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D5.5 System Integration. Final System and Live Demonstration

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Author(s):	Gabriella Cortellessa, Amedeo Cesta, Antonio Damasceno, Anette Forsberg, Cipriano Galindo, Lars Karlsson, Andraz Kozelj, Annica Kristoffersson, Maria Linden, Amy Loutfi, Francisco Melendez, Eleni Odontidou, Andrea Orlandini, Filippo Palumbo, Ana I. Perez, Davide La Rosa, Marcello Turno.
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Deliverable Summary

This document reports on the final integrated system at M36, which has been deployed in the testsites. It includes a brief description of the fifteen testsites, covering the particularities and technological issues experienced. The final set of hardware and software components are described, remarking the main improvements with respect to previous versions, while in-deep details are given in the correspondent deliverables from WP2, WP3, and WP4.

The final prototype is the last evolution along this three years project and has been iteratively adapted to the users' feedbacks. The last users' impressions gathered by an on-line bug tracker tool during the last year have raised the enhancements integrated in the final prototype and described in this document.

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1. Introduction

1.1 Scope of the document

This document describes the final version of the integrated GiraffPlus system which has been deployed in the fifteen considered testsites.

Along the three-years project, the WP5 had the goal of integrating the different components of the evolving GiraffPlus system coming from the results of WP2, WP3, and WP4, and its deployment in the selected testsites. The reaction to the users' feedback and new requirements has been of paramount relevance as it is revealed when comparing the final prototype of the GiraffPlus system to the initial version reported in M12. Among the main features of the final integrated prototype of the system the following can be highlighted:

- A secure communication middleware that manage information from the testsites to centralized databases implementing security and replication mechanisms.
- Integration of a set of environmental, wearable, and physiological sensors that seamlessly operate without affecting the normal life of the primary user (PU).
- Integration of a mobile robot within home environments which can be remotely driven, including secure features for autonomously navigating between different locations of the home as well as for automatically performing the dock operation.
- High-level services have been integrated for visualizing data from testsites in a personalized and secure way. Gathered user data is managed to generate temporal reports, visual representations, real-time and long-term visualizations. Mechanisms for inferring the activities carried out by the PU based on raw data has been also integrated in the system serving as a powerful tool for secondary users (SU) and healthcare professionals in the early detection of health problems and deterioration.
- Additional mechanisms to improve the user interaction such as reminders and messages have been implemented.
- Alerts, and security mechanisms have been integrated in the final prototype of the GiraffPlus system. They include, for instance, the generation of automatic alerts when an abnormal situation is detected like the lack of connectivity of a testsite. In this way the responsible is directly alerted by a phone message or e-mail to react accordingly (as shown in D5.4).
- An on-line bug tracker tool has been considered to collect users' feedback and technical issues.

1.2 Deliverable structure

The deliverable is organized as follows: section 2 provides a summary of the use of the final prototype of the GiraffPlus system within the deployed testsites, revealing some of the particularities found in each case. The total deployed testsites include the six already installed by

M18 and nine new testsites deployed by M30. Section 3 describes the final version of the GiraffPlus prototype, detailing the main hardware and software components considered. The final version of the system and the improvements carried out during the last year have been originated in response to the i) users' feedback gathered by the on-line bug tracker tool Mantis described in D6.3 and ii) the reviewers' comments. Section 4 describes the live demonstration considered as MS4 in the DOW. This demonstration will take place during the review meeting and consists on presenting the GiraffPlus features using a deployment within the meeting room and nearby areas.

1.3 Deviations with respect to the plan

This deliverable has been resubmitted to include additional information related to the live demonstration (section 4) that we could not envisage until some feedback from the meeting hotel about the provided facilities were given. This version of the deliverable now includes a description on the live demo that will be presented during the review meeting.

2. Test sites Summary

In M18 the GiraffPlus prototype was deployed at 6 testsites as described in D5.3. These testsites were updated with an improved version of the system as well as 9 new testsites were deployed by M30 (D5.4). In total, 15 testsites, 5 in each country, have been installed and maintained in the last part of the project. This section covers a short description of the 15 testsites deployed in the GiraffPlus project highlighting the final remarks regarding the technicalities and the main issues found during their utilization and the solutions/decisions adopted.

2.1 Test sites in Italy

Testsite IT-1

Brief PU description:
She is a 94 year old widower, cognitively very active and with a good knowledge of computer. She has a blog of her own in which she shares her everyday life, her tales and poems. The work as a writer and the management of her blog occupies most of her daytime. She lives alone and receives a home-help service for two hours a week and for that provide support for the grocery shopping and housekeeping tasks. Because of arthritis she has restricted mobility and she is unable to leave the house except with the assistance of a family member. The user also suffers from high blood pressure that constantly monitors through the daily control of blood pressure and pharmacological therapy. The user has three children and two grandchildren who visit her weekly. Through the blog has over the years built her own social network that manage independently from home via computer communicating with the many people that write her every day.

Usage of the system
The user has had the entire system for one year in her home (October 2013-October 2014).

Informal CGs: The informal caregivers (relatives) of this woman were willing to use the system and the various services but they were limited by the lack of Internet connection in their own home. In addition, they found it difficult to reserve time to sit in front of the computer and call her using often a regular phone out of convenience. They however received SMS in case of emergencies sent through a call from the Giraff robot.
Overall, any other data were inspected from the secondary users (see below) and from GP engineers that communicated with the informal caregivers in case of specific problems or issues related to the Health status of the primary user. As a consequence, informal caregivers felt reassured by the presence of the GiraffPlus system appreciating even this indirect type of monitoring.

HP Secondary users: a physician of the ASL RM A and two psychologists monitored the lady through the system and also connected to her house via the Giraff robot. Their aim was to test the system as a means of intervention for social support and remote monitoring.

The HP users used the complete set of services and components provided by the system along the entire year of experimentation.

Technical difficulties and problems

In this case the main difficulties have been:

- Overall the sensors and the integrated system worked correctly and the user felt more secure and safer at home. Despite this, some problems emerged with one of the physiological sensors. Specifically, with the blood pressure device that sometimes detected wrong parameters, namely too high values with respect to the real condition of the old lady. Also, often the physiological data were not received properly because of disconnections of the tablet from the network.
- An issue raised by the user was related to the robot display going bright during night hours and shining in the apartment disturbing her during sleep.
- Problems with the sound and video in the Giraff robot during several calls that were solved. In general, weak and not stable Internet connection affected the usage of the robot.
- Problems while driving the robot due mainly to time lags caused by weak internet connection.
- The user noticed increased electrical consumption related to the usage of the system.
- The old lady also expressed the need of having more active services from the robot component. This feedback inspired the definition and implementation of additional services implemented within the robot as part of the DVPIS@Home component during the third year of the project.

Interventions to cope with the found technical difficulties

Different prototypes of the GiraffPlus system have been used in this testsite. In each of its updates most of the problems commented before were solved. Additionally, the new requirements on more active services have been considered for the implementation of additional functionalities in the DVPIS@Home.

Deployment date and removal of the system

This testsite was deployed in M25. The robot and the complete system were removed at the end of October 2014. In fact, a need of a more continuous type of assistance mainly due to deterioration in her health status and frailty emerged. Then, the user has decided to move to a nursing home near the home of one of her relatives. Overall the lady appreciated the ability of the system to make feel her safer at home.

Testsite IT-2 (dropped out)

Brief PU description:

She is a widow 93 years old. She lives alone, and is still active. She is a housewife, and does house works. She is still very autonomous in house work, such as cleaning and preparing food. She is not afraid to go out of her home even if she has some walking problem. She has some problems with a fluctuating blood pressure. She wears hearing aid. She suffers from emphysema with asthma crisis and arthrosis. She has 4 sons. We involved two of them who filled in the pre-evaluation questionnaires. The sons make visits quite regularly to their mother and saw in GiraffPlus a means for her to feel safer at home. The system could also allow lowering the need to physically go there and in general to optimize the support managing the interactions among them.

Usage of the system

Informal CGs: A son and a daughter used the DVPIS to monitor their mother living at home. They did not communicate through the robot because the primary user decided not to use the robot afraid of not receiving physical visits by relatives at home.

HP Secondary users: a physician of the ASL RM A and one psychologist were supposed to act as HP SU but the PU decided to not have contacts with them via robot.

Technical difficulties and problems
In this case the main difficulties have been:

- Problems with the sound and video in the Giraff robot during several calls that were solved. In general, weak and not stable Internet connection affected the usage of the robot.
- False alarms of the environmental sensors and fall detector sensor.

Interventions to cope with the found technical difficulties
Additional maintenance to solve the false alarms of the sensors were needed.

Deployment date and removal of the system
The user has employed the entire system for three months (November 2013 – middle of March 2014). She thought it was not useful for her preferring a personal relation with a formal caregiver who live closely, so she found the use of the technological system not needed.

Testsite IT-2Bis (replacement for IT2)

Brief PU description:
He is an 80 years old widow. The user is a retired engineer still very intellectually active. He has a very high knowledge of computers. Three years ago he had a stroke resulting right hemiparesis and motor disability that force him to use a wheelchair for moving in and out of the home. During the day he receives support from two in-home nurses that support him in the care and hygiene practices and in daily housekeeping tasks (cleaning the house, preparing meals). During the night, he prefers to stay alone in the house.

Usage of the system
The user is using the robot and he is availing of the entire system since October 2014. He regularly takes blood pressure and glycaemia values.

Informal CGs: His son lives in France and visits his father every 15 days. The son is using the GiraffPlus system to make virtual visit to his father through the robot as well as to inspect both environmental and physiological data related to the health status of the old man.

HP Secondary users: a physician of the ASL RM A and one psychologists are using regularly the system with the aim to test the system as an aid for social support and remote cognitive intervention.
Additional secondary users are operators of a volunteer association that provides tele-assistance who periodically examine data of the assisted persons and possibly visit him through the Giraff robot. In fact, the primary user is an assisted person of the tele-assistance association and here we are testing the combination of services and comparing the effectiveness and added value of the GiraffPlus services.

<u>Technical difficulties and problems</u>
In this case the main difficulties have been:

- This test site sometimes suffered from problems related to a poor Internet connection that interfered with the system usage. This causes the disconnection of the system and the unavailability of data for short period of times.
- Often the physiological data were not received properly because of disconnections of the tablet from the network or because of failures in Internet connection.
- Problems with the sound and video in the Giraff robot during several calls that were solved. In general, weak and not stable Internet connection affected the usage of the robot.
- Problems while driving the robot due mainly to time lags caused weak Internet connection.
- Another difficulty of this test site is due to the constant presence of two persons inside the house that makes interferes with an accurate recognition of activities inside the house.

<u>Interventions to cope with the found technical difficulties</u>
Most problems for this testsites come from a poor internet connection and no actions were possible to solve this issue. The new alert mechanisms on the status of the house and the connection were interested in the GiraffPlus system to inform both the GraffPlus developers but also the secondary users about the disconnection periods.

<u>Deployment date and removal of the system</u>
The system has been installed recently in M32 as a replacement of IT2 and for this reason it will be kept active at least till the end of February. We are also considering to leave the system longer since the users are willing to use it.

Testsite IT-3

<u>Brief PU description:</u>
She is an 80 years old widower. She lives alone and she is a self-sufficient person for her activity of daily living but she needs help for grocery shopping and some housekeeping tasks, so she receives a home-help support for a few hours a week. She suffers from neuropathic pain, renal insufficiency and she had suffered an ictus episode in the past. Her health conditions adversely affect her mobility. The user moves into the house with the help of a walker and she is unable to go out except with the assistance of a family member.

<u>Usage of the system</u>
The user has been using the entire system since June 2014.

