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D 4.1 Annual technical report on implemented mobility M12

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Deliverable Summary

This document details the work carried out during the first year of the project with the aim of improving the Giraff robot mobility. These improvements are intended to provide the robot with safer navigation capabilities and facilitate the interaction between users and the Giraff robot through a robust communication system and a suitable interface which provides useful information on the environment and allows users to easily operate the robot.

In particular, the work done in this first year has been mainly:

- The analysis of the requirements for the semi-autonomous navigation.
- The development of an initial software architecture including the algorithms and techniques to enhance the Giraff application with the semiautonomous capabilities.
- Improvements on the user interface, according to the needs identified in tests performed with real users.

Content

1 Introduction

The main objective of the ExCITE project is to evaluate the user requirements for social interaction that enables embodiment through robotic telepresence. This evaluation is performed in situ, on a PanEuropean scale and with a longitudinal perspective. An existing prototype, called *Giraffe*, is deployed to the targeted end-users to provide embodied telepresence. In a nutshell, the Giraffe robot consists of a screen and a camera mounted on a simple robotic base that can be teleoperated. The participation of real end-users will permit us to improve of the prototype during the project.

An additional goal of ExCITE is the development of algorithms and techniques that help the user in the teleoperation task, gaining in safety and robustness. The Machine Perception and Intelligent Robotics group (MAPIR) from the University of Málaga addresses these issues under three key points:

- Provide Giraff with safer mobility within domestic, non-modified scenarios.
- Improve the client-side user interaction through a high-level command interface.
- Optimize platform motion and interaction according to user evaluations.

Throughout this document the progress of these tasks during this year is presented.

2 Improvement of Giraffe Mobility

The current system consists of two applications, called *Pilot* and *Giraff*. The Pilot application runs on the client computer permitting a trained user to teleoperate the system by means of video and audio data gathered from a camera and a microphone installed on the robot. The Giraff application runs on the Giraffe robot controlling the robot's motors and transmitting video and audio to the end-user. Both applications are connected through internet or P2P.

The MAPIR group is responsible for analyzing and developing the needed functionality for improving the Giraffe mobility with the aim of releasing the user from tedious or hard maneuvering, for example, crossing doors or passing through narrow corridors. An additional component of the system, called *Navigation Assistant* (see figure 1), is envisaged to provide a featured control of the Giraffe, including for instance, the following characteristics:

- To provide simple semi-autonomous mechanisms to safely guide the Giraffe to near destinations specified by the client user through a schematic map of the environment. It can be useful, for instance, to traverse doorways and long corridors.
- To endow Giraff with a basic level of obstacle avoidance, which permits the client user to drive the Giraffe in a more relaxed and safer way.

For the development of a Navigation Assistant application some hurdles have to be overcome. Firstly, the sensorial system of the Giraffe should be enhanced for the obstacle detection ability. The chosen sensors will also determine how to face the robot localization problem, which is relevant for the development of simple navigation techniques. Data communication between the current architecture and the Navigation Assistant in different situations should be also studied. Finally, but not less important, the Wi-Fi signal coverage within the environment, from which the success of the robot teleoperation depends on, should be sensed and taken into account for robust navigation, e.g. notify the client user about the risk of moving through a certain area due to a low detected signal. Next sections describe these issues in detail.

