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Empirical Study and Design of Multimodal Ambient Assisted Comfort Services for Senior Citizens

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Abstract **-** The growing size of the aging population is becoming a significant issue for many countries, which can be helped through use of ambient assisted living systems to allow seniors to live at their homes longer. Many previous works have focused on the emergency and autonomy services, and lack studies on comfort service. The purpose of this paper is to present an empirical study of using multimodal interfaces in ambient assisted comfort services for senior citizens targeting participants at their home, with a prototype system that supports both traditional and multimodal interaction methods. Scenarios have been defined that include common tasks such as item finding, communication, media access, and setting calendar events. 15 senior citizens have answered questionnaires and scale rating questions from each performed scenario. The comparison between traditional and multimodal interfaces were done through a set of evaluation criteria including efficiency (time), pleasantness, fatigue, naturalness, ease of learning, and perceived efficiency. The results showed that all the participants have enjoyed the multimodal interface, and showed better efficiency than traditional interaction method.

Keywords**:** Multi-modal, Natural user interfaces, Smart home, Elders, Comfort services.

1. Introduction

The rapidly growing issue of aging population has been widely recognized as a global and national problem. Many researchers have pointed out that in next ten to thirty years, care facilities will not able to support the amount of aging population, and the global organizations and governments hope the elderly can remain in their house as long as possible (Brown and Murphy, 1989; Ijsselsteijn et al., 2007; Inglis et al., 2003). With the advancement of the technologies, the everyday lives of senior citizens, who still live at their home and without the help of care professionals could potentially improve, though the senior citizens may have more difficulty with, or are simply afraid to adopt, the newest devices and software, because of the age-specific needs issues and product's lack of design considerations for this user segment. However, their quality of life would be greatly enhanced, if they could also take advantages of the new technologies in their daily life.

The concept of Ambient Assisted Living (AAL) was originally derived from the Weiser's concept of ubiquitous computing (1991), where the computing devices are all dissolved into our daily objects and environment, so the user could interact with the computing system more intuitively, such as using voice, gestures, or via everyday objects with integrated digital informatics. Design and development of such AAL systems requires a better understanding of how senior citizens interact with new natural interfaces with different modalities and how these modalities and associated interfaces can be used and combined to provide an effective interaction system when performing typical domestic tasks.

The living assistance services have been mainly classified into three categories (Nehmer et al., 2006): emergency treatment services, autonomous enhancement services, and comfort services. Previous studies have focused on the emergency and autonomous due to the priority, because the comfort services are perceived as not as important and with less social impact compared to the first two (Nehmer et al., 2006). In contrast, other studies have shown that being socially involved and more active while getting older, will be more beneficial to the seniors' well being (Doyle et al., 2012; Ganesan and Anthony, 2012). Thus, the comfort services have the same importance and social impact as first two categories.

Technologies have been advanced in recent years, with numerous commercialized natural interface devices and smart objects. It is now possible to use these methods within an AAL environment. Since the interaction mode in an AAL is typically ubiquitous (D'Andrea et al., 2009), being able to understand how and why the user would use certain modality for certain tasks is essential. Many studies have evaluated these natural interfaces individually, but not yet a system that has integrated a set of natural interfaces and smart objects as a multimodal interface for an AAL environment. A multimodal interface encourages users to communicate with technology naturally by utilizing all of the human senses (Bourguet, 2003). Thus, many questions are unanswered. For instance, would users prefer to use their voice to activate a videophone call or use gesture to do so? Maybe the user would still like to use the traditional physical phone-like object to perform such task. How well does our target population perform day-to-day computational tasks using various modalities within an AAL environment? Our research addresses the problem of how multimodal interfaces can be used for AAL systems to provide comfort services.

Based on these unanswered questions, following research questions were considered for this study:

1. *How senior citizens react to the use of a multimodal digital interface?*
2. *How do different modalities compare for performing common tasks?*
3. *What modalities are more suitable for these tasks in the context of a smart home?*

The main contributions of this study are:

1. Comfort services in smart homes: We learned the importance of comfort service category and the impact it has for our target population. This resulted in the study of AAL systems from a novel point of view that focuses on comfort services.

2. Multimodal interface for common everyday tasks: Through existing studies, we have selected four tasks that are important and essential for senior citizen's daily life. We developed a multimodal system that provides different options for performing these tasks.