Informal CGs: The informal caregiver is the woman's son who lives relatively close to her. He is very interested in the GiraffPlus system and uses DVPIS regularly to have a contact with her mother and to monitor her movements and physiological parameters. More specifically, he is using the DVPIS to inspect both environmental and physiological data related to the health status of the woman and the security of the home environment. He constantly provided us with feedback on problems, bugs and also possible improvements on the system, including new services. This feedback also inspired the definition of new services that have been implemented during the third year of the project's development.

HP Secondary users: a physician of the ASL RM A and one psychologist are using regularly both the GiraffPlus system with the aim to test it as an aid for an intervention of social support and remote monitoring. The two HP users are using the complete set of services and components provided by the system.

Technical difficulties and problems

In this case the main difficulties have been:

- The system is working quite well in this test site. The fall detector sensor sent false alarms sometimes, but overall it has been quite useful in different situations. Indeed there have been at least two serious alerts during the experimentation due to a fall of the woman. The system was able to send an alarm signal in both cases. Nevertheless the way the alarm message was delivered was not judged as very effective, specifically when the fall occurred during the night and the son was not able to easily recognize the severity of the message sent to him. This also emphasizes the fact that the Giraffplus system should be seen as a socio-technological system where a combination of technology and people is used to ensure monitoring and care. In this respect we decided to include the woman in the list of users assisted by a volunteer organization able to provide H24 assistance and to combine the use of the helpline association services with those provided by GiraffPlus.
- Problems with the mode of operation of the physiological monitor device, i.e., difficulties to handle the blood pressure cuff and the lancet for the glucose meter from the PU side.
- Problems with the sound of the Giraff robot during several calls that were not solved completely.
- The semi-autonomy navigation module has been recently installed but presented some problems in this specific house due to its particular layout that produces bad localizations of the robot. The secondary users are not using that particular service.
- Few false alarms in the smoke sensor.

Interventions to cope with the found technical difficulties

Some maintenance visits were needed to check the system and the false alarms. The semi-autonomous motion of the robot is being tested in the testsite since a short period of time, and some adjustments are ongoing. Additional specific training sessions for explaining the psychological devices usage have been performed both on site and through connections via the robot. The woman is now taking regularly the measurements. Many suggestions for new functionalities available through the DVPIS have been incorporated in the latest version of the system and are now currently under test in this test site.

Deployment date and removal of the system

The testsite was deployed in M30. The system is still active in this test site and will remain active at least until the review meeting. In general we are also considering the idea of maintaining the test site even after the end of the project for two reasons: 1) the users are willing to continue using the system; 2) we would like to continue studying the combination of the services provided by the system with those provided by the tele-assistance organization.

Testsite IT-4

Brief PU description:

She is a 73 year old widower, very active. She lives alone and she is a self-sufficient person. She suffers from angina pectoris and ischemic heart disease that push her to strict medical controls and to follow a precise pharmacological therapy. She has a high knowledge of computers and she had an experience as a worker in a tele-assistance service for elderly people. She is interested in using the system mainly for its ability to send alarms in case of problems and also for monitoring the blood pressure constantly keeping also track of the long-term data. She also appreciates the use of the robot as a means to communicate with other people.

Usage of the system

The user is using the robot and she is availing of the entire system since June 2014.

HP Secondary users: a physician of the ASL RM A and one psychologist are using regularly both the robot and DVPIS with the aim to test the system as an aid for social support and remote monitoring.

Additional secondary users are operators of a volunteer association that provides tele-assistance who periodically examine data of the assisted persons and possibly visit her through the Giraff robot. In fact, the primary user is an assisted person of the tele-assistance association and here we are testing the combination of services and comparing the effectiveness and added value of the GiraffPlus services.

Technical difficulties and problems

In this case the main difficulties have been:

- Sometime the physiological data were not received properly because of disconnections of the tablet from the network or because failures in Internet connection.
- Problems with the mode of operation of physiological monitor devices, i.e., difficulties to handle the blood pressure cuff and the lancet for the glucose meter from the PU side.
- Problems with the sound in the Giraff robot during several calls that were not solved in some cases.
- Problems while driving the robot due mainly to time lags caused weak internet connection.

Interventions to cope with the found technical difficulties

It was necessary to ask several times the intervention of the user or a technician to manually restart the tablet device and the PC box. This was fixed with the last version of the Intellicare application which can work without the participation of the PU.

Deployment date and removal of the system

This testsite was deployed in M30. It will remain active till February at least and also possibly longer due to the idea of experimenting the combination and improvements of services that are integrated with those provided by the tele-assistance association.

Testsite IT-5

Brief PU description:

She is an 86 years old widower. The user has a rather large social network and her lifestyle is still very active and dynamic. She suffers from hypertension that she keeps under control with cardiology specialist check up and taking regular pharmacological therapy.

Usage of the system

Informal CGs: Her son use the robot only for emergency situations such as, for instance, in case of no answer on the phone or other abnormalities highlighted from the DVPIS. He uses the DVPIS habitually for monitoring environmental circumstances, especially in case of absence of the mother from home.

HP Secondary users: a physician of the ASL RM A and one psychologist were supposed to act as HP SU but they had the only possibility to have contact with the PU by phone twice a month. The user claims that she wants to be contacted by the robot only by her son. They have used DVPIS regularly to test the efficacy of the system as a mean for remote monitoring services.

Technical difficulties and problems

In this case the main difficulties have been:

- Overall no major technical problems where encountered in this test site. Both sensors and the robot worked fine. A false alarm from the fall sensor made the old lady scared, so she decided not to wear it. The son of this lady regularly used the DVPIS and the robot with no particular problems.
- Although the user declares to have systematically used the device for the measurement for blood pressure, it was not possible to receive data because of plausible disconnections of the tablet device from the network.
- The robot was somehow judged as too big and in some circumstances the lady claimed that a phone call would be better than using the system.
- The user does not feel a clear need of testing the functionalities of the entire system. Probably her very active lifestyle may have played a key role in personal involvement and in her predisposition to use the system.

Deployment date and removal of the system

This testsite was also deployed in M30, while the system was removed at the end of November 2014.

2.2 Test sites in Sweden

Testsite SE-1bis (SE6 in D5.4)

Brief PU description:
This short-running test site was deployed as a replacement of SE-1. The woman is 75 years old and has a rich social life with many activities ongoing. She has a long experience using Skype on her computer to communicate with her son and grand child who lives abroad. She has some decreased vision.

Usage of the system
The test site deployment included the Giraff robot and the environmental sensors. No physiological sensors were deployed since the PU had no need for physiological monitoring.

Informal CareGivers (CGs): There were three informal CGs (2 sons, 1 brother) at this test site, who connected through the Giraff robot but they did check the environmental, physiological, nor activity data and reports provided by the DVPIS, since they did not have interest in monitoring the daily life of the PU. The son who lives abroad was the most frequent user of the GiraffPlus system but the interaction was somewhat limited because of the large time difference. The other son lives nearby and she mostly saw him in person rather than via Giraff. Her brother connected via the robot occasionally when not travelling.

Formal CGs: There were two formal CGs connecting to this test site (one occupational therapist and one physiotherapist). Both of them used the robot and DVPIS.

Technical difficulties and problems
The main technical problems were related to the Giraff robot. It was perceived as being difficult to steer and sometimes turned to the right when steered from remote.

Interventions to cope with the found technical difficulties
Technical visits were required to check the mechanical parts of the robot. The problems seemed to be related to a broken wheel encoder which was replaced, solving the issue.

Deployment date and removal of the system
This testsite was deployed in M30 and removed on October 24th 2014.

Testsite SE-2

Brief PU description:
He is 82 years old widower. He has had the GiraffPlus system for fifteen months during which he has moved from a house to an apartment. He had a low experience of internet communication technologies but enjoyed the communication with others via the Giraff robot that he baptized “Axel". He has a post stroke condition and a weakened balance. For this reason, he uses a rolling walker indoors and an electric wheel chair outdoors.

Usage of the system
Informal CGs: There were three sons and one grandchild using the Giraff robot. They did not have interest in monitoring the PU data, and thus they did not use such features from the DVPIS software.

Formal CGs: There were two formal CGs connecting to this test site (one occupational therapist and one physiotherapist). Both of them used the robot and DVPIS.

Technical difficulties and problems
Although it was perceived as being useful to monitor the PUs blood pressure using the blood pressure sensor, the handling of the device was too complex for the PU. He could not:

- manage the cuff
- handle the early versions of the tablet app which required user intervention to send the data.

Additionally, there were some problems with the WiFi-range in his first housing, this was due to a a concrete wall running through his house.

Interventions to cope with the found technical difficulties
A new version of the Intellicare table app has been released that automatically receives and stores the physiological data without the user intervention. In order to solve the poor WiFi coverage, a repeater was installed in the house. The new service for alerting about the connection status of each testsite was useful in this case to discover the problem of the poor internet connection.

Deployment date and removal of the system
This testsite was deployed in M22 in the first house of the PU. In April he moved to a smaller apartment and the GiraffPlus system was also moved to the new location. The GiraffPlus system was removed on his new apartment on October 24th.

Testsite SE-3

Brief PU description:
She is 80 years old and has a post stroke condition and a decreased balance. For this reason she uses a rolling walker outdoors. When not being at rehab, she spends most of her time in her home. The highlight of her time is when she is visited by her grandson who is one of the informal CGs.

Usage of system
Formal CGs: There were two formal CGs connecting to this test site (one occupational therapist and one physiotherapist). Both of them used the robot and DVPIS.

Technical difficulties and problems
The PU received instructions on how to use the blood pressure sensor but never used it. She had problems putting on the cuff and was not really motivated to use it.
There were no problems with the Giraff robot deployed. Some problems were found with the motion sensors, which have to be attached to the walls and sometimes fell down in this testsite.

Interventions to cope with the found technical difficulties
Maintenance visits were required to relocate some environmental sensors.

Deployment date and removal of the system
This testsite was deployed in M28 and removed on October 22 2014.

Testsite SE-4

Brief PU description:
He is 78 years old and lives alone. His wife lives in a separate apartment. He enjoys using his computer and internet. He has a weakened health: post stroke, chronic obstructive lung disease, heart infarction and decreased balance. For this reason he uses a walker outdoors but he falls frequently. When not being at community day-care center (twice weekly), he spends most of his time at home.

Usage of system
The GiraffPlus system including the robot, environmental sensors and the blood pressure sensor were deployed at this test site. The PU enjoyed taking his blood pressure and created his own blood pressure graphs in Excel using the data collected via the device.

Informal CGs: The wife received help in installing the DVPIS software on her computer and also guidance in how to maneuver the robot. She was afraid on using the robot and failing at docking but she did not want to use the semi-autonomy feature of the robot, so she used the Giraff robot only to a low extent.

Formal CGs: There were two formal CGs connecting to this test site (one occupational therapist and one physiotherapist). Both of them used the robot and DVPIS.

Technical difficulties and problems
Because of an uneven wall, the charging plates on the first docking station were displaced.

There were some problems related to the tablet and the blood pressure sensor:
- There were some network disturbances where the tablet was positioned, and thus physiological data were not transmitted sometimes. For this reason the data was manually sent when one of the formal CGs came to visit the PU.
- the blood pressure cuff leaked and had broken.
- the tablet stopped charging. It was discovered that the charger was broken.

Interventions to cope with the found technical difficulties
The docking station, the blood pressure cuff and the tablet charger were replaced. The tablet was located in a different room to avoid network disturbances.

Deployment date and removal of the system
This testsite was deployed in M28 and removed on October 27th 2014.

Testsite SE-5

Brief PU description:
She is 73 years old. She lives in an apartment in an elderly complex. She spends a lot of her time with the other residents, in the common areas. She has a low knowledge of computers. She has a post stroke condition and diabetes. She has a decreased balance and uses a rolling walker indoors and wheelchair outdoors.

