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Human Machine Interaction Platform for Home Care Support System

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***Abstract*—There has been a tremendous increase in the costs of caring for older adults owing to the fact that societies are aging around around the world. This has led to a decrease in the number of caregivers who are able to assist. Investigative studies indicate that older adults require social as well as physical support for their well-being which prompted researchers to use social and cognitive robots and advanced human machine interaction devices. However, most of these studies have shortcomings when it comes to providing means of a natural interaction with the machine. With speech being the most natural way for human communication and the huge developments in the Internet of Things and smart homes, equipping a robotic system with powerful natural speech interaction capabilities to maintain a conversation with an elderly while being linked to other smart home devices shows a promising direction. This paper describes a scalable and expandable system with main goal of designing a natural speech-enabled system for older adults that is capable of linking to multiple active agents with minimal integration efforts. The system makes use of the power of commercially available digital assistant systems, integrated with an intelligent conversational agent, robotics, and smart wearables. The main advantage of the system is that it could provide a portion of the population, namely older adults and the disabled, the flexibility of interacting naturally with powerful social robots in smart home environments, hence providing them with much needed independence.**

***Index Terms*—Social robots, Human-Robot Interaction, Elderly care, Artificial Intelligence, Speech Interaction, Ambient Assisted Living**

I. Introduction

Many parts of the world currently witness a decrease in birth rates combined with a longer life expectancy. According to the World Health Organization (WHO), the percentage of older adults (people of age over 60 years [1]) is expected to rise from 12% in 2015 to 22% by 2050 [2]. This trend, along with older adults' desire to live independently at their own homes [3] calls for innovative care solutions, independent of human intervention. Some technological solutions were proposed to look after older adults including mobile applications [4], smart wearables, as well as utilizing virtual assistant systems and social robots; all aiming at keeping the elderly at their homes for as long as possible and providing them with quality care. Robotics are currently being heavily researched for human assistance and several task-oriented robots are already operating in different human-centered environments such as domestic robots [5], helping children with autism [6], and elderly care [7], [8]. Recently, an idea that has been gaining a lot of interest is creating robots that are able to both interact with humans and provide services. This field can be linked to the field of human-machine interaction and is known as human-robot interaction [9].

Elderly care is an area of substantial growth where social robots would play an important role in interacting with humans. The use of robots for such an end can be attributed to the various ways robots have merged into our daily lives and proved useful in a myriad of tasks. As a result, several researchers took on the topic and started conducting studies to understand the capabilities they need to help the aging population such as [7], [10]–[15]. Other researches ([3], [16]–[18]) focused on making these technologies acceptable by older adults, their family members, and caregivers and provided guidelines for research and development of such technologies to remove the barriers that come in way of their adoption. Considering implementations, some of the noteworthy works include the ACCOMPANY project [7], HomeMate [8] and Hobbit robots [19], as well as SocialRobot [20]. Besides that, [10], [12] and [13] suggest the inclusion of social robots in an environment with other smart agents designed for different tasks to result in a more useful system for elderly care. This is supported by the findings in [17] that the technologies created for older adults are expected to be most successful when they require little effort to integrate into the environment they live in and daily routines. These works shed a spotlight on how social robots can be combined with other smart devices to augment their intelligence and result in a more versatile and useful system.

However, a concern arises when it comes to utilizing such high tech solutions with the elderly; the technological barrier. In fact, some older adults may not be comfortable with technologies such as smart phones or touch screens [21]. Therefore, it would be more useful to provide a method of natural interaction that they can directly make use of in friendly and straightforward manner. Speech has always been considered the most useful medium of interaction with older adults, who have usually experienced difficulty interacting with small screen size and touch interfaces.

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In light of the great advancements in virtual assistants like Alexa and Google Assistant (GA) and their powerful speech recognition capabilities, utilizing such commercially available solution becomes a promising idea. In fact, previous work tackled the idea of integrating Alexa in a multi-robot system [22] and showed it could facilitate natural control by humans in a robotic environment. A downfall of utilizing such solutions is that the elderly would be forced to own and be physically close to one of the devices that support the specific virtual assistant. On the other hand, if the same solution were to be developed for all available digital assistants to suit all users, each would have to be developed and maintained separately to accommodate for different application programming interfaces (APIs).

