Gym at Home - A Proof-of-Concept

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Abstract. The average life expectancy has increased in the last decades, but it is still necessary to promote a healthy and active aging. Although older people need to have more caution when doing exercise, it is an important aspect to maintain a healthy and active life. Access to facilities by older people to do exercises in groups and having someone guiding them in the execution of the exercises usually poses challenges for them, due to transportation-related limitations. Our goal is to enable older people to do exercises in their homes, allowing them to have exercise plans that meet their needs. Group exercises with their friends is also an important feature to motivate them to exercise more often. In this paper, we propose a proof-of-concept of a smart gym at home system based on defined scenarios and its installation in a near-real scenario. The proof-of-concept provides a guide to a given exercise plan, with video demonstrations of each exercise. The interaction of the system was carefully thought, since older people are typically not comfortable with technologies. The main interaction method in this proof-of-concept is speech, since the users are distant from the system's devices while doing the exercises.

Keywords: Active aging · Physical exercise · Health at home · Virtual gym · Speech interaction

1 Introduction

According to the Eurostat, between 2019 and 2050, the median age is projected to increase by 4.5 in Europe [1]. The aging of the population began a few decades ago and is mainly due to the increase in average life expectancy and low birth rate. Due to this factor, it is more important than ever to look for ways to improve the quality of life of older people, with physical exercise playing a major role in this improvement [2].

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Unfortunately, older people are more prone to suffer certain types of injuries due to a lack of knowledge about the most correct posture while performing some exercises [3] with bad postures can result in more serious injuries, resulting in longer and more difficult treatment. To prevent this problem, it is necessary that older people are properly instructed on how to perform certain exercises.

Aging and the need for health care for older people have been increasing [4]. On the other hand, citizens' access to healthcare is decreasing [5]. Therefore, it is essential to invest in prevention, creating conditions for the elderly to stay longer at home and at the same time be more active and healthy, thus improving their quality of life.

For many older people, wellness and health services, namely the gym and physiotherapy, are difficult to access, both due to travel and cost. This makes it impossible for them to take advantage of these services. Probably, in a few decades, it will be possible for anyone to have their own set of equipment at home, capable of helping in the practice of physical exercise. At the same time, a physical therapist would be receiving the same information regarding the execution of the exercise plan and monitor progress, providing suggestions and an exercise plan appropriate for each person.

The goal of the "Casa da Saúde" or "Health Home" project is to provide autonomy, control of own life, and better living conditions to older adults staying at home. To achieve this goal, a real home was designed, as illustrated in Fig. 1, and is being built especially for the project. This home will integrate a variety of novel solutions to monitor and support an older person living in it.

Fig. 1. On the left figure, the 3D model of the house of the "Health Home" project ("Casa da Saúde" in Portuguese) being built at Rovisco Pais Rehabilitation Center in Portugal (https://www.roviscopais.pt). The house consists of a large and central living room connected to the kitchen, a main bedroom with private WC (right side in the left figure) and a guest room and WC (left side). In the right figure, the construction of the house.

For the first phase of the project, in 2022–2023, there are three main objectives that were selected as the most important to be addressed:

1. Support of inhabitant's activities, that is, the exploration of technological solutions that facilitate certain aspects of the person's daily activities (e.g., checking food validity);
2. Global health state monitoring, installing systems that allow the monitoring of the person's health in a non-intrusive way;
3. Prevention and rehabilitation, by the introduction of systems that allow the prevention of certain occurrences associated with age and clinical conditions or rehabilitation following these occurrences.

The main goal of this work is to develop a smart gym system that motivates the elderly to stay active at home. To do this, we will make use of new technologies to support traditional approaches, in order to support the execution of physical exercises through demonstrative videos. The goal is that the user will not feel alone while exercising, so that he or she will feel more motivated, that is, he or she can interact with other users who are also practicing exercise.

2 Related Work

To find related work, a query was carried out on Google Scholar. Several keywords were used to query for literature, namely: (1) home gym old adults; (2) personal healthcare in gym; (3) interactive elder assistant. From all the results obtained in the query, a smaller list of recent papers were selected based on the similarities and functionalities of the envisioned system. They are briefly presented next.

