Towards Enhancing Communication Between Caregiver Teams and Elderly Patients in Emergency Situations

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Keywords: Healthcare Robotics, Interacting Robots at Home, Graphical User Interfaces, Web-based Interaction, Mobile Platform, Evaluation Study.

Abstract: The paper presents a framework developed for facilitating care giver staff to interact with an elderly person in an emergency situation alone at home. The framework uses an autonomous mobile robot (ARTOS) as a communication medium in the home environment to establish a communication channel. The novel idea in this work is to facilitate emergency responding teams by also providing them access and control over the robot through mobile devices. The user evaluation study of the developed framework demonstrates the effective usability of the system even by users having no prior experience or training.

1 INTRODUCTION

The elderly population in developed countries is steadily increasing (Lehr, 2007). In many situations these people live alone in their homes and this requires urgent assistance in case of some emergency situation happens to the person. Currently, many research groups are devoting their efforts in developing robots that can perform several tasks in a typical home environment. They focus normally on performing some activity in the home environment like fetching objects (Graf et al., 2009), folding laundry (Ciocarlie et al., 2010), etc. In some cases, a robotic platform has also been used as a communication medium between the elderly person and a family member or a caregiver staff (Merten et al., 2012; Rumeau et al., 2012). These robots can be more beneficial if they can provide support to the health care staff when an emergency happens to an elderly person. One such support would be to initiate the call to the health care staff informing about the situation, other possibilities would be to allow the robot to be remotely controlled without the need of any sophisticated hardware (Deegan et al., 2008; Mehdi et al., 2014).

The main contribution of our current work is development of a framework for establishing communication between the elderly person and the emergency responding teams via a mobile robotic platform and performing evaluation studies describing the effectiveness of the developed approach. It is an extension to previously developed interfaces (Mehdi et al., 2014) where only staff at health care center was able to communicate with the elderly person using the mobile robot as a platform.

In order to illustrate the concept and developed framework, this paper has been organized as follows. Section 2 presents an overview of communication mediums used during an emergency scenario. The framework developed for establishing communication between the caregivers and the emergency teams is described in Section 3. This section also describes the communicating partners in detail. Section 4 describes the communication between the partners. Section 5 provides details of the conducted evaluation studies as well as discusses the results. Finally, Section 6 provides the conclusion and gives directions to the future work.

2 RELATED WORK

Crucial parts of the emergency response environments are interaction between different entities in the environment and the channels available for this interaction. Many emergency services around the world have upgraded their hardware and software to meet the demand; however, vast majority of them still rely on the voice communication solutions as a primary source of information when most up-to-date information is

Atif Mehdi S., Avtandilov A., Rukh Humayoun S. and Berns K..
Towards Enhancing Communication Between Caregiver Teams and Elderly Patients in Emergency Situations.
DOI: 10.5220/0005492401180126
In *Proceedings of the 1st International Conference on Information and Communication Technologies for Ageing Well and e-Health* (ICT4AgeingWell-2015), pages 118-126
ISBN: 978-989-758-102-1

required. Many previous works (Reddy et al., 2009; Paul et al., 2008; Kyng et al., 2006) have been tackling the issues in systematic approach to these frameworks.

Reddy et al. raised questions about the crisis management and how technologies could affect the emergency services (Reddy et al., 2009). They concluded that the teams of first responders and the service center have strong socio-technical aspect in interaction as well as pointing out that team-to-team and team-to-emergency sight communication are difficult to organize. On the other hand, Paul et al. found the role of technologies in the process as uncertain due to the opinion provided by the physicians participated in the study (Paul et al., 2008). While Kyng et al. took a closer approach into how interactive such services could be, by setting specific challenges to the existing systems handling emergencies (Kyng et al., 2006). By illustrating the important role of the live video feed when handling an emergency, they provided sufficient proof that such solutions may be beneficial.

