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D1.3 System Reference Architecture

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Deliverable Summary

After a brief overview of the GiraffPlus system, the document relates the user requirements presented in D1.1 deliverable to the three main components of the system namely: Physical environment and Software infrastructure: (WP2: middleware, sensors, and Giraff robot); Intelligent Monitoring and Adaptation Services (WP3: context recognition module and configuration planner); and Data Visualization, Personalization ad Interaction Services (WP4: general data store, personalization module and interaction module). The user requirements are then translated into technical requirements considering the results of the deliverable D1.2. The technical requirements are directing the architectural structure and the development of the system. In accordance with them the following sections present the overall structure of the system and an outline of the components with special emphasis on integration. Security and privacy are then considered and finally compliance with European standards. The document includes also three appendices: a more detailed description of the integration of the Giraff robot in the system, a presentation of possible scenarios for GiraffPlus and a review of related commercial systems and research European projects.

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1 Introduction

1.1 Scope of the document

The document describes the technical requirements of the system, its architecture and its components. The scope of the document is to establish a commonly agreed specification of the system in terms of components, functionalities and interfaces among components that is in agreement with the results of the deliverables D1.1 and D1.2 and the Description of Work for the project. It also gives to all participants of the project a clear view of the complete system and on how the components they develop are integrated and interfaced with the rest of the system.

1.2 Deliverable structure

The document gives first a brief general view of the GiraffPlus system and an example application to introduce the project. A short summary of the GiraffPlus project novelty follows. The core part of the document is the translation of user requirements from D1.1 to technical requirements (section 2) and the description of the system architecture and the modules of the system (section 3). The important aspects of privacy and security and compliance to EU standards are considered in sections 4 and 5. The section about privacy and security is preliminary as further analysis of the system is needed that will be based on the architectural and communication decisions that are documented in this report. Finally three appendices describe: the details of the integration of the Giraff robot in the system; the possible user scenarios that we envision for GiraffPlus; and a summary of related commercial systems and research European projects.

1.3 GiraffPlus system overview

The GiraffPlus system collects daily behaviour and physiological data from distributed sensors, performs context recognition and long-term trend analysis, presents the information via a personalized interface and also supports social interaction between primary users (elderly) and secondary users (formal and informal caregivers). Secondary users can virtually enter the home for a visit or to respond to an event generated by the system. Primary users can also request a virtual visit at any time.

From the perspective of the primary user the most visible component of the system is the Giraff robot that is used to receive calls and initiate calls. The robot is teleoperated by secondary users and can move in the home, talk with the elderly and see the elderly and the home. In the primary user's home there are also a number of sensors that are to the extent possible discreetly placed and not visible. The elderly interacts directly only with a number of physiological sensors, which are selected according to the needs of the primary user.

Secondary users of the systems are family, friends, informal and formal care givers and health professionals. They access the system via a computer. We envision two main kinds of secondary users of the system: the users that connect with the Giraff robot and medical personnel that examine trends of collected data. The first kind of users, besides the ability to communicate with the Giraff robot, can also see significant information about what has happened in the home, for instance activities that the elderly has done and physiological parameters that have been measured. Medical personnel see the information collected off-line and can analyse trends in the data, for instance a decline of physical activities during a longer period of time. The interface to the secondary users can be personalized and the users can select what information they are going to monitor in agreement with the primary users.

An additional feature of the system that was not considered in the original description of work, but that we intend to investigate, is the possibility for the elderly to also see the information elaborated by the system in an interface in the home. We will also investigate if the elderly could have the possibility to see in the interface which secondary users can access the different kind of information.

Finally, the system can also **rise alarms and send warnings** for instance in case of falls or in case of abnormal physiological parameters.

1.3.1 Giraffplus system scenarios

The GiraffPlus system can be used in several situations. We have considered a number of possible scenarios for the system ranging from monitoring the period after de-hospitalization, to daily activity monitoring by an informal caregiver, and monitoring a physiotherapy protocol. In appendix 2 we describe the scenarios that we currently envision for the GiraffPlus system.

To clarify how the GiraffPlus system can act in a real situation, let us summarize one of the scenarios, namely handling the period after de-hospitalization.

One of the recurring problems among the elderly is the handling of de-hospitalization: elderly who are discharged to return home cannot receive the same regular and continuous level of control by the medical staff that they had at the hospital. This can unnecessarily prolong the stay at the hospital with additional cost for health care and additional discomfort for the elderly. The GiraffPlus system can be a means to still check regularly the status of the elderly and directly react in case of deterioration of health. GiraffPlus may support the users in two directions:

- Health monitoring: In this case GiraffPlus would allow monitoring the vital parameters after de-hospitalization, possibly those specifically connected to a given pathology. Moreover, in this case, ensuring a continuous and frequent contact, a doctor could also better assess the need to change and customize the therapy protocol. The aim is to check if a certain therapy or just the post-hospital period proceeds properly and, if necessary, to support a doctor with evidence to the need to change the treatment and or to personally visit the elderly.
- Psychological monitoring: In general the GiraffPlus system can contribute to maintain a continuum with the care and support received in the hospital, also ensuring that the monitoring service is more frequent. Obviously the monitoring service could be a combination of remote (through the tele-presence robot Giraff) and physical assistance (through a real visit).

1.3.2 Novelty of the GiraffPlus project

The main novelty of the GiraffPlus system from the user perspective is the combination of the following: an easy communication tool, including the possibility to see the other person and to move in the environment; the possibility to have meaningful and personalized information about what has happened in the home; the collection and monitoring of physiological parameters, and the rising of alarms and warnings in case of need.
There is a clear need of a system with such functionalities in the western societies where the elderly population is increasing and in fact there is already a market for products of this kind. A large amount of companies have been newly established in most industrialized countries offering monitoring solutions where several parameters are monitored and information is sent via internet and/or mobile phones. In appendix 3 we present a selection of the many solutions currently provided for monitoring elderly in their homes. Most of the solutions use wireless motion or contact sensors on doorways, windows, walls, ceilings, cabinets, refrigerators, appliances or beds to track seniors' movements, and temperature sensors. The systems also generally offer hand-held or wearable "panic buttons." Also Tunstall, one of the companies in GiraffPlus, offers such a solution, ADLife - activities of daily life monitoring solution, that combines an alarm button with alarms given by sensors and monitoring of simple activities of daily living. Most of the sensors that GiraffPlus intends to use are currently used in the ADLife solution. These sensors form a good basis also for the GiraffPlus system and the fact that many commercial systems are currently using it in at home application shows that today the technology is reliable and easy to use. The availability of many commercial solutions also shows a need for monitoring and an acceptance of the technology as a help, confirming our finding with respect of user requirements.
The novelty of the GiraffPlus system with respect of such solutions is that it builds over the level reached by the latter and uses high level reasoning for context recognition, configuration planning and personalization and interaction services. No commercial system is currently available that addresses this aspect.

The novelty of the GiraffPlus system from a research perspective is the development of a system combining sensors and a teleoperated robot with high level reasoning including context recognition, configuration planning and personalization and interaction services. An important aspect that sets GiraffPlus apart from other research projects is the evaluation of the system in real homes for extended periods of time. This requires solutions that are reliable, robust and also

acceptable from the users´ perspectives. In addition the system needs to be perceived as really use-worthy to be used for such a length of time.
In recent years, the EU has funded a number of projects promoting independent living for elderly. The AAL (Ambient Assisted Living) Joint Program is focused exactly on this topic. Several AAL projects address smart homes for the elderly. The ones most related to this project are outlined in appendix 3. The solutions proposed by the AAL projects are based on established technologies. They are developed in a close loop with the users, and the projects are expected to result in commercialization in the near future. However, the solutions tend to be specific for a certain class of illnesses and the scientific novelty can be limited. In many of them, services provided are mostly based in a one to one correspondence between sensors data and actions that the system performs. Conversely, GiraffPlus proposes to focus on changing needs via long term monitoring of complex behaviours and the use of high level reasoning. This will allow the system to recognize and react to more sophisticated human behaviours, and will support the provision of services in response to long-term physiological trends. These capabilities are paramount in early diagnosis and prevention, and constitute what we believe is a key factor for uptake.

The EU has also financed many FP6 and FP7 projects that have some similarities with the GiraffPlus project. A list of projects and how they related to GiraffPlus is presented in Appendix 3. The FP6 and FP7 projects tend to address more general problems with respect to the AAL projects and develop more advanced systems (often including autonomous robots). However, the results of these projects are farther from commercialization, both in terms of technological maturity and in terms of affordability. User evaluations tend to be more limited than those carried out in AAL projects. The GiraffPlus project combines a challenging research development with a thorough evaluation that is similar to the kind of evaluation done in an AAL project. Our effort on evaluating useworthiness is unique and from this point of view, we propose a middle ground between AAL-like user evaluations (which are appropriate for products that have a 2-year time to market) and Framework Programme projects (where user evaluation is focused purely on refining research prototypes). We also advocate a way to introduce the technology that is non-obtrusive and even enjoyable.
Additional projects related to ours are the ones that aim at creating a common platform for AAL, like universAAL on top of which to develop intelligent software applications for the end users. It is our intention to be aligned to the universAAL results, to reuse the Open Source software released by them.

1.3.3 High level structure of the system

To achieve the ambitious goals outlined above the system needs a number of components that are integrated in a well-functioning and robust system. GiraffPlus is an Ambient Intelligence System composed by a telepresence robot and a network of sensors integrated in the system via a middleware and allowing remote access and storage of the data. This part of the system constitutes the physical environment and software infrastructure module. The information collected by the sensors are elaborated, analysed and reasoned about in the monitoring and adaptation services module. Finally the data visualization, personalization and interaction services present the output of the system to secondary users and to the primary user in the home. The secondary users accessing the information are visitor via the Giraff robot and medical personnel reviewing the data in a longer term perspective. Figure 1 illustrates graphically the components of the system. On the left the **Giraff telepresence robot** is shown. The robot uses a Skype-like interface to allow caregivers to virtually visit an elderly person in the home. The Giraff robot is enhanced with semi-autonomy in order to increase safety and ease-of-use. The GiraffPlus system also includes **a network of sensors.** Data from these sensors are processed by an **advanced context recognition system** based on constraint-based reasoning which both detects events on-line and can perform inference about long term behaviours and trends. **Personalized interfaces for primary and secondary users** are developed to access and analyse the information from the context recognition system for different purposes and over different time scales. An important feature of the system is an infrastructure for adding and removing new sensors seamlessly, and to automatically **configure** the system for different services given the available sensors. This is done using planning techniques. These features provide an adaptive support which facilitates timely involvement of caregivers and allows monitoring relevant parameters only when needed.

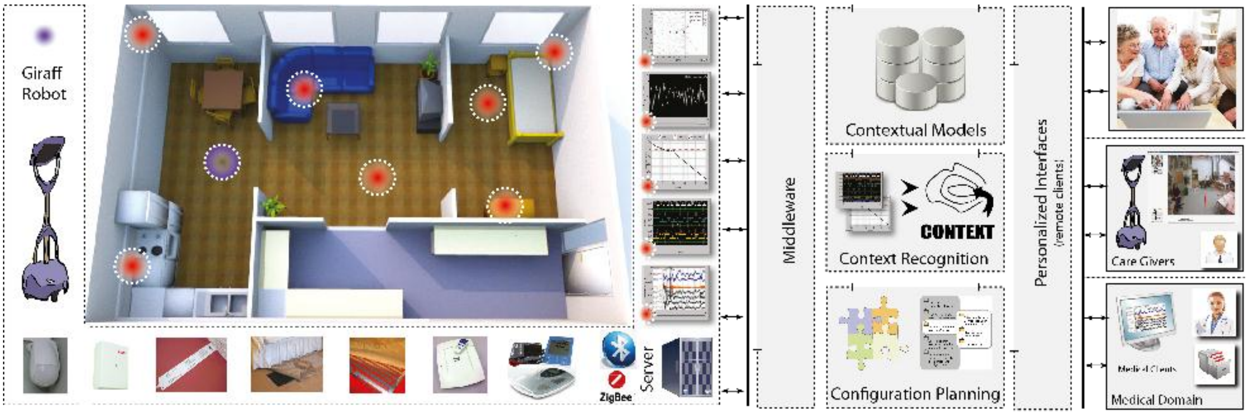

Figure 1 The GiraffPlus structure

The components of the GiraffPlus architecture can be combined in 3 main modules:

1. Physical environment and Software infrastructure: (WP2: middleware, sensors, and Giraff robot)
2. Intelligent Monitoring and Adaptation Services (WP3: context recognition module and configuration planner)
3. Data Visualization, Personalization ad Interaction Services (WP4: general data store, personalization module and interaction module)

In the following sections we consider how the user requirements reported in D1.1 can be translated in technical requirements for each of the modules. In the next section the GiraffPlus architecture is presented and the components in each of the modules are outlined in details with special emphasis on the interfaces among components.

2 Mapping user requirements into technical requirements

In this section the user requirements described in the deliverable D1.1 are translated to technical requirements for the three main modules of the system: Physical environment and Software infrastructure; Intelligent Monitoring and Adaptation Services; and Data Visualization, Personalization ad Interaction Services.
In some cases additional technical requirements are considered that originated in the interaction among part of the system and are not directly related to the user requirements.

2.1 Requirements for physical environment and Software infrastructure

2.1.1 Scope

This module consists of four components: sensor networks, middleware, data storage and Giraff robot. The physical environment of the primary user is sensed and modified by sensor networks and actuators. The middleware abstracts the sensor network as services that will be provided at higher layers (e.g. context recognition) in terms of topics following a publish/subscribe pattern. The data retrieved from sensors and the events triggered by the upper layers will be stored in a data storage system for further and future processing following the same pattern. More details on this module and its components are given in section 3.2.
We first propose a list of user requirements that are strictly related to these components, and that are then mapped into technical requirements for the system in section 2.1.4. In section 2.1.3 we present use cases for the middleware part of the system that generate additional technical requirements for specifically this part of the system that is not directly accessible by users.

2.1.2 User Requirements

The following user requirements have been presented in the D1.1 and are relevant for this part of the system.

Serial/ Ref	***Capability Descriptor***	***Requirement Statement***	***Validation Criteria***	***Priority***
1. Person				
1.a. Physiology Monitoring				
1.a.1	*Monitoring of vital signs*	*GiraffPlus shall monitor vital signs over different day periods for a variable amount of time*	*GiraffPlus provides the capability to measure over time some of the vital signs of the elderly: e.g., heart rate and/or breathing during day and/or night for a certain number of days or weeks*	***K***

1.a.2	*Detecting the presence of body fluids*	*GiraffPlus shall detect the presence of body fluids in different places at home*	*GiraffPlus provides the capability to detect the presence of sweat and/or urine and/or blood on sofas and/or beds*	***D***
1.a.3	*Monitoring blood pressure*	*GiraffPlus shall monitor blood pressure over different day periods for a variable amount of time*	*GiraffPlus provides the capability to monitor the elderly person blood pressure during day and/or night for a certain number of days or weeks (time and frequency of the measurement can be defined)*	***K***
1.a.4	*Monitoring blood glucose levels*	*GiraffPlus shall monitor blood glucose levels (glycemia) over different day periods for a variable amount of time*	*GiraffPlus provides the capability to monitor the elderly person blood glucose levels (glycemia) during day and/or night for a certain number of days or weeks*	***K***
1.a.5	*Monitoring blood oxygen saturation*	*GiraffPlus shall monitor blood oxygen saturation (oximetry) over different day periods for a variable amount of days*	*GiraffPlus provides the capability to monitor the elderly person blood oxygen saturation (oximetry) during day and/or night for a certain number of days/weeks/months*	***K***
1.a.6	*Monitoring body temperature*	*GiraffPlus shall monitor body temperature over different day periods for a variable amount of time*	*GiraffPlus provides the capability to monitor the elderly person body temperature during day and/or night for a certain number of days/weeks/months*	***O***
1.a.7	*Determining whether the person suffers from incontinence*	*GiraffPlus shall help in understanding whether the elderly person suffers from incontinence over different day periods for a variable amount of time*	*GiraffPlus supports the caregiver in understanding whether the elderly person suffers from episodes of incontinence during day and/or night for a certain number of days or weeks*	***D***
1.a.8	*Monitoring body weight*	*GiraffPlus shall monitor body weight over a (variable) period of time*	*GiraffPlus provides the capability to monitor the elderly person body weight during day for a certain number of days/weeks/months (time and frequency of the measurement can be defined)*	***K***

1.a.9	*Monitoring Heart function*	*GiraffPlus shall monitor Heart function over different day periods for a variable amount of time*	*GiraffPlus provides the capability to monitor the elderly person Heart rate during day and/or night for a certain number of days or weeks*	***K***
1.a.10	*Monitoring sleep activity*	*GiraffPlus shall monitor sleep activities over different day periods for a variable amount of time*	*GiraffPlus provides the capability to monitor whether the elderly person is moving a lot while sleeping during day and/or night for a certain number of days or weeks*	***O***

Table 1 Physiological parameters that the users wish to monitor and are relevant to physical environment and software infrastructure

Serial/ Ref	***Capability Descriptor***	***Requirement Statement***	***Validation Criteria***	***Priority***
1. Person				
1.b. Social Interaction Monitoring				
1.b.1	*Facilitating contact between the person and healthcare professionals*	*GiraffPlus shall facilitate the communications between the elderly person and authorized healthcare professionals in different day periods*	*GiraffPlus provides an additional and easy way of communication between the elderly person and healthcare professionals responsible of his/her health status. Communications may occur at different times during the day. The person (or more than one) to communicate with should be authorized and can change.*	***K***
1.b.3	*Facilitating contact between the person and home care assistance*	*GiraffPlus shall facilitate the communications between the elderly person and authorized home care assistant(s) in different day periods*	*GiraffPlus provides an additional and easy way of communication between the elderly person and the home care assistant(s) responsible of his/her health status. Communications may occur at different times during the day*	***K***
1.b.4	*Reminding medications*	*GiraffPlus shall remind important medication events with some time regularity for a variable amount of time*	*GiraffPlus provides the capability to send reminders to the elderly person on the medicine assumption or medications in particular hours of the day and/or night for period of time whose length can be defined*	***K***

1.b.6	*Facilitating contact between the person and family members*	*GiraffPlus shall facilitate the communications between the elderly person and family member(s) in different day periods*	*GiraffPlus provides an additional and easy way of communication between the elderly person and family member(s). Communications may occur at different times during the day*	***D***
1.b.7	*Allowing emergency call*	*GiraffPlus shall enable authorised secondary users to make an emergency call through the tele-presence robot*	*GiraffPlus should allow authorized caregivers to perform an emergency call through the tele-presence robot in order to monitor the status of the elderly person in the house.*	***K***

Table 2 Social communication functionalities that the users wish from the system relevant to physical environment and software infrastructure

Serial/ Ref	***Capability Descriptor***	***Requirement Statement***	***Validation Criteria***	***Priority***
1. Person				
1.c. Activity Monitoring				
1.c.1	*Detecting the position*	*GiraffPlus shall detect the position of the elderly person inside the house over different day periods for a variable amount of time*	*GiraffPlus provides the capability to detect the position of the elderly person inside the house in particular hours of the day and/or night for a certain number of days or weeks*	***K***
1.c.2	*Monitoring the movement*	*GiraffPlus shall monitor the movement inside the house over different day periods for a variable amount of time*	*GiraffPlus provides the capability to monitor the movement of the elderly person in particular hours of the day and/or night for a certain number of days or months*	***K***
1.c.3	*Detecting the absence of movement*	*GiraffPlus shall detect the absence of movement of inside the house over different day periods for a variable amount of time*	*GiraffPlus provides the capability to detect the absence of movement of the elderly person inside the house for a period of time which can be defined.*	***K***

1.c.4	*Temporal monitoring of the position*	*GiraffPlus shall temporally monitor the elderly person's position inside the house*	*GiraffPlus provides the capability to detect how much time the elderly person spends in the bed/kitchen/sitting/etc. for a certain number of days or weeks*	
1.c.5	*Detecting changes of habit*	*GiraffPlus shall provide evidence that helps to detect changes in elderly person's habit in ADL/IADL inside the house for long-term monitoring*	*GiraffPlus provides the capability to monitor changes of habits for long-term monitoring, e.g., the elderly person wakes up too late with respect to usual standard and/or he/she spends more time than usual in personal cleaning*	
1.c.6	*Monitoring of night activities*	*GiraffPlus shall monitor the night activities of the elderly person inside the house over different day periods for a variable amount of time*	*GiraffPlus provides the capability to detect how many times the elderly person gets out of bed to go to a particular place and/or how much time he/she stays there (monitoring for a certain number of days or weeks)*	***D***
1.c.7	*Monitoring cooking ability*	*GiraffPlus shall monitor the cooking activities of the elderly person inside the house for a variable amount of time*	*GiraffPlus provides the capability to gather information that help to monitor the ability of the elderly person to prepare for lunch and/or dinner over a certain number of days or weeks*	***O***
1.c.8	*Monitoring the time spent for preparing lunch*	*GiraffPlus shall monitor the time spent by the elderly person for preparing lunch for a variable amount of time*	*GiraffPlus provides the capability to help understanding the time spent by the elderly person to prepare for lunch for a certain number of days/weeks/months*	***O***
1.c.9	*Monitoring the time spent in different home places*	*GiraffPlus shall monitor the time spent by the elderly person in different places inside the home for a variable amount of time*	*GiraffPlus provides the capability to understand the time spent by the elderly person in the shower and/or bath for a certain number of days or weeks*	***O***

1.c.10	*Monitoring the use of refrigerator at home*	*GiraffPlus shall monitor the frequency with which the refrigerator is opened by the elderly person over different day periods for a variable amount of time*	*GiraffPlus provides the capability to detect the frequency with which the refrigerator is opened by the person for a certain number of days or weeks*	***O***
1.c.11	*Monitoring the social interactions activity*	*GiraffPlus shall monitor the frequency of the social interactions of the elderly person over different day periods for a variable amount of time*	*GiraffPlus provides the capability to detect prolonged periods of time spent by the elderly in complete solitude in the house without contacts with the external world.*	***O***
1.c.12	*Detecting decline in mobility*	*GiraffPlus shall help monitoring a decline in the mobility of the elderly person for a variable amount of time*	*GiraffPlus provides the capability to help understanding whether the elderly person presents difficulty walking and/or difficulty maintaining balance for a certain number of days or weeks*	***K***
1.c.13	*Detecting absence of the elderly person*	*GiraffPlus shall detect the absence of the elderly person in the house during unusual period for a variable amount of time*	*GiraffPlus provides the capability to detect the absence of the elderly person overnight for a certain number of days or weeks*	***K***
1.c.14	*Monitoring the use of home appliances*	*GiraffPlus shall monitor the use of home appliances by the elderly person over different day periods for a variable amount of time*	*GiraffPlus provides the capability to monitor over time the use of the stoves or other appliances by the elderly person in particular hours of the day and/or night for a certain number of days or weeks*	***D***
1.c.15	*Detecting Falls*	*GiraffPlus shall detect whether the elderly person falls inside the house for a variable amount of time*	*GiraffPlus provides the capability to determine whether the person falls to the ground and remains there unable to get up*	***K***

1.c.16	*Monitoring the time spent in bed*	*GiraffPlus shall be able to monitor how much time the elderly person spends in bed over different day periods for a variable amount of time*	*GiraffPlus provides the capability to monitor whether in the morning the elderly person keeps staying in bed and/or whether she/he does not get up*	***K***
1.c.17	*Monitoring person balance*	*GiraffPlus shall help monitoring the elderly person's ability to maintain balance for a variable amount of time*	*GiraffPlus provides the capability to help monitoring the person's ability to maintain a stable standing position for a certain amount of days or weeks*	***K***

Table 3 Activities and situations the users wish are monitored by the system relevant to physical environment and software infrastructure

Serial/ Ref	***Capability Descriptor***	***Requirement Statement***	***Validation Criteria***	***Priority***
2. Environment				
2.a. Home environment				
2.a.1	*Detecting dangerous environmental situations*	*GiraffPlus shall detect potentially dangerous environmental situations*	*GiraffPlus provides the ability to monitor selected home environment factors like: gas leaks and/or risk of fire inside the house*	***K***
2.a.2	*Detecting misplaced objects inside the house*	*GiraffPlus shall detect the presence of misplaced objects inside the house*	*GiraffPlus provides the ability to detect the presence of misplaced objects in the environment that could cause risk of falls*	***K***
2.a.3	*Detecting open doors*	*GiraffPlus shall detect for open doors in the house*	*GiraffPlus provides the ability to detect whether selected doors inside the house are open (or remain open)*	***K***
2.a.5	*Detecting gas leaks*	*GiraffPlus shall detect the presence of gas leaks inside the house*	*GiraffPlus provides the ability to detect the presence of gas leaks inside the house*	***K***
2.a.6	*Monitoring temperature*	*GiraffPlus shall monitor the temperature inside the house*	*GiraffPlus provides the ability to monitor the presence of extreme temperatures (e.g., too hot or too cold) inside the house (too hot and too cold should be defined over time)*	***D***

2.a.7	*Detecting risky situations*	*GiraffPlus shall detect the presence of risky situations inside the house*	*GiraffPlus provides the ability to detect the presence of smoke in the environment potentially risky for the development of fire inside the house or for the elderly health*	***K***
2.a.8	*Detecting water leaks*	*GiraffPlus shall detect the presence of water leaks inside the house*	*GiraffPlus provides the ability to detect water leaks inside the house that may cause flooding and risk of falls*	***K***
2.a.9	*Detecting taps status*	*GiraffPlus shall detect the status of taps inside the house*	*GiraffPlus provides the ability to detect whether taps have been left open inside the house to avoid the risk of spills of water in the floor and, consequently of falls*	***K***

Table 4 Environmental parameters that the users wish the system to detect relevant to physical environment and software infrastructure

Serial/ Ref	***Capability Descriptor***	***Requirement Statement***	***Validation Criteria***	***Priority***
3. Robot				
3.a. Appearance				
3.a.1	*Shapes*	*GiraffPlus shall deploy a tele-presence robot with graceful aspect in the home environment*	*GiraffPlus shall include a tele-presence robot with a nice-to-look aspect*	***D***
3.a.2	*Dimensions*	*GiraffPlus shall deploy a tele-presence robot with suitable size*	*GiraffPlus shall integrate a tele-presence robot with dimensions suitable to be placed in the home environment of the elderly person and to safely navigate within it*	***K***
3.a.3	*Materials*	*GiraffPlus shall include a tele-presence robot made of a suitable material*	*The material of the Giraff robot is positively assessed by the elderly*	***D***
3.a.4	*Colors*	*GiraffPlus shall deploy a tele-presence robot with customizable colors*	*The colors of the Giraff robot can be adapted to the house furniture style*	***D***

3.a.5	*Screen positions*	*GiraffPlus shall deploy a tele-presence robot with adjustable screen position according to the elderly person position*	*GiraffPlus integrates a tele-presence robot capable of adapting the screen at the standing/sitting/lying position of the elderly person*	***K***
3.b. Sounds and Voice				
3.b.1	*Avoid noises*	*GiraffPlus shall deploy a tele-presence robot producing no noise in the home environment of the elderly person*	*GiraffPlus must deploy a tele-presence robot with no noisy engine and/or unpleasant sounds*	***K***
3.b.2	*Adjustable sound settings*	*GiraffPlus shall deploy a tele-presence robot with adjustable sounds settings*	*The voice and sounds setting of the tele-presence robot can be easily adjusted*	***O***
3.b.3	*Voice Controls*	*GiraffPlus shall deploy a tele-presence robot capable of executing voice commands (after receiving voice commands by the elderly person)*	*GiraffPlus integrates a tele-presence robot capable of reaching the charging station or to move to some positions after voice commands by the elderly person*	***O***
3.c. Hardware Configuration				
3.c.1	*Adjustable dimensions*	*GiraffPlus shall deploy a tele-presence robot capable of being physically reconfigured in terms of the height*	*GiraffPlus includes a tele-presence robot that can be adjusted according to the height of the elderly person.*	***K***
3.c.2	*Night Vision*	*GiraffPlus shall deploy a tele-presence robot endowed with a night vision camera*	*GiraffPlus must deploy a tele-presence robot that can be operated also with reduced light conditions in the home environment*	***K***
3.c.3	*Adjustable Screen*	*GiraffPlus shall deploy a tele-presence robot allowing the physical reconfiguration of the screen in terms of the height*	*GiraffPlus must deploy a tele-presence robot capable of adapting the screen at the standing/sitting/lying position of the elderly person*	***K***

3.c.4	*Open to sensors installation*	*GiraffPlus shall deploy a tele-presence robot open to sensors installation*	*GiraffPlus must deploy a tele-presence robot on which some sensors (e.g., a blood pressure assessment device) could be installed*	***O***
3.c.5	*Open to object allocation*	*GiraffPlus shall deploy a tele-presence robot open to object allocation*	*GiraffPlus must deploy a tele-presence robot on which some objects (e.g., a glass or medicine) could be placed*	***D***
3.d. Position in the Home Environment				
3.d.1	*Positions*	*GiraffPlus shall deploy a tele-presence robot suitable to be placed in different rooms in the home environment according to the elderly person preferences*	*The GiraffPlus tele-presence robot can be placed in the room where the elderly person spends the major amount of time during the day*	***K***
3.d.2	*Limitations to mobility*	*The GiraffPlus tele-presence robot shall be allowed to access the rooms in the home environment according to the elderly person preferences*	*The GiraffPlus tele-presence robot must access only the rooms in the home environment in which the elderly person allows its access (e.g., the living room, the kitchen, etc.)*	***K***
3.d.3	*Charging station position*	*The charging station of the GiraffPlus tele-presence robot shall be placed in different place in the home environment according to the elderly person preferences*	*The charging station of the GiraffPlus tele-presence robot can be placed in every place of the house according to the elderly person's preference*	***K***

Table 5 User requirements with respect to teleoperated robot relevant to physical environment and software infrastructure

Serial/ Ref	***Capability Descriptor***	***Requirement Statement***	***Validation Criteria***	***Priority***
5. Overall system				
5.a. Primary user services				
5.a.9	*Obstacle detection*	*GiraffPlus shall deploy a tele-presence robot capable of detecting obstacle in the home environment of the elderly person*	*GiraffPlus must integrate a tele-presence robot capable of navigating the home environment of the elderly person automatically detecting and avoiding obstacle*	***K***
5.b Costs				
5.b.1	*Low cost*	*GiraffPlus shall be a low-cost system*	*GiraffPlus should maintain an affordable cost (to be defined with a specific project activity)*	***K***

Table 6 General user requirement for the system

Serial/ Ref	***Capability Descriptor***	***Requirement Statement***	***Validation Criteria***	***Priority***
4. Sensors				
4.a. Appearance				
4.a.1	*Shapes*	*GiraffPlus shall provide sensors with graceful aspect*	*GiraffPlus must include sensors with a nice-to-look aspect (e.g., that appear as ornaments)*	***D***
4.a.2	*Dimensions*	*GiraffPlus shall deploy sensors with reduced dimensions*	*GiraffPlus must deploy sensors with dimensions suitable to be placed in the home environment of the elderly person*	***D***
4.a.3	*Materials*	*GiraffPlus shall deploy sensors with suitable materials*	*GiraffPlus integrates sensors the material of which is positively assessed by elderly people.*	***D***
4.a.4	*Colors*	*GiraffPlus shall deploy sensors with different colors*	*GiraffPlus integrates sensors with colors that can be well integrated with the house furniture style*	***D***

4.b. Integration in the home environment				
4.b.1	*Aspects*	*GiraffPlus shall provide sensors to be gracefully integrated within the home environment of the elderly person*	*GiraffPlus must provide sensors that elderly judge nice to see and with nice colors*	***K***
4.b.2	*Positions*	*GiraffPlus shall provide sensors suitable for installation in different home environment positions according to the elderly person preferences*	*GiraffPlus must provide sensors that can be installed in different home environment positions, e.g., avoiding some rooms for privacy reasons*	***D***
4.b.3	*Limited numbers*	*GiraffPlus shall provide a limited number of sensors to be installed in the home environment according to the elderly person preferences*	*GiraffPlus can be installed with a minimum number of sensors which is decided by the users in accordance with the specific monitoring needs (ability of customization)*	***K***
4.b.4	*Sensors camouflage*	*GiraffPlus shall provide the possibility to camouflage sensors according to the elderly person preferences*	*GiraffPlus must provide the possibility to camouflage sensors as part of the ornament in the home environment*	***K***
4.b.5	*Attached to the robot*	*GiraffPlus shall provide the possibility to attach sensors to the robot*	*GiraffPlus must provide sensors that could be attached to the robot, e.g., blood pressure assessment device*	***O***

Table 7 User requirements with respect to sensors relevant to physical environment and software infrastructure

As expected many of the user requirements in D1.1 are related to this part of the system. In fact, the users have many expectations with respect to the Giraff robot that is the most visible component of the system. Also the presentation of physiological parameters and the recognition of activities required by the users are based on the availability of sensor data and therefore depend on this part of the system. The users have also several requirements regarding the sensors themselves.

In the following section we consider use cases that are related to the middleware part of the system and give additional requirements to the system. The section on technical requirements then summarizes all requirements in a tabular form.

2.1.3 Detailed Use Cases

In the following, the use cases for the physical environment and software infrastructure related to the middleware are presented. The actors are other services of the system or the devices themselves.

The main actors considered in the diagrams are:

- **Sensor Network**: Representing the group of specialized transducers with a communications infrastructure intended to monitor and record the conditions of the physical environment.
- **Giraff System**: Representing the Giraff robot, the devices attached to it and the software modules installed on it.
- **Data Storage System**: Representing the database that stores the sensed data and activities, together with its management software components.
- **Data Visualization, Personalization and Interaction Services**: Representing the part of the architecture responsible for creating user-oriented and personalized services
- **Intelligent Monitoring and Adaptation Service**: Representing the context recognition and configuration planning services.

In the following we consider several use case diagrams and at the end of the section we present the overall use case diagram.

2.1.3.1 Publish Sensor and Activity Data

In Figure 2 the use case diagram for publishing the sensor and activity data is depicted. Any kind of event or change of state sensed by the sensor networks in the environment has to be published to the system and made available to other components. The middleware offers this possibility abstracting the sensors as topics. Potentially the Giraff robot could also offer the possibility to carry sensors, in this way becoming an actor that publishes the sensed data.

