GiraffPlus: A System for Monitoring Activities and Physiological Parameters and Promoting Social Interaction for Elderly

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Abstract. This chapter presents a telehealth system called GiraffPlus supporting independent living of elderly in their own home. GiraffPlus system is a complex system which monitors activities and physiological parameters in the home using a network of sensors. The elaborated information is presented to the primary user, the elderly, and to secondary users like health care and home care providers and possibly to family members as a help to assess possible health and wellbeing deterioration, provide acute alarms, and support health procedure. The secondary users can also visit the elderly via the Giraff, a teleoperated robot that can communicate and move in the home under the control of the secondary user. The chapter focusses in particular on the deployment of the system in six real homes in Sweden, Italy and Spain. The chapter outlines the technological various components used, the expectations of the users and the evaluation method.

1 Introduction

An emerging application area for intelligent systems is the use of such system in the home and for domestic use. In particular, applications which concern individuals

Z.S. Hippe et al. (eds.), *Human-Computer Systems Interaction: Backgrounds and Applications 3*, Advances in Intelligent Systems and Computing 300,
DOI: 10.1007/978-3-319-08491-6_22, © Springer International Publishing Switzerland 2014

with special needs, disability or in general promote an improved life quality are particularly interesting for these new technologies. This application area poses a number of key challenges from a human systems interaction perspective. Such a system should be in operation for long periods of time and should interact and be used by non-experts which may even suffer from cognitive decline. The system should also be able to cope with unexpected situations or events for which it may not have been pre-programmed. Therefore, there are not only technological challenges to deploying such systems at home, but also the ability to thoroughly evaluate such system is essential in order to ensure that the system can fulfill the needs of the intended users. In this chapter we present a system developed with an EU project called GiraffPlus. GiraffPlus is a complex system which can monitor activities and physiological parameters in the home using a network of sensors distributed in the home. The sensors can measure e.g. blood pressure or detect e.g. whether somebody falls. They can also assess where the person is, if is sitting in the couch or lying in bed, if he is using electrical appliances or opening cupboards or the fridge. Different services, depending on the individual's needs, can be pre-selected and tailored to the requirements of both the older adults and health care professionals. At the heart of the system is a unique telepresence robot, Giraff, which lends its name to the project. The robot uses a Skype-like interface to allow e.g. relatives or caregivers to virtually visit an elderly person in the home (see Fig.1). The GiraffPlus system monitors daily activities of the elderly and provides a visual interface which allows care givers to see a summary of the activities. The physiological data can also be viewed in the context of the daily activity of the users. The monitoring is complemented with a social interaction component where health professionals and elderly can discuss the collected data during visits made via the Giraff robot.

Fig. 1 The GiraffPlus system deployment in a home

In the GiraffPlus system, the interaction between humans and the system occurs with several modalities. Firstly, there is an interface that shows the data collected by the system to health and homecare professionals and can be used both offline or during the visits with the Giraff. Secondly, family and friends are able to connect to the system and see parts of the information according to their level of authorization to the data. Thirdly, the elderly has the possibility to see his or her own data which has been collected by the system. Finally, all the information is stored in a database and can be retrieved for any specific time window enabling therefore long term analysis of the data.

Special emphasis in the project is given to evaluations and input from the users so that the system can have an empathetic user interaction and address the actual needs and capabilities of the users. The GiraffPlus system is already installed in 6 homes of elderly people distributed in Sweden, Italy and Spain and will be installed and evaluated in a total of 15 homes. These evaluations will drive the development of the system. This chapter presents the user expectations, the preliminary evaluations of the system and the deployment of the first version of the system in the six homes. The chapter also provides the initial evaluation results after a first period of use.

The chapter is organized as follows: A general description of the technological components of the GiraffPlus system is given in Section 2. Section 3 provides a description of the selected test sites, the evaluation methodology and the deployment of the system. Finally a discussion, conclusion and outline of planned work in the project are given in Section 4.