Usage of system
She has diabetes since several years and has a well-functioning routine to measure, and analyze her blood sugar. For this PU it was decided that she would continue with the already existing routine.

Formal CGs: There was one nurse assistant working at the PUs primary health care center who regularly connected to the Giraff robot. There were also two formal CGs connecting to this test site (one occupational therapist and one physiotherapist). Both of them used the robot and DVPIS.

Technical difficulties and problems
The PU complained on the Giraff screen being very bright and that she had to hang something on it to make it darker in her bedroom. Later, the screen of the Giraff turned completely black.

The PU was initially disturbed by annoying beeps coming from alarms raised by the VI+, i.e. the base station for the environmental sensors.

Interventions to cope with the found technical difficulties

The screen problem was fixed after a software update. The VI+ unit was temporary removed in order to reconfigured it and make it completely quite.

Deployment date and removal of the system
This testsite was deployed in M28 and removed on October 22nd 2014.

2.3 Test sites in Spain

Testsite ES-1

Brief PU description:
He is an 84 year old widower, very active and dynamic. He enjoys learning about technology: he is taking informatics classes, and recently he joined a digital photographic course. He goes often to the Senior citizens center and takes part in the cultural events and travels that they organize. He likes dancing and usually goes dancing once a week with some friends. He has the GiraffPlus software installed in his computer and likes driving the Giraff robot through his house and showing

it to his friends and relatives. He has a good health but with the typical problems of the age, e.g. a high blood pressure.

Usage of the system

Informal CGs: His relatives use only the robot to connect to the PU, and they do not have a regular routine to do it. His daughter was the one who called more frequently, every two days or so, but lately she is very busy because of work. His granddaughters are both of them very busy because they work and have little children, so they find very hard to find the time to sit in front of the computer and use the system. They usually get him through the phone because they can do it from their mobiles in their way to some place or from work.

HP Secondary users: The GP is using the robot and DVPIS.

Technical difficulties and problems

In this case the main difficulties have been:

- To handle the tablet for the physiological sensors. Often the physiological data were not received properly because of disconnections of the tablet from the network or because the Giraff application was not open.
- Repeated false alarms in the falling sensor.
- Problems with the rotor neck of the Giraff robot that finally led to the replacement of the robot.
- Problems with the installation of software in SUs computers, in many cases because of their antivirus.

Interventions to cope with the found technical difficulties

The problems with the tablet were solved with the latest version of the Intellicare software. Some technical visits to this testsite were needed to replace the rotor neck of the Giraff, as well as additional support was needed to install the GiraffPlus software in the SUs computers. Problems for installing the software has leaded to the new service of the GiraffPlus system for connecting and visualizing information through the DVPIS@Mobile, which only needs internet connection and a browser.

Deployment date and removal of the system

The testsite was deployed on M22. Currently, the system has not been removed because the primary user is very collaborative and involved with the project team, willing to continue the experience. We plan to take advantage of this opportunity to continue our tests on the robot semiautonomy algorithms.

Testsite ES-2

Brief PU description:

He is a 77 year old man. Not a very active person. He enjoys reading, doing crosswords, playing the guitar and writing. He is in not very good terms with his family, but he has friends living nearby and participates in cultural and social events frequently. He has a hearing impairment and heart problems.

Usage of the system

He has been without the Giraff robot since March of 2014 because he thought it was not useful for him and occupied a lot of space. He was offered the falling sensor, but he decided not to use it, because he preferred one that works outside also. For him the physiological sensors were the most useful ones, especially the blood pressure device that used frequently.

Informal CGs: His relatives and friends were not willing to use the GiraffPlus system, despite having done the preevaluation and received the software. The only positive answer was the acceptance of one of them to be the end receiver of the falling sensor alarms.

HP Secondary users: One GP acted as HP for this testsite, connecting occasionally to the DVPIS

Technical difficulties and problems

In this case the main difficulties have been:

- To handle the tablet for the physiological sensors. Often the physiological data were not received properly because of disconnections of the tablet from the network or because the GiraffPlus application was not open.
- Big size of the Giraff robot and difficulty in hearing the person who called him.

Interventions to cope with the found technical difficulties

The problem with the physiological sensors were solved with the last version of the Intellicare software. The volume of the robot was properly adjusted since this user had some audition problems.

Deployment date and removal of the system

The testsite was deployed on M22.The robot was removed in March of 2014 and the complete system was removed the 26th of November 2014.

Testsite ES-3

Brief PU description:

She is an 85 year old widow. A very active person, but she has mobility problems, so she has to use a walker. She has recently retired from her job as a president of a charity foundation for cancer care but she still is involved in some Foundation works. She uses computer every day and also a tablet to read her mails, etc. she lives in a small house inside the Foundation's facilities, which is very convenient to her because she lives independently, but with a quick access to medical facilities.

Usage of the system

Informal CGs: Her friend used the robot occasionally, but she preferred going to visit her personally or using the phone. She used DVPIS more often.

HP Secondary users: Her GP also preferred calling her by phone if he needed it because he found it quicker. He used the DVPIS once a week or every two weeks and he proposed some activities that he would be interested in monitoring through the system, like for instance "moving at home" given the mobility problems of the PU. For this, a new rule in the context recognition was included as well as new features in the DVPIS@Home to show the last movements of the user based on the motion sensors.

Technical difficulties and problems

In this case the main difficulties have been:

- To handle the tablet for the physiological sensors. The nurses that used it for measuring PU's physiological data often had problems with the connection.
- Repeated false alarms in the falling sensor.
- Problems with the driving of the robot.
- Problems with the installation of the GiraffPlus software in SUs computers, in many cases because of their antivirus.
- Problems to monitor movements of the primary user in the house.

Interventions to cope with the found technical difficulties

New functionality was added to DVPIS to show the movement of the PU in the house.

The problems with the tablet were solved with the latest version of the Intellicare software. Some additional support was needed to install the GiraffPlus software in the SUs computers, check the robot, a reconfigure the falling sensor. Problems with the installation of software was solved by the inclusion of the new DVPIS@Mobile that permits SU to connect to the GiraffPlus system counting only on internet connection.

Deployment date and removal of the system

The testsite was deployed on M29 and removed the 26th of November 2014.

Testsite ES-4

Brief PU description:

He is a 79 year old widower, not very active. He has mobility problems because of a leg and he stays sat most of the time. He also has diabetes and blood pressure problems. He likes using the computer and uses it regularly to check mails and talk through skype with a friend that lives abroad. He lives in a social flat granted by the city council and also his lunch is provided by the social services and delivered to his house every day. He does not have household help, but he would need it because he is not able to do it by himself.

Usage of the system

Informal CGs: His brother has used the robot frequently, although he did not use the DVPIS. His son was only interested in receiving the emergency calls.

HP Secondary users: The GP from ESTS1 and 2 was acting also as his HP, using both, the robot and the DVPIS.

Technical difficulties and problems

In this case the main difficulties have been:

- To handle the tablet for the physiological sensors. Often the physiological data were not received properly because of disconnections of the tablet from the network or because the GiraffPlus application was not open.
- Problems with the rotor neck of the Giraff robot that led to the replacement of the piece.
- Problems with the installation of the GiraffPlus software in SUs computers.

Interventions to cope with the found technical difficulties
This testiste suffered from the same problems that ES-1. The actions taken here were the same.

Deployment date and removal of the system
This testsite was deployed on M29 and removed the 5th of December 2014.

Testsite ES-5

Brief PU description:
She is an 82 year old widow, very active and dynamic. She enjoys learning about informatics. She uses WhatsApp and Facebook regularly to be in contact with her family that is very important for her. She is very involved in her Church and takes part in all the social and cultural events organized by them and also in some Foundations events. She has blood pressure and heart problems.

Usage of the system
Informal CGs: Her daughter uses DVPIS occasionally, not at regular basis. She also has called her mother through her Giraff robot.
HP Secondary users: Two GPs belonging to the Primary care facilities where the daughter works are the HPs. They have used both, DVPIS and the robot occasionally, when they have the time to do it from their work.

Technical difficulties and problems
In this case the main difficulties have been:
- Lack of an internet connection in the Health centre where the three SUs work
- To handle the tablet for the physiological sensors. The physiological data were not received properly because the user did not turn the tablet on before taking the measures or because failures in Internet connection.
- Problems with the sound in the Giraff robot during several calls that were solved.
- Initial problems with the installation of Pilot in SUs computers, because the mails were in English.

Interventions to cope with the found technical difficulties
The lack of connectivity in the health centre was solved by buying an USB-router and hiring a 4G wireless connection. Problems with the tablet, as in other cases, were solved with the last version of the Intellicare software.

The internalization implemented in the last versions of the prototype, providing proper language translations solved the problem of receiving mails in English.

Deployment date and removal of the system

This testsite was also deployed on M29 and it has not been removed yet, as in the case of ES-1, the primary user is willing to continue with the installed GiraffPlus system and thus we will exploit this situation to conduct conduct longer experiments on the robot autonomy.

Final Giraffplus integrated system

The testsites described in the previous section have been all deployed using the final GiraffPlus prototype that includes the improvements reported in M30. This final prototype has been evolving from its initial phase according to the work considered in the DoW but also according to the continuous users' feedback, their recommendations and suggestions. The intense use of the system has also revealed some technical problems which have been studied and solved by adding new services and software/hardware solutions to the system. In order to manage the users' feedback and track the reported bug, the on-line bug tracker Mantis has been considered. Next, the set of components (hardware and software) of the deployed final GiraffPlus system, focusing on the improvements achieved in the last year, are summarized. For a detailed description, please refer to D2.4, D3.4, and D4.3.

3.1 Hardware components

3.1.1 Environmental sensors

Tunstall sensors (presented in D5.3, section 4.2) are managed by the device called Lifeline Vi+. It is a hub that receives the events triggered by the sensors based on the needs of each particular user. The Lifeline is connected to a computer through the USB TAPIT. In this way, events triggered by the sensors are directly communicated to the GiraffPlus middleware through a dedicated OSGi driver module.

Considering some of the technical difficulties reported in the testsites (and summarized in section 2) due to the environmental sensors, e.g. unreliable readings or attachment to walls, a new set of sensors have been integrated and tested next to the already working Tunstall ones, providing redundancy over different manufacturers and technologies as well as gaining in system interoperability.

The selected sensors are Z-Wave devices, operating on a protocol called indeed "Z-Wave" that uses low-power radiofrequency communication working at 868Mhz (Europe version). Besides the sensors exposing similar functionalities with respect to the Tunstall ones (like door contact or presence), some of these Z-Wave devices can also act as actuators, allowing to remotely control appliances or lights by turning on/off internal switches. Moreover, power monitoring plugs, reporting detailed energy consumption, allow to track and to possibly detect user activities based on power utilization.

The Z-Wave sensors automatically form a mesh network based on one or more controller, allowing nodes to communicate even if they are not directly visible each other. Furthermore, the mains powered nodes act as repeaters, allowing covering big spaces without the need of adding more controllers. A compact USB Z-Wave controller has been used to interface with the sensor network, avoiding the need to put an additional dedicated gateway. A detailed description of these sensors can be found in D2.4, section 3.2.