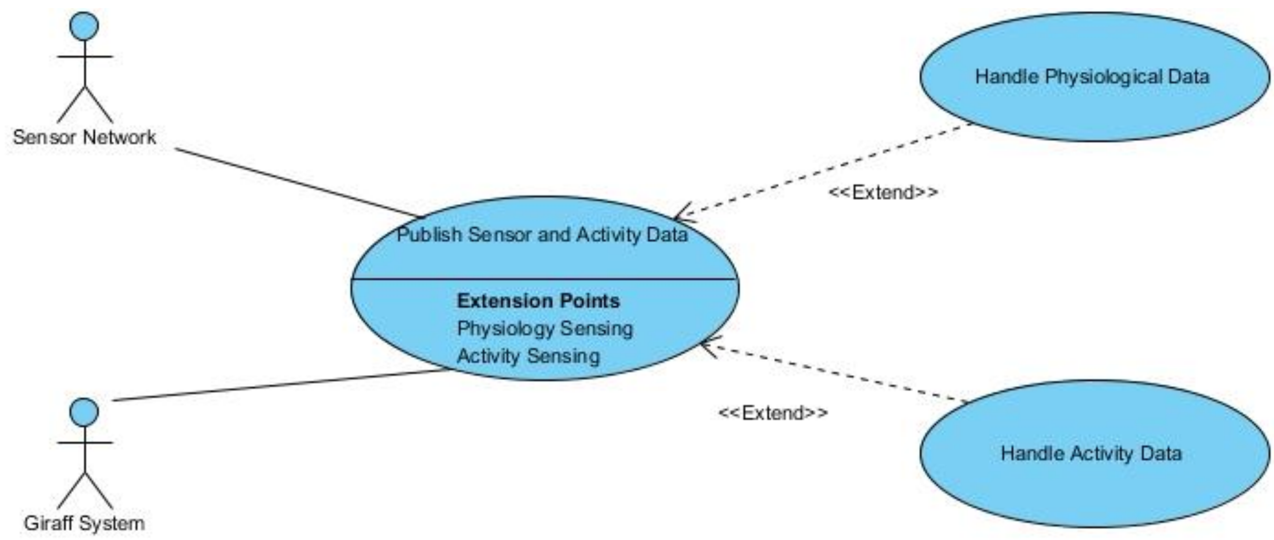

Figure 2 Publish Sensor and Activity Data.

2.1.3.2 Subscribe to Sensors Topics

In Figure 3 the use case diagram for subscribing to the topics representing the sensors deployed in the environment is depicted. The data storage system, data visualization service, personalization service, intelligent monitoring and adaptation service are actors that have to subscribe to the topic representing the sensors in order to monitor and receive in real time the sensed data and the changes on the sensor status. The data storage system has to subscribe to the sensors topics in order to maintain historical sensor data and historical activity data. This use case is depicted in Figure 3.

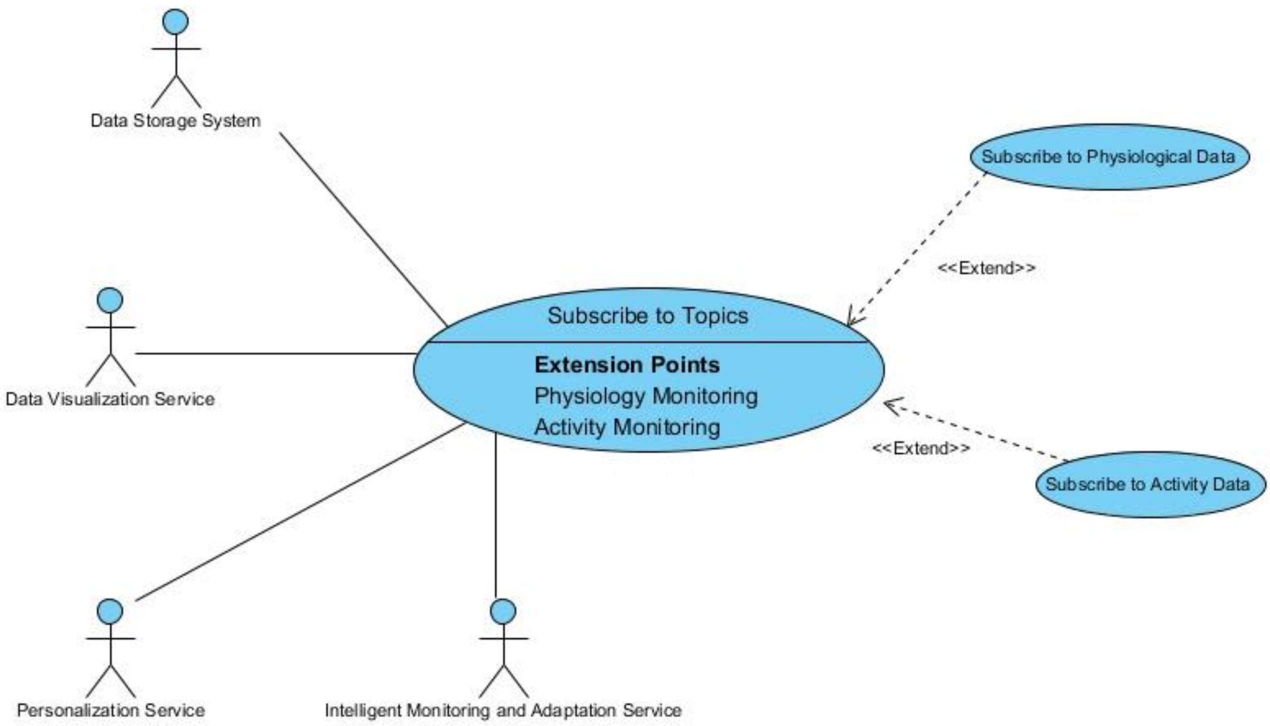

Figure 3 Subscribe to Sensors Topics.

2.1.3.3 Configure Sensors

In addition to the publish/subscribe feature, the software infrastructure has to be able to export the properties of the sensors and actuators present in the environment. This capability must offer a set of methods to allow the intelligent monitoring and adaptation service to configure properly the sensors and to send commands to change the status of the sensors and actuators. This use case is depicted in Figure 4.

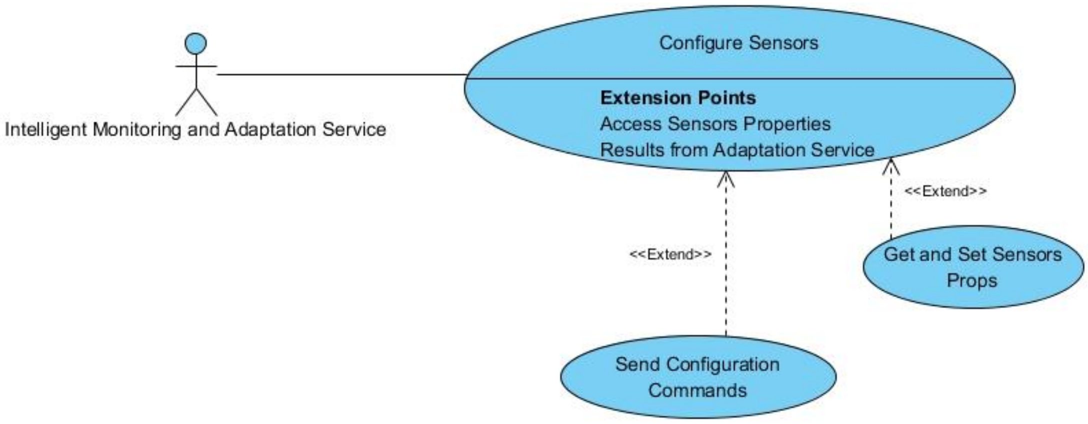

Figure 4 Configure Sensors

2.1.3.4 Invoke Commands

The middleware shall provide the functionality to send commands to the actuators present in the environments. This use case is shown in the overall use case diagram (see Figure 5).

2.1.3.5 Publish events

The intelligent monitoring and adaptation service should be able to publish events for the exchange of sharable info about changes in the system and its environment, and to inform an interested subscriber that the event has happened in the context of its run-time environment. This use case is shown in the overall use case diagram.

2.1.3.6 Overall Use Case Diagram

Figure 5 represents the overall use case diagram of the physical environment and software infrastructure with respect to the middleware.

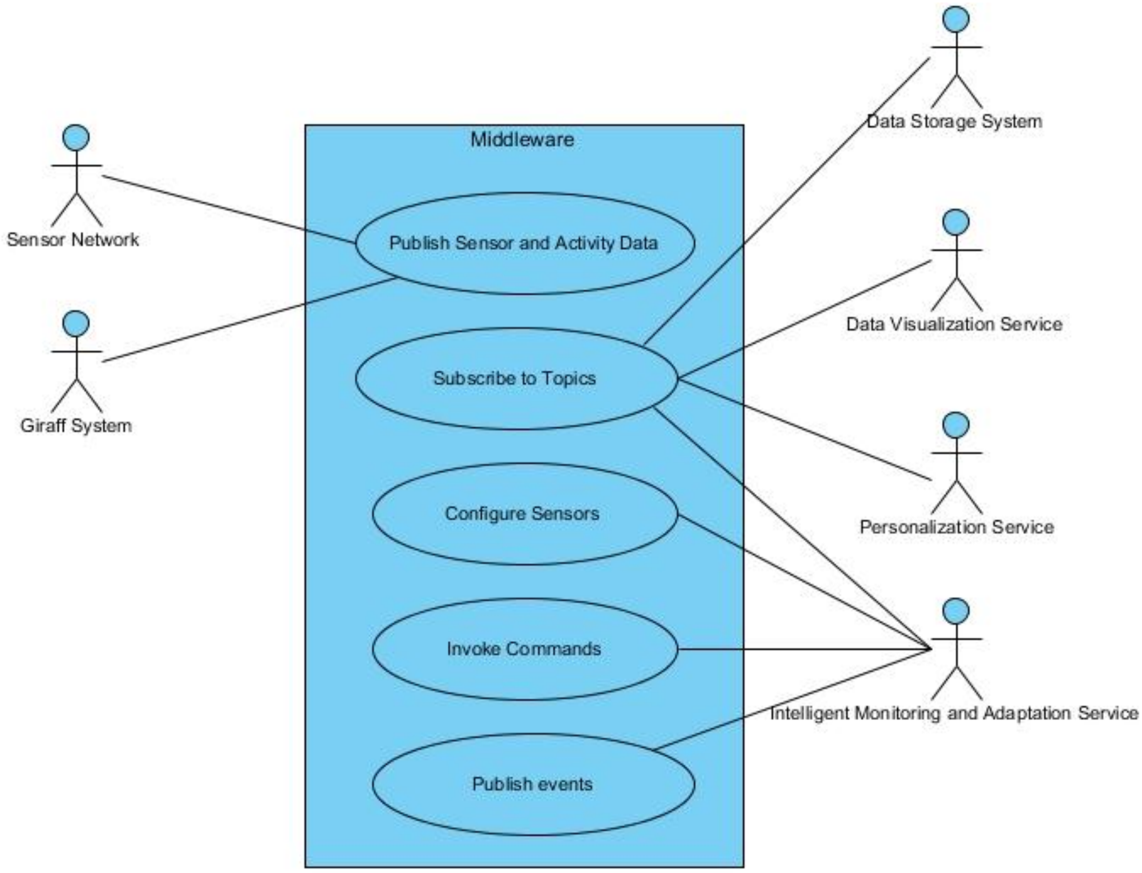

Figure 5 The Software Infrastructure Use Case.

2.1.4 Technical Requirements

In the following section we consider all the technical requirements related to this part of the system. We first consider the requirements related to the middleware and then the technical requirement related to user requirements.

With respect to user requirements all physiological parameters and social communication functionalities of the user requirement list are translated to technical requirements. With respect to activity recognition, we select most of the one present in the user requirements with the exception of monitoring cooking ability and social interactions, both considered optional by the users. Regarding environmental parameters we select all besides detecting misplaced objects. This is considered a key requirement; however it is outside the scope of this project as it would imply major changes in the hardware and software components of the system to allow the recognition of objects. Moreover a system that can recognize objects could also potentially “see” the person possibly decreasing the acceptance of the system from the users due to privacy concerns.

2.1.4.1 Middleware

According to the use cases presented in the previous section, the physical environment and software Infrastructure module presents the following technical requirements with respect to the middleware. These technical requirements are not directly related to user requirements, but are needed for the system overall.

TR ID	***Description***	***Priority***
4.01	*The Middleware shall be able to abstract the devices present in the environment in order to easily access their properties and infer useful information from them.*	***K***
4.02	*The Middleware shall be able to provide the possibility to access the properties of the sensors and actuators present in the environment in order to configure properly the environment.*	***K***
4.03	*The Middleware shall be able to provide a subscription mechanism to other modules in order be updated on the status of the sensors.*	***K***
4.04	*The Middleware shall be able to provide a publishing mechanism to other modules in order to let them publish the results of their activity.*	***K***

Table 8 Technical requirements for the middleware

We intend to satisfy all the technical requirements listed above during the course of the project.

2.1.4.2 Sensors

In the table below the sensors that are used in the project are presented in accordance with the choices made regarding user requirements and the information in D1.2 about what sensors are needed for fulfilling the user requirements.

TR ID	***Description***	***Provider***	***UR ID***	***Priority***
4.05	*Blood pressure monitor*	*Intellicare*	*1.a.1* *1.a.3*	***K***
4.06	*Glucose meter*	*Intellicare*	*1.a.4*	***K***
4.07	*Detection of body fluid sensors*	*Tunstall*	*1.a.2* *1.a.7*	***D***
4.08	*Blood oxygen saturation monitoring*	*Intellicare*	*1.a.5*	***K***
4.09	*Thermometer*	*Intellicare*	*1.a.6*	***O***
4.10	*Scale*	*Intellicare*	*1.a.8*	***O***

4.11	*Pulse oximeter*	*Intellicare*	*1.a.9*	***K***
4.12	*Zenicor system ECG*	*Zenicor*	*1.a.10*	***O***
4.13	*Bed/Chair Occupancy Sensor*	*Tunstall*	*1.c.1* *1.c.5* *1.c.6* *1.c.16*	***K***
4.14	*FAST Passive InfraRed motion detector*	*Tunstall*	*1.c.1* *1.c.2* *1.c.3* *1.c.4* *1.c.5* *1.c.6* *1.c.9* *1.c.12* *1.c.13*	***K***
4.15	*Door usage*	*Tunstall*	*1.c.5* *1.c.7* *1.c.8* *1.c.10* *2.a.3*	***O***
4.16	*Electrical Usage Sensor*	*Tunstall*	*1.c.5* *1.c.7* *1.c.8* *1.c.14*	***D***
4.17	*Fall sensor*	*Tunstall*	*1.c.15*	***K***

4.18	*Carbon Monoxide Detector (wireless)* *Telecare Flood detector* *Gas shut off valve* *Natural gas detector* *Smoke detector (wireless)* *Heat Detector* *Temperature extremes sensor*	*Tunstall*	*2.a.1* *2.a.5* *2.a.6* *2.a.7*	***K***
4.19	*Medication dispenser*	*Tunstall*	*1.b.4*	***K***
4.20	*Sensor for balance*	*Body worn inertia sensors available as research prototypes*	*1.c.17*	***K***
4.21	*Detector at lights*	*Photo detectors common available*	*2.a.4*	***K***
4.22	*Detector at taps and flood detector*	*Tunstall*	*2.a.8* *2.a.9*	***K***
4.23	*Sensor at main door to see who enters and exit*	*Cameras commonly available*	*1.c.13* *1.c.11*	***O***

Table 9 Sensors needed in the system related to user requirements and sensor provider

The majority of the sensors listed are from the partners of the project Intellicare and Tunstall and are therefore available. Other sensors like photo detectors are commonly available. Regarding the sensors for balance and ECG, the possibility to use them will need to be investigated in case they will be considered essential in the project and it will be decided to include them in the system. Notice that regarding requirement 4.23 using cameras could raise privacy issues, as it is an optional requirement we will carefully consider if to include it in the system or not.
According to the user requirements additional properties are important for sensors in general. Such properties are specified below in additional technical requirements.

TR ID	***Description***	***UR ID***	***Priority***
4.24	*The appearance of the sensors in term of shapes, dimensions, materials, and colors should be to the extent possible nice-to-look (e.g., appear as ornaments), suitable to be placed in the home environment of the elderly person, with colors that can be well integrated with the house furniture style and of material which is positively assessed by elderly people. The sensors should also have a low cost.*	*4.a.1* *4.a.2* *4.a.3* *4.a.4* *4.b.1* *5.b.1*	***D***
4.25	*Sensors should be installed only in specific home environment positions, e.g., avoiding some rooms for privacy reasons*	*4.b.2*	***D***

4.26	*It should be possible to install the system with a minimum number of sensors which is decided by the users in accordance with the specific monitoring needs (ability of customization)*	*4.b.3*	***K***
4.27	*To the extent that is feasible the possibility to camouflage sensors as part of the ornament in the home environment should be provided*	*4.b.4*	***K***
4.28	*To the extent that is feasible sensors that could be carried by the robot can be provided, e.g., blood pressure assessment device*	*4.b.5*	***O***

Table 10 General technical requirements for the sensors

Regarding requirement 4.23 and 4.27 we will try to satisfy them in the project however as the project does not develop its own sensors we are limited by what is available in the market.
Regarding the requirements on position and number of sensors we will satisfy them in the project.
Requirement 4.28 is optional and will not be prioritized in the project.

2.1.4.3 Giraff robot

The teleoperated mobile Giraff robot allows users to visit the assisted person in his/her home via an embodied robotic presence through which the visitor can communicate and at the same time move about in the environment. The Giraff robot is placed in the home of the elderly and is used to connect to healthcare professionals as well as family members. The Giraff robot is supported and developed by a Swedish SME, Giraff Technologies AB. It consists of a screen and web camera, speaker and microphone mounted on a simple robotic base that can be teleoperated. The camera and screen is a pan-tilt unit which enables a greater and controllable field of view, while the height of the unit is easily adjustable.
The user requirements related to social communication (1.b.1, 1.b.3, 1.b.6, 1.b.7) are already satisfied by the Giraff platform.
Several hardware and software changes to the current Giraff telepresence device and system are required to meet the other user requirements described above. Changes to the physical appearance including the base dimensions are the most challenging. The consortium will continue to make design tradeoffs between desired features, time and expense as the project progresses. In the table below we first define the technical requirements for the Giraff robot and then give also some estimation of feasibility.

TR ID	***Description***	***UR ID***	***Priority***
4.29	*Automatic height adjustment: Required to provide important "social cues" such as sitting at a table or being at the bedside.*	*3.a.5* *3.c.1* *3.c.3*	***K***
4.30	*Light for night navigation: Required when a visitor must navigate in the dark, such as a night visit.*	*3.c.2*	***K***

4.31	*Different product ID: Users have expressed desire for different physical appearances, including shape, color and size (specifically, a smaller base).*	*3.a.1* *3.a.2* *3.a.3* *3.a.4*	***D***
4.32	*Sound and voice: the Giraff robot should not produce noise and the sound should be adjustable. The robot can be controlled by voice.*	*3.b.1* *3.b.2* *3.b.3*	***O***
4.33	*Open to sensors installation and object allocation*	*3.c.4* *3.c.5*	***O***
4.34	*Position in the home environment: the Giraff robot and the charging station can be placed in any room of the home. The elderly can decide the rooms accessible to the robot*	*3.d.1* *3.d.2* *3.d.3*	***K***
4.35	*Touch screen: A user screen for greater resident interaction has been indicated as important.*	*5.a.1*	***K***
4.36	*Auto-navigation*	*5.a.9*	***K***
4.37	*The Giraff robot needs to be integrated with the GiraffPlus system*		
4.38	*The Giraff robot needs to be integrated with other applications*		
4.39	*The Giraff platform should maintain a low cost*	*5.b.1*	***K***

Table 11 Technical requirements for the Giraff robot

Regarding the requirements to adjust automatically the height of the Giraff neck and adding a light for night navigation, these enhancements are feasible. The first is in the current development plan for the robot. The second is not in the current Giraff+ development plan but could be added if the initial trials prove its importance.

Regarding the different product ID, the color of the plastics is relatively easy to change if the new color can be agreed upon. It is possible that changing the color to a “warmer home” color could satisfy most of the user concerns about appearance. Changes in physical appearance are possible but more difficult; also there is needed a clear definition of what changes are wished. Reducing the base size is difficult because it will de-stabilize the device vertically, especially during acceleration and deceleration, or going over a door threshold.

The Giraff robot is already relatively silent when it navigates and latest design features reduced noise via software control of the motherboard fan. The audio volume is already adjustable. Voice control of the robot is possible through software but can be unreliable; therefore we do not expect to be able to implement this change in the course of the project.

The requirement that the robot should be open to sensors installation and object allocation could be satisfied, but it depends on the specific sensors and objects. Specifically, there are USB ports available for attachment of devices, and the robot also has WiFi connections available in all bands at 2.4 and 5 GHz. As this is an optional requirement, we will not prioritize this aspect in the project.
The position in the home environment of the Giraff robot and the charging station can be clearly decided by the user and the elderly can decide the rooms accessible to the robot.
A touch screen for greater resident interaction is possible to include and the hardware modification is relatively easy but this obviously implies new applications running on the Giraff device itself, which would have to be defined and developed.
Auto-navigation is a core aspect of the project and will be implemented. Changes to the current Giraff software are required to allow other applications or navigation commands to assume control of the serial port that control the motors via an API. This is in the current Giraff robot development plan.
The technical requirements 4.37, 4.38 are related to the integration with the system and not to specific user requirements. The Giraff system (Giraff, Pilot and Sentry) will have to interface with the Giraff+ system for certain operations including making a call/visit to the Giraff. The requirements for this interaction are defined in this document. The evolving Giraff+ requirements may require other applications to be run on the Giraff, such as interfacing to other devices via Bluetooth, or auto-navigation routines based on localize mapping. While the applications can be developed independently of the Giraff system they must be integrated with the Giraff. While it is not possible to scope this requirement without defining these applications, the need to integrate other applications is comprehended in the overall GiraffPlus development plan and the Giraff software architecture will be modified to accommodate these applications. The architecture is described in this document.
It is clearly an aim of the project to keep the cost of the system low to promote the commercialization of the system. There is some opportunity for reducing costs in the current design; however, volume production is required for any significant improvements.

2.2 Requirements for Intelligent Monitoring and Adaptation Services

2.2.1 Scope

The intelligent monitoring and adaptation services consist of two components: context recognition and configuration planning. The former processes data from the sensor network in order to infer higher-level activities; the latter adapt the sensor network by setting up subscriptions in order to supply the former with the data it needs. The context recognition component represents data and activities in a time-line (stored in a database), which can be accessed by the data visualisation services (see 4.3). The personalization services (see 4.3) can select what activities to infer and what inference rules to employ.

2.2.2 User Requirements

The following user requirements have been presented in the D1.1 and are relevant for this part of the system.

Serial/ Ref	*Capability Descriptor*	*Requirement Statement*	*Validation Criteria*
1. Person			
1.a. Physiology Monitoring			
1.a.7	*Determining whether the person suffers from incontinence*	*GiraffPlus shall help in understanding whether the elderly person suffers from incontinence over different day periods for a variable amount of time*	*GiraffPlus supports the caregiver in understanding whether the elderly person suffers from episodes of incontinence during day and/or night for a certain number of days or weeks*
1.a.10	*Monitoring sleep activity*	*GiraffPlus shall monitor sleep activities over different day periods for a variable amount of time*	*GiraffPlus provides the capability to monitor whether the elderly person is moving a lot while sleeping during day and/or night for a certain number of days or weeks*

Table 12 Physiological parameters that the users wish to monitor relevant to intelligent monitoring and adaptation services

Serial/ Ref	*Capability Descriptor*	*Requirement Statement*	*Validation Criteria*
1. Person			
1.c. Activity Monitoring			
1.c.1	*Detecting the position*	*GiraffPlus shall detect the position of the elderly person inside the house over different day periods for a variable amount of time*	*GiraffPlus provides the capability to detect the position of the elderly person inside the house in particular hours of the day and/or night for a certain number of days or weeks*
1.c.2	*Monitoring the movement*	*GiraffPlus shall monitor the movement inside the house over different day periods for a variable amount of time*	*GiraffPlus provides the capability to monitor the movement of the elderly person in particular hours of the day and/or night for a certain number of days or months*

1.c.3	*Detecting the absence of movement*	*GiraffPlus shall detect the absence of movement of inside the house over different day periods for a variable amount of time*	*GiraffPlus provides the capability to detect the absence of movement of the elderly person inside the house for a period of time which can be defined.*
1.c.4	*Temporal monitoring of the position*	*GiraffPlus shall temporally monitor the elderly person's position inside the house*	*GiraffPlus provides the capability to detect how much time the elderly person spends in the bed/kitchen/sitting/etc. for a certain number of days or weeks*
1.c.6	*Monitoring of night activities*	*GiraffPlus shall monitor the night activities of the elderly person inside the house over different day periods for a variable amount of time*	*GiraffPlus provides the capability to detect how many times the elderly person gets out of bed to go to a particular place and/or how much time he/she stays there (monitoring for a certain number of days or weeks)*
1.c.7	*Monitoring cooking ability*	*GiraffPlus shall monitor the cooking activities of the elderly person inside the house for a variable amount of time*	*GiraffPlus provides the capability to gather information that help to monitor the ability of the elderly person to prepare for lunch and/or dinner over a certain number of days or weeks*
1.c.8	*Monitoring the time spent for preparing lunch*	*GiraffPlus shall monitor the time spent by the elderly person for preparing lunch for a variable amount of time*	*GiraffPlus provides the capability to help understanding the time spent by the elderly person to prepare for lunch for a certain number of days/weeks/months*
1.c.9	*Monitoring the time spent in different home places*	*GiraffPlus shall monitor the time spent by the elderly person in different places inside the home for a variable amount of time*	*GiraffPlus provides the capability to understand the time spent by the elderly person in the shower and/or bath for a certain number of days or weeks*
1.c.10	*Monitoring the use of refrigerator at home*	*GiraffPlus shall monitor the frequency with which the refrigerator is opened by the elderly person over different day periods for a variable amount of time*	*GiraffPlus provides the capability to detect the frequency with which the refrigerator is opened by the person for a certain number of days or weeks*

1.c.11	*Monitoring the social interactions activity*	*GiraffPlus shall monitor the frequency of the social interactions of the elderly person over different day periods for a variable amount of time*	*GiraffPlus provides the capability to detect prolonged periods of time spent by the elderly in complete solitude in the house without contacts with the external world.*
1.c.12	*Detecting decline in mobility*	*GiraffPlus shall help monitoring a decline in the mobility of the elderly person for a variable amount of time*	*GiraffPlus provides the capability to help understanding whether the elderly person presents difficulty walking and/or difficulty maintaining balance for a certain number of days or weeks*
1.c.13	*Detecting absence of the elderly person*	*GiraffPlus shall detect the absence of the elderly person in the house during unusual period for a variable amount of time*	*GiraffPlus provides the capability to detect the absence of the elderly person overnight for a certain number of days or weeks*
1.c.14	*Monitoring the use of home appliances*	*GiraffPlus shall monitor the use of home appliances by the elderly person over different day periods for a variable amount of time*	*GiraffPlus provides the capability to monitor over time the use of the stoves or other appliances by the elderly person in particular hours of the day and/or night for a certain number of days or weeks*
1.c.15	*Detecting Falls*	*GiraffPlus shall detect whether the elderly person falls inside the house for a variable amount of time*	*GiraffPlus provides the capability to determine whether the person falls to the ground and remains there unable to get up*
1.c.16	*Monitoring the time spent in bed*	*GiraffPlus shall be able to monitor how much time the elderly person spends in bed over different day periods for a variable amount of time*	*GiraffPlus provides the capability to monitor whether in the morning the elderly person keeps staying in bed and/or whether she/he does not get up*
1.c.17	*Monitoring person balance*	*GiraffPlus shall help monitoring the elderly person's ability to maintain balance for a variable amount of time*	*GiraffPlus provides the capability to help monitoring the person's ability to maintain a stable standing position for a certain amount of days or weeks*

Table 13 activities and situations the users wish are monitored by the system relevant to intelligent monitoring and adaptation services

2.2.3 Detailed Use Case

The use cases described in the following are based on request from secondary users conveyed through the personalization services. We see as actors the combination of a human user and the personalization services. Figure 6 describes the uses cases. A number of use cases can be derived from the user requirements above, but they all follow the same pattern and for brevity we only list a small subset of them (those derived from 1.a.10 “monitor sleep”, 1.a.7 “monitor incontinence”, and 1.c.1 “detect position”). The rest of the use cases are analogous. The sequence of activities of these “Personalization + user” use cases is shown in Figure 7. For completeness, we also include the activity of displaying the stored timeline data, although strictly speaking that belongs to the visualisation services.

It is important that the system is adaptable, both in terms of services and in terms of available sensors. Therefore, we also include the following use cases (Figure 6) which are not explicitly mentioned in the user requirements:

- The user can request monitoring of some novel activity, which can be monitored with the available sensors but which requires the addition of some new inference rule to the activity recognition.
- A technician can add a new sensor, which is detected by the sensor network. The technician also needs to provide information to the configuration planner about what kind of sensor it is and the context in which it is used (e.g. location).
- A technician can remove a sensor, which is detected by the sensor network. The configuration planner should be informed by the sensor network that this sensor no longer is available.
- A sensor can malfunction, which is detected by the sensor network. The configuration planner should be informed by the sensor network that this sensor no longer is available.

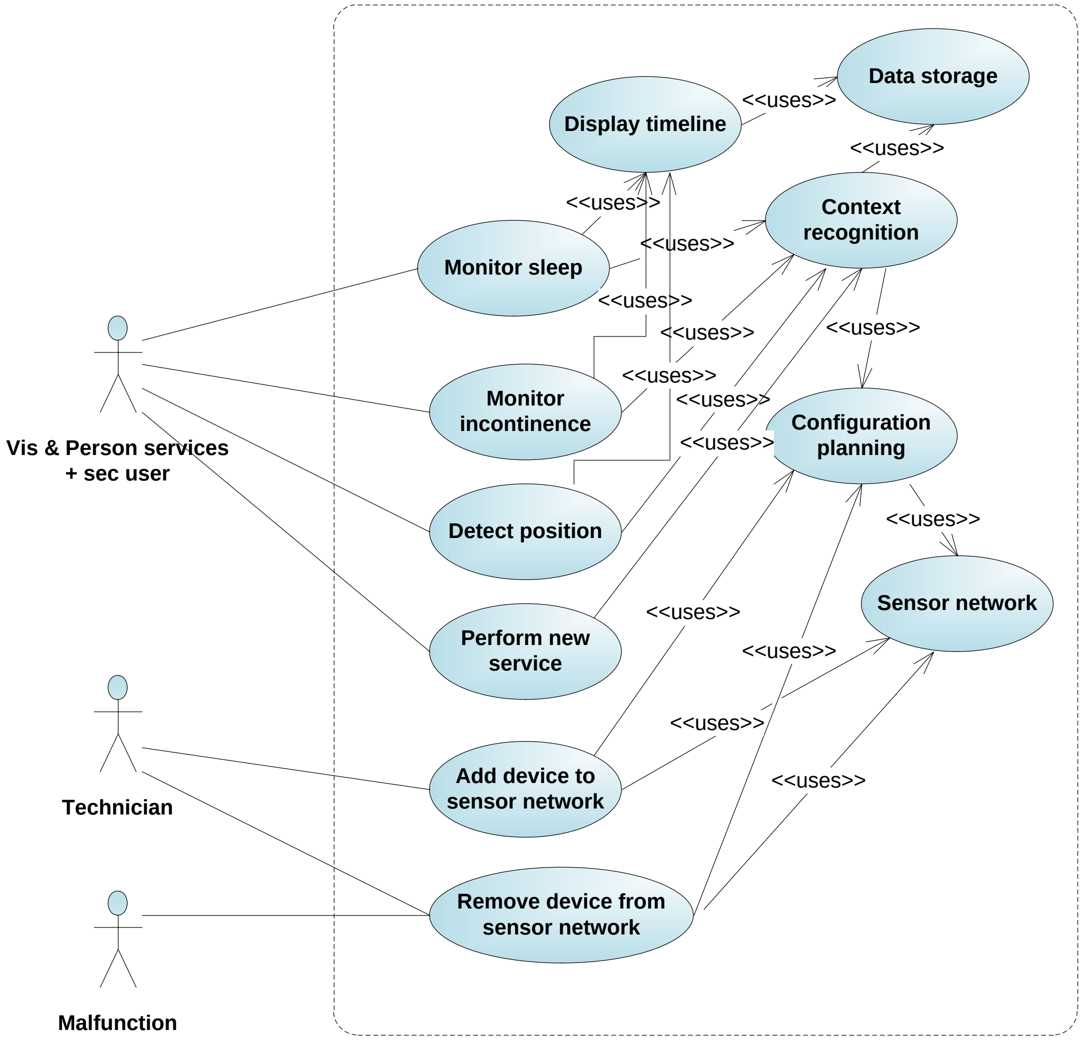

Figure 6 Use cases for Intelligent Monitoring and Adaptation Services

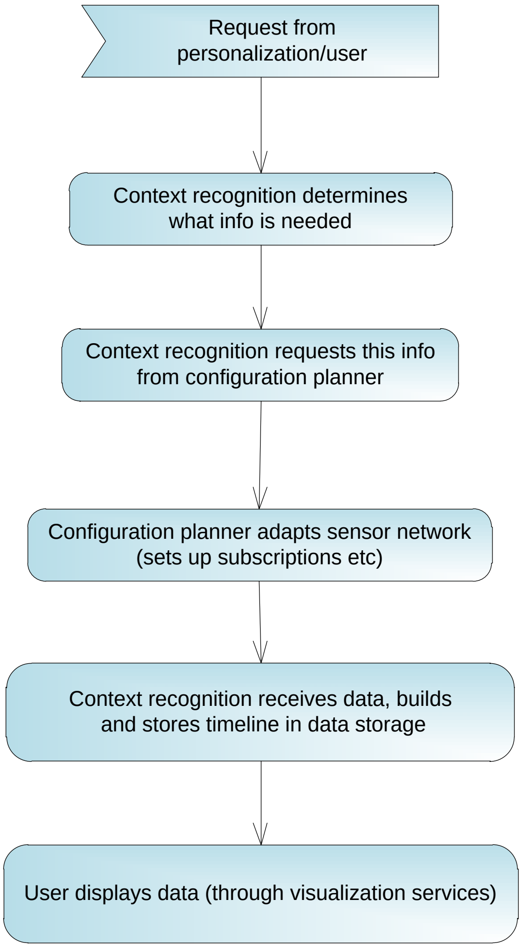

Figure 7 Activities in "visualisation/personalization and user" use cases

2.2.4 Technical Requirements

According to the above use cases, the Intelligent Monitoring and Adaptation Services module presents the following technical requirements (Table 14). Among the activity monitoring functionalities we translate to technical requirements all user requirements besides monitoring the social interactions activity (1.c.11) as it is considered optional and is not clear how to implement it.

