Draft Version
Published in Proceedings of Ro-Man 2012

Technical Improvements of the Giraff Telepresence Robot based on Users' Evaluation

J. González-Jiménez, C. Galindo, J.R. Ruiz-Sarmiento
System Engineering and Automation Dpt., University of Málaga,
Campus de Teatinos, 29071 Málaga SPAIN

Abstract— **Telepresence robots are teleoperated robotic systems that allow users to virtually visit a remote place and interact with the environment through their sensorial and motor capabilities. This technology has a great potential to facilitate remote interaction and social communication with people, in particular with the elderly. This paper presents some technical improvements for one of such a robot: the Giraff telepresence platform. These improvements, raised by users' experience, are related to a safer and easier driving of the platform, including auto-docking to the recharging station, obstacle detection, and displaying the robot position in a sketch map of the visited place.**

I. INTRODUCTION

Telepresence refers to a combination of technologies that enables a person to be virtually present in a remote place. Widespread telepresence tools nowadays are video-conferences applications running on personal computers like Skype, Messenger, etc.

Robotic telepresence is an interesting variant based on the integration of Information and Communication Technologies (ICT) onto robotic platforms, providing the user with a higher grade of interaction with the remote environment. The exploitation of telepresence robots for social interaction has caught the interest of the research community since decades. A pioneer example is the Personal Roving Presence (PRoP) robot [1], which, equipped with a multimedia set, allowed users to remotely move around in an office environment and to interact with the surrounding people.

In the last years, telepresence robots have found two special niches of applicability: healthcare [2] and social interaction for the elderly [3]. The latter is particularly in the spotlight given that, in our current society, elder population is increasingly suffering from isolation, a problem that seems to worsen in the years to come. Under this perspective, robotic telepresence is a promising tool that strives for motivating social communication with relatives and friends, helping in mitigating the loneliness of the elderly population.

According to recent studies, well-known video-conferencing applications, though massively and intensively adopted by young people, are not fully accepted by the elderly ([4], [5]). The main reason is that, in general, elders are not technological users willing to use computers. Moreover, they typically live alone and demand warmer and more natural communication channels than those offered by videoconferences. Also, and not less important, telepresence robots can be a suitable and an affordable mean for caregivers to monitor elder patients at home.

These issues are in the core of the Ambient Assisted Living (AAL) Joint Programme, an initiative promoted and funded by several AAL partner states and the European Commission. The work presented in this paper has been developed within the ExCITE project funded by the AAL Programme [6]. The main objective of EXCITE (Enabling SoCial Interaction Through Embodiment) is to evaluate the user requirements for social interaction through robotic telepresence. To conduct such an evaluation, a telepresence robot called Giraff (see figure 1) is deployed at several elder's homes and improved overtime according to the feedbacks from both primary users (the elder) and secondary user (the people who teleoperate Giraff, that is, the visitors).

In this paper we identify the major technological problems arisen from users of the Giraff telepresence robot and present some improvements related to the robot mobility and teleoperation. Concretely we describe:

i. An algorithm that automatically docks the robot to the recharging station using the onboard camera. This improvement releases the visitor from such a tricky, unpleasant chore.
ii. The integration of an obstacle detector based on the sensory data provided by a radial laser scanner. This prevents Giraff to bump into objects unnoticed by the operator or simply to warn him/her about their presence in the nearby.
iii. The enhancement of the teleoperation graphical interface with a 2D sketch map where the Giraff position is marked in real time. This information has demonstrated to give the visitor a clearer spatial sense about where the robot is and what is being seen.

It is worthy to underscore that the presented improvements and techniques, though tailored here to the Giraff robot, are extensible to other telepresence robotic platforms.

This work has been supported by the EXCITE project, funded by AAL (Ambient Assisted Living) Program and Instituto de Salud Carlos III. Corresponding author: cipriano@ctima.uma.es

The structure of the paper is as follows. Section 2 describes the Giraff telepresence robot. Next, technological feedbacks and comments gathered from users are presented. Based on that, in section 4 we go through three of the improvements we have incorporated to Giraff. Finally some conclusions and future work are outlined.

