A Case Study of Socially and Physically Assistive Robots in Human-Robot Interaction

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***Abstract*—The report examines the planning and execution of interactions and interventions by socially assistive robot Pepper and physically assistive robot TurtleBot. It is divided into two parts: social engagement with Pepper and physical assistance with TurtleBot. The report outlines the persona chosen, goals, and the HARE model used to plan engaging conversations and activities. The effectiveness of social engagement is monitored, resulting in a final routine implemented with Pepper. Additionally, physical needs of the persona are addressed and physical assistance is planned using TurtleBot, with adjustments made based on effectiveness. The home environment is simulated using ROS and Gazebo, and the report reflects on the practical experience, emphasizing the importance of robustness in the experiment. The report concludes by summarizing essential findings and proposing directions for further work, including developing sophisticated robot behaviors and conducting user studies for evaluation. The report highlights the significance of effective planning, ethical considerations, and user feedback in improving the interactions of socially and physically assistive robots and demonstrates the potential to enhance the quality of life for those in need of assistance.**

I. Introduction

Robots are increasingly being utilized to assist individuals with disabilities, health issues, and, more significantly, the elderly with reduced mobility or lacking immediate assistance and care.

The purpose of this study is to examine the development and assessment of socially and physically assistive robots designed for individuals with disabilities, with a specific emphasis on Claudia's persona. Claudia is a 54-year-old woman who lives alone and has partial blindness due to severe glaucoma and diabetes. She works part-time as a social worker for Kirklees Council but has lost confidence in visiting people's homes due to her deteriorating sight. As a result, she now works from home. A few months ago, she fell and hasn't been able to exercise much, resulting in frailty. Her diabetes is causing poor circulation and swelling, making her health even more challenging. Claudia's only daughter lives in Australia and often feels lonely living alone. This scenario is not unique, as the ageing population is growing, and the prevalence of visual impairments and mobility issues is also increasing [1].

Part A discusses developing and evaluating socially assistive robots using the HARE model. Pepper interacts with Claudia to provide mental support, alleviate loneliness, and accompany her. The report presents the experimental results, including limitations, ethical and safety considerations, and recommendations (table I).

In Part B, the report discusses the development and evaluation of physically assistive robots using the HARE model. The findings present the experimental results using ROS for the planned interaction with Claudia and the Turtlebot3 robot to deliver medication at specific times. Furthermore, the report examines limitations, ethical and safety considerations and provides recommendations (refer to table I). Lastly, the key results and conclusions from the socially and physically assistive elements of the practical will be summarized, along with directions for future work.

II. Part A – Socially Assistive Robots

A. Methods

The main objective of Part A was to showcase how a socially assistive robot like Pepper can assist Claudia, who is partially sighted and lives alone, with her daily routine. The HARE model was used to design the scenario, and an interaction flow graph was created to plan the experiment. Below is a User flow graph 1 in our case Claudia to showcase the design of the experiment.

The experiment used Pepper, a humanoid robot developed by SoftBank Robotics. Claudia was acted by one of our group members. Claudia's persona and her needs were considered when designing the scenario. Pepper interacted with Claudia in a friendly and engaging manner, using a combination of verbal and visual cues for accessibility. The experiment was conducted in a quiet and well-lit room to ensure Claudia could easily interact with Pepper.

The scenario involved a series of tasks that Claudia typically performs in her daily routine, from waking up in the morning to taking a nap in the afternoon. Pepper initiated the interaction by greeting Claudia and asking how she was feeling. Pepper then provided Claudia with two options for clothing, followed by options for breakfast. Pepper also reminded Claudia to take

Human	Health Conditions	Severe glaucoma and diabetes leading
	Occupation	Part-time social worker with Kirklees Council
	Changes in Activity	Lost confidence in visiting people's homes due to deteriorating vision, limited mobility due to a fall a few months ago
Activity	Task 1	Provides Claudia with companionship on daily tasks, in making daily routine exercises and connecting to her daughter.
	Task 2	The robot here assists Claudia take her the prescribed medicines on time by delivering it to her in any part of the house.
Robot	Pepper bot	We have used Pepper's Gesture, Voice, and Its capability to display images as an integral interaction element for the subject
	Turtlebot (Waffle Pi)	The hardware capabilities of motion with Lidar and its ability to connect to the beacon near the subject has been used for our task
Enviornment	Task 1	Physical environment consists of subject's home. The Social factors would be the absence of humans for immediate help for the subject.
	Task 2	Physical environment consists of subject's home.The Social factors would be the absence of humans for immediate help for the subject.

