The role of intelligent telepresence robots for continuously caring elderly people at home

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Abstract

With the COVID-19, telepresence robots have re-gained a particular attention as tool to keep in contact with people remotely. Over the years, a lot of studies have demonstrated the efficacy of telepresence robots for communication with respect to other typologies of devices. However, most of the works have focused on the short-term interaction between the robot and the users. Herein, we put the effort to design telepresence robots for continuously caring elderly people in the domestic scenario. With this purpose, in this work, we integrate different AI-driven services, developed inside the SI-Robotics project, to enhance the capabilities of a commercial robotic platform and to provide ecological interaction over time.

Keywords

Telepresence robots, Remote home assistance, Elderly people, Robotics&AI

1. Introduction

Telepresence robots are mobile robotic platforms generally endowed with a display, microphone, speakers, and camera, to enable people to virtually interact from a remote location. Over the years, telepresence robots have been largely exploited in several applications from the remote education [1, 2] to facilitate the museum visits [3, 4], from elderly people assistance [5, 6, 7] to patients support during COVID-19 pandemic [8, 9]. Although telepresence robots have been validated in multiple contexts as tool to keep in touch with people and reduce the isolation, the effectiveness of their use in the long-term period is still an opening question. Indeed, as some examples have demonstrated in the past, introducing robots in real-time scenario (e.g., at school [10], at shopping mall [11, 12]) can bias the interaction as a consequence of the novelty of the technology and the curiosity of people in the first days of experience. But, after realizing the limited robot's functionalities with respect to their expectation, people start neglecting robots, by reducing their efficacy.

Given these premises, inside the project called SI-Robotics (SocIal ROBOTics for active and healthy ageing), we are currently investigating how to design and develop advanced and

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customized human-robot interaction for continuously supporting elderly people at home.

2. Motivation

Recently, studies have estimated an increment of old-age dependency ratio (number of people age 65 or above compared to those age 15-64) from the current 28% to 50% by 2060. Traditionally, ageing causes a physiological decrease of motor, sensory and cognitive abilities in people that might impede them to be self-sufficient and live alone at home (i.e., the place where the most would prefer to stay). In other words, it has emerged the necessity of developing healthcare services, for instance telepresence robots, for continuously assisting elderly people in the daily activities [13, 14] and to monitor them in order to detect the occurrence of impairments and dementia [15]. In the case of telepresence robotics, despite the advance of the robotic platform in recent years [16], their use is still mainly relegated to the remote videoconferencing (e.g., call) [17, 18, 19, 20], having no or very limited autonomy [21] and attention to privacy [20]. Long-term usability and acceptability of these platforms, however, require a certain level of autonomy of the robot, for instance to facilitate the teleoperation for the users that are not very familiar with technology (e.g., family members of the assisted persons, as well as doctors and nurses) as well as to implement proactive and user-centered services designed to keep elderly people company and stimulate them from the cognitive and the physical side (e.g., when the robot is not used for remote communication) [16, 22, 6]. The next sections will provide an overview of the AI based services designed inside the SI-ROBOTICS project, considering the dual role of the robot: (a) being a companion for the *primary user* (i.e., the elderly); (b) being an intelligent intermediary for the *secondary users* (i.e., the remote users) to monitor and to interact with the person at home.

3. The roles of the robot & the design of AI-services

To support the continuous interaction (e.g., during all the day), with respect to other works [23, 24, 20], the robot can be used in the two modalities inside the same system: *video conferencing* to enable the remote communication between the *primary* and *secondary* user; *intelligent and autonomous companion* where the robot operates for assisting the elderly people at home by implementing *Communication & Cognitive exercises*, *Physical exercises* and *Navigation* functionalities. A schematic representation of the system is shown in Fig. 1. The shift of the robot's role is determined by the *Timeline-based planner & executor* that copes with the *Local Task Manager* module and are responsible for the decision-making process. Indeed, if the one side, robots are expected to implement reactive behaviors (e.g., look for the person when he/she does not answer to the robot, avoid obstacles, modify the dialogue, etc.), on the other robots have to operate inside predefined boundaries to be acceptable and to adapt to the necessities of people. Therefore, the first is in charge of planning the personalised activities supporting elderly people (e.g., *GoingTo*, *LookForPerson*, *Cognitive Exercise*, *Physical Exercise*, *VideoConferencing*, *Dialogue*) [25], determining the temporal interval and the corresponding parameters (e.g., the most suitable physical exercises from the specific physiological status). The latter re-adapts the scheduled tasks evaluating the feasibility of performing them in the specific real-time situations