TR ID	***Description***	***UR ID***	***Priority***
4.29	*The Intelligent Monitoring and Adaptation service shall be able to interpret sensors data from body fluid, fall and balance sensors in time and give an assessment whether the person suffers from incontinence, has difficulties with balance, has fallen and/or moved and store this data as part of a time line in a database.* *Parts of the sensor interpretation (before context inference) will be done by dedicated processes started by the configuration planner.*	*1.a.7* *1.c.12* *1.b.15* *1.b.17*	***K***

4.30	*The Intelligent Monitoring and Adaptation service shall be able to interpret sensors data about bed/chair occupancy, motion, door opening, and light in time and give an assessment about sleep and night activity and store this data as part of a time line in a database.* *Parts of the sensor interpretation (before context inference) will be done by dedicated processes started by the configuration planner.*	*1.a.10* *1.c.6*	***K***
4.31	*The Intelligent Monitoring and Adaptation service shall be able to interpret sensors data about bed/chair occupancy, motion, door opening, and light in time and give an assessment about the position of the person and the movement in the home in particular temporal monitoring of the position, detecting the absence of movement, monitoring the time spent in different home places including time spent in bed and detecting the absence of the elderly person.* *It shall be able store this data as part of a time line in a database.* *Parts of the sensor interpretation (before context inference) will be done by dedicated processes started by the configuration planner.*	*1.c.1* *1.c.2* *1.c.3* *1.c.4* *1.c.9* *1.c.16* *1.c.13*	***K***
4.32	*The Intelligent Monitoring and Adaptation service shall be able to give an assessment about habits, based on sensor data from bed/chair occupancy, motion, door opening, light and electrical usage sensors.* *It shall be able store this data as part of a time line in a database.*	*1.c.5*	***O***
4.33	*The Intelligent Monitoring and Adaptation service shall be able to give an assessment about cooking and eating based on sensor data from bed/chair occupancy, motion, door opening, light and electrical usage sensors.* *It shall be able store this data as part of a time line in a database.*	*1.c.7* *1.c.8* *1.c.10* *1.c.14*	***O***
4.34	*The configuration planner shall be able to obtain information from the sensor network about the available sensors and their positions.*	*Extra*	
4.35	*The configuration planner shall be able to obtain information from the sensor network about added or removed/malfunctioning sensors, and take this information into account while processing requests from context interaction and (in the case of removal) update any running configuration that is affected.*	*Extra*	

Table 14 Technical requirements for intelligent monitoring and adaptation services

We have the intention to satisfy all the technical requirements listed above.

Some additional technical requirements are common to all use cases:

- Data flows from sensors can be directed (using the middleware subscription mechanism) to the context recognition system, possibly via intermediary processing.
- The configuration planning system has access to semantic information regarding the location and other important properties of the sensors in the sensor network.
- The context recognition component can store timeline data in the database.
- The required sensors should be available in the sensor network.

In addition, the following requirements follow from the “Technician” and “Malfunction” user cases:

- Devices (sensors, actuators) can be added to or removed from the sensor network.
- Malfunctioning sensors can be detected by the sensor network.

2.3 Requirements for Data Visualization, Personalization and Interaction Services

2.3.1 Scope

The **Data Visualization, Personalization and Interaction Service** is the part of the architecture responsible for creating user-oriented and personalized services. More specifically, the module provides to the different end-users suitable interaction modalities and specific intelligent services.

- The module can be broadly described as constituted by a Front-End, i.e., an ***Interaction Service*** in charge of providing all the human users with basic GiraffPlus interfaces and a Back-end responsible for providing intelligent services and personalization capabilities. The back end in turn is composed of the **User Oriented Services** module and **Personalization Services** module. The former is responsible for providing some proactive/reasoning services to the users, while the latter is in charge of maintaining users´ *profiles* so as to tailor both services and interaction to the involved specific persons.

More details on this module will be given in Section 3.6. We now propose a list of User requirements that are related to this component, also mapping them into technical requirements for the system to be developed.

2.3.2 User Requirements

The following user requirements have been presented in the D1.1 and are relevant for this part of the system.

Serial/ Ref	***Capability Descriptor***	***Requirement Statement***	***Validation Criteria***	***Priority***
1. Person				
1.b. Social Interaction Monitoring				
1.b.1	*Facilitating contact between the person and healthcare professionals*	*GiraffPlus shall facilitate the communications between the elderly person and authorized healthcare professionals in different day periods*	*GiraffPlus provides an additional and easy way of communication between the elderly person and healthcare professionals responsible of his/her health status. Communications may occur at different times during the day. The person (or more than one) to communicate with should be authorized and can change.*	***K***
1.b.2	*Periodic reporting to secondary users*	*GiraffPlus shall provide both formal and/or informal secondary users with a periodic report on ADL/IADL*	*GiraffPlus provides the capability to send relevant information on the elderly person daily activities to a secondary user (e.g., a close relative and/or a doctor).*	***K***
1.b.3	*Facilitating contact between the person and home care assistance*	*GiraffPlus shall facilitate the communications between the elderly person and authorized home care assistant(s) in different day periods*	*GiraffPlus provides an additional and easy way of communication between the elderly person and the home care assistant(s) responsible of his/her health status. Communications may occur at different times during the day*	***K***
1.b.4	*Reminding medications*	*GiraffPlus shall remind important medication events with some time regularity for a variable amount of time*	*GiraffPlus provides the capability to send reminders to the elderly person on the medicine assumption or medications in particular hours of the day and/or night for period of time whose length can be defined*	***K***
1.b.5	*Notifying the house presents an unusual setting to caregivers*	*GiraffPlus shall provide caregivers with direct notice if the house presents an unusual setting (first potential evidence of a personal disorder)*	*GiraffPlus provides the capability to inform caregivers if the lights are still on and/or if doors are open during the night*	***O***

1.b.6	*Facilitating contact between the person and family members*	*GiraffPlus shall facilitate the communications between the elderly person and family member(s) in different day periods*	*GiraffPlus provides an additional and easy way of communication between the elderly person and family member(s). Communications may occur at different times during the day*	***D***
1.b.7	*Allowing emergency call*	*GiraffPlus shall enable authorised secondary users to make an emergency call through the tele-presence robot*	*GiraffPlus should allow authorized caregivers to perform an emergency call through the tele-presence robot in order to monitor the status of the elderly person in the house.*	***K***
1.b.8	*Warning notice to secondary users*	*GiraffPlus shall provide both formal and informal caregivers with warning notice in case of possible danger of the elderly person*	*GiraffPlus provides the capability to send to authorized home care assistant and/or close relatives warning notice in case of possible danger of the elderly person*	***K***

Table 15 Social communication functionalities that the users wish from the system relevant to visualization, personalization and interaction services

Serial/ Ref	***Capability Descriptor***	***Requirement Statement***	***Validation Criteria***	***Priority***
5. Overall system				
5.a. Primary user services				
5.a.1	*Reminder*	*GiraffPlus shall provide reminders to the elderly person through the tele-presence robot*	*GiraffPlus provides the capability to send reminders the elderly person to perform medications, assume medicines, and/or special events (e.g., a birthday)*	***K***
5.a.2	*Alarm*	*GiraffPlus shall provide alarms to the elderly person in case of emergency through the tele-presence robot*	*GiraffPlus must provide the elderly person with alarms in case of gas leaks and/or risk of fire*	***K***

5.a.3	*Memorandum*	*GiraffPlus shall provide a memorandum repository access through the tele-presence robot*	*GiraffPlus should be able to associate pictures and/or tunes to the act of reminding the elderly person of relevant information*	***O***
5.a.4	*Recording function*	*GiraffPlus shall record and store audio/video/picture memorandum through the tele-presence robot*	*GiraffPlus provides the possibility to record and store audio and/or video and/or picture to store relevant info through the tele-presence robot*	***O***
5.a.5	*Internet access*	*GiraffPlus shall enable internet access through the tele-presence robot*	*GiraffPlus provides the possibility to access the internet using the tele-presence robot*	***D***
5.a.6	*Book reader*	*GiraffPlus shall provide book reader service through the tele-presence robot*	*GiraffPlus provides the capability of reading a book through the tele-presence robot*	***D***
5.a.7	*Language selection*	*GiraffPlus shall be able to customize its interface according to the nationality of the elderly person*	*GiraffPlus integrates a robot the language of which can be selected according to the elderly people nationality*	***D***
5.a.8	*Medical support*	*GiraffPlus shall support rehabilitation activities*	*GiraffPlus provides the capability to allow the elderly person to receive support during rehabilitation and/or post-hospitalization periods*	***K***
5.c Privacy and data protection				
5.c.1	*Authorized data access*	*GiraffPlus shall allow access to personal data only by authorized personnel only for legally authorized purposes.*	*GiraffPlus should adhere to the currently existing EU data protection directive and should be tested with respect to agreed security protocols that will be defined as system requirements in D1.3.*	***K***
5.c.2	*Data Protection*	*GiraffPlus shall protect stored data against accidental and/or unlawful destruction/loss/alteration as well as unauthorized or unlawful storage, processing, access or disclosure.*	*GiraffPlus should adhere to the currently existing EU data protection directive and should be tested with respect to agreed security protocols.*	***K***

5.c.3	*Data security policy*	*GiraffPlus shall implement a suitable data security policy with respect to the processing of personal data.*	*GiraffPlus should adhere to the currently existing EU data protection directive and should be tested with respect to agreed security protocols.*	***K***

Table 16 User requirements for the overall system relevant to visualization, personalization and interaction services

2.3.3 Detailed Use Case

In the following, the use cases for Data Visualization, Personalization and Interaction services are presented. In addition to the usual end users considered in the GiraffPlus project, a new actor has been considered: the GiraffPlus Engineer.

Three main actors have been considered in the diagrams:

1. **Primary End User**: Representing the person which will actually live within the GiraffPlus system.
2. **Secondary End Users**: Representing the persons directly in contact with the Primary End User through the GiraffPlus system. Secondary users can be further classified in two different classes:
    a. *Healthcare professionals*: individual healthcare provider such as a doctor or a nurse.
    b. *Caregivers*: a close relative or a friend that takes care of the primary end user.
3. **GiraffPlus Engineer**: Representing the persons that have the responsibility to install and configure the system in the elderly’s house.

In the following we consider several use case diagrams and at the end of the section we present the overall use case diagram of the data visualization, personalization and interaction services.

2.3.3.1 Accessing the System

In Figure 8, the use case diagram for accessing the system is depicted. Both secondary users and GiraffPlus engineers are required to access the system (primary users will not be requested in general to access the system as *they are living in the GiraffPlus ambient* unless an identification is needed to differentiate data from different users, for instance in case of physiological parameters). Then, the user has to perform an authentication step, thus, ensuring a proper security policy, and, then, select a primary user (and so, the related GiraffPlus ambient), in order to access the different system services. Finally, the user can also manage his/her system account.

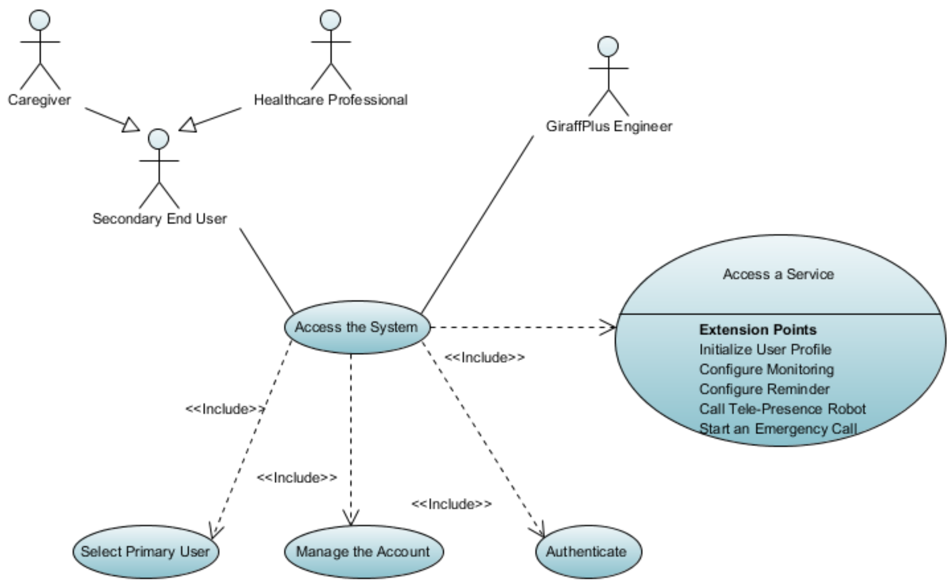

Figure 8 Accessing the system

A first service provided to the secondary user is the ability to configure primary user's profile. In this regard, Figure 9 depicts the use case related to the primary user profile initialization procedure. Then, once accessed the system and selected a primary user, the secondary user is able to initialize the selected primary user profile providing the information to perform automatic reasoning activities.

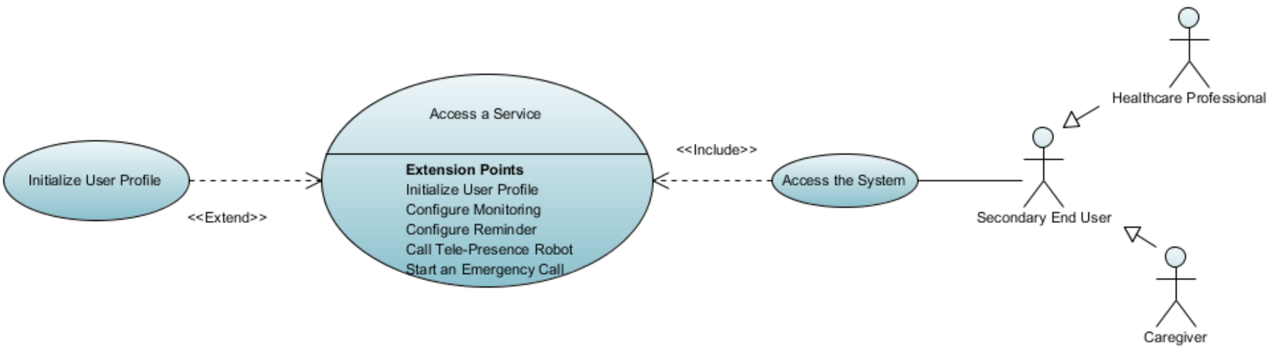

Figure 9 Initialize profile

Another service the secondary user may access is the monitoring service. The detailed use case for the monitoring service is provided in Figure 10. Once accessed the system and selected a primary user, the system allows the secondary user to configure the monitoring service. Then, the secondary user can activate/deactivate a monitoring task. In this way, the system will provide the secondary user with current and historical user activities as well as current and historical specific sensor data. In case the system detects dangerous situations, both primary and secondary users would receive suitable warnings/alarms according to the specific level of criticality of the situations. Finally, both primary and secondary users will be able to receive periodic reports (if requested).

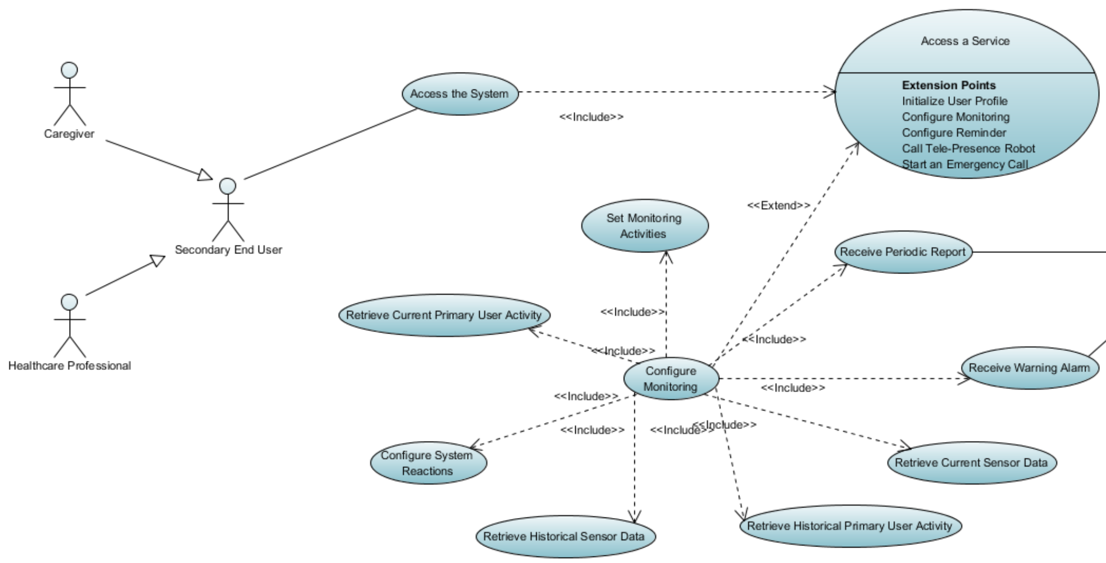

Figure 10 Monitoring configuration

An additional service offered by the GiraffPlus system is the Reminder, i.e., a service that aims at providing messages to the users of the system in order to remind important actions and/or events such as the assumption of medicines, some physical activities, etc. In Figure 11, the use case for the reminding service is depicted. Both primary and secondary users can configure the reminder (e.g., asking the system to provide a specific sound the user would hear), set a reminder (e.g., asking to recall to assume a specific medicine) and receive a notification (i.e., being acknowledged that is the time for medicine assumption). In order to access the reminding service, secondary users are requested to access the system as well as to select the primary user that should receive the notification.

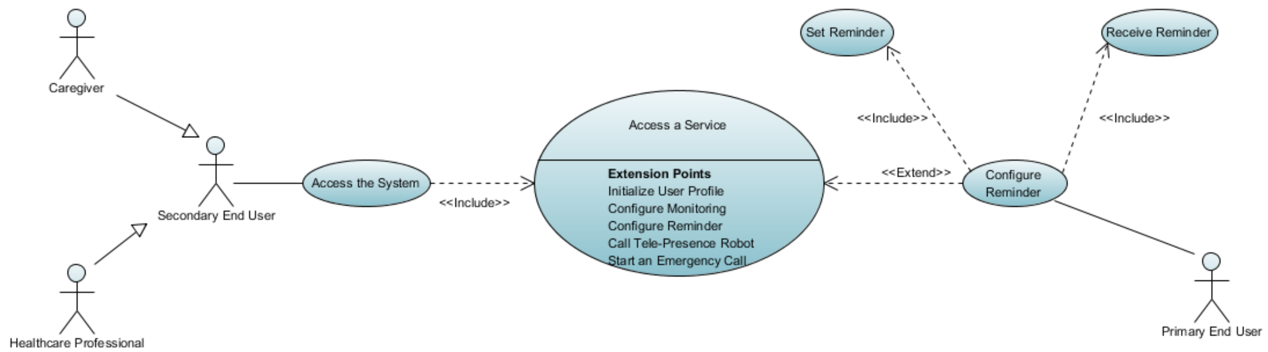

Figure 11 The reminding service

Another service offered by the data visualization, personalization and interaction component is the ability to perform calls through the tele-presence robot. Once accessed the system and selected a primary user, secondary users can call the primary user through the Giraff robot and, in special circumstances the secondary user can also choose to start an emergency call. Figure 12 shows the related use case diagram.

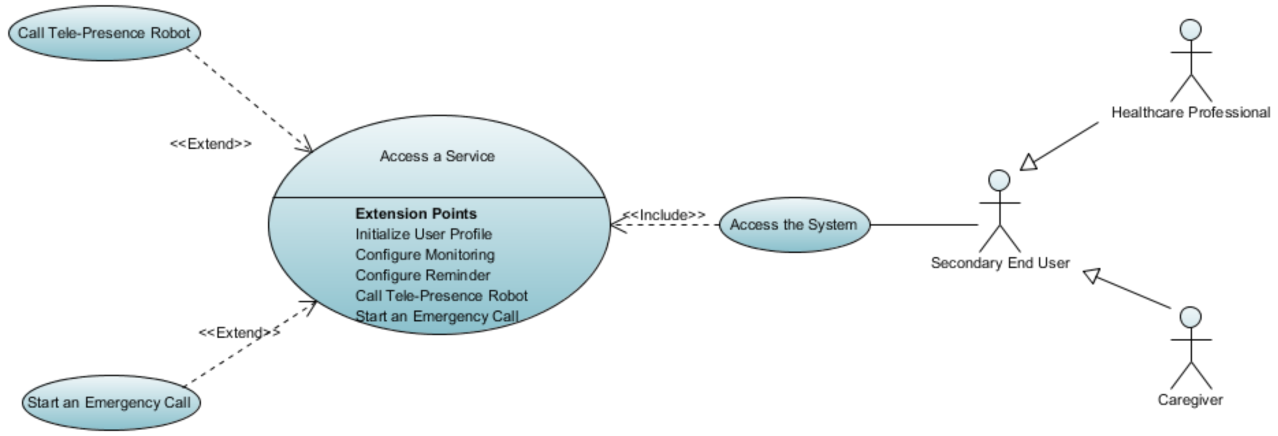

Figure 12 The Giraff tele-presence robot

Figure 13 describes the use cases for the personalization service. The role of the personalization service is to produce personalized data analysing both current and historical sensors data as well as current and historical detected activities.

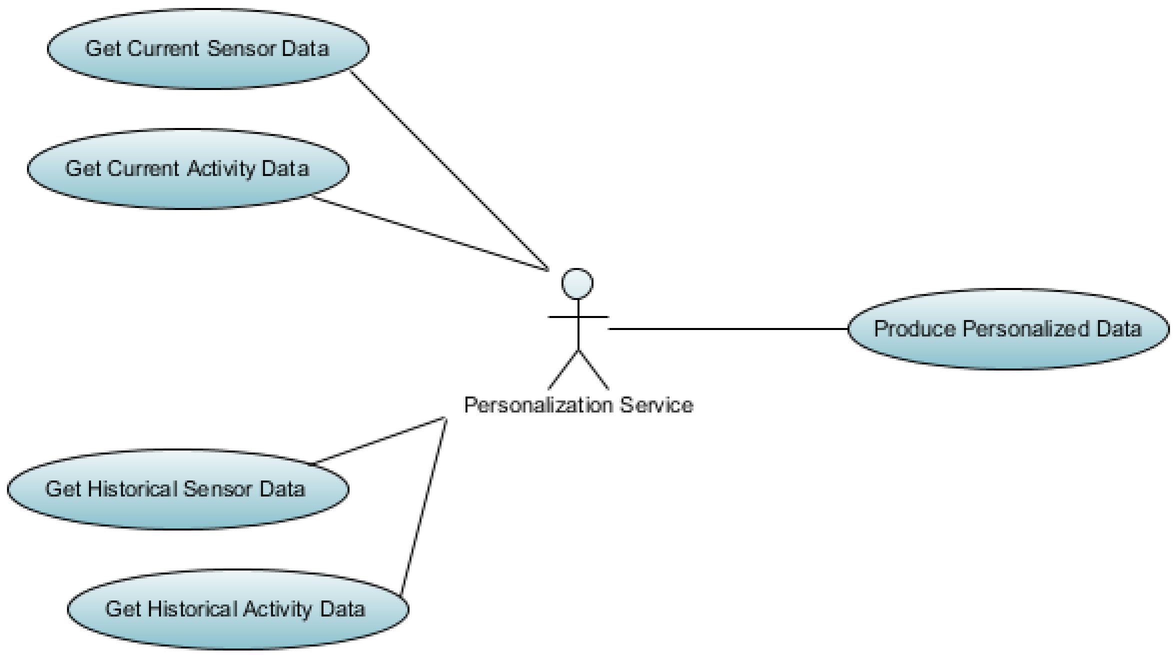

Figure 13 Personalization services

In some specific cases, the Data Visualization, Personalization and Interaction services can also generate proactive information that may be displayed as a warning/reminder notification. This kind of information is represented through actions and is generated by specialized user oriented services starting from personalized data. When needed, actions will be executed and consequences will be displayed on primary user interface and/or secondary user interface. Figure 14 represents a use case about the user oriented services module.

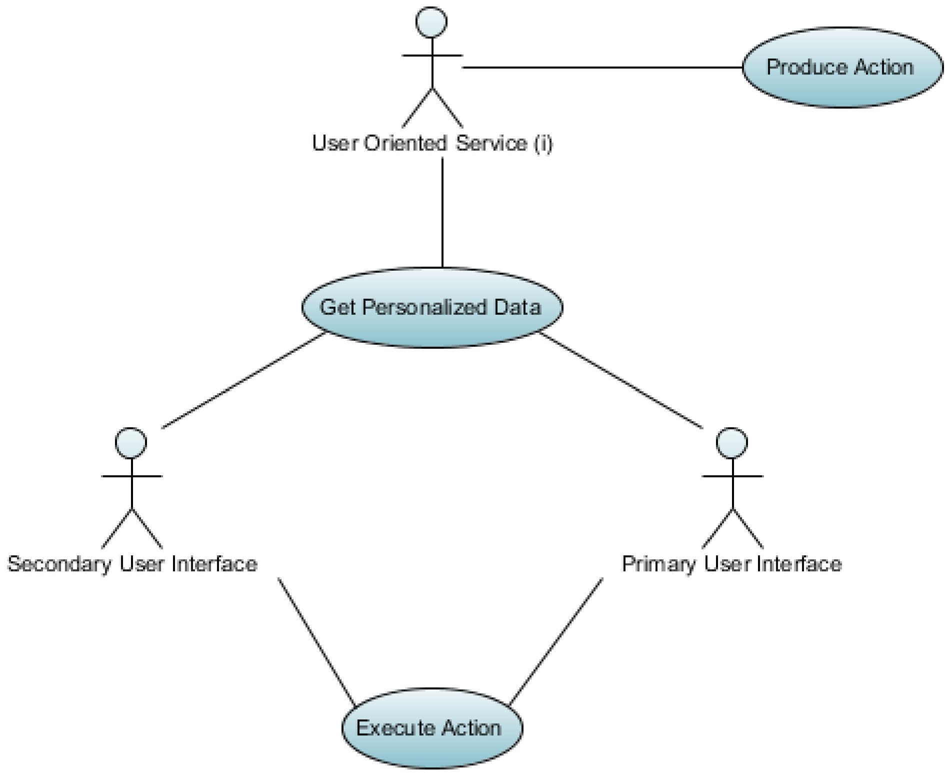

Figure 14 User oriented services

2.3.3.2 Overall use case diagram

Figure 15 represents the overall use case diagram of the data visualization, personalization and interaction services.

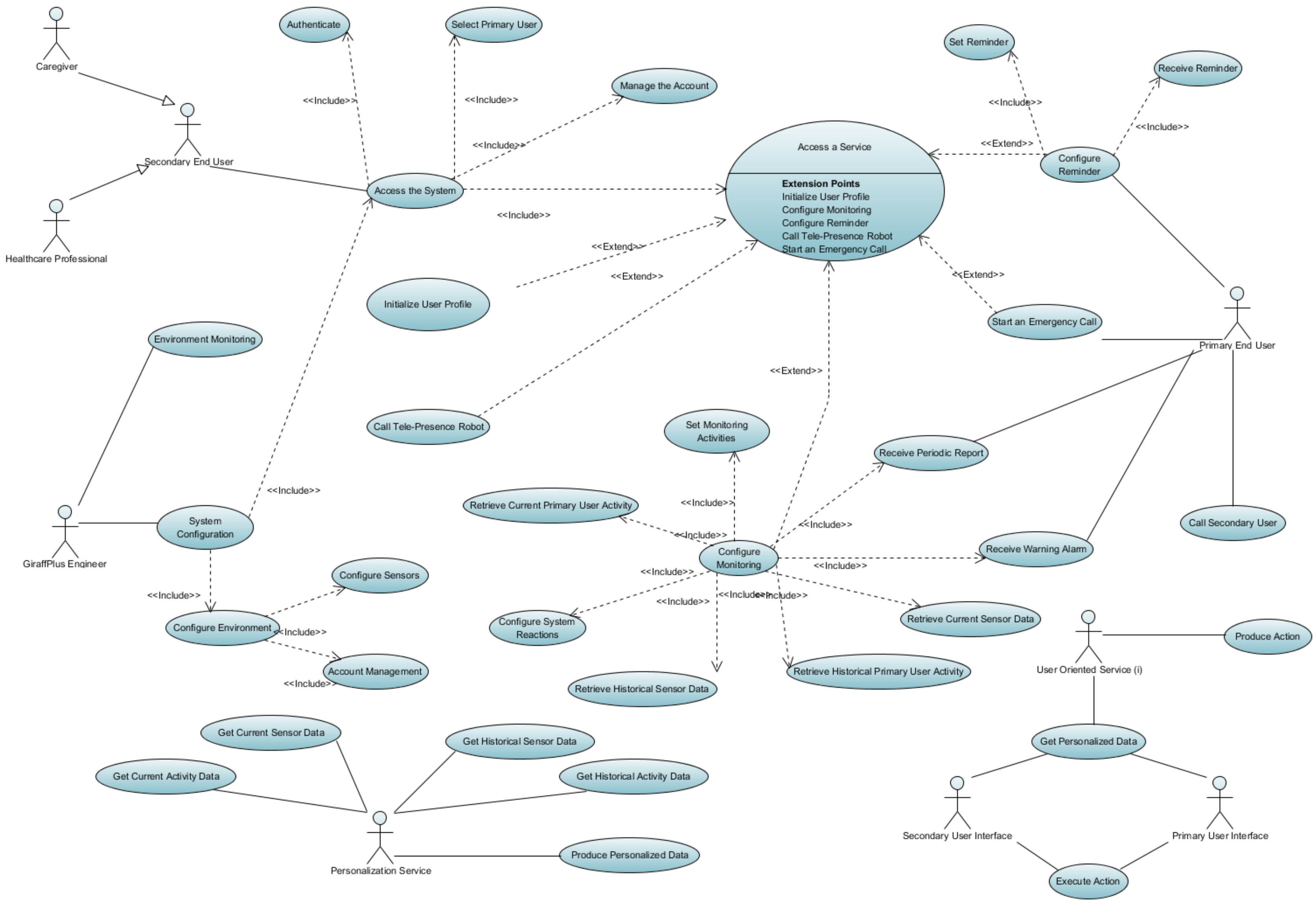

Figure 15 Data Visualization, Personalization and Interaction Services Use Cases

2.3.4 Technical Requirements

According to the above use cases, the Data Visualization, Personalization and Interaction Service module presents the following technical requirements. Among the social communication functionalities we translate to technical requirements all user requirements besides notifying that the house presents an unusual setting (2.a.2) as it is considered optional and is not clear how to implement it. Also additional services given by the tele-presence robot like internet access, reading books, possibility to record and store audio, video and pictures (5.a.3, 5.a.4, 5.a.5, 5.a.6) could be possible, but would require a more complex interface for the elderly to the system and are outside the scope of this project.

TR ID	***Description***	***UR ID***	***Priority***
4.36	*The Data Visualization, Personalization and Interaction service shall be able to provide additional and easy way of communication between the elderly person and healthcare professional, home care assistants and family members responsible of his/her health status.*	*1.b.1* *1.b.3* *1.b.6*	***K***
4.37	*The Data Visualization, Personalization and Interaction service the system shall be able to generate periodic reports containing relevant information on the older person daily activities to a secondary user and, if required, to the same primary user.*	*1.b.2* *1.b.8*	***K***
4.38	*The Data Visualization, Personalization and Interaction service shall be able to produce proactive information that can be sent to both primary and secondary users. In particular, the system shall be able to produce reminders to the older person concerning medicine assumptions or medications in particular hours of the day and/or the night. The system shall also be able to send warning notices to secondary users in case of danger for the older person.*	*1.b.4* *5.a.1* *5.a.2* *5.a.3*	***K***
4.39	*The Data Visualization, Personalization and Interaction service shall be able to inform secondary users in case lights in the house are still on and/or doors are open during night.*	*1.b.5*	***O***
4.40	*The Data Visualization, Personalization and Interaction service shall be able to provide interfaces with multiple languages which can be selected according to the elderly people nationality.*	*5.a.7*	***D***
4.41	*The Data Visualization, Personalization and Interaction service shall be able to allow the elderly person to receive support during rehabilitation and/or post-hospitalization periods.*	*5.a.8*	***K***

4.42	*The Data Visualization, Personalization and Interaction service shall allow an authorized secondary user to virtually access the house (through the robot or alternative means) in any moment and even without a specific answer from the primary user*	*1.b.7*	***K***
4.43	*The Data Visualization, Personalization and Interaction service shall support the secondary users (e.g., through warnings, visual information, etc.) in identifying and avoiding obstacles during the virtual visit through the Giraff robot*	*5.a.9*	***K***
4.44	*GiraffPlus should adhere to the currently existing EU data protection directive and should be tested with respect to agreed security protocols to insure data security and protection and access to personal data only by authorized personnel and only for legally authorized purposes.*	*5.c.1* *5.c.2* *5.c.3*	***K***

Table 17 Technical requirements for the data visualization, personalization and interaction services

We have the intention to satisfy all the technical requirements listed above.

3 GiraffPlus architecture, functionalities and interfaces

3.1 Overall architecture

This section describes a tentative architecture of the GiraffPlus system. The scope of the section is to establish a commonly agreed specification of the system in terms of components, functionalities and interfaces among components. It also gives a clear view of the complete system and on how the components are integrated and interfaced with the rest of the system.