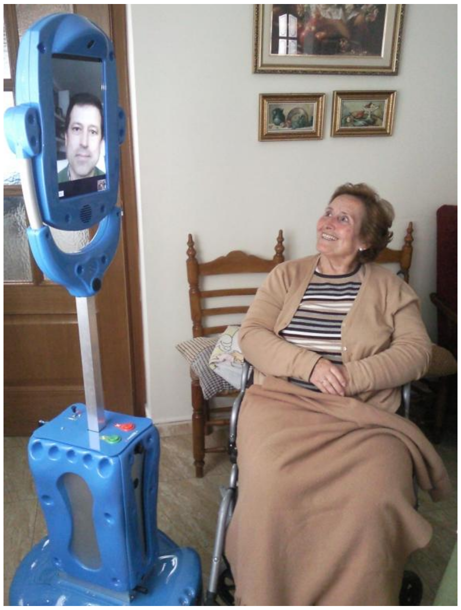


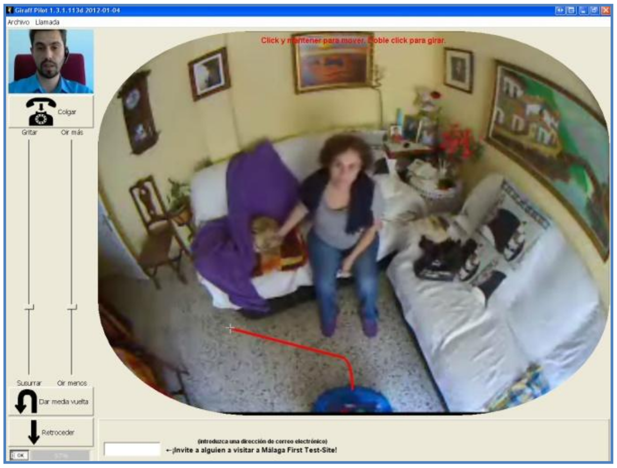
Figure 1. The Giraff telepresence robot. The visitor embodies the robot simulating a real visit to the elder person.

II. THE GIRAFF TELEPRESENCE ROBOT

The Giraff robot is built upon a motorized wheeled platform endowed with a videoconferencing set, including camera, microphone, speaker and screen. Giraff permits a virtual visitor to move around, perceive the environment (audio and video), and chat with the user. The height of the Giraff, the streaming of the visitor camera on the screen, and the possibility of tilting the Giraff's head help in establishing a friendly interaction with the user who can really experience that the visitor is at home.

From a technical point of view, Giraff relies on a low-cost onboard computer running Windows XP. The batteries of the Giraff last, approximately, two hours and can be charged by docking the system to a station plugged to the domestic electrical installation.

The Giraff manufacturer (Giraff Technologies AB [7]) provides software solutions to operate the system. The teleoperation software, called Pilot, is essentially a graphical interface for easily driving the robot and controlling the standard videoconference options, i.e., to initiate/hang-up a call, and to adjust the speaker and microphone volume (see figure 2). At the Giraff side, a server is continually running, accepting calls and providing the needed functionality for videoconferencing and motion commands. All the actions demanded to the elder, i.e. adjust the volume, and answer/hang-up calls, are comfortably accomplished with a remote controller. Thus, one of the major advantages of the Giraff telepresence robot is that neither the user nor the visitor need any technological skill and they both can interact with Giraff in an intuitive and natural way.



Click y mantener para mover. Doble click para girar.

(introduzca una dirección de correo electrónico)

←¡Invite a alguien a visitar a Málaga First Test-Site!

Figure 2. The Pilot application. The visitor can drive the robot by selecting a destination point in the image. The commanded path is marked with a line.

