Immersive virtual environment as a promising tool for the elderly-friendly assistive robot design

Jeonghwan Kim[a], Choongwan Koo[a] and Seung Hyun Cha[a]

[a]Department of Building Service Engineering, The Hong Kong Polytechnic University, Hong Kong
E-mail: jeonghwan.kim@polyu.edu.hk, choongwan.koo@polyu.edu.hk, seung-hyun.cha@polyu.edu.hk

Abstract

As the population of older people continues to rapidly grow worldwide, assistive robots for older people are become more important to maintain their social, physical and psychological well-being. Although the idea of having these robots is an enticing prospect, there are many barriers for older people to adopt the robots in a daily life such as a negative attitude toward a robot, inadequate robot design, confined living environment. Therefore, the in-depth understanding of such barriers prior to adopting the robots is required so as to boost intimate interaction with and acceptance of assistive robot technology. This study thus aims to suggest a guideline that helps understand such barriers with a focus on relationships among the three aspects, namely human, robot, and environment. It then proposes Immersive Virtual Environment (IVE) as a tool to evaluate various scenarios of Human-Robot Interaction (HRI), so that it will help find optimal design solutions for assistive robots in consideration of the relationships among the three aspects. This research has great potential to contribute to the design principles of the assistive robots as well as space and environment planning for assistive housing.

Keywords –

Assistive robot, Healthy aging, Immersive virtual environment, HRI

1 Introduction

Many countries are facing demographic transition towards aging society. Based on the recent report [1], the number of people in the world aged over 60 years, is projected to grow by 56 percent between 2015 and 2030. Consequently, the demand of well-being of older people has become an important social issue that needs to be addressed in near future. One of the primary goal of aging society is to promote healthy aging [2]. Healthy aging is a concept that older people can take an active part in society and enjoy an independent and high quality of life [3]. Many researchers have been developing various types of robots to support and assist the older people in their home, and it has been widely recognized as one of the effective ways to address population aging issues in terms of social interaction (e.g. talk, play, etc.) [4, 5] and physical interaction [6, 7].

However, most of these studies and technologies have suffered from a lack of well-grounded and comprehensive considerations of both living environment and the unique characteristics of older people, which may leads to the low technology acceptance rate [8]. The existing literature on technology acceptance for the elderly mainly focuses on the learning and supporting environment in accordance with the physical and cognitive debility [9, 10]. To fill this gap, this study emphasizes the importance of living environment and human aspect of older people when developing and deploying an assistive robot in their living environment. Further, we propose the use of immersive virtual environment as a tool to evaluate design alternatives of assistive robot.

2 Literature review

Over the past decade, there has been an increasing amount of literature on the Human-Robot Interaction (HRI). Many researchers have developed the assistive robots, and successfully commercialized their products, such as Care-O-Bot (Assistive robot, Fraunhofer, Germany), Robear (Nurse robot, Riken, Japan), Paro (Companion Robot, SoftBank, Japan). These robots are capable of detection, grasp, moving, placing, hand-over an object to elderly [11]. To provide these assistance, the most importantly, robot must be equipped with a high standard of safety features as well as behavior, and appearance (e.g. gaze, blink, speech, human-likeness, etc.). Despite these technical advancements in robotics, human and environmental aspects were often disregarded [12, 13]. In this paper, we investigate human and environmental aspect in assistive robot for elderly.

2.1 Living environment

To date, some studies have identified a link between robot and environment [14-16]. Tan, Mohan [16] has emphasized the importance of five factors of robot-friendly environment, which comprise observability, manipulability, activity, and safety. For example, proper design of corridor, door knob, mechanism of artifacts, and materials were proposed for the safe interaction. However, the studies have focused particularly on the mobile and commercial robots with specific purposes, not on assistive robots serving humans in a daily living environment. Meng et al. [17] proposed design principles for an assistive robot for elderly and put emphasis on the role of software capability to provide cost efficient flexibility and to accommodate various levels of task requirement, user abilities, and personal environments without sacrificing cost and functionality. Furthermore, It is reported that many older people live in a confined and relatively small flat in land scarce urban area, which might hinder physical interaction between human and robot [18]. As operation and mobility of assistive robot require and occupy the space, specifics of a robot (such as size, behavior, work envelope) assistive robot should consider their living environment (e.g. size of space, interior design, etc.).