For these reasons, the current work combines Automatic Speech Recognition (ASR) in virtual assistants with an open-source framework for dialogue management (chat bot), and robotic systems to provide full freedom of development and ease of linking to any existing system that enables external input and output. In other words, we unify the 'brain' of the system so that it is able to provide the same functionalities across multiple platforms. Thus, providing older adults and the disabled the flexibility of interacting with powerful social robots in a smart home environment. The rest of the work is organized as follows, Section II covers the work done to understand the senior citizens' needs, the systems implemented for them, the shortcomings of the previously proposed systems, and how they are addressed in the current work. Section III illustrates the system architecture and explains how the system works in more detail. Results from the implemented system are explained in Section IV and the work is concluded in Section V.

II. Literature Review

The authors of [12] provide a review of existing robot implementations for elderly care and mention the ways social robots can assist the older adult population. The paper also showcases different ways robots can help older adults through (i) reminding them of medications, (ii) assisting them with physical activities, (iii) improving their cognitive abilities by engaging them in appropriate activities, and (iv) providing a human-like companion which can engage in a conversation and emotional support to fight loneliness.

ACCOMPANY [7] (Acceptable Robot Companions for Ageing Years) was a long term project that aimed to create a social robot for elderly care. At first, a study was conducted which divided the users into three groups: formal caregivers (such as nurses), informal caregivers (family), and the elderly, and assessed the problems each group sees in elderly care. The study concluded that robots can help in promoting independent living of older adults by providing physical assistance and assisting in mobility. It can also remind them to take their medication, eat, or drink, as well as connect them with their families. As a result of that survey, they utilized the Care-o-Bot 3 to create a robot with the ability to recognize users and know the whereabouts of the elderly using a fixed camera in the house as well as RFID (Radio-frequency identification) tag kept with the elderly. The robot was also capable of learning the user's routine through interaction and accordingly suggest personalized activities based on the situation. The suggestions and interactions were all done through a graphical user interface on a tablet touch screen. This work was extended in [11] where a study was conducted on the acceptance of users of the Care-O-bot 3 developed. While the elderly in the study were happy with the overall experience, they expressed more interest in a robot that would be able to fetch objects as well as contact their caregivers in case of an emergency such as a fall and be adaptable to their specific needs. Moreover, the study concluded that the development of social behaviour and skills should be addressed.

In [14] and [15], other attempts were made to identify the tasks for which older adults require a robot and concluded that the elderly need robots that can assist with, but not completely take over, daily tasks such as getting in and out of the shower, taking off their shoes, or cleaning the house. In addition, they also see great benefit from a robot that is able to carry out a conversation, remind them of their medications, read to them, or play games. Moreover, a study was conducted in [8] on the requirements of the elderly and it proposed an elderly care robot, HomeMate, able to provide entertainment (movies or music on demand), run errands, play games, and remind the elderly of their appointments and medications as well as help them in keeping in touch their relatives and friends. HomeMate is also able to operate using fixed voice commands and gestures.

Previous research in social robots for elder care have limitations in terms of usability, sensor capabilities, reasoning, and systems integration. In [10] and [11], the robots lacked speech interaction capabilities. This was tackled in HomeMate [8] but the user was limited to specific structured commands. In addition to that, the idea of utilizing other means of intelligent systems was not tackled in HomeMate. Such agents in a home environment can include virtual personal assistants, sensors such as cameras, RFID or heartbeat sensors, and home appliances such as TVs or refrigerators.

Technological advancements are moving us more and more towards an age where all devices are controlled in the cloud in what is called the Internet of Things (IoT). Incorporating robots in that system would enable it to work seamlessly with all other parts. However, a problem that persists is that every system works on its own. For example, smart home solutions provided by GA are different from those provided by Alexa and each requires its own interface and creating skills to accommodate new services in different ways. Therefore, combining all devices together with a robot would be more difficult. Moreover, existing commercial solutions for speech interaction make it hard for developers to incorporate their own designs and limit the flexibility of the system.

