Design of a Kiosk Type Healthcare Robot System for Older People in Private and Public Places

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Abstract. In this paper, we introduce a healthcare robot system for older people and its experiments in private and public spaces. We designed a healthcare robot system and healthcare functionalities, and conducted a long-term study in a real environment. Our healthcare robot system consists of three parts: a kiosk type service robot platform, a healthcare software system with healthcare service modules, and a medical server system. 1) The kiosk type service robot platform is used for giving helpful information to older people through a touch screen. 2) The healthcare software system is designed to enable easy modification of healthcare service modules according to the purpose of the robot. 3) The medical server system stores health information of older people for managing their health conditions. For validating our software design and implementation in real environments, we deployed this healthcare robot system in private and public places of a retirement village. In these experiments, older people interacted with the robots and used healthcare functionalities for over 12 weeks. During the experiments, the robots sent records of the interactions to our medical server. The server provides this information to clinicians who are supervising the older peoples' health status. When the experiments were completed, the participants completed questionnaires. The results showed that older people in private places used the healthcare service for checking their health conditions, and older people in public places like to use the entertainment services. We confirmed that our kiosk type robot can help older people as well.

Keywords: Healthcare robot system, caring of older adults, health condition management, healthcare service, private homes, rest home lounges

1 Introduction

Our society is rapidly moving toward an aged society with the older population rising sharply [1-2], which is a big concern for care service providers in the future [3-4]. Older people will be troubled with illness as a result of a degenerative loss of brain function [5]. Therefore, they will require long-term care, but it will be challenging to provide care due to the lack of care staff [6-9]. Animal therapy is one of the successful solutions to help older people in care facilities [10-11], but they may carry infectious diseases, and may bite or cause physical damage [12]. Instead of live animals, companion and assistant robots have been used, such as the therapeutic robot PARO, a baby harp seal robot intended to have a calming effect on patients in hospitals and nursing homes, similar to animal-assisted therapy [13-14]. The doglike robot AIBO developed by SONY achieved success in the robotics market [15]. People, who live alone as well as older people, feel happy when caring for and living with AIBO. Robots can also help older people by providing assistance with daily life and in managing people's conditions. Researchers have developed several types of companion and assistant robot systems and found that companion and assistant robots can have positive effects on both psychological and physical outcomes [16-19].

In our previous research, we have designed an assistant robot system to provide companionship and healthcare support to older people. We have studied how to improve quality of life and health conditions of older people through several long-term studies. Our first long-term study was an acceptability study with 53 participants from 2008 to 2009. This study found that robots are acceptable to older adults [20]. In our second long-term study, we deployed robots in a retirement village from 2010 to 2011. We asked residents and staff at a retirement village what they would like a robot to do and look like so we could design a dedicated healthcare robot appropriately [21, 30]. We developed a healthcare robot system HealthBots to do some of these tasks. We tested HealthBots in a cross-sectional study at a retirement village, and found that staff and residents could interact with the robot and that peoples' attitudes towards robots improved after meeting it [22]. After improving some aspects of HealthBots, we carried out a two-week observational study in the lobby of the retirement center to test aspects of feasibility and acceptance [24]. We carried out a range of experiments in private and public spaces in a retirement village and hospital from the fourth quarter of 2011 as our third long-term study [5, 12, 23, 31]. This study included six investigations, and five kinds of robot platforms such as PARO, Guide, Charlie, iRobi, and Friend robots: 1) A cross-over randomized trial in the independent units, 2) A non-randomized trial in the lounge areas of the rest homes and hospitals, 3) An observational study in the public areas, such as Reception, Café and Medical center, 4) An interview study with Paro and Guide robot in the dementia unit with residents, staff and relatives, 5) A randomized trial of Paro in the hospital and rest home, and 6) fall monitoring of the older people in daily life. We used Charlie and iRobi robots as healthcare robot platforms in the first study, and Charlie and Guide robots as healthcare robot platforms in the second study.