3.1.2 Wearable sensors

A new wearable device, with respect to the previous Pebble smartwatch presented in D2.3, section 2.3.1, has been considered for the integration into the GiraffPlus system in order to measure additional physiological parameter like the heartbeat frequency or the elderly movements. The device is the Gear Live smartwatch manufactured by Samsung. This device runs Android 4.4 Wearable and has many sensors: optical heart rate meter, accelerometer, gyroscope, compass and a step counter. Since it runs Android, it seamlessly pair and work with any recent Android phone or tablet.
Some tests were carried out to evaluate the reliability and the accuracy of the smartwatch heartbeat sensor. To achieve this, a Garmin Cardio chest strap has been used in conjunction with the Gear Live during daily activities. The results show that the sampled values of the smartwatch are very reliable when the wrist is almost still, while if moving the accuracy consequently decreases. An issue detected with the watch is the potential loss of the heart rate sampling if the watch is not tightly fastened on the wrist. A full explanation of the device and the tests performed can be found in D2.4, section 3.3.

3.1.3 Android-based sensors

A pulse oximeter sensor and an acceleration sensor combined into a monitoring system based on a smart-phone android device have been integrated in the final GiraffPlus prototype. The system can publish data via an android interface.

Sensors set
The developed system includes a pulse oximeter for measuring physiological data and an acceleration sensor, inbuilt in the smart-phone device. Additionally, blood pressure values can be included as a user input. All the data from the pulse oximeter is sent to the phone using Bluetooth technology. Both Serial Port Profile and Health Device profile communication protocols are supported.

Processing device
All the data sent by the sensors are received, stored and processed by the android based smart-phone. Two types of on-line analysis are currently deployed: a) danger point detection (pulse abnormal variations) b) fall detection (using the orientation tracking).

Remote monitoring
Once a dangerous situation has been detected, the processing device generates an alarm and sends a notification to the current user. If this alarm is not cancelled by the patient itself, it is forwarded further to the remote server, which can be subsequently replaced by the GiraffPlus middleware. GPS coordinates can be additionally sent to help in patient localization. Another available option is to forward all the measurements to the server every predetermined interval of time and perform an on-line observation of the current health conditions.

The developed system is able to carry out continuous monitoring of main physiological parameters, which provides a better insight on the medical profile of the patient. It is moreover essential in case patients are required to be monitored outside the smart-home environment.

Apart from the hardware integration (middleware on the phone connects to the *mqtt broker* running on the home service), we implement a joint reasoning approach. Context recognition of the home environment is communicating with the android device regarding the fall risk probability and informs secondary users in case of emergency.

As described in D5.4, the android-based sensor platform was successfully integrated into the GiraffPlus platform. As a result MDHPulseOximeter and MDHFallDetector were added to the system (via Engineering GUI) as complementary sensors. Subsequently, a number of real-life tests were initiated to perform continuous monitoring of physiological parameters and assess both entities in terms of user acceptance, data collection and communication reliability.

Additionally, alarm notification functionality based on Pushover application has been tested into the monitoring process. With latest improvement complementary sensors are able to communicate with caregivers directly in case fall alarm has been triggered.

Several modifications of the android based monitoring system were developed during the latest phase of the GiraffPlus project. The standard modifications implied the integration of the mobile-based system into the global system monitoring through the special middleware application developed especially for android devices. All the measurements (pulse rate, oxygen saturation, body movement, fall event) were extracted on a continuous basis, automatically synchronized with the system and become available to all type of users on-line via DVPIS.

Special requirements were discussed while working with different test groups in Italy and Spain. Based on several requests a new modification of the system was developed in order to split pulse rate monitoring and fall event monitoring into two parallel processes. A special focus was made on simplification of the user interface to make monitoring system available for elderly users.

Unlike the first version of the program, the latest application is not integrated via GiraffPlus middleware into the global database, but generates direct notifications to the secondary users in case of abnormal situation or fall event detected during the monitoring. The latest version of the system was successfully tested at one of the testsites in Sweden in collaboration with a local homecare facility.

Both modifications can be run simultaneously on the same device if required and be a part of the global monitoring system.

3.1.4 The Giraff robot

The Giraff robot is a telepresence device that allows a remote user to connect and make a visit. It includes a camera with a fisheye lens, microphone, speaker and a 13.3" LCD screen mounted on top of a base that you can control remotely and move around in the remote location. The 13.3" LCD can turn 180 degrees to let the user see who is calling and to interact with the Giraff.

The user interface on the Giraff robot contains an answer button, a hang-up button, a volume knob and a touchscreen so the user can interact with the DVPIS system. Everything else is controlled by the remote user to simplify the robot usage. The Giraff robot also includes a charging station where it charges its battery when it is not in a call.

Both on the pilot and robot side a plug-in API exist so the DVPIS application and the robot's autonomy algorithms are able to interact directly with the Giraff system. This will allow instant access for the user to connect to the Giraff.

The new version of the Giraff robot v4.0, integrated in the final prototype of the GiraffPlus system, includes new features that cope with the main technical difficulties found by the users, i.e. related to the image and sound quality. Although a low bandwidth or shortcuts in the internet connection are the main sources of this problem, a new high resolution camera is integrated in the last version with 720p resolution. The new camera also gives the ability to drive in dark rooms and allows to zoom. Status indicators like on/off status, charging status and battery status are used. Moreover, a feature that allows the Giraff robot to charge when it is off was employed.

A new software update was implemented regarding the tilt motor which allows the head to spin, since some technical issues were faced.

The new software version (v2.4) for both Giraff and Pilot that was developed and released includes new features for the 4.0 version Giraffs related to the night vision and height adjustment. The feature of sending an alert when a Giraff is not charging has been developed.

Moreover, a new platform including an alpha version of the Pilot/Giraff software and a new Sentry was developed. The new Giraff/Pilot version for the GiraffPlus was released during September. Finally, a bug fix related to the Pilot and the semi-autonomous drive sharing control of the motors was done and this fix contributed to a new developer's release.

3.2 Software components

3.2.1 DVPIS

The DVPIS is the part of the GiraffPlus system devoted to deliver services toward the different human users. The DVPIS module has been incrementally enriched of functionalities during the project to better serve the utilization of the system by end users. The general software architecture is composed of (1) a *back end* that is responsible for reasoning on both the data gathered and the user features to synthesize the appropriate and personalized content for the users; (2) a *front end* that is responsible for presenting the information and services to the different categories of users allowing them also levels of interactions with the system services.

In fact, as already described in other deliverables (e.g., D1.1, and D4.1 and D4.2) the users of the GiraffPlus system are of different types and categories. This is reflected in the implementation of different instantiations of the DVPIS that allows responding to the different needs. The main subdivision of users is between *primary users* who are the old users living at home where the GiraffPlus system is installed and the secondary *users* who are persons that use the system from outside the house to inspect data of primary users and/or receive alarms in case of emergency. In response to this first important subdivision the DVPIS has two main user interaction environments, namely the DVPIS@Office, toward the secondary users, and the DVPIS@Home, toward the primary users and delivered through the Giraff robot.

The final GiraffPlus system integrates the final release of both the @Office and @Home that are the results of the cyclic evaluation-development loop that ensures the GiraffPlus user-centered approach.

Both components are extensively described in specific deliverables. In the following subsection we briefly summarize the main features of both modules.

3.2.1.1 @Office

The DVPIS@Office is the software environment dedicated to allow access to the GiraffPlus system by secondary users. In particular it contains services for both formal and informal caregivers that can inspect the data gathered in the house both in real time and by asking queries on long-term stored data. Through the DVPIS@Office it is also possible to use the Giraff Pilot to virtually visit the primary uses and communicate with the house.

The DVPIS@Office is designed as a single application that according to user identification allows accessing different set of services. In particular the systems allows to distinguish between formal caregivers that are interested to follow multiple primary users and informal caregivers that usually need to access a single primary user data for both monitoring and interaction.

Just for showing the main initial differences we include two figures. A healthcare professional usually follows multiple people and the advantage that GiraffPlus can offer to her/him is to facilitate the work from remote. Such professionals, after authentication, are offered the summary view in Figure 1 that with the use of colour signals send some initial information and facilitate priority identification.

Figure 1 – A possible instance of the DVPIS@Office for a medical doctor

For example in the figure the professional can see there has been an Alarm on TestSite_IT_4 and this identifies an immediate priority. It is also possible to notice that the red on Physiological Status may suggest that there are data to check for TestSite_IT_2Bis, etc. This summary information has been added as an additional information layer for this class of users that are particularly relevant for the project.

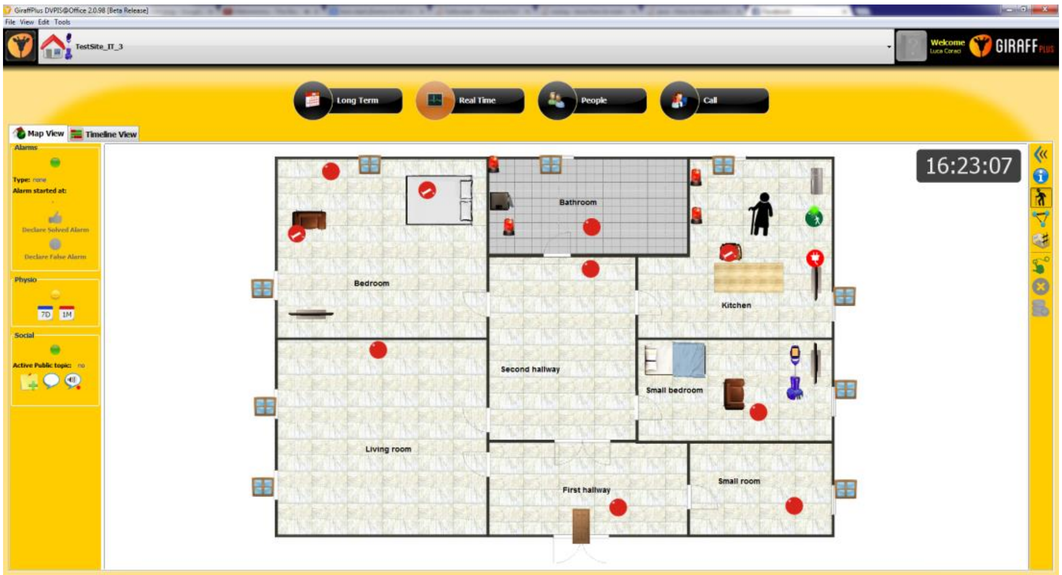

Figure 2 – An instantiation of a DVPIS for an informal caregiver.

The informal caregiver (here we first target the son/daughter of an old person) is assisting a single person hence she/he, after authentication, enters in the screen of Figure 2. The initial screen directly gives information on the monitored home showing the summary information on the side bare on the left, the home map in the main information central area, and the usual panel command on the right.

In both situations the DVPIS@Office enable access to different panels of various services developed in the project. It allows inspecting the environmental data, the physiological data and also the result of the context recognition module. Additionally it is possible to also ask daily/weekly or monthly report for the main activities in order to observe possible deviations from routines; finally it is possible to make a call to the robot to visit the home from remote. For specific screens and information of the various functionalities see the DVPIS user manual included in the D4.3. It is worth underscoring that the final version of the DVPIS incorporates several changes made in response to the feedback received during the evaluation phase and specifically in these last six month of evaluation.

Additionally, to consider the new user requirement emerged from the long-term assessment of the system, that is related to the need of accessing data from a smartphone, in the final part of the project a mobile version of the @Office environment has been developed in the WP4 as a specific activity to broaden the utilization of the produced functionalities (see specific dedicated section of this document).

3.2.1.2 @Home

The idea to use the robot to present additional information to the old person at home has been identified as an interesting possibility during the focus groups and the interviews reported in D1.1.

