions.

A Fourth Layer? Integration with the Community

Review of other research conducted on ambient intelligence solutions, suggests that a fourth category of solutions can be developed that would extended those shown in Figure 1. This new category will include solutions that will enable users to integrate with their community, meeting their "need to belong" [2] and also encourage them to change their behavior is order to meet community goals.

An example of better integration with the community would be solutions that allow users to electronically participate in town/city council meetings and also electronically vote in elections and referendums [5], removing spatial barriers to involvement. Solutions that encourage users into positive habits have also been investigated in [10, 11]. The four solutions investigated are Persuasive Art which uses animated pictures to provide feedback on the user's exercise habits, a Virtual Aquarium that provides feedback on proper tooth brushing techniques, Mona Lisa's Bookshelf which provides feedback on the organization, or lack of it, on an open bookshelf in a student lab and EcoIsland which provides feedback on the environmental impact of a family's action [10]. These raise the user's

awareness to issues that are currently difficult to obtain feedback on.

This fourth category would also include meeting the last two "deep needs" of the elderly (Zejda 2010). The third and fourth needs of the elderly are to *feel competent* and to *be helpful*. Ambient intelligence technology that allows them to be a vital part of the community will be well received.

DESIGN CONSIDERATIONS AND GUIDELINES

The previous section presented research on varying uses for ambient intelligence technology. This section discusses guidelines for designers in order to encourage user appropriation of the developed solutions. The guidelines are separated into integration of solutions, considering the user's emotional response and the importance of privacy and security to the user.

Integration of Solutions

By definition, successful ambient intelligence solutions should fully integrate with the user's environment to the point where the user no longer remembers that the technology is present. The In-Home Monitoring System which was developed and installed into the home of 6 elderly people was able to achieve this complete integration [3]. The system included wireless pressure switch mats, sensors on cabinet doors, a stove temperature sensor and a bed sensor to detect presence, respiration, pulse and movement. The system was evaluated in the participatory evaluation tradition, where the elderly were informally interviewed and any issues with the system were discussed. The results indicated three phases to the appropriation of the system [3]. The first phase, lasting about 2-3 weeks, was familiarization, where the residents got accustomed to the system. This was followed by adjustment and curiosity (also lasting 2-3 weeks) where the users continued to think about the recent additions to their home. The third phase was integration, where the elderly came to accept the technology and no longer thought about its presence.

The phases of familiarization, and adjustment and curiosity provide a good framework to consider guidelines for the successful implementation of ambient intelligence solutions. The following sections discuss guidelines for each of these phases.

Familiarization

Kaasinen et. al have discussed with a group of 94 people (users and experts) different use cases in order to generate some general user requirements [9]. The use cases were generated as part of the MIMOSA project and are directly related to ambient intelligence solutions that are used primarily through personal mobile devices. Authors discussed with users the implementation of tags to allow them to actively access functionality from objects. An example would be reading a tag on an advertisement to obtain more information or to buy the product/service. The following design guidelines were obtained [9]:

- The user suggested that tags should be marked consistently for easy recognition and should be easily read by their device.
- Applications that launch by themselves based on the context were desirable. If this couldn't be achieved then applications should launch quickly "with a single button".

A focus group session was conducted with the elderly by Niemala et. al [13]. The focus group sessions were conducted in Finland and Spain, and were made of between 4 to 10 elderly people (3 groups) and 2 to 3 medical experts (2 groups). One of the key findings was the importance of building applications that were easy to use even with physical (eyesight and dexterity) and/or cognitive deficiencies.

The evaluation of the UAS system by the elderly lead to the following conclusions regarding the initial familiarization of technology [7]:

- The elderly that were interviewed indicated that it was important to them that their care professionals are able to answer basic questions regarding the operation of technology that they were recommend. The elderly require these answers to become familiar with the new technology that has been added to their homes.
- It was also important to the elderly that they were informed and consulted with before changing their home environment. Changes that are implemented without their consultation can be perceived as negative even if the benefits are clear.