This paper focuses on the design of the healthcare robot system with the Charlie platform and Charlie experiments in the first and second investigation of our third long-term study. Fig. 1 shows the use of Charlie for measuring the vital signs of an older adult in a rest home. Charlie has healthcare functionalities including measuring vital signs, Skype calls, a brain fitness game, and some entertainment functions. Our healthcare robots manage the health status of older people by helping them to measure their vital signs and sending the results to the medical server for giving their medical information to doctors. In addition, older adults interact with the healthcare robots, play a brain fitness game, and watch music videos. The interaction histories are recorded in the medical server for analysis by clinicians. For validating the software design and implementation of HealthBors and its services in real environments, we conducted the studies at Selwyn Village in New Zealand, which has several levels of care including hospitals, rest homes, and private apartments. We have deployed three Charlie systems in private apartments in the first investigation, and two Charlie systems in public spaces (one at each at a rest home and a hospital) for over 12 weeks in the second investigation. Participants complete questionnaires rating the healthcare robot system.

Fig. 1. An older adult measures his blood pressure through our healthcare robot, Charlie, in a rest home. The robot helps older people to measure their vital signs without the aid of caregivers, nurses or family members, and records the data for healthcare providers to check.

2 Healthcare Robot System: HealthBots

2.1 Overview of healthcare robot system

We developed a healthcare robot system with a service robot platform, a software system with service modules, and a medical server system. We can use several kinds of service robot platforms as a healthcare robot system in HealthBots according to the users and purpose. Fig. 2 shows the Healthbots system overview with a kiosk type robot Charlie. Older adults can measure their vital signs, such as blood pressure. They also interact with healthcare robots for using healthcare service functions such as a brain fitness game and entertainment. The measured vital sign results and interaction records are sent to our medical server system, and then clinicians can review them for managing the health conditions of the older adults.

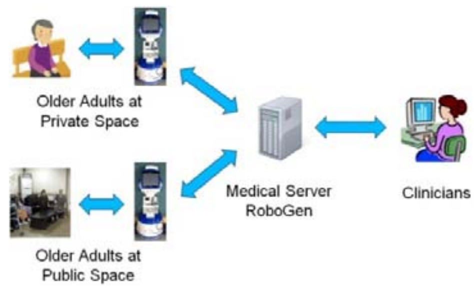

Fig. 2. Overview of the healthcare robot system, Healthbots. Robots help older adults in various spaces and send information such as vital signs and interaction records to the medical server, RoboGen. Doctors and psychologists access the medical server and check the health status of the older adults.

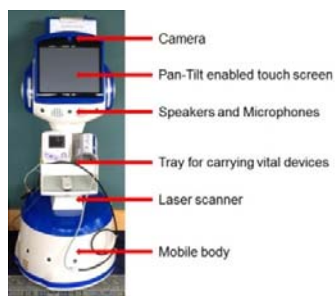

Fig. 3. The kiosk type robot platform, Charlie. It consists of a camera, a Pan-Tilt enabled touch screen, speakers, microphones, ultrasonic sensors, bumper sensors, a laser scanner, two single board computers and a 24V Li-Polymer battery.

2.2 Kiosk type Service Robot Platform

The kiosk type robot platform Charlie is shown in Fig. 3. The robot platform is from Yujin robotics in South Korea and is originally designed as a serving robot in cafes and restaurants, and for assisting teachers in schools; it has a friendly appearance and tray for carrying items. Charlie is a differential drive mobile robot 1.2 meters high, powered by a 24V Li-Polymer battery, and consists of a camera, a rotatable touch screen, speakers, microphones, ultrasonic sensors, bumper sensors, a laser range finder and two single board computers. User responses were received via the touch screen and HealthBot responds to participants with synthesized speech, visual output on the screen, and movements. The touch screen helps the older people who have hearing or speaking difficulties by showing messages or pictures. Charlie's synthetic speech is generated through a diphone concatenation type synthesis implemented with Festival speech synthesis system [25] and used a New Zealand accented diphone voice developed at the University of Auckland [26]. Expression was added to the synthetic speech through an intonation modeling technique [27] called 'Say Emotional'. For map building and navigation, Charlie uses the StarGazer robot localization system [28]. The system requires small passive silver dot landmarks installed on the ceiling of the robot work-space at approximately one meter separation. A map of the area was built using the built-in map building module of the robot.