Additionally, the PUs of our test sites also expressed the need of more active services available through the GiraffPlus system. To this purpose, the consortium has decided to develop a version of the Giraff robot with a touch screen and part of the work in the WP4 has been dedicated to develop a new service starting from such an improved platform. The result is the module called DVPIS@Home which is an independent software component which runs on the robotic platform and is able to control the robot screen, dialogue with the command modules of the robot, dialogue with a specific DVPIS@Office through a connection supported by the GiraffPlus middleware. The @Home service guarantees an additional communication channel from outside the home to inside and vice versa.
The module main functionalities are: (1) **Avatar** that preserves the “telepresence” service that the Giraff robot provides. This means that the teleconference functionality is always possible in combination with other functionalities. The Giraff application has been indeed embedded within the @Home so as to maintain the possibility for secondary users to visit the older user’s apartment through the telepresence robot; (2) **Messages**: an environment has been designed to allow the primary user to receive messages from secondary users or reminders and suggestions. Messages and reminders maintain both the textual and the spoken form; (3) **Shared space**, an additional environment that endows users with a shared space through which it is possible to exchange material and that could foster a discussion on the health status and habits of the old person. For example, this panel allows showing personal data to the primary user (e.g., physiological measures), exchanging pictures or audio files by integrating the telepresence with further information content as a support to the interaction between primary and secondary users.

The final version of the @Home has been further enriched with functionalities after both a continuous laboratory test and a dialogue with a selected number of end users of the running test sites. In particular several functionalities have been added for: (i) control of the physical height of the robot via a touch; (ii) control of the rotation of the screen via a touch; (iii) the support of ***text messages*** that can be both read by the old users through the robot’s screen and listened to by means of a text to speech module embedded in the @Home. Additionally the @Home enables receiving ***audio-recorded messages*** produced both by the secondary and to send messages to the @Office produced by the primary; (iv) the empowerment of the capability of robot interaction by showing and verbalizing the physiological measurements as soon as they are registered in the GiraffPlus middleware so as to give a sense of companionship to the older person; (v) the setting of a shared space in which the secondary is able to send the primary both pictures, audio and video messages to give a sense of augmented communication environment.

3.2.1.3 DVPIS@Mobile

As also highlighted in the summary of the testsite description, any secondary user (i.e. doctor) in charge of monitoring or analyzing the data from a specified home is bound to a desktop application and office workstation, thus making it hard to have the data at hand at any time and any location. Provided the doctor has any kind of hand-held device with a data connection to the internet, a web application makes accessing the data much easier regardless of the doctor’s current location. Data is in a form optimized for the web and mobile devices, which allows you to have instant overview of necessary data.

At the moment, the application displays the vital datasets, which includes: sensor data for the selected sensors, alerts, and user activity.

When connected to the application, a welcome screen (Figure 3) immediately displays all the homes available for the logged-in user (name displayed on top), based on his certificates and roles defined in EngineerUI application.

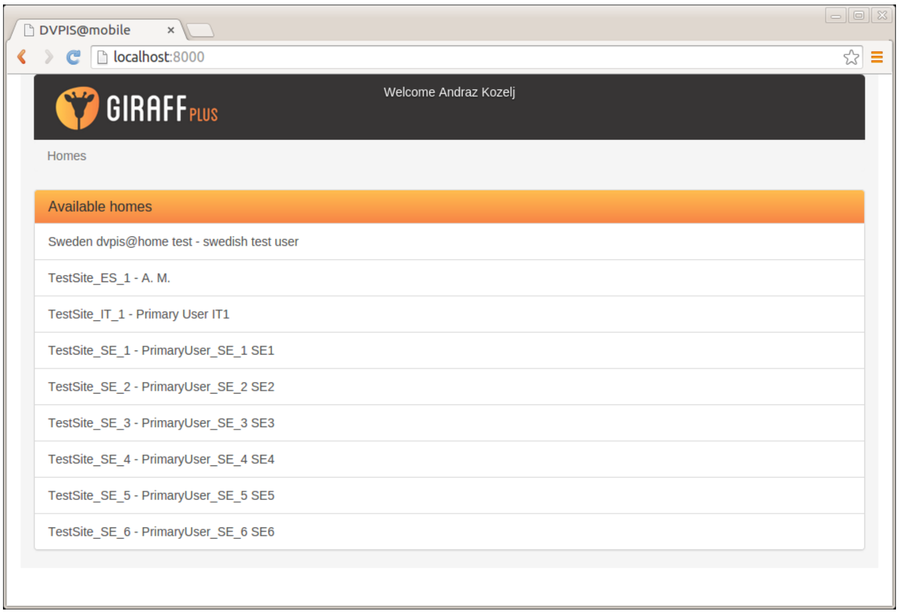

Figure 3. Welcome screen

The user can select a home and see the room/sensor configuration. Displayed are all the rooms and sensors within them (Figure 4), plus a special section “General, Unbound sensors”, which contains all sensors that are not fixed in a specific room but gather data about the user.

On top the primary user name, birth date and last known Physiological, Social and Alarms indicators are displayed. Here the user selects the sensors he is interested in and continues to the next screen to display the data.

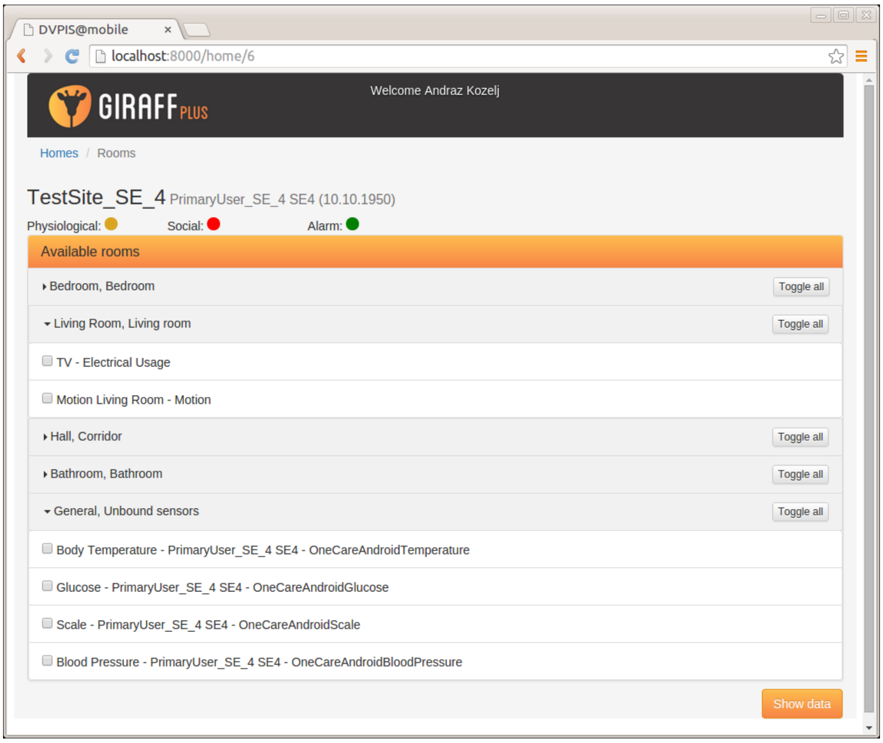

Figure 4. List of rooms and sensors available

All the sensors data is presented in a timeline, which can be scrolled to review past data (Figure 5). Only a part of the data is loaded, other data is loaded on demand, as you scroll through the timeline. Different kind of data is presented here:

- single data points (alerts, motion sensors activity, blood pressure measurement)
- time-ranges for certain activities (electrical usage, activities)

Data display is compressed, clustered, for more details you must zoom-in to access single data points. There are different time-range view presets (14 days, week, today) for different zoom factors. Zoom can also be manipulated by mouse-wheel and pinching in mobile devices. The system is not real time, but it updates every minute. Thin red line on the right side of timeline presents the current time, while dark background on timeline covers the time range for which the data is displayed. Last update timestamp is noted on top of the timeline.

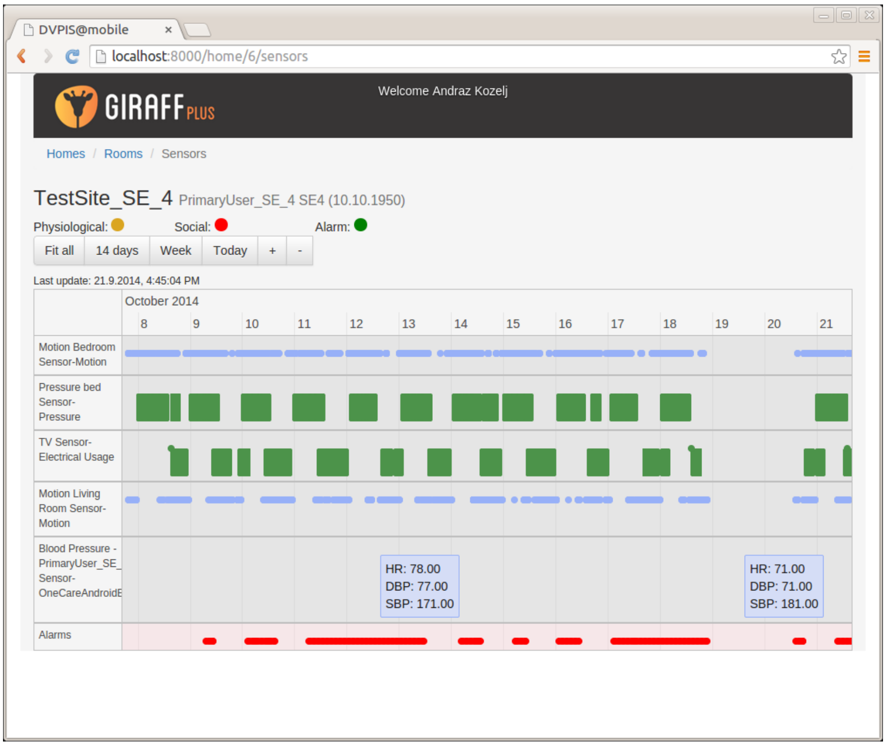

Figure 5. Sensor data and alerts display

A click on the data point reveals more information about the event (see Figure 6).

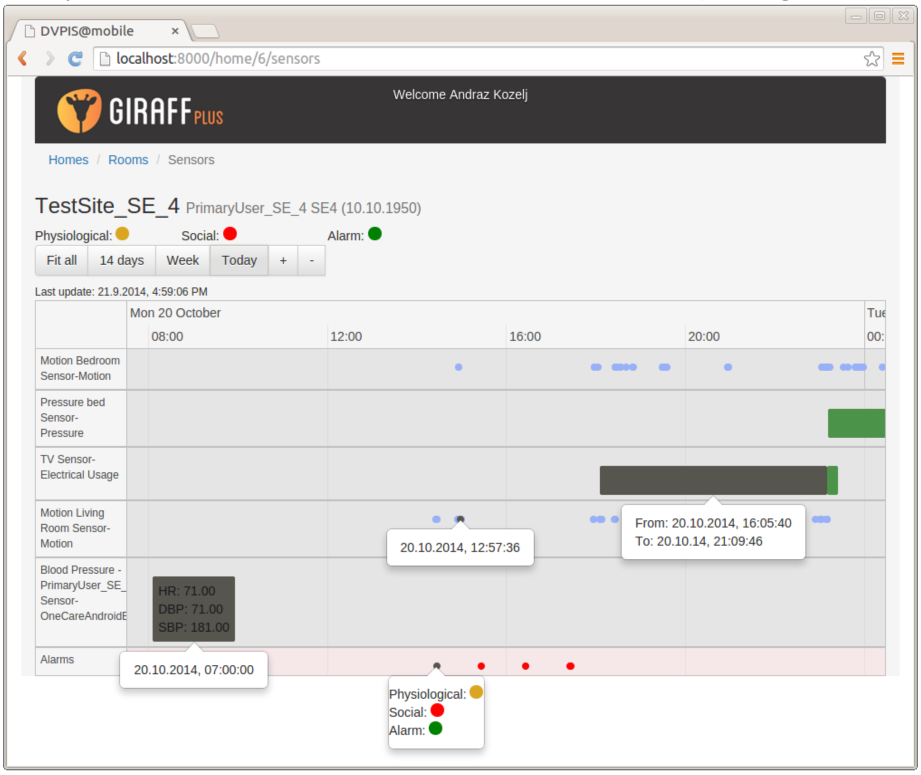

Figure 6. Data point details

Technical details on the DVPIS@Mobile can be found in D4.3

3.2.2 Context Recognition and Configuration Planning

The context recognition service is a Representational State Transfer (REST) service that runs as a servlet on a central Tomcat server. Queries to this service are done with a lightweight API which is embedded in several services that run on the client computer or on the central server. All computations are done on the central server when querying an activity. Such queries can be made by users through the DVPIS, in the activity and long term trend analysis views. The context recognition in turn gets sensor data from the data storage. The context recognition can also send alarm messages to Pushover clients.

