Robohealth: Smart Room Interface for Hospital Patients

Marcos Sacristan, Alberto Brunete, Miguel Hernando, Ernesto Gambao
Centre for Automation and Robotics
Universidad Politecnica de Madrid
Madrid, Spain
alberto.brunete@upm.es

Abstract—The Robohealth project is a coordinated project whose main objective is the development of assistance and rehabilitation robots in hospital intelligent environments, contributing, in this way, to the improvement of the National Health System. This article presents one of the subprojects of the Robohealth project whose objective is the development of intelligent environments for patients living with robots that actively support people in their daily lives in domestic, professional and public environments. In these intelligent spaces a new, intuitive and immersive interaction between the environment and its devices, robots and users is necessary. As a demonstrator of the developed technology, a prototype of a smart hospital room equipped with home automation equipment and a robotic assistance arm is presented.

Index Terms—Smart Spaces, Smart Enviroments, Robotics, Patients

I. INTRODUCTION

Smart Spaces or Smart Enviroments consist of infrastructures (integration of sensors, actuators and processing), intelligent interfaces and robots that actively support people in their daily lives in domestic, professional and public environments. In these intelligent spaces a new, intuitive and immersive interaction between the environment and its devices, robots and users is necessary. In today's domestic environments proliferate electronic devices such as TV, music devices, computers, mobile phones and tablets. Increasingly, the integration of home and building automation systems is in charge of controlling climate, security and various electrical devices (lights, blinds, etc.) forming intelligent environments. This integration can be transferred to hospital environments or in places where it is required to assist people with reduced mobility, a limited cognitive capacity or chronic illnesses that create a dependency situation. It is in these new environments where patients, caregivers and assistance robots must coexist, and that is why robots must be able to communicate with both people and the intelligent environment. To guarantee an adequate functioning of robotic care and rehabilitation systems, it is necessary to have a system capable of guaranteeing the interaction between the human and the robotic systems in a simple and effective way. Likewise, it is necessary a communication

system between the robots and the intelligent environment, which allows the robot to perform the same tasks that the human would perform. In the case of humans with special needs, this type of interaction is particularly relevant because it can contribute significantly to an improvement in their quality of life. The main objective of this project is to design, develop and test an advanced system of interaction between humans, robotic systems and the intelligent environment that allows an efficient collaboration among all of them.

II. DEMONSTRATIVE ROOM OF SMART HOSPITAL ENVIRONMENTS

In order to guarantee the proper functioning of a smart hospital environment, it is required to have a system capable of ensuring the interaction between human and robotic and domotic systems in a simple and effective way. With these ideas in mind, a demonstrative room has been designed for the project, where several technologies which will allow a patient with reduced mobility and even speaking limitations to communicate and interact both with the medical staff and the devices in the room, are being tested.

Various kinds of disabilities can carry a loss of personal autonomy in their day-to-day tasks due to mobility limitations. Setting up a simulated hospital room inside our lab also allowed us to experiment with the different devices a patient can control and interact with, as well as the possible tools and interfaces which accomplish these tasks, reinforcing his independence and therefore his quality of life. This improvement would also imply reducing the need for family caretakers and medical staff, granting more efficiency in terms of time dedication by the health services.

A. Room description

The test room can be seen in 1. To facilitate the patient stay the room should have the ability to modify the environment in both illumination and shutters (1 and 3). It should also count with network connected sensors, so that the room and patient parameters are monitored (5). The bed should be motorized (6). Thanks to a multimodal interface (4) the patient will be able to communicate with both the medical personnel and the rest of the room. For those patients with reduced mobility, the system counts with a robotic arm (2) designed

Fig. 1. Room

Fig. 2. Network infrastructure

Fig. 3. Robotic Arm

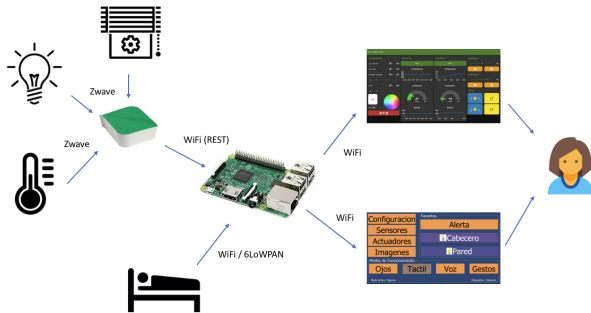| Test	Repetitions	Accuracy	Repeatibility
1	10	<4mm	<5mm
2	9	<5mm	<6mm

TABLE I
ACCURACY AND REPEATABILITY

for this purposed environment, which will allow to place the graphic interface on predefined positions in order to ease the interaction with the patient.