3. User study on gesture and voice based interfaces: We conducted a novel user study that provides data from the senior citizens, who performed all the tasks at their home. This is an important factor, because the participants are completely relaxed and most of them have also enjoyed the study. Based on the first hand data we gathered from the participants, the experiences the user had are evaluated from ratings and comments.

2. Related Work

As Sadri's survey paper (2011) indicated, supporting for independent living for elderly is one of the main applications for ambient intelligence. In next 5 to 10 years, the percentage of the senior citizen will be higher than the youth. The predicted expenses on health care or chronic diseases will no longer be affordable to many governments. Some pioneering AAL projects include Robocare (Bahadori et al., 2004), AHRI (Haigh et al., 2006), and MINAml (Niemelä et al., 2007), and these projects have created a good foundation in the field of AAL. A few newer projects and system will be reviewed in the course of this section.

As previously mentioned, researchers believed all three AAL services categories are equally important and critical for the older adults, but they have given more attention to the first two categories (Ijsselsteijn et al., 2007; Weiser, 1991). Moreover, researchers have generally agreed that an AAL should have characteristics: invisible, mobile, context aware, anticipatory, communicating naturally, and adaptive (Weiser, 1991; Kleinberger et al., 2007).

Before introducing the interaction methods within the AAL, we will first take a look at the infrastructure of the AAL, since it is a complex and intelligent system and it is worth investigating how it works in order to have characteristics mentioned above. Nick and Becker (2007) have worked on a monitoring and assistance component including a hybrid processing/executing unit, which uses case-based and situation-recognition-based approaches to monitor and adapt the planned and running treatments. So the system is context aware of the users and able to anticipate the upcoming commands and execute them accordingly. Storf et al. have also done similar work (Storf et al., 2009), who proposed a multi-agent, and event-driven approach for recognizing emergency situations or unusual behaviors.

Lezoray et al.'s dynamic adaptation approach (Lézoray et al., 2011) is also being used in an Ambient Assistive Living environment. In additional to the underlying technologies and approaches, other researchers have focused on the interface of their system. For instance, D'Andrea et al. (2009) have proposed a multimodal pervasive framework for ambient assisted living environment, which divides the framework into four levels, the acquisition/presentation level, the analysis level, the planning level, and the activation level. Similarly, Kernchen et al. (2004) created a conceptual framework integrating a multimodal user interfaces and ubiquitous sensorised environments in order to provide better user experiences. However, their study was theoretical, and did not provide any practical details, such as the kind of modalities and interaction methods would be involved, and the type of tasks the users would perform within their system.

3. Research Overview

By reviewing previous works, a gap can be identified between the fundamental technologies of AAL and the interaction design for the targeted audience. The objective of this study is to create and evaluate a multi-modal based system-integrating tasks from the comfort services category within a smart environment to help aging population to maintain same life quality as their abilities decline. In order to investigate a range of comfort services, four tasks were identified: Item Finding, Using Reminders, Communication, and Browsing Images. Moreover, one of these four tasks may have been studied in one of the previous studies to test certain functionality of a technology and may have accompanied with a user study. Nevertheless, not many studies have implemented all these tasks into one application with the proposed interaction modalities, such as gesture, voice and smart objects (Nehmer et al., 2006; Kernchen et al., 2004; Turunen et al., 2009). Other studies may have tested many scenarios with more than one task, but they may only implemented using one interaction modality, such as speech (Vacher et al., 2012; Portet et al., 2013) or gesture (Ganesan and Anthony, 2012). Our study aims to utilize use body movement based gesture input, voice input, and handheld devices with smart objects to form a multimodal evaluation system with all the tasks mentioned above.

4. System Design

In order to create a capable AAL evaluation system as described in the previous chapter, applications were developed specifically for the user study (Fig. 1).

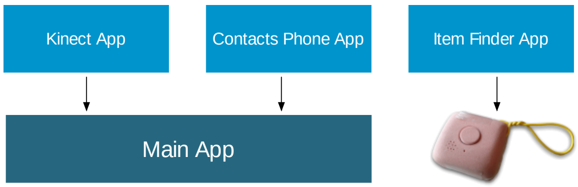

Fig. 1. The structure of the prototype system.

4.1.1 Main Application

The Main app is the hub for hosting all the scenarios and their tasks, and it is also responsible for communicating with the Server application for receiving NUI inputs, and the Phone app for getting command from the user's selection.