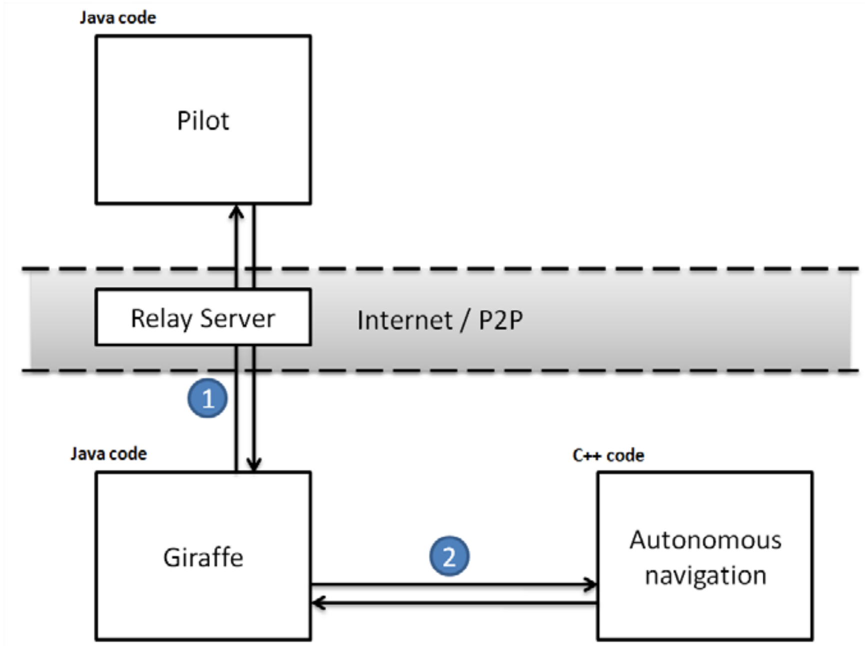

Figure 1. Applications of Giraffe system and their interrelations.

2.1 Sensorial System

Current sensorial system of Giraffe is limited to a low resolution camera. Although there are in the literature some works addressing safe robot navigation using a single camera, there are two factors that prevent us against its use:

- The quality of the Giraffe's camera is low (due to bandwidth constrains).
- Vision computer algorithms normally exhibit a high computation burden.

Due to these limitations we have added a new sensor on the Giraffe system, a laser scanner from Hokuyo [2] (URG-04LX-UG01 model, see figure 2), which is widely used in the robotic community for navigation and localization purposes. This kind of sensor presents interesting features:

- Relatively cheap (around 700€).
- Suitable for small environments.
- A high field of view, up to 270° degrees.
- High resolution and frequency, up to 0.25° angular resolution at 40 Hz.

Figure 2. Hokuyo laser scanner model URG-04LX-UG01.

At the present time we are also studying the possibility of adding cheaper sensors like Kinect [3] (see figure 3). This sensor provides both intensity and range (depth) data. Furthermore, a motorized base endows it with a tilt movement up to ±28°. The main features of this sensor are the next:

- Low cost: 150€.
- A Field of view of 43° vertical by 57° horizontal.
- A frame rate of 30 frames per second (FPS).
- Both intensity and range images have a resolution of 640x480 pixels.
- An operational range from 1.2 to 3.5 meters.

Figure 3. The Kinect sensor.

However, this sensor suffers from some important limitations:

- The lower limit of the operational range, 1.2 meters, creates a *blind zone* in front of the sensor. Into this zone the robot is not able to detect the presence of obstacles, which become an important drawback for the development of navigational algorithms.

- The huge amount of raw data that the sensor provides hampers the real time processing of the gathered information. Concretely, each range image is composed of 640x480=307200 pixels, which translated to (*x*,*y*,*z*) coordinates gives a total of 921600 real numbers. Thus, it is necessary to study how to decimate this data without losing useful information.

2.2 Localization problem

In order to provide the Giraffe with an improved mobility, it must be able to self-localize in the environment, i.e., to assess its position and orientation. A conventional way for addressing such a problem is to localize sensorial data within a map of the environment previously built. That is, there are two separated phases to be solved: 1) building the map and 2) matching sensorial data within the map.

We have already solved the first phase for robot localization with the Hokuyo sensor. The Giraffe robot is manually driven within the desired environment, saving information from robot wheels encoders (odometry) and range data. This information is then used for offline generating a map (see figure 4) through grid-map matching algorithms like ICP<ref>.

For the second phase, a Particle Filter based approach [1] is being studied and implemented. Although particle filters work well, their computational requirements are typically high, so at this initial stage we aim to test the performance of these techniques on the limited resource machine onboard of the Giraffe.