Martinho et al. [6] proposed a prototype for an intelligent coach application "CoaFEld" with the goal of reducing the impact of aging in terms of physical, cognitive, social, and emotional deterioration. This allows for motivational strategies to persuade older people to be healthier and to stay connected to these systems. The application was developed using a cognitive virtual assistant to interact directly with the users, which plays and communicates with them through different emotions. It is also able to adapt to each user, aware that each person has their own personal characteristics, and will consequently react differently to each one. Information technology was developed following a microservice-oriented architecture. The system is composed of three main components: a user web application, an API (Application Programming Interface) gateway, and a set of microservices.

Another recent application, GymCentral, was proposed by Báez et al. [7]. It explores the design and validation of a virtual fitness environment focused on older people. From a tablet, users can access a virtual room and connect with others to do group exercises online. The app consists of two interfaces, one for the people doing the exercise and one for the trainers who can be in contact with doctors or physiotherapists. Users have access to different rooms and features within the app such as reception, locker room, classroom, schedule, messages, and progress report, just like in a real gym. The progress of users can be monitored manually or automatically with sensors placed at the place of exercise.

Vigorous, long and exhausting exercise can cause major long-term health problems, such as heart disease, kidney failure, and high blood pressure, especially in people with a weak immune system. Ahanger et al. [8] developed a smart treadmill with the capability to find health vulnerabilities of the user.

More oriented to virtual assistants, Basanta et al. [9] proposed a system allowing older people to control home appliances using voice and gestures. This system was designed so that the users, even with their health problems, can easily do their routines, for example, open/close blinds or turn on/off heaters without major problems.

Khaghani-Far [10] conducted a study on the use of home training applications (fitness apps) for older adults. To this end, a total of 200 apps for mobile devices, consoles and computers were explored. The study analyzed five aspects:

– Type of app - training apps, tracking apps (they do not offer training but are important to detect physical aspects in the user such as heartbeat, breathing, etc.), training games (training in the context of games).
– Interaction - technology used during training and for interactions with the app.
– Monitoring - mechanisms used to measure the user's performance in relation to the exercise.
– Coaching and tailoring - types of instructions and feedback given during training.
– Motivation - defines how the apps motivate the users to start and continue exercising.

A summary of Khaghani-Far results, comparing the applications in different aspects, is present in Table 1.

Although not all papers describe a home gym for older people, Table 2 identifies some of the aspects present in each paper. Information in the table makes clear that the creation of systems for performing exercises at home has a large margin for improvement and inclusion of several innovative features with the potential of benefiting their older users. For example, voice-based interaction or video are not commonly adopted.

3 Method: User-Centered Development

To design and develop of the smart gym at home for older people, a methodology based on a user-centered design was used [11,12]. The first step begins with understanding the target audience and the creation of a Persona, which are based on the behaviors of real people. This is followed by the creation of scenarios for the persona. The scenarios allow the extraction of the main requirements for the system. This approach is essential to develop a system that is usable and meets the users' needs.

Table 1. Summary of the results of the study on fitness apps, from [10].

Design Dimension	Current Applications	Research Opportunities
Interaction	Mobile and game consoles provide input and output mechanisms that best facilitate interaction. Both platforms have higher adoption of bidirectional and multimodal interfaces.	We need to study how applications use these ingredients to implement usable interfaces.
Monitoring and sensing	Automatic detection of activities are preferable for older adults, especially when it comes to objective measures. Still, self-reporting is widely used as a method for data collection, despite potential effects in adoption and precision of readings.	Because the integration of sensors in fitness applications is limited (with the exception of applications in game consoles that offer motion-tracking capabilities during training), we need to further explore and exploit sensor integration.
Coaching and tailoring	Training programs supervised by an expert human coach are preferable for older adults. However, most of the applications on the outlined markets rely on hybrid solutions (technology and self-coaching), focusing mainly on exercise prescription.	We need to better incorporate expert human coaching support.
Persuasion and motivation	The few studies on persuasion strategies to boost adherence, especially in older adults, show strong evidence of the benefits of using persuasion strategies, and especially social strategies.	Few training applications exploit these features, other than allowing users to reflect on their activities. This presents a clear opportunity for applications that exploit these aspects

3.1 Main Persona

Mrs. Maria is a 73-year-old woman who lives in a house in a low population density. She has some health problems, such as hypertension, diabetes, memory problems, reduced motor function, and vision problems, requiring health monitoring. In addition, she is not comfortable interacting with modern technologies.