All the above-mentioned work took widely the theoretic approach to the problem; however, most of the work providing the real communication and engineering solutions are developed in the industry trying to meet market needs. Most pervasive approach in the industry developed by Motorola[1] provides a solution for the emergencies occurring in largely accessible public spaces, relies on the government's access to the CCTV recordings in real time, dedicated emergency channels and possibly a large impact. It aims at improving response times, enhancing safety for responders, and enabling better communication with emergency service center. This approach is based on a steady ground of communication technologies finely tuned for the needs of first responders; however, it lacks the individuality while tackling bigger problems. As much as it is effective in the aforementioned type of emergencies, it lacks individual approach when only one patient is endangered and does not provide interactive communication with the emergency scene.

Other solutions in the market like Mobile Solutions[2] and PK[3] take another approach trying to strengthen communication between different emergency services such as firefighters, medical personnel and law enforcement by providing extended database support with immediate access to records tackling mostly management problems. Mobility for the command center is showcased by PK. It could be installed on-site and serves as an authentication center and issues tasks to all service members using hand-held devices.

As these industry approaches target communication between the first responders and their command centers, they lack of the channels that are difficult to organize (Kyng et al., 2006), namely live video feed from the place where emergency occurred when it is in the comfort of patients home. These communication strategies consider facilitating interaction between the diseased person and the service center. Although this is important but these do not provide any framework for establishing communication between the emergency responding team and the person in distress, which could be helpful in better informing both the team and the person.

3 METHODOLOGY

The main emphasis in this paper is to develop a framework for establishing communication channel between the Emergency Responding Team (ERT) and the elderly person in an emergency situation at the home environment. Since it is not known in advance which ERT will be able to reach the person at earliest; therefore, the emergency situation is reported to the Health Service Center (HSC). The HSC is then responsible to send the request to the ERTs and contact information is provided to only that ERT which accepts to undertake the responsibility. The responsible ERT can then communicate with the person using the autonomous mobile robot as a platform and navigate it in the home environment to understand the situation. Figure 1 gives an overview of the complete framework.

3.1 Autonomous Mobile Robot

The Autonomous Robot for Transport and Service (ARTOS) (see Figure 2) has been developed at the Robotics Research Lab, University of Kaiserslautern in order to investigate challenges in providing to elderly people living alone in their homes. The robot is capable of driving autonomously in the home environment and detects obstacles using its laser scanner, ultrasonic sensors, and bumper sensor. It is also capable of learning the daily routine of the person and searching the person using the learned routine (Mehdi, 2014). The robot can also be teleoperated by caregiver staff at health service center using a joystick in the Graphical User Interface (GUI) to observe the home environment (Mehdi et al., 2014).

[1]http://www.motorolasolutions.com
[2]http://www.elliottmobilesolutions.com
[3]http://www.pk.nl

