MID-TERM TECHNICAL REPORT

EPD 30.537 DESIGN PROJECT – MSc Robotics & Automation

Team Name: **RobotDuet**

Project Title: **Smart Personal Companion**

Team Members:

- **Shi Wei (ID:1009656)**
- **Anandakumar Kavyakrithika (ID: 1009623)**

Mentors: **Prof. Mohan Rajesh Elara & Prof. Foong Shaohui**

Submission Date: **26 June 2025**

TABLE OF CONTENTS

1. ABSTRACT

Loneliness and social isolation have become a public concern in Singapore, especially among the elderly. With an ageing population, this presents a crucial challenge for the healthcare system in Singapore. Current solutions are invasive and expensive, which deters the elderly from seeking treatment. To address this issue, we are proposing a mobile robotic companion that is operated by voice commands and is able to accompany the elderly anywhere and anytime.

2. BACKGROUND & MOTIVATION

Singapore has an ageing population, and more elderly people prefer to retire alone at home. The problems most commonly faced by them are loneliness and social isolation. There are various reasons for loneliness among the elderly, but the common factor is the lack of companionship. To address this problem, various types of therapeutic robots, such as Paro and social robots like ElliQ, have been developed. However, Paro, despite being able to effectively lower stress levels among the elderly, is too expensive to be purchased for personal use. ElliQ can provide companionship according to the elderly's personality and interests. However, it over-communicates and is restricted to a limited space.

Thus, in this paper, we propose a mobile robotic companion that can improve the elderly's mental well-being by identifying their emotional needs through conversations and responding accordingly. It is also able to provide physical companionship and follow the elderly when commanded.

3. LITERATURE REVIEW

3.1. Literature Review 1: No playing around with robots? Ambivalent attitudes toward the use of Paro in elder care

This paper examines the perceptions of users in healthcare settings, including older adults, healthcare professionals, and family caregivers, regarding the use of PARO. Interviews were conducted individually to learn more about their opinions. The result has been a mixed response, with some users appreciating PARO's companionship and the emotional support it provides, while others criticize its infantilization of elderly users and its inability to offer genuine human interaction. This can be seen from Figure 1.1. Ethical concerns were also raised about PARO's ability for genuine concern and how it might be perceived in different cultures. The study suggests that it is important to implement robot therapy after thoughtful consideration of respecting users' dignity and context.

> *OPN9*: "*It is not a being, [its] such a strange thing, and that I can turn it on when I feel like and turn it off again when I have had enough. No, I can't imagine that [using Paro]. If it is something to give to a child and [the child] has a little fun with it, yes, why not? But no, as an adult, no [Paro is not for me]. Not at all*."

Figure 1.1 A response from an older participant who was interviewed.

3.2. Literature Review 2: ElliQ, an AI-Driven Social Robot to Alleviate Loneliness: Progress and Lessons Learned

This paper addresses the effectiveness of ElliQ, a social robot, in reducing loneliness among the elderly. ElliQ can actively initiate conversations and adapt to users' personalities and interests. It has become a part of a routine for many users and has reduced loneliness by about 80%. This is evident from Figure 1.2, as shown below. However, there is an uncertainty about the long-term engagement of ElliQ, as the survey was conducted for only about thirty days. Some users were also not welcoming of the robot's proactive nature and faced technical issues during the trial. Limitations of ElliQ were also addressed, were the robot's communication with users is limited to the place it's placed. The robot provides only one-dimensional responses, causing users to feel less connected with it. In conclusion, ElliQ can provide companionship to the elderly, but it does have its limitations and does not replace human care completely.