2.3 Healthcare Software and Service Modules

The HealthBots should have several healthcare service modules according to the purposes of deployment, users and places. This means that healthcare service modules should be modified easily without any changes of the HealthBots software architecture. In addition, various experts from health psychology, gerontology, health informatics as well as engineers should be able to modify the behavior scenario of HealthBots according to the requirements of experiments. For these reasons, we designed a behavior scenario based HealthBots software architecture comprising three logical layers as shown in Fig. 4: a hardware layer, a middleware layer, and a behavior layer [33].

The hardware layer is for the hardware systems of HealthBot, which consist of the operating system and two different types of hardware: proprietary and non-proprietary. Proprietary hardware is the hardware associated with the basic robot platform, such as two single board computers and controllers. Non-proprietary hardware is the hardware added for healthcare service modules, such as the blood pressure meter, blood oxygen saturation meter, blood glucose meter, cameras, microphones, etc.

The middleware layer consists of three parts: a robot middleware, service modules, and a behavior execution engine. The robot platform has a ROCOS framework developed by Yujin robotics as a robot middleware. The behavior execution engine starts and stops the service modules by commands from the behavior layer. The service modules communicate with several web-services for information retrieval and update, and are integrated with third-party applications for providing added

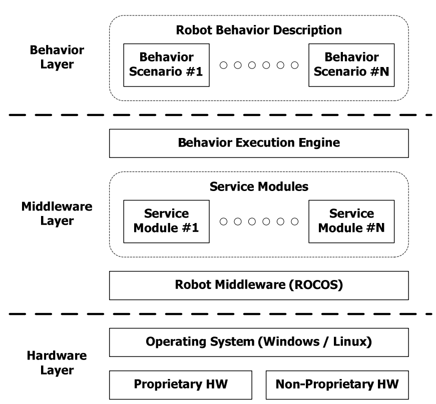

Fig. 4. Overview of the healthcare software system. It consists of three layers: a hardware layer, a middleware layer, and a behavior layer.

functionality.

The behavior layer consists of a number of behavior scenario files, which are different according to the purpose of system and experiments. The behavior scenario files describe robot behavior as a finite state machine, which can easily be modified by various experts from health psychology, gerontology, and health informatics as well as by engineers. The front-end of the application with the selected behavior scenario is developed using Flash/ActionScript 3.0 and the back-end is developed using C++.

In this study, Charlie has three service modules: a blood pressure service module, an entertainment service module which contains music videos, and pictures, and a web surfing function. A brain fitness game service module plays brain games, developed by Dakim [29].

2.4 Medical Server System: RoboGen

We developed a medical server system, RoboGen [32], for storing health information including vital signs measurement records and records of interactions between HealthBots and their users. It hosts a website application portal for carers to log in and monitor on data from users of HealthBots. Users and family members as well as specialists such as doctors, nurses, and psychologists can access the user data through the RoboGen website. This central data server is built using the Microsoft ASP .NET and MVC framework and a Microsoft SQL server. The robot connects to RoboGen through web-services.

3 Experimental Method

3.1 Overview of Experiments

We had two different investigations with five Charlie robots by deploying in three different parts of Selwyn village in New Zealand: private apartments for the first investigation, a rest home and a hospital for the second investigation, and a total of 99 older adults used the robots (6 older adults in the private apartments, 60 older adults in the rest home, and 33 older adults in the hospital). Selwyn village is a non-profit retirement complex in Auckland, New Zealand. The 26 acre village has around 650 residents, and provides progressive care from independent living units through hospital and dementia care [22]. For the recruitment of participants, we presented our research, and residents who were interested in using robot were recruited voluntarily for these experiments.

The first investigation was done in private apartments with Charlie and iRobi robots, which were described on other publications [31]. In the experiments with Charlie in the first investigation, 6 older adults were recruited, and 3 older adults were given individual Charlie robots in their apartments for 6 weeks. The robots were then moved to 3 different apartments for another 3 residents.