2 The Deployed System

In this section we briefly present the GiraffPlus system. A more detailed description of the system is in [Coradeschi et al. 2013]. The **Giraff telepresence 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 behaviors and trends. **Personalized interfaces for primary and secondary users** are developed to access and analyze 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.

The specific instance of the GiraffPlus system that has been deployed at the test sites includes the components described below.

2.1 Hardware Components and Middleware

The kind of sensors deployed in the test sites are described below. Fig. 2 shows the sensors. For each test site a specific group of sensors is selected depending on the home topology.

Passive Infrared Detectors (PIR). The passive infrared detectors are wireless movement detectors that can be used to detect the presence of the user in a particular room. Once a movement is detected, the PIR sensor generates a signal to the GiraffPlus middleware. This information is essential to register and monitor the activity of the user.

Fig. 2 Presence sensor, Electrical power consumption, Occupancy sensor, universal sensor, door contact

Electrical Usage Sensor. This sensor sends a radio signal to the GiraffPlus middleware, when a connected electrical appliance is switched on/off. It is intended to indicate when primary users have used a particular appliance, such as a kettle, microwave, etc.

Occupancy Sensor (bed/sofa/chair). Occupancy sensors are pressure pads that can be placed on mattresses, sofas, chairs, etc. to check the time the user is resting. They need to be connected to a universal sensor to transmit the information to the Giraffplus middleware.

Door Contact. This sensor detects when two objects are close. It is typically used for doors, windows, cabinets, etc. to detect when they are opened/closed. It needs to be linked to a universal sensor in order to transmit the information to the middleware.

Universal Sensor. The Universal sensor enables wired devices and other equipment to raise wireless alarm calls and appropriate radio messages to home units using Plug and Play functionality. When the attached device is triggered, the Universal sensor sends the appropriate message, permitting the elements connected to the GiraffPlus middleware, e.g. the Context Recognition module, to be aware about the current situation.

Physiological Sensors. The physiological sensors include a kit composed by an android tablet and assessment kit that measures weight, blood pressure and glycaemia.

Android-Based Mobile Phone and a Pulse Oximeter. The main purpose of the sensor is a continuous monitoring of physiological parameters (pulse rate and oxygen saturation) and fall detection using the accelerometer in the mobile phone.

Giraff Telepresence Robot. The Giraff robot is a telepresence device that allows remote users to connect and make a virtual visit. It includes a zoom camera with a wide-angle lens, microphone, speaker and a 13.3" LCD screen mounted on top of a base that the visitor can control remotely and move around in the remote location. The 13.3" LCD can turn 180 degrees to let the user see who is calling and to interact with the Giraff. The device is specifically designed to work in home settings and provides visual/social cues for the user, such as lowering to a sitting position when at a table or bedside. The Giraff robot can be seen in Fig.1.

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

The **middleware** provides communication functionalities between software components deployed at home and on secondary user's personal computer.

Heterogeneity and distribution of both hardware and software resources is hidden by the middleware. Instead of providing different components at different levels of the system to access storage and context recognition functionalities, the current middleware architecture includes dedicated modules at the same level. Similarly, any device configured at home can be accessed in a homogeneous way by local and remote services.

The buses used to announce and discover resources installed at home (service bus) and the buses to access sensors' readings (context bus) need to be managed by a message broker that is installed on the same home server and it is accessed through the VPN by the remote clients.

In addition to communication capabilities, the current middleware layer presents APIs to retrieve historical and real-time sensor data and to query for activities in the monitored home environment.

A **remote Database** is used where all the sensor data and the elaborated information is stored and easily accessed by all components of the system.

2.2 Context Recognition and Configuration Planner

Context recognition and the configuration planner are important components of the system in order to give meaning to the sensor data. The former recognizes the activities performed in the home (e.g. eating-dinner, sleeping, food-cooking, and moving) on the basis of the sensors data. An activity has an extension in time, and it typically involves changes in observable state variables. 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.

Given a task, the **configuration planning** is the problem of generating a functional configuration of a networked robot system consisting both of mobile robots and sensors and actuators distributed in the environment that solves that task. In a functional configuration, sensory, computational and motoric functionalities belonging to the different devices are connected with communication channels.