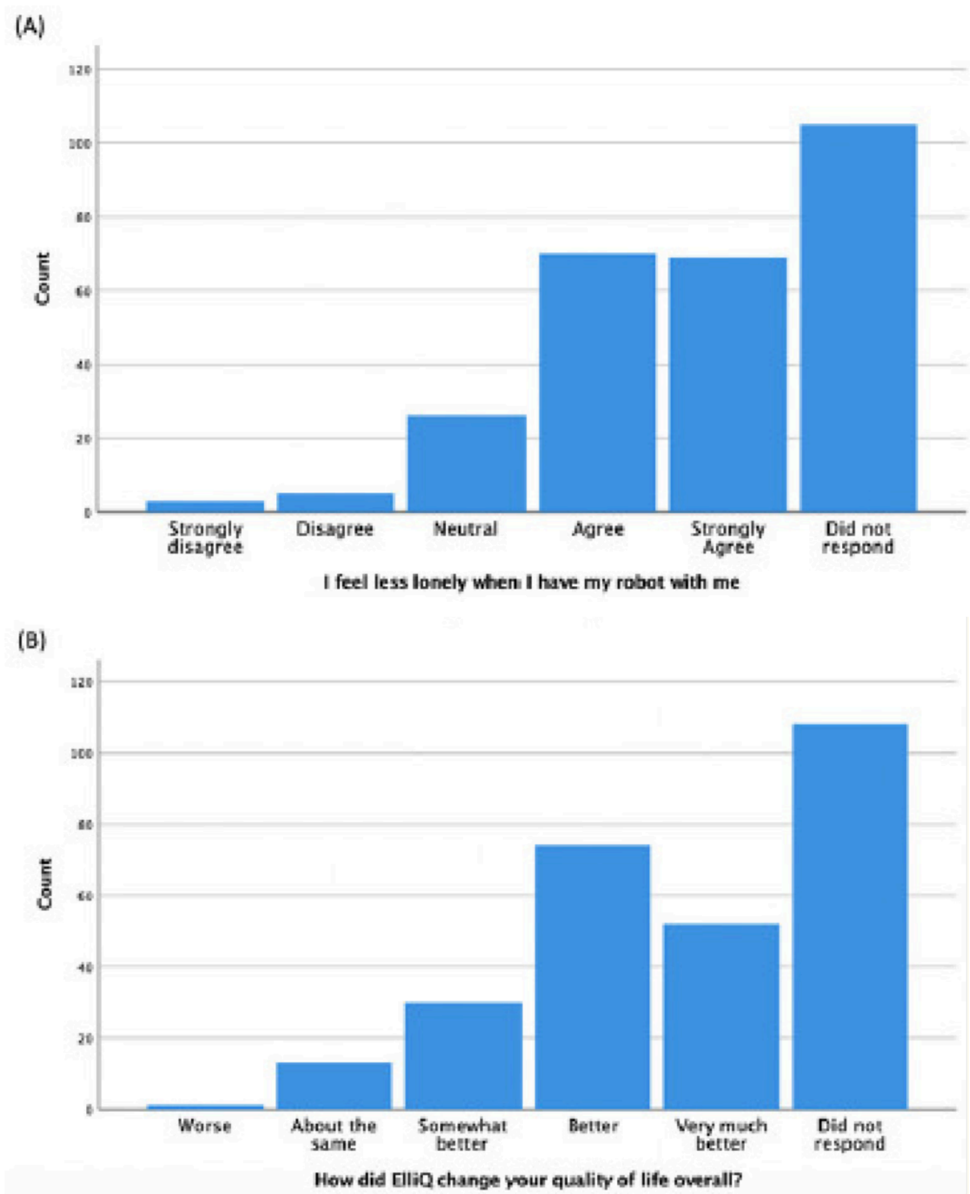

Figure 1.2 Survey results from the trial conducted

3.3. Literature Review 3: Social Robot Interventions in Mental Health Care and Their Outcomes, Barriers, and Facilitators: Scoping Review

This paper analyses the role of social robots in mental health and their impacts. About fifteen different social robots were analysed, and most of them showed promising results. The robots were successful in improving the patient's mood and reducing loneliness and anxiety. They were also effective in reducing caregiver burden by allowing caregivers to focus more on other important professional or daily tasks. However, there are technical issues, integration issues, and ethical concerns. Technical issues included difficulty in operating the touchscreen and preprogrammed functions, and the voice recognition system was inadequate. Some integration issues that were highlighted were the facilities' lack of space allocation for the robot storage and interaction with users. There was also a concern for an increase in caregiver burden. Ethical concerns were also raised about the privacy and over-reliance on social robots. In conclusion, social robots are effective in alleviating loneliness and reducing anxiety, but they do have setbacks, and it is important to conduct more rigorous and large-scale trials to confirm their long-term efficiency.