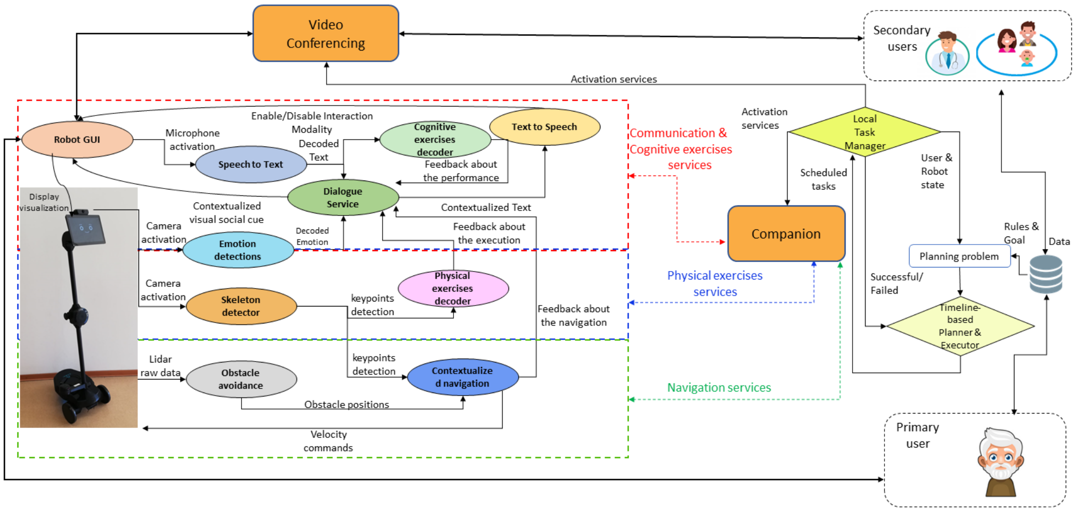

Figure 1: The telepresence and the AI-based services on the proposed platform.

and calling the corresponding sub-services according to the relations in the Fig. 1. For instance, before starting a session of cognitive and physical exercises, first, the *Local Task Manager* requests the activation of camera and then verifies the presence of person close to the robot as well before starting a *Dialogue* it requires the activation of the microphone (e.g., through the robot interface). In this way, the system can consider constraints related to *privacy*, by postponing and/or changing the programmed activity when the camera/microphone are not enabled.

Given the importance of creating a bond between the robot and the elderly person to be acceptable, the system personalises the interaction not only by differentiating the plan of the daily activities, but also in terms of feedback provided (e.g., dialogue and content displayed on the robot's tablet). Indeed, we aim creating an emphatic interaction through the *Emotion recognition* module that estimates the person's emotional status [26](e.g., angry, contempt, disgust, happy, natural, sad, surprise) and triggers different dialogues (e.g., when the person is sad, the *Dialogue service* proposes sentences for the robot to make the person smile, when he/she is angry to understand the reasons) and/or the change of the animation on the tablet.

Finally, the architecture includes the *Contextualized navigation* module that manages autonomous and semi-autonomous robot's movements (e.g., when the user also provides direction commands to the robot). This module is designed to facilitate the teleoperation by freeing the human to control any detailed manoeuvres as in the manual modality, and by reaching some navigation goals according to the robot's perception (e.g., the position of the elderly provided by the skeleton tracker and the surrounding obstacles) [27] and target positions where some activities are expected to be performed (e.g., the predefined place where the session of physical exercises should start).

It is worth highlighting, as represented in Fig. 1, the system exploits the dialogue and the robot's perception to both provide feedback to the user and to acquire information on the user himself/herself (e.g., cognitive and physical score (e.g., number of correct exercises performed), geometric features of the environment, user's preference). Thus, the several modules are not independent among them, but, on the contrary, they exchange specific data (e.g., decoded text, decoded emotions, decoded keypoints, obstacle detections) that can activate autonomous behaviors (e.g., not a priori determined at the planner level), such as the implementation of extra dialogues starting from the feedback achieved during the execution of the physical and the cognitive exercises and the output of the navigation.