The system described here is an all-in-one solution that harvests the power of pre-existing smart devices and brings them together to provide the elderly with a flexible, seamless means of interacting with a robotic system there to serve their needs in the most natural way to humans; speech [23]. After reviewing previous systems in the field ([3], [4], [7], [8], [12], [14]–[18]), the most important tasks required for the system to perform were deduced. These tasks will be tackled in the current work and include the following:

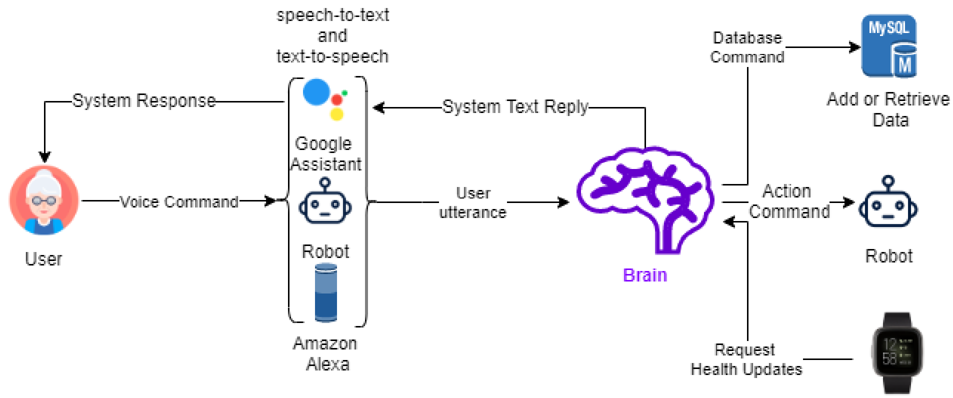

Fig. 1. System Architecture

- provide a natural way of interaction through speech
- reminding the elderly of medications and appointments
- flexibility of integrating other smart agents
- control robots to move, autonomously navigate, and retrieve objects

III. System

Fig. 1 depicts the high level architecture of the system and shows how the user speech command gets transcribed using the automatic speech recognition (ASR) in digital assistants. The transcribed text is then interpreted by the natural language understanding and dialogue management module which resides in the system's brain. It extracts the user's intent and sends the action to the appropriate agent. For example, if the response required is a spoken response, the text response is conveyed back to the user, while if the command is to move a physical agent, it is sent over to the robotic system. We define three kinds of interactions that would allow expansion of the system without major changes in the underlying architecture

1) Static Command: a command where the user asks for an action that does not require any action in the physical environment. This includes medical requests and generic enquiries from the assistant.
2) Dynamic Command: a command which has to be routed to the robot to execute including moving, navigating, or fetching an object.
3) Conversation: a generic interaction which is intended to create a more natural conversation. This is used to create a form of multi-turn dialogue which comes closer to how humans interact together.

A. Speech Interaction

Speech understanding occurs over four stages; ASR, pre-processing, interpreting, and running the policy, as demonstrated in Fig. 2. First, the automatic speech recognition engine on-board of any agent receives the voice command from the user and transcribes it to text and sends it over to *Rasa*; which is an open-source framework for intelligent chat bots [24]. Rasa is divided into two components that take care of the next two stages. The first component is the NLU, which performs all required pre-processing such as removing white

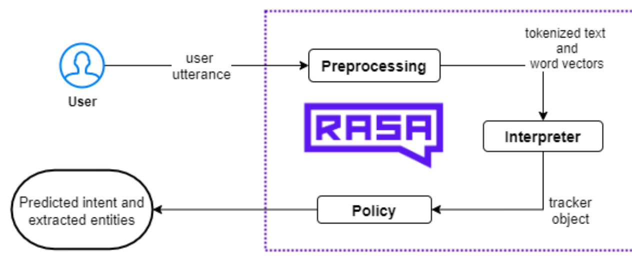

Fig. 2. Speech Interaction data flow

spaces and tokenizing the text. The output is then passed to an interpreter that is able to extract intents and entities and add them to a dictionary [24]. Entities are information provided in the user's input required for completing a certain action. The extracted information is stored to keep record of the state of the conversation in a tracker object. The tracker is sent to Rasa Core which decides the next action to perform by running it through the policy. The current policy utilized in the Rasa framework is a Recurrent Embedding Dialogue Policy (REDP) [25] which is inspired by the neural embedding model proposed in the Starspace algorithm [26]. REDP makes use of supervised word vectors which is extracted from the provided training data. Unlike the Starspace algorithm, REDP takes into account the history of the conversation stored by the tracker and is therefore able to learn which of the previous actions and user utterances are important. It is also able to train on a small amount of data and is language agnostic [25]. The chosen action then updates the tracker for future reference. Rasa is a core part of the brain of the system which links all system modules and agents and stores and retrieves information amongst all agents. Since the brain is built to receive input in form of text and send commands to the target agent, the system is capable of providing identical capabilities across all input and output agents.