3.2 Example Scenario

One of the defined scenarios addresses the execution of an exercise plan, presented next. Integrated in the scenario description are shown, inside square brackets, the requirements related to each passage. They are classified as functional (F) or non functional (NF).

Table 2. Comparing features described in the different works

Papers	[9]	[6]	[10]	[7]	[8]
Year	2017	2022	2016	2017	2022
Home	✓		✓	✓	
Elder	✓	✓	✓	✓	
Info Exercise		✓		✓	✓
Video					✓
Voice Interaction	✓	✓			
Gestures	✓				
Simulation	✓	✓	✓	✓	✓
Monitoring	✓	✓	✓	✓	✓

Mrs. Maria wants to **perform the exercise plan that her physical therapist made for her** for today. She turns the system on by using the voice command "Call" [`voice interaction - F`] or by using the system's remote control [`interaction via control - F`].

The interface is projected on the wall [`interface projection - F`].

The system asks Mrs. Maria "What do you want to do today?" [`voice interaction - F`] [`system initiative - F`] [`system timely response - NF`]. She is presented with two options [`give few options - NF`]:

- a specific exercise plan made by the physiotherapist accompanying Mrs. Maria [`having exercise plans - F`] [`physiotherapists can add exercise plans - F`].
- all exercise plans available in the system [`list of exercise plans - F`].

Mrs. Maria selects the exercise plan option made by the physiotherapist [`select exercise plan made by the physiotherapist - F`] who accompanies her by saying "Physiotherapist plan" [`voice interaction - F`] [`timely response of the voice recognition system - NF`] [`interaction through the control - F`], a short description of what is to be done is displayed on the wall [`exercise plan description - F`].

The system says/shows "When you are ready say Start" [`system initiative - F`] [`practical and simple interactions - NF`]. Mrs. Maria prepares everything in the room and says/selects "Start" [`voice interaction - F`] [`interaction via control - F`].

The exercise is then showed to her using a video with a demonstration [`show demonstration video of the exercise - F`].

Each time Mrs. Maria wants to do the next exercise, she tells the system "I finished the exercise, you can move on to the next one" [`voice interaction - F`].

At the end of the exercises, Mrs. Maria loved the plan and so she gives a positive evaluation by saying "Rate" and "4 stars" [`voice interaction - F`] [`self-evaluation of performed exercises - F`] [`practical and simple interaction - NF`].

3.3 Requirements

The set of defined scenarios enabled the extraction of requirements for the system, which were divided into the functional and non-functional requirements listed below.

Functional Requirements

- A large part of the system functionalities must be voice-controlled
- Display exercise plan information consisting of text, image and/or video
- Display a video demonstrating the exercise to be carried out
- Capture and stream video of the user doing the exercises
- Receive video of other users of the system doing the exercises
- Allow the person to choose if they want to share their exercise session with other users or not
- Allow the person to choose which users they want to see doing their exercises
- Allow physical therapists to add exercise plans
- Ability to follow the person using a camera with PTZ (Pan-Tilt-Zoom) capabilities
- Self-evaluation by the user of a exercise plan
- Ability to monitor exercises
- Ability to recognize if the person did the exercise correctly
- Interaction by gestures

Non-Functional Requirements

- Simple and intuitive interface
- Interactions with the system must be practical and simple
- Timely feedback from voice recognition system
- Give few options to interact with the system at a time
- Processing must be local
- The processing units in which the modules run should be small in size and low in cost
- The video system module must be capable of High quality video
- Web Connection must be always available
- Microphones that pick up sound at a distance