4. The implementation on a commercial robot

The AI-based services previously described have been modularly implemented inside the Robotic Operating System (ROS)[1], the standard de facto in robotics, where each module corresponds to a ROS node. However, the transfer of the AI-based services to a commercial robot has required the introduction of additional constraints in the design. First of all, a significant limitation is associated with a few resources capabilities in terms of computing power and memory available. To deal with this aspect, we have designed an emotion recognition algorithm that depends on a thin deep architecture with only 3.9M number of parameters with respect to the 50-100M necessary in the standard approaches, reaching the 87.71% of average accuracy [26]. Coherently, we wrapper the *MediaPipe Pose*[2] library inside a ROS package, for its capability of also running in mobile phone without requiring GPU with respect to the traditional algorithms in robotics such as *OpenPose*[3] and *SPENCER People Tracking*[4].

Secondly, to respect the privacy and save resources on the robot, all the services are switched off at the beginning per default except for the *Timeline-based planner & executor* and *Local Task Manager* and activate one by one when needed through ROS services.

Given the central importance of the communication in the system, the dialogue module (composed by the *Speech-to-text* and the *Dialogue service*) relies on the Google API[5] and RASA[6] library for learning automated and contextualized robot answers at each iteration. While the navigation system exploits the ROS *Navigation stack*[7] for computing the best trajectories for the robot to reach the computed navigation goal [27].

5. Pilot test and Conclusion

We are testing the integration of the proposed AI-services on the commercial robot, Ohmni robot, mounting two RGB cameras and a 2D lidar for robot's perception and telepresence purposes. The platform supports ROS via a *Docker virtualization* layer. In the ongoing pilot tests, we are evaluating the synchronization of the information exchanged between the multiple

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[1] https://www.ros.org/

[2] https://google.github.io/mediapipe/

[3] https://github.com/CMU-Perceptual-Computing-Lab/openpose

[4] https://github.com/spencer-project/spencer_people_tracking

[5] https://cloud.google.com/speech-to-text

[6] https://rasa.com/

[7] http://wiki.ros.org/navigation

modules and the feasibility of the proposed services in the domestic scenario (e.g., not structured environment), representing still a challenge for roboticists (in Fig. 2).

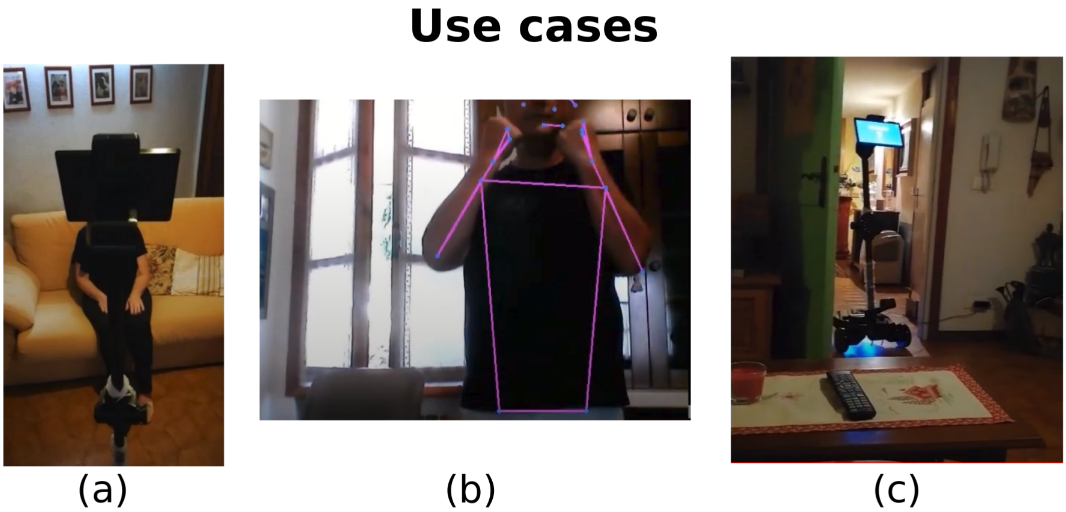

Figure 2: Use cases for testing the integration of the different AI-services on the robotic platform: (a) the dialogue during the *cognitive exercise*, (b) the execution of physical exercise, (c) the navigation in the domestic environment.

The results of the first tests spotlight some limitations of the current robotic platform not only in terms of limited resources but also regard the battery life when all the services are active simultaneously. Furthermore, the services related to the robot's perceptions (such as skeleton tracker, emotion recognition) can be influenced from the light conditions as well as the performance of the *speech to text* is strongly conditioned from the noise in the environment (however it has been testing with the typical domestic sounds such as radio, TV and home appliances active).

Future steps will include the validation of the system with the final potential users, by focusing on different levels of robot's autonomy correlated with the acceptance in terms of privacy.

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