4.1.2 Kinect app for Natural Interface Input

As the Windows Runtime Application has not supported Kinect sensor yet, the Kinect app was developed as a middleware for the Kinect sensor and the Main app to communicate with each other. The Kinect app is developed based on the Windows Presentation Foundation (WPF) framework. Besides the gesture and voice recognition feature, the Kinect app also has network functionality, which can send converted gestures and voices as commands to the Main app. By using the Kinect Toolbox toolkit (http://kinecttoolbox.codeplex.com), the Kinect app is able to recognize gestures such as, swipe left /right, and clock-wise circle from each hand separately. Microsoft speech platform SDK was used for recognizing the voice commands from the user. By using the experiment method Wizard of Oz, the researcher has created a set of commands, which are used in the evaluation system, so the user can use these commands to control the system smoothly.

4.1.3 Phone App

The application developed and deployed to the smart phone is based on Windows Phone 8 SDK. The main function of the application is to display the frequent contacts for making video &audio calls by simply taping on each contact's image.

4.2 Item-Finder Hardware

A model casing was designed and created for the Bluetooth PCB board produced by Ace Sensor for Item Finder Task. When they need to find their belongings, such as glasses, or keys, they just need to tap on their smart phone, this hardware will flash lights and make sounds.

4.3 Usability Considerations

Measuring the overall satisfaction of different interaction modalities is one of the major criteria for this study, therefore, age-related issues have been considered during the design processes. To begin with, main app has a fixed menu on the top of the app showing all tasks. Secondly, all the font size and controls are intentionally enlarged to assist weaker sights. Thirdly, the color scheme for each scenario is matched with the name of each task's color coding (e.g. the color used in item finding interface would be the combination of blue and purple as the name of the tasks were blue and purple), which hopefully will let the participants be more confident and get familiar with the system easier.

5. User Study

The purpose of this user study is to evaluate the prototype multimodal system using these criteria: pleasantness, ease of learning, easy-of-use, efficiency (time), fatigue, naturalness and perceived efficiency. Each task includes two parts performing the same task but compares the traditional input methods (e.g. mouse and keyboard) versus the natural user interfaces (e.g. voice, gesture, and tangible interface).

Fig. 2. The experiment setup.

All our participants were healthy seniors, and based on their age, they tend to have normal aging symptoms, such as declined cognitive level, and weaker motor skills. 15 participants (5 male, 10 female) were recruited for this study, whose ages were between 50 and 75, and most of the experiments were taken place at participants' home, with one exception where the tasks were performed in a board room, but it has been setup as a home-like environment (Fig. 2). Participants rated the criteria for each task using a 1-5 Likert scale.

6. Discussion

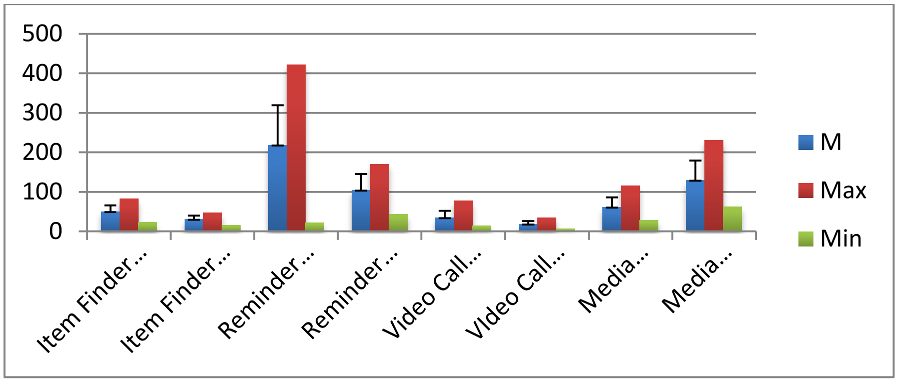

Fig. 3. The M/Max/Min/SD of the time spent completing tasks.

Table 1. The M/Max/Min/SD scale rating points by Criteria.