The work by [Lundh et al. 2008a], [Lundh et al. 2008b], [Lundh et al. 2009] offers a centralized solution to the problem, which has been successfully employed in an intelligent home test bed. A related approach for multi-robot systems is AsyM TRe-D [Tang et al. 2005], [Parker et al. 2006]. ASyMRTe-D works by connecting functionalities, belonging to different robots, into coalitions. The GiraffPlus configuration planner may produce configurations that change over time, in particular when actuation (pre- and post-conditions of actions) is involved. The configuration planner makes the sensor network providing the information (state variable values) that the context recognition system needs, and may also change state variables through actuation. A particular important capability of the GiraffPlus configuration planner is to handle many requests at the same time.

Context recognition is a fundamental capability of the proposed system. Context recognition addresses the general goal of providing the system with the capability of inferring context about the human user(s) and of the environment, including its ubiquitous sensors and actuators. In the particular sub-case of human context recognition, this capability often goes under the name of activity recognition. The context recognition system 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). Similar constraint-based approaches to inference in the domain of domestic activity monitoring include [Cesta et al. 2010], [Pollack et al. 2003].

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 derives activities from them. 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.

2.3 Interacting with the User

The GiraffPlus system uses different modalities to interact with the users. The secondary users receive reports of the activities and physiological parameters and can see these information on-line via an interactive program (Fig 3 A and B). The elderly can see the information in the Giraffe robot touch screen (Fig 3 C and D).

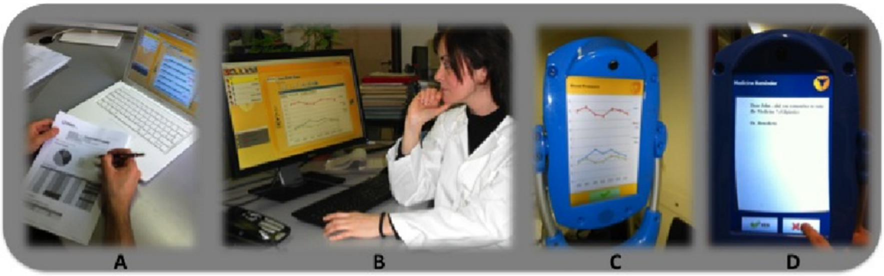

Fig. 3 Interaction modalities of the GiraffPlus system

The secondary users can also connect to the Giraff robot using the interactive tool (Fig. 4 left). Fig. 3 B and C shows a graphical representation of the physiological data, while Fig. 4 right shows a representation of the activities performed in a period of time.

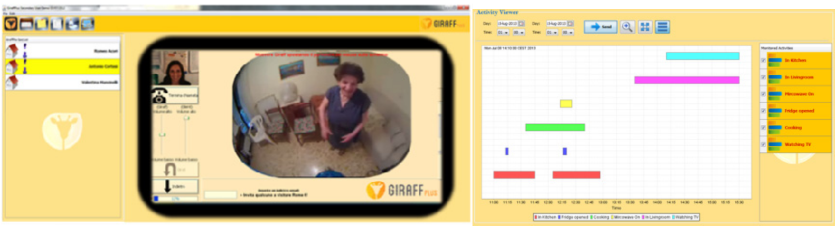

Fig. 4 (left) tool to connect to the Giraff robot; (right) representation of activities

3 Long Term Evaluation

3.1 User Requirements

The GiraffPlus system is being developed on the basis of user requirements from both primary (elderly living in their apartment), and secondary (health care professional or family members and friends) users. Overall a **total of 325 users** (among primary and secondary) have been involved in this initial phase. Qualitative and quantitative research has been carried out in the Sweden, Spain and Italy, to elicit user requirements and expectations in terms of type of services as well as system design and appearance. The study started with a literature review, followed by focus groups and questionnaires. Specifically, the results of the focus groups have been validated via questionnaires and workshop with users. Some qualitative cross-cultural analysis has also been performed