4. PROBLEM STATEMENT

From our Literature Review, we realised that there is a need to develop a more personalized and movable solution that provides companionship and alleviates loneliness among the elderly. Hence, we decided to develop a mobile robotic companion that can be voice commanded and can analyse the emotions of the elderly through conversations and respond accordingly. The robotic companion can also follow the elderly and accompany them anytime, anywhere.

5. TECHNICAL GAPS & CHALLENGES

Current social robots have many limitations that hinder their practical and emotional effectiveness. We have analysed three major existing social robots, namely Paro, ElliQ, and Kebbi, and have listed their technical gaps and challenges below in the table presented in Figure 1.3.

Robot	Key gap	Challenge summary
Paro	Intelligence & Sensing	No true AI, no adaptation, tactile-only interface
ElliQ	Physical Interaction	No mobility or physical expressiveness
Kebbi	Robust Perception & Learning	Weak emotional modeling, error-prone CV/SR in real-world use

Figure 1.3: Table showcasing the three popular robots and their technical gaps and challenges.

PARO, ElliQ, and Kebbi each have their key technical limitations. Firstly, PARO lacks intelligence, mobility, and interactive sensing, making it emotionally comforting but unable to move around. Secondly, ElliQ offers strong voice-based interaction but suffers from a lack of mobility, limited emotional understanding. Lastly, Kebbi is expressive and can interact better compared to the other two, but faces challenges in providing strong voice recognition ability in real-world settings. Across all three robots, the common gaps include weak context awareness, limited personalization, and insufficient multimodal integration.

6. PROJECT OBJECTIVES & GOALS

This project aims to develop a personalized robot companion that overcomes the key limitations of existing solutions like PARO, ElliQ, and Kebbi. Integrating a well-rounded perception through vision and speech, enhanced emotional understanding, and mobility, the robot companion can provide thoughtful and engaging companionship for the elderly. It is designed to support multiple roles, such as caregiver and assistant, while ensuring user privacy, natural communication, and context-aware behavior in real-world settings.

7. PROPOSED APPROACH AND DESIGN

To build a more intelligent and interactive companion robot for the elderly, we propose a two-part technical approach that enhances both user interaction and environmental perception. Firstly, natural language voice control via Amazon Alexa, and secondly, biologically inspired echolocation using microphone arrays. In this section, we will also address our approach to mapping and localization, and obstacle detection.

7.1 Robot Mapping and Localization

The TurtleBot3 is used to first map the environment using ROS 2-based Simultaneous Localization and Mapping (SLAM) and LiDAR. The inputs from the sensors are then used to construct a 2D map of the environment, which in this case is a classroom that we have segmented into different rooms to simulate a house. With the map obtained with various obstacles in the different rooms, the robot is now able to navigate autonomously towards each room once the navigation pose is provided.

For Obstacle detection, the LiDAR and Camera are used to identify different obstacles such as chairs, doors, and tables through the camera topic that classifies the different objects that were detected. When these objects are detected, the robot companion avoids them and tries to find an alternative path to move towards the elderly. In the case of closed doors, the robot will send alerts to Alexa to request the elderly to open the door for entry or allow access to the robot to enter the room. If the elderly are unable to respond after a long period, an emergency alert will be sent by Alexa to the family of the elderly through the Alexa application.