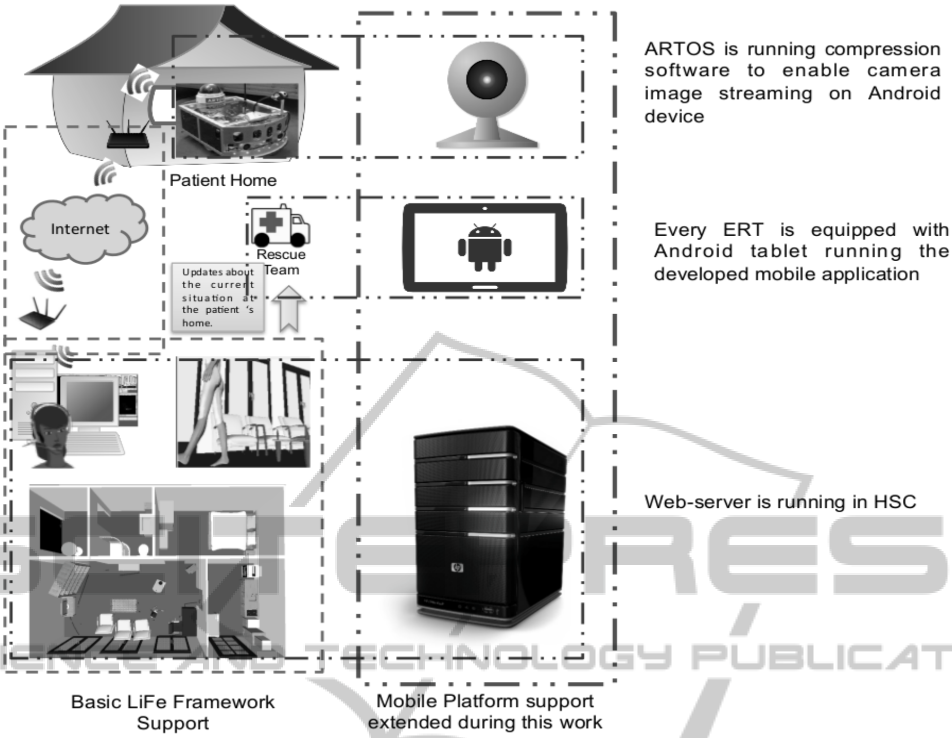

Figure 1: Overview of the developed framework.

Figure 2: Autonomous Robot for Transport and Service (ARTOS).

3.2 Health Service Center

The Health Service Center (HSC) is the first point of contact that receives the emergency help request from ARTOS. After receiving the request, they can teleoperate the robot to evaluate the situation in hand and verify any false alarm. The GUI (see Figure 3) at the center provides them with the view of the home using camera on the robot. After verification they can transfer the help request to the mobile teams to respond the emergency situation.

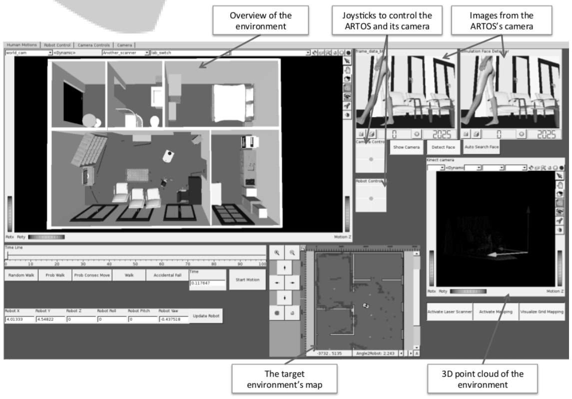

Figure 3: The GUI at HSC that visualizes the elderly person's home environment and provides interactions to control ARTOS and the camera.

3.3 Emergency Response Teams

Emergency Response Teams (ERTs) respond to the elderly person in an emergency situation. After receiving the information from HSC, they can use ARTOS as a communication medium to evaluate the situation at home and to talk with the person in distress.

4 COMMUNICATION BETWEEN ENTITIES

The emergency situation is notified by the ARTOS to the staff at HSC on their Graphical User Interfaces (GUI). The notification contains the information about the person and the possible emergency situation. The staff member at HSC can view the map of the home environment and the obstacles in the environment as detected by the sensors installed on the robot using the GUI. The staff member can also remotely control the robot using the GUI to access the situation and rectify in case a false alarm has been generated.

In case a valid emergency situation is recognized, the staff member at HSC can dispatch a message to notify all the ERTs or the nearest ERT about the situation. This is performed using the developed web server running at the HSC. The web server communicates with the Google Cloud Messaging (GCM) Services for dispatching the notification. The staff member can also monitor the location of each ERT by tracking their GPS coordinates in the integrated Google Maps. The web server at the HSC handles communication, feedback, status updates and database queries with the mobile application installed on the ERT mobile devices. It has been developed as a multi-user web-interface that can automatically prioritizes lists of ERTs and pending emergencies, which allows HSC staff to act effectively and can decrease time needed to respond to an emergency request.

An Android application has been specifically developed for the ERTs, to communicate with both HSC and ARTOS to receive most up-to-date information about the patient, their location, and the situation that they are about to get involved. The functionality of the application includes receiving live video image from ARTOS, joystick control of the robot to explore the environment, status reports to the HSC, database access for extended information about the patient, and navigation options. Figure 4 and Figure 5 show screenshots of the developed mobile app for the ERTs with the options of map selection and ARTOS control. The mobile app receives and interprets the messages received from the GCM. The message received contains information about the patient, address and Skype id of ARTOS. The GUI of the application facilitates the ERT in determining the acceptance or rejection of the job. In case of acceptance, it further receives the information about the Skype id and IP address of the ARTOS. Once the vital information is received, ERT can directly communicate with the person in distress and does not require HSC, which significantly decreases the stressful job at HSC. Figure 6 depicts the communication between ARTOS, HSC and ERTs.