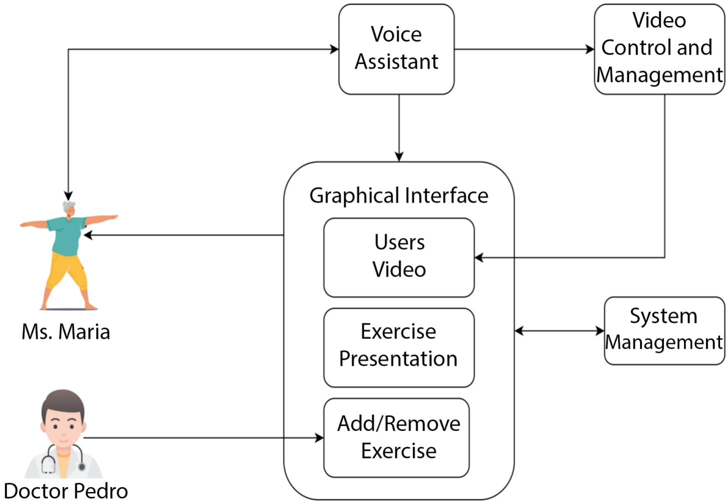

Fig. 2. General Architecture, composed by the main modules: System Management; Voice Assistant; Graphical Interface; and Video Control and Management.

4 Architecture

The architecture of the system follows a decoupled approach, as illustrated in Fig. 2, consisting of four modules: graphical interface, voice assistant, system manager, and video management and control. The system has two types of user: the older person and the physical therapist.

The older person is the main user, who interacts with the system mainly by voice. The user can choose and control which exercises he wants to do and also control the video camera. Additionally, the user can also move forward, restart, and pause the videos of the exercises. The physical therapist is the user who adds and/or removes exercises from the system's database. Using a web interface, the physical therapist can add exercises with name and description, as well as add a demo video or a demo image for each exercise.

The voice assistant module receives audio from the user and interprets what was said. If it recognizes that an action has been requested, a message is published so that other modules can receive it and process the request. The assistant also interacts with the user, giving feedback on what was understood. The graphical interface module encompasses everything that is displayed in the user interface and is subdivided into three sub modules: user video, exercise presentation, and add/remove exercises. The video management and control module sends video to the graphical user interface (GUI) and can receive messages from the voice assistant to change the camera orientation. The system manager module controls the storage of exercise data and exercise plans and provides the exercise information to the GUI module.

5 Implementation

The implementation of our prototype followed a decoupled approach. Modules are implemented separately to facilitate future updates or addition of new modules to the system. To allow the communication between most of the decoupled modules of the system, the MQTT protocol was used. MQTT is a message exchange protocol that follows the publisher subscriber model, where a broker is responsible for receiving and delivering the messages. In addition to this communication method, a REST service was created to manage the information in the database regarding the users and exercises.

Voice Assistant – One of the main challenges of this work was to create an accessible and easy way for the older users to interact with the system. To enable this, a virtual assistant capable of understanding natural language was developed using the following three tools:

- RASA[1] - used to develop virtual assistants. Composed of two main parts: Rasa NLU (Natural Language Understanding) and Rasa Core. Rasa NLU is responsible for understanding the user's intention from text and extracting the important information. Rasa Core is responsible for defining the flow of the conversation and what responses are to be given by the assistant.
- Vosk[2] - enables the development of applications with local speech recognition.
- Pyttsx3[3] - allows for speech synthesis.

A new model was trained for RASA to support the interaction for our system in Portuguese. The module is capable of providing feedback but also publishing the intent to other modules, namely the interface and video modules.

User Interface – The GUI was implemented in C#, using WinUI3[4]. The interface focuses on giving the user the information of the plan and exercises and presenting the videos of the different users. In order to facilitate the use of the system, it is possible to interact with the system by voice. There are features associated with commands, i.e., when the assistant sends a command, the associated function will be automatically executed (only when the command is known). The available functions include: view exercise; choose exercise/plan; play video.

User and Exercise Service – This service handles all the persistent information regarding of our system. It was implemented as a REST service using Flask[5] and SQLite[6]. The service offers methods to retrieve the list of exercises, user sessions, and add/remove exercises.