TABLE I
HARE MODEL

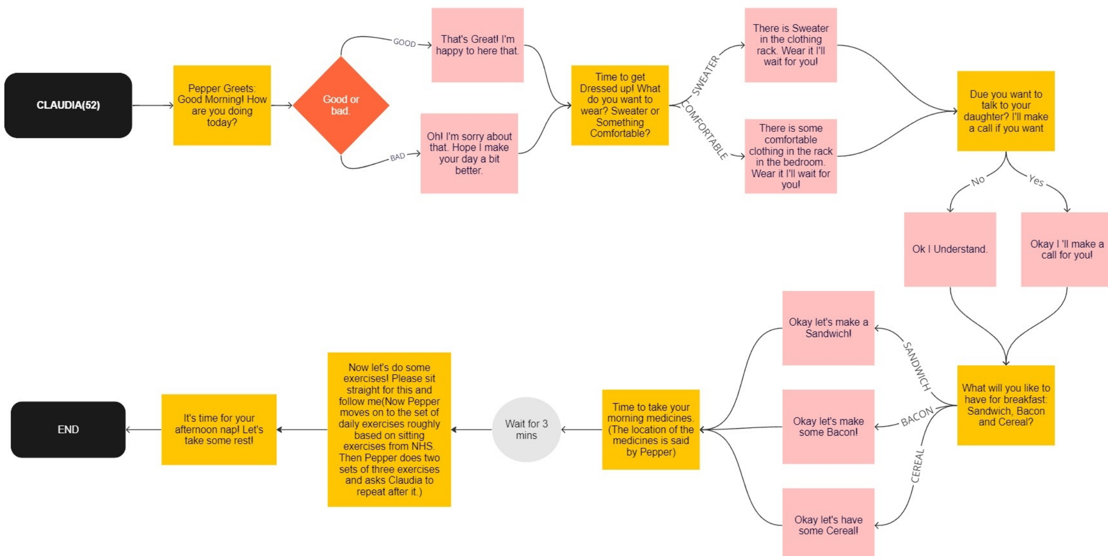

Fig. 1. flow chart describing the whole process

her morning medication and provided her with the location of the medicine.

The next set of tasks involved physical exercises, as Claudia's lack of mobility had made her frail. Pepper demonstrated a set of exercises based on the sitting exercises [2] from the NHS and asked Claudia to follow along. The interaction ended with Pepper reminding Claudia of the appropriate time for an afternoon nap. The experiment was conducted with a sample size of one, and the results were based on the feedback provided by the team members' experience. The experiment was recorded using a camera and audio recording equipment for later analysis.

The experiment aimed to showcase how a socially assistive robot like Pepper can assist people with disabilities in their daily routines. The experiment's limitations included the small sample size and the limited scope of tasks performed. Ethical and safety considerations were taken during the experiment.

Overall, the experiment demonstrated the potential for socially assistive robots to assist people with disabilities in their daily routine, providing them with increased independence and quality of life.

B. Results

We designed the robot, Pepper, to assist Claudia in her daily routine. Pepper was programmed to perform various tasks, including awakening Claudia up, helping her dress, selecting breakfast options, reminding her to take her medication, and guiding her through daily exercises. Additionally, it provided Claudia with the option to call her daughter in Australia.

During the course of the experiment, Claudia interacted with Pepper by selecting the options provided on the screen. Based on the feedback received from the individual playing Claudia, she responded positively to the robot's prompts and expressed her appreciation for the assistance. Claudia found the robot's ability to guide her through daily exercises, particularly helpful, especially considering that she had not been exercising regularly since her fall. Furthermore, Claudia was pleased with the robot's ability to enable her to make calls to her daughter. Pepper's Demonstration.

One limitation of our experiment was that the design of the exercises for Claudia needed to be more specialized for her with advice from a Practitioner. However, she could still benefit from the verbal and movement guidance offered by Pepper.

In conclusion, our socially assistive robot, Pepper, successfully assisted Claudia with her daily routine. Claudia found the robot's assistance helpful, and the experiment was conducted considering safety. The experiment's limitations include not getting an exact set of exercises for Claudia., but overall, the experiment demonstrated the potential for socially assistive robots to improve the quality of life for individuals with disabilities. Further work is needed to refine and expand the design of the robot and explore its potential applications in healthcare and other settings.

C. Discussion

This experiment aimed to explore the potential of socially assistive robots in supporting individuals with limited vision and mobility in their daily routines. The results indicated that Pepper's interaction with Claudia was positive and effective in assisting her with various tasks and exercises.