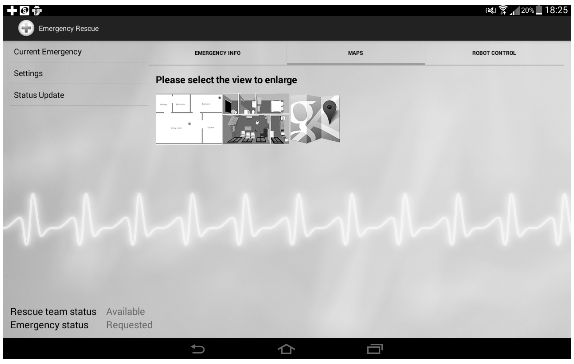

Figure 4: A screenshot of the developed mobile app for the ERTs that shows the availability of three maps, i.e., map for ARTOS location in the home environment, the home environment 3D map, and the Google map to the elderly person home. Clicking on any of them shows in full screen the selected map.

Figure 5: A screenshot of the developed mobile app for the ERTs that shows the camera view of the ARTOS, while the joy stick on the right side of the screen is used to control the ARTOS movement.

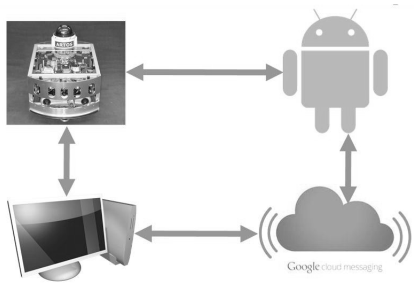

Figure 6: Communication between the server at HSC and ERT using Google Cloud Messaging. Once information is received by the ERT, they can directly communicate with ARTOS using the developed Android App.

5 THE EVALUATION STUDIES

The main contribution of our framework is establishing a communication platform between the health care staff at various levels (e.g., between the staff at HSC and the mobile response teams) and the elderly person at home. However, in our conducted evaluation studies we mainly focused on the mobile platform that we developed to be used by the mobile ERTs.

We conducted the evaluation studies at two stages. The first evaluation study was carried out with three usability experts using the heuristic evaluation (Nielsen and Molich, 1990; Nielsen, 1994) approach. This evaluation ran on the first implemented prototype of the developed mobile app and the goal was to find out the possible usability flaws in the mobile app using the ten heuristics proposed by Nielsen (Nielsen, 1994). Based on the results of this evaluation study by experts, we redesigned our mobile app user interface and made the suggested changes.

The second evaluation study was conducted with 10 participants having different background using the controlled task-based evaluation experiment approach. They were also given closed-ended and open-ended questionnaires at the end of experiment in order to know their feedback. These participants were mostly researchers and students from the University of Kaiserslautern, as the goal of the second evaluation study was to analyze whether the developed mobile app (which will be eventually used by ERTs) is easy to use without any prior training or expertise.

In the following subsections, we provide details of the conducted heuristic evaluation study followed by the user evaluation study in the controlled environment.

5.1 The Heuristic Evaluation Study

The heuristic evaluation study was done with three usability researchers from the Computer Graphics and HCI group of the University of Kaiserslautern. They evaluated the first implemented prototype of the mobile app using the ten heuristics and ranked the user interface giving a number from 0 to 4, where 0 means no problem at all while 4 means usability catastrophe (Nielsen, 1994). The goal was to find out usability issues in the early stage of the mobile app development in order to improve the design and UI based on this evaluation.

A list of tasks were given to these experts consisted of the main features of the developed mobile app: i.e., managing settings, performing status updates, giving response to the emergency requests, establishing Skype call with the patient, sending feedback to the server, observing elderly person's household map, route planning with Google Maps, and controlling the ARTOS with joystick control option.