7.2. Voice Command Integration

We are implementing voice control using Amazon Echo Dot 5 and creating custom skills using the Alexa Skill. For example, when a user provides a command "Alexa, ask TurtleBot3 to come to the bedroom," the command is first captured by the Amazon Echo Dot device. Next, the spoken input is converted into a text-based intent and sent to a custom Alexa Skill designed to interpret movement instructions. The intent is then passed to an AWS Lambda function, which acts as the backend processor and translates the intent into a robotic command and publishes it via MQTT to an AWS IoT Topic. The TurtleBot3 robot, which is subscribed to this topic, receives the command in real-time and executes it using ROS (Robot Operating System), thereby enabling the robot to move towards the targeted location. This can be seen from Figure 1.4 as shown below.

To better relate emotionally towards the elderly, Alexa is also able to identify the different emotions of the elderly through daily conversations, and the robot responds accordingly to the different emotions. For example, if the elderly seem to be sad through the conversations, Alexa will send a message to the TurtleBot 3 to accompany the elderly and speak encouraging words to motivate them. Alternatively, there is also a "Follow Me" mode that will be implemented within the robot companion to follow the elderly around the house. For example, if the elderly commands the robot companion to "Follow me, companion", the robot will follow the elderly around the house and provide companionship anywhere. Thus, allowing elderly users to not only control the robot hands-free using simple natural language but also improve accessibility and interaction.

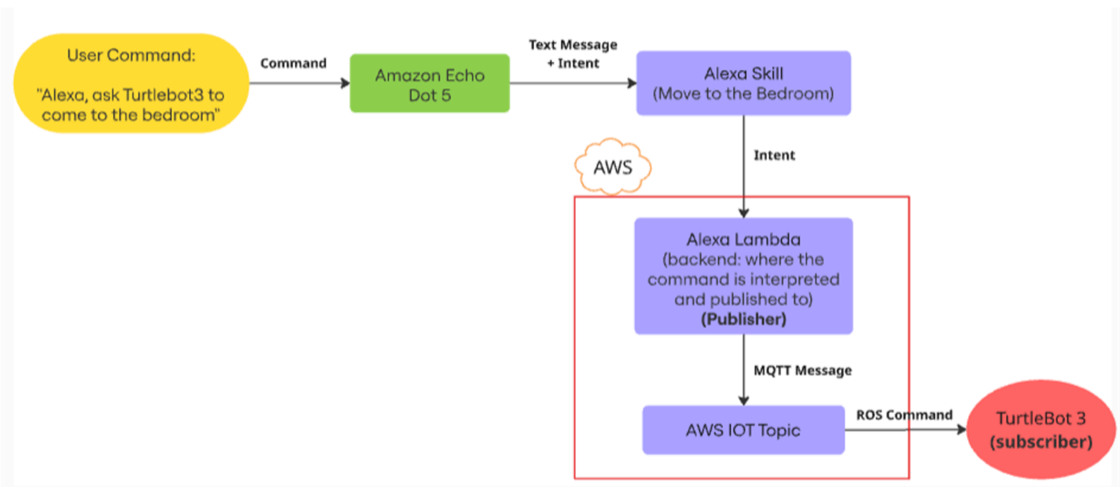

Figure 1.4 System architecture for Voice Command using Alexa

7.3. Echolocation for Enhanced Navigation

To enhance autonomous navigation through the different rooms, we are integrating echolocation capabilities using microphone arrays into the TurtleBot 3. This bio-inspired system allows the robot companion to sense its surroundings by detecting sound reflections. It also allows the robot companion to identify human presence even in low-light or cluttered environments, acting as a complementary system to the current usage of LiDAR and Camera. For example, the microphone arrays pick up sound for help from one of the mikes and will move towards the direction the sound is coming from. If an obstacle is detected in the path by the sensors, the robot then stops and moves to the targeted position using an alternative path. The robot continues to identify the direction the sound is coming from and navigates through obstacles to reach the elderly. This can be seen from Figure 1.5 below. With the implementation of the microphone arrays and the

LiDAR, the robot companion becomes more responsive and context-aware, and suitable for home environments.