The second investigation was done in a lounge of the rest home and the hospital with Charlie and Guide robots, which were described on other publications [5]. For the experiments with Charlie in the rest home, we deployed one Charlie robot in a lounge of the rest home, which accommodates 110 residents and employees 47 staff, and 60 older adults were recruited. For the experiments with Charlie in the hospital, we deployed another Charlie robot in a lounge to the hospital, which accommodates 67 residents and employees 51 staff, and 33 older adults were recruited. We continued our experiments in the rest home and the hospital for twelve weeks. After each interaction, users were able to rate the functionalities of the healthcare robot system.

Table 1. Instructions and Wording of the Appropriate Healthcare Functionalities and the Suitability of using Kiosk type Healthcare Robot System Questionnaire. BP means the blood pressure measurement service module, EN means the entertainment service module, and BG means the brain fitness game service module.

Measure	Scale instructions	Items				
Usage of healthcare service module (same in BP, EN, BG)*	Please circle the number that best corresponds to how useful you find the healthcare service module. I think this service is …	0 Poor	1 Acceptable	2 Good	3 Excellent	
User satisfaction about the robot in private space (1 question)	Q1. Please circle the number that best corresponds to how much you enjoyed using the robot today.	0 Not at all	1 A little	2 Moder-ately	3 Quite a lot	4 Very much
User satisfaction about the robot in public space (4 Questions)	Q1. Please circle the number that best corresponds to how much you enjoyed using the robot.	0 Not at all	1 A little	2 Moder-ately	3 Quite a lot	4 Very much
	Q2. Please circle the number that best corresponds to how useful you found the robot.	0 Not at all	1 A little	2 Moder-ately	3 Quite a lot	4 Very much
	Q3. Please circle the number that best corresponds to how you would rate your interaction with the robot.	0 Not at all	1 A little	2 Moder-ately	3 Quite a lot	4 Very much
	Q4. Please circle the number that best corresponds to how much you would like to interact with the robot again.	0 Not at all	1 A little	2 Moder-ately	3 Quite a lot	4 Very much

3.2 Procedure

We demonstrated how to use the robots to interested staff and residents two weeks prior to starting the experiments. Staff managers were provided the duty phone number of the researchers to contact if there were any issues with the robots. Research assistants were available at the village to respond to any issues.

For the first investigation in the private apartments, participants were able to interact with the Charlie within their apartments as much or as little as they liked over the six week period. Six residents used Charlie robots. At first three participants used Charlie for six weeks, and then the other three participants used Charlie for six weeks. At the end of each interaction, participants had the opportunity to complete questionnaires on the robot about their satisfaction with each service module and their overall evaluation.

For the second investigation in the rest home and hospital, participants were able to interact with Charlie as much or as little as they liked over a twelve week period. When they interacted with Charlie, they entered their personal information so that their identity was known. At the end of each interaction, participants had the opportunity to complete questionnaires on the robot about their satisfaction with each service module and their overall evaluation. Some participants also completed written questionnaires about their quality of life, depression and perceptions of the robots, which are not the focus of this paper.

4 Experimental Results and Evaluations

As well as validating the HealthBots software design and implementation by a real, long term deployment in older care facilities, on multiple, heterogeneous robots, there are two aims of the analyses of the data gathered: 1) to determine the appropriate healthcare robot functions in the two different locations, 2) to evaluate the suitability of this healthcare robot system in the two different locations. Other papers on the results of the experiments conducted at this time at the village are published or in submission [5, 12, 20-24, 30-34].

4.1 Appropriate Healthcare Robot Functions according to location

Firstly, six participants who were not familiar to robot used our HealthBots system including three main services, such as the blood pressure measurement, entertainment contents, and the brain fitness game, over a 12 week period, and we confirmed that the HealthBots software design and its services work well in real environments. Secondly, we found the appropriate healthcare functionalities according to the place the robot was deployed by measuring the usage of healthcare service modules. The instructions and wording of the rating questions on the robot are shown in Table 1. The items were the same in all service modules such as blood pressure measurement, entertainment, and brain fitness. Participants were asked how useful they found the healthcare service using a scale from 0 (Poor) to 3 (Excellent), after people used healthcare service modules. The questions were displayed on the robot itself and people answered by touching their selected answer on the screen. Then, Charlie sent the results to Robogen for storage.