[1] https://rasa.com/.
[2] https://github.com/alphacep/vosk-api.
[3] https://github.com/nateshmbhat/pyttsx3.
[4] https://learn.microsoft.com/en-us/windows/apps/winui/winui3/.
[5] https://flask.palletsprojects.com/en/2.3.x/.
[6] https://www.sqlite.org/index.html.

Video Service – One of the objectives of our project is to make the older users feel accompanied. The camera module presents a solution for capturing and transmitting video to friends, in real time, of him performing the exercises. The Reolink E1 Zoom camera[7] was used for this purpose, which offers PTZ capabilities, allowing more control. The user can change the direction of the camera or move the focus closer or further away. The camera provides an API which enables our system to control it programmatically. The YouTube platform[8] was used to stream the videos to other users.

6 First Results

Considering the development stage (proof-of-concept), this section presents information regarding results of the development, focusing on the user interface (graphical and Conversational Assistant) and an initial deployment demonstration.

6.1 User Interface

The GUI consists of a series of specialized screens that enable the selection of plan/exercises, present rich information regarding each exercise, such as the visualization of a video, and allow the visualization of video of friends doing the same exercise plan.

The first screen, shown in Fig. 3 A), allows the user to navigate to the exercise plan or see the list of all exercises, as presented in Fig. 3 B). In the next screen, the user selects the exercise, after clicking on `Start`. The video screen will appear and the video will start playing automatically.

The essential screen, seen in Fig. 3 C), sequentially presents information regarding each exercise integrating the selected plan. This screen features the name of the exercise at the top, the video guide of the exercise at the bottom, and the video stream of the user's friends doing the same exercises on the right. At the end of the video, the interface asks if the user wants to move on to the next video or, if there are no more exercises, if he/she wants to end the plan.

6.2 Conversational Assistant

The assistant enables the interaction with the system using natural language. To activate voice recognition, the user must use the wake-up sequence "Olá Maria" (portuguese for *Hi Maria*). After that, the user can speak with the system to: navigate the user interface; start/pause the video; go to the next or previous exercise; and control the camera.

[7] https://reolink.com/product/e1-zoom/.
[8] https://www.youtube.com/howyoutubeworks/product-features/live/.

