Human Interface Considerations for Ambient Assisted Living Systems

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Abstract

Systems for assisted living that support people in their own home are becoming ever more important internationally as social and economic demands change. In our research, the intended users were frail elderly living in their own home who suffered from memory loss and could benefit from prompting. We took a design science research approach and designed and built a prototype system. The system was built around RFID tags used as fixed landmarks and attached to moveable objects along with a portable interrogator. Commercially available hardware and software was used. Two system search methods were developed: history recall, using continuous object tracking and real-time object location sensing. Usability testing of the system using a small group of healthy university staff was undertaken in order to learn more about the interface between the device delivering the information and the usefulness of history recall versus real-time object location sensing for locating lost objects around the home. We found the history recall method worked well but the real-time object location sensing needed fine tuning with regard to the human interface. We recommend future interfaces include media additional to visual display and voice recognition such as haptic feedback.

Keywords: Assisted Living Systems, Assisted Living Technology, Ubiquitous Computing, Radio Frequency identification (RFID), Usability

1. Introduction

As the world's population ages, systems which are simple to use, low cost and designed to assist those with memory loss to maintain independence has long been recognised as a field of increasing importance [1,2]. While models such as task-technology fit, and technology acceptance deal with the use of new technology in defined environments, assisted technology devices have a greater impact on the lifestyle of the user. Building confidence that the system will work when required, that it will not be obtrusive to the user or their co-habitees, and that it will reduce rather than increase the difficulties of everyday living are key elements of assisted living systems. In some ways the device needs to act as a companion rather than a tool, being available when needed but being acceptable to live with when not. Our objective was to develop such a companion device.

The target user population of the prototype were outpatients suffering from memory loss who would benefit from an electronic prompt for where they last left a particular item. The intended users were novices and with only a fundamental knowledge of how to work a Personal Digital Assistant (PDA). Given the type of users according to Basrur and Parry [3], the system needed to be:

1) Easy to use.

2) Low in cost.

3) Low in infrastructure (preferably using hardware they will already likely possess such as handheld devices).

4) Compact in size (as they will have to carry it).
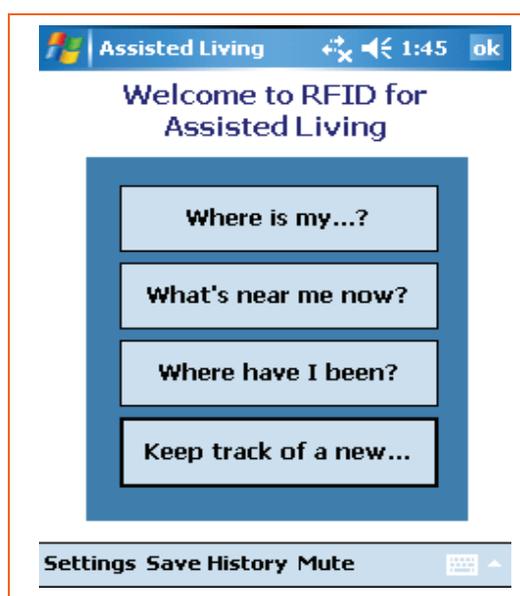
Figure 1: *Assisted living prototype main menu.*

We developed a prototype assisted living system to locate losable objects in the home with a user interface that included an easy-to-use touch screen interface with four large and simple menu buttons representing four simple menu choices (see Figure 1). The underlying model for object location in this system is called the Aura Object Location model. In our project we theorised about how the object location system would work. However, we didn't know if the approaches would actually work. Therefore, we asked the following research questions:

What aspects of the Aura Object Location user interface are important to the user for locating personal belongings within the home?

How useful is the 'Where is my…?' search? (Movement history)

How useful is the 'What is near me now?' search? (Real-time location sensing)

2. Methods

We used a design science research approach [4] to conduct our investigations and undertook a rapid prototype design software development approach [5]. Design Science is specifically related to the development of artefacts and has design, development and evaluation phases. To explore this research question we designed and developed a software application prototype and undertook some preliminary usability testing.

A PDA is an accepted device [6] to interface with assisted living systems because of the mobility of the device, the relatively large screen size and the availability of touch screen technology. Systems that have implemented

laptops in the home have struggled to gain acceptance from the user groups due to complexity of operation and lack of acceptance of the laptop device [7]. Ballegaard, Bunde-Pedersen and Bardram [7] suggest that the television and the telephone are more accepted devices.

2.1 The Prototype

The application software prototype was developed to record the presence of objects that were within a person's "aura" at specific "landmarks". The aura is a user's personal space, either on the body or very close to the body. The aura concept is based on the work of Satoh[8]. A landmark is a location. (For a more detailed description see [9,3]).