III. USER EVALUATION OF THE DRIVING EXPERIENCE

The key idea of the ExCITE project is to improve the Giraff telepresence robot according to the users' feedbacks. This includes, among others, an evaluation of the driving experience of the "visitors" using the current version of the *Pilot* software. For that, we have deployed Giraff robots in 5 different houses in the province of Malaga (Spain) which were teleoperated by a total of 15 people (both genders). The average age of the drivers was 34 years (from 24 to 49 years), and they had different technological skills. All of them used the Pilot application for the first time and experienced several driving sessions with at least two different Giraffs (and therefore places). The evaluation given by the drivers on their general experience is shown in table 1.

Questions	**Evaluation**
Giraff general driving	4
Difficulty of moving in a straight line	4
Difficulty for turning	3,75
Camera image quality	3,375
Screen tilt movement	3,625
Pilot Interface	4,25
Learning curve	4,75
First general impression	4,25
Difficulty for docking	3,375

Table 1. Results of the evaluation of some aspects of the driving experience of the Giraff telepresence robot, which were evaluated from 1 [poor/difficult] to 5 [good/easy].

Analyzing the results, aspects like the impression about the driving experience, the appearance of the interface, and the learning curve, received the higher marks, which highlight the ease of teleoperating the robot. On the other hand, the lowest mark is for the camera image quality, which hampers the visitor to be aware of obstacles in the surroundings, and limits some maneuvers like the docking operation, which has been also identified as a tricky task.

Additionally, personal interviews with the users have revealed that, in spite of the utility of the Giraff telepresence robot, some of the issues raised in our evaluation, e.g. difficulty for docking, may hinder the communication and interaction with the elder person, which is the ultimate aim of the system. Concretely, users have identified three possible points to increase the autonomy and improve the interaction experience with Giraff, namely 1) Automatic docking, 2) Obstacle detection and warning, and 3) Information about the Giraff position (localization).

IV. IMPROVEMENT OF THE GIRAFF TELEPRESENCE ROBOT

This section details the implemented solutions to cover the technical improvements raised by the users. These improvements rely on state-of-the-art algorithms and techniques from the mobile robotic field.

A. Automatic docking at the recharging station

Docking the Giraff is a mandatory operation each time a visitor concludes a telepresence session. By doing so, in the next visiting session it is guaranteed both that the Giraff battery is recharged, and the visitor, who may not be very familiar with the place, can start the driving from a known location.

Figure 3. Image provided by the Pilot application taken during a manual docking operation. The recharging station is marked with a yellow arrow for illustrative purposes.

As pointed out by the user evaluations, although the camera image and motion controls of Giraff are suitable for driving the robot, the docking operation becomes a tricky and demotivating maneuvering. They sometimes complain about this operation and contrast it with the much easier “phone hanging” operation. This feeling can be clearly understood from figure 3, where it can be noticed that the recharging station (marked with an arrow) is almost imperceptible and usually placed in narrow and cluttered spaces.

To relieve the user from this chore we have developed an algorithm that 1) uses the onboard camera to automatically detect the docking station and 2) takes the Giraff control to approach it. This algorithm works as follows:

```
while not acknowledgment of operation success repeat
    a) Localize the recharging station (RS) in the image.
    b) Compare the position of the RS in the current image, ‘Current RS position’,
       with respect to the expected position of the RS when the robot is docked,
       ‘Docked RS position’
    c) Generate motion (advance and turning) commands to minimize the error
       between the ‘Current RS’ and the ‘Docked RS’ positions.
end
```

The implemented approach has been tested in a number of scenarios and under different lighting conditions proving the reliability and robustness of the process that yields a success rate close to 100%. Given the quality of the camera image, the distance to detect the docking station is limited to 2.5 meters.

Next, the two processes of our auto-docking algorithm, i.e. detection of the recharging station and generation of motion commands, are described in detail.

Figure 4. Detail of the recharging station of the Giraff robot. The pattern used for localizing the docking station is placed centered on it.