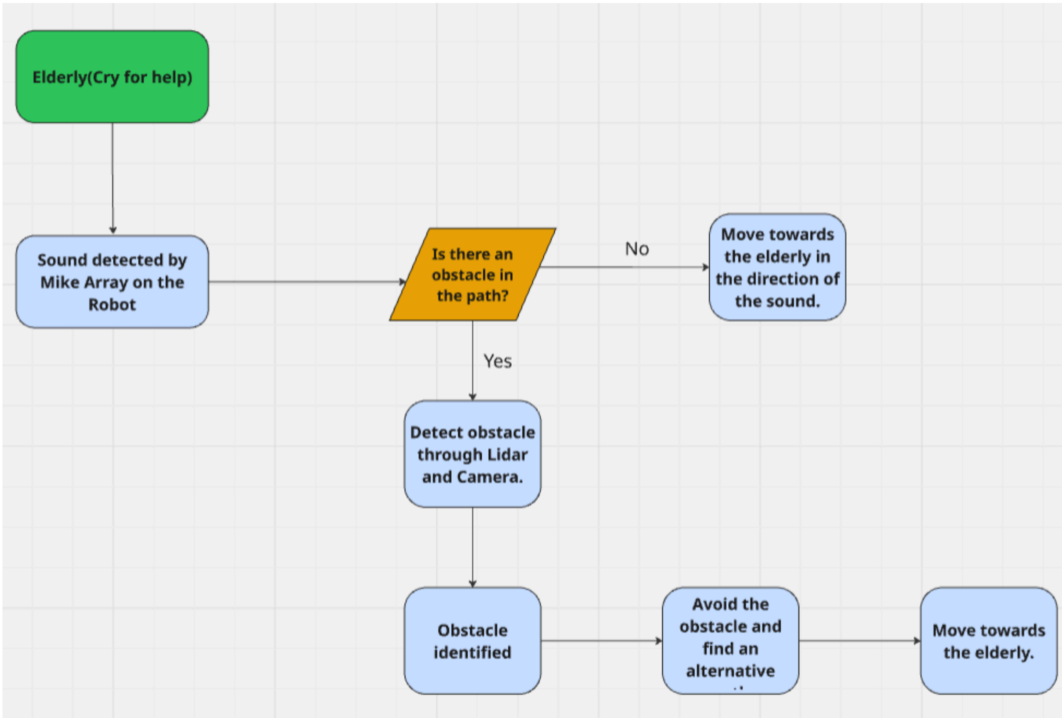

Figure 1.5 Flowchart for Echolocation using a Mike Array

8. DESIGN THINKING PROCESS & METHODOLOGY

We are adopting a user-centred design thinking process to develop the robot companion for the elderly. Firstly, in the Empathize phase, we have performed extensive research on the challenges faced by elderly individuals living alone, particularly the emotional and social issues linked to loneliness, by analysing and evaluating various research papers. Secondly, for the Define stage, we identified the various technical gaps and challenges with current social robots and structured our aim to develop a personalized mobile robotic companion to alleviate loneliness among the elderly and provide companionship. This became a key focus for all our subsequent work. Thirdly, in the Ideate phase, we brainstormed multiple concepts to enhance TurtleBot3, including voice control, emotion recognition through voice commands, and the Follow Me mode to provide companionship anywhere, anytime. Next in the Prototype phase, we will implement SLAM-based navigation in a simplified home simulation using Gazebo, allowing us to test the robot companion's behavior in a simulated environment. Lastly, in the Test phase, we will be conducting various tests around the classroom set-up to test the robot companion in real-world settings and collect test results and feedback to iterate and refine our design.

9. SIMULATIONS(Preliminary results)

To test and validate our robot's navigation, perception, and interaction capabilities, we employed

Gazebo, a powerful 3D robotics simulator. In our simulation, a custom environment consisting of four connected rooms was created to mimic realistic indoor scenarios. A TurtleBot3 model was deployed in this virtual space, equipped with sensors such as LIDAR and a depth camera.