In addition to the physical living environment, many studies have been empirically investigated the importance of learning environment during the adoption of new technology for elderly [19-21]. For example, if we provide hands-on experience with teaching and guide support to elderly, it will increase long-term viability and acceptance. Therefore, along with living space, their social environment that can support the learning should be considered as well for elderly-friendly assistive robot design.

2.2 Human factors

Because of limited competence of older people such as lack of functional, biological, sensory/perceptual, cognitive capability, social abilities, and behavior skills, older people seem struggling to learn, adopt and accept the modern technology, including assistive robot [6, 22]. In this regard, technology acceptance has been studied from a variety of perspectives. Information systems, sociology and human-computer interaction researchers have come up with various models incorporating factors and phases to predict adoption that, in turn, will lead to persistent use.

Existing literature identifies numerous barriers for the elderly using technology tools, which is possible to categorize them to elders' physical and mental status. The barriers due to impairments of elders' physical status are cognitive (memory and processing speed, visual, auditory, and motor control abilities [23]). The mental barriers are attitudinal (manner of feeling or behaving; [24, 25]) privacy concerns, security [26], safety (monitoring elderly in their private home; [27-31]), and total replacement of humans with technology tools such as robots [32, 33]. Also, much of the literature on human factors in HRI has emphasized the importance of perceived safety, usefulness, self-efficacy, learning support, and experience, etc. of the user [34, 35]. Moreover, when it comes to acceptance, satisfaction, and trustworthiness of the robotic technology, many studies have supported the fact that these perceptions toward robots are influenced by the user's sociodemographic factor. Particularly, Chen and Chan [8] noted that technology acceptance of elderly are also affected by individual attributes, health, and ability characteristics, as well as facilitating conditions. Particularly, Tapus, Ţăpuş [36] claims that personality match between the user and the assistive robot may enhance the acceptance, which suggesting the importance of human aspects in robot design. In this paper, we address these issues to provide an requirement and guidelines that overarching relationship of these factors to the design of the elderly-friendly assistive robot.

2.3 Requirements and guidelines for elderly-friendly robot and environment

Based on the previous literature, we propose requirements for an elderly-friendly robot and its environment. Elderly-friendly assistive robot should be fitted into a living environment, which roboticists are required to investigate the feasibility of the robot prototype in various scenarios and conditions. In particular, if the living environment is small and limited, which is a common living condition of elderly, sophisticated design of hardware or mechanical systems as well as software systems are required to provide the functionality that they needed. For example, human size robot (e.g. Care-o-bot) may not be useful in a confined flat. Instead, small and wall-mounted type of assistive robot may provide the functionality without sacrificing space utilization for daily living.

Furthermore, to provide robot assistive housing for the future elderly, architects should consider the concept of robot-embedded housing, which designates an extra space for an assistive robot. For example, a home-version of Kiva systems would be deployed to help carry heavy objects for elderly, but the nature of their operation is based on the interaction between Kiva and marker (or other types of reference system), an invisible marker or such references needs to be installed, and architects should take into account this design factors.

Also, user acceptance is essential part of robot design. For example, human-like appearance (e.g. facial expression) for better communication and control is recommended for all kinds of interactive robots. Therefore, roboticists need to take affective interaction into account when designing an elderly-friendly assistive robot.

All things considered, we propose a comprehensive and integrated interaction network among elderly–robot–environment, as depicted in figure 1.

3 Immersive virtual environment as a tool for robot and environment design

As we address in the previous section, there are many factors that needs to be taken into account for elderly-friendly assistive robot. When dealing with many different impacting factors, implementing an experiment that evaluates the human perception of actual robots becomes overwhelming pragmatically and financially. To mitigate these issues, the use of Immersive Virtual Environment (IVE) can be a great alternative. IVE are proven to increase both experimental control and mundane realism, which leads to the enhancement of participants' engagement, thereby increasing experimental impact. Many research also supported the use of IVE in construction by measuring the sense of presence while each participant performed office-related activities in both IVE and physical environment.