The configuration planning service works by reconfiguring the preprocessing module of the context recognition module of the context recognition service. The latter can request sensor data from the data storage, preprocess this data in various ways (e.g. thresholding, aggregating) and then make it available to the inference module of the context recognition service. The configuration of the preprocessing module is specified in an XML file. Hence, the configuration planner outputs configurations as XML-files which are read by the context recognition. The configuration planner is not actively used on the test sites, though: it has been more practical do perform that work manually. It is likely to be more useful in a larger-scale commercial deployment where the cost for engineers is an issue.

Also, we have integrated a Long Term Trend Analysis to the DVPIS. This module queries the Context Recognition in the same manner as the activity viewer, and then computes and displays selected statistics. Please refer to D3.4 for further detail.

3.2.1 Robot Motion Control

The final version of the semi-autonomous robotic platform has been integrated into the GiraffPlus system and deployed at the test sites. However, an intense use has only been carried out in four of them (two in Italy and two in Spain). The main reason was the lack of interest of the secondary users to leave the control of the robot to a software program and preferred the manual driving option. Nevertheless, the integration of the semi-autonomy features in all the robots, the deployment and installation of the latest version of the robotic platform in all the houses, and the navigation tests carried out, yield a valuable experience and validate the developed semi-autonomy algorithms (the details of the latest version can be found in deliverable D2.4).

The information gathered during this period has been essential to evaluate and improve each of the steps required to make the semi-autonomy available for users. These steps are:

1. Installation of the additional sensors, their controllers, and the robotic control architecture on each robot.
2. Setting up the semi-autonomous robotic platform in the primary user environment and the construction of maps for localization and navigation.
3. Semiautonomous navigation tests in the primary user´s home and system tune up.

Installation of additional sensors, their controllers, and the robotic control architecture on each robot

This procedure starts with the installation of the necessary hardware components to provide a Giraff robot with semi-autonomous navigation capabilities, that is, obstacle detection and avoidance, localization, navigation, mapping, etc. The installation of the additional software (drivers, third party programs and the robotic control architecture) is done remotely by a technician from the UMA team through the remote access tool provided by Xlab (ISL-Online). The software installation is simple and does not take more than 30 minutes once the additional hardware is properly connected to the robot. However, the physical integration of the RGB-D camera on the robot requires some more work because of design limitations, both aesthetic (see Figure 7) and technical (see Figure 8). These operations must be performed in situ and may take about an hour.

Figure 7. The RGBD camera cannot be placed directly on the neck as in previous versions. Instead, it must be mounted using a L-shaped mounting bracket.

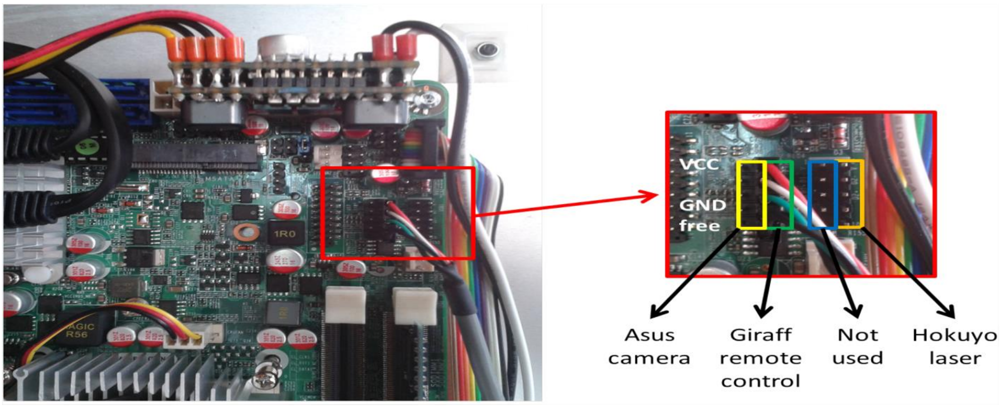

Figure 8. Due to the lack of appropriate connectors for additional hardware in the external usb ports of the robot, it has been necessary to access the motherboard and connect devices to a different USB controller.

Setting up the semi-autonomous robotic platform in the primary user environment and construction of maps for localization and navigation

Once the additional hardware and software are properly installed, the deployment of the semi-autonomy algorithms takes place in the house of the primary user. This procedure is more complex than the first step: it consumes about 5 hours in total, taking into account the working time for the deployment and for the generation of maps, which is done in remote.

After the deployment is complete and the robot is available in the house, the map generation process begins with a telepresence call, where the technician drives the robot through the different rooms of the house and gets the data needed to generate the map[1]. During this teleoperated navigation, the technician takes notes of the house layout, and subsequently generates an appropriate topology with a list of reachable destinations. These destinations can be selected by secondary users as places in the house where the robot navigates autonomously (see examples of geometrical maps, topology, and destinations in Figure 9). Both, data collection and the subsequent installation of the generated map are performed remotely through the ISL-Online tool.

Figure 9. Geometrical maps, topologies and relevant destinations (numbers) specified as navigation targets for secondary users for three of the deployed testsites.

Semiautonomous navigation tests in the primary user´s home and system refinement

The final part of the deployment is testing the complete system in the environment of the primary user. The tests are performed remotely through the secondary user interface with technical options enabled. These options allow the engineer to edit the topology and navigation labels in order to improve the performance of the autonomy. In Figure 10, the model of the test site IT3 environment is represented. This model consists of the geometric map and topology (Figure 10-left), and the schematic map with interactive labels (Figure 10-right). The nodes of the topology assigned as navigation targets (interactive labels) are shown in red on the geometric map.

[1] J. Gonzalez-Jimenez, C. Galindo, F. Melendez-Fernandez, J.R. Ruiz-Sarmiento, "Building and Exploiting Maps in a Telepresence Robotic Application", 10th International Conference on Informatics in Control, Automation and Robotics (ICINCO), Reykjavic, Iceland, 2013.

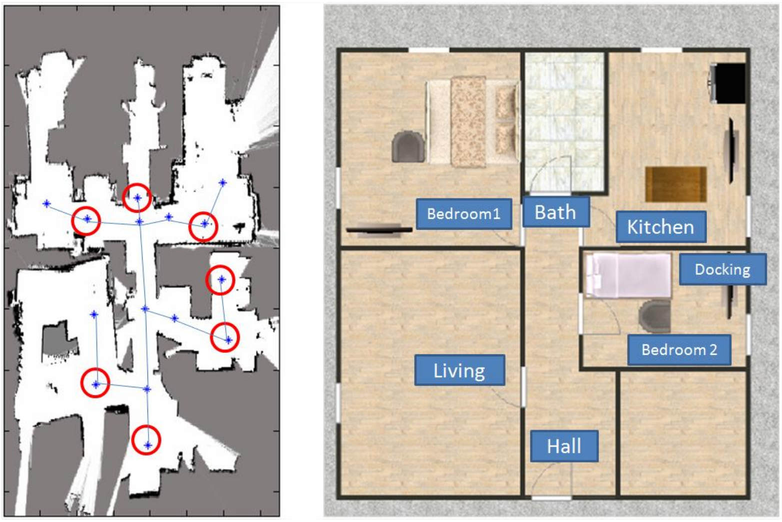

Figure 10. Left, Geometric, topological map from testsite IT-3. Right, schematic map from the same house.

Once the autonomous system is ready, the GiraffPlus technician commands autonomous navigations to all available destinations (by clicking on the interactive labels) and monitors the autonomous system performance while the robot follows the path to the requested target. The second test carried out by the engineer is driving the robot throughout the house using the collaborative control. During these two tests, the technician identifies potential problem areas, which according to the experience in GiraffPlus, can be classified into three groups:

- Low wifi signal intensity.
- Loss of self-localization.
- Non-detectable obstacles.

In some cases direct and simple actions can solve the detected problem, like for instance asking the primary user to perform a minimal modification of the environment (i.e., opening a door or moving a lightweight furniture), but in some other cases, the engineer has to change the topology to avoid autonomous navigations to the problematic destinations. In the following, different situations of these use cases are illustrated using our experience in the test site IT3. In particular, we illustrate four use cases:

- A successful example of initialization of autonomy, self-localization, collaborative navigation and autonomous navigation.
- A problem caused by an undetectable obstacle that can be solved by modifying the topology.
- A mislocalization problem solved by using the relocalize command.
- An unsolvable problem (glass doors) that causes the restriction of the use of autonomy in an area of the house.

Use case #1.- Successful operation

In Figure 11, the sequence of a successful use case of the semi-autonomy is shown. A secondary user navigates from the charging station, *Docking* to a specific location of the house: *Bedroom 1*. The red line in the geometric map indicates the location of the robot in each moment of the navigation. The action starts at point 1 in the figure, which indicates the beginning of the autonomous activities when the secondary user makes the call. At that time, the command

RELOCALIZE_AT: Docking is executed. This command runs automatically when the system detects that the batteries are charging and there is a node in the topology called *Docking*. This operation results in the red line (location of the robot) jumping from point 1 to point 2 in the figure. Once the self-localization is completed, the user decided to perform a navigation using the collaborative control to point 3 and finally commanded an autonomous navigation to the final destination: *Bedroom 1* (point 4 in the geometrical map).

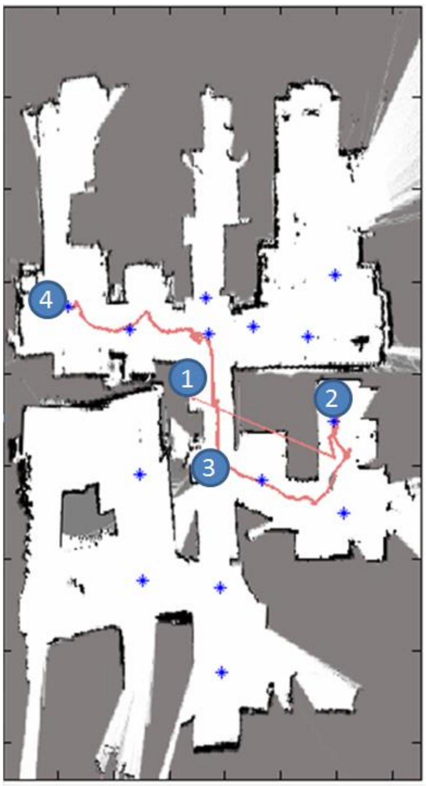

Figure 11. Sequence of a successful use case of a semiautonomous navigation from Docking to Bedroom 1 in test site IT3.

Use cases #2.- Non-detectable objects: topology redesign

The second case presented is a situation where a change in the topology improves the robot autonomy by reducing the risk of collision with an obstacle which is hard to detect. The limitations in the field of view of the RGB-D cameras make obstacles above 1.20 m. hardly detectable when the robot approaches them (Figure 12). There is a very common situation in households, more specifically, in the kitchens, where shelves are fixed on the wall and do not reach the ground. If there is enough free space around the obstacle, the GiraffPlus engineer can modify the topology to make the robot navigate via a safe path as an alternative trajectory (Figure 13).