Adjustment and Curiosity

The evaluation of the UAS system by the elderly lead to the following conclusions regarding the adjustment and curiosity phase [7]:

- The elderly commented that the UAS system prototype included a lot of wires. They were also uncomfortable with the amount of devices that had been added to their home.
- Since the UAS system was in prototype phase, there were numerous false alarms especially in the weeks following initial installation. Some of the elderly found this quite upsetting especially when the alarm went off for habitual behavior. For example one of the elderly would spend a long time in her corridor. This would set off the alarm because the system interpreted this as a fall and thought that she needed assistance. It was important to be able to tweak the system to allow for atypical but safe behaviors of the elderly.
- Some of the technology implemented with the UAS system would also hum and had LEDs that would be clearly visible at night. Some of the elderly found this to be frustrating. One even pulled out the cable to make it stop, which disabled the whole system.

Kaasinen et. al also found that users appreciated having control over which sensor measurements are recorded and analyzed [9].

Overall, users placed importance on technology that doesn't alter the way they do things but enhances it. Ambient intelligence solutions that fit into their lives without disruption and is easy to customize, is more likely to be integrated into their lives.

Considering the User's Emotional Response

Applying human psychology theories when designing ambient intelligence has the potential to yield solutions that change human behavior. Additionally, if the ambient intelligence solutions elicit appropriate emotional responses from the users, the chance of the product being integrated into the user's daily routine increases. This is especially true for solutions in the category of integration with the community. Since the solutions do not have an immediate benefit that is evident to the users, the right 'tone' is required to convince users to continue using the product.

One example of this type of ambient intelligence solution is the Virtual Aquarium, which provides users feedback on their teeth brushing process [11]. As the user brushes their teeth with a 'smart' toothbrush, the animation clears algae growth from the tank and the fish start to dance. If the user does not brush their teeth for long enough, the fish become sick and may die. If the user practices 'good' brushing over a number of days, the fish multiply.

The Virtual Aquarium provides guidelines on how to use evocative media to encourage a change in the user's behavior [11]. The Virtual Aquarium employs positive emotional reinforcement through multiplying fish to encourage users to brush their teeth. This is particularly important during the early stages of use to increase acceptance of the product. Negative emotions are used to convince the user to re-start good brushing practices. However, the authors hypothesize that this alone will not be effective, since negative emotions invoke rational thought in people. Strong negative emotions will be more effective when used with cognitive information to encourage behavior change. Long-term use will also benefit from cognitive information as the positive emotional attachment to the virtual fish wears off. Limited testing (8-12 days) with 7 volunteers shows that teeth brushing practices improved from less than 3 minutes to over 3 minutes with the introduction of the Virtual Aquarium. However due to resource constraints, statistically valid data was not realizable.

Kimura and Nakajima further emphasize that negative reinforcement is not effective and can lead to user's abandoning positive behavior entirely [10]. This was illustrated with one of the participants of the Persuasive Art solution, which used a variety of animated pictures to encourage users to exercise. An example is a tree that grows when the user exercises regularly and withers and dies without exercise. One of the subjects found the withered tree to be "revolting" and discontinued the trial.

Kimura also provides some guidelines on changing the behavior of a group instead of just the person [10]. Mona Lisa's Bookshelf superimposed an image of Mona Lisa over a neatly ordered bookshelf. If a book was removed or moved, the image assigned to that book was also removed and moved to the new location of the book. Additionally if books were not read 'Mona Lisa' would age until a book was removed from the bookshelf. This solution was not successful in encouraging the students to keep a neat bookshelf. Individuals in the group did not take responsibility for the bookshelf, so if one person returned a book in the wrong place, other students would not correct the location in order to complete the image. Interestingly, the students were more intrigued with the distorted image and felt no compulsion to correct it. The aging Mona Lisa was also ignored as it was assumed that 'other' students would take out a book.

In contrast, EcoIsland was more effective in encouraging positive change in a group. An animation of an island was setup in the living rooms of 6 family homes (20 person is total) [10]. The island had avatars for each of the family members which displayed updates if the members completed environmentally friendly activities such as taking the train instead of driving by car. If environmentally friendly activities were not undertaken then the island would start sinking. The study showed that displaying each member on the family's island was effective in encouraging individuals to act positively. 83% of people conducted more environmentally friendly actions after the system was enabled for all members of the family. However data was not collected for long enough to evaluate the change (or lack of it) in environmentally friendly behavior.