An introduction of the mobile app was given to these experts before they started to evaluate it. Further, the task description from the users' point of view was also given to them. They were also allowed to ask details about any UI element or task during the evaluation. In order to maintain the settings, the same person was given the chance to explain the mobile app and tasks during the evaluation. A form was given to these experts in order to record their feedback regarding the ten heuristics and their overall comments regarding any particular task or UI element.

Figure 7 shows the feedback of these three experts using the ten heuristics, where the score indicates the average of their given ranking in all tasks. The feedback indicated that some changes needed to be done for preventing errors and extending the visibility of the system status. However, there was not any major usability problem or usability catastrophe. The worst average grade of 2.0 from one expert was received in the category of help and documentation criteria. As our mobile app is intended to be used for professional purposes by ERTs, help and documentation must be sufficient for users with any level of competency and should provide in-depth review of the features. Other major issues were in the cases of fifth and ninth heuristics (average score of 1.25 and 1.08 by all experts, see Figure 7), which indicated insignificant lack of clarity on how to prevent and recover from errors.

These experts also gave their suggestions for improving the usability of the developed mobile app, e.g., to introduce status fields of the rescue team and the current emergency. These suggestions were then analyzed and taken into account while developing the final version of the app.

5.2 The User Evaluation Study

The goal of this conducted user evaluation study was to analyze whether the developed mobile app is easy to use without any prior training or expertise. Therefore, we were interested in finding out the effectiveness, efficiency, and user satisfaction aspects of our developed app, as it will be used by ERTs for communicating with the HSC and the elderly person in the emergency situation. The following metrics were derived from the GQM model (Basili et al., 1994).

- *Metrics for effectiveness:* We measure and compare the percentage of corrected completed tasks.

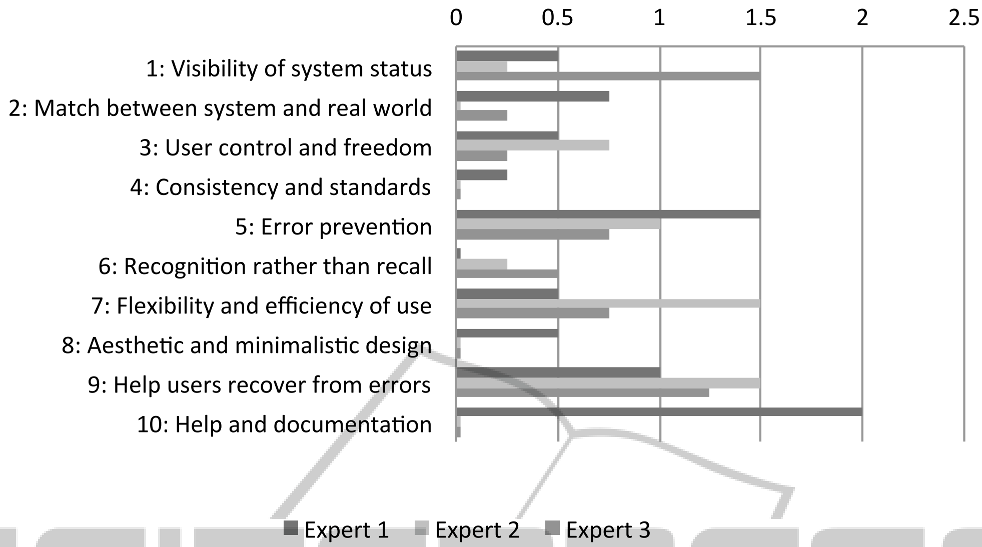

Figure 7: Average score of the mobile app UI using the ten heuristics.

- *Metrics for efficiency:* We measure and compare the time needed for completing each task.
- *Metrics for user satisfaction:* We collect participants' feedbacks and compare them.