The simulation allowed us to evaluate the robot's ability to: Navigate autonomously through rooms using ROS 2 Navigation Stack; Avoid static obstacles and pass through narrow doorways; Respond to voice commands and detect user presence (in extended scenarios).

Using Gazebo significantly accelerated our development process by enabling safe, repeatable, and cost-effective testing. It also provided a flexible platform for integrating and debugging various ROS 2 packages before deploying them to physical hardware.

10. CHALLENGES FACED

There are two major challenges that we are currently facing in implementing the voice commands and enhancing navigation using echolocation. Firstly, there is a challenge in creating a bridge between Mosquitto MQTT Broker to AWS IoT, to allow exchange of data between the AWS IoT and the TurtleBot 3 through MQTT messages. It is essential to download the Mosquitto broker onto the Amazon EC2 instance, which acts as a local gateway, to create a bi-directional connection between the Amazon IoT and the TurtleBot 3. However, there seems to be a connectivity issue with running the EC2 instance and its compatibility with the SUTD network. Without a connection, the bridge cannot be established and modified to exchange messages between Alexa and the TurtleBot3.

Secondly, another major challenge is the lack of knowledge in implementing microphone arrays to capture the direction of sound and allowing the robot to navigate accordingly. Currently, we do not have any prior knowledge about microphone arrays and their functions. Hence, we are unsure about its ability to capture cries of help from the elderly while ignoring background noise and allowing the Turtlebot 3 to identify the direction the sound is coming from. Current libraries are available about implementing microphone arrays with ROS2, but it is essential to perform more research on this topic and modify the code to suit our project needs within the short time period provided to us.

11. CONCLUSION & FUTURE STEPS

In conclusion, we have proposed a personalized mobile robotic companion that can provide companionship and alleviate loneliness among the elderly, anytime, anywhere. The robotic companion is controlled through voice commands and is also able to detect the emotions of the elderly and act accordingly. The Follow Me mode allows the companion to follow the elderly around the house and provide them with physical companionship at all times. However, there are challenges encountered in executing the voice command function and enhancing navigation through echolocation. However, with more extensive research and tests conducted, these issues could be resolved before the final showcase.

For the upcoming weeks, we are planning to improve the voice command function and address any issues while working on achieving enhanced navigation through echolocation. We aim to achieve voice command function and allow the Turtlebot 3 to navigate through the test environment autonomously. Then, logic will be implemented to allow the robot to speak encouraging words after analysing the elderly's emotions through conversations. Meanwhile, we will also be testing out the microphone array and its efficiency in responding to the cry of help. Then, we will focus on making the robot follow the direction of the sound to help and test its ability to detect obstacles along the way.