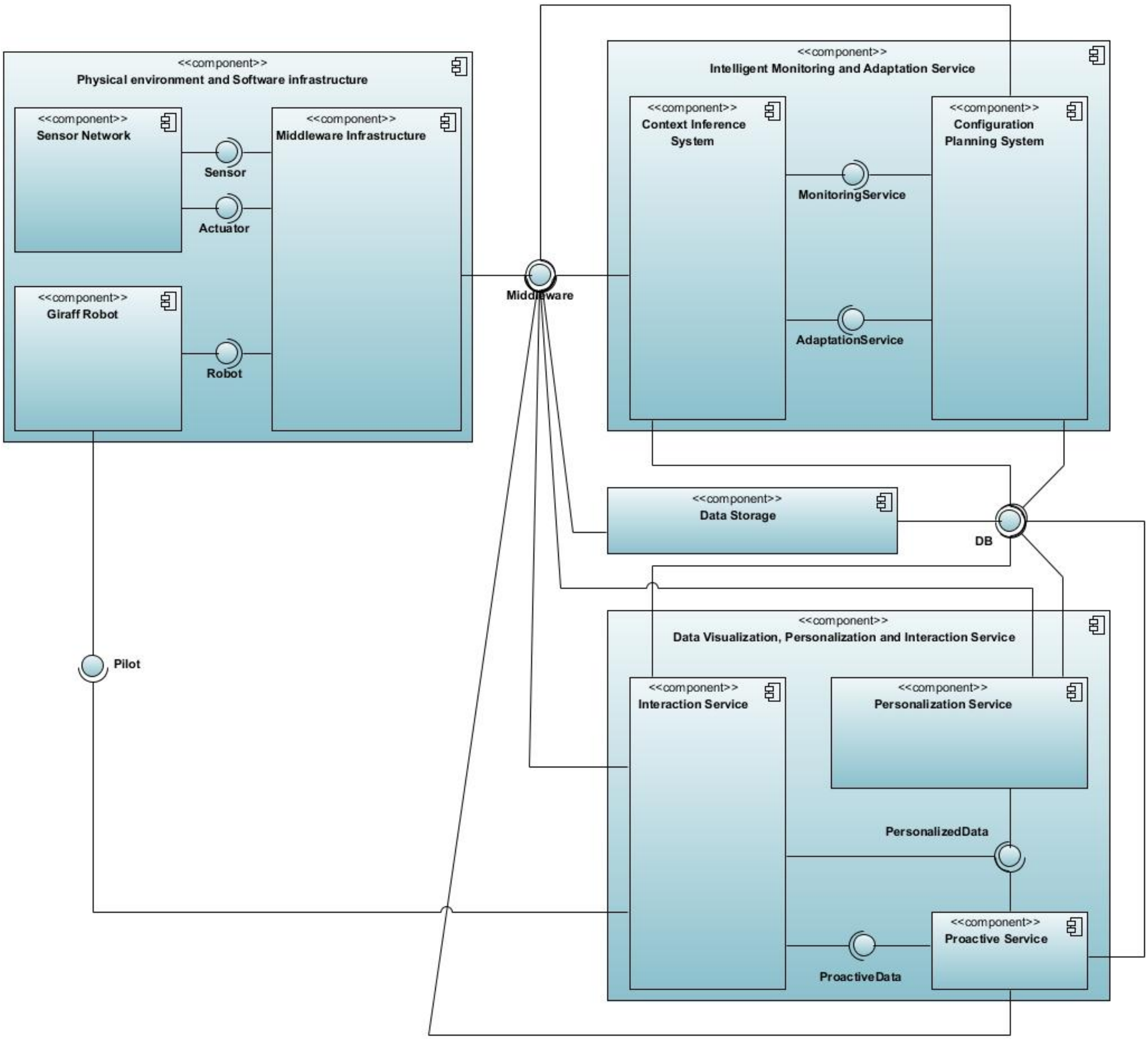

Figure 16 The GiraffPlus system architecture

Figure 16 shows the general component diagram of the GiraffPlus system. In particular, four main components have been identified:

(a) *Physical Environment and Software Infrastructure*,
(b) *Data Storage*,
(c) *Intelligent Monitoring and Adaptation Service* and
(d) *Data Visualization, Personalization and Interaction Service*.

The ***Physical Environment and Software Infrastructure*** component represents the basic level of functionalities of the GiraffPlus system. All the data services are grounded on functionalities of this part of the system. This module is also in charge of providing the common and interoperable communication service. In particular, the

- ***Middleware Infrastructure*** implements the ***Middleware*** service (for example, exploiting MQTT and ZigBee protocols) constituting a gateway shared among all the system components.
- The role of the ***Sensors Network*** is to gather the data generated by the sensors (deployed in the elderly home) as well as to provide the rest of the system with the (possibly pre-processed) collected data.
- The ***Giraff Robot*** component implements the GiraffPlus tele-presence functionalities, also providing a ***Pilot*** service to remotely control the robot.

The ***Data Storage*** component is responsible for providing a general database service for all the data generated by parts of the system and providing data access functionalities. Specifically, the role of this component is to manage a database containing all the data collected through the Middleware service and generated by other system's components (for instance, the Sensors Network). Additionally, it enables other components to access the information and reason over it (also considering historical evolution). It is worth to mention that this part was not envisaged explicitly in the DOW but has been inserted to guarantee permanent data to be gathered as well as to offer the general possibility to use the future long-term experimentation as a benchmark gathering.

The **Intelligent Monitoring and Adaptation Service** is the component responsible for context/activity recognition and configuration planning. This part of the system encompasses two general reasoning systems namely:

- The ***Context Inference System,*** which is in charge of implementing the requested monitoring activities by means of context/activity recognition and relies on a timeline-based representation of the data generated by the sensors;
- The ***Configuration Planning System,*** which is responsible for providing suitable configuration settings for the Sensors Network according to the requested monitoring activities.

The **Data Visualization, Personalization and Interaction Service** is the part of the system responsible for creating user-oriented service. A broad way to summarize the module is to provide different end-users with suitable interaction modalities for the available services.
The module is subdivided into a Front-End:

- The ***Interaction Service***, the basic front-end of GiraffPlus to all the human users' contacts. It will provide visualization services adapted to the different interaction created within the system. Depending on the classes of end-users, personalized services and specific dialogue boxed are offered which take into account his/her specific needs/roles.

And a Back-end that is based on two basic services:

- The ***Personalization Service*** acts as a back-end of the Interaction service and is in charge of collecting and keeping up-to-date all the data needed to generate personalized interactions. It basically creates and dynamically maintains *profiles* for all the end users involved in GiraffPlus and also provides some reasoning services specifically tailored for the persons involved (e.g., the reminding setting and associated dialogues).

- The **Proactive Services** are responsible for collecting specific functionalities to prepare content to be sent from the technological modules to users. Examples of GiraffPlus proactive services can be for example the Reminder, and the Warning Report Builder.

Finally, the interconnections among components are also relevant. In this regard, a crucial role is played by the Middleware service as it provides the central connection point that is shared by all the components according to the needed information exchanges. For instance, the Sensor Network provides the Data Storage with the data collected through the sensors and that need to be placed in the database; the Context Inference System retrieves the sensors data (from the database) and exploits them in order to reason on the person/ambient status; the Configuration Planning System selects the set of sensors needed to implement a requested monitoring activity; the Personalization Service dynamically provides user profiles that are stored in the database. It should be however be noticed that the different components have the possibility to access data from the physical environment either through the middleware or through the data storage component.

Part of the system will be implemented using a cloud computing solution. There will be a centralized database and some services (Intelligent Monitoring and Adaptation Service) will be running on the GiraffPlus cloud infrastructure and not locally in elderly home.

3.2 The Physical environment and Software infrastructure

The UML diagram in Figure 17 describes the main components of the Physical Environment and Software Infrastructure services. In the component diagram the main components of the module are presented: the sensor network, the Giraff system and the middleware infrastructure.

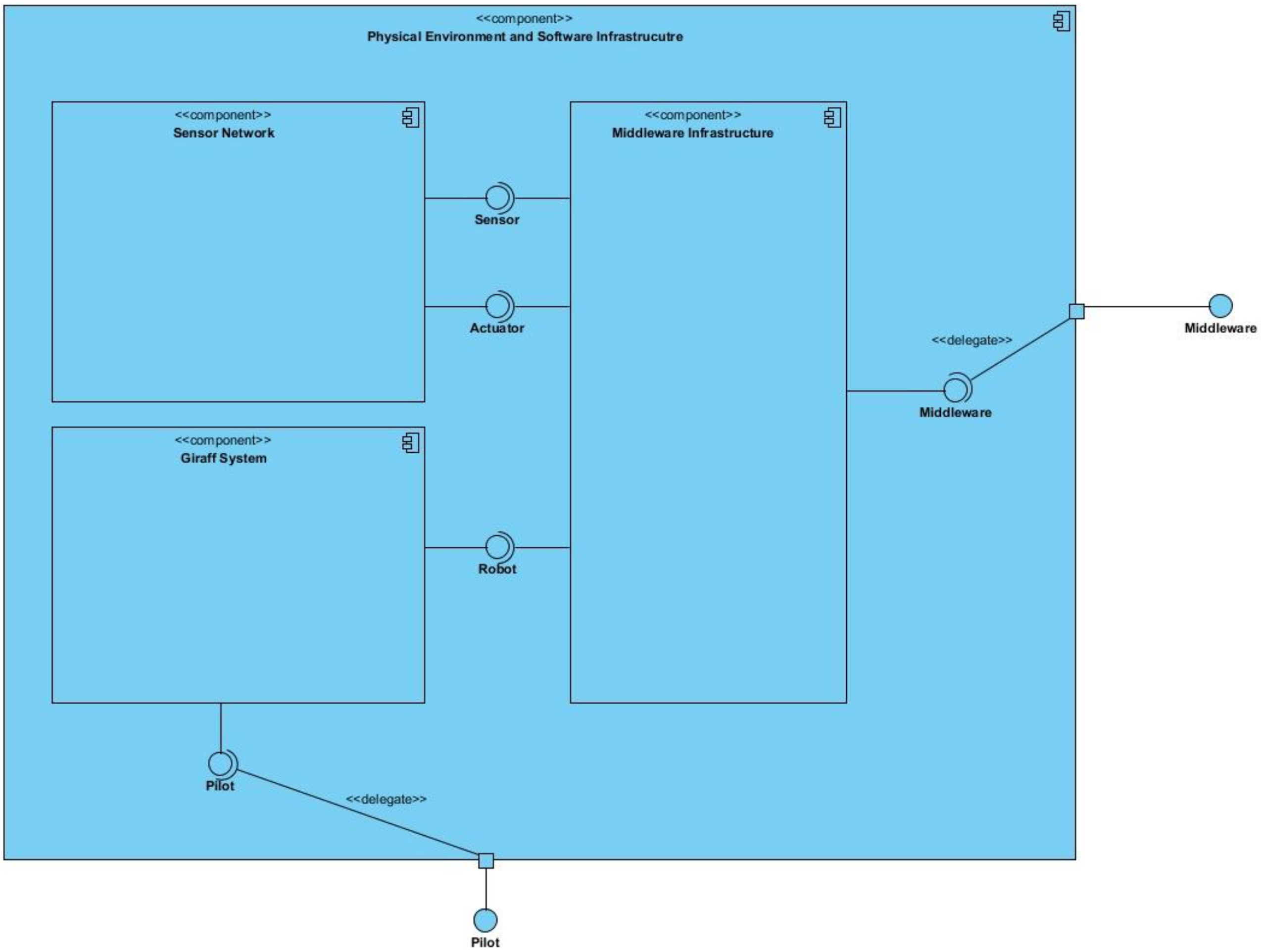

Figure 17 Main components of Physical Environment and Software Infrastructure services

The middleware acts as a middle layer offering a common interface to other system components for communicating between each other. The middleware infrastructure abstracts the underlying devices such as sensors and actuators and the robot in order to enable other system components to access the sensed data, to configure the devices and to send command to actuators.

3.2.1 Middleware

The universAAL project is the most recent European initiative aimed at delivering a software platform for AAL, which started to consolidate the architecture and software developed in recent research projects like PERSONA, SOPRANO, OASIS, and mPOWER. The project is still on-going, however the first results are already available at architectural level. One of the major tenet of the universal approach is to separate the reference architecture used to lay out the smart-home environment from the concrete architecture and implementation used to realize the intelligent services. This abstraction allows the design of different platforms, for example the ones based on different paradigms and technology but still sharing common building blocks. In this way, common building blocks enable the creation of an ecosystem by ensuring interoperability at the level of interface or functional services.
The universAAL middleware is one of the most important building blocks in universAAL and the GiraffPlus middleware is inspired to the concrete architecture developed by universAAL and partially derived from the PERSONA project. In particular, we agree to offer the same level of functionalities for the discovery of devices and services available on the local network, the

eventing of all the context information collected and further elaborated by intelligent reasoners by means of a context broker, and for accessing to the services offered by the smart environment independently from the location of the services. In PERSONA project intelligent buses realized those functionalities, namely the Context, Service, Input and Output buses. In universAAL reorganization has been proposed. The Input and Output bus have been merged and now called User Interaction Broker. Also a new specialized communication bus has been added, called Control Broker, to manage all the initialization steps and management of the resources during the smart environment set up. In GiraffPlus the components of our system will use three different buses/brokers: the Context Bus, the Service Bus and the Control Bus. The UI Bus is not contemplated in this moment, because the novel interaction approach mediated by the Giraff tele-presence robot was not considered in universAAL and we will evaluate any compatibility or enhancement with the universAAL model at a later stage. Another aspect not consider in the GiraffPlus framework is the semantic approach of universAAL, which brings to a description of the services in terms of RDF triples. Although the complexity of this approach will be hidden behind annotated interfaces and other automated tools, we will maintain a standard service representation but still providing all the necessary information. When finished, the GiraffPlus will be compatible at the level of reference architecture with universAAL-based systems. It means that with some simple adapter, the components used in GiraffPlus will be able to run in a universAAL-based system.

The middleware infrastructure presents three main components: a hardware abstraction layer, a publish/subscribe service and a RESTful service. The hardware abstraction layer is responsible for giving direct access to the hardware resources (sensors, actuators and the robot) to the upper layer. The publish/subscribe service is the module that gives to other system components the possibility to subscribe to the data published by the devices abstracted from the underlying layer. This component is needed to monitor the physiological and activity data from sensors. The RESTful service is a module that allows other system components to set and retrieve the properties of the devices present in the environment through a RESTful API (GET, PUT, POST, and DELETE). The two modules described in the diagram are used to realize the above mentioned brokers: the publish/subscribe service will be used for implementing the Context broker, the RESTful service the Service Broker and a combination of them the Control Broker.

The UML component model in Figure 18 shows an in depth view of the middleware component.

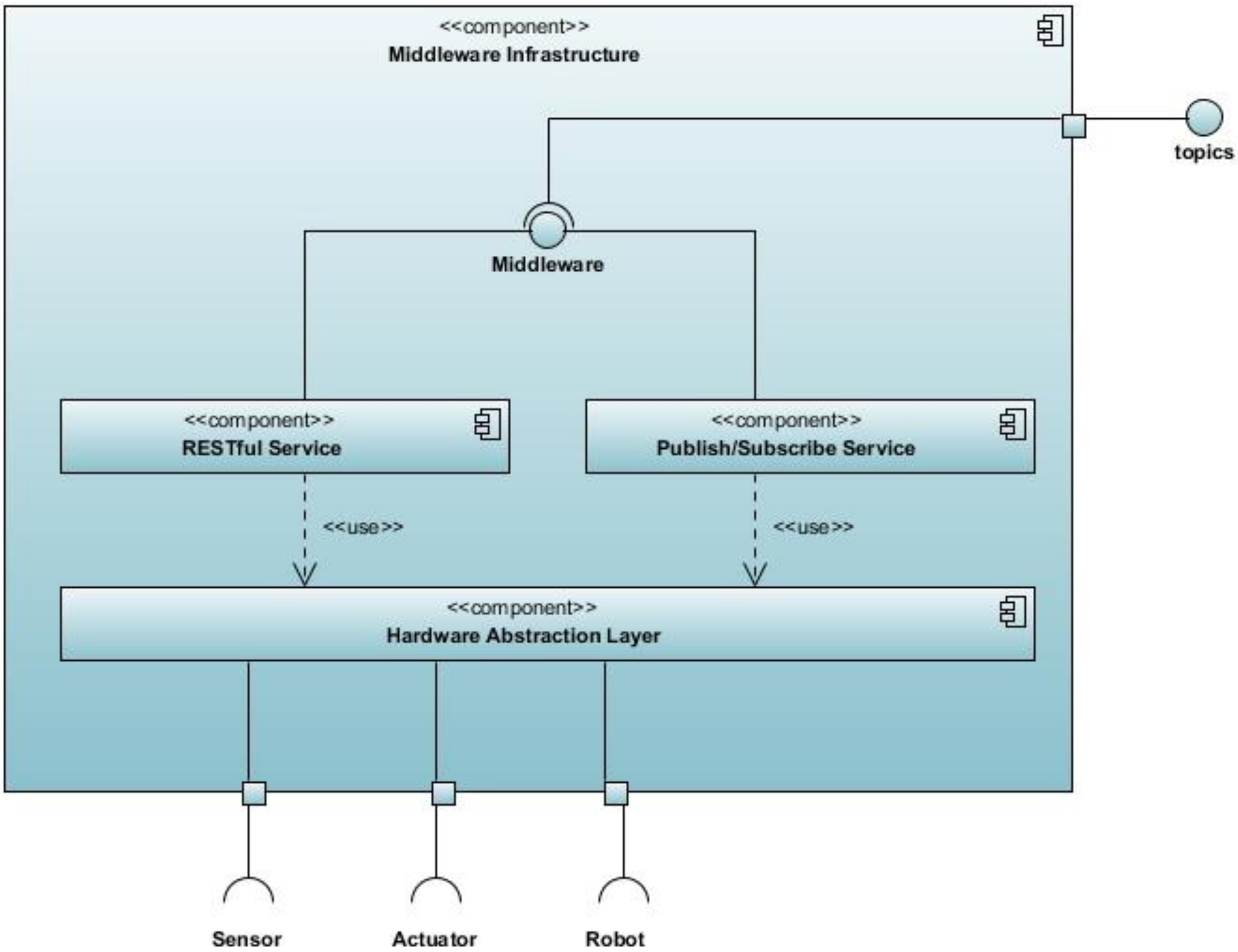

Figure 18 An in depth view of the middleware component

The main idea is to provide a publish/subscribe mechanism for accessing the context information about the physical environment and physiological data. This information will be exposed as different topics:

- one topic for discovery and description of devices and services
- one topic for context analysis

The details about the middleware interface will be illustrated in the following section.

3.2.2 Middleware Interface

The middleware will provide a common interface with some core functionalities to allow other system components to interact with the sensors and actuators present in the sensor network and on the Giraff system.

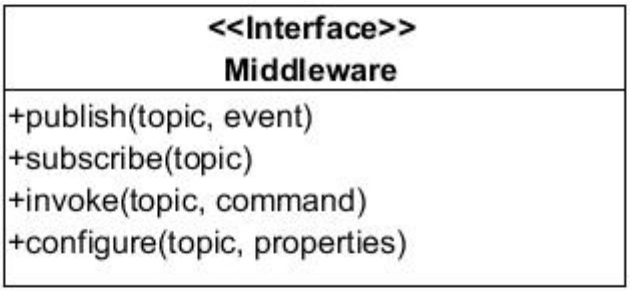

Figure 19 A draft middleware interface

The middleware will provide methods with a publish/subscribe pattern to access and expose context information about the physical environment and physiological data. This information will be exposed as topics. The topic used for discovery and description of devices and services, called *serviceBus,* will have this kind of format:

```
/home/room/deviceType/id/property/status
```

Any changes in a property status will be published. This method will be also called by other system components in order to publish an event triggered by some context analysis performed. In this case it is envisaged to use the topic format:

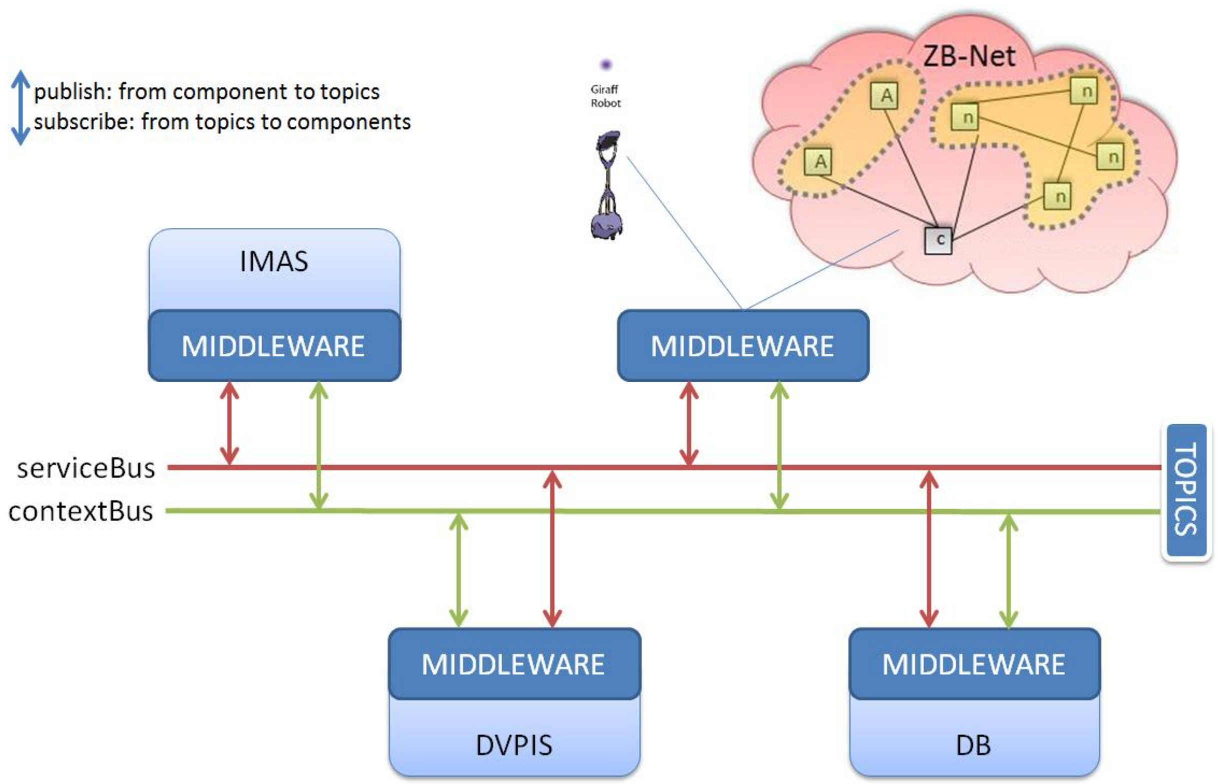

Figure 20 Interaction between components and topics

3.2.3 Description of sensors to be used in the project

In the following section we briefly describe the most important sensors that will be used in the system. We first consider the sensors that are going to be used for monitoring physiological parameters, then the sensors for monitoring activities and behaviours and finally the sensors used to alert of emergency situations.

Monitoring of physiological parameters

The sensors for blood pressure monitoring, glucose level measurements, temperature measurements, weight and oxygen saturation are provided by Intellicare.

The *blood pressure monitor* has a cuff that should be placed around the upper arm. The measurement is performed automatically, and the system provides automatic averaging of three measurements within two minutes and detects pulse irregularities during the measurements. For an accurate measurement, the measurement procedure is crucial, i.e. rest before the measurement is recorded and placement of the arm at the same level as the heart. Thus, the patient or relative helping out with the procedure needs education to assure the validity of the measurements. For high accuracy, it is also crucial to use a cuff of correct width in relation to the size of the arm; otherwise the blood pressure will be systematically over or under estimated. This is of special importance if the system will be used by several persons. There are 2 widths available and the cuffs are adapted to the arm.

The *glucose meter* is recommended to be used before and after a meal by patients with diabetes, to control the glucose level and adjust the insulin injection. The system uses a small sample volume of blood, 0.5 μl and the blood sample is performed by use of a so called safe strip injection, which avoids hand contact with the test strip. The test is received within 5 s.

Intellicare provides these two sensors, the *blood pressure monitor* and the *glucose meter* as a kit, since many people with diabetes also has high blood pressure, but for the GiraffPlus project it would be feasible to also provide these units separately.

The *thermometer* measures the temperature in the ear and deliverables a result in 1 s. The measurement can show whether a person has fever or not. During the measurement, it is important to direct the measurement probe towards the eardrum, which is richly perfused by blood; otherwise a too low temperature will be measured. Practically, this can be avoided by carefully direct the probe towards the eardrum, making several measurements, and use the highest value as the temperature.

By the *weight scale*, changes in weight can be monitored. This is an important warning in patients with heart failure as a sign of increased body water and load for the heart.

The *pulse oximeter* provided by Intellicare is called NONIN OnyxII. The device is certified compliant to the Continua™ Version One Design Guidelines. It connects via Bluetooth 2.0 Wireless Technology and can connect to communication devices (cell phones, PDAs,PCs, etc.). It is designed to meet the requirements of the emerging open standards such as the Bluetooth Health Device Profile (HDP), IEEE11073 and Continua. It has a Store & Forward Memory with up to a minimum of 20 single point measurements allowing patients to take readings outside of the home and transmit the time-stamped data once they return. It provides a SmartPoint™ Technology that eliminates the guesswork of determining which oximetry values to use for analysis. Using a sophisticated algorithm, it provides a fast and accurate snapshot of the patient's SpO_2 and pulse rate. The Onyx II, Model 9560 sends the SmartPoint spot-check data within 30 seconds from turn-on. It has an extended range of up to 100 meters (Class I) and a new power saving feature that automatically adjusts transmitted power based on distance from the main unit. This feature allows for approximately 600 spot checks on 2 AAA batteries.

The *Zenicor system* can be used for registration of 1 channel *ECG* with the purpose of arrhythmia investigations and screening for arterial fibrillation among risk groups. The system uses dry electrodes, and recordings are performed by direct contact of the thumbs and the ECG is transferred by mobile phone technology.

Tunstall provides two *fall sensors*, either worn around the wrist or waist. The sensors raise an alarm in case of a fall. If normal activity is detected after the fall, the alarm can be canceled.

Tunstall also provides a system for *detection of body fluid sensors* or *enuresis sensor*. The sensor should be placed between the mattress and sheet, and provide a warning on detection of moisture.

To investigate the balance, there is a *sensor system based on inertia sensors*, i.e. three axis accelerometer and gyroscopic sensors, available as a research prototype within the project. The system will need adaption for specific user groups (e.g. detection of tremor), but has the potential to allow more advanced motion analysis and classification.

Behavior and activity monitoring

This section describes sensors that can fulfill the user requirements for monitoring of living habits or local activity. Further, the operation, special requirements and limitations are described. All sensors described here except the main door monitor are provided by Tunstall. Other sensors could also be used in the system if needed and in particular ZigBee devices as described in the D1.2. Several solutions will be investigated further on in the project.

Typically several *FAST Passive InfraRed motion detectors (PIR*) are provided, placed in the bedroom, the bathroom and other rooms according to needs. From these, information about the time spent in bedroom, visits to the bathroom etc. can be monitored.

The *Electrical Usage Sensor* is plugged in between an electrical apparatus, such as a water boiler, and provides information about how often the water boiler, or other apparatus, is used.

Door usage can be monitored by the *Universal sensor*. Both the case where the door normally is open and normally closed can be monitored; also internal doors, as a bedroom door, or the door of a refrigerator can be monitored.

Using the *Bed/Chair Occupancy Sensor*, the presence of a person can be determined. The sensor is a pressure sensitive mat and detects pressure / no pressure and requires a Universal sensor. In combination with a PIR, it can report more complex activity behavior (bed sensor turns off, bath room PIR turns on, etc.)

The *Medication Dispenser* automatically dispenses medication and provides audible and visual alerts to the user each time medication should be taken. If the user fails to access the medication dispenser, an alert is raised to the monitoring centre. Two types of different sized dispensers are available, depending on the amount of medicine needed.

The lights status in a room can be detected by *photo sensitive sensors*. Such a system will indicate if the light has been left on during the night, and can be set to provide warnings.

To *monitor who enters and exit a house, web or video cameras* can be placed at main door. This will, however, require some ethical considerations, and also special permissions from local authorities.

Emergency situation detection
This section describes sensors that can fulfill the user requirements for detection of emergency situations. Further, the functionalities, special requirements and limitations are described. All sensors described are provided by Tunstall.

Telecare *Flood detector* provides an early warning of flood situations, such as taps being left on. It should be placed on a flat surface close to a bath, wash basin, toilet or sink. Tap status (if someone lefts the tap in an open position), can be detected indirectly by the flood sensor provided by Tunstall.

The wireless *Carbon Monoxide Detector* provides warnings in case of dangerous CO levels.

The *natural gas detector* provides an early warning of dangerous levels of gas. It can be linked to the *Gas Shut Off Valve* to automatically cut the gas supply off, if a leak is detected.

The wireless *Smoke detector* alarms if smoke is detected and also provides auto low battery reporting. As a complement, the wireless *Heat Detector* provides additional protection against the risk of fires in rooms where smoke detectors are unsuitable e.g. kitchen. The detector raises an alarm when the temperature reaches between 54°C and 62°C.

The *Temperature extremes sensor* monitors for low and high temperature extremes in addition to the rate of rise in temperature. The sensor helps to minimize the risks associated with changes in temperature.

3.2.4 Integration of Tunstall sensors in the system

The sensors provided by Tunstall are described in section 4.1.4.2 and consist of: waist worn fall sensors, FAST Passive InfraRed motion detectors (PIR), Electrical Usage Sensor, Door usage also called the Universal sensor, Bed/Chair Occupancy Sensor, Flood, Carbon Monoxide Detector and wireless Smoke detector.

Tunstall will expose a data port on his gateway (Connect+ social alarm) in the physical environment through a USB dongle named the Tapit USB. The data will primarily be alerts raised by the sensors. To facilitate the integration, the middleware will use a wrapper that exposes the devices to the hardware abstraction layer.
Other components can access data from sensors subscribing to the topics that the middleware will publish.

3.2.5 Integration of Intellicare sensors in the system

The solution that Intellicare will provide is shown in
Figure 21.

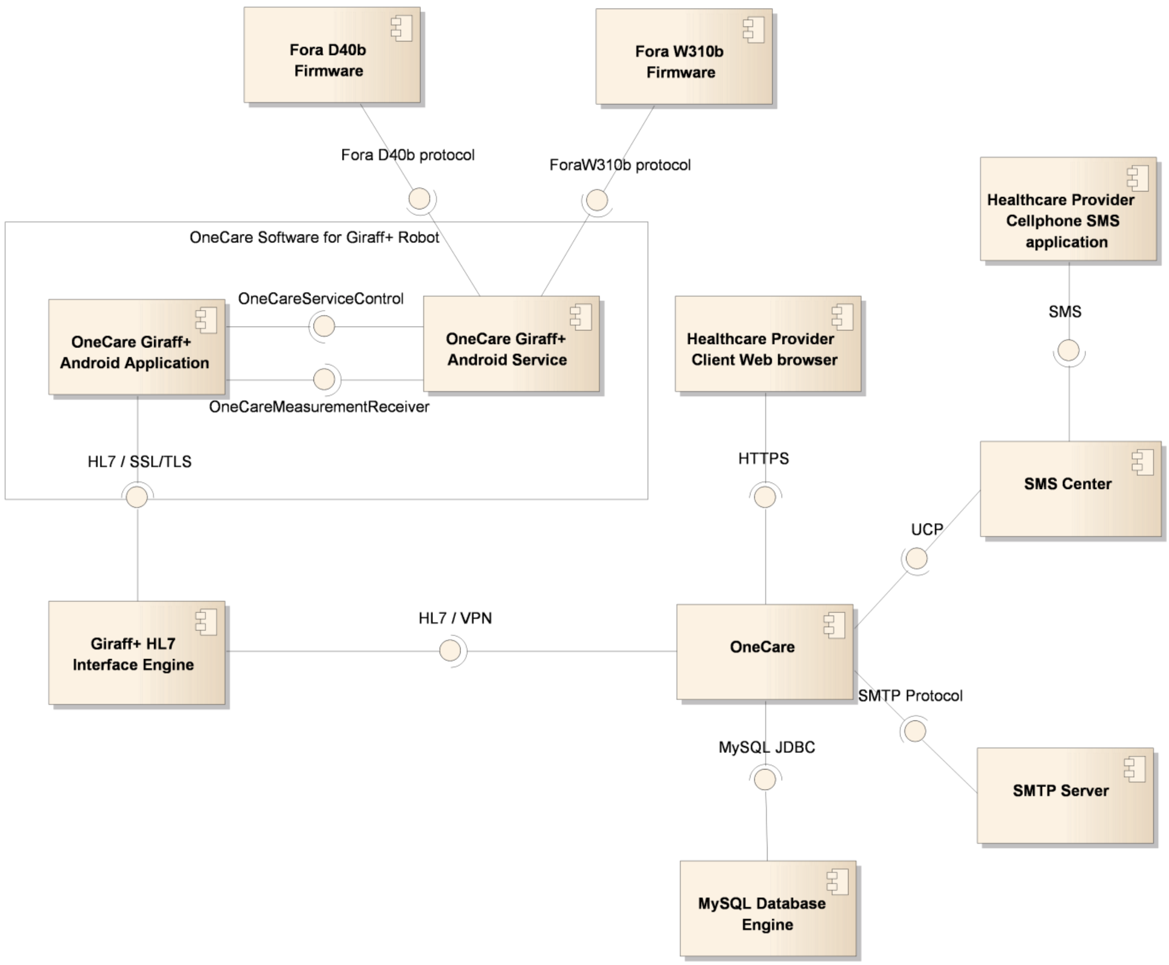

Figure 21 Intellicare overall architecture

To facilitate the integration in the Giraff+ system, the Intellicare solution will use the middleware interface to publish the sensed data and the alarms raised as topics. How the Intellicare components interact with the middleware infrastructure is shown in the following UML component diagram (Figure 22).