Recently, affordable Virtual Reality (VR) headset is on the market, and thanks to advanced game engine software such as Unreal and Unity 3D, building a virtual environment have been easier than before.

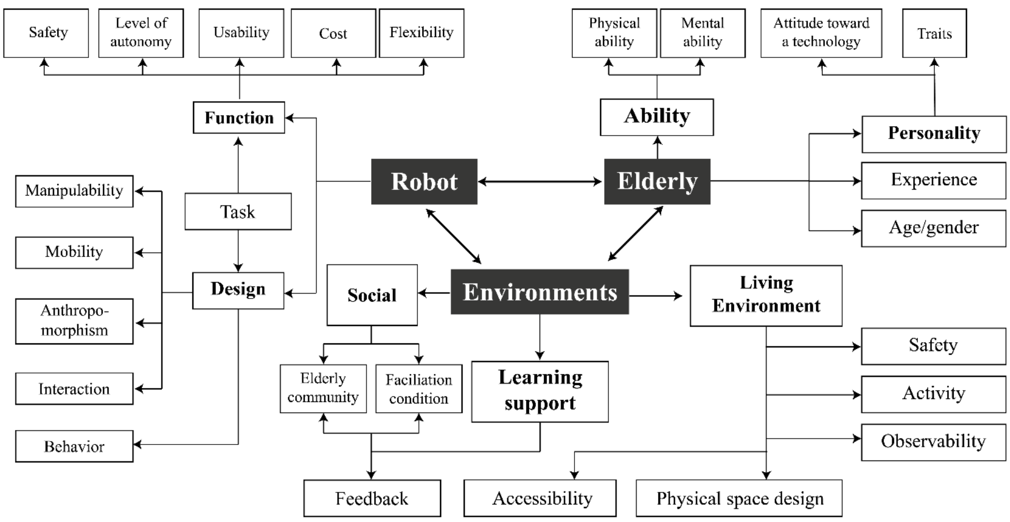

Figure 1. Relationships among factors of robot, elderly, and environment

3.1 Hardware settings

IVE requires a set of hardware components; a computer, VR headset (Head-mounted display), and tracking devices. Firstly, Oculus Rift Head-Mounted Display (HMD) will be used to provide immersive virtual experience for the user. A game engine renders two slightly different images shifted horizontally creating an illusion of depth to provide stereoscopic views. Also, Oculus Rift has a tracking system to send an appropriate data to the computer, which determines the user's position and orientation in virtual space. The range of position tracking would be limited to 2-3 meters depending upon wired connection of Oculus Rift so that experimental area should be within 2 meters as well. Multi-modal interaction has become available such as gesture (e.g. Leap motion) and virtual hand (e.g. Oculus Touch) so that it would be useful for evaluation of physical interaction or communication.

3.2 Software settings

Generally, a game engine is an essential components (e.g. position and orientation, camera, light, renderer, etc.) for creating a virtual environment. The game engine is connected to the data stream that linked to hardware settings (e.g. Oculus Rift) so that the computer can generate rendered images based on the tracking movement of the user.

One of the benefit of using IVE is the capability to offer immersion to the user. People can easily maintain high mundane-realism while interacting with experimental virtual environments. However, this effectiveness of IVE has been deeply linked to the sense of presence, and immersion. Presence is defined as the subjective experience of being in one place or environment, even when one is physically situated in another, and immersion into virtual reality is a perception of being physically present in a non-physical world, which can be quantifiable. Providing enough presence and immersion plays an important role to evoke an emotion and response from the user. For example, improper interaction design of virtual environment can result in the major health issues such as disorientation or nausea, which dramatically reduces sense of presence.

3.3 Implementation of IVE

Based on the hardware and software settings, many of human-robot interaction scenarios and hypotheses can easily be validated. For instance, a hypothesis–limited living space will decrease perceived usefulness of assistive robot.– can easily validated with the use of IVE (Figure 2), also any design flaws of robot can be tested in advance, which provide a valuable feedback to roboticists and architects. In order to evaluate user's perception towards an assistive robot and environment, psycho-physiological measure as well as survey can be used to accurately validate their emotion toward an assistive robot.