1) Detection of the recharging station

To facilitate the detection of the recharging station in the Giraff video image, a simple, distinctive pattern is placed on it. The pattern consists of a white piece of paper with three black circles (figure 4). This particular pattern has been selected because it can be easily detected by a combination of well-known computer vision techniques and because it is distinctive enough to avoid false positives in a typical home environment.

The algorithm for localizing the pattern (see figure 5) works iteratively by segmenting the images into regions. These regions are obtained by first producing an edge image with the Canny detector [8] and then selecting those closed contours which satisfy a set of geometrical constrains, like size, compactness, alignment and separation between the regions.

For speeding up this process, once the pattern is detected in a certain region of the image, called Region of Interest (ROI), the subsequent iterations only focus on such a candidate region to confirm the existence and displacement of the pattern as the robot moves. In case the pattern is not found in two consecutive iterations, the ROI is expanded to cover the entire frame.

As commented before, given the limited resolution of the camera, the proposed algorithm successfully works up to a distance of 2.5 meters from the recharging station. As the robot approaches the station, the appearance of the pattern changes in the image, and consequently the geometrical constrains are dynamically adjusted with the distance. Also, for a better coverage of the scene, the tilt of the Giraff head switches between two inclinations.

This algorithm has been implemented in C++ using the OpenCV library [9] for efficient image manage and processing.

2) *Automatic Guidance to the Docking Station*

Once the pattern is detected in the image, a sequence of robot motion commands are generated to bring it to a pre-established image position, where it should be observed from the docked position.

Let $\mathbf{c}_f=(x_f,y_f)$ be the final position of the center of the pattern in the image when the robot is docked. Let $\mathbf{c}_c=(x_c,y_c)$ be the current position of the pattern in the image (see figure 6). As mentioned, the basic idea is to generate the proper sequence of motion commands to bring c_f to c_c.

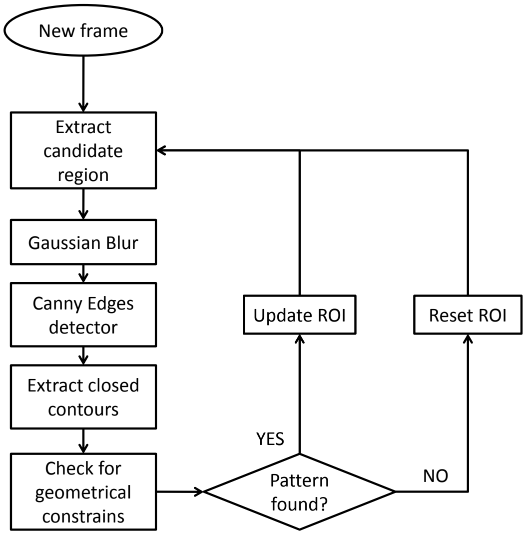
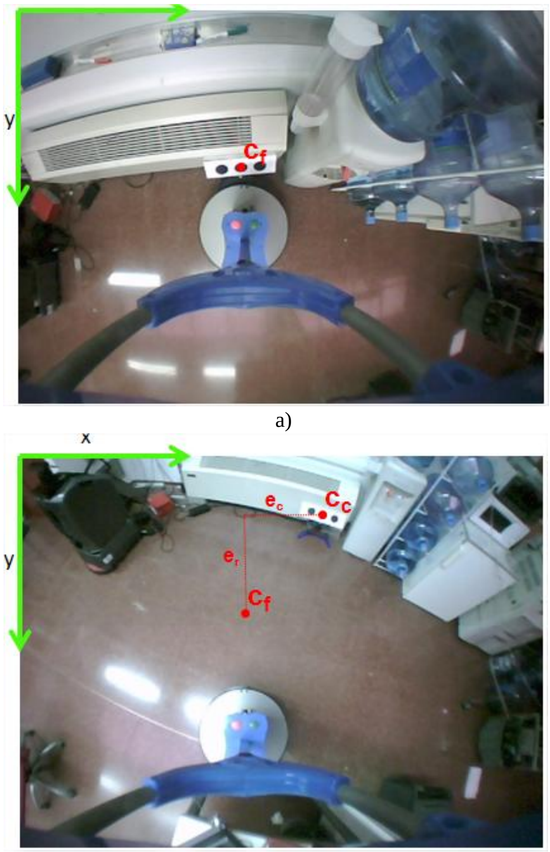