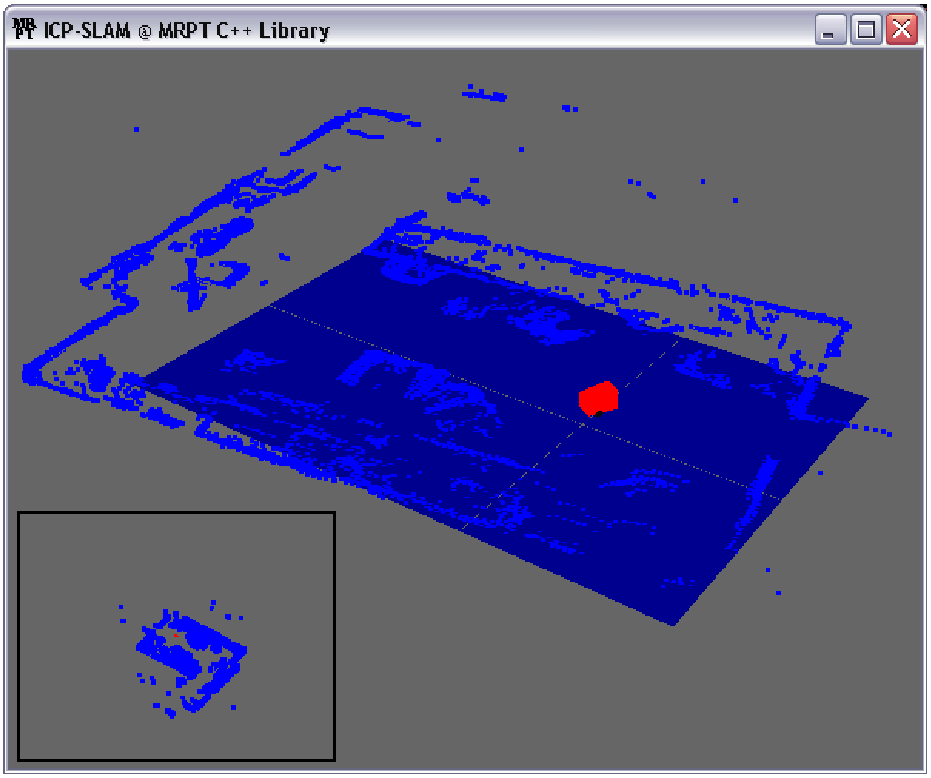

Figure 4. Built metric map by ICP-SLAM application after the environment data acquisition process.

2.3 Data interchange between applications

Within the envisaged architecture for improving Giraffe mobility, some extra information has to be passed between the different components (see figure 1 again).

Between Giraff and Navigation Assistant. Since they are both running on Giraffe, the communication between them can be implemented through a TCP socket.

- Information about Giraffe position (from wheels encoders), as a pose estimation of the robot, should be passed to the Navigation Assistant.
- Navigation Assistant may need to command the Giraff, for instance to override the user commands in order to avoid obstacles.

Between Giraff to Pilot

- The Giraff application must send additional information about the environment to the Pilot, for instance, a map of the apartment. These two applications are connected via internet through an intermediary *Relay* server that negotiates the communications between different networks. This server could store the map generated by the Giraff application, and will send it to the Pilot application at the beginning of it execution.

Between Pilot and Navigation Assistant.

- Pilot GUI should contain some extra functionality useful for maintaining and showing the environment map and robot localization computed by the Navigation Assistant. Thus, for instance the Pilot GUI can receive the current position of the robot and plot a mark on a map, like in figure 6. The relay server will be also considered in this case given these two applications are not directly connected.

In order to implement these functionalities and the exchange of information between the different applications, intensive support from the Giraff AB team will be required.

2.4 Wi-Fi signal coverage

The intensity of domestic Wi-Fi signals largely vary within different rooms, even it can appear shadowed zones where the signal intensity could not be sufficient for maintaining an internet connection (see figure 5). Entering into a shadowed area during the teleoperation process will cause the loss of the connection and consequently the control of the Giraffe robot. Areas presenting low intensity signal will also affect negatively to the teleoperation task with longer delays and jitters. The current system does not tackle the Wi-Fi variability problem, leaving the responsibility to the users. A desirable aspect, we are currently analyzing for improving the Giraffe system, is to enable it to continuously monitor the Wi-Fi signal. This ability will permit the Giraffe to warn the user about the shadowed areas and to recover the robot when the connection has been lost by, for instance, automatically moving it to a location with a good signal level.