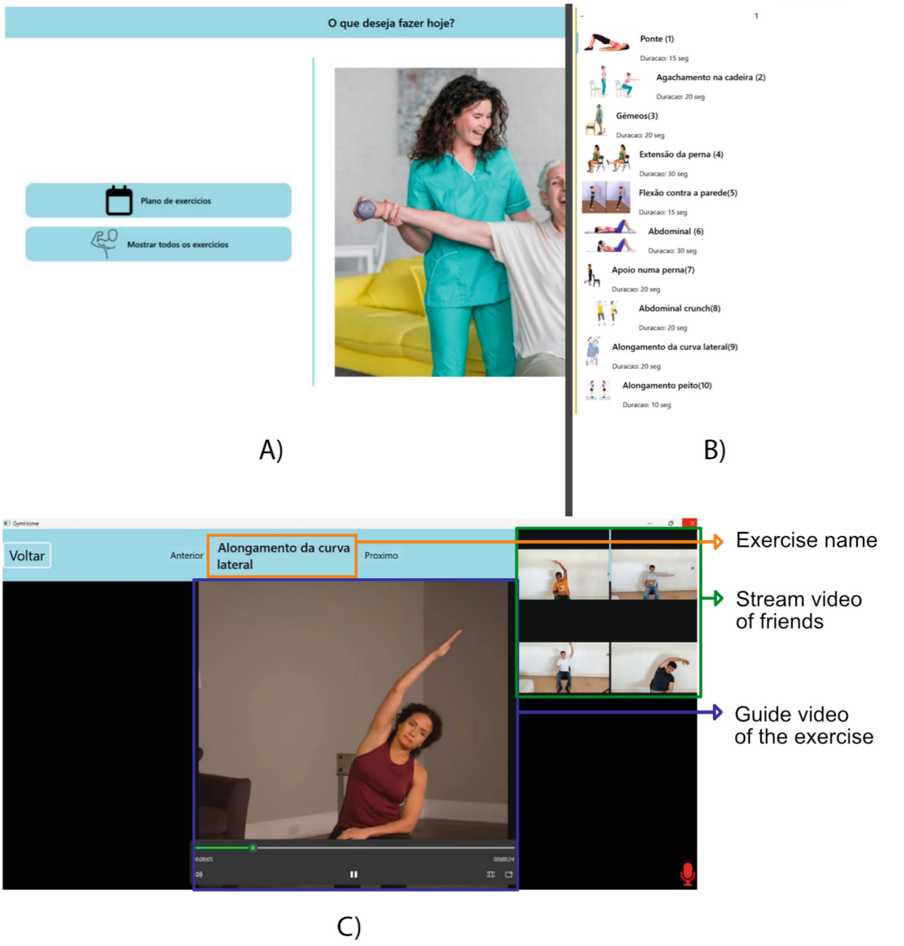

Fig. 3. Screens with different parts of the user interface in Portuguese: A) Main screen; B) Screen with the list of exercises; C) Presentation of the exercise and the video from other users.

As a representative example of navigation in the User interface by voice, Fig. 4 shows a possible conversation between a user (Rafael) and the assistant (Maria). In Fig. 4 a) the user wants to start a plan from the beginning and in b) the user adjusts the focus of the camera.

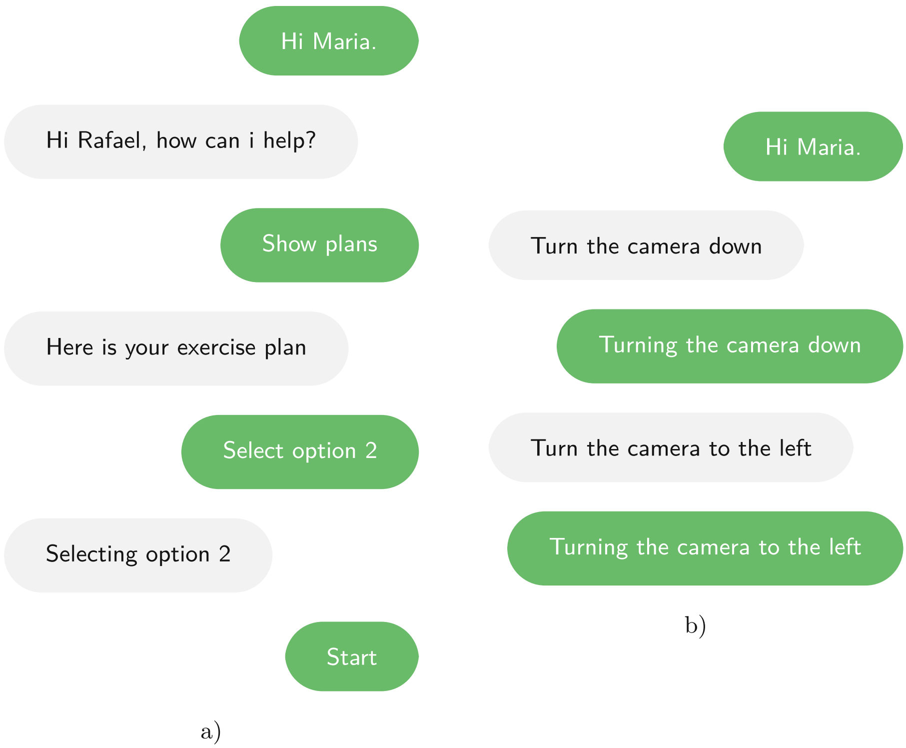

Fig. 4. Voice interaction example, demonstrating: a) navigation in system functionalities by voice; b) controlling the camera. The user dialog is in green bubbles and the system in gray. (Color figure online)

6.3 Deployment

To enable the demonstration of the proof-of-concept and its potential, an initial deployment was made in an environment approximating the real scenario. One of our institute research labs, dedicated to Ambient Assisted Living research, with some of the usual furniture we can encounter at home (e.g., a bed) and the dimensions of spacious living room, was selected. The deployment, shown in Fig 5, uses a mini-computer running the system, a router to provide connectivity, a mic/speaker ready for meetings, a wireless camera with PTZ capabilities, and a video projector.