Figure 5. Flow diagram of the developed pattern detection algorithm.



a)

b)

Figure 6. a) Position of the center of the pattern when the robot is docked. b) A frame taken while executing the process.

Concretely, we consider the Giraff commands, *turn* and *advance*, to reduce independently the errors $e_c = x_f - x_c$ (error in the columns of the image) and $e_r = y_f - y_c$ (error in the rows of the image), respectively. In other words, we are simplifying a two-inputs(x_f,y_f)/two-outputs(x_c,y_c) control problem as two separate control loops, with separated control actions (see figure 7):

- turn the robot to reduce the error in *x* coordinates
- move forward the robot to reduce the error in *y* coordinates.

We have implemented the simplest (but effective) control action: turn/advance with an angular/linear velocity proportional to the error e_c/e_r by means of the functions Kp_x, and Kp_y empirically tuned for the motors' controller of the Giraff. The loop pattern localization and navigation is iterated until the robot reaches the station. Each iteration takes 63 milliseconds on average, which produces smooth movements and guarantee satisfactory results. A video of the automatic docking operation can be watched at *http://www.youtube.com/watch?v=qzZWrOpgVy4*.

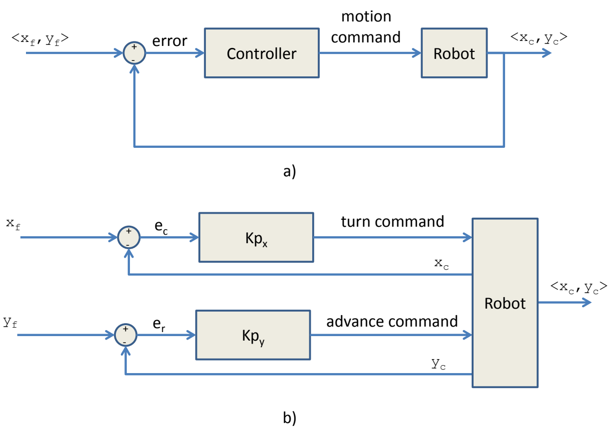


Figure 7. a) Control scheme for the auto-docking operation. b) Simplification assumed here where the problem is decoupled into two proportional control loops.

B. Obstacle Detection

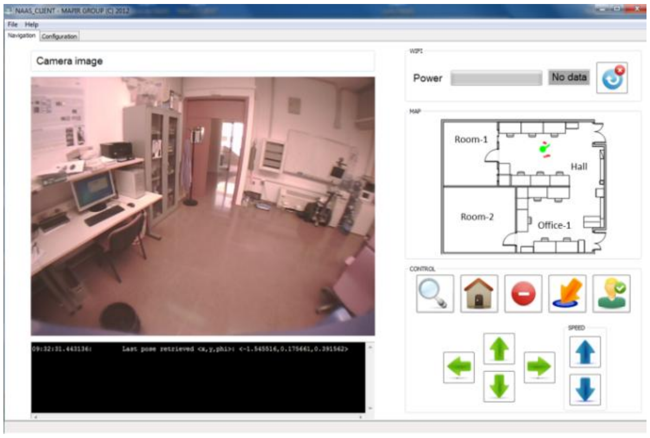
One of the major concerns when teleoperating a mobile robot is that of detecting obstacles to avoid bumping into objects in the surrounding. This situation happens in practice because of a number of reasons: poor dexterity of the operator, distraction, unforeseen obstacles, etc. To reduce this undesirable (sometimes fatal) situation to a minimum, we have provided the Giraff with an obstacle detector, running concurrently with its manual guidance system.