Criteria	Definition of Metrics	Significance (using Mann-Whitney U Test)	Mean Rank	
			Traditional	Multimodal
Pleasant	How pleasant is it to use this system?	0.009	51.840	67.160
Ease of Learning	How easy is it for using this system for the first time?	0.077	64.680	54.320
Naturalness	Do they feel that the system is natural to use	0.027	54.200	65.800
Fatigue	As seniors, would the system tiring them by utilizing all the modalities?	0.771	58.700	60.300
Perceived Efficiency	Was the system more efficient to use than traditional computing system?	0.106	54.640	64.360

We use Mann-Whitney U (MWU) Test to determine the significance of our parameters (devices) in changes in evaluation criteria. Compared to other tests such as T-test, MWU provides greater efficiency in case of non-normal distributions such as Likert ratings. According to the results above (Fig. 3; Table 1), the targeted senior citizens have enjoyed using our multimodal interface. For example, from the rating scale questions, and the post study questions, their answers have clearly stated that they found the multimodal system is very "fun to use". They also felt the system is more effective than the traditional input method, which can be validated by the time for finishing each task. They also provided comments on how they would like the system to be improved, such as the gesture recognition. The data has indicated, within the multimodal interface, voice and tangible interfaces have been favored the most, and the gesture-based interface was less desirable due to many factors. One factor would be the nature of how Kinect sensor works; it emits infrared light and analyzes the reflected infrared light. This mechanics work fine in an ideal environment, where is dark, and with no direct sun light. However, during the experiment with some of the participants, it was impossible to find a place at their home that would avoid the bright sun light. This environmental factor was one of the major reasons why the gesture recognition was less favored.

6.1 Source of Error & Limitations

Even though multiple measuring and researching methods were used during this study, some possible sources of errors exist in our study. First of all, due to the time constraints, it was not realistic to have interviews with each participant and analyze the data using proper qualitative methods, because it was not feasible and would exhaust the subjects too much. Therefore, the answers from the participants may not reflect their opinions fully, due to the non-interactive nature of the paper-based questionnaires and possible confusions about questions. Secondly, the environmental factor mentioned above may also provided the participants improper perception on gesture based interaction method, which will be something to consider by the AAL application designers and developers. Also, since the experiment was set in each participant's home, there are certain variables, such as time of the day, day of the week, or the general state of the participants that may not always be consistent and affect the study. Furthermore, the participants were very generous to donate their time to perform all the tasks and answer the questions. Sometimes, they may have tried to fill in the answers as a way to please the researcher; especially all the participants had a pleasant experience doing the entire task from the experiments. One other source of the error may be due to difficulties in understanding the language. Three participants were not native English speaker, and one of them was unable to perform the reminder task. Her answers were also very contradicting throughout the questionnaires. The rest of two non-English speaker participants also did not understand every part of the study. Lastly, even though a tutorial was given at the beginning of the experiment for each participant, the ease of learning involved with memorizing the gestures, voice command and using the system was also a possible source of error. Some participants were saying that they had issue remembering the gestures and voice commands. Our study was limited to only 4 simple tasks and our designed gestures/commands. The type of tasks and gestures used in our study could also affect the results, as these results could be different if the tasks and gestures were defined more appropriately.

7. Conclusion

As the aging population grows rapidly, the lack of proper and sufficient caregivers and facilities to accommodate this increase becomes a significant issue. It is valuable to explore other possibilities as early as possible. Increasing the number of the years that elders live independently can reduce the expenses for the healthy and long care facilities significantly. Ambient Assisted Living environments implement advanced technologies into seniors home, providing them emergency, autonomy and comfort services, so the aging population can maintain the same quality of life, and stay in their homes much longer. A number of studies have been conducted on this topic, but a significant lack of studies in comfort services with multimodal interfaces have been identified.

The work presented in this paper has developed a prototype system with a multimodal interface, allowing participant to use their gesture, voice and smart objects to perform their day-to-day tasks. By conducting an empirical study with 15 senior citizens, we have shown that such multimodal systems can improve ambient assisted living systems for comfort services. Our study was limited to 15 participants, and 4 simple tasks. It would be beneficial if more participants could be involved, and the participants could perform more extensive tasks. Future studies should also involve more qualitative research methods, such as focus group, and interviews to completely understand and study the participants' feedbacks and experiences.

References

Bahadori S., Cesta A., Grisetti G., Iocchi L., Leone R., Nardi D., Oddi A., Pecora F., Rasconi R. (2004). RoboCare: pervasive intelligence for the domestic care of the elderly. Intelligenza Artificiale, vol. 1, no. 1, pp. 16–21.

Brown A. S., Murphy D. R. (1989). Cryptomnesia: Delineating inadvertent plagiarism. Journal of Experimental Psychology: Learning, Memory, and Cognition, vol. 15, no. 3, p. 432.

Bourguet, M.L. (2003). Designing and Prototyping Multimodal Commands. Proceedings of Human-Computer Interaction (INTERACT'03), pp. 717-720.