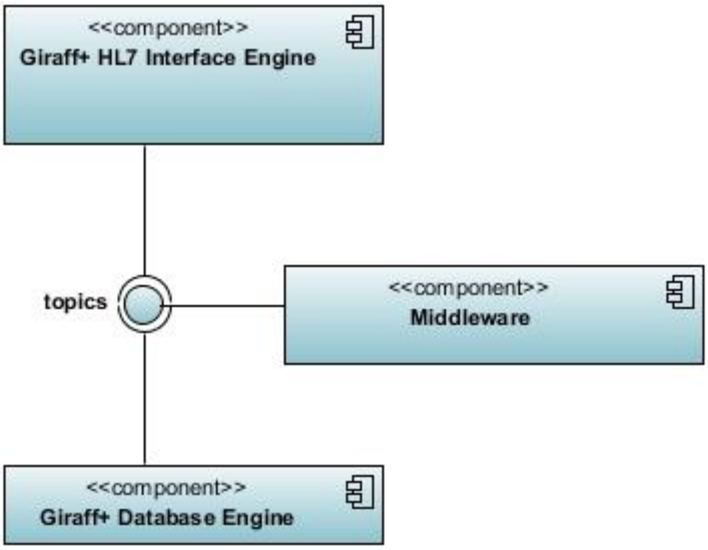

Figure 22 How the Intellicare components interact with the middleware infrastructure

3.2.6 Integration of additional sensors in the system

The Zenicor system (used for ECG recordings with the purpose of arrhythmia investigations and screening for arterial fibrillation among risk groups) records one channel ECGs and transfers it using mobile phone technology. The ECG is stored on a server provided by Zenicor and data are accessed from this server. In case this sensor will need to be integrated in the GiraffPlus system we will need to analyse what would be the most efficient way to collect these sensor data.
The motion analysis system of body worn inertia sensors is computer based. Data is fully accessible from the sensor node and integration into GiraffPlus will be straightforward.
Photo detectors to determine the light status are commonly available and data is fully accessible from the sensor node and integration into GiraffPlus will be straightforward.
Web or video cameras are commonly available and data is fully accessible from the sensor node and integration into GiraffPlus will be straightforward.

3.2.7 Remote Access

One of the most important goals from the perspective of the software support on the GiraffPlus project is the ability to establish the connection with the gateways at primary users' homes. By accomplishing this, it will relieve the supporting personnel of having to drive to remote locations (which could be very far away) in cases when one of the GiraffPlus components would break down. The supporter would simply login to the remote gateway (for example, by using the SSH tool) in fix the problem at hand (in worst case reinstall the Giraff+ software on that gateway).

However, establishing the connection with the gateways is far from trivial. The majority of them will be behind the firewall (router) which means they won't even have the public IP address to connect to. For solving this issue **Virtual Private Network** technology could be utilized (*http://en.wikipedia.org/wiki/Virtual_private_network*). Virtual private network (VPN) is a private network that connects remote (and often geographically separate) networks through the Internet. The security is provided through the encryption of the network traffic. For example, a VPN could be used to securely connect the branch offices of an organization to a head office network through the public Internet. VPNs typically require remote users to be authenticated and make use of encryption techniques to prevent disclosure of private information to unauthorized parties present on the network(s) the VPN goes through.

Through VPNs, users are able to access functionalities across networks, such as remote access to resources like files, printers, databases or internal websites in a secure manner. VPN remote users get the impression of being directly connected to the central network via a point-to-point link.

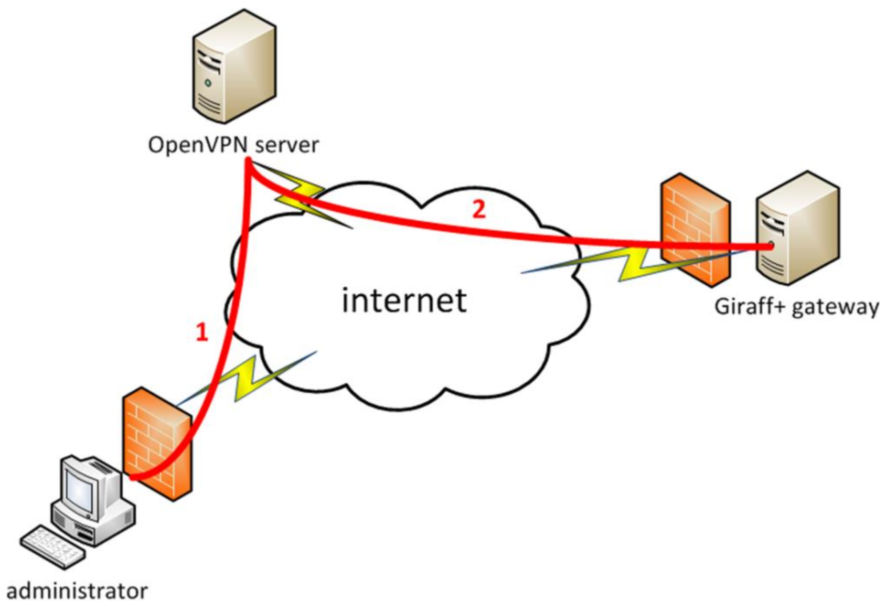

Figure 23 Connection to the Giraff+ gateway

Figure 23 shows how the VPN can be integrated in the Giraff+ infrastructure. The technology used in this purpose is **OpenVPN (http://openvpn.net)**, which is currently the most popular open source implementation of the VPN techniques. It uses a custom security protocol that utilizes SSL/TLS for key exchange. It is capable of traversing network address translators (NATs) and firewalls. When the administrator wants to connect to remote gateway, it first connects to the Giraff+ VPN server (see the connection labelled with “1” in the figure). If it is successfully authenticated (i.e. its credentials match the one stored on the VPN server) it becomes a part of the private network in which the gateway is also present. At this point, the remote gateway can be accessed, for example, by using SSH.

One of the greater advantages of the VPN over similar technologies for traversing firewalls (e.g. tunnelling) is the persistence of the VPN connection. If the network connection is broken at any given point in time and is later re-established, the VPN connection will also be re-established automatically. The VPN software can even be configured to establish the connection automatically at boot time. This simplifies the management of the infrastructure significantly, since the Giraff+ gateways will always be accessible.

The VPN connection can be used for the administration tasks in Giraff+ project. In addition it could also be used to connect the dislocated data storages (different instances of MongoDB in replica set) in the secure closed network. For accomplishing this separate VPN subnet can be created that will only be used by the data storages. This can make the data replication simpler since all the database servers will share the same address space. Additionally, connecting the database instances with VPN can also improve security and data confidentiality. At this point we should notice that the VPN technology will be used for the maintenance of the GiraffPlus gateways. It will not be used when transferring the video and audio stream from the Giraff robot due to the efficiency reasons. For that, different means of traversing the firewalls will be used, if necessary (most likely the proxying).

3.2.7.1 Software updates

During the course of the project a number of different tests sites will be employed. Also later, when the GiraffPlus system gets commercialized, there will be a number of locations where the system is deployed. So as soon as the new version of the GiraffPlus software is available, it will have to be pushed to all these remote sites in an efficient manner.

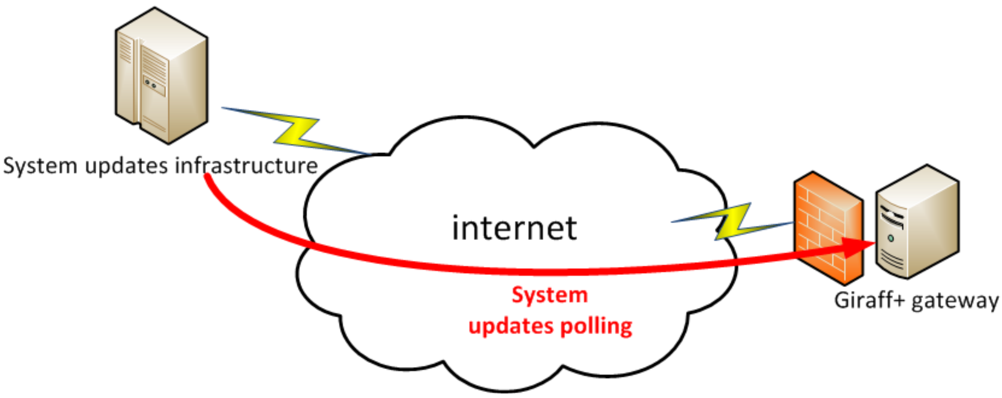

Figure 24 the updating of the software versions

Figure 24 shows how the VPN is used in the GiraffPlus infrastructure. In order to mitigate the issues with the firewall traversing, the gateway is periodically polling the GiraffPlus infrastructure for updates.

Currently we have defined two approaches for software updating:

- the synchronization of the application files using tools such as rsync,
- the implementation of a special GiraffPlus component that will be in charge of retrieving the current version of the classes transparent from the user (in a similar way Google Chrome is updated).

The software updating approach will be chosen based on the needs of each GiraffPlus component.

3.2.8 GiraffPlus cloud infrastructure

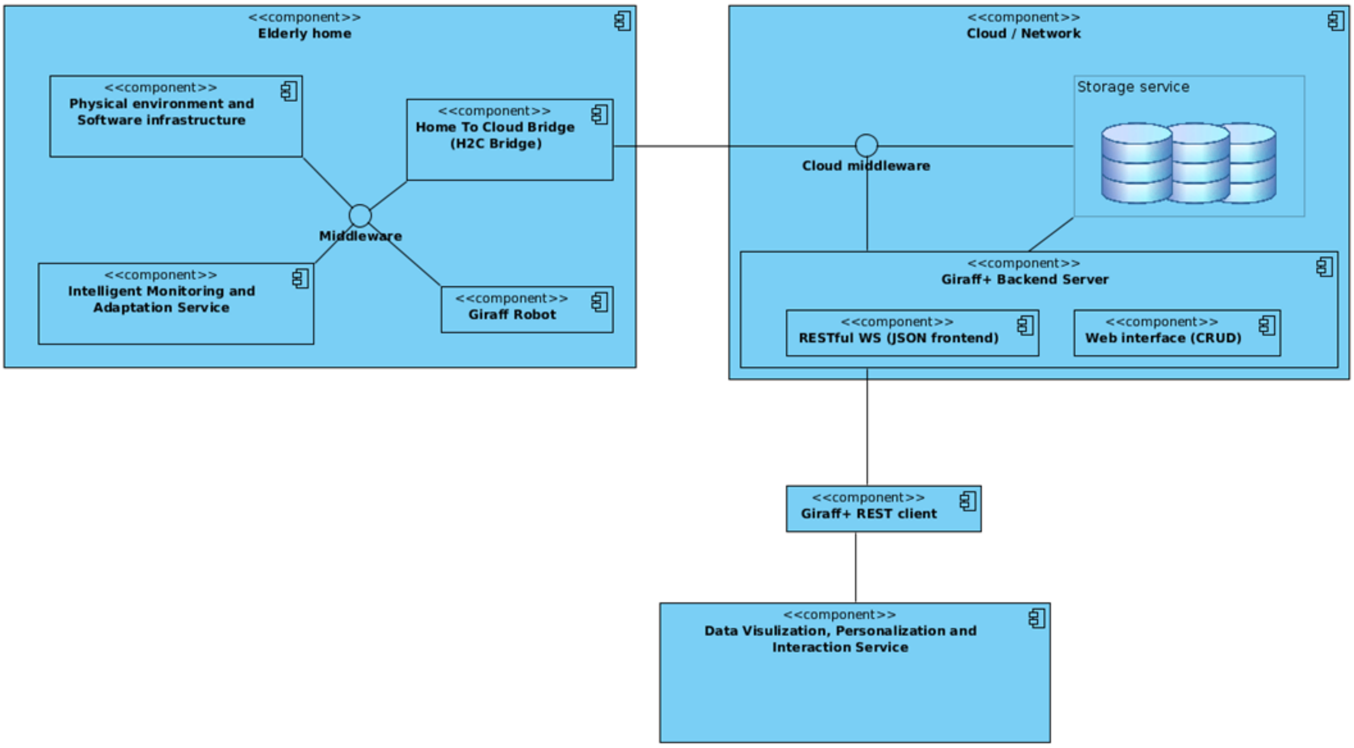

Figure 25 The GiraffPlus cloud infrastructure

The GiraffPlus cloud infrastructure will be responsible for collecting data in a secure and reliable manner and for providing fast access to secondary users. In addition, it will provide flexibility for migration of GiraffPlus services responsible for context recognition and configuration planning system (Intelligent Monitoring and Adaptation Service) into the cloud.

With regards to the proposed middleware, the GiraffPlus Cloud will provide similar infrastructure on a larger scale. The main component will be replicated middleware, based on the same message formats and rules that will combine different local instances into the cloud infrastructure. To bridge the transition and provide transparent access to all the services (i.e. storage service) H_2C Bridge (Home To Cloud Bridge) will be prepared, which will be responsible for connecting each of the local middleware instances to the cloud.

The goal is to create transparent infrastructure for services to access all other services seamlessly, either locally or remotely. Since the design of local and remote middleware will be very similar, it will be also possible to migrate local services (i.e. context recognition) to the cloud with little effort. On the other hand it is as flexible that would be possible to install all cloud components (database, backend server, etc.) locally in elderly apartment and serve data to WP4 clients directly from locally available web services.

3.2.8.1 Main features

Provide fast and reliable data access for secondary users (IVS, PerS)
The main goal is to provide fast and reliable data access for Data Visualization and Personalization and Interaction services. In order to facilitate connectivity RESTful web services will be defined, which will provide interface to retrieve data. Additionally they will enable the sending of the commands and configuration changes back to the GiraffPlus components, relying on the cloud infrastructure.

Secure, reliable and fast central storage
The goal is to provide central storage for the GiraffPlus system, which will be responsible for storing all the data collected by the physical services, as well as the data produced by other components (monitoring and adaptation services, interaction and personalization services). Additionally, it will also store configuration data (sensor data, security restrictions, …) and logging data from all the software components in the system (all logs will be centrally available, and therefore it will be easier to maintain and debug the system).
We have decided to use a storage solution that would enable us to safely and efficiently store large amounts of gathered data without limitations of a pre-defined data model since all kinds of data that are to be stored is not yet known. We have therefore decided to use a MongoDB database, which is flexible, scalable and can handle large volumes of data. The technology is heavily used in enterprise world and has been proved to be secure and reliable.
All the stored data will be automatically replicated among prepared instances of MongoDB (replica-set), which will provide automatic failover and automatic recovery (disaster recovery) of member nodes.
Data retrieved from the middleware (locally) will be automatically collected and transferred to the central storage system by the H_2C Bridge (Home to Cloud Bridge), and made available to all other relevant components in real-time, taking into account the security permissions for each of the component and connected users.

Flexibility and scalability
The cloud infrastructure will be developed in a way that will work reliably and consistently on all platform-as-a-service vendors including the industry leading Cloud Foundry, Amazon Web Services and Google App Engine.
In order to guarantee maximum privacy we can even establish a private cloud using existing PaaS open source infrastructure. This cloud would be controlled by GiraffPlus consortium. However, for the duration of the project, Xlab will provide test infrastructure to run GiraffPlus backend services.
The use of cloud technologies will make the system scalable - providing the ability to easily provide additional storage or computing power if required.

Transparent infrastructure for GiraffPlus services
The goal is to provide cloud infrastructure that will be similar to middleware used inside the home, except on a larger scale. It will be based on a messaging system (MQTT) that will mirror internal middleware, whose main functionality will be to collect data (and store it in central database) and transfer messages, created by IVS and PerS, back to the middleware.
However, since the technology used will be similar to the middleware, it will also be possible to migrate services (that are not required to run locally) to the cloud -- Communication with database

and Physical environment and Software infrastructure will be transparent for migrated services, therefore only minor adjustments in the configuration will be required.

3.2.8.2 Cloud components

H_2C Bridge
H_2C Bridge is located in the elderly home and is responsible to provide bi-directional connectivity with the GiraffPlus cloud. It will be responsible for collecting data available through middleware and sending it to the central database. On the other side it will transfer messages and commands from remote clients and services (i.e. IVS and PerS) and publish them to the middleware.
In case that local services will require data that cannot be cached locally (older data, aggregated data, …), the component will expose an interface for accessing the central storage.

Cloud middleware (MQTT or RabbitMQ)
Cloud middleware will replicate the design of local middleware, with the addition to provide the ability to connect remote services (Data storage service) and combine all locally installed instances under the same secure and reliable cloud infrastructure.
The messages formats and rules will be the same as used in local middleware and defined in WP3, therefore the communication between the two will be straightforward, provided by H_2C Bridge.

GiraffPlus Central Storage
(see below, 5.2.1.8 Data Storage)

3.2.8.3 GiraffPlus backend server

Spring framework
The Spring framework is an open source application framework of the enterprise Java platform.
It provides a powerful and flexible collection of technologies:

- ***Data access:*** Support for traditional RDBMS as well as new NoSQL solutions (MongoDB), map-reduce frameworks and cloud based data services.
- ***Security:*** Authorization control for all tiers and authentication integration to dozens of providers.
- ***Cloud ready:*** works reliably and consistently on all the platform-as-a-service vendors including the industry leading Cloud Foundry, Amazon Web Services and Google App Engine.
- ***Frontends:*** Complete support for modern web technologies including REST, HTML 5, conversations and AJAX.
- ***Mobile:*** Web support for the most popular mobile client platforms, such as Android and iPhone.

The Spring framework will be used at the core of the GiraffPlus cloud infrastructure. It will be responsible to provide fast and secure access to the central data storage, it will expose RESTful web services (that will enable secondary clients to connect to the GiraffPlus cloud) and also host the CRUD web interface (CRUD - create, read, update, delete).
Industry standard secure authorization mechanisms (LDAP - username and password or X.509 support - certificates) will be used to provide different privileges for users to access collected data

and to send messages back to infrastructure (for example, the relatives would only be able to access context recognition data, where administrator of the system would be able to access all the collected data from each of the elderly homes and would be able to send configuration commands back to the GiraffPlus services).

RESTful Web Services (JSON frontend)
For connectivity between clients developed under WP4 (IVS, PerS) and the GiraffPlus system, standard client-server architecture will be introduced. On the server side, RESTful web services will be exposed, this will provide the ability for the clients to securely connect to the GiraffPlus infrastructure and gain access to data stored in database service as well as to send commands back to the infrastructure. It will provide:

- Access point to connect secondary clients (IVS and PerS) with the system
- Interfaces to access data: physical data, context data, configuration data, aggregated data (by time or horizontally within group of services/sensors)

Java-based GiraffPlus REST client
To connect secondary clients (IVS and PerS) with GiraffPlus system, a Java-based REST client will be prepared, through which clients will be able to retrieve the needed data as well to send messages and data back to the system.
It will be implemented as a java library that will be used by client applications and will provide all interfaces needed to for authentication, data retrieval and pushing information back to the system.

3.2.9 Data storage

The goal is to provide central storage for the GiraffPlus system, which will be responsible for storing all the data collected by the physical services, as well as the data produced by other components (monitoring and adaptation services, interaction and personalization services). Additionally, it will also store configuration data (sensor data, security restrictions, …) and logging data from all the software components in the system (all logs will be centrally available, and therefore it will be easier to maintain and debug the system).

The storage solution that will be integrated into GiraffPlus system will provide infrastructure to safely and efficiently store large amounts of gathered data without limitations of a pre-defined data model since all kinds of data that are to be stored is not yet known. For this purpose, **MongoDB database** will be used, which is flexible, scalable and can handle large volumes of data. The technology is heavily used in enterprises and has been proved to be secure and reliable.
All the stored data will be automatically replicated among prepared instances of MongoDB (replica-set), which will provide automatic failover and automatic recovery (disaster recovery) of member nodes.

Data retrieved from the middleware (locally) will be automatically collected and transferred to the central storage system by the H2C Bridge (Home to Cloud Bridge), and made available to all other relevant components in real-time, taking into account the security permissions for each of the component and connected users.

3.2.9.1 GiraffPlus Central Storage

In the GiraffPlus project we will need to store a substantial amount of data coming from each GiraffPlus test site. What data is to be stored will be determined during the course of the project, but some of the data will be:

- data coming from individual GiraffPlus instances (homes):
  - configuration data
  - data regarding placement of different sensors and actuators, security restrictions data, etc.,
  - data coming from installed sensors,
  - data coming from the Giraff platform,
  - data coming from the monitoring and context recognition components,
  - logging data of different software components for easier system maintenance and debugging,
  - alarms triggered by different components,
- data from secondary users
  - documents related to primary users of the GiraffPlus instances

3.2.9.2 NoSQL database

The NoSQL family of database systems offers certain advantages of the classical RDBMS (Relational Database Management Systems). Some of these are:

- **flexible data models** – changes to the data model are much easier than with RDBMS
- **elastic scaling** – replica sets, sharing, etc.
- can handle much **larger volumes** of data than RDBMS
- **lower cost** – using clusters of cheap commodity servers
- **easier administration** – automatic failover, data distribution, simpler data models.

Despite the advantages listed above the NoSQL databases also have some setbacks. These challenges may not be as important to developers, as they are to enterprises.
Some of these are:

- many of these databases are still in the development phase with many key features yet to be implemented,
- support may be lacking opposed to the high level of support provided by some RDBMS vendors,
- queries and analyses require significant programming expertise using NoSQL databases,
- NoSQL databases, despite their design goal of being easy to set-up and maintain, still require significant effort to install and maintain.

3.2.9.3 MongoDB

MongoDB (from ”humongous”) is an open source document-oriented NoSQL database system. Instead of storing data in tables as is done in a ”classical” relational database, MongoDB stores structured data as JSON-like documents with dynamic schemas, making the integration of data easier and faster.
It supports sharing (i.e. partitioning of data) architecture, enabling horizontal scaling across multiple database servers. Once the amount of data outgrows the resources of a single database

server, MongoDB converts to a shared cluster automatically managing failover and balancing of database nodes with few or no changes to the original application code. Thus the system will be able to efficiently store large amount of long-term data gathered in the GiraffPlus system.
MongoDB also supports asynchronous replication of data, adding automatic failover and recovery of database servers. Replica sets - cluster of synchronized database nodes - offer the following advantages:

- **data redundancy**
  all data is asynchronously replicated on all member database servers,
- **automated failover/high availability**
  as long as there is at least one member database server running, the data remains available,
- **distribution of read load**
  same data may be read from any server in the replica set thereby reducing the read load to individual servers.

GiraffPlus storage
To take full advantage of MongoDB we plan on setting up a MongoDB system consisting of multiple shard nodes, with each node a replica set itself consisting of multiple asynchronously replicated MongoDB instances. For the development phase of the GiraffPlus project we plan on setting up an environment consisting of two MongoDB shards, each a replica set of three MongoDB instances. Additional replica sets will be added at a later time, should the need arise during the course of the project. All these MongoDB instances will be set up in the private cloud provided by XLab and restricted to the GiraffPlus virtual network.

Data model
One of the advantages of using a NoSQL database system is that it eliminates the need for a predefined data model. We plan to define a rough data model in the architecture planning stage by analysing types of data to be stored in the database, which will help optimize the database system, yet keeping the whole system extensible and open to the addition of new kinds of data during the course of the project.

Data collection
The plan for data collection is to write a client application that will connect to the middleware infrastructure, listen to all relevant communication passed through the middleware and store data in the database. The implementation of the client will depend heavily on the middleware system but it will have to be optimized to handle large volumes of data generated by the GiraffPlus system.

Access to data
To enable various GiraffPlus components to retrieve documents from the database and insert new documents we will define a separate component with a well-defined REST interface.

3.3 Giraff robot

The Giraff system (Giraff, Pilot and Sentry) must have some basic interface capabilities with the GiraffPlus system. An API defining these requirements is detailed in Appendix 1, and is the basis

for defining a protocol for the required operations. The philosophy of this API is that the GiraffPlus system (and not the Giraff robot system itself) always maintains the database of record for any information required for interactions between GiraffPlus and Giraff, and always takes precedence over what information might reside in the Giraff system. The API also assumes that the GiraffPlus system manages all calls between the Giraff and the secondary users, and simply passes call information to Giraff to actually connect the call. Regarding integration of the Pilot client into the DVPIS, the goal is to create a Java .jar wrapper that allows the DVPIS to integrate the Pilot application. However, for now the Pilot can be operated as a separate application without compromising the overall GiraffPlus concept, for the sake of moving into trial phase as quickly as possible.
The main components of this API are:

- Passing login credentials from the GiraffPlus UI to the Pilot UI so that the user does not have to login in twice with separate credentials.
- Initiating a call from a user to the Giraff.
- Responding to a request from the Giraff or other system component to make a call to a user.
- Issuing auto-navigation commands to the Giraff.

3.4 Semi-autonomy of Giraff robot

The improvement of the semi-autonomy of the Giraff robot, to be tackled in task 2.6, will be carried out in five sub-tasks:

- **Selection of suitable sensors**. A thorough study will be carried out regarding the sensors available in the market for a reliable and inexpensive perception of the environment. The selected sensor(s) will be integrated into the Giraff robot and they will be exploited for obstacle detection and map building.
- **Map Building.** Design and implementation of algorithms for the offline construction of a geometrical map of the workspace.
- **Giraff Localization within the workspace.** Design and implementation of localization algorithms aimed to estimate the position of the Giraff within its workspace, using the geometrical map constructed in the previous task.
- **Reactive Navigation.** Development and integration of specific algorithms for safely negotiating obstacles while moving to a given destination.
- **Collaborative Control.** Design and implementation of algorithms for combining the obstacle avoidance behavior and the user's commands in a collaborative way.

The first sub-task has already finished, concluding with the selection of the Kinect sensor as the best solution taking into account the requirements of price and reliability. The rest of sub-tasks will be carried out by implementing seven software modules as described below.

1. **Sensor grabber.** This module will implement the functionality for regularly saving data from the sensors mounted on the Giraff robot (i.e. Kinect, odometry, etc.). The information stored by this module will be used to offline build a geometrical map of the robot workspace (i.e. a house).

2. **Offline map builder.** This software component will build a geometrical map of the robot workspace from the sensor measurements stored by the Sensor grabber module. Due to the computational requirements of map building algorithms, this component will not be executed on the Giraff robot but in any other computer, e.g. the one of the secondary user. The result will be a file encoding a point-based geometrical map that will be loaded into the Giraff robot for self-localization. As a first approach, we plan to build a two-dimensional map of the robot workspace, emulating a 2D laser scanner from the Kinect measurements, but other possibilities can be considered as constructing 3D maps from the 3D point cloud generated by the Kinect sensor.

3. **Self-localization.** This module will implement the functionality for continuously estimating the pose (position and orientation) of the robot within the environment given the geometrical map built by the Offline map builder. The pose will be estimated by matching the current sensorial information with the map. Depending on the sensor data and the considered map, this process could be one of the following:
    a. 2D-2D. This method matches 2D scan data with a 2D map. 2D data is emulated from the Kinect 3D observations by only considering horizontal slices from the 3D cloud.
    b. Multiple 2D-3D. This method matches a number of 2D scans at different heights using a previously built 3D map.
    c. 3D-3D. This method, more computationally demanding, matches 3D scans with a 3D map.

    The self-localization module exhibits a significant computational burden which depends on the amount of data and the matching technique considered, being 3D-3D map matching the most time consuming option. Given the limitation of the Giraff onboard computer, a thorough study will be carried out to properly choose the most convenient and reliable technique.

4. **Map manager.** This module will show a schematic map of the environment manually constructed upon the geometrical map. A schematic map annotated with labels and representing the environment in terms of topological places like rooms, corridors, etc will enable the secondary user to visualize the robot pose as well as allow him/her to specify target points on the map as robot destinations.

5. **Autonomous motion.** This module will implement the functionality to translate the destinations marked by the user on the map to reactive navigation commands, so that the Giraff robot navigates to the specified positions negotiating obstacles. We will also investigate the possibilities for a dependable topological navigation between places of the house. This autonomous behavior will demand performing route planning between different topological entities of the map (e.g. to go from the kitchen to the corridor).

6. **Reactive navigation.** This module generates navigation commands to the Giraff's motors (linear and angular velocities) to move to nearby places avoiding obstacles. For avoiding obstacles it will rely on 3D information provided by the Kinect sensor, which allows obstacle detection at different heights within a range between 0.5 to 3.5 meters.

7. **Collaborative control.** This module will implement the needed functionalities to combine

teleoperated navigation with reactive navigation, enabling the user to teleoperate the robot within the environment in a safer way, i.e. avoiding obstacles. To that end, the user driving command will be considered as an indication of the robot motion orientation which must be conveniently corrected by the collaborative controller to negotiate the obstacle in that direction.

Details about the figure are given in appendix 1.

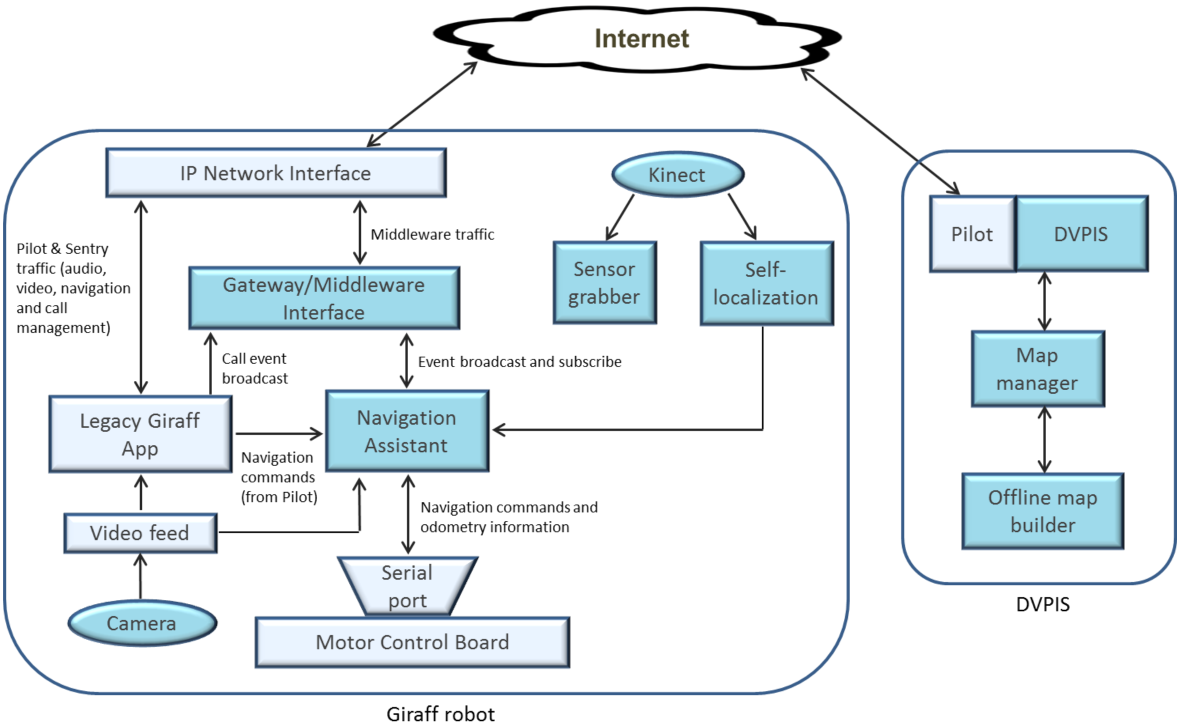

Figure 26 Diagram of the software modules considered for task 2.6

To implement these modules we need to overcome a number of issues. Some of them that have already been detected are:

- Limited FOV (Field of View) of the Kinect sensor. The Kinect sensor has a FOV of 58º in the horizontal plane and 45º in the vertical one. This limited FOV (when compared to 2D laser scanners) represents a challenge for the Offline map builder and Self-localization modules:
    - The offline map builder works by aligning sequences of range scans provided by the sensor. A limited FOV of the sensor hinders the alignment process (especially when the robot rotates), yielding inaccurate maps.
    - Self-localization works by matching every scan provided by the sensor with the built map. Again, a limited FOV hinders the pose estimation algorithm to find a correct estimation due to local minima during the matching process.

A possible solution to tackle the limited FOV of the sensor would consist on using 3D information from the Kinect sensor, for both, map building and Self-localization. This implies the design and implementation of 3D matching algorithms with the subsequent complexity and computational burden.

- Odometry Accuracy. The Giraff robot has four wheels: two for steering and two swivel casters. The latter are required for vertical stabilization of the robot, but they affect to the movement of the robot, especially when they are transversally oriented. Furthermore, the four wheels act like four footholds which must be perfectly balanced so that the steering wheels are always touching the floor. In practice the steering wheels often slip on the floor, leading to imprecise odometry measurements. This issue affects to the offline map builder and the self-localization modules which both rely on the robot odometry as initial pose estimation for the alignment of scan data. Imprecise odometry measurements may lead these processes to fail, a problem that is even worsened when the sensor has a reduced FOV, as it is the case. A possible mechanical solution to enhance the odometry measurements could be to improve the robot balance, by uniformly distributing the robot weight over the four footholds, avoiding the driving wheels to slide on the floor. To that end, it could be convenient to reduce the friction of the swivel casters, especially when they are oriented transversally. A more practical and in accordance to the state-of-the-art solution is to study the possibility of implementing an algorithm to compute visual odometry using the information provided by the Kinect sensor. The latter, more promising solution will be investigated in the next months.

Finally, some words are in order on how the Giraff robot will be integrate with the rest of the system. Conceptually, in the GiraffPlus system, the Giraff telepresence robot plays a twofold role: on the one hand it allows social interaction with the elderly. On the other hand, it is a powerful means to get visual evidence of the elder health condition as well as environmental information from the house, that is, it serves as another “sensing” device of the system. An example of integration of the Giraff robot into the GiraffPlus system is the possibility of providing it with information relevant for the activity recognition module, such as the robot localization within the house in order to filter out false positive of presence sensors because of the robot activity.

3.5 Intelligent Monitoring and Adaptation Services

The UML diagram in Figure 27 describes the main components of the intelligent monitoring and adaptation services. There is the **context recognition component**, and the **configuration planning component**, and in addition a number of separate functionality components (each a process executing a specific program) can be dynamically activated and terminated by the configuration planner. The different components can interface with the sensor network, data storage and personalization services via the middle ware: this is indicated by UML interface sockets in the figure.

These components will be implemented in Java, and will be deployed to the virtual machines in the GiraffPlus cloud (see section 3.2.8).