B. Automation devices

Making use of several technologies associated with IoT (Internet of Things) and pursuing to connect them via a control gateway, wireless standard are used in the test room, such as the 802.11 family and related protocols. Currently the room make use of the next standards simultaneously: Z-Wave, 6LowPAN (Contiki), WiFi and Bluetooth. There are humidity, illumination, temperature, movement and reed (for the entrance door) sensors. As actuators, there are automated lights (on/off and regulation) and roller-shutters. A block description of the network infrastructure can be seen in Fig. 2.

A hospital bed has also been connected and included in the network. Starting from a common adjustable bed, its upper and lower parts have been sensorized to be able to remotely control them. In this way the system becomes another node of the room, so that the interface can handle it, knowing the inclination of it in real time. This also allows the medical staff to register the posture data in order to be used in studies about the resting impact it has on the evolution of the patient.

C. Low-Cost Robotic Arm

The arm is designed to carry on its end a tablet that could be positioned in several predefined positions, which allow an easy interaction by the pat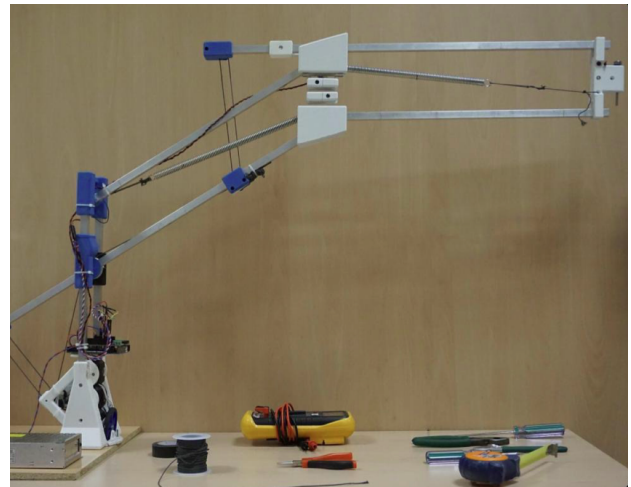ient, through voice commands, gestures, eye gazes or touch screen commands. The main objective is to guarantee the patient safety so that in any case the arm could apply force or harm the patient. With this in mind we designed an actuator system based on wires and springs-base gravity-balanced, so that if the patient pushes the arm in any direction, it moves mechanically in that direction.

It is designed mainly for patients with reduced mobility or without it (temporary or permanent), although it could also facilitate the human-room interaction for the rest of patients. It was necessary to motorize the arm in order to keep the device always at a minimum distance and angle with respect to the patients face (for eye tracking).

Using G15 Smart servomotors, capable of performing up to 20W with low operating torque, it is physically impossible for them to pose a risk for the users. Also this choice of servomotors implies a mechanic amplification throughout the movement drive in the designed prototype. The motors are placed at the base and their torque will be transmitted to the joints through wires, the most smooth and silent option.

The result of the last version can be seen in Fig. 3 with a range of movement somewhat less than 50cm on the X axis and somewhat less than 90cm on the Z axis. It is able to carry a load of 780g. Two repeatability tests have been performed with the results seen in Table I. It can be concluded that although the accuracy is not very high, it is sufficient for the application sought.

D. Multimodal Interfaces

For the tablet placed at the end of the robotic arm, we have developed an application that act as user interfaces to control the room. This test room, as said previously, is allowing us

Fig. 4. Tablet Interface

Fig. 5. Node-RED Interface

to improve the control interfaces in the closest way possible facing the final experience that the patient will have.