Fig. 5 shows the average score of each healthcare service module according to its location. We found that participants liked to use three healthcare services overall, but there were differences according to the location. The participants in the private apartments were satisfied with the blood pressure measurement service and the brain fitness game service than entertainment service. Especially, the use of the entertainment service decreased as time went on. It may be that as older adults living independently are not in an environment that monitors their blood pressure every day, so they wanted to check their blood pressure in their homes. On the other hand, the participants in the public spaces were satisfied with the entertainment service. There were some differences between the participants in the rest home and the hospital. The participants in the rest home were satisfied with the brain fitness game service and entertainment service more than those in the hospital. On the other hand, the participants in the hospital were satisfied with the blood pressure measurement service more than those in the rest home.

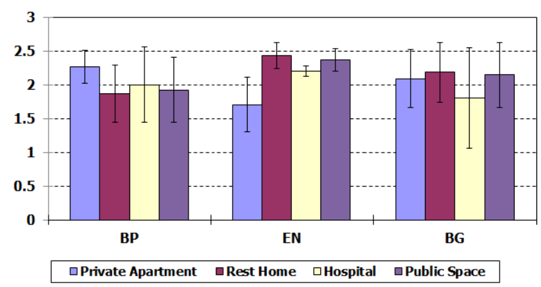

Fig. 5. The average score of each healthcare service module according to place. BP means the blood pressure measurement service module, EN means the entertainment service module, and BG means the brain fitness game service module. The data for the public space was obtained from the participants in the rest home and hospital, and used for comparing with the results of the private space.

4.2 Suitability of using our Healthcare Robot System according to location

We evaluated the suitability of using the kiosk type healthcare robot system according to the place by measuring the user satisfaction with the robot. Questionnaires were different for different places; one question to the participants in the private apartments and four questions to the participants in the public spaces such as the rest home and the hospital. Instructions and wording of the questionnaire for each place are shown in Table 1. The questions were asked on the Charlie's touch-screen. Then, Charlie sent the results to the Robogen server for storage. Fig. 6 shows the average score on each question about the user satisfaction with the robot according to the location. The participants in the public spaces were satisfied with using the kiosk type robot, but the participants in the private apartments did not give high scores although they enjoyed using Charlie.

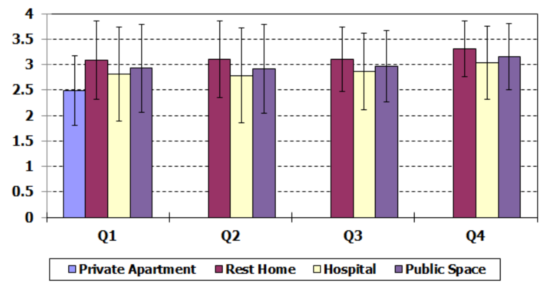

Fig. 6. The average score of each question about the user satisfaction about the robot according to place. Q1 is how much the user enjoys using the robot. Q2 is how useful the user found the robot. Q3 is how user would rate his interaction with the robot. Q4 is how much user would like to interact with the robot again. The data for the public space was obtained from the participants in the rest home and hospital, and used for comparing with the results of the private space.

5 Conclusions

We completed a 12-week study on appropriate services of a healthcare robot system for older people in private and public spaces. We designed the healthcare robot system, HealthBots, and deployed it to Selwyn village, which had several levels of care as well as various care facilities such as hospitals, rest homes, and private apartments. We used three Charlie robots in the private apartments, two Charlie robots in the public places, the rest home and the hospital, for the long-term studies. From the results, we found some important points, in addition to verifying that our software system was deployed and working on multiple, heterogeneous robots for a long period in different field environments. Older people in the private places (their own homes) used the healthcare service mostly for checking their health conditions. Older people in the public places used the entertainments functions most, especially in the rest home. We expect that the entertainment contents should be updated often when a robot is used for a long time to avoid the user becoming bored with the content. A kiosk type robot platform is quite good for the healthcare robot platform, but may be more acceptable in rest-home and hospital lounges than in private homes, which may be due to its size. In future work, we will study a cost benefit analysis when healthcare robot systems are employed in a family doctor's practice and in peoples' homes in the community.

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