In the following sections, we present the main interfaces to the rest of the GiraffPlus system, we give an introduction to the central concepts of the Intelligent Monitoring and Adaptation Services, and we present the two major components in some more detail.

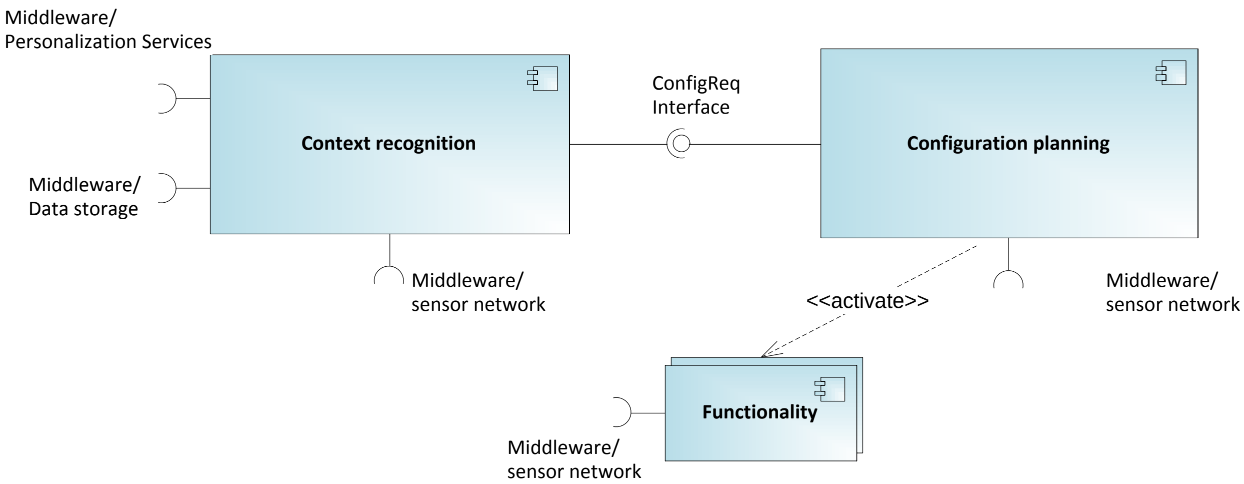

Figure 27 Components of the intelligent monitoring and adaptation services

3.5.1 Interfaces

Most of the communication occurs through the middleware, as described in section 3.2.1. However, there are specialized protocols for communication with other components on top of that.

- **Sensor network**: the configuration planner can make requests for subscriptions of data, and the context recognition can receive data using those subscriptions.
- **Personalization services**: the context recognition can receive requests for activities to be monitored, and requests to select specific inference rules, or modify/create inference rules. It can also provide the personalization services with information about what activities and inference rules are available, or selected.
- **Data storage:** the context recognition can store and retrieve timeline data. As language, we will use JSON (as MongoDB supports this, see section 3.2.9.3).

3.5.2 Concepts

The Intelligent Monitoring and Adaptation Services view the environment abstractly as a collection of **state variables**, which at each point in time have some values. These state variables may represent for instance:

- Aspects of the layout of the apartment (rooms, furniture, etc.)
- Position and motion of individuals in the apartment (e.g. person1 in bedroom, on bed, not moving)
- Position and motion of various items in the apartment (e.g. book1 on table in bedroom, giraffe robot in living room)
- Status of various items in the apartment (e.g. light on/off, machine on/off, door open/closed)
- Various physiological parameters of the individuals in the apartment (e.g. heart rate of person1, weight of person1)

A state variable may be static or dynamic. It may be observable directly through sensors, or it may be indirectly derivable from other state variables (at least in some circumstances). Some state variables may be controllable, i.e. they can be changed in a predicable manner by the sensor network.

The sensor network is viewed as a collection of devices (**sensors** and possibly also **actuators**, including those mentioned in Table 9) which can be configured and connected in different ways.

Each sensor can potentially obtain the values of one or more of the state variables, depending on the current state and on how the sensor is configured. Sometimes, a state variable is not directly obtainable, but it has to be derived from the data from one or more sensors in the network. Sometimes, some other state variable may need to be changed in order to obtain a certain state variable. An actuator can alter one or more state variables.

There are also purely computational processes (**algorithms**) for processing sensor data at various levels of refinement (or producing control) as part of the sensor network.

A **functionality** is a program that either operates directly on a sensor or actuator, or processes data from and/or delivers data to other functionalities. Note that a sensor or actuator can realize several functionalities, depending on what program is connected to it.

Functionalities can communicate with each other through their inputs (of different types and contents) and outputs. They may also require certain state variable assignments to function properly (e.g. a camera may require the light to be on), and/or they may modify certain state variables (i.e. switch on the light).

A **configuration** of the sensor network consists of:

- What functionalities are active and how they are configured.
- How outputs and inputs of functionalities are connected to each other, by using the subscription mechanism of the middle ware.

The configuration (together with the current state) determines what state variables are monitored.

Figure 28 shows four simple examples of configurations. The first one simply interprets data from a single motion detector in a certain room and writes the result in a state variable in the context recognition time line. The second one combines data from multiple motion detectors and writes the result in several state variables. The third one provides a connection from a luminosity sensor to a controller for the blinds of a window which should be closed under certain conditions. The fourth one reads data from a state variable and invokes appropriate controls of the blinds. (Note that these configurations are just included for illustrative purposes, and may not be realized in the actual system).

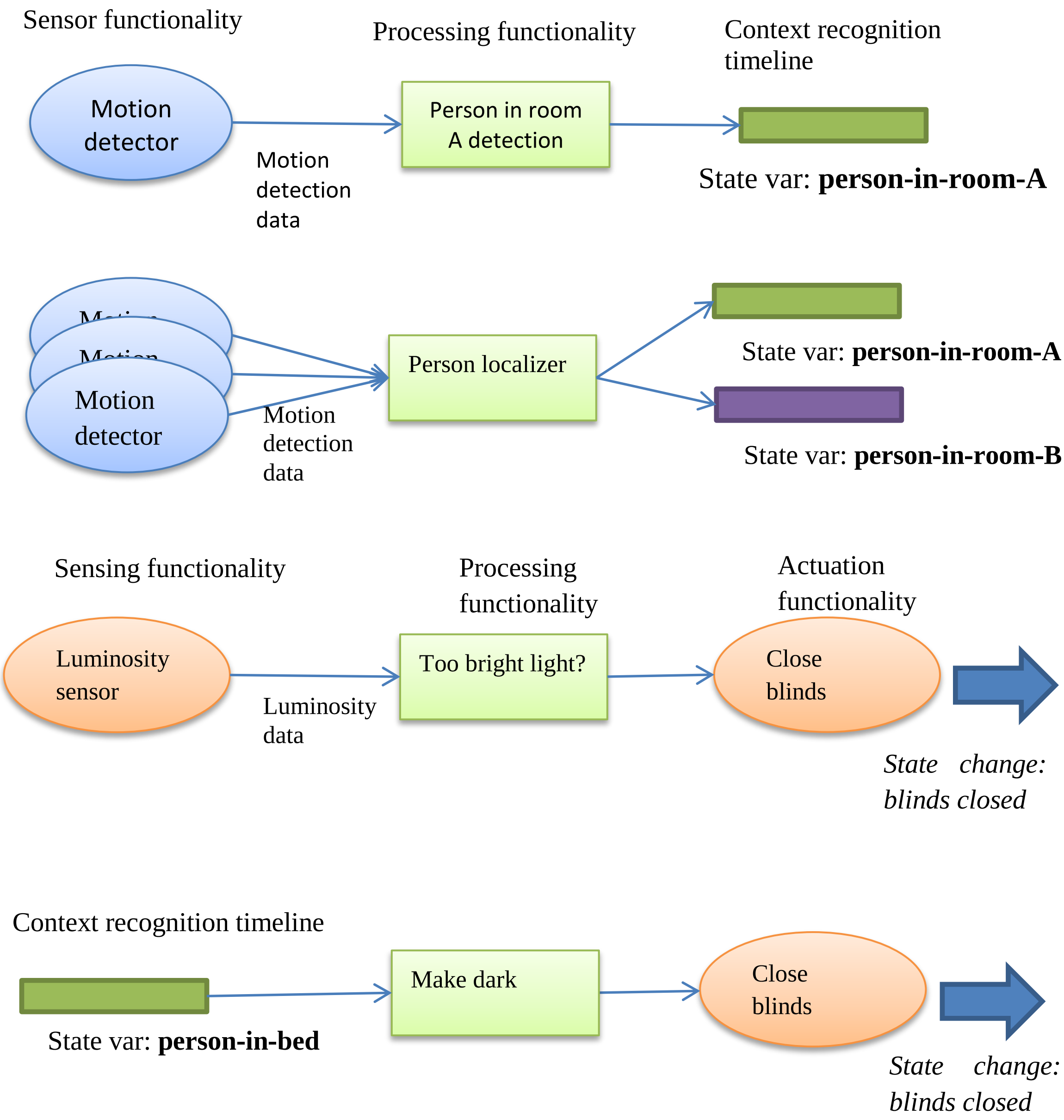

Figure 28 Some example configurations

3.5.3 Configuration planner

The configuration planner makes the sensor network provide the information (state variable values) that the context recognition system needs, and may also change state variables.

Internal information:

- Descriptions of functionalities (sensors, actuators, algorithms) and their properties: input, output, causal preconditions and postconditions. The inputs and outputs are flows of data (i.e. values of state variables), the preconditions represent conditions on state variables before the functionality starts, and the postconditions represent how state variables are changed by the functionality (i.e. actuation).

- Information about the environment, such as layout of the apartment (how rooms are connected etc.)
- Current configuration

Information from sensor network and data storage:

- Current estimated state (i.e. values of relevant state variables)
- Available sensors and actuators

Information from context recognition system:

- List of state variables to monitor, and possibly also state variables to change.

The task of the configuration planner is to configure the sensor network in terms of subscriptions (and possibly also giving parameters to functionalities) so that the state variables requested by the context recognition system are monitored. It also directs this data to the context recognition system.
For instance, context recognition may ask the configuration planner to supply the state variable "person-in-room-A" and the latter can then generate and deploy the first of the configurations in Figure 2.
The configuration planner should also be able to adapt to changing conditions, e.g. functionalities added, removed, or malfunctioning, or changes in certain state variables (e.g. light =off).
The configuration planner may produce configurations that change over time, in particular when actuation (pre- and postconditions) is involved.

3.5.4 Context recognition

Besides state variables, the context recognition system also deals with **activities**. An activity has an extension in time, and it typically involves changes in state variables (e.g. eating-dinner, sleeping, food-cooking, and robot-moving).

Internal information:

- **Time line(s)** with state variables and activities. The time line is a partial mapping of state variables and time to values and from activities and time to {on, off}. The time line is also stored in the database for long-term access. See Figure 29 for an example.
- **Context models**, including **context rules** for deriving activities from state variables and other activities (example in Figure 29). These derived activities may involve actuation, e.g. in the form of an alarm.

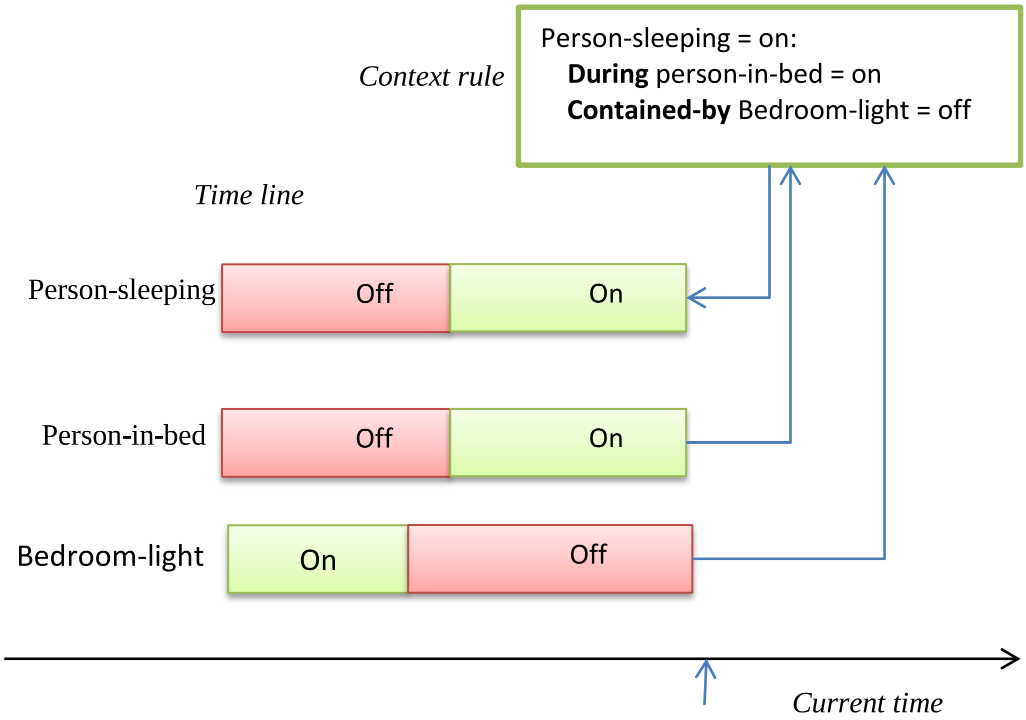

Figure 29 Example of time line (simplified) where an activity (Person-sleeping) is inferred from state variables obtained from sensor network (Person-in-bed and Bedroom-light) according to a context rule

From sensor network (as configured by configuration planner)

- Values of requested state variables (i.e. sensor data).

From personalisation services: There are multiple instances of the services, relating to different secondary users with different needs. Each of them can provide:

- Requests for state variables and activities, including time constraints (e.g. movement activities during night time, heart rate measurement once every morning).
- Selections of rules in context model for deriving activities.

Given the requests from services, the context recognition system determines what state variables need to be monitored and requests these variables from the configuration planning system. It then continuously receives data about these state variables from the sensor network, enters them into the time line and derive activities from them. The activities are in turn entered into the time line and so on.
The context recognition system may also change its request for state variables to the configuration planner, depending on what activities comes up or are expected to come up. And it may request changes of state variables (actuation) when certain activities are triggered.
Some physiological state variables, e.g. ECG, cannot be processed by the context recognition system but should just be stored for processing with more adequate tools. However, it is important to maintain the relation (e.g. temporally) to the information in the time line (database).

3.6 Data Visualization, Personalization and Interaction Services

The module described in this section is dedicated to the user interaction functionalities of the GiraffPlus system in a broad sense. We envisage the creation a flexible combination of capabilities that offers a number of different services from basic ones to more elaborate. To serve such a flexibility of use we designed a module composed of three different components that can be combined according to the different needs (Figure 30).

It is worth underscoring that the chosen architectural design of this component aims at guaranteeing functionalities that cover both the User Requirements collected in the first months of the project, reported in the D1.1 deliverable, and the general ideas inserted in the project Annex 1. A further level of detail dealing specifically with the implementation aspect will be described in subsequent documents related to the R&D workpackage work.

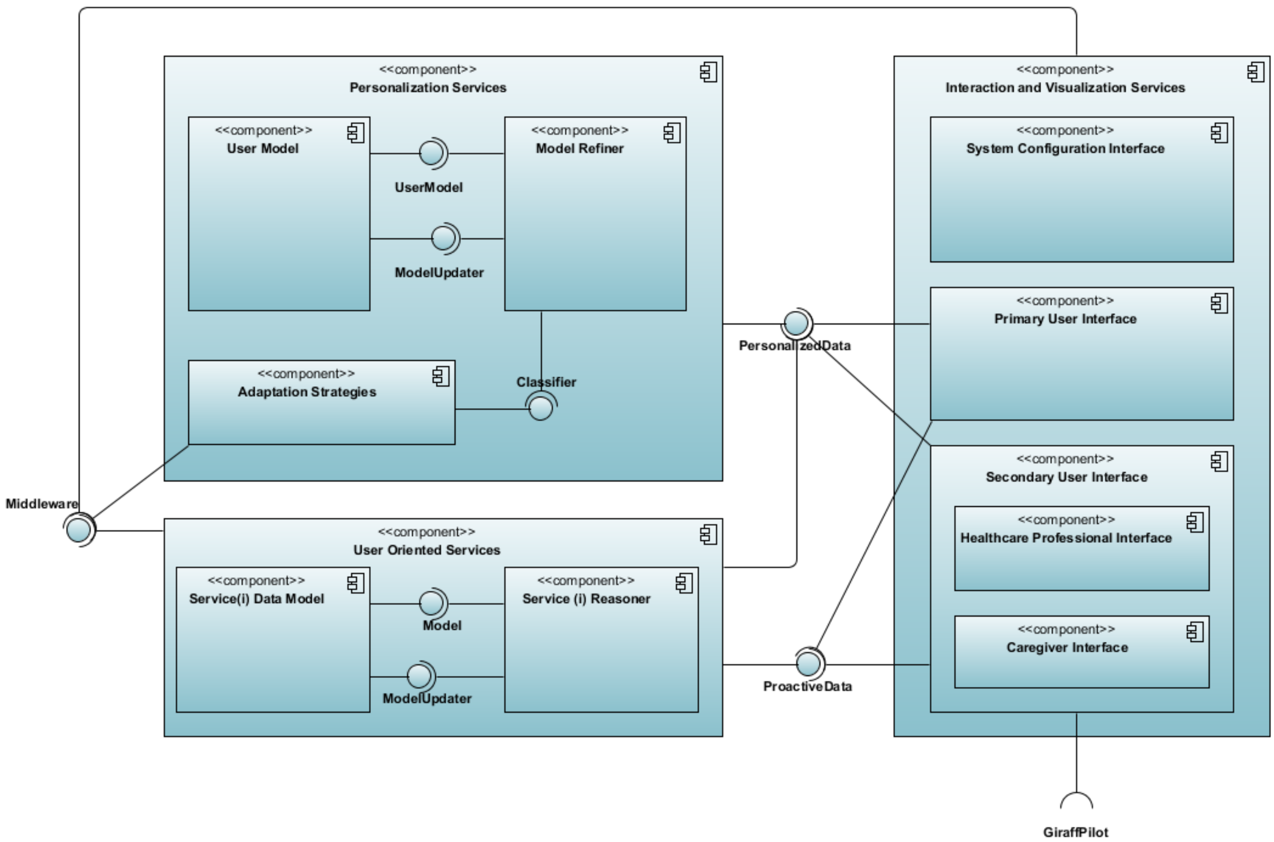

Figure 30 Data Visualization, Personalization and Interaction services component diagram.

Figure 30 shows the three main blocks of the Data Visualization, Personalization and Interaction Services component:

- **Interaction and Visualization Services**
- **User Oriented Services**
- **Personalization Services**

Each of these modules in meant to add specific functionalities to the Data Visualization, Personalization and Interaction Services. At the same time, the whole module is meant to be an integrated software component with front-end and back-end functionalities. The *Interaction and Visualization Services component* represents the direct front-end functionalities and is responsible for instantiating all the capabilities to be in direct contact with users. The *User Oriented Services* component creates a set of intelligent functionalities that provide a set of services tailored to the specific user's needs. The idea of this module is to support a number of particular services that are strictly connected to requests from *classes* of users. In some way, this is the place where specific data analysis or action synthesis can be done if the need arises during the development of the project. As basic functionalities, the module will contain: the Reminder, a functionality that emerged as a specific user request from the D1.1 analysis, and the Filtering activity that adapts GiraffPlus information and services according to users' need. The *Personalization Services* will act on top of the other two modules, constantly feeding them with information on how to personalize both the interaction (e.g., personalized interaction) and the specific intelligent services (e.g., personalized reminders) to the person who is using a specific instantiation of the GiraffPlus system.

Interaction and Visualization Services Following the use case diagrams presented in the first part of this report we have identified sub-modules to better serve classes of users.
The *System Configuration Interface* is the graphical user interface and interaction panel that allows the intervention of the GiraffPlus Engineer in the system. This functionality will deposit information through the middleware infrastructure to specific configuration files stored in the database for all the services to read.
The *Primary User Interface* is the interaction environment of GiraffPlus dedicated to the primary user. Such interaction will be used initially to delivery simple reminds, and to allow the primary user to read dedicated digest *reports* on the data gathering activity and to receive both *warnings* and *alarms*. To deploy these functionalities, we are considering using the Giraff platform. In order to enable the primary users to answer simple information requests, and to set themselves some reminders, the enhancement of the Giraff with a touch screen will be considered.
The *Secondary User Interface* represents the functionalities toward the secondary users. Given the pre-existing differences among classes of secondary users specific sub-modules are made explicit: interaction services are divided into *Healthcare Professional Interface*, dedicated to healthcare professionals and Formal Caregiver in general, and *Caregiver Interface*, customized for informal caregivers.
The interface for the healthcare professionals provides functionalities to access the system as system authentication, account configuration and specific service access. Other provided functionalities are primary user's profile initialization, tele-presence calls through the Giraff robot, and emergency calls. Through the Secondary User Interface, secondary users have complete access to both current sensor data and historical ones; additionally they can examine both current and previous primary user activities.
Finally, secondary users can set desired reactions of the system to specific detected configurations, set the monitoring and configure the plan reminder setting or editing reminders to receive. The Secondary User Interface is used to display periodic *reports*, *warnings* and *alarms*.
It is worth underscoring how the Giraff robot pilot is imported as an external functionality and customized in a homogeneous look-and-feel together with the other functionalities. More innovative uses of the pilot will be explored in research activities of the project and are outside the scope of this report.

As a final comment, this module is the one in charge of what in the DOW is called the IVS. Clearly those services have been revised following the first user driven iteration described in D1.1

User Oriented Services This component provides features for generating content and executing actions that will be displayed through the graphical user interfaces. Examples are *warnings*, *alarms* and/or *reminders*. The generic component is characterized by a *Service Data Model* component, which maintains a model of the provided service, and a *Service Reasoner* component that, possibly taking input from the Personalization Services component, manipulates information of the data model to produce the actual result of the service to be passed on to the Interaction module.

Personalization Services This component is dedicated to the implementation of the personalization services introduced in the project DoW. It is worth saying that in some parts of the DoW the personalization was referred toward Primary Users, indeed, as confirmed by analysis of User Requirements, it is worth saying that personalization activities should also concern Secondary User interfaces. As a consequence the whole module will be designed as a general module for *user profiling* and *modeling* that generates personalization information for the other two modules in the Data Visualization, Personalization and Interaction Services. Introducing broadly the functionalities internal to the module we can say that taking historical information from the middleware, the *Adaptation Service Component* extracts relevant features needed to classify the user. The current model of the user is maintained by the *User Model* component. Following rules generated by the *Adaptation Strategies* component and from the current profile of the user who is accessing the system, the *Model Reasoner* component provides a classification of the user according to which the customization is performed.

3.6.1 Input Interfaces

Given the general schema followed in the GiraffPlus architecture to transmit all the information exchanged among modules through the middleware infrastructure, the physical connection with other modules is achieved through the connection with the middleware module. Nevertheless, the information exchanged is dependent on source and destination of middleware messages.
In order to operate to its full potential, the Data Visualization, Personalization and Interaction Services module requires the following input from other modules:

- *Current sensor data*, coming from sensor network, are used to visualize information about current state of the house.
- *Historical sensor data*, coming from data storage module, are required to display historical information about the state of the house and, through filtering, to produce periodical reports.
- *Current activities*, taken from context inference system, are used to display information about current activity.
- *Historical activities*, from data storage module, are used to display information about elderly's activities over time.
- Configuration planning system related data.
- *Personalization rules*, from data storage, required by the personalization services.
- *Specific service related data*, from data storage, used to retrieve information about a specific service such as the reminder.

3.6.2 Output Interfaces

The Data Visualization, Personalization and Interaction Services module provides output mainly to the users in terms as graphical interfaces. Some output is provided to the other system components in any case:

- Warning and alarms *recognition rules*, to the context recognition component, required by the system to automatically recognize dangerous situations in the house.
- Reminder and other services related data, to the data storage, required, in a second time, by the user oriented module to perform specific service activities.
- *Actions*, to the Giraff robot, required to perform basic operations on the Giraff robot.
- *Activity recognition rules*, to the context recognition component to perform activity recognition tasks.
- Configuration planning system related data.

4 Privacy and security requirements

4.1 Privacy and security requirements

In the GiraffPlus project, we are dealing with personal data, data that sometimes can be very sensitive, both in the sense that it is important that data is not corrupted, and in the sense that personal data must not be revealed to unauthorized persons. Generally in the data dependency and security areas, requirements are divided into the following principles: *confidentiality*, *integrity*, and *availability*, plus often also *authenticity* and *non-repudiation*. In addition, *legality* has been proposed as an additional principle. We will describe the relevance of each of these principles to the data in the GiraffPlus project, and what methods are suitable to use to ensure privacy and security of the data.
The use of cloud services in the GiraffPlus project makes the security concerns regarding the backend server relevant to all components of the cloud environment. Similarly, intra-cloud communication must have a security level comparable to that of server-storage communication links.

4.1.1 Confidentiality

Confidentiality aims at preventing unauthorized access to data. The general ground for confidentiality is that exposing data to unauthorized persons would cause harm or other adverse effects, typically to the proper user or owner of the data.

When dealing with personal data like the ones in the GiraffPlus project, confidentiality is very much linked to *personal integrity*. Monitored physiological as well as environmental parameters can be sensitive to disclosure. A third concern is the disclosure of the collection process itself.

Confidentiality of collected physiological data in the GiraffPlus project
Physiological data, data that is collected to monitor the physical status of a person, of course reveals a lot of information about the physical status of that person. An example can be monitoring of heart activity. A recording of e.g. ECG or heart rate variability can reveal that the monitored person is suffering from a heart condition. Information about this is sensitive, and there can be many reasons not wishing to reveal such a condition, ranging from pure personal privacy (e.g. a person may not wish his or her neighbours to know about the heart condition), to concerns about economic effects (e.g. a person may not wish his or her life insurance company to raise the life insurance premium because of the heart condition).

Confidentiality regarding sensitive personal data of this kind is also regulated by law in most countries. It is in most cases thus not only a strong wish from the monitored person, but also a legal requirement, to guarantee confidentiality of the monitored physiological data.

Confidentiality of collected environmental data in the GiraffPlus project
Environmental data does not automatically raise the same privacy and legality issues as physiological data. However, in many cases environmental data can be just as sensitive. While information about e.g. the temperature in the kitchen may most often be harmless if revealed to unauthorized persons, other types of information may reveal physical conditions or social activities that the monitored person wishes be kept private. Such simple information as how often

and for how long the bathroom is used can reveal sensitive information. Information about the presence or absence of a certain person in a certain room may also be very sensitive.
While confidentiality regarding environmental data is not always regulated by law, the above concerns make it very appropriate to treat environmental data the same way as physiological data. It is thus a recommendation that all data receive the same treatment with respect to confidentiality, independent of whether it is physiological data or environmental data.

Confidentiality with respect to the collection process
Sometimes it is not enough to protect data from disclosure. Sometimes the very process of data collection reveals information. From the fact that a data collection is on-going, it is possible to draw some conclusions, e.g. that the monitored person may have a condition that requires monitoring. Hiding that data monitoring goes on can be extremely difficult. Confidentiality should however always be used to conceal the type of data being collected.

For the GiraffPlus project, it can be concluded that the deployment of a Giraff in the home, and the installation of monitoring sensors and communication equipment in the home, will be more revealing than the data traffic itself. It should thus not be a requirement to attempt to hide the communication itself. The type of data should however be concealed from unauthorized access.

4.1.2 Integrity

Integrity here means data integrity, i.e. that data cannot be tampered with. Both physiological data and environmental data must be protected from tampering. This includes data en route from sensors to the GiraffPlus middleware, data going from the middleware to the data storage, as well as the stored data itself.

Integrity of data en route
Confidentiality in the form of encryption, together with authentication that the sender is the correct sensor, addresses the integrity problem of data en route. Hence, no special mechanism or method is required for integrity of data en route if confidentiality and authentication is solved.

Integrity of stored data
Data stored in the database must not be tampered with. Cryptographic checksums address this problem. The risk of erasure or unavailability of data stored will be addressed when addressing the availability principle below.

4.1.3 Availability

Availability of data means that data should be available to the proper user at the required time. In GiraffPlus, we can again differ between real-time data accessed from the sensors, and data accessed from the data store.

Availability of real-time data
Accessing real-time data means fetching data from sensors, over the networks. This means that the main issue for availability of real-time data is the dependability of the networks. The GiraffPlus system has two types of networks: the wireless sensor network between sensors and middleware, and the network between the middleware and the data storage.

Dependability of the wireless sensor network
The main threat to the wireless sensor network is unavailability due to lack of connectivity between sensor nodes or between sensor nodes and gateway. The reason for this lack of connectivity could be intentional or unintentional. In any case, the effect is a lack of connectivity that is hard to solve. Using redundancy on the link layer can somewhat solve this problem, but against a full-fledged denial-of-service attack on the wireless sensor network there is really no remedy inside wireless network regulations (prohibiting increasing transmission power significantly) except abandoning the wireless network in favour of a wired network. The risk of such an attack on the wireless sensor network of the GiraffPlus system is however small, and the suggestion is to not try to counter this threat.

Dependability of the network from middleware to data storage
The network from middleware to data storage can be of several types: mobile data, broadband to the home, modem over POTS, etc. All these networks have one thing in common: the network operator will have taken measures to keep the probability of availability high. However, even these systems do sometimes fail. For an operational system, it should be considered to have redundancy in the connection, with some fall-back should the primary connection fail. For the first GiraffPlus prototype, however, network redundancy could be considered optional.

Availability of stored data
Availability of stored data relies on the network to the data store discussed above. Additionally, the data storage itself should be dependable, meaning that there should ideally be redundant servers geographically separated. For the first GiraffPlus prototype, geographical separation could be considered optional, while server redundancy should be required at least on the level of data being resilient enough to survive disk crashes.

4.1.4 Authenticity

Authenticity here means that that it is possible to verify the sender of a particular piece of data, in order to avoid impersonator sensor nodes providing false data, or impersonator servers providing false data. Authenticity is a very important requirement in the face of safety-critical systems, but any system dealing with people should be free from risks that unauthorized entities supply false data to the system.

Authenticity is achieved using some kind of verification process, an authentication. Authentication requires cryptographic mechanisms that guarantee that identities cannot be cloned or forged.

In the GiraffPlus system, it should be possible to authenticate sensors and servers in the system.

4.1.5 Non-repudiation

Non-repudiation means that the sender of data should not be able to deny sending the data in question. If the sender is authenticated as discussed above, and if the data integrity is guaranteed, then the non-repudiation problem is solved. There is thus no need for any separate method or mechanism for non-repudiation in the GiraffPlus system.

4.1.6 Legality

Each country has its own legislation regulating the use of personal data. For sensitive data like medical data including physiological data from monitoring, requirements are often stringent. Encryption of data and proper handling of decryption keys are required. In some countries, among them notably Sweden, legislation is strict regarding personal data irrespective of the type of data. In order to comply with such legislation, any collected data must be treated as sensitive data.

Similar to the above discussion on confidentiality, for legal reasons it makes sense to treat all data as if it was sensitive medical data.

4.2 Methods to insure privacy and security of the data

The investigation of methods to insure privacy and security of the data is an important aspect for the project. In this respect we need to consider both the system that will be placed in the test sites by month 18 of the project and the final system that could be commercialized after the project. This document clarifies the architecture of the system and the communication structure and is the base of the future work in selecting the methods for insuring privacy and security of the system. In the following section we give some preliminary indications of what can be needed to satisfy this aspect.

Confidentiality
Confidentiality in the first prototype
Confidentiality in the first prototype can be solved by shared symmetrical keys. For wireless links, encryption is sometimes already provided by the standard. Data stored should be encrypted to avoid unauthorized access.
Confidentiality in later prototypes
For later prototypes, a key management system like Public Key Infrastructure (PKI) should be considered.

Integrity
Integrity in the first prototype
Integrity for stored data is for hard disks provided by hardware. To avoid data loss in case of disk crashes, redundant disks or a RAID system should be used.
Integrity in later prototypes
No additional mechanisms are required in later prototypes.

Availability
Availability in the first prototype
For the first prototype, existing networks and network solutions are sufficient.
Availability in later prototypes
For later prototypes, redundant network paths should be considered for increased availability.

Authenticity
Authenticity in the first prototype
For the first prototype, authenticity can be achieved by shared symmetric keys and nonce challenges to authenticate the communication counterpart.

Authenticity in later prototypes
For later prototypes, the use of certificates should be considered together with the PKI infrastructure mentioned above.

Legality
Legal aspects on the first prototype
Assuming that the Swedish legislation is the strictest of the laws affecting GiraffPlus, the following are the requirements by Swedish law regarding personal data:

- Personal data must not be stored or processed, unless the person in question has given written permission to the storage and processing.
- Sensitive personal data must not be stored or processed, unless the person in question has given written permission to the storage and processing, or, storage and processing is purely for research and the research project has received an ethical approval from the authorities.
- Stored data must not be used for any purpose other than that stated in the written permission and/or ethical approval.

For the GiraffPlus project, this means that written permission from all monitored persons is required; else the monitoring has to receive an ethical clearance. It is also inferable from the requirements that unauthorized access to stored data must be prevented. The GiraffPlus project has already received ethical clearance in Sweden.

Legal aspects on later prototypes
For the later prototypes, the same requirements as for the first prototype apply: written permission from all persons, or an ethical clearance from the authorities.

5 Compliance with European Standards

Trends in Information and Communication Technologies (ICTs) and evolution of the Medical Devices (MDs) to Personal Health Devices (PHDs) led towards the delivery of new health services and so called service for independent living and wellbeing [1]. This fast evolution inevitably led to interoperability issues partially due to the historical fragmentation of the healthcare system at national and regional level. One the most relevant organization aiming at harmonizing this much diversified landscape is the industrial alliance named Continua Healthcare [2]. The end-to-end architecture proposed by Continua Alliance is based on the ISO/IEEE 11073 family (X73) of standards [3][4][5][6][7][8] The first version of the standard was initially designed to address *Intensive Care Unit* (ICU) scenarios focused on covering medical devices´ interoperable communication at the ***Point-of-Care*** **(PoC)** of the patient. The later development of new portable and wearable ***Personal Health Devices*** **(PHDs)** with high quality sensors and which are based on wireless technologies (such as Bluetooth or ZigBee) together with the increase of broadband access to multimedia networks has fuelled the evolution of the standard towards an optimized and more lightweight version adapted to these new technologies and ubiquitous contexts for PHDs.