B. Robotic System

After Rasa understands the user intent as a robotic command, it sends the command over to the robotic system. The system here exhibits independence between the input and output sources. This means that the brain does not need to understand

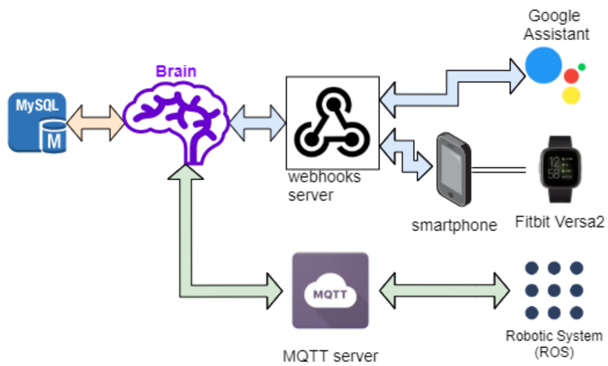

Fig. 3. System Communication

how the task is performed, thus more capabilities can be added to individual agents without having to change any of the system architecture. The robot in this work is simulated using *ROS* (Robot Operating System) [27] and Gazebo, which is an open source robotics simulator offered by the Open Source Robotics foundation.

C. Communication

The system architecture in this work is composed of several agents that communicate with a central brain. Sending data back and forth through the system requires real-time and efficient communication method. Therefore, the system in hand utilizes two protocols that are used in IoT (Internet of Things) applications; webhooks [28] and MQTT (message query telemetry transport) [29]. Input devices such as the personal assistants sends the recognized text using webhooks on an endpoint that runs Rasa to find the appropriate response. Rasa then sends the reply to the digital assistant as a response to the request received. Webhooks are also utilized in communicating with a Fitbit smart watch to detect heart rate and acceleration. MQTT messages are used with robots since it supersedes other communication protocols in integrating robotics into IoT environments [30].

The robotic system contains a central node in the ROS network which is in charge of waiting for messages and performing the action by utilizing different robots' capabilities. This node resides on an agent that does all the processing and data sharing required by the robotic system. It is, therefore, a form of centralized data processing [22] where only one agent does all the 'thinking' and distribution of tasks. This unit has preset commands registered to each robot in the network and is able to direct the commands appropriately to the correct robot within the ROS network. Fig. 3 depicts how the data is transferred between the separate agents. The main use of such an architecture is that agents can be added or removed easily without major changes in the system and without changing the infrastructure making the system modular and easily extensible.

IV. Implementation and Results

The system was implemented, fully functional, and tested with a conversational agent (Google Assistant), a robot, a smart wearable and the central brain. A google action was created to start sending the parsed text to Rasa and accepting responses which is triggered by the user saying "*I want to speak to my care system*". Messages are processed by the system as described earlier and the user's intent gets extracted along with the how confident the system is of the classification. In this section, we show how the system responds to different user intents.

Tests were run to check how the system perform with two types of dialogues. The first focuses on static commands which mainly consider health updates and requests from the older adult. The second test shows how the system responds and understands dynamic commands which involve a robotic agent performing a navigation command. It is important to mention that the commands are not scripted and are generalized using sample training data. This shows how the system is capable of providing a natural way for interaction with little or no training or memory from the user, meeting the recommendations from older adults feedback in previous studies such as [8], [31].

A. Static Commands

Table I shows a sample interaction where the user starts with a greeting then asks the system to add a medication to their reminders. Here, we exhibit how the system is capable of handling incomplete requests. Since the time to take the medicine is vital to the reminder, the system should make sure the user mentions it. In the test interaction the system detects that the time was not mentioned and requests it from the user, therefore ensuring all information required for the action is properly extracted.

At that point, the system has added that medication to a *MySQL* database which is pre-populated with other medications as well. The user then asks what their current health situation is. This causes the brain to communicate with the smart wearable (Fitbit) and retrieve the latest heart rate reading. These readings are also streamed at a fixed rate and saved in the database to allow for health summaries and tracking the status of the user to be able to alert for any dangerous changes. After the health update, the user enquires about the kind of medicine they have to take on Sunday. The system can be seen to respond with the same medication added previously as well as another medication previously available in the database.