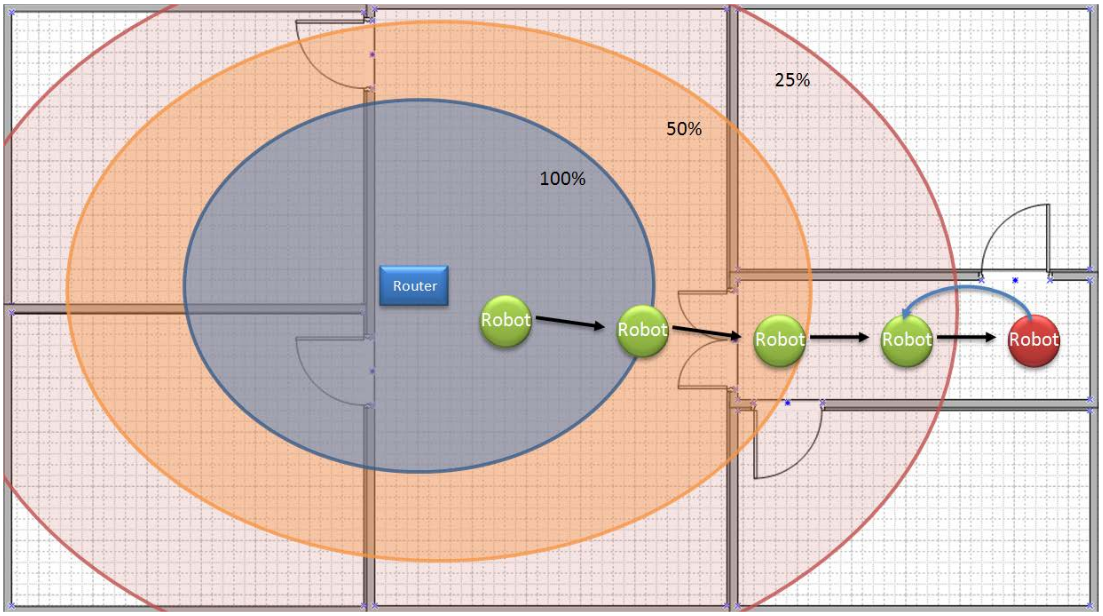

Figure 5. Sketch of a house with a router and the intensity of its Wi-Fi signal as colored oval-shaped circles. Green circles represent a possible location of the Giraffe robot when it is correctly connected to internet, and black lines, the commanded movements. The Red circle represents a location where the robot has lost the internet connection, and the blue line is the needed movement for recover it.

3 Improvement of Giraff Interface

The client user interface has to be featured to cope with the commented improvements in the Giraff mobility. Figure 6 shows a tentative appearance of the GUI where a map of the environment and different options are considered. Some remarks on their functionality are:

- Map: the user clicks over the map for an unattended navigation from the current position to the clicked destination. The user gets back the control of the Giraff when it reaches the target position or when s/he gives another command.
- Options:
    - "Re-localization" of the robot, useful if the robot fails in computing its position. The user indicates through the map of the environment the place where the robot actually is.
    - "Update map". During the Giraff lifetime, the location of house's objects can be changed, making the localization algorithm to produce erroneous results. In this case, the client user can guide the Giraff to build an update map of the environment.

Additionally, we have conducted an evaluation of the Pilot GUI and the driving experience. In the next sections a summary of the comments of the 8 users involved in the tests and some suggestions are presented.