One approach to user requirements analysis in an assisted living system is to investigate the specific requirements of the targeted group of users. However, Mynatt & Rogers [10] put forward the concept of universal design which promotes participation and integration of the needs of all users so that the early adoption of home technologies by younger adults will help ensure their availability and expectation of use by those same adults as they age. In our approach we used currently available technology. We identified specific hardware and software functionality that would need to develop to meet the needs of frail elderly assisted living users.

3. Hardware Specification

We developed our application on a HP iPAQ hx2495 Pocket PC and a Feig LR2000 RFID interrogator (13.5Mhz) with serial Bluetooth to provide wireless connectivity and loop antenna. The interrogator alone weighs 1.6kg (including metal housing which is non-removable as it conducts heat away from the electronic circuitry – please note that eventually, the interrogator will sit on the person). Including a closed cell battery providing 9 volts and other equipment, it weights approximately 2.5kg. We used commercially available gen-1 RFID tags (passive & read only) either in adhesive label or key tag configuration. At the time of development, this was the best commercially available equipment to give the required read range without going to Ultra High Frequency (UHF) equipment and active tags.

3.1. Software Specification

The system was developed on a Pocket PC running Windows CE, (wirelessly) linked to a RFID reader. Windows CE was chosen as the more architecturally stable platform at the time of writing. Also, there was wider and more native support for speech recognition and natural handwriting recognition on Windows CE devices.

The application software was developed using the Windows CE platform and the .net programming environment, as it provided all the necessary tools to program for Win-

dows Mobile. The application was programmed in C# .net making use of the Pocket PC emulator (that can emulate the loading time and the interface of the Pocket PC), and the database engine Microsoft SQL Server CE that works on the Pocket PC platform (installs with .net framework).

A software application was developed for the Pocket PC platform. The application maintained a database of RFID tag identifiers, corresponding to both easily-losable objects (e.g. cordless telephone, wallet, keys and glasses) and fixed locations (landmarks) (e.g. nightstand, refrigerator). The database was updated with known object tags as they came into range and details of landmark tags also in range at the time. From this information, the user could request the last recorded location of any object known to the system. The user can add, modify and remove landmark and object tags from the system. Unrecognised tags (those that have never been set up, and those that have previously been removed) were ignored as these may represent any RFID tag (such as item tags on store merchandise). Interaction with the system was via a combination of speech recognition/synthesis and on-screen display.

3.2. Usability Testing

Usability testing encompasses a number of methods that allow potential users of a technology, or representatives of those users, to interact with the technology at various stages of its development. The choice of method depends on a number of factors including the stage of development of the technology, and the nature of its use [11]. In this case a laboratory-based approach was used, involving the cooperation of healthy volunteers, who were asked to perform a number of tasks using a prototype of the system. Data collected recorded a qualitative interpretation of the users' reactions and experience with the device and the collaborative improvement of the device via user comments and suggestions.

3.3. Usability Testing Method

The usability testing process used was based on the simulated prototyping method [12]. At the beginning of the testing period each tester was informed of the usability testing process and was reminded that the tests were a reflection of the software application and not of themselves. They were then provided with a brief walkthrough/ demonstration of the features the RFID for assisted living prototype. Each tester was reminded that they could use the system in any way they felt comfortable with to complete their tasks, and could ask for assistance at any time.

During the tests one of our team members was with the tester to provide information and feedback about the testing process. Another team member moved tags in and out of range of the RFID reader during the testing phases, to simulate the tester's aura. The third team member was responsible for recording and managing the results of each test.

Before the testing began, two scenarios were developed for the testers to attempt. The two scenarios related to object location within the system and they were:

(i) movement history

(ii) real-time location sensing

Usability templates used in this project were adapted from [13]. Ethical approval was obtained to undertake the testing with healthy testers from AUTEC. Synopsises of each of the test tasks are now provided beginning with test scenario 1.

3.3.1. Test Scenario 1: The "Where is my…?" Search (Movement History)

This scenario tested searching for a lost item using the "Where is my…?" interface. In this scenario, we attempted to simulate the loss of an item while still leading the tester through the test environment to build their 'mental map' of the area and landmarks. This was done by having the tester deposit several identical items, differentiated by their (invisible) RFID tags alone. We then asked the user to find one of these items. Though they may remember where each was placed, they will have no way of knowing where the particular item requested was left – it could be at any of the locations where they left an item.

The tester was given a stack of ten small tagged items, all identical (blank notebooks). They were instructed that when they entered the test environment, they were to place one of the items on each of the 10 locations they could see marked with a large X in fluorescent masking tape.