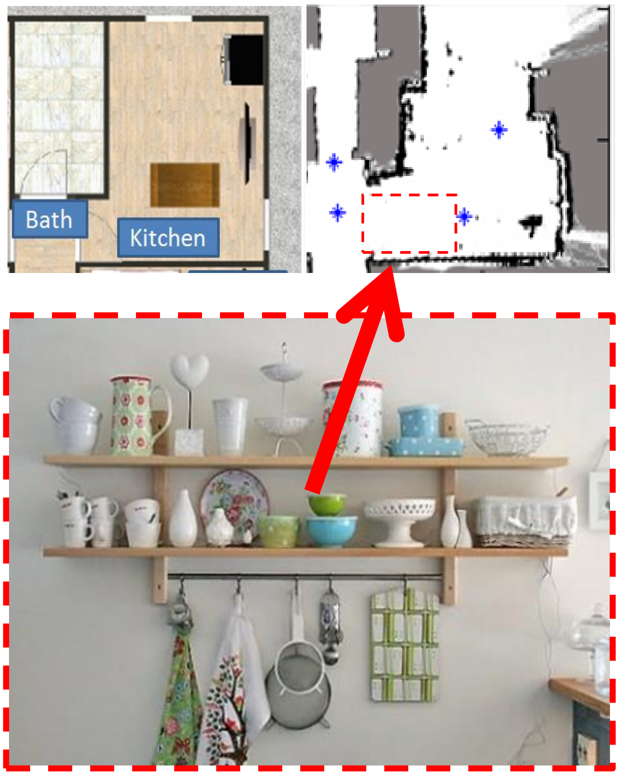

Figure 12. Furniture such as shelves above 1.20 m. are outside of the field of view of the RGB-D camera.

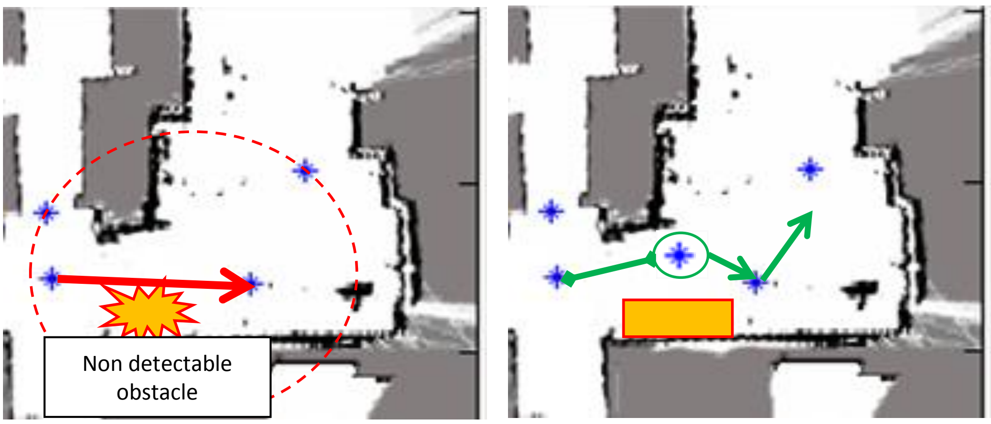

Figure 13. Left, part of the initial topology created by the GiraffPlus engineer. Right, modified topology with an additional node that allows the robot to plan a safe path away from the dangerous obstacle.

Use cases #3.- Errors in self-localization: relocalizing the robot

This case reveals the limitations of the self-localization algorithm when the robot cannot reach its destination autonomously due to a mislocalization error. This is, however, a recoverable situation with the help of the secondary user, by taking the manual control of the robot and, executing a "RELOCALIZE_AT" command at the appropriate location on the map.

The main cause of this type of incident is the low quality of the odometry in the wheels of the robot. Figure 14 shows the robot incoherent navigations because it is mislocalized. It is also noticeable that the location of the robot is displayed outside the navigation area (point 1 in the figure), representing the wrong localization of the robot when it is lost. After the "*RELOCALIZE_AT*" command requested by the driver, the self-localization system starts to converge again and moves the pose of the robot from point 1 to point 2 to finally be located in the correct position (point 3). Note that in the jumps of the location from point 1 to point 2 and from point 2 to point 3, the robot is not moving; the user has the manual control and the changes are produced by the self-localization system, in the calculation of the correct localization.

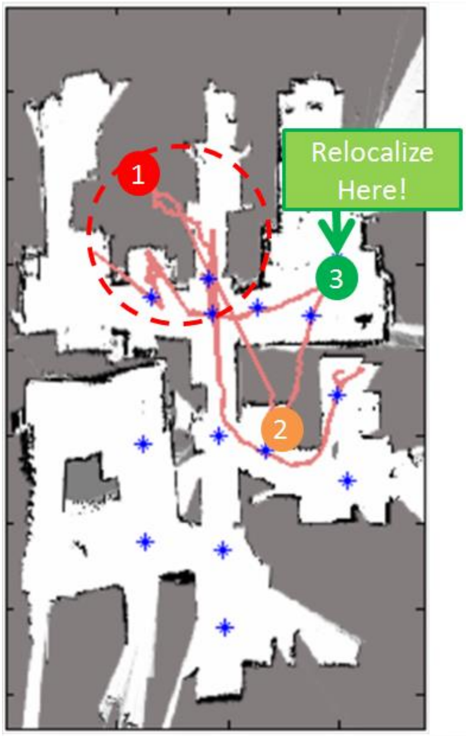

Figure 14. Example of wrong behavior of the self-localization system (point 1) and its recovery after a RELOCALIZE_AT command.

Use cases #4.- Exclusion of conflictive areas from the topology

Finally, a case is presented in which the robot cannot navigate autonomously because the perception system becomes unstable. This situation occurs mainly in places with glass doors or large mirrors that reach the floor. In these cases, neither the RGB-D camera nor Hokuyo laser can detect the obstacle. In addition, if there is too much light, the sensors saturate and therefore, both the security and the self-localization systems fail. The only way to address this problem is to exclude these zones from the autonomous navigation areas by removing all the related nodes from the topology (Figure 15). Thus, the robot can only get there when manually guided.

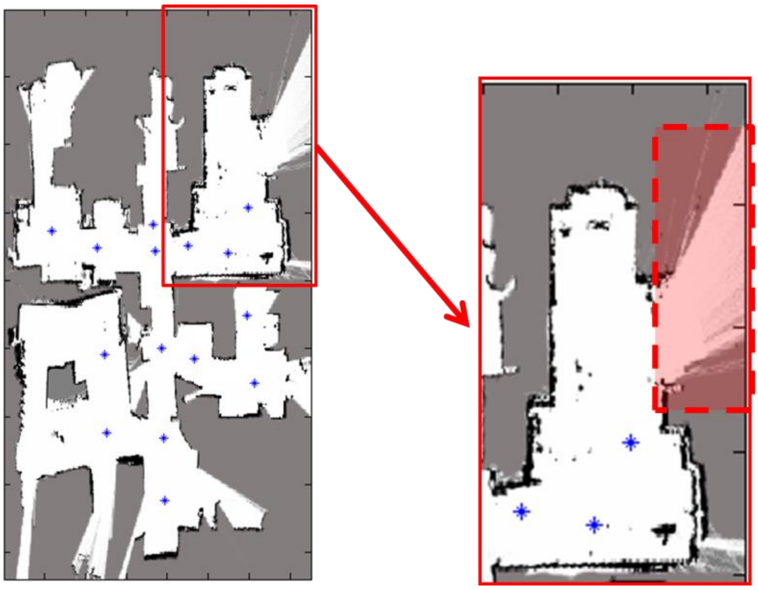

Figure 15. The rays projected by the Hokuyo laser and the RGB-D camera pass through the glass and the robot interprets that there is no obstacle. For security reasons, this area was excluded from the topology.

3.2.2 Intellicare Android Application

The Intellicare android application transmits physiological data from the Intellicare devices, e.g. blood preasure/sugar sensor device, scale, and fall detector, to the GiraffPlus middleware, that is, it serves as a bridge connecting Intellicare solutions to the integrated GiraffPlus system. The Intellicare android application is in fact a set of two applications:

- OneCare Tablet GiraffPlus Edition: The application that collects data from physiological sensors and delivers data to the GiraffPlus middleware and data storage.

- OneCare WakeLock: Application which runs in background to enable seamless middleware and tablet application update.

The use of the tablet and the Intellicare android applications have been found to be a source of usability problems as reported in section 2. Therefore the apps have been accordingly modified to reduce the PU user intervention as much as possible. Concretely, the most important differences from OneCare Tablet GiraffPlus edition to the regular OneCare Table edition are:

1. System governance is provided by GiraffPlus Infrastructure. Sensor creation and announcement, user identification and data transmission using middleware and MQTT functionalities.
2. Other than initial configuration the application does not need user intervention. Initial setup is based on middleware configuration and the start of the OneCare Tablet Widget. From this moment the user just needs to use the sensors, data is seamlessly sent to the GiraffPlus infrastructure.

3. Updates are performed without the need of user confirmation. This functionality is achieved with the help of the OneCare WakeLock App which ensure proper restart after an update pushed by Google Play services.

3.2.3 Remote Access & Data Storage

This section describes the mechanisms used for sensor data collection, storage, and retrieval in the final prototype of the GiraffPlus system. The security protocols and remote access tools considered in the deployed testsites are also detailed.

3.2.3.1 Sensor data collection

Data collection and storage is managed centrally through a MQTT[2] server, which can be accessed by all the sensors and middleware components.

MQTT is a lightweight telemetry publish-subscribe protocol, ideal for the GiraffPlus use case. MQTT broker allows for a distributed architecture and easier scalability, if needed.

An MQTT listener is implemented on the server side, which captures the data and stores it in daily collections.

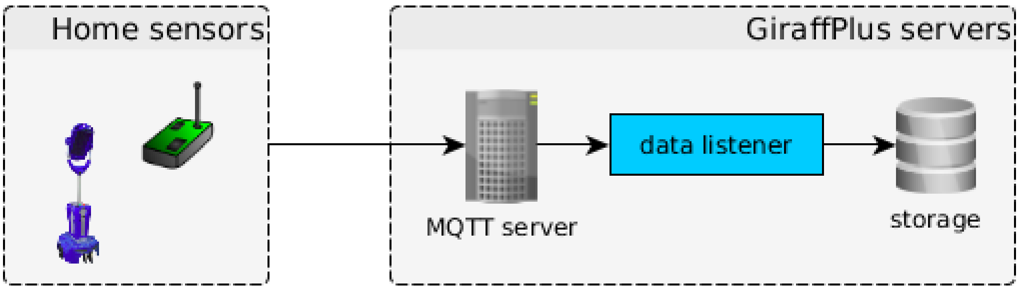

Figure 16. Sensors send data to a central server, where data processing and storage occur

3.2.3.2 Sensor data storage

Received data is stored in a daily collection, which is then compressed during the night and stored for long-term storage. This way we can achieve faster response for current day queries and save on the storage space needed for all the data.

Redundancy and Backup

Data is stored locally in a distributed storage network on OpenStack[3] platform. There are three separate Mongo[4] database instances, which are kept synchronized and act as redundancy set. The

[2] http://mqtt.org
[3] http://www.openstack.org/
[4] http://www.mongodb.org/

database operations (queries, access time, storage times) are monitored. In case of high database latency, additional replica sets can be provided together with sharding.

Additionally, one of the instances is regularly automatically backup to a separate node and keeps the latest state of the data.