12. REFERENCES

1. *Tenzin Wangmo, Duong, V., Felber, N.A., Jiao, Y., and Emilian Mihailov (2024b). No playing around with robots? Ambivalent attitudes toward the use of Paro in elder care. Nursing Inquiry, 31(3). doi:https://doi.org/10.1111/nin.12645.*
2. *Broadbent, E., K. Loveys, Ilan, G., Chen, G., Chilukuri, M.M., Boardman, S.G., P.M. Doraiswamy and D. Skuler (2024). ElliQ, an AI-Driven Social Robot to Alleviate Loneliness: Progress and Lessons Learned. JAR life, 13. doi:https://doi.org/10.14283/jarlife.2024.2.*
3. *Guemghar, I., Pires de Oliveira Padilha, P., Abdel-Baki, A., Jutras-Aswad, D., Paquette, J. and Pomey, M.-P. (2022). Social Robot Interventions in Mental Health Care and Their Outcomes, Barriers, and Facilitators: Scoping Review. JMIR Mental Health, 9(4), p.e36094. doi:https://doi.org/10.2196/36094.*
4. *Silveractivities.com. (2019). Social Robot For Seniors in Singapore. [online] Available at: https://silveractivities.com/kebbi-social-robot.*
5. *Jiang, M. (2020). Build an Alexa-controlled robot with AWS RoboMaker | Amazon Web Services. [online] Amazon Web Services. Available at: https://aws.amazon.com/blogs/robotics/build-alexa-controlled-robot/ [Accessed 3 Jul. 2025].*
6. *Amazon Web Services. (2020). How to Bridge Mosquitto MQTT Broker to AWS IoT | Amazon Web Services. [online] Available at: https://aws.amazon.com/tw/blogs/iot/how-to-bridge-mosquitto-mqtt-broker-to-aws-iot/?fbclid=IwAR0JU9mTSQ0NK70NBHrmnJj0uvuTxwqqM1_K0rjpRAIczNOu5rWWAC2U2pg [Accessed 3 Jul. 2025].*
7. *Hsieh, A. and Liu, H. (2020). Alexabot. [online] GitHub.com. Available at: https://github.com/yahsiuhsieh/alexabot.*
8. *Spencer, Terry (2023). Chatty robot helps seniors fight loneliness through AI companionship. [online] AP News. Available at: https://apnews.com/article/artificial-intelligence-robot-elliq-senior-citizens-a343409477b7aea350254f94daf52eb7.*

13. APPENDICES

Appendix A: Timeline

# 1	Ideation and Research	Assigned to	Start Date	End Date	Assign ed	age Comple ted
1.1	Initial project idea and scope	Both	5/22/2025	5/29/2025		100
1.2	Literature review on elderly care robots and related tech	Anandakumar Kavyakrithika	5/22/2025	5/29/2025		100
1.3	Initial team role assignment	Both	5/22/2025	5/26/2025		100
2	**Designing of Protoype**					
2.1	System architecture design	Both	5/27/2025	6/24/2025		0
2.2	Select core hardware (e.g., sensors, microcontroller, platform)	Both	5/29/2025	6/24/2025		0
2.3	Finalize the projectidea	Both	5/26/2025	6/24/2025		0
3	**Turtlebot3**					
3.1	Begin camera-based human detection (e.g., O	Shi Wei	6/15/2025	7/15/2025		0
3.2	Environment setup	Anandakumar Kavyakrithika	6/15/2025	7/15/2025		0
3.3	Implement real-time object/human tracking (e	Both	6/15/2025	7/15/2025		0
3.4	Integrate obstacle detection sensors (e.g., ultı	Shi Wei	6/15/2025	7/15/2025		0
3.5	Combine tracking + navigation + simple avoid	Both	6/25/2025	7/15/2025		0
3.6	Test complete following system in a simulate	Both	6/25/2025	7/15/2025		0

Figure 1.6 Timeline for Project Part 1

4	**Voice Interaction & Command Function**					
4.1	Map recognized commands to robot actions (	Anandakumar Kavyakrithika	7/15/2025	8/5/2025		0
4.2	Integrate TTS (text-to-speech) for robot's voca	Anandakumar Kavyakrithika	7/15/2025	8/5/2025		0
4.3	Test	Both	7/15/2025	8/5/2025		0
6	**Final system assembly and testing**					
6.1	Final system integration	Both	8/5/2025	8/10/2025		0
6.2	Final debugging & testing	Both	8/5/2025	8/10/2025		0
7	**Final report and presentation**					**0**
7.1	Final presentation and demo	Both	8/11/2025	8/17/2025		0
7.2	Submit full report and documentation	Both	8/11/2025	8/17/2025		0