Each location was somewhere between waist and chest height, such as a desk, shelf or chair. The tester did not have to 'hunt' for these locations – they were marked so as to be immediately obvious on approach. Any item may be left at any of these locations and they had a reasonable amount of time to complete this objective (3 minutes).

At the end of the scenario, they were asked to find two particular objects from the ten they had just put down. There was no way to do this by sight, as the items were identical. They only knew the names of the items they were looking for as a recipe book and an address book. Performing a "Where is my…?" search should have given the user the last known location of each of the two items they were looking for. They were asked to physically retrieve only the two items, using the Pocket PC to assist them. The scenario was considered explicitly failed if they returned one or more incorrect items.

3.3.2. Test Scenario 2: The "What's near me now?" Search (Real-time Location Sensing)

This scenario tested searching for a lost item without exact history, using the "What's near me now?" interface (the walk around search). In this scenario, a small RFID tagged item was hidden in a room (such as a key placed under a folder). This item was pre-placed and its history loaded into the database – the history contained several of

the landmarks the user learnt in scenario 1, spaced five to ten seconds apart, ending with 'you' (the item was in aura, but not near a landmark). These landmarks provided a trail to a general area – for example:

Last Seen Near…	At…
(the) Elevator	10:00:00 AM
(the) Hallway by Reception	10:00:10 AM
(the) Hallway by The Office	10:00:15 AM
(the) Office Door	10:00:25 AM
You	10:00:30AM

Table 1: *Location history.*

The information in Table 1 may be interpreted as the following scenario:

After reaching the office door landmark, the item was placed somewhere away from any landmark. However, it should have been relatively obvious from the history that the item was likely to be in the office somewhere – the user appeared to have walked straight from the elevator to the office door, and then placed the item somewhere without passing the office door again. The object was therefore inside or outside the office, close to the door and not near any other landmark. This history was available only if the user chose to view it of their own accord. They were told that the item was in the office. If they chose to view the item history to help their search, the scenario provided a useful history (as there likely would be if the system were in actual use). This scenario did not rely on the set-up for scenario 1.

	Respondent				
	#	#	#	#	#
Background	**1**	**2**	**3**	**4**	**5**
Age	33	34	60	61	49
Gender	F	F	M	F	F
Pocket PC Experience	N	Y	N	N	N
English First Language	N	Y	Y	Y	Y

Table 2: *Tester Background.*

3.3.3. Usability Testers

Five testers were selected on the basis of convenience from university staff. We selected users who might be sympathetic to our needs and chose mostly allied staff rather than academic staff to get a better representation of everyday users of the system. None of the testers were elderly (over the age of 65); however, only one of our testers was familiar with the Pocket PC environment (see Table 2). Each tester undertook scenario 1 and scenario 2 simultaneously. All testers were healthy testers and memory loss was simulated as part of the test scenario.

4. Results

The results are divided into two sections relating to the test scenarios undertaken by the testers. The first section presents results from test scenario 1 – movement history and the second section presents results from test scenario 2 – real-time location sensing.

4.1. Test Scenario 1: The "Where is my…?" Search (Movement History)

All of the tasks for the first test scenario were completed successfully by all testers (see Table 3).

Task	Yes	No
Main Menu: Was the tester able to identify at first glance where to go to find their lost item?	5	0
Recipe book: Was the tester able to easily identify which item they were searching for from the list?	5	0
Recipe book: Was the tester able to understand where the recipe book was?	5	0
Address book: Was the tester able to easily identify which item they were searching for from the list?	5	0
Address book: Was the tester able to understand where the address book was?	4	1

Table 3: *Observations from Task One, (N=5).*

One tester was unable to understand where the address book was. The tester went to the right location, but was unsure about the item (retrieved the paper placed in the recycling bin instead of the book on the television).

At least two testers made use of the speech output to locate items. One of these testers appeared to make use of the speech output exclusively (listened to the voice and did not look at the display). One tester did not actually walk into range of the clock tag, due to that tag being against the wall. This was noticed for various landmarks in subsequent tests.

4.2. Test Scenario 2: The "What's near me now?" Search (Real-time Location Sensing)

The "what's near me now" search task was a little more difficult for our testers to understand, although only one of the testers could not complete the tasks (see table 4). However, given the type of users targeted, it is possible that this is an indication that the "what's near me now test" needs some attention.

Task Description	Yes	No
Main Menu: Was the user able to identify at first glance where to go to search for items/landmarks are were currently in range?	4	1
Was the user able to interpret what was on screen?	4	1
Was the user able to successfully find the missing item without any help from the facilitator?	4	1

Table 4: Observations for Task Two, (N=5).