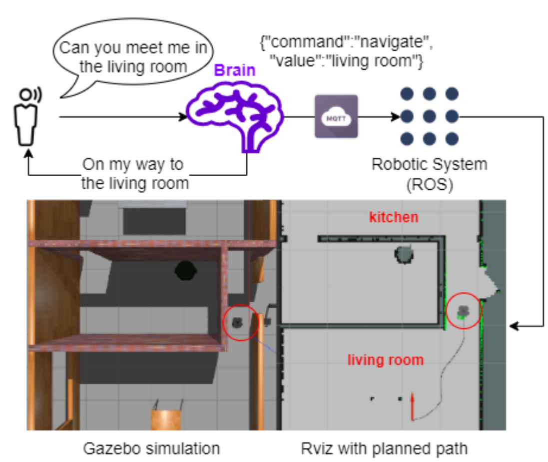

Fig. 4. Demonstration of robotic navigation with speech input

TABLE I
EXAMPLE OF A MORE COMPLICATED INTERACTION WITH MULTIPLE ACTION REQUESTS

User Utterance	Extracted Intent: Confidence	Entities	Response
Hello	*greet*:1.0		Hey!
Remind me to take alpha on Sunday	*request_medication*: 1.0	med_name: alpha, Date: Sunday	Can you tell me what time, including a.m. or p.m?
Set that at 11 am	*request_medication*: 1.0	med_name: alpha, Date: Sunday, Time: 11 am	Ok I will remind you of alpha on Sunday at 11 am. Do you need me to do something else?
What is my health status today?	*health_enquiry*: 0.94		Your heart rate is currently 70.
Ok, what pills do I have to take on Sunday?	*ask_med*: 0.97	Date: Sunday	You have to take alpha at 11 am and beta at 3 pm.
No, thanks	*thanks*: 0.97		Glad I could help!

B. Dynamic Commands

Capabilities of the system extend beyond conversation and saving and retrieving information to incorporate robotic systems which proven to be of great use to the older adults population in previous studies. Most robotic systems available that are able to receive commands using speech depend on scripted commands which should be followed by the users [8], [22]. This calls for familiarity with the system as well as memorization of the available commands. This is remedied in the current work to allow older adults to request actions from helping robots in a natural way as if they were communicating with a human care giver. Table II shows a sample of the utterances the user could use and the extracted message the brain then directs to the robotic agents. The structured command allows the brain and the robotic system to be independent. A sample was tested where the robot is requested to move around. The user can guide the robot to specific location (ex. living room) and then ask the system to store its current location with a given name, thus enabling the elderly to store locations of interest for faster retrieval enabling more effective human-robot collaboration and faster task achievement. Figure 4 shows a simulated robot (turtlebot3) navigating to the living room after the user says ”*Can you meet me in the living room*” and the system successfully extracts the user’s intent.

TABLE II
FLEXIBLE INTERACTION WITHOUT PRESET COMMANDS

User utterance	Extracted Command
move forward 1 meter, go straight, go forward, move to the front	{command: ”go”, value: ”1”}
turn 90 degrees, rotate 90, turn to the right, turn anticlockwise	{command: ”turn”, value: ”90”}
go backward 3 meters, take 3 steps back, move back 3 meters	{command: ”go”, value: ”-3”}
go to the kitchen, come meet me in the kitchen, navigate to kitchen	{command: ”navigate”, value: ”kitchen”}

V. CONCLUSION

The architectural framework described in this paper can integrate various technologies such as robotics, natural language interfaces, and sensors to create an integrated intelligent system to assist in the care of older adults. The system demonstrates flexibility of integration with pre-existing smart home solutions and shows how it could provide a more natural and adaptable form of interaction to provide different services across agents. The system designed and built is able to understand several user commands and respond correctly and adapt by requesting data when incomplete information is provided for a particular task. Moreover, the system was linked to Google Assistant, a robotic system, and a smart wearable which are independent, illustrating the modular nature of the system.

The next step in this work would be to carry out an experiment with older adults to test the usability and acceptability of the conversational agent compared to a system with more rigid commands. It is expected that the more intelligent system will be favored by the participants as it does not require memorization and allows for natural interaction. Such an intelligent conversational system can be extended later to a more social agent that is capable of conducting longer and more generic conversations, thus providing the older adults with the social support they need. Furthermore, the methods for adding agents and more capabilities to existing agents will be standardized to allow for a system that can be customized with different agents according to the specific user’s needs and preferences.

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