We combined these metrics as suggested by the Technology Acceptance Model (Venkatesh et al., 2003). For collecting the participants' feedbacks on how to improve the developed mobile app, we chose an open-ended questionnaire form in order to collect their comments. We formulated the set of hypotheses as:

- **H1:** We expect an effectiveness of more than 90%, which means that in total participants accuracy of the completed task would be at least 90%.
- **H2:** On average, both groups (i.e., the little or inexperienced group and the experienced group) achieve nearly the equal efficiency in completing the given tasks.
- **H3:** Participants agree that the developed mobile app is acceptable and useful for collaborating with HSC and ARTOS robot for handling the emergency request and for performing the rescue operation.

5.2.1 Study Design and Experiment Settings

Based on the identified goals and hypotheses, we designed this study as a controlled experiment under laboratory conditions with a maximum time frame of 45 minutes per participant. This allowed us enough time to have basic introduction explaining what is the idea behind the developed mobile app and what kind of environment participants will be interacting with.

We ran the study with 10 participants (6 males, 4 females), who were researchers and students from the University of Kaiserslautern having different backgrounds. Only one of them had prior experience in dealing with emergency situations. However, four of the participants had very little or no experience at all in using smartphones or smart tablets, while remaining six participants were experienced users of smartphones. Further, four of the participants never had any experience of robotics while five of them had some basic experience of robotics. The remaining one participant was an expert in robotics. The age range of participants in this study was from 20 to 44 years with a median of 27.8 years old.

The participants were given four tasks to complete one by one. Completion of the tasks was timed and participants had a chance to ask questions during the experiment in case they run into some technical difficulties or unable to complete the task by themselves. An evaluator was there to carefully write down the comments participants had upon completion of each task in order to make sure that immediate feedback is possible. After tasks were completed, participants were presented with two questionnaires forms: closed-ended questionnaires form and open-ended questionnaires form. The closed-ended questionnaires form was based on nine questions, where each question offered a selection from six options on a Likert scale (Likert, 1932) (scale of 1 to 5 to show how much participants agree with the given statement and an additional option "Don't know"). The open-ended questionnaires form was aimed at general feedback in which the participants were asked to list any pros and cons they have identified in the developed mobile app and an opportunity to voice any other comments or suggestions.

The test was performed in the environment of the laboratory, with the participants seated in an office chair with no table and the tablet was freely in their hands. Participants were interacting with the mobile app using the standard touch features with no prior access to the platform in order to ensure no prior training or familiarity with the features.

5.2.2 Tasks Description

The test consisted of the following four tasks:

- **Task 1:** After an emergency request is issued: find the basic information about the patient, plan the route to the patient home on the Google map, and accept the emergency request.
- **Task 2:** After an emergency request is issued: initiate a Skype call and then decline the emergency request.
- **Task 3:** After accepting an emergency request: open additional options for the emergency situation, explore the map of the elderly patient household, control the robot using the joystick, and navigate it to the patient.
- **Task 4:** As a team leader of the new started shift: enter your team details in the app settings and update the availability status.

5.2.3 Results and Discussions

In this subsection, we briefly discuss the results of the study. Overall, results of this conducted user evaluation study indicate satisfactory results in both groups.

From the effectiveness perspective, all of the participants were able to complete the tasks successfully and accurately, which shows a high rate of effectiveness and proves that the developed mobile app is easy to operate. This also proves our hypothesis H1 in which we were expecting that on average participants would be able to accurately complete the tasks at least 90% of the total tasks.

The results from the efficiency perspective (i.e., the time completion) are listed in Figure 8, which shows the average time completion per task for the both groups (i.e., little or inexperienced users and experienced users). Participants from both groups do not show any significant differences in time completing any of the tasks. This demonstrates that the developed mobile app is easy to use and does not require much experience in order to complete the task. The main task (i.e., Task 3) that took most of the time was navigating the robot using the joystick and this is natural due to the speed of ARTOS. This brings us to the importance of the closed-ended questionnaires (see Table 1) and open-ended feedback from the participants. Even though most of the participants agreed that "It was easy to handle the robot with the joystick", the average grade of 3.8 is the lowest comparing to other features used in the developed mobile app. This was due to the security features of the robot navigation system and participants' unfamiliarity with the environment. In the real life scenarios, trouble of making yourself familiar with a new environment could facilitate emergency response team's actions when they arrive to the endangered person's house and when time matters the most. Overall, the results shown in Figure 8 prove our hypothesis H2, in which we were expecting nearly the equal efficiency from the participants with little or no experience compared to the experienced participants.