D'Andrea A., D'Ulizia A., Ferri F., Grifoni P. (2009). A multimodal pervasive framework for ambient assisted living. "Proc. of the 2nd International Conference on PErvasive Technologies Related to Assistive Environments," Corfu, Greece, June10-12, p. 39.

Doyle J., O'Mullane B., McGee S., Knapp R. (2012). YourWellness: designing an application to support positive emotional wellbeing in older adults. "In Proc. of the 26th Annual BCS Interaction Specialist Group Conf. on People and Computers," Birmingham, UK, Sep.12-14, pp. 221-226.

Dishman E. (2004). Inventing wellness systems for aging in place. Computer, vol. 37, no. 5, pp. 34–41.

Haigh K. Z., Kiff L. M., Ho G. (2006). The independent lifestyle assistant: Lessons learned. Assistive Technology, vol. 18, no. 1, pp. 87–106.

Ganesan S., Anthony L. (2012). Using the kinect to encourage older adults to exercise: a prototype, "in CHI'12 Extended Abstracts on Human Factors in Computing Systems," Austin, USA, May 5-10, pp. 2297–2302.

Ijsselsteijn W., Nap H. H., de Kort Y., Poels K. (2007). Digital game design for elderly users "Proc. of the 2007 Conf. on Future Play", Toronto, Canada, Nov. 15-17 pp. 17–22.

Inglis E. A., Szymkowiak A., Gregor P., Newell A. F., Hine N., Shah P., Wilson B. A., Evans J. (2003). Issues surrounding the user-centred development of a new interactive memory aid. Universal Access in the Information Society, vol. 2, no. 3, pp. 226–234.

Kernchen R., Presser M., Mossner K., Tafazolli R. (2004). Multimodal user interfaces in ubiquitous sensorised environments. "Intelligent Sensors, Sensor Networks and Information Processing Conf.," Proc. of the 2004 IEEE, pp. 397-401.

Lézoray J.-B., Segarra M.-T., Phung-Khac A., Thépaut A., Gilliot J.-M., Beugnard A. (2011). A design process enabling adaptation in pervasive heterogeneous contexts. Personal and Ubiquitous Computing, vol. 15, no. 4, pp. 353–363.

Kleinberger T., Becker M., Ras E., Holzinger A.,Müller P. (2007). Ambient intelligence in assisted living: enable elderly people to handle future interfaces. Ambient Interaction, Springer, pp. 103–112.

Kowtko M. (2012). Using assistive technologies to improve lives of older adults and people with disabilities. "Systems, Applications and Technology Conf. (LISAT)", IEEE, Long Island, USA, pp. 1–6.

Nehmer J., Becker M., Karshmer A., Lamm R. (2006). Living assistance systems: an ambient intelligence approach. "Proc. of the 28th Int. Conf. on Software engineering," Shanghai, China, May 20-28, pp. 43–50.

Nick M., Becker M. (2007). A hybrid approach to intelligent living assistance. "in Hybrid Intelligent Systems 7th Intl. Conf.," pp. 283–289.

Niemelä M., Fuentetaja R. G., Kaasinen E., Gallardo J. L. (2007). Supporting independent living of the elderly with mobile-centric ambient intelligence: user evaluation of three scenarios. Ambient Intelligence, Springer, pp. 91–107.

Portet F., Vacher M., Golanski C., Roux C., Meillon B. (2013). Design and evaluation of a smart home voice interface for the elderly: acceptability and objection aspects. Personal and Ubiquitous Computing, vol. 17, no. 1, pp. 127–144.

Sadri F., (2011). Ambient intelligence: A survey. ACM Computing Surveys (CSUR), vol. 43, no. 4, p. 36.

Storf H., Kleinberger T., Becker M., Schmitt M., Bomarius F., Prueckner S. (2009). An event-driven approach to activity recognition in ambient assisted living. Ambient Intelligence, Springer, pp. 123–132.

Turunen M., Kallinen A., Sànchez I., Riekki J., Hella J., Olsson T., Melto A., Rajaniemi J.-P., Hakulinen J., Mäkinen E. (2009). Multimodal interaction with speech and physical touch interface in a media center application. "Proc. of the Intl. Conf. on Advances in Computer Entertainment Technology," pp. 19–26.

Vacher M., Portet F., Rossato S., Aman F., Golanski C., Dugheanu R. (2012). Speech-based interaction in an AAL context. Gerontechnology, vol. 11, no. 2, p. 310.
Weiser M. (1991). The Computer for the Twenty-First Century. Scientific American, vol. 9, pp. 94-104.