Robust and reliable methods for automatic obstacle detection typically rely on range sensors, like radial laser scanners. Although different options can be considered, such as infrared or ultrasonic sensors, we opted here for a Hokuyo radial laser scanner URG-04LX-UG01 [10] attached to the base of the Giraff robot, as shown in figure 8. This type of sensors has a mature technology widely used in autonomous robotic systems for carrying out not only obstacle detection, but also mapping and localization. The main features of the selected model are: a field of view of 240º degrees with a resolution of 0.36º, an operational range up to 4 meters and a working frequency of 10 Hz.

Upon the range data provided by the Hokuyo laser scanner, the obstacle detector checks for ranges under a certain threshold, identifying the presence of a potential obstacle. In our implementation ranges under 30 cm trigger the actuation of the detector in two different ways: 1) it warns the teleoperator about the existence of an obstacle and 2) it stops the robot to avoid an imminent collision.

Warnings about potential obstacles are communicated to the driver through both, visually and acoustically signals. In the current implementation, different thresholds are considered to warn the driver about the presence of distant obstacles. In this way, the frequency of the acoustic signal (a beep) is proportional to the distance to the obstacle, that is, to the danger level. Additionally, the part of the scanner reading corresponding to the detected obstacle is displayed around the robot (see figure 9).

Figure 8. The Giraff telepresence robot. The hokuyo sensor (marked with an arrow) is placed on the base where it scans 240º in a plane parallel to the ground. Some range scans have been recreated in the figure for illustrative purposes.



```
09:32:31.443136:        Last pose retrieved <x,y,phi>: <-1.545516,0.175661,0.391562>
```

Figure 9. Graphical interface used for testing the Giraff robot. Note the schematic map of the environment where a small, green circle indicates the position and the orientation of the robot. Around it, some red points appear indicating the proximity of obstacles (one of them, a trash bin that can be hardly seen in the image on the left).

C. Giraff Self-Localization

Giraff drivers have also identified the utility of knowing the position of the robot within the environment. This is especially useful when the visitor is not familiar with the house, for example a caregiver who visits a number of patients every day. The proposed solution consists of adding to the interface a schematic map of the house where the current position and orientation (i.e. localization) of the robot is continuously displayed.

The problems of robot localization and mapping have been intensively studied in mobile robotics literature, given rise to an important sub-discipline known as SLAM (Simultaneous localization and Mapping) [11]. We consider here a simplified solution based on well-known and off-the-shelf techniques that consist of: i) the offline construction of a fixed geometrical map of the environment using an ICP-based method, and ii) the online robot localization by a particle filter approach. More information can be consulted in [12], [13] and [14].

1) *Map building*

For building the map, the Giraff robot is driven within the remote environment, while saving information from the robot wheel encoders (odometry) and range data from the radial laser scanner. This information is offline processed by an ICP-based (Iterative Closest Point) technique [12] to generate a 2D geometrical map (see figure 10-left). The quality of the generated map will, obviously, affect the accuracy of the localization, so the constructed map is checked by an operator who can manually tune some parameters for better results. This is important since the map is built only once and we must guarantee that eventual small variations in the environment, e.g. opening/closing doors, do not cause the self-localization process to fail.

At this step, the generated geometrical map is also used to manually construct a schematic map of the environment that can be enriched with objects like furniture, descriptive labels, etc., for enhancing the visualization experience (see figure 10-right).

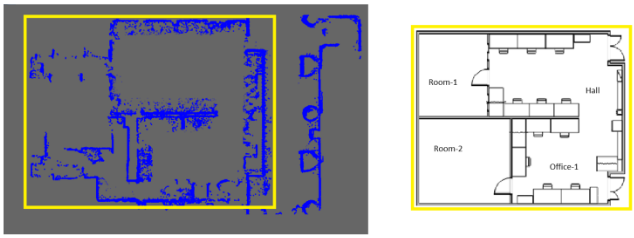


Figure 10. Left, point map generated by ICP. Right, hand-made schematic map that includes some pieces of furniture and descriptive labels.