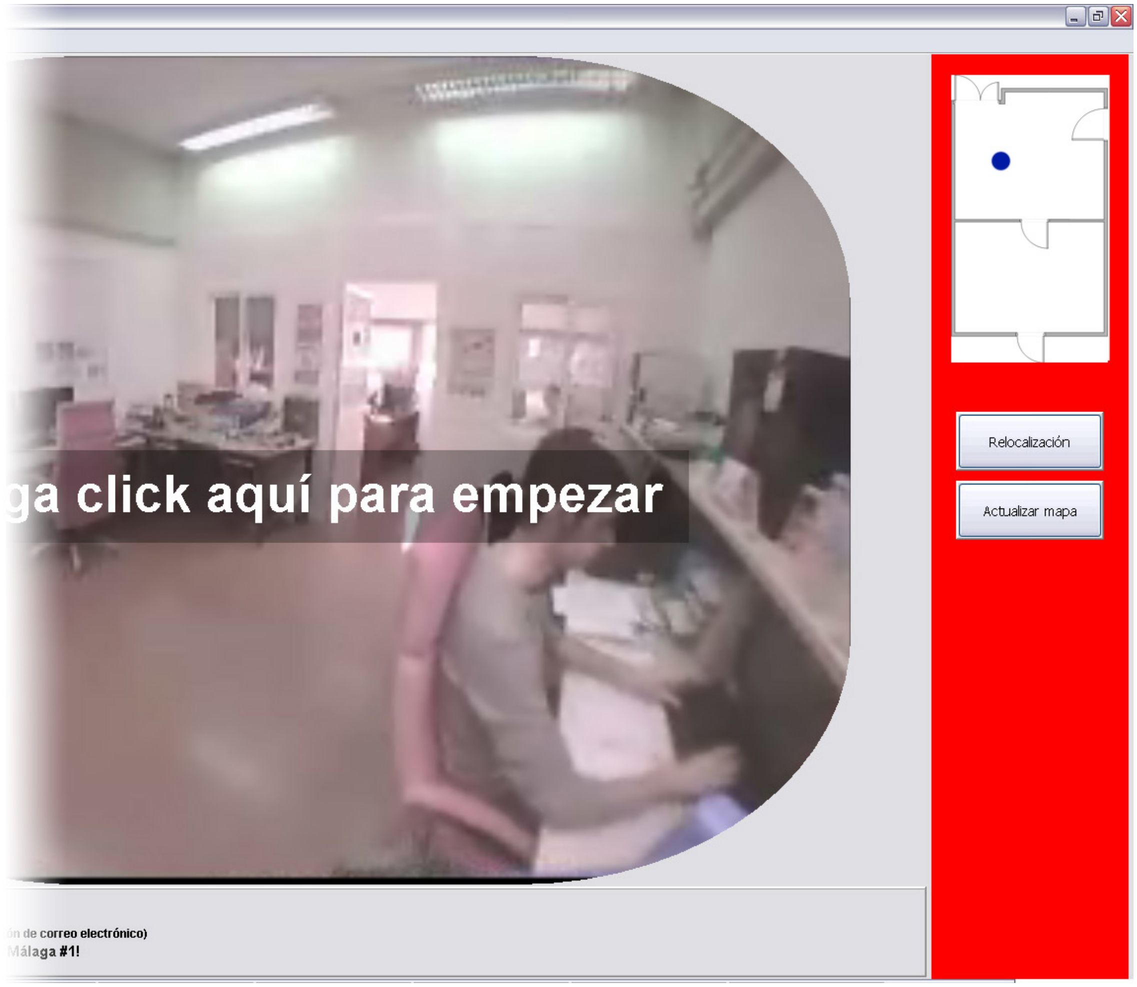

Figure 6. An example of possible new functionalities added to the Pilot application for supporting localization and navigation tasks.

4 Testing Giraff

Before conducting real experiences on end-user sites, we have carried out an intensive 3-day test to check the following aspects:

- Connection between Pilot and the Giraff applications.
- Pilot-Giraff connection robustness.
- Batteries' performance.

4.1 Wireless Configuration

We have used three different wireless routers:

- Cisco - Linksys WRT320N.
- Thomson TCW *710. ISP: Ono. Upload speed: 300Kb. Download speed: 12Mb.*
- Xavi 7968. ISP: *Telefónica, Upload speed: 128Kb, Download speed: 600Kb.*

The first one, initially recommended by Giraff AB, works at 5 GHz and it's located in our laboratory[1]. The other two are standard 2.4 GHz routers installed by two of the most common ISPs in Spain. We have noticed the importance of a 5 GHz router when the environment is saturated of wireless networks and other interferences.