1) Tablet-base interface: One of the most relevant aspects is the ability to control the room and robot in a multimodal way. For this purpose, the interaction is being mainly developed for a high performance tablet (Surface 4), with access to the domotic network and the robotic arm. With this tablet it is possible to control them via touch screen, voice, gestures or eye commands. Currently all the systems have been tested separately and they are in a merging stage:

- Tactile control. Provided directly by the tablet. The GUI will emit events as a result of the interaction with its elements on the touch screen.
- Voice control. In a development phase, it is based on the previous knowledge of a series of commands in a tree of options. There have been tested recognizers online (Google Speech API) and offline (Julius).
- Gesture control. The control system is based on the 3D Kinect sensor which, because of the native OS Windows 10 of the tablet, allows us to embed this sensor directly.
- Eye control. An innovative aspect of this interface is that, based on the data given by the device Tobii EyeX, the system is bale to react to commands made by the patient gaze and winks. The interface in this case was designed specifically so that the error rate made by focusing the eye on a point is minimized. This is the main reason the Surface 4 is the chosen system, because the GazeTracking device requires a high computing performance and the SW is developed on a Windows OS. Simultaneously, although still in a preliminary stage, we are working on the possibility of obtaining this same data using exclusively the default camera of the device (with a much more limited resolution).

2) Node-RED User Interface: We have also developed another user interface, which includes the visualization and control of ZWave devices, as well as those with 6LoWPAN and Wifi protocol. The interface is based on Node-RED, a programming tool for wiring together hardware devices, APIs and online services in new and interesting ways. It provides a browser-based editor that makes it easy to wire together flows using the wide range of nodes in the palette that can be deployed to its runtime in a single-click. The SW is based on Node.js, and in our case the system which runs Node-RED is a Raspberry Pi 3 Model B.

We have programmed five segments or Node-RED flows for this Project, and their tasks are:

- Handle the Raspberry, in particular monitoring the CPU and its temperature, as well as the remote shut down option.
- Control the physical devices from the ZWave network, as well as the visualization of their data. Veralite Smart Controller is the provider of this network.
- Command the adjustable bed actuators. A small web server located on a ESP32 Shield operates by Wifi and receives the orders of increasing or decreasing wirelessly the angle of the header and lower part of the bed, maintaining the original wired remote controller operative.
- Measure data such as the temperature or bed inclination thanks to Zolertia devices. These modules are able to communicate with each other using 6LoWPAN/IPv6. This protocol enables constrained devices to run IPv6 stacks, closing the gap between network domains, and actually making the deployment and maintenance of such networks an easy task, using common protocols on top as UDP, TCP, HTTP, MQTT, CoAP and others. Two of these Zolertia modules are part of a small sensor network, while a third module (connected to the Raspberry) acts as a Border Router, linking the mesh to internet.
- Manage messages with MQTT. We are able to monitor all the distinct devices in the room and send to the subscriber of the topic /devices the state changes of each and everyone of them. The purpose of it is that present developments such as the Windows app can subscribe to the messages of this topic and obtain the information of the room, relieving the tablet of doing this task in periodic petitions.

3) Augmented Reality Interface: Finally, an augmented reality interface has been developed to add another type of interface to the system. In this case we are using an augmented reality glasses, the Moverio BT200 by Epson and some paintings as targets where the information is displayed. The paintings are placed all around the room. Besides decorating, they serve as monitorization and control of the devices near
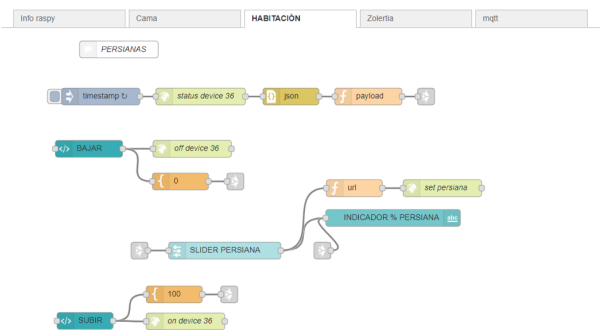
Dispositivos	5m	4.5m	4	3.5m	3m	2.5m	2m	1.5m	1m	0.5m
Gafas RA Epson Moverio BT-200	NO	NO	NO	NO	NO	NO	NO	NO	SI	SI
Huawei Honor 8	NO	NO	NO	NO	NO	NO	NO	SI	SI	SI
BQ E5	NO	NO	NO	NO	NO	NO	NO	SI	SI	SI
Samsung Galaxy s7	NO	NO	NO	NO	NO	NO	NO	SI	SI	SI
Huawei P9	NO	NO	NO	NO	NO	NO	NO	SI	SI	SI