2) *Localization*

For the Giraff localization, we rely on a Particle Filter-based implementation developed in a previous work [13]. This method estimates the pose (position and orientation) of Giraff within the already known map through a probabilistic Bayesian framework that resembles Montecarlo simulation. More information about this technique can be found in [13], [14].

Given the limited performance of the Giraff onboard computer and the considerable computational burden of the particle filter algorithm, the localization process is executed at 2Hz and with a reduced (but sufficient) number of particles. For visualization purposes, the estimated position of the robot is displayed on the schematic map at a higher rate by using information from the robot odometry, which works at 10Hz.

V. CONCLUSIONS AND FUTURE WORK

This paper has presented improvements in the mobility of the Giraff telepresence robot based on the feedback of users. The featured robot is now able to automatically dock into the recharging station, warn the driver about close obstacles, automatically stop when there is an imminent collision risk, and provide the pilot with additional information like the current position of the robot within a schematic map of the environment.

Our next short-term step is to validate the proposed solutions with the drivers, checking whether the improvements fit on their expectations. In the long-term work, we envisage additional improvements on the autonomy of telepresence robots, like for instance the autonomous navigation between different rooms of the environment and the addition of new devices like the Kinect sensor, which would enable the robot to perceive the environment in 3D.

REFERENCES

[1] Paulos E. and Canny J., *“Social tele-embodiment: Understanding presence,”* Autonomous Robots, vol. 11, no. 1, pp. 87–95, 2001.

[2] Boissy, P, Corriveau, H., Michaud, F., Labonté D., and Royer, M. “*A qualitative study of in-home robotic telepresence for home care of community-living elderly subjects.”* J. Telemedicine and Telecare vol. 13 pp.79-84, 2007.

[3] Feil-Seifer, D. and Mataric, M. *“Defining Socially Assistive Robotics”*. In Proc. of IEEE Int. Conf. on Rehabilitation Robotics (ICORR-05), Chicago, IL, pages 465-468, 2005.

[4] Turner P., Turner S., and Van de Walle, G. “*How older people account for their experiences with interactive technology.”* Behaviour and Information Tech.”, vol. 26 n. 4. pp. 287-296, 2007.

[5] Wood, E., Willoughby, T., Rushing, A., Bechtel, L., and Gilbert, J. *“Use of Computer Input Devices by Older Adults”*. Journal of Applied Gerontology, vol. 24 n. 5, pp. 419-438, 2005.

[6] AAL Programme webpage: http://www.aal-europe.eu/

[7] Giraff Technologies AB: http://www.giraff.org/

[8] Canny, J., *“A Computational Approach To Edge Detection,”* IEEE Trans. Pattern Analysis and Machine Intell., vol. 8, n. 6, pp. 679–698, 1986.

[9] OpenCV webpage: http://opencv.willowgarage.com

[10] Hokuyo: http://www.hokuyo-aut.jp/

[11] Fernandez-Madrigal J.A. and Blanco J.L. “*Simultaneous Localization and Mapping for Mobile Robots: Introduction and Methods”*, IGI Global, 2012.

[12] Paul J. Besl and Neil D. McKay. 1992. *“A Method for Registration of 3-D Shapes”.* IEEE Trans. Pattern Analysis Matching Intelligence. 14, 2, 239-256.

[13] Blanco J.L., Gonzalez-Jimenez J., Fernandez-Madrigal J.A., *"Optimal Filtering for Non-Parametric Observation Models: Applications to* Localization and SLAM", IJRR, vol. 29, n.14 (2010).

[14] Thrun S., Burgard W., and Fox D.. *“Probabilistic Robotics”*, September 2005. Publisher: MIT Press.