In the tests, Giraffs # 1 and #2 were placed in our laboratory, and Giraff #3 was moved to one of our houses. Next scheme shows under which wireless routers runs each Pilot and Giraff applications:

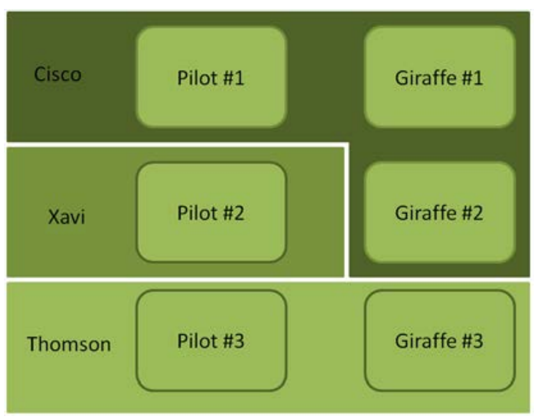

Figure 7. Routers used in the tests and under which each application runs.

Notice that in our tests we have connected to every Giraff from each Pilot application, that is from the three possible locations.

[1] At the beginning of our test we had another Cisco router which works at 2.4GHz, but Giraff doesn't work well with it, having many connection problems. Changing to 5GHz version solved them.

4.2 Connection between Pilot and Giraff

First functionality tested was the connection robustness between the Pilot and Giraff applications. We have counted a total of 50 connections (see table below), considering both normal and emergency calls.

	Giraff called		
From a Pilot executed under router	Giraff #1	Giraff #2	Giraff #3
Cisco	9	11	10
Thomson	2	5	5
Xavi	2	4	2

All the connections were successfully established, being the time of Giraff and video initialization typically shorts (sometimes video initialization was slower, taking between 5 and 10 seconds).

4.3 Pilot-Giraff connection robustness

We understand that we are under a robust connection when:

- Video sequence is fluid.
- Time since you click over the image (sending a command) until the robot reacts is short.
- Connection doesn't fall down during the tests.

We have completed around 19 hours moving (or being connected to) Giraffs within the two different scenarios aforementioned. In all this time we have experienced only two exceptions (which were solved by simply restarting the Giraffs):

- During a test, and after 25 minutes of connection, the communication between the Pilot and the Giraff was lost without any message, ending both the Pilot and Giraff applications in their initial screens.
- In another test, the Pilot application could not see the Giraffs which were apparently connected.

A suggestion here is that when the Giraff loses the wifi connection while a communciation has been established, because of network jitters or short disconnections, it should reconnect automatically.

4.4 Batteries life

Last aspect under check is the Giraffs battery life. For this test we have conduced four experiments, two with Giraff #1 and two with Giraff #2. In all cases the robot was in movement around a half hour, and the rest of the time stopped but maintaining the call.

The results range from around three hours of autonomy for Giraff #1 and two and a half for the Giraff #2.

4.5 Pilot and driving evaluation

Given a number of our stuff have been involved in different tests, they have been asked about the Pilot GUI and the driving experience. The average age is 28 years (from 24 to 35 years) of both sexes.

In a scale from 1 (bad) to 5 (good), the mean evaluation for some general issues is:

Questions	**Evaluation**
Giraff general driving	4
Difficulty of moving in a straight line	4
Difficulty for turning	3,75
Camera quality	3,375
Tilt movement	3,625
Pilot Interface	4,25
Learning curve	4,75
First general impression	4,25
How difficult is to use the Docking Station	3,375

Analyzing these experiences we have some suggestions arisen by the users that tried the system:

- Camera tilt is commanded by simply moving the mouse over the screen which produces involuntary movements. It would be better to activate this using the right-button for instance.
- Font color used to indicate the battery level percentage is white, and the slide is gray, so it's so difficult to see the percentage.
- Keyboard shortcuts for “Turn” and “Back up” for a more fluid navigation.
- Reproduce a sound in the Giraff when a Pilot application disconnect from it, so you don't have to look the Giraff screen to check if the call is still on.
- Sometimes battery icon in Pilot GUI doesn't appear.