X73 Point of Care defines a reference model oriented to agent-manager architecture based on a well-defined object oriented paradigm that guarantees extensibility and reusability. *X73 Personal Health Device* pursues the creation of a framework for device communication, providing new features for the communications model, such as Plug-and-Play by means of an optimized Finite State Machine (FSM) which models the MD behavior, or independence of the new transport technologies enabling the replacement of MDs or PHDs in the e-Health service with minimal set-up.

The ISO/IEEE 11073 family of standards is an expandable collection of normative references and device-specific specifications. The relevant core standards were initially defined as part of the Health Informatics Point of Care medical device communication:

Nomenclature (Part 11073-10101)

It defines a set of vocabulary term and its semantic descriptions upon which the rest of the standard is based and the medical data is mapped, which will be the Common Nomenclature. The content of this name library is considerably large and far to be complete, as medical vocabulary from several different fields needs to be adopted.

Domain Information Model (Part 11073-10201)

The DIM is an object-oriented model that consists of objects, their attributes, and their methods, which are abstractions of real-world entities in the domain of medical devices. Objects are considered managed objects which can be accessed by management services. The set of object instances available on any medical device forms the medical data information base (MDIB). The MDIB is a structured collection of managed objects representing information provided by a particular device. For example, an agent device has several objects and attributes that represent information and status for the device.

Application Profiles and Transport Profile (Part 11073-20101 & 30200 & 30300)

The purpose of these profiles is to provide different mechanisms to perform connection management (establishing, holding and releasing a logical communication channel) and information exchange procedures (requesting and acknowledging data packets). Data will be transferred from the agent to the manager following either a baseline or polling retrieving schema, operating upon a Finite State Machine designed to provide a connection status flow.

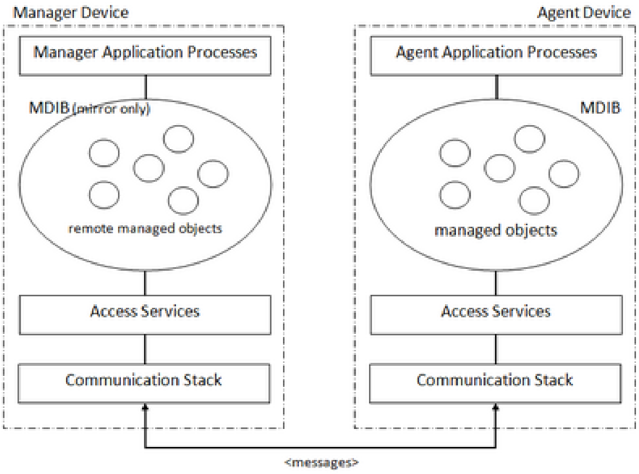

Figure 31 The Manager-Agent Communication model

The evolution of the ISO 11073 PoC standard into ISO 11073 PHD is summarized by the following figure, with a new specification part called Optimized Exchange Protocol (Part 11073-20601) which reuses the concepts introduced by the previous specification and defines a transport layer for communication with devices independently form the technology. Therefore the same Domain Information Model and the same Finite State Machine representing the device association can be used with Bluetooth or ZigBee devices.

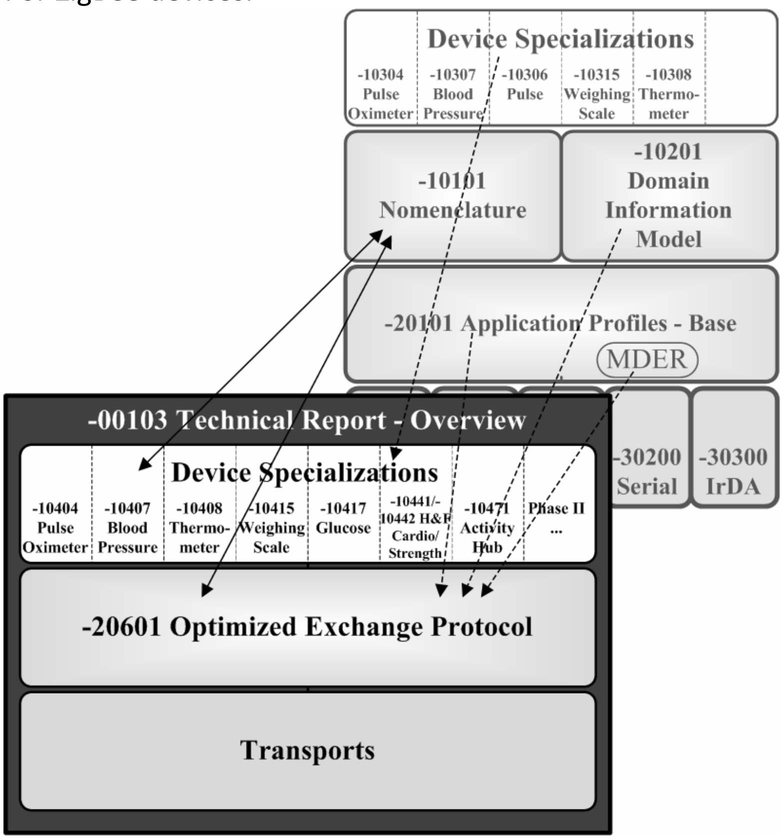

Figure 32 The evolution of the ISO/IEEE x73 PHD

The overall ISO/IEEE 11073 PHD system model is divided into three principal components:

- Domain Information Model (DIM) - characterizing information managed by an agent as a set of objects
- Service Model – providing data access primitives that are sent between the agent and manager to exchange data from the DIM (Get, Set, Action, and Event Report)
- Communication Model - between agents (devices) and managers

An Agent-Manager connection is always a point-to-point connection. The dynamic behaviors of agents and managers are defined by a connection state machine on each side reported in the figure below. Only after a proper association and configuration the Agent device enters in the operational mode and may send the required information according the Service Model.

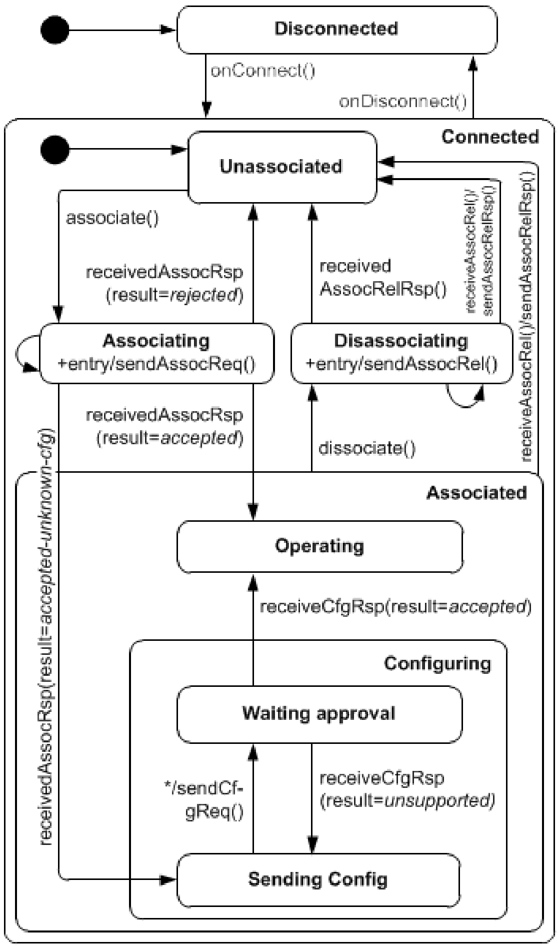

Figure 33 The Finite State Machine to associate Mangers with Agent devices

The primary focus area of ISO/IEEE 11073 is depicted in

Figure 34. There are two types of devices: Agent Devices, that's sensors and medical devices like thermometer, blood pressure monitor, weighing scale and pill dispenser, and Manager Devices which are typically cell phones, Personal Computers, Set Top Boxes. In turn Manager Devices have higher level interfaces to communicate with remote services on Internet (Wide Area Network).

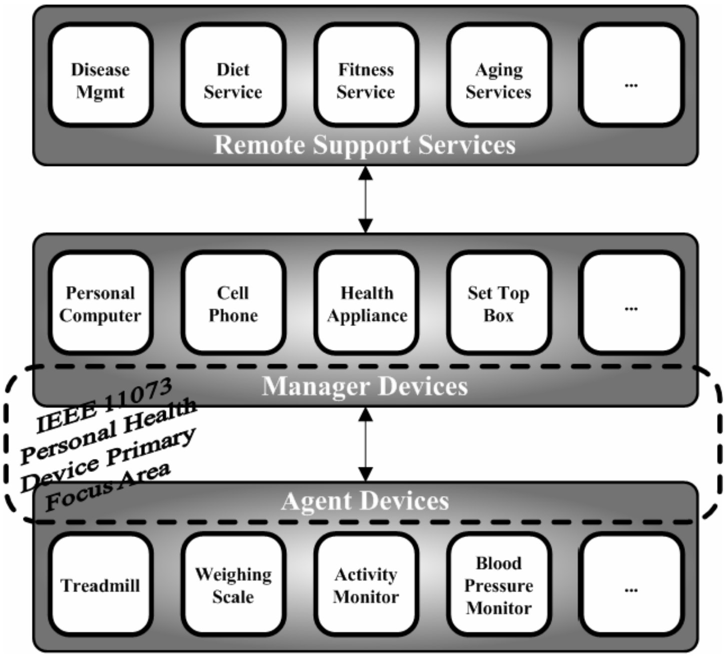

Figure 34 The 3-layerd architecture: Agents, Managers and Remote Services

Continua Alliance included this architecture in a wider scenario (see Figure 35), which involves many other stakeholders around the healthcare domain. In particular, in the Wide Area Network are identified services and protocols used by Telehealth Service Centers and Hospitals. The standards used in those contexts are mainly from W3C organization for the transport of the information (i.e. Web Services) and domain specific standards like HL7 [9] and DICOM [10].

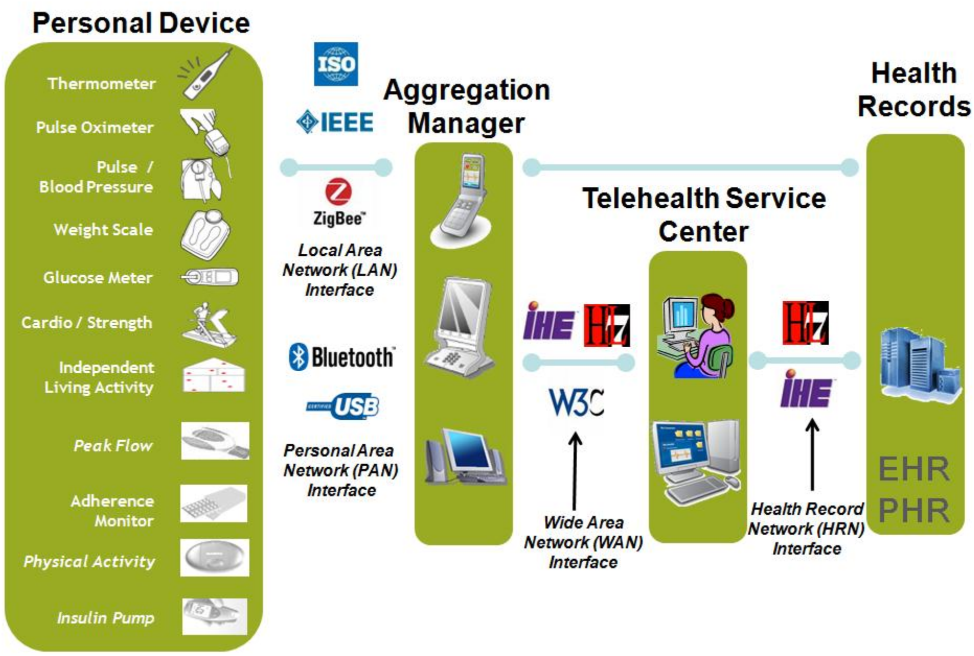

Figure 35 The End-To-End Continua Architecture and Standards

Another relevant initiative in this field is **Integrating Healthcare Enterprise (IHE**) [11]. It is an initiative by healthcare professionals and industry to improve the way computer systems in healthcare share information. IHE promotes the coordinated use of established standards such as DICOM and HL7 to address specific clinical need in support of optimal patient care. IHE promotes integration within and across all units of the healthcare enterprise. Several IHE domains address interoperability issues of interest to multiple clinical fields. The currently active IHE domains are: Anatomic Pathology, Cardiology, Eye Care, IT Infrastructure, Laboratory, Patient Care Coordination, Patient Care Devices, Quality Research and Public Health, Radiation Oncology, Radiology.

The Technical Framework promoted by IHE is a detailed, rigorously organized document that provides a comprehensive guide to implementing the defined integration capabilities. The Technical Framework delineates standards-based transactions among systems (generically defined as IHE Actors) required to support specific workflow and integration capabilities. Transactions are exchanges of information between actors using messages based on established standards (such as HL7, DICOM and W3C). Each transaction is defined with reference to a specific standard and additional detailed information, including use cases. This is done to add greater specificity and ensure a higher level of interoperability between systems.

5.1.1 Standards used in GiraffPlus

With respect to the GiraffPlus system, the end-to-end architecture defined by Continua Alliance has the following impact. Devices used in GiraffPlus belong to two categories: medical and environmental devices. The medical devices provided with the Intellicare solution are standardized by the parts: ISO/IEEE P11073-10417 Glucose Meter, ISO/IEEE P11073-10407 Blood Pressure monitor and ISO/IEEE P11073-10415 Weighing scale. The Environmental devices used in GiraffPlus have some overlapping with devices standardized by the X73 Family, in particular the Activity Hub Device defined by the specification part ISO/IEEE 11073-10471 concerns the use of some environmental sensors. However this specification part is still at an early stage. It identifies fewer sensors than the ones we are thinking to deploy and install in our test sites.

It is worth to notice that Intellicare's medical devices are hidden behind the Intellicare gateway, and GiraffPlus system is integrated directly with their gateway. The same approach is used with the Tunstall gateway; the environmental data are collected by means of the Tunstall's gateway. It means that, apart from the integration of alternatives devices based on ZigBee protocol, the Intellicare and Tunstall's gateways should implement the interfaces defined for the so called Aggregation Managers (x73) and represent, in terms of Continua E2E architecture, Application Hosting Devices connected on the Wide Area Network.

Intellicare and Tunstall are both interested in integrating Continua compliant solutions, and they have already planned the migration to standards promoted by Continua, however in GiraffPlus, the focus is mainly on the internal elaboration of the sensed data to react and eventually anticipate the user needs. In this sense is not imperative to adopt standards used in the wide area network (WAN). The main components that will use data collected from the gateways are software components "virtually" deployed in the local area network (LAN). The internal communications are abstracted and realized by the middleware that will be compliant to the universAAL architecture but will use simpler transport protocols currently adopted in the context of the Internet of Things and Cloud Computing. The communication middleware in GiraffPlus will be based on W3C standards like HTTP used for the Restful services and MQTT for the eventing mechanism. MQTT is not formally standardized, but the protocol is available with a royalty-free

license, and As of August 2011, there is an open call for participation on standardization[1], with the intent to submit to a formal standards body in the near future.
Nevertheless, parts of the X73 family specification can be reused even by the GiraffPlus middleware. For example, even if the x73 Nomenclature is very large and mainly oriented to clinicians, many keywords and objects defined in many device specifications (i.e. ISO/IEEE 11073-104XX parts) can be reused as topic for the MQTT's publish-subscribe mechanisms. Even small part of the HL7 protocol could be adopted to describe structured information transported with MQTT.
Figure 36 summarises the communication links among components of the GiraffPlus architecture with references to the main standards. In particular the Telehealth Service Center is depicted with dotted lines because such use case is not implemented with our test sites, even though gateways produced by Intellicare and Tunstall allow this connection in line with Continua Guidelines. The same use case may be implements by the cloud infrastructure used by GiraffPlus, even if it is out of the scope of the project. Apart from the ZigBee gateway, the communications among the controlled devices and their gateway are not highlighted because for a rapid prototyping GiraffPlus considers those links as proprietary protocol and our system is integrated directly with the Gateway acting as brokers. In case of alternative devices based on ZigBee protocol we will use only certified devices manufactures by third parties and all components must be compliant to the X73 Family standards.

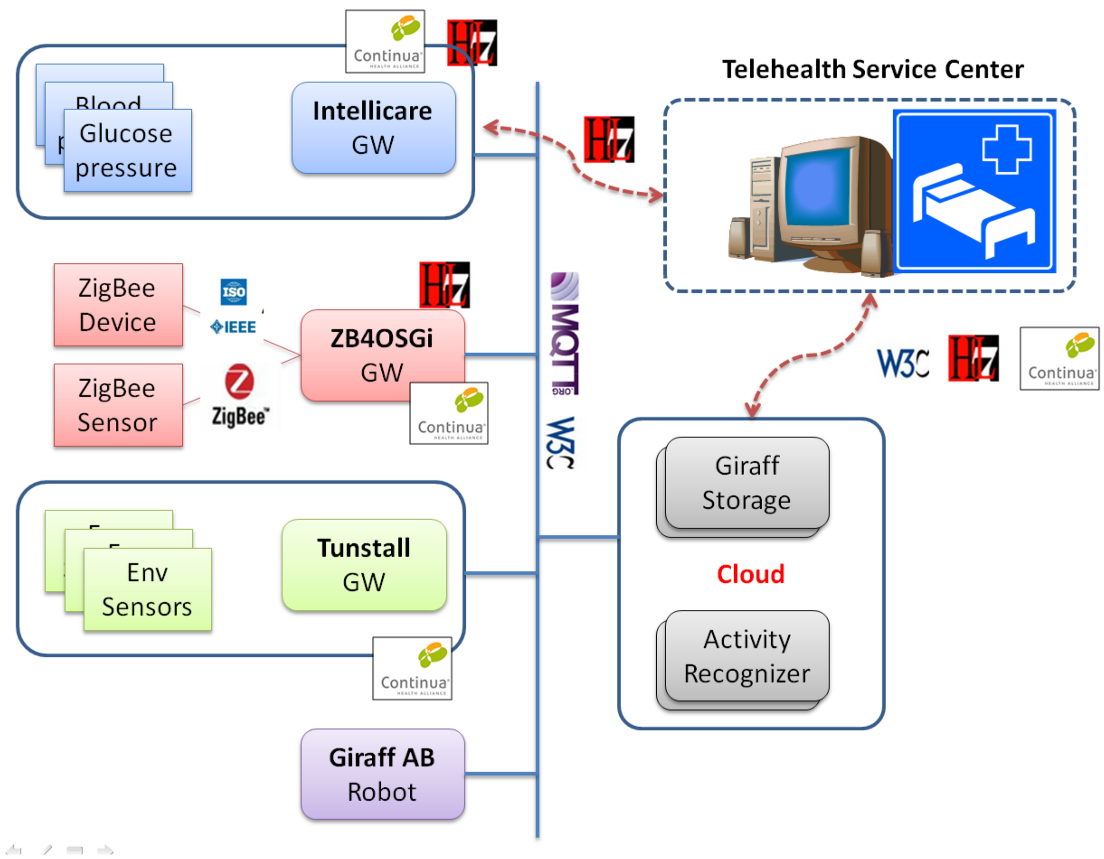

Figure 36 The Main GiraffPlus components and used standards

[1] http://mqtt.org/2011/08/open-invitation-to-join-the-mqtt-standardization-discussion

6 Conclusions

In this document we have first considered how the user requirements outlined in Deliverable D1.1 can be translated in technical requirements. Almost all user requirements could be translated in technical requirements that are going to be addressed in the project.

The deliverable outlines the architecture of the system and is mainly focused on the integration of the different parts. This has also been the biggest challenge in the first 6 months of the project.

The technical requirements and the architecture of the system match the description of work. Naturally the part that has most been developed from the original Description of Work is the middleware and the integration of the sensors and robot in the system. An additional aspect that we intend to investigate and that was not considered in the Description of Work is the interaction with primary users. In particular we would like to give the possibility to the primary users to see the information collected and the results of the reasoning and analysis of the system. Possibly the primary users should also be able to see who has access to the information to insure that the primary user has given is consent to the sharing of information and is aware about who is accessing it.

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Appendix 1: Giraff Robot Integration Requirements & System Architecture

This document defines the requirements for the interface and interactions between the GiraffPlus home care system and the mobile telepresence system (the Giraff system in the current project) that is integrated into GiraffPlus. It also defines the major architectural components and concepts specifically regarding integration. This document does not define the actual API protocols but provides the foundation for the protocols that will implement these requirements.

Definitions

1. G+ System – GiraffPlus system, refers generally to any and all components of the GiraffPlus architecture that manage information and processes that could interact with Giraff.

2. DVPIS – Data Visualization, Personalization and Interaction Service, the main user interface to the G+ System. We refer to this only in the broad sense without specifying which components of the DVPIS might interact with Giraff.

3. Robot – the Giraff mobile telepresence device used in GiraffPlus. It is part of the Physical Environment and Software Infrastructure in the GiraffPlus architecture. To simplify the reading here we refer to Giraff as the Robot to avoid confusing it with the GiraffPlus System.

4. Pilot – the Giraff remote client that is used to connect to and navigate the Robot. It is a software application the runs in Windows in its current configuration.

5. Sentry – the database used to manage Giraffs, users, groups, visit records, etc. It is accessed through a standard browser with a user ID and password.

6. Call – a connection between Robot and Pilot (or DVPIS)
    a. Pilot (or DVPIS) Call (from Pilot to Robot)
    b. Robot Call (from Robot to Pilot/DVPIS)

7. Primary End User – person living in the home with the G+ System (e.g. elderly person)

8. Secondary End User – a person interfacing with the DVPIS and/or Pilot who wants to connect to the Robot or who the Robot wants to connect to. This could be a formal/professional or informal/family caregiver.

9. Callout User – Secondary End User that the Robot calls out to when a Call is initiated from the Robot side (Robot Call). There could be more than one Callout User, a priority list or even alternate contact methods such as email, SMS, etc.

10. Gateway – the Middleware Infrastructure gateway shared by all system components in the physical environment, and the main interface between the Robot and the G+ System. In the current architecture concept this interface resides in the home, and may combine a routing and computing device (e.g. a “Raspberry”). When we refer to “broadcasting to the Gateway” we mean sending a message to the Middleware using the protocol defined by the architecture team.

Basic Principles and Assumptions

The basic principle guiding the architecture and integration requirements is simplicity. We try to simplify the interaction (information query and transfer) between GiraffPlus and the Robot, Pilot and Sentry as much as possible. Specifically, the requirements try to limit interaction to call management. This is an important point because the current Giraff System (Robot, Pilot and Sentry architecture) manages certain processes internally such as configuring a Robot or defining a Callout User. The integration requirements could become quite complex if these processes need to be managed through the G+ System or the DVPIS, requiring all components to be fully integrated into the G+ System.

From this principle we make several assumptions about how the G+ System and the Robot interact. These assumptions drive the overall system requirements:

1. *The integration will only deal with "operational" processes and not "setup" processes.* It is assumed that the initial Robot configuration (e.g. language selection and other display information) is managed by Sentry, and that the G+ System only manages operational processes like making a Call. If the G+ System needs to store any setup information we assume it is manually synchronized to the Sentry. Setup process synchronization will be defined at a later time.

   For example, we understand that there will be a "system administrator" component of the DVPIS that allows, for example, a technician to configure sensors or update the physical environment. This person would likely need to also configure a Giraff and/or Giraff users, requiring access to Sentry. We assume this access will be achieved via a simple link to the Sentry website but that Sentry will otherwise be accessed as a stand-alone system.

2. *The G+ System is the database of record for all information relevant to the Robot, Pilot and Sentry.* Said differently, any operational information that the G+ system needs to manage call processes, etc. is assumed to be maintained by the G+ System, including information that Sentry may maintain to complete its own stand-alone operations.

   For example, information on Callout Users is assumed to be maintained by the G+ System, even though the Sentry also has Call User information in its own database. The G+ System information takes precedence over Sentry information, and Sentry (or any other Giraff component) takes its instructions from the G+ System.

3. Further to the above assumption, *the G+ System manages all Robot Calls.* Pilot itself will never initiate or receive a Robot call but rather the DVPIS or perhaps some other component based on a contextual inference.

   This means, for example, that when the Robot initiates a Call (i.e. the Primary User "presses the green button") the G+ System always determines the Callout User and then manages the connection as a DVPIS Call (from DVPIS to the Robot). In this situation the Robot would *not* refer to Sentry for Callout User information. *This assumption greatly simplifies the requirements and minimizes potential conflict between the G+ System and Sentry databases.*

4. *Robot video display management is done by G+ System (e.g. the DVPIS).* If the DVPIS wants the Robot to display something other than the video image (e.g. a graphic display,

medication reminder, patient chart, other image, photo, video, etc.) we assume that the DVPIS manages that display through the camera control application/driver that feeds the Pilot client. Therefore Pilot is always taking its image from the camera driver and the DVPIS manages that content. *This assumption greatly simplifies the interaction between the G+ System, Pilot and the Robot, and allows display content to be developed without a complex interaction with the Robot.*

Note: It is possible that a display overlay feature could be developed within the scope of the GiraffPlus project. In this case Pilot would take additional display information from the DVPIS and manage its display directly on the Robot. This would certainly provide a more elegant interface for the Primary End User but no commitments can be made yet.

DVPIS – Pilot Integration Requirements

From these assumptions we can define the DVPIS – Pilot integration requirements in a straightforward way:

1) The goal in the GiraffPlus project is to integrate Pilot into the DVPIS by means of a Java .jar plug-in. This will allow the DVPIS to present the Pilot GUI as part of the overall DVPIS and even alter its appearance as appropriate. For the first trials Pilot can run as a separate application running in parallel with the DVPIS – indeed, the prototype DVPIS operates this way already today. Trials can comment and continue as the integration of Pilot into the DVPIS is refined over time.

2) An API will be defined between the DVPIS and Pilot that allows the DVPIS to access and deliver certain information from/to Pilot. These items include:

   a) Login credential information: Once the Secondary End User as logged into the DVPIS these same credentials should be used to login to Pilot (the Secondary End User should not have to login twice).
   b) Robot selection: The Pilot call management screen presents all Giraffs the user has access to, but the DVPIS client is “home-centric” – that is, it already knows which Robot it will connect to. Therefore the DVPIS should be able to select the Robot transparent to the Secondary End User and simply connect the call.
   c) Call type: The Secondary End User can connect to the robot via a “normal” Call (where the Primary End User must answer the Call) or an “emergency” Call (where the connection will be made even if the Primary End User does not answer). This assumes that the Secondary End User has emergency access via Sentry and this has already been configured.

   d) Pilot call initiation response: When Pilot initiates the Call it should respond to the DVPIS on the status of the connection:
      i) Successfully connected
      ii) Robot was connected to another Secondary End User
      iii) Robot was offline or Pilot could otherwise not see the Robot
      iv) Other failure reason?

   e) Pilot call termination response: When the Call is terminated Pilot should tell the DVPIS when the Call has ended and why:

i) Secondary End User ended Call
ii) Primary End User ended Call
iii) Some fault condition ended Call such as network outage (we need to define whether a single fault condition is sufficient here, or whether multiple conditions are needed, such as a network outage vs. an application crash on the Robot).

Note: We describe this API as an interaction between Pilot and the DVPIS. However, any other G+ System component could in principle access these Pilot features via the API.

3) To respond to a Robot Call (the Robot requesting to connect to a Secondary End User)

a) The request could be initiated by the Primary End User via the Robot remote control (the “green button”) or by some other event occurring in the Giraff application.

b) In all cases the request broadcasts an event using the defined middleware message protocol. This is a critical point because it means the Giraff will not initiate a call via Sentry as it does today, but instead will broadcast an event and let the G+ System decide how to respond to it. There might be a “hunt group” of Secondary End Users that can be reached either online or via some offline means (such as email or SMS). Or the request might be routed to a 24-hour monitoring center.

c) By whatever processes takes place with G+ System, ultimately the DVPIS initiates the Call from Pilot to the Robot according to the requirements in 2. above. In other words, from the Pilot and Sentry perspective, this looks exactly like a Pilot Call. Again, this greatly simplifies the API requirement, and avoids database conflict in the Robot trying to initiate its own Call and interact directly with Pilot and Sentry.

4) Visit log information

We assume that the G+ System manages all logging information about Calls, Users, etc. Although Sentry has visit log capabilities it is simpler to bypass this and let the G+ System manage this information to avoid conflict and the complexity of integrating Sentry into the G+ System architecture. It is likely that this information is integrated or correlated with other G+ System information anyway (such as an alarm or other event) so it does not make sense to create a protocol where it retrieves this information from Sentry.

Giraff Navigation Assistance Requirements

In some cases the Robot needs to navigate automatically or semi-automatically to a location. Based on the above assumptions, it does not matter how the Call is initiated or connected, but only how the navigation information is communicated between the G+ System and Pilot and/or Robot.

Note: Auto-navigation should always “involve” the Secondary End User, especially at this stage of the technology development. For example, if the Secondary End User wants to auto-dock he can press a button initiating the process but he should monitor the progress until the action is done. We should never let the Secondary End User “walk away” while an auto-navigation task is in progress, or let Giraff initiate such a task (e.g. directing the Robot to go to a certain location where a sensor has indicated a problem) before the Secondary End User is present at the DVPIS and/or Pilot. An exception to this rule is “WiFi recovery” as described below (in this scenario, the Secondary End

User is by definition not connected to the Robot).

Following this “involvement” rule simplifies development work and allows deployment much faster because we do not have to be as concerned about auto-navigation failure scenarios, since the “human in the loop” (Secondary End User) can intervene and take back control if something goes wrong. It is always an option to add more autonomous actions as confidence in the system increases.

There are several technical challenges in the navigation assistance requirements:

- There will be scenarios where both the Secondary End User and the navigation assistance software are sending navigation commands to the Robot. There must be rules that arbitrate who has control and when.

- The serial port on the Giraff motor board can only be controlled by one resource at a time. Said differently, the Giraff software architecture was not designed with the concept in mind of multiple resources “competing” for control. A new module in the architecture must be introduced if this is required.

- The video stream in the Giraff is not currently configured as a shared resource. If multiple resources need access to it, this component must be redesigned.

- It is not clear for a given scenario whether navigation should be controlled on-site in the Robot or from the DVPIS. It seems there are some scenarios where on-site control is required, but it is easier to enforce the “involvement” rule from the DVPIS. A related question is where to keep localization mapping information, which is required for some navigation scenarios.

We propose the following software architecture on the Robot to address these challenges (see diagram below):

- A new “Navigation Assistant” module will be introduced that handles all auto-navigation tasks. As shows in the diagram below it controls the serial port to the motor board.

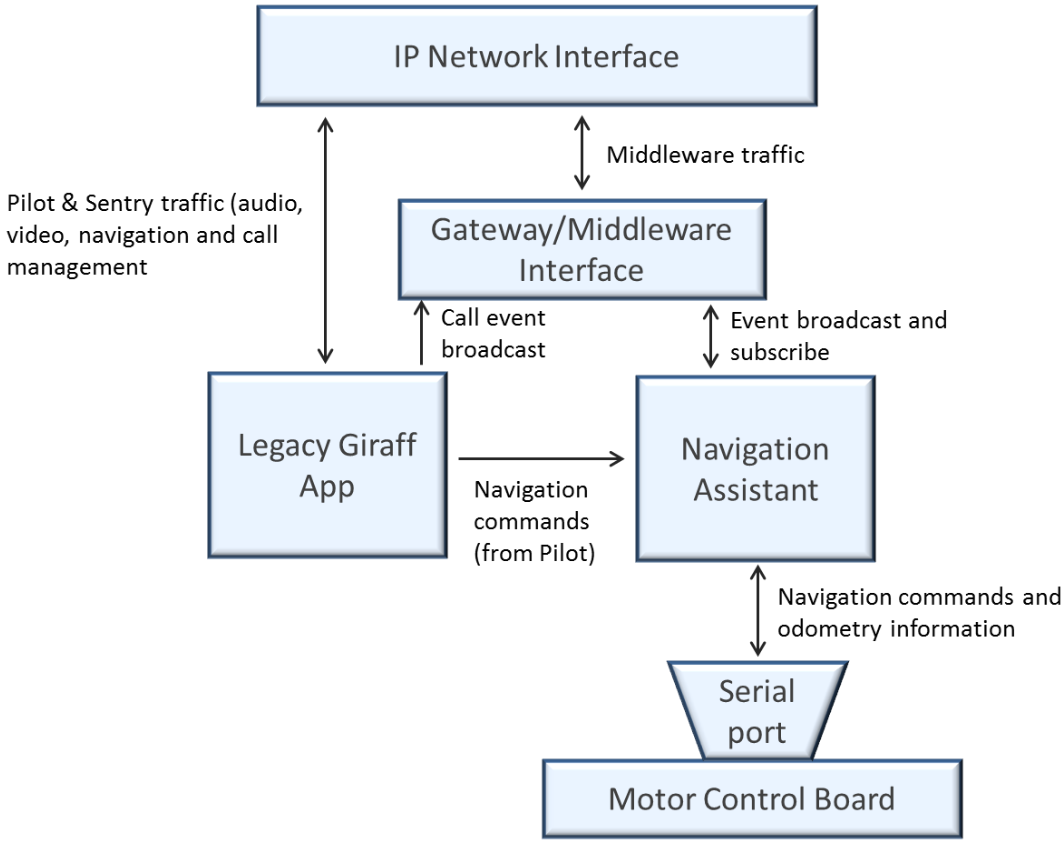
- The existing “Legacy Giraff” application will be modified in two ways: First, navigation commands (that come from the Pilot) will be passed to the Navigation Assistant instead of directly to the motor board. Secondly, Call initiation actions will not initiate a Call as they do today, but instead will broadcast a message to the Middleware as described above.

- A new “Assist Enable” button will be introduced in the DVPIS. By pressing this button the Secondary End User indicates that he wants navigation assistance where available, and by un-pressing it indicates he does not want assistance. There may be a separate button for automatic docking since it is not always clear when the Secondary End User wants to dock.