One of the critical benefits of Pepper's interaction was its ability to provide a personalized experience to Claudia. The options provided to her for dressing up and breakfast, as well as the ability to call her daughter, showed how the robot could cater to her individual preferences and needs. This personalization is crucial in making the robot more engaging and effective in assisting individuals in their daily routines.

Another critical aspect of the interaction was the use of visual aids. The images displayed on the Pepper screen made it easier for Claudia to understand the options. Additionally, the seated exercises were made more accessible with the visual aids provided by Pepper. This use of visual aids is an essential consideration for individuals with limited vision, as it can significantly enhance their experience with the robot.

It is worth noting that while the interaction was effective, there were some limitations to the system. One such limitation was the lack of physical assistance provided by Pepper and the lack of personalized advice for Claudia from a practising physician. While the robot could provide guidance and reminders for various tasks, it could not physically assist Claudia with activities such as dressing up or taking her medicines. This limitation highlights the need for physically assistive robots to complement socially assistive robots in providing comprehensive support for individuals with limited mobility.

Ethical considerations were taken into serious consideration as Claudia has daily interactions with the robot. One potential challenge that may arise is the possibility of loss of human interaction and social isolation, which could lead to obsessive behaviour and attachment issues by solely relying on the robot. Moreover, there is a need to establish a proper set of protocols for privacy protection of Claudia and her surroundings. For instance, only the doctors and psychiatrists taking care of Claudia should have access to her data. Furthermore, there should be restrictions on the robot not to enter certain areas if requested by the user or if the user feels uncomfortable having the robot present.

In conclusion, the experiment showcased the use case of pepper in supporting individuals socially by supporting them in daily tasks, helping them keep track of health(in our case rehabilitation) and provide a sense of presence to individuals alone in trying times.

III. Part B – Physically Assistive Robots

A. Methods

The main objective of this part was to showcase how a physically assistive robot like TurtleBot3 [3] can assist a person from the given personas. The persona chosen is Claudia, who is partially sighted and lives alone and needs help with her daily medication routine. The HARE model was used to understand human activities and environments better. The workflow of the planned interaction is given in Fig. 2.

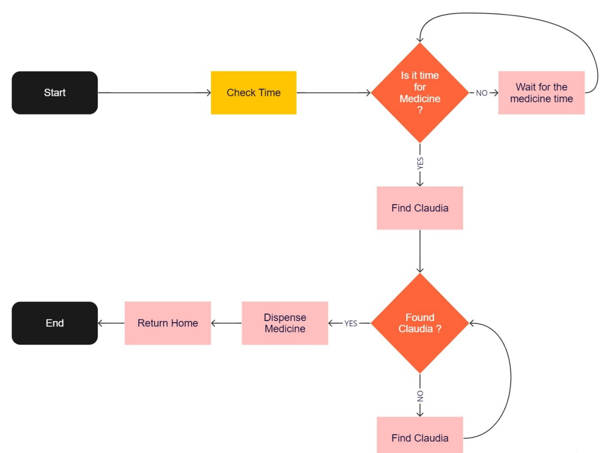

Fig. 2. Flow chart of the planned physically assistive task

The experiment setup was simulated in the Gazebo simulator [4] of the Robot Operating System (ROS). An example map of a modular house has been considered the home of our persona, Claudia. Turtlebot3 is a small programmable robot generally used in research and product prototyping. As the intended direction of this experiment is to develop the software, only the software specifications were considered rather than the robot's hardware.

This experiment aims to determine whether our TurtleBot can help Claudia by delivering her medicines at the stipulated time and helping her effectively consume them. The experiment site, Claudia's house (seen in fig. 3 below), was modelled first. Then, we made TurtleBot map the house to ensure it finds Claudia in the least amount of time possible. According to the doctor's advice, the robot is programmed to deliver medicine at specific times throughout the day directly to Claudia's location. This was made possible by asking the robot to find the 'beacon location' and navigate to that location on the map, which is already stored in its memory. We are assuming the beacon is something that can be attached to Claudia in the form of earrings or other forms of jewellery.