Two users did not understand that the "What's near me now?" form automatically refreshed. That is, they could move the device around the environment and the display would always reflect what was near them without the need to select any option on the device. One tester was able to complete the scenario by opening and closing the form, the other required facilitator assistance to complete the scenario. One user did not initially realize how the "What's near me now?" option worked and waved the Pocket PC around, apparently without looking at it. They may have been expecting audio output, as in the first scenario. The user with prior Pocket PC experience generally moved more quickly and confidently through the interface than the others.

In this particular part of our project we wanted to explore the user interface currently available in the market. We tested two methods of user interaction with the interface: 1. Where is my…? (movement history) and 2. What's near me now? (real-time location sensing).

In our testing we had 100% success with all testers being able to quickly understand and use the movement history method. The testers seemed to appreciate the speech output aspect of the application.

However, our real-time location sensing method was not as easy for our testers to understand conceptually or to use. Perhaps some of this difficulty was due to the software interface which automatically updated location information without giving a sign to the user that it was doing so. As speech output was not implemented with this part of the application, it is difficult to say whether having speech output to announce the detection of new objects and landmarks would be useful or a hindrance.

5. Discussion

The specific findings from our study were as follows. "Where is my" as a concept was easy for our testers to understand, but the fuzzy response was not. So, when the PDA responded that the tag was 'last seen near the coffee table', it was not clear what near meant. That is, does near mean within reach of the user, or within one or two steps of the user.

In terms of the movement history search, we found that there was a fuzzy interpretation aspect to information provided to the user to help them locate the object. For example, our prototype reported that the glasses object was last seen near the side board table. We could find no studies on how users might interpret the concept of 'near'. To some users this might mean within 30 centimetres and to others, it might mean three metres. We suspect that this might relate to individual interpretations of personal space.

With the real-time location sensing search we found that without any audible prompt to signify that there has been some update in the user interface, many users were not aware that another object was detected unless they studied the device continuously. In a real world application, it will be important to find ways that a user might be informed that the interface has been updated, or might like to be informed of changes without creating distraction and annoyance with the system. These might be related to the volume and type of audible signal or they might be related to other types of ambient information.

"What is near me now" automatically updated, but there was no signal to the user that it had updated, so there was no signal for the user to look again. To beep or not to beep was a conundrum. Beeping is really frustrating for the user, but no easy way to tell the user that the information has been updated exists to our knowledge. So, the user had to wander around the environment with their eyes clued to the PDA.

Placement of tags within the environment was very important. We found that placement of tags against walls

was not suitable in a large open room environment assuming an aura radius of ~75cm as users did not walk close enough to the walls. An added benefit of this approach was that it reduced the likelihood of through-wall landmark conflict

5.1. Future Work

This task is what Adam Greenfield refers to as Artificial Intelligence (AI) hard [14]. Artificial Intelligence is a difficult area. The textual interface and the technical confines of the PDA where quite limiting in this experiment. Ideally, we wanted to have a voice activated system, but such software development kits were not available and to develop one would have been a distraction to the primary goal of the research. However, a voice activated system remains a challenge for future projects.

Technology currently becoming available could address the issue of how to communicate information to the user without using the visual channel which is already fully occupied in search of the missing object. One solution might be to communicate extra information to the user using haptic feedback. Tang et al [15] experimented with haptic feedback and found that users could perceive haptic feedback while being visually occupied. Haptic feedback refers to using the human sense of touch to convey information. An example available in the current market is the blue tooth wrist band vibrator that can be set to vibrate when the user's mobile phone rings (figure 2). The existence of such a device demonstrates that systems that use haptic feedback were commercially available means that such a device could be incorporated into the prototype system in the future.

Figure 2: *Example of haptic feedback - BluAlert Bluetooth vibrating wristband.*

In this paper we report on usability testing where we simulate the aura concept due to the size and bulk of the actual RFID interrogator equipment. Future usability testing should focus on integrating lighter and less intrusive

FID interrogator equipment to allow the testers to use the system fully and for a longer period of time in more realistic scenarios.

6. Conclusion

In this part of our project we set out to test the practicability of the Aura Object Location model by designing a prototype system and undertaking some laboratory-based usability testing. In particular, we tested the "Where is my…?" and the "What's near me now…?" aspects of the Aura Object Location model. In our usability testing with healthy testers we found that the "Where is my …? object location method was very successful even though there was some ambiguity in the feedback given to the user such as the exact meaning of the word near. We found the 'What's near me now …? object location method to be less successful, primarily because of the difficulty of feeding back details to the user. We plan further research with a more fully developed prototype testing with testers with more relevant background to the target users incorporating clinical expertise through collaborative endeavour.

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