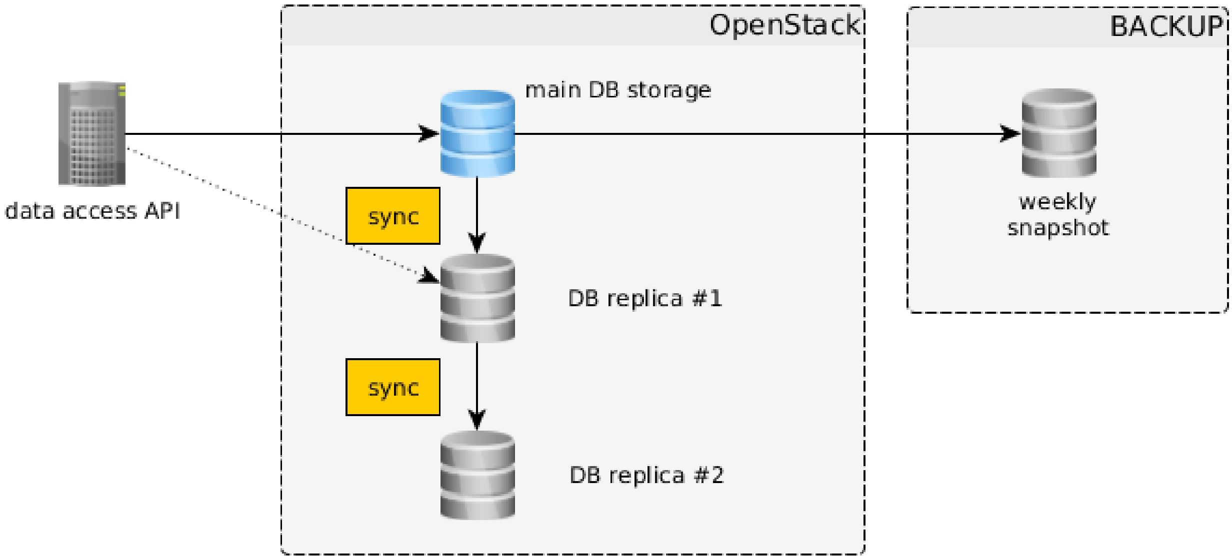

Figure 17. Database replica sets and backup on separate node

The shown architecture allows us:

- performance monitoring
- data redundancy
- high service availability
- full scalability options

In case a part of network or other infrastructure fails, we have redundant data copies and sources, which allow the services and systems to operate nominally with minimum downtime.

This kind of setup provides us with high quality of service and allows separation of certain data subsets, if any laws or regulations require special data treatment.

3.2.3.3 Sensor data retrieval

RESTful WS
Data access is centralized for all of the components of the Giraff Plus platform in form of RESTful web service. It is implemented on Java Jersey platform, running on an Apache Tomcat server.

Data is stored in separate collections and can be processed individually for each entity:

- homes

- organizations
- users
- sensors
- user interface translations
- configuration files storage

“Homes” data wraps together all the accessible sensors and activity data for a single monitored home throughout its rooms.

“Organizations” and “Users” collection include data about the entities involved in the project and all the users and monitored patients.

“User interface translations” collection contains different language packs for DVPIS@Office application.

Along with the sensor data are stored also different configuration files, such as:

- home configuration
- context-recognition activity rules

Sensor Data Queries
Additionally all the data stored can be accessed via query consisting of the following parameters/criteria:

- date/time range
- individual sensor

All data is stored in JSON format, which can be easily processed by most of the endpoints.

Scalability
Setup with a web service for data access is open for scalability options in terms of multiple server instances with a load balancing system.

Individual data access point load can be monitored and problems reported in real-time.

API as OSGI module
A lightweight API, following the functionality of the RESTful service, was implemented as an OSGI module and is now part of many middleware components, that can access and manipulate data in an efficient way.

3.2.3.4 Install and Maintenance Service

As part of the Install and Maintenance Service, a simple web graphical user interface was implemented, that would enable the administrators to easily enter and edit the test sites (homes) configuration description.

The Install and Maintenance Service is written in Java, using the Play framework and the user interface is based on Bootstrap. EngineerUI is also connected to the GiraffPlus CA and can issue a certificate for each of the entities in either JKS or BKS format

The application allows the "engineers" to edit or insert data about new homes and their configuration as described in previous deliverables.

From M30, this service has been improved by allowing the engineers to add translations for the internationalization feature of the DVPIS (see Figure 18).

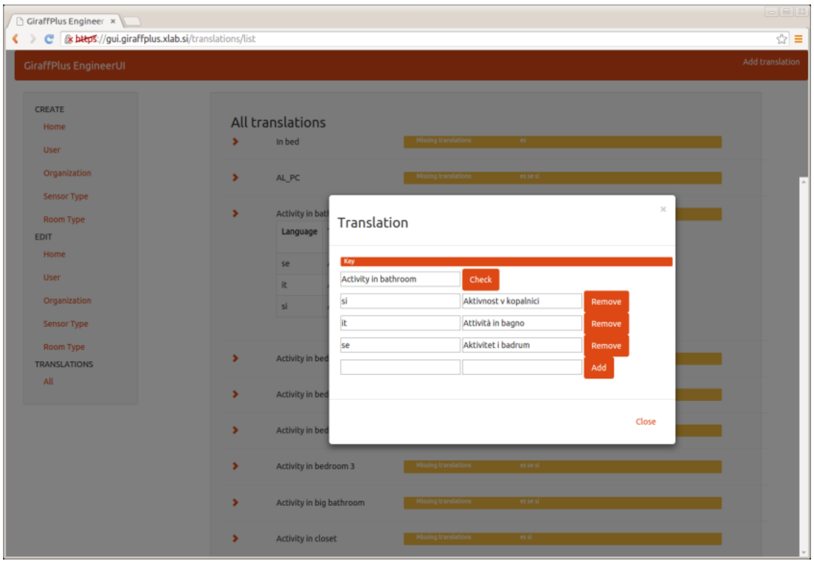

Figure 18. Adding a translation to an activity

3.2.3.5 Security

To protect the delicate data we expose it only to the people and systems that can provide a valid authentication token.

Part of the GiraffPlus project is also an established GiraffPlus Certificate Authority, which issues X.509 certificates used to authenticate communication endpoints and initiate SSL protocol. The CA also maintains the certificate revocation list.

Communication
All communication channels towards the data storage services must explicitly use SSL encryption based on GiraffPlus CA certificate.

Figure 19. Secure communication channel

User authentication
User authentication is performed with user certificates issued by GiraffPlus Certificate Authority.

Each issued certificate identifies a user, which must be listed as one of the users in the data service Users collection. If user cannot be identified as an active user, the access is denied to the user.

A valid certificate must be provided in DVPIS@Office at login and to be able to use DVPIS@mobile web application, the same certificate must be imported in the browser keystore.

User authorization

Each home has users attached as:
- primary user – the actual patient
- secondary user – doctors and monitoring staff
- engineer – GiraffPlus staff, taking care of technical issues and device monitoring

User roles for particular homes are managed by the GiraffPlus Engineer GUI interface.

Access Control List
Since all the GiraffPlus components access the data through a single point, a more detailed Access Control List system can be established at time of the commercialization of the project and maintained via an extension of the EngineerUI web application.
Data Distribution

At the moment all the data is stored in a single database, with replica sets and backup mechanisms in place. But if any of the local laws or regulations require the data to be stored at a specific location or specific conditions regarding maintenance, the data handling can be extended to satisfy those requirements via extra data replications, separation and shading.

3.2.4 Middleware

The final version of the middleware, comprising both the mobile and the desktop versions, has been deployed in all the test sites and is used as a communication layer upon which the several GiraffPlus components announce services and exchange messages. Some new features have been added since D5.4 that extend the middleware functionalities and increase the overall robustness.

The main enhancement is the implementation of a mechanism to send remote commands that allows clients to control any actuator registered in the homes, for instance a wall plug able to switch on or off the connected appliances. This functionality exploits the *control bu*s, a logical channel used by the middleware to carry control messages. A detailed explanation of this work can be found in D2.4, section 2.1.

Additional improvements made to the desktop version are:

- Mechanism to notify user application about connectivity issues by using a callback that signals whenever the connection drops or is established
- Separate thread for each callback execution with relative exception management to increase robustness against user faulty code
- Fixed a rare but potential message loss condition
- Improved the local backup mechanism: after a connection outage, the locally stored messages are sent to the MQTT broker only if they represent a change of a service descriptor, while they are sent directly to the database if they represent context information

Regarding the mobile version, the following changes have been made:

- Improved the binding/unbinding procedures between the android middleware modules to increase the reliability of the automatic update process
- WiFi recover procedure that resets the radio device after 15 minutes of absence of connection, fixing an apparent issue with the tablet wireless module

A real-time monitoring service, running on top of a middleware instance, has also been implemented to continuously check the home status and notify through a mail if any location goes offline for more than 6 hours. This service offers also a web page, with restricted access, allowing the engineers to check the home and tablet live status. More information about this can be found in D2.4, section 2.3.

3. Live Demonstration

This section illustrates the live demonstration of the final GiraffPlus prototype which constitutes the MS4. This demo aims at proving the integration of the different components (hardware and software) summarized in this document that take part of the prototypes deployed in the PU homes.

The proposed demo consists of deploying a complete GiraffPlus system within the meeting room and its surroundings. More specifically the pursued idea will be to recreate an apartment and make an installation of the GiraffPlus system. This integrated system will serve to demonstrate the different functionalities developed in WP2, WP3, and WP4 along the whole project specifically focusing on the third year of work. It is important to remark that the commitment of the consortium to carry out this demo is highly challenging from the technical and logistic points of view, given the available period for its preparation (only one day before the meeting) and the uncertainty about the type and characteristics of the services provided by the hotel, e.g. wifi connectivity, or the rooms' layout for which we only account with a couple of pictures in advance. This choice is also motivated by the idea of demonstrating the maturity level achieved at the end of the project, the portability of the system that will allow deploying, configuring, and start a new testsite in a limited time period.

Following the meeting agenda, the idea is to have the complete system installed and use it during the different WPs presentation to show the various advances of the third year. Examples of features that will be shown are:

- High level services provided by DVPIS for real data visualization and personalization. A Giraff robot will be employed in the meeting room to show the functionality implemented in the last year for sending text and voice messages to the PU. All the new functionalities of the DVPIS@Home directly come from new requests of users of the test sites.
- High level services provided by the Context Recognition and shown in DVPIS will be also presented. Different environmental sensors will be deployed in the surroundings of the meeting room simulating an apartment. Some rules will be defined to prove the inference of simple activities that could raise alerts to be sent to a smartphone, via pushover.
- The integration of new devices and sensors will be also presented showing how they can be easily connected to the GiraffPlus system.
- Finally, the robot semiautonomous abilities will be shown. For this part of the demo the foyer of the meeting room is considered to test the collaborative control of the robot as well as the autonomous docking system based on laser data.

As part of this live demo, the reviewers will have the opportunity to visit one of the deployed testsites in Italy and directly interact with the real users. An interpreter will be available for the translation from English to Italian and viceversa.

4. Conclusions

This document has reported the final version of the integrated GiraffPlus prototype which has been deployed and tested in fifteen testsites in Sweden, Italy, and Spain.

The deployment of multidisciplinary technologies, i.e. sensors, computer systems, user services, mobile robots, etc. within real homes becomes a challenge which is not free of hurdles. Additional hindrances appear when the targeted users are elder people and not technological users who do not feel familiar nor comfortable using computers and devices.

A closed loop interaction with the different users involved in the GiraffPlus system, i.e. primary users, healthcare professional, and relatives, has contributed to the continuous evolution of the integrated system solving the most critical technical problems as well as adapting to the different requirements arisen along the project.