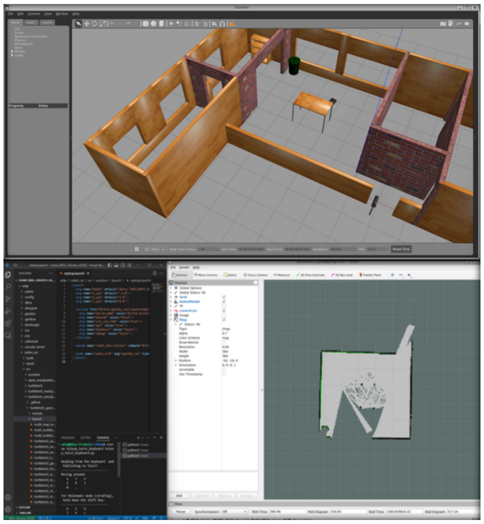

Fig. 3. Experiment site in Gazebo

After confirmation of delivery, Turtlebot navigates itself to the home position, which is set in a secluded space so that it doesn't interfere with Claudia's mobility.

B. Results

Our experiment was conducted on the persona Claudia, a 54-year-old social worker with partial sight due to severe glaucoma and diabetes. Claudia lives on her own, and her limited mobility has made her quite frail.

Based on this persona, the physical task we decided to assist Claudia with the TurtleBot is the timed medication. As Claudia has limited mobility, timed medications are essential as she lives alone. Therefore, our TurtleBot will be in a secluded corner at Claudia's home and will move out to deliver the medicines directly to Claudia according to the prescribed times. TurtleBot's Demonstration.

The whole house was mapped at the beginning of the experiment, and then a custom node in ROS was created for finding the beacon; find the rqt graph for the available node in figure 4 below. A beacon was generated as a specific coordinate on the map, and there are multiple locations in the house set as a beacon. Trials were conducted to see if the node was working perfectly, and TurtleBot was able to reach all of those locations through a perfectly navigated route at the stipulated time. This confirms the success of the experiment.

C. Discussion

We aimed to deliver medications on time using the TurtleBot, and from the above results, we can safely say that the intended outcome has been achieved.

Using this study alleviates Claudia's need to constantly remember that she must take her medication at a specified time. Due to Claudia's limited mobility, the robot delivering medication to her via the beacon could spare her the tedious effort of finding them and ensuring that they are all consumed.

While the experiment was successful, the robot itself has some critical limitations. It is unable to detect the presence of a human. Let us assume a case of a beacon being set aside. If so, the bot would administer the medication without being able to determine whether the mission was successful. Additionally, if there is an obstacle, such as a locked door, it would get stuck as it tries to seek an optimal route. Limitations like these highlight that a software-focused prototype does not meet the needs of our persona. We require a more customized solution for physical assistance needs.

Ethical considerations were taken into account while experimenting. The TurtleBot will navigate itself to the beacon but will also look for any obstacles in its path and think about taking a different route to avoid those not on its current map, including humans that are not a part of the experiment. Additionally, a lidar sensor—which only calculates distances and not images—is used when mapping and navigating. This ensures that any future users or participants in the experiment will have their privacy protected.

TurtleBot3 was programmed with safety considerations in mind. It is designed to avoid obstacles and stop if no safer route is available. Additionally, it is programmed to stay in a secluded corner so that it does not affect the normality in houses. These safety measures ensure that the robot can work safely in a domestic setting without endangering people or property.

This study demonstrated the successful implementation of a physically assistive robot, TurtleBot3, to help Claudia with her daily medication routine. The robot navigated the house and delivered medication to Claudia at the stipulated time. However, the study also highlighted the critical limitations of a software-focused prototype and the need for more customized solutions for physical assistance needs. We made sure to consider ethics and safety measures to ensure that the robot is safe to use in homes without posing any risks to people or property. Our study highlights the potential of physically assistive robots in enhancing the quality of life for individuals with limited mobility.

IV. Reflection

Our group conducted two experiments with assistive robots, Pepper and TurtleBot, to explore their potential to improve the lives of individuals with disabilities. We demonstrated strengths in collaboration, communication, and ethical considerations while recognizing areas for improvement.

Throughout the experiments, we learned the importance of personalisation, visual aids, and clear communication in enhancing the user experience. We also recognized the need for physically assistive robots to complement socially assistive robots for comprehensive support. We gained insights into the limitations of the software-focused prototype and the significance of specialized solutions.