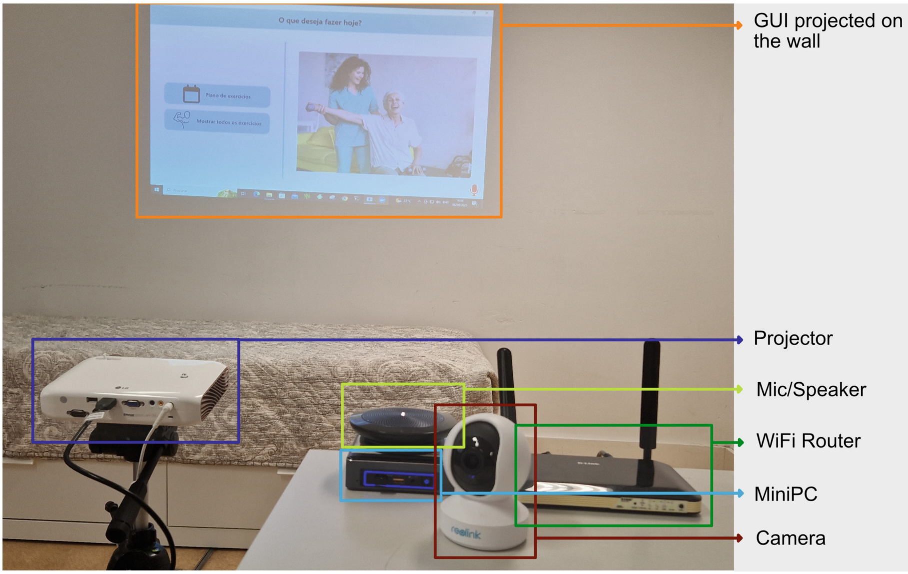

Fig. 5. All the hardware components used in the deployment of the proof-of-concept developed.

6.4 Initial Demonstrations

The deployment allowed us to test and demonstrate the system in a near reality scenario. One of the public demonstrations already performed was based on one of the scenarios defined to derive the system's requirements. In the scenario, Ms. Maria wants to perform the exercise plan that her physical therapist prescribed for her. She carries out the steps needed to select the plan but, before she starts, she needs to adjust the camera to focus on her position.

Figure 6 shows images from the video recorded during the demonstration[9] using the deployed gym system proof-of-concept. The first image presents the main screen, the second and third the steps to select the exercise, fourth and fifth the control of the camera position, and sixth making the exercise.

[9] https://www.youtube.com/watch?v=AxsVyO-H1ss.

Fig. 6. Screenshots from the video demonstrating the use of the system, illustrating the navigation from the main screen to the exercise screen. Video in Portuguese can be accessed at https://www.youtube.com/watch?v=AxsVyO-H1ss.

7 Conclusion

With the aging of the world population, it is necessary to develop health systems capable of supporting the older people in their daily lives and to promote active and healthy aging. Thus, it is important to define strategies to persuade and motivate older people to make and maintain positive behavioral changes.

In this project, "Casa da Saúde", we implemented a system targeted at older people that enables them to exercise in the community from the comfort of their homes. We believe that the system developed has the potential to improve the quality of life of older people by increasing their physical and, consequently, mental well-being.

The goal to create a proof-of-concept system to guide older users to motivate and do exercise was reached. The system is able to provide information about the exercise performed and can also show the video of other users. Additionally, the system is easy to use, with the virtual assistant supporting natural interaction by listening to the user's speech.

Future Work

This proof-of-concept demonstrated the importance of this work, but improvements can be made, namely: improving the responsiveness of the conversational voice assistant, making the interaction with the assistant more natural, and improving the feedback of the graphical interface (e.g., having a caption showing what the assistant understood). Also, the decoupled nature of the architecture enables easy addition of new modules or features, such as a module that enables the camera to follow the user and monitor exercise execution and a module providing gesture interaction. Finally, the deployment of the future house will allow the evaluation with real people in real scenarios.

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