Fig. 8. Results obtained getting close to the target

Dispositivos	0.5m	1m	1.5m	2m	2.5m	3m	3.5m	4m	4.5m	5m
Gafas RA Epson Moverio BT-200	SI	SI	SI	SI	SI	SI	SI	NO	NO	NO
Huawei Honor 8	SI	SI	SI	SI	SI	SI	SI	SI	SI	SI
BQ E5	SI	SI	SI	SI	SI	SI	SI	SI	NO	NO
Samsung Galaxy s7	SI	SI	SI	SI	SI	SI	SI	SI	SI	SI
Huawei P9	SI	SI	SI	SI	SI	SI	SI	SI	SI	NO

Fig. 9. Results obtained going away from the target

A survey has been carried out with 12 individuals and the results show that 92% prefer the mobile phone over the AR glasses and that 100/

2) Eye control: The Eyes mode has two methods of interaction to make a click: wink and staring at the same point for a specified period of time. A survey over 15 people show that most of them prefer staring (4.6 out of 5) over winking (4.1 out of 5).

IV. Conclusion

The new domotic and robotic technologies allow to improve the quality of life of the people. Its application to the development of intelligent hospital environments offers additional advantages to people with reduced mobility, cognitive problems or chronic diseases. In this article, different demonstrators of the use of these technologies in the field of health have been presented.

Acknowledgment

References

[1] A.Valero-Gmez, P.de la Puente, D.Rodriguez-Losada, M.Hernando, P.San Segundo. Arquitectura de integracin basada en Servicios Web para sistemas heterogneos y distribuidos: aplicacin a robots mviles interactivos. Revista Iberoamericana de Automtica e Informtica industrial. 10: 85-95. 2013

[2] H.Noguchi, T. Mori and T. Sato. Construction of data accumulation system for human behavior information in room. International Conference on Intelligent Robots and Systems, 2002. IEEE/RSJ.

[3] M.Hernando, E.Gambao. Teleprogramming. Capturing the intention of the Human Operator. Advances in Telerobotics. 31/2007: 303-320. 2007

[4] J.D.L. Pinta, J. Maestre, E. Camacho, and I.G. Alonso, Robots in the smart home: a project towards interoperability. International Journal of Ad Hoc and Ubiquitous Computing, 7:192 201, 2011.

[5] A. Badii, I. Etxeberria, C. Huijnen, M. Maseda, S. Dittenberger, A. Hochgatterer, D. Thiemert, and A.S. Rigaud, Companionable- mobile robot companion and smart home system for people with mild cognitive impairment. Journal of Nutrition, Health and Aging, 13:113, 2009.

[6] M.E. Pollack, S. Engberg, J. Matthews, S. Thrun, L. Brown, D. Colbry, C. Orosz, B. Peintner, S. Ramakrishnan, J. Dunbar-Jacob, C. McCarthy, M. Montemerlo, J. Pineau, and N. Roy, Pearl: A mobile robotic assistant for the elderly.
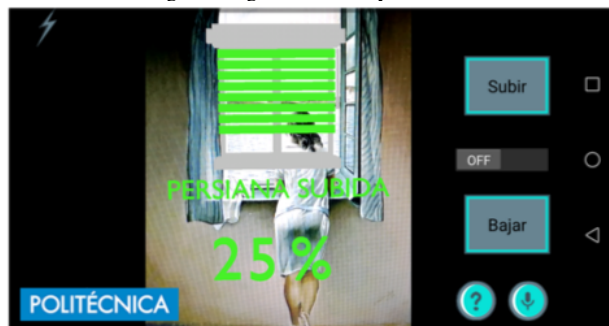
Fig. 6. Roller-shutter control flow in Node-RED

Fig. 7. Augmented Reality Interface

(a) Shutters

(b) Lighting

to them. When pointing with glasses to the paintings, the user can see images overlapped over the paintings as shown in the Fig. 7. Then, the user can interact with the device, for example switching the light on and off, or moving the shutter up and down. It is also possible to use the application on mobile phones.

III. Preliminary results

1) Augmented Reality Interface: The app has been tested on different devices: Epson Moverio BT-200 glasses and mobile phones Huawei Honor 8, BQ E5, Samsung Galaxy s7 and Huawei P9. The detection distance depends on the device. REsults can be seen in Fig. 8 and Fig. 9. In the worst case it is necessary to be 1m away from the target, but with an average camera 1,5m is ok.