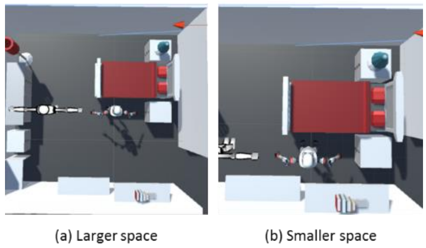

Figure 2. IVE settings for evaluation of assistive robot in different scenario

4 Conclusion

It is obvious that assistive robot for elderly will soon become more prevalent in a domestic environment. This paper has argued the importance of living environment and human aspect of elderly-friendly assistive robot. The main goal of current study was to establish considering factors for the design of assistive robot and its environment, and to suggest IVE as a promising tool for evaluating these factors efficiently. This research has great potential to contribute to the design principles of the assistive robots as well as space and environment planning towards assistive housing or robot-embedded housing. Further experimental investigations are needed to estimate elderly's perception towards an assistive robot and to examine more closely the links between robot and environment.

References

[1] United Nation, *World population ageing 2015.* Department of Economic and Social Affairs PD, 2015.

[2] Clarke, P. and E.R. Nieuwenhuijsen, *Environments for healthy ageing: a critical review.* Maturitas, 2009. **64**(1): p. 14-19.

[3] Agren, G. and K. Berensson, *Healthy ageing: a*

challenge for Europe. Swedish National Institute of Public Health, 2006. **2006**: p. 29.

[4] Bemelmans, R., et al., *Socially Assistive Robots in Elderly Care: A Systematic Review into Effects and Effectiveness.* Journal of the American Medical Directors Association, 2012. **13**(2): p. 114-120.e1.

[5] Flandorfer, P., *Population ageing and socially assistive robots for elderly persons: the importance of sociodemographic factors for user acceptance.* International Journal of Population Research, 2012. **2012**.

[6] Meng, Q. and M.H. Lee, *Design issues for assistive robotics for the elderly.* Advanced Engineering Informatics, 2006. **20**(2): p. 171-186.

[7] Solis, J., *Development of a human-friendly walking assisting robot vehicle designed to provide physical support to the elderly.* IFAC-PapersOnLine, 2016. **49**(21): p. 656-661.

[8] Chen, K. and A.H.S. Chan, *Gerontechnology acceptance by elderly Hong Kong Chinese: a senior technology acceptance model (STAM).* Ergonomics, 2014. **57**(5): p. 635-652.

[9] Broadbent, E., R. Stafford, and B. MacDonald, *Acceptance of Healthcare Robots for the Older Population: Review and Future Directions.* International Journal of Social Robotics, 2009. **1**(4): p. 319.

[10] Peek, S.T.M., et al., *Factors influencing acceptance of technology for aging in place: A systematic review.* International Journal of Medical Informatics, 2014. **83**(4): p. 235-248.

[11] Hendrich, N., H. Bistry, and J. Zhang, *Architecture and Software Design for a Service Robot in an Elderly-Care Scenario.* Engineering, 2015. **1**(1): p. 027-035.

[12] De Santis, A., et al., *An atlas of physical human–robot interaction.* Mechanism and Machine Theory, 2008. **43**(3): p. 253-270.

[13] Bicchi, A., M.A. Peshkin, and J.E. Colgate, *Safety for physical human–robot interaction*. Springer handbook of robotics. 2008. 1335-1348.

[14] Elara, M.R., N. Rojas, and A. Chua. *Design principles for robot inclusive spaces: A case study with Roomba*. in *2014 IEEE International Conference on Robotics and Automation (ICRA)*. 2014.

[15] Mohan, R.E., et al., *Designing the robot inclusive space challenge.* Digital Communications and Networks, 2015. **1**(4): p. 267-274.

[16] Tan, N., R.E. Mohan, and A. Watanabe, *Toward a framework for robot-inclusive environments.* Automation in Construction, 2016. **69**: p. 68-78.