5 End-user Sites

In this section, the two end-user sites where the Giraffe will be tested are described. Tests on the first scenario, the particular home of a widow lady, have recently started and no results are available yet. For the second one, some contacts have been made with a regional caregiver center to select a candidate user.

Pilot Scenario #1

End-User: Widow, around 65 years old, living with one of her sons, but spending a lot of time completely alone. The home has an ADSL connection.

Client-User(s): Family.

End-User Description.

Physical Aptitudes: She presents certain physical limitations, but she is self-sufficient: she can walk, cook, and clean. She is also affected from diverse diseases, like degenerative osteoarthritis, and digestive problems.

Mental Aptitudes: She has fully mental capabilities for maintaining a conversation, phoning, watching TV, etc., however she is not a technological user and, thus she does not use computers, nor is familiarized with videoconference.

Emotional Requirements: The end-user is a widow for more than ten years. She tries to keep occupied but she is lacking of personal relations; she only meets their relatives from time to time.

Client-User Description.

A client-user for this pilot scenario will be any of her relatives living in different cities or countries who desire to maintain with her a warmer interaction as well as to check how she is coping with her daily life. Although the main goal of this scenario is to test the Giraff system for providing emotional support, the client-users could also solve any other problem, like checking the performance of home appliances.

Pilot Scenario #2

End-User: Elder person, between 65 and 80 years old, living alone in her house.

Client-User(s): Nurse or caregiver plus relatives.

End-User Description.

Physical Aptitudes: The elder person should be self-sufficient, i.e. to be able to move around and to perform basic activities, taking care of her/his own personal hygiene, feeding, etc.

Mental Aptitudes: It is necessary to keep a conversation between End and Client users, so good mental capabilities are required.

Although these basic self-sufficient abilities are needed, elder people have often some health and mental problems that should be monitored to prevent risky situations.

Client-User Description.

A Client-User for this scenario could be a nurse or other qualified personnel. Giraff permits this client to perform the next chores:

- Revision of the needed medication, particularly for chronic patients that need to take any periodic medication as insulin, pain pills, cardiovascular medication, etc.
- Monitoring of certain health indicators as blood pressure, temperature, sugar test, etc. with the help of the end-user.
- Interview / chat to check whether any other new pain, symptom or physical or mental problem has appeared.
- Visual check-out of mobility, self-sufficiency at home, etc.
- Giving basic help directions in case of emergency, for instance food intoxication.

Furthermore, though it is not the main objective of this scenario, the interaction end-user/client becomes a distraction for the elder people.

6 Conclusions

During this period we have advanced considerably in our goals. The analysis of the requirements for a semi-autonomous navigation using the Giraffe system has been completed, and initial software architecture for fill out them has been presented. Furthermore, we have partially finished the map building task, remaining to add this functionality to the Pilot GUI. The needed data interchange between the Giraffe system applications has been listed too. We have also presented the necessity of recover the internet connection when it is lost due to a Giraffe navigation through a zone of the house with a bad Wi-Fi signal intensity.

Regarding user evaluations, two possible scenarios have been described, and we have started working on one of them. Previous to these final test scenarios we have conducted several experiments evolving different aspect of the Giraffe system performance.

Analyzing this experience we have some suggestions:

- Camera tilt is commanded by simply moving the mouse over the screen which produces involuntary movements. It would be better to activate this using the right-button for instance.
- Font color used to indicate the battery level percentage is white, and the slide is gray, so it is so difficult to see the percentage.
- Keyboard shortcuts for “Turn” and “Back up” for a more fluid navigation.
- Reproduce a sound in the Giraffe when a Pilot application disconnect from it, so you don’t have to look the Giraffe screen to check if the call is still on.
- Sometimes battery icon in Pilot GUI doesn’t appear.

7 References

[1] Sequential Importance Resampling at MRPT webpage: http://www.mrpt.org/Particle_Filter_Algorithms
[2] Hokuyo Homepage: http://www.hokuyo-aut.jp/
[3] Kinect Homepage: http://www.xbox.com/en-GB/Kinect