Figure 1.7 Timeline for Project Part 2

Appendix B: Simulation Screenshots

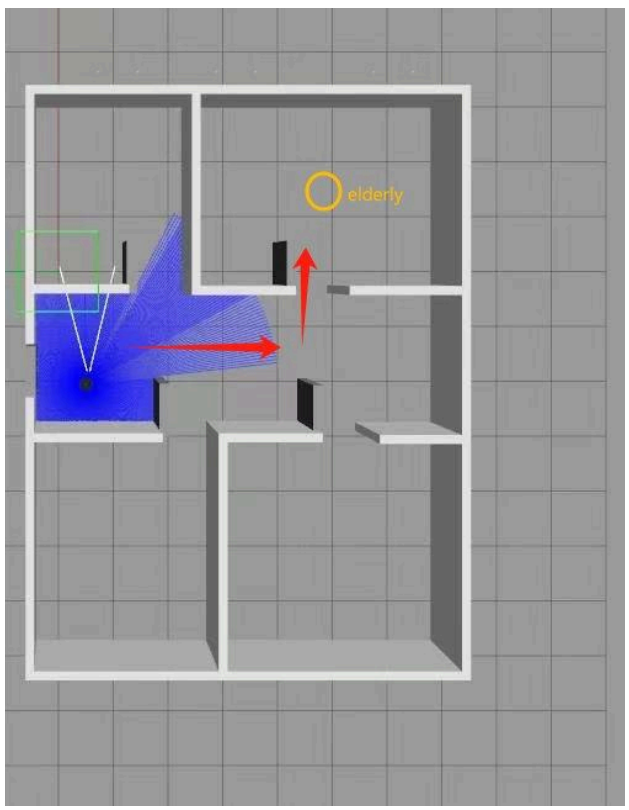

Figure 1.8 Simulation Result 1

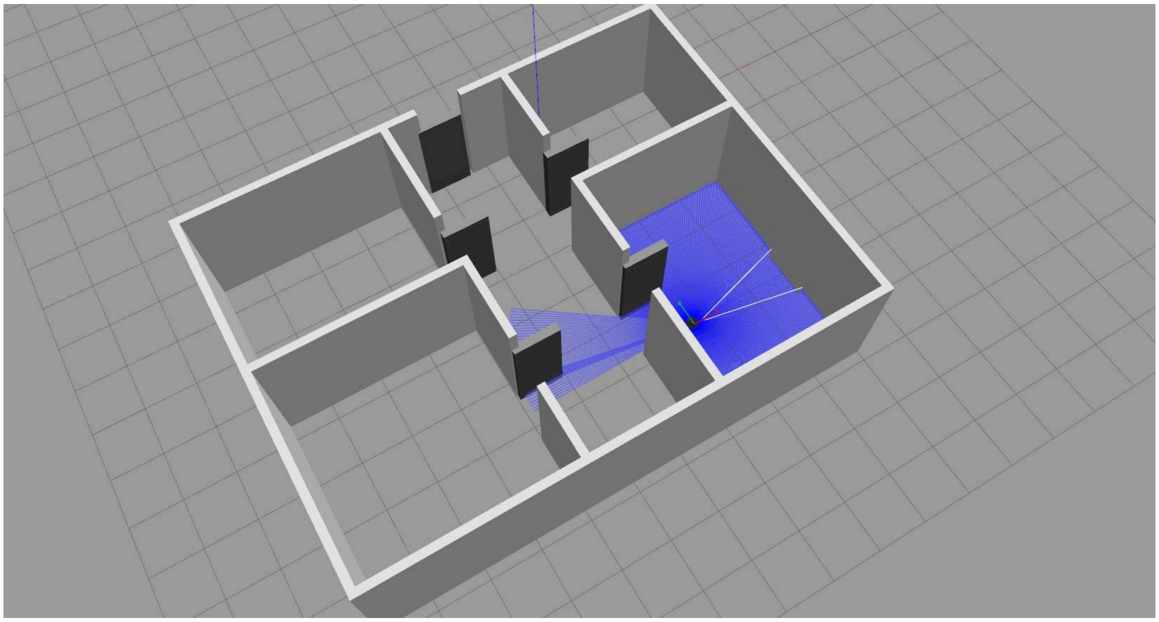

Figure 1.9 Simulation Result 2