[17] Meng, Q. and M.H. Lee, *Design issues for assistive robotics for the elderly.*

[18] Litwak, E. and C.F. Longino, *Migration patterns among the elderly: A developmental perspective.* The Gerontologist, 1987. **27**(3): p. 266-272.

[19] Louie, W.Y.G., D. McColl, and G. Nejat, *Acceptance and attitudes toward a human-like socially assistive robot by older adults.* Assistive Technology, 2014. **26**(3): p. 140-150.

[20] Wu, Y.H., et al., *Acceptance of an assistive robot in older adults: A mixed-method study of human-robot interaction over a 1-month period in the living lab setting.* Clinical Interventions in Aging, 2014. **9**: p. 801-811.

[21] Kim, S., et al., *Acceptance of mobile technology by older adults: a preliminary study*, in *Proceedings of the 18th International Conference on Human-Computer Interaction with Mobile Devices and Services*. 2016, ACM: Florence, Italy. p. 147-157.

[22] Bemelmans, R., et al., *Socially assistive robots in elderly care: A systematic review into effects and effectiveness.* Journal of the American Medical Directors Association, 2012. **13**(2): p. 114-120. e1.

[23] Czaja, S.J., et al., *Factors predicting the use of technology: Findings from the center for research and education on aging and technology enhancement (create).* Psychology and Aging, 2006. **21**(2): p. 333-352.

[24] Ellis, R.D. and J.C. Allaire, *Modeling Computer Interest in Older Adults: The Role of Age, Education, Computer Knowledge, and Computer Anxiety.* Human Factors, 1999. **41**(3): p. 345-355.

[25] Skymne, C., et al., *Getting used to assistive devices: Ambivalent experiences by frail elderly persons.* Scandinavian Journal of Occupational Therapy, 2012. **19**(2): p. 194-203.

[26] Harrefors, C., K. Axelsson, and S. Sävenstedt, *Using assistive technology services at differing levels of care: healthy older couples' perceptions.* Journal of Advanced Nursing, 2010. **66**(7): p. 1523-1532.

[27] Boström, M., S. Kjellström, and A. Björklund, *Older persons have ambivalent feelings about the use of monitoring technologies.* Technology and Disability, 2013. **25**(2): p. 117-125.

[28] Caine, K.E., A.D. Fisk, and W.A. Rogers, *Benefits and Privacy Concerns of a Home Equipped with a Visual Sensing System: A Perspective from Older Adults.* Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 2006. **50**(2): p. 180-184.

[29] Miskelly, F.G., *Assistive technology in elderly care.* Age and Ageing, 2001. **30**(6): p. 455-458.

[30] Magnusson, L. and E.J. Hanson, *Ethical issues arising from a research, technology and development project to support frail older people and their family carers at home.* Health & Social Care in the Community, 2003. **11**(5): p. 431-439.

[31] PETERSSON, I., LILJA, M., & BORELL, L., *To feel safe in everyday life at home – a study of older adults after home modifications.* Ageing and Society, 2012. **32**(5): p. 791-811.

[32] Lundberg, S., *The results from a two-year case study of an information and communication technology support system for family caregivers.* Disability and Rehabilitation: Assistive Technology, 2014. **9**(4): p. 353-358.

[33] Kristoffersson, A., et al., *An Exploratory Study of Health Professionals' Attitudes about Robotic Telepresence Technology.* Journal of Technology in Human Services, 2011. **29**(4): p. 263-283.

[34] Demiris, G., et al., *Older adults' attitudes towards and perceptions of 'smart home'technologies: a pilot study.* Medical informatics and the Internet in medicine, 2004. **29**(2): p. 87-94.

[35] Daniel, K.M., C.L. Cason, and S. Ferrell, *Emerging technologies to enhance the safety of older people in their homes.* Geriatric Nursing, 2009. **30**(6): p. 384-389.

[36] Tapus, A., C. Ţăpuş, and M.J. Matarić, *User—robot personality matching and assistive robot behavior adaptation for post-stroke rehabilitation therapy.* Intelligent Service Robotics, 2008. **1**(2): p. 169-183.