Nakajima and Yamabe [11] and Kimura and Nakajima [10] both indicate that considering the user's emotional response can encourage users to appropriate the technology. However, all the evaluations discussed lack statistical validity to make definitive conclusions. Furthering this line of research with larger sample sizes and durations could lead to a better understanding of creating solutions that users will incorporate into their lives, even if they do not derive direct value.

Privacy and Data Security

By their very nature, ambient intelligence technologies will require a large amount of information about the user to be stored and analyzed [2, 6]. This information allows ambient intelligence solutions to be intuitive and adaptable. Friedewald et. al suggests that privacy is important because it has the following characteristics [6]:

- Privacy as empowerment – people need to be able to control the distribution of their personal information.

- Privacy as utility – Privacy is useful for providing protection against nuisances such as unsolicited phone calls and emails.
- Privacy as dignity – People want to be free of "unsubstantiated suspicion". They also want to maintain equilibrium in relationships which is not possible when one person knows more personal information than the other.
- Privacy as a regulating agent – Privacy laws can be perceived as "a tool for keeping checks and balances on the powers of a decision-making elite".

In particular, people perceive their homes as a place where they can be free to do what they want without judgment or suspicion [6]. As a result, ambient intelligence at home will be able to gather the large amounts of data about people's personalities, health and finances. Ambient intelligence should [6]:

- Give users control over personal data. They should be able to choose and have access to the information that is gathered, stored analyzed and shared.
- They should be secure from theft. Ambient intelligence will store a lot of information such as biometric data which will give thieves access to people's money, possessions and information.
- They should be secure from 'malicious' attacks.
- Governments and other organizations such as insurance companies and employers should not have access to information which will allow them to discriminate between people.

Ambient intelligence will raise new issues that need to be address. For example, ambient intelligence solutions that read physiological symptoms will make it easier to analyze how a person feels about something [6]. In the past this has been hidden behind user's expressions. How will people react to technology that knows how they feel?

The emphasis on maintaining privacy differs by age and culture [6]. The research presented here shows that one of the concerns of the elderly when using ambient intelligence technologies is privacy and security of data [7, 13]. For example, having tags attached to medication packages will allow ambient intelligence solutions to keep track of their contents to ensure that they are taken appropriately. However if the information is not secure it would be possible for other people to identify the kinds of medication that are being taken without the users knowledge [9]. The elderly are concerned that if their insurance company or employer finds out that they have not followed their prescription, then they will no longer be eligible for medical subsidies [13]. Hence, one of the key requirements of identifying tags is that where required, the privacy of the user is secure [9].

The perception of security was also important to the elderly. Feedback from the elderly for the UAS system indicated that the video telephony system which included a camera attached to their television made the elderly occupants feel like they were being watched [7]. In some cases they even turned it off.

As with most products, people will tend to accept ambient intelligence that breaches their privacy if they perceive that the benefits outweigh the risks [3, 6]. Ambient intelligence solutions for emergency treatment and autonomy enhancement will be allowed greater transgressions on privacy than ambient intelligence comfort services or community integration.

CONCLUSIONS

This review discussed two aspects of ambient intelligence – areas of application and design guidelines. The areas of application are emergency treatment, autonomy enhancement, comfort services and integration with the community. Each of these categories has great potential for ambient intelligence to be applied if solutions that meet the user's requirement are developed.

Design guidelines for three aspects of ambient intelligence solutions were also discussed:

- Integration of Solution – Products that do not change the way the users work and are also easy to customize will be favored by users.
- The User's Emotional Response – Positive emotions are powerful when trying to change the way a user behaves. Negative emotions should be couple with cognitive information to have greater effect. In group situations, it is important to expose every individual's actions in order to cause behavioral change.
- Privacy and Data Security – Users prefer to have control over the information that is being measured, analyzed and stored. However, users are likely to adopt solutions that breach their privacy, if the benefit outweighs the risks.

FUTURE WORK

This paper has provided a starting point for designers who are developing ambient intelligence solutions. Categories and examples of applications for ambient intelligence have been given in order to help designers generate new ideas for ambient intelligence solutions. The design guidelines discussed provide a framework for designers to consider important user requirements when they develop the solutions.

In the future, it is recommended that designers incorporate these guidelines. They should also continuously obtain feedback from users to ensure that design efforts are focused on creating solutions that user's will readily adopt and integrate into their lives.

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