Our group exhibited effective collaboration, open communication, and a shared focus on addressing the persona's

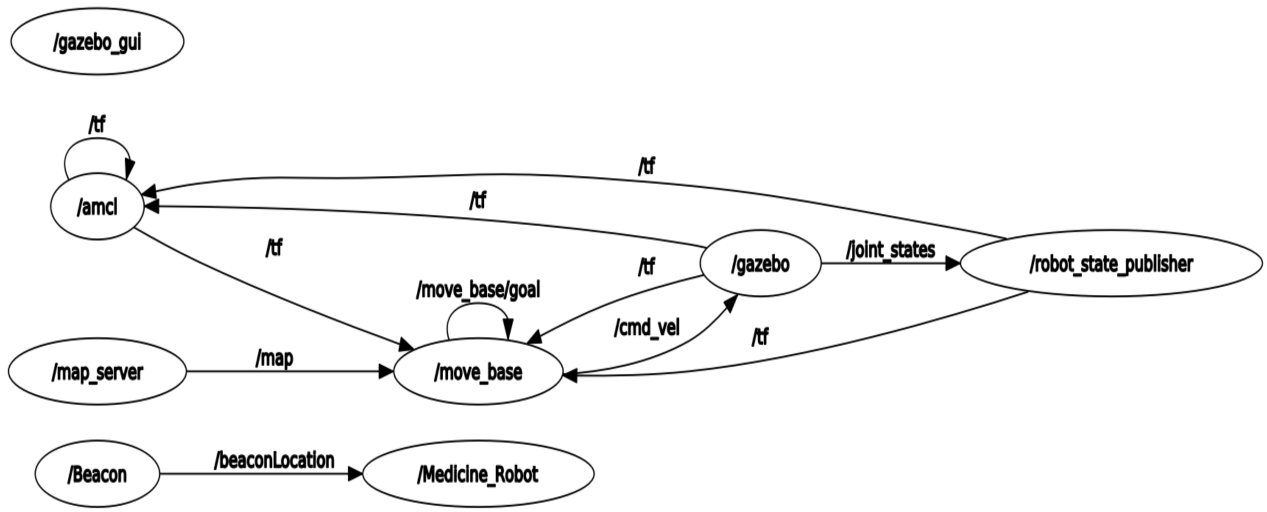

Fig. 4. All the ROS nodes used in the experiment.

needs. We encountered circumstances that highlighted the need for specialized solutions and customization to better cater to individual needs.

Based on our analysis, we recommend increasing the sample size in one experiment and consulting with experts to design specialized exercises. Exploring additional scenarios and including more participants would provide diverse perspectives and validate the effectiveness of the robots. Ethical considerations such as privacy protection and the ability to decline assistance without judgment should be prioritized. Hardware enhancements should be explored to address limitations in the software-focused prototype, focusing on the robot's ability to detect humans and obstacles. Safety measures and privacy protection should be integrated throughout the development and deployment of assistive robots.

Our group experimented with assistive robots, learning about personalisation, visual aids, and communication. We recognized the need for physical and socially assistive robots to complement each other and identified limitations in the software-focused prototype. Recommendations include increasing sample size, consulting experts, exploring scenarios, and prioritizing ethics, safety, and hardware enhancements.

V. Conclusion

The two experiments discussed in the previous sections demonstrated the potential of socially and physically assistive robots in improving the quality of life for individuals with disabilities. In the first experiment, the socially assistive robot, Pepper, was able to assist a partially sighted social worker, Claudia, with various daily tasks. The results indicated that Pepper's interaction with Claudia was positive and effective in assisting her with these tasks.

On the other hand, the second experiment aimed to determine whether a TurtleBot3 robot could assist Claudia with her daily medication routine. The robot was programmed to deliver medication at specific times throughout the day directly to Claudia's location, which was made possible by asking the robot to find the 'beacon location' and navigate to that location on the map. The results showed that the robot could successfully deliver medication to Claudia at the stipulated time. However, the study also highlighted the limitations of a software-focused prototype and the need for more customized solutions for physical assistance needs.

The two experiments suggest that assistive robots have great potential to improve the quality of life for individuals with disabilities. While socially assistive robots like Pepper can help with daily tasks and improve overall well-being, physically assistive robots like TurtleBot3 can provide targeted assistance with medication delivery and other physical tasks. Further research is still needed to refine and expand their design and explore potential use cases in healthcare and other settings.

Moreover, the comprehensive research endeavours have accentuated the ethical imperatives and indispensable safety precautions involved in the intricate development of assistive robots engineered to operate seamlessly within household premises. Safeguarding individuals' welfare and preserving property remains paramount throughout the design and implementation processes. The culmination of our investigations underscores the utmost significance of tailoring these robotic systems to impeccably cater to the individualized requirements of persons with disabilities, thereby offering them the necessary assistance and support while simultaneously honouring and cherishing their inherent autonomy, privacy, and dignity.

References

[1] WHO, "Visual impairment and blindness.," 2020.
[2] NHS, "sitting-exercises.," 2020.
[3] Robotis, "Turtlebot3 - ros wiki,"
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