- When Assist Enable is “off” the Navigation Assistant takes no navigation actions on its own and simply passes the navigation commands from the Legacy Giraff application to the serial port. When Assist Enable is “on” it arbitrates between Legacy Giraff navigation commands (that are in fact Secondary End User commands) and auto-navigation actions. For example, if the Secondary End User is driving down a hallway and about to bump into a wall, the Navigation Assistant can substitute commands from Legacy Giraff (that would cause the

Robot to hit the wall) with commands based on its own obstacle detection that avoid the collision. Similarly, if the Secondary End User is about to drive the Robot down a staircase, the Navigation Assistant would substitute these commands with its own commands to stop.

- The Navigation Assistant should also recognize when the Secondary End User has stopped (specifically, when the Legacy Giraff application sends the command to stop the motors, based on the Secondary End User releasing the left mouse button). This enforces the "involvement" rule.



The proposed architecture has several advantages over previous concepts:

- Modification to the Legacy Giraff code is minimized and interaction between the Legacy Giraff application and the Navigation Assistant is also minimized.

- The team working on the Navigation Assistant module (U. of Málaga) can proceed relatively independent of the Giraff team. Close collaboration is only required for integration testing.

- No module is required to arbitrate control of the serial port. The Navigation Assistant controls it at all times, yet the Secondary End User has ultimate control via the Assist Enable button.

- The code developed in the Pilot software for sharing the video stream (used in the Pilot-based auto-docking prototype) can probably be re-deployed in the Legacy Giraff code, also minimized the effort required.

- No modifications are required to the Pilot code. Specifically, it does not have to arbitrate navigation commands from different sources as previously envisioned.

- As before, this architecture avoids the need to integrate Sentry into the G+ System architecture.

Finally, we address the question of localization mapping information. The map will be stored in the G+ System database and used simultaneously in the DVPIS and Navigation Assistant. The map is built previously by driving the Robot around the residence, and when activated shows the layout of the residence (rooms, doorways, hallways, etc.), the location of the Robot and any relevant location information for other sensors or events (e.g. the likely location of a Primary End User who may have fallen).

The map can assist a Secondary End User who is not familiar with the residence in going to the desired location, and is also used by the Navigation Assistant for certain tasks. The Navigation Assistant can also pass progress information back to the DVPIS via the middleware, to display on the map where the Robot is (and it can do this independently of the Legacy Giraff or Pilot modules, also simplifying the architecture from previous concepts).

Other Applications Onboard the Robot

We know that the Robot platform may be required to interface with or even be host to other devices and applications as the GiraffPlus architecture evolves. The following integration requirements can probably accommodate these scenarios:

a) Any device that resides onboard the Robot (e.g. a motion sensor such as the Kinect box, or perhaps a biometric device) will interface to the Robot through one of two protocols:
   i) USB (which could also be the interface for a Bluetooth or other wireless protocol)
   ii) WiFi at 2.4 or 5 GHz, using the Robot's existing WiFi interface

b) Any application that resides onboard the Robot (e.g. related to a motion sensor, or the Navigation Assistant) must be able to run in an embedded Windows 7 environment. Any programming language can be used as long as it satisfies the other integration requirements.
   i) This requires the Robot to be re-designed to increase the capacity of the processor, upgrade to Windows 7, increase the hard drive space and improve memory reliability and volatility by switching to a solid-state hard drive. All of this is in progress.
   ii) All communications outside the Robot required by these applications will be IP-based and will communicate through the Robot WiFi interface.

c) All communications between these devices/software modules and the Robot, unless otherwise agreed, will be via the defined messaging protocol through the Middleware.

Appendix 2: GiraffPlus Possible Scenarios

PROPOSED SCENARIOS IN D1.1

In addition to the detailed list of user requirements presented in this document these three months of work also allowed us to obtain indications for possible *scenarios* for the GiraffPlus system. Specifically, GiraffPlus has been initially conceived as a general and customizable system that can support different types of users in different ways.

The idea to pursue in the subsequent months of work could be to focus on *usage scenarios* that could be fully implemented and tested by the evaluation plan.

GiraffPlus scenarios of usage

In this section we provide a sketch of three possible scenarios that were recurrent in the focus group analysis, and that could deeply inspire the use case definition that will be one of the objectives of Task T1.4. For each of the three scenarios, we will provide a brief description, the type of users involved, the possible role of GiraffPlus, the sensors and the main parameters to be monitored and relevant to the case study and, finally, the more relevant involved UR.

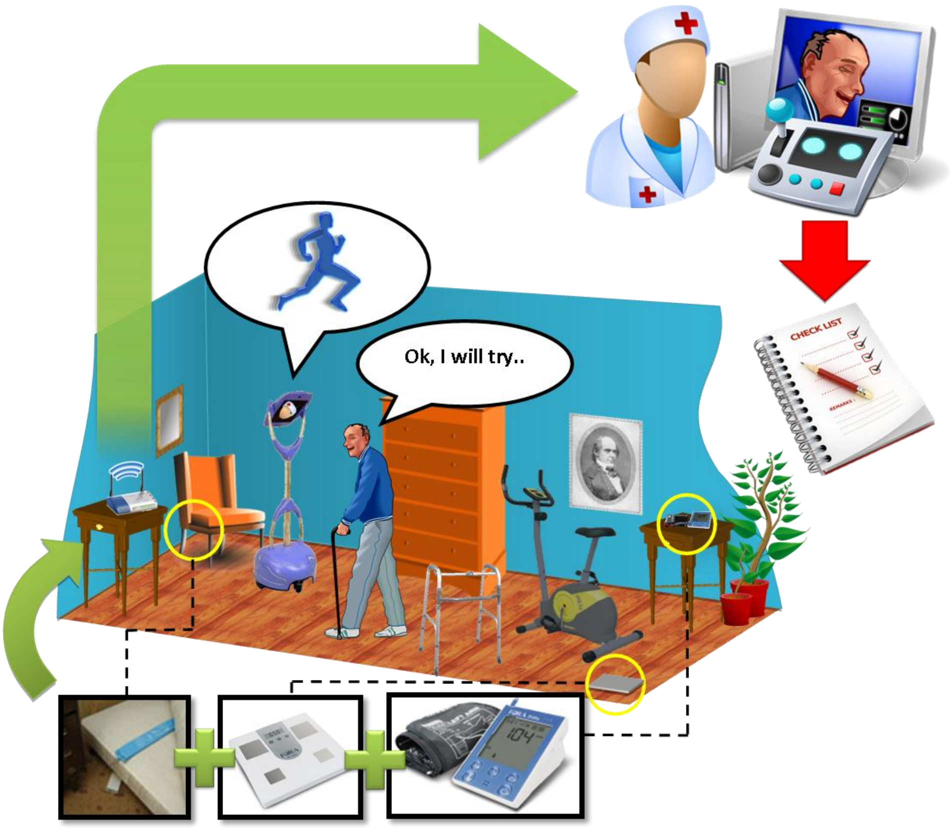


Figure 37 Scenario N. 1: monitoring a physiotherapy protocol

Scenario N. 1: monitoring a physiotherapy protocol

The first usage scenario covers the case of an elderly user who is following a protocol of physiotherapy rehabilitation. In

Figure 37, a schematic idea of the scenario is given: GiraffPlus could be a means to continue such a support.

The following table summarizes the main actors involved and a possible role of the GiraffPlus system:

Primary Users	*An elder person at home following a physiotherapy treatment protocol*
Secondary User	*A physiotherapist who monitors the elderly during rehabilitation*
Role of GiraffPlus	*In a rehabilitation protocol, the physical therapist tries to restore the ability to move in a patient. In this perspective, the physical therapist assigns to the elderly a rehabilitation protocol strictly related to his/her physical activity. GiraffPlus could register relevant information such as for example: how long the patient spends in total in bed, sitting, standing and moving. The information may be submitted periodically to the physiotherapist at the level of detail or as a cumulative data. In this way the therapist could have an objective measure of the physical activity of the patient and possibly correct the protocol itself. In fact, the time spent in certain activities is "normal" only within certain limits. Physiotherapy protocols for elderly persons mainly include different exercises for walking, balance and lower extremity strength. Balance could be evaluated using exercises performed on a balance board with sensors. Sensors on the person measuring walking distance covered during the day would also be helpful for the physical therapist when adjusting the exercise protocol. Providing historical data would also enable the therapist to do some statistics.* *Another important service could be to create a "Rehabilitation Forum", through which, thanks to robots Giraff, the physiotherapist can make rehabilitation session.*
Sensors and relevant parameters	*Mainly environmental parameters and the Giraff robot*
Main involved URs	*UR 1.b.1 Facilitating contact between the person and healthcare professionals* *UR 1.c.3 Temporal monitoring of position* *UR 1.b.2 Periodic reporting to secondary users* *UR 1.c.5 Detecting changes of habit* *UR 5.a.8 Medical support*

Scenario N. 2: monitoring after the de-hospitalization

One of the recurring problems among the elderly is also the case of de-hospitalization: elderly people who are discharged to return home and do not receive regular and continuous support by the medical staff. In such cases, the problem is the inability/difficulty to maintain a constant and frequent contact between the staff and the elderly person, maybe also worsened by the fact that many elderly people also have a few relatives at home. The **Error! Reference source not found.** gives a schematic idea of the scenario: GiraffPlus could be a means to continue such a support.

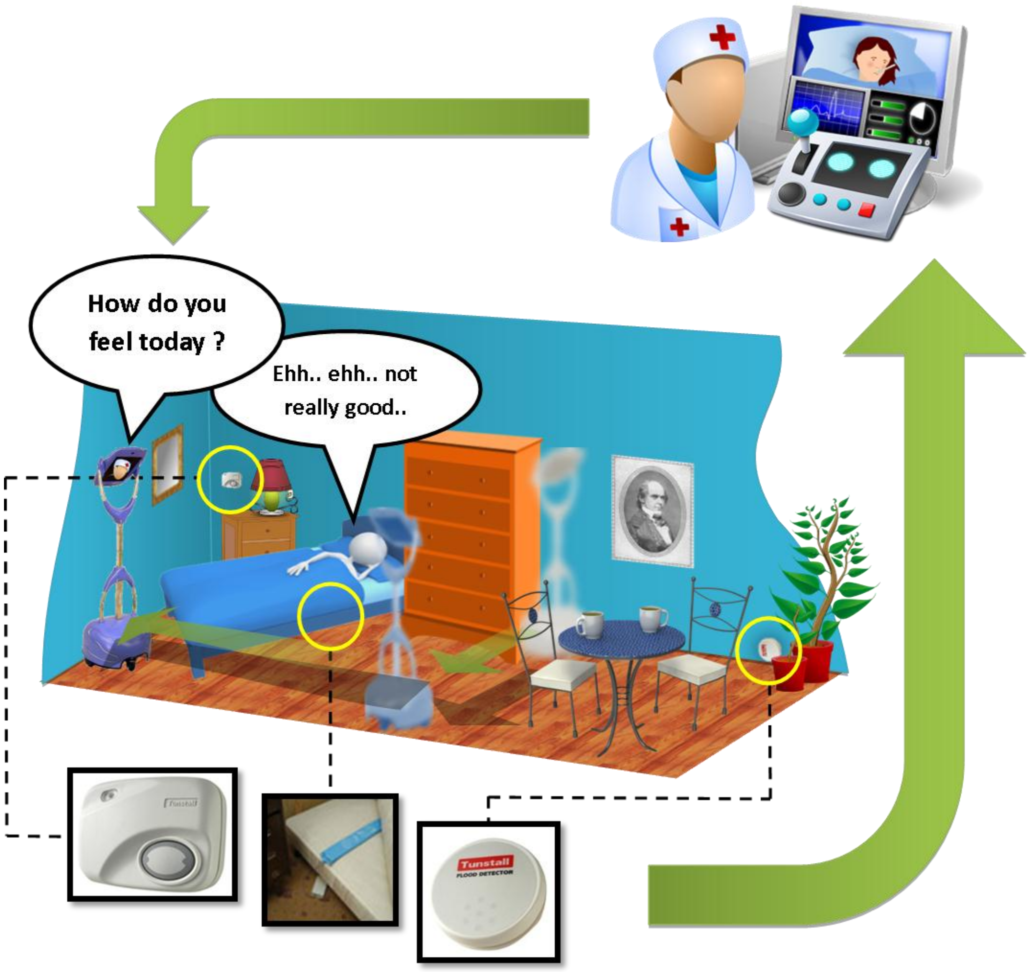


Figure 38 Scenario N 2: monitoring after de-hospitalization

The following table summarizes the main actors involved and a possible role of the GiraffPlus system:

Primary Users	*An elder at home after a period in hospital;*
Secondary User	*Medical staff monitoring physiological parameters* *Psychologists or social operators*
Role of GiraffPlus	 *GiraffPlus may support in two directions:* ***2.a Psychological monitoring**: In general the Giraff presence can contribute to maintain a continuum with the care and support received in the hospital, also ensuring that the monitoring service is more frequent. Obviously the monitoring service could be a combination of remote (through the tele-presence robot Giraff) and physical assistance (through a real visit).* ***2.b Health monitoring**:* *In this case GiraffPlus would allow monitoring the vital parameters after de-hospitalization, eventually those specifically connected to a given pathology.* *Moreover, in this case, ensuring a continuous and frequent contact, a doctor could also*

	better assess the need to change and customize the therapy protocol. The aim is to check if a certain therapy or just the post-hospital period proceeds properly and, if necessary, to support a doctor with evidence to change the treatment and or to personally visit the elderly.
Sensors and relevant parameters	*Mainly physiological sensors/parameters and the Giraff robot*
Main Involved URs	*UR 1.b.1 Facilitating contact between the person and healthcare professionals* *UR 5.a.8 Medical support* *UR 1.a.1 Monitoring of vital signs* *UR 1.a.4 Monitoring blood glucose levels* *UR 1.a.9 Monitoring heart function*

Scenario N. 3: daily activity monitoring by an informal caregiver

The third scenario would be to use GiraffPlus for a daily monitoring of the elderly person by an informal caregiver (e.g. a son or a close relative).

Figure 39 gives a schematic idea of the scenario: GiraffPlus could be a means to detect risky situations as well as provide warning to secondary users.

Figure 39 Scenario N 3: Daily activity monitoring by an informal caregiver

The following table summarizes the main actors involved and a possible role of the GiraffPlus system:

Primary Users	*An elder at home after living alone and assisted by an informal caregiver;*

Secondary User	*A son or a close relative of the elderly people who takes care of him/her; municipal home-care givers*
Role of GiraffPlus	*In this scenario, a possible role of the GiraffPlus system could be to "detect" a risky situation such as falls. According to pre-defined emergency protocols, GiraffPlus is to provide the related secondary users (e.g., a close relative) with a warning message.* *Other useful services could be for instance monitoring some environmental events and overall understand the activities of the person inside the house, e.g., monitoring of usual activities in the different rooms.* *All this info could be presented to the informal caregiver as an objective evidence of particular situations.*
Sensors and relevant parameters	*Mainly physiological sensors and parameters and the Giraff robot*
Main involved URs	*UR 2.a.7 Detecting risky situation* *UR 1.c.15 Detecting Falls* *UR 1.b.8 Warning notice to secondary users* *UR 1.c.9 Monitoring the time spent in different home places* *UR 1.b.2 Periodic reporting to secondary users*

The three scenarios are mainly examples of the possible usage of the GiraffPlus system. They can be further elaborated and reinforced by means of additional dedicated interviews and workshops with the involved users and become the use cases of the GiraffPlus system.

ADDITIONAL SCENARIOS

A number of additional scenarios have emerged after the completion of the deliverable D1.1. We outline them here in the following sections.

Monitoring of chronic disease people

In the future there will many chronic patients. They could for example have high blood pressure, diabetes, and will not be completely independent. A possible scenario for GiraffPlus would be to consider the regular monitoring of chronic disease. All the physiological parameters could be monitored or for instance we could monitor specific ones. The patient could be checked remotely and medical personnel could give the patient indication of how he should behave and what he should do.

Monitoring of a person in risk of becoming dependent

It is generally important to be able to asses if a person is at risk to not be capable anymore to live independently, but need assistance in the daily life. To this purpose usually a number of scales are used: e.g. Barthel or Pfeiffer. The Barthel index is expressed by a score and re-applied over time thus indicating improvements or deterioration. An additional test that is of interest is the MMSE test. This test can be used to assess any deterioration over time of cognitive abilities. If some of them are varying with respect to the norm one could infer that the person is at risk. They are usually administered by nurses and are focused in daily activities. People over 65 living alone should have this assessment at least once a year. Then, if something is outside the norm the nurse can decide to do it more often for instance every 6 or 3 months. The GiraffPlus system could check regularly these scales focusing at least on 4 dimensions: eating, cleaning-hygiene, dressing and mobility. GiraffPlus could help assessing those parameters not only by facilitating the dialogue with the patients but also exploiting the environmental data gathered through the sensors. These

data could be a more objective evidence of the status of the person to be used in combination with the scales to assess the level of independency. In addition the GiraffPlus system can help in deciding the frequency with which to assess these scales and can therefore be used to personalize the frequency of the assessment. For instance, if the GiraffPlus system shows a good trend of the person a decision can be taken to give the regular assessment less frequently. On the other end the GiraffPlus system could for instance automatically detect some changes in the daily activity and suggest to the nurses that the test should be performed. In addition the test could also be administrated via the Giraff robot.
The system could also give some warnings or alarms to the nurses. A warning may be for instance connected to forgetting medicines or in general to a change of routines, while an alert can occur with a fall, a gas leak, or physiological parameters outside the norm.

Test apartment at Stockholm hospital
A special case of the de-hospitalization scenario is a case of a test apartment used by a hospital in Stockholm to check how much assistance and support a person will need after the exiting from the hospital. Patients that have had a stroke or have had a damage to the brain, can stay in the apartment for 4 days and try to live autonomously. The patients are not necessarily elderly, however the problem encountered by these patients are similar to the ones encountered by elderly at the onset of mental debilitating illness like dementia and Alzheimer. The activities the person does are monitored and an assessment is made if the person will need technological helps like reminding and/or a personal assistant. The apartment is already provided of sensors and of the Giraff robot.

Appendix 3: Related projects

Technology for elderly is currently a very active research topic. Of specific interest for this project are systems that monitor elderly in their home and/or offer virtual communication between care givers and family and the elderly. In particular we consider commercial systems currently in use focusing of the sensors used and the functionalities available. Further we consider EU projects that have a similar focus of GiraffPlus. There also we are mainly interested in the sensors used and the available functionalities.

MONITORING SYSTEMS CURRENTLY IN USE

The western world is facing arising challenge of a growing elderly population in need of monitoring and a lack of formal and informal care givers that can be available continuously. To meet this need a number of companies are offering monitoring solutions where several parameters are monitored and information is sent via internet and/or mobile phones. Some of the leading solutions are the following:

- **GrandCare** (grandcare.com) sends cellphone alerts whenever a user-defined set of parameters is breached
- **Ideal Life** (ideallifeonline.com) monitors symptoms associated with heart failure and diabetes. It offers a number of devices, including a scale, a blood-pressure meter and a glucose monitor that automatically send data to the company's Web site, where it can be examined by a caregiver. Text messages or e-mail alerts can also be sent automatically to a caregiver's smartphone
- **Health Sense** (www.healthsense.com) offers a more comprehensive High Tech Gadget monitoring system. With a large variety of sensors it can monitor for instance sleeping patterns, shower and toilet use, if the stove has been left on
- **BeClose** (http://beclose.com/) tracks daily routine. If there are disruptions, it sends alerts in real time by phone, email, or text message. The sensors used are motion sensors, sensors at doors, occupancy sensors for bed, chair and toilet, sensors for water leaks. A dashboard shows a snapshot of simple daily activities and routines.
- **CloseBy Network** (http://www.closebynetwork.com/) uses a combination of sensors and software tied to a web application. Families choose what to monitor, how to receive the information, and who should be sent alerts. Alerts can be sent for instance if one leaves and returns, gets out of bed, opens the refrigerator or medicine cabinet, if he is moving normally about the house, if there is no activity within a specified time, or if the "contact me" button for help is pushed.
- **Added Care Assistant™** (http://www.addedcareservices.com/) includes weight scale, pulse oximeter, glucometer and blood pressure cuff. Information gathered is compiled in charts for review by family and physicians. It also offers the possibility to uploading photos and videos, to use a simplified email and SMS text-messaging program, to do cognitive skill games and trivia. Finally, it gives access to streaming music, news and weather.
- **AttentiveCare** (http://www.caregivertech.com/) provides caregivers with the possibility of videoconference with care receivers. It also provides an Observation Mode videoconferencing feature. Observation Mode establishes a one-way videoconference, allowing the caregiver to observe the care receiver's living environment without engaging or disrupting the care receiver. Caregivers can create reminders consisting of a text message and an optional audio alert. Caregivers can upload digital pictures to the care

receiver's system through AttentiveCare's Slideshows feature. A journal lets caregivers create text entries discussing observations, activities, and events related to the care receiver. Caregivers may keep a list of any medications and contact information.

- **In-home Monitoring** (http://www.oakwood.org/) establishes the ability to link seniors with a personal emergency response system. It includes: Vital Sign Monitoring, Personal Help Buttons, Two Way Voice Communication, Motion Detectors, Door and Window Contacts, Smoke Detectors and Carbon Monoxide Detectors.
- **SaferAging™** (http://www.saferaging.com/) combines an emergency pendent with an automated sensor system detecting the current temperature inside the home, whether recent motion was detected, and whether there was pillbox activity. The family describes the normal activity profile for the elderly and this is used to identify exceptions that might be an early indicator of an issue (e.g., excessive nighttime activity, no pillbox activity detected). Each day, the family is sent the updated dashboard for the elderly person; a family member can also add reminders to the senior's calendar. When SaferAging does detect a potential issue, it reaches out to people responsible via phone, text and email. The system also provides a daily activity graph, which allows for a quick visual recognition of behavioral patterns.
- **Care Technology Systems** (http://www.caretechsys.com/home-health) gives home care providers a number of tools to monitor elderly. In particular the system is able to detect if somebody enters or leave a room and falls. The falls can be detected only in the night and the detection is based on the fact that a person has been out of bed for 20 minutes and no movement is perceived in any room. The system can gives alerts to a designated family member, caregiver, trusted neighbor or their call center. The system offers also biometric devices, including a blood pressure cuff, weight scales, glucometer and pulse oximeter.
- **Philips's Medication Dispensing Service** (managemypills.com) uses a tabletop device that can be loaded with up to 60 doses of medication, each contained in a small plastic cup. When programmed by a nurse or family member, the dispenser will remind users with a spoken message that their medication is ready. Pushing a button releases a dosage cup into a tray.

The one above is just a selection of the many solutions currently provided for monitoring elderly in their home. Most of the solution use wireless motion or contact sensors on doorways, windows, walls, ceilings, cabinets, refrigerators, appliances or beds to track seniors' movements, and temperature sensors. The systems also generally offer hand-held or wearable "panic buttons." Also Tunstall, one of the company in GiraffPlus offers such a solution, ADLife - activities of daily life monitoring solution, that combines an alarm button with alarms given by sensors and monitoring of simple activities of daily living. Most of the sensors that GiraffPlus intends to use are currently used in the ADLife solution. These sensors form a good basis also for the GiraffPlus system and the fact that many commercial systems are currently using it in at home application shows that the technology is today reliable and easy to use. The availability of many commercial solutions also shows a need for monitoring and an acceptance of the technology as a help, confirming our finding with respect of user requirements.

The GiraffPlus system builds over the level reached by the system described above and uses high level reasoning for context recognition, configuration planning and personalized interface. No commercial system is currently available that addresses this aspect. In the following section some EU research projects that partly consider a similar challenge are considered.

RELATED EU-PROJECTS

In recent years, the EU has funded a number of projects promoting independent living for elderly. The AAL (Ambient Assisted Living) Joint Programme is focused exactly on this topic. Several AAL projects address smart homes for the elderly. The ones most related to this project are outlined below. Where the information is available we also outline the sensors and functionalities in the project:

• BEDMOND is a system for early detection of Alzheimer´s disease and other neurodegenerative diseases where data from home sensors are processed by an activity recognition system and arranged by a rule based engine. The system then sends a report to a physician who makes a judgment. http://www.bedmond.eu/

• eCAALYX is a system for collecting physiological and movement-related data from home-based and wearable sensors. It includes sensors for the measurement of heart rate, ECG and pulse oximetry/SPO2 (Saturation of Peripheral Oxygen) and an accelerometer. The sensors are worn in a pocket of a t-shirt. The system can recognize simple activities like standing, laying, walking, and sitting. http://ecaalyx.org/

• HAPPY AGEING is a system for lifestyle monitoring, for issuing reminders and detecting lack of activity or unusual behaviors. The system also includes navigation assistance and personal assistance. http://www.aal-europe.eu/calls/funded-projects-call-1/happy-ageing

• HOPE is a system for people with Alzheimer's disease which can provide alarms, alerts and communication with health professionals. It has sensors for tap open, door open, stove left on, temperature, humidity, smoke, It then give reminders and warnings via voice. http://www.hope-project.eu/index.asp

• ROSETTA is a system for people with Alzheimer´s and Parkinson´s disease. It triggers alarms in case of unexpected/deviant (in)activity and gives reminders when there is an appointment or at the moment an activity like cooking is interrupted. The sensors used are among others: camera and motion detectors. During the first two weeks, the 'normal' pattern is determined. The system signals important changes by yellow and red dots on the screen, for example in the use of shower or washbasin in the bathroom or the bath. The system can make the distinction between getting out of bed at night with an aim or aimlessly as getting out of bed aimlessly is typical of dementia from an intermediate stage. Getting out of bed with an aim might be going to the toilet or to the refrigerator. http://www.aal-rosetta.eu/

• AMICA (Autonomy, Motivation & Individual Self-Management for COPD patients). The project developed a multifunction biomedical sensor, incorporated in a dedicated mobile device. The main functions are: records of breathing and heart rate, physical activity and tracheal sounds; display of variables and physiological parameters relevant to COPD and respiratory-related dysfunctions; early detection of exacerbations; remote monitoring and home-based care. The detection of COPD exacerbations is done through the use of a multifunction biomedical system able to yield continuous and sporadic data on heart, breathing and physical activity. http://www.amica-aal.com/

6th and 7th Frame Programme EU-projects that are related to this project include:

• FLORENCE (Multi Purpose Mobile Robot for Ambient Assisted Living) is a project that develops an autonomous robot integrated in a smart home. Services for social connectedness, coaching, care support and safety will be developed and evaluated in living labs. The Florence robot is a wheel-based, 1,5 meter high, screen-based robot with no arms. Sensor input is based on a 2D laser scanner, 3D structured light (Kinect) and an (optical) camera. http://www.florence-project.eu/

• KSERA (Knowledgable SErvice Robots for Aging) is a project that aims at developing a service robot for elderly persons (based on the Nao humanoid platform), in particular those with pulmonary disease. The project addresses mobile robot behavior such as navigation and following, monitoring of physiological and behavioral data, and human-robot interaction. A Kinect is used to analyze the performance of participants. The data is used to determine the trajectory of the user's movements. Those are than correlated with the movements of the robot. The findings can be used to modify the robot's behavior in order to motivate the user to perform better. http://ksera.ieis.tue.nl/

• SRS (Multi-Role Shadow Robotic System for Independent Living) is a project that focuses on the development and prototyping of remotely-controlled, semi-autonomous robotic solutions in domestic environments to support elderly people. The robot acts as a shadow of its controller and helps the elderly to perform practical tasks. It has a manipulator that can be used to fetch and carry objects. http://www.srs-project.eu

• MOBISERV (an integrated intelligent home environment for the provision of health, nutrition and mobility services to the elderly) is a project for developing proactive personal service robotics for supporting independent living. The robot can issue warnings and alarms. Technologies such as biosensors and smart textiles will be utilized. http://www.mobiserv.eu/

• CONFIDENCE (Ubiquitous care system to support independent living) is a project where the user of the system will wear a few tags, whose positions are determined using radio technology. The tags' coordinates will be used to reconstruct the user's posture and this information, together with some environment information, will be analyzed to decide whether to trigger an alarm. The base-station is placed inside the house and is able to determine the position of each tag in the three dimensional (3D) space. A smart-phone is the interface of the system with the user. The user wears small size tags, either in the form of bracelets to be worn in wrists and ankles or in the form of necklaces or the tags may be sewed into the clothes (socks, underwear, etc.). Other small devices can be placed in specific positions such as the bed, chairs. If an alarm is triggered the system makes a phone call to the user. If the user picks up the phone, he/she is requested to indicate that he/she feels well by pressing a button. This stops the alarm. The user decides who the system is calling in case of an alarm or warning: a relative, friend or to the emergency services. If the user does not pick up the phone in a certain time, the system makes a phone call to the first telephone in the list provided by the user. If nobody answers the phone, the system will call the following telephone in this alarm receiver list. The system will explain to the call recipient the reasons of the alarm or warning. http://www.confidence-eu.org/

• MonAMI (Mainstreaming on Ambient Intelligence) is a project focused on developing a technology platform to deliver services using standard technology and using an innovative interface, involving an embodied conversational agent. The system can detect falls, lack of activity or presence in restricted areas, abnormal lighting, temperature and humidity levels in the home, smoke and gas leakage, open/unlocked doors and windows. The user can via a user interface check the status of devices in the home such as shutters, lights, doors, windows and appliances as well as information on the temperature, humidity and presence/movement in the home both when at home and away from home. He can also control devices such as shutters, lights, doors and appliances with his/her user interface, both when at home and away from home. The user can program the system so that the different devices function automatically such as lights turn on when someone enters a room. Finally the system can give reminders and provide games. http://www.monami.info/

• PERSONA (Perceptive Spaces Promoting Independent Aging) develops a platform to build a broad range of AAL Services like shopping assistant, nutritional advisor, agenda and reminders, activity monitoring to trigger alarm, modeling of the behavior of the user for a certain period of time.
• HeartCycle aims at providing a closed-loop disease management solution being able to serve both Heart Failure (HF) patients and Coronary Heart Disease (CHD) patients, including possible co-morbidities hypertension, diabetes and arrhythmias. This would be achieved by multi-parametric monitoring and analysis of vital signs and other measurements. A patient loop interacting directly with the patient will show the health development, including treatment adherence and effectiveness. A professional loop alerts of the need to revisit the patient's care plan, and of possible adverse events. The sensors used are cuff-less blood pressure, wearable SpO2, inductive impedance, electronic acupuncture system. Further sensor development will be done with respect to: Contact-less ECG, Arrays of electret foils, Motion-compensation in ECG, Cardiac performance monitor (bio-imped.). http://www.heartcycle.eu/
• Renewing HeALTH (REgioNs of Europe WorkINg toGether for HEALTH) aims at implementing large-scale real-life test beds for the validation and evaluation of innovative telemedicine services. In 9 European regions with pre-existing telemonitoring and health coaching programs, the programs are extended to large scale pilots and evaluated in order to provide evidence on the use of telemonitoring in real life settings. Applying the Model for Assessment of Telemedicine (MAST) on a total sample of 7900 patients suffering from Chronic Obstructive Pulmonary Diseases (COPD), the project provides the foundation for evidence of the effects of telemedicine services and Personal Health System (PHS). Regions and partners collaborate to manage issues such as integration, patients' involvement and user perceptions, as well as transferability of knowledge and results pooled by the project to other regions in Europe. It is funded by the ICT Policy Support Programme (ICT PSP) - Competitiveness & Innovation Programme (CIP)
http://www.renewinghealth.eu/

The solutions proposed by the AAL projects listed above are based on established technologies. They are developed in a close loop with the users, and the projects are expected to result in commercialization in the near future. However, the solutions tend to be specific for a certain class of illnesses and the scientific novelty can be limited. In many of them, services provided are mostly based in a one to one correspondence between sensors data and actions that the system performs. Conversely, Giraff+ proposes to focus on changing needs via long term monitoring of complex behaviors and the use of high level reasoning. This will allow the system to recognize and react to more sophisticated human behaviors, and will support the provision of services in response to long-term physiological trends. These capabilities are paramount in early diagnosis and prevention, and constitute what we believe is a key factor for uptake. The FP6 and FP7 projects tend to address more general problems and develop more advanced systems (often including autonomous robots). However, the results of these projects are farther from commercialization, both in terms of technological maturity and in terms of affordability. User evaluations tend to be more limited than those carried out in AAL projects. FLORENCE, KSERA, and MOBISERV differ from Giraff+ in their focus as they are centered on autonomous robot solutions that present a different set of challenges with respect to our project. SRS differently to our project is focused on a robotic system performing tasks and controlled remotely. CONFIDENCE differs from Giraff+ by being focused on posture recognition. HeartCycle and Renewing HeALTH have a different focus with respect to our project, but they are interesting with respect of the sensors that are used and that could be used also in our project.

MonAMI is focused in the platform more than in the services. Finally, PERSONA is a large project aimed to developing a middleware supporting many different services. Activity monitoring to trigger alarms and modeling of user behaviors for a certain period of time has commonalities with what we intend to develop in Giraff+; however our project´s focus on the recognition of more complex daily behaviors that can involve interleaved activities and events over both short and long periods of time, therefore supporting both reactive system behaviors (e.g., alarms) and trend analysis. Comparing to the PERSONA architecture we aim at developing special purpose reasoners based on different context models and engines which extend the capabilities of the PERSONA´s situation reasoner. In addition we will develop versatile user interfaces which support both real time viewing of what is happening in the elderly persons‟ home and aggregating and analyzing data extending over longer time periods. The system is also adaptable to the particular needs of different individuals and situations. In addition, our effort on evaluating useworthiness is unique and from this point of view, we propose a middle ground between AAL-like user evaluations (which are appropriate for products that have a 2-year time to market) and Framework Programme projects (where user evaluation is focused purely on refining research prototypes). We also advocate a way to introduce the technology that is non-obtrusive and even enjoyable. Additional projects related to ours are the ones that aim at creating a common platform for AAL, on top of which to develop intelligent software applications for the end users. In particular universAAL aims to standardize an open platform and reference specification for AAL and consolidates other relevant projects results like SOPRANO, MPOWER, PERSONA, OASIS, VAALID, AALIANCE. It is our intention to be aligned to the universAAL results, to reuse the Open Source software released by them.