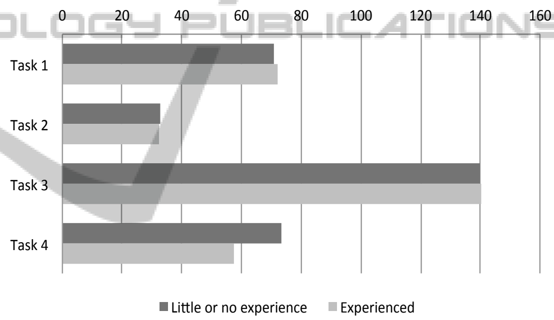

Figure 8: Average time completion in seconds of participants in both groups.

When we look at the participants' feedback in the closed-ended questionnaires (see Table 1), we observe an average score of more than 4 in most of the cases, which shows high acceptance ratio of our mobile app amongst the participants. However, in question 3 (regarding the handling of robot through joystick) and question 4 (recovering from mistakes) we see a lower score. As described above, the first reason was in difficulty of handling the ARTOS while in the second case few of the participants were unfamiliar with the Android platform that allows users to go back to the previous stage through the Back navigation button. Overall, the results of participants in the closed-ended questionnaires also prove our hypothesis H3, in which we were expecting a high acceptance ratio from the participants.

Further, the feedback provided by the open-ended questionnaires reveals the particular features of the mobile app participants were or were not satisfied with. The open-ended questionnaires were built

	1	2	3	4	5	N/A	Median
1: It was easy to see the current status of the system	0	1	1	5	3	0	4
2: It was easy to change Team availability status	0	1	2	0	7	0	4.3
3: It was easy to handle the robot with the joystick	0	2	2	4	2	0	3.8
4: It was easy to recover from mistakes	0	0	3	3	2	2	3.9
5: I found it easy to locate the needed features in the layout of the app	1	0	1	4	4	0	4
6: It was easy to complete provided tasks	0	1	0	3	6	0	4.4
7: It was clear from the icons the intended features they represent	0	0	1	2	7	0	4.6
8: I found the interface easy to use	0	0	1	6	3	0	4.2
9: I would recommend to use this system for emergency scenarios regularly	0	0	0	4	4	2	4.5

Table 1: Participants' feedback in closed-ended questionnaires form. Here, 1 means "strongly disagree" and 5 means "strongly agree". The last column shows average score of all participants.

around the idea that the participant will give some basic feedback upon completion of every task and the evaluator will write it down, and after the participant completes all of the tasks he/she will be allowed to list pros and cons of the mobile app as well as giving any other general feedback. The collected open-ended feedback showed participants' appreciation towards the clarity in the GUI's visualization, namely the icons that were always reflecting the feature underneath it. They were also sharing their positive experience on how the interface was clear and reflecting the purpose of the mobile app. Among the cons participants were listing lack of the source for help when something was unclear and noting that they were ready to operate the robot if it was moving around faster; therefore, saying that it was a little slower than they expected. One of the other common feedback responses was initial confusion with the log in mechanism for the team. Participants expected to be allowed to put their personal details in the mobile app, while they actually only needed to pick their identification (the badge number) to log in, which was specifically implemented to reduce time it takes to log in and avoid possible typos when entering the details.

6 CONCLUSIONS

This paper has demonstrated the use of a framework that can facilitate communication channel between an elderly person in emergency situation at a home environment, health service center and emergency responding teams. The autonomous mobile robot, AROTS, provides the channel for establishing this communication. The possibility of remotely controlling ARTOS to analyze the situation by moving the robot to different rooms and observe the images sent by the robot, enriches the user experience.

In the future, we plan to perform detailed evaluation studies in real environment settings to check the feasibility and effectiveness of the complete framework. Further, we also intend to develop a communication channel between different emergency responding teams in order to provide a better collaboration between these teams to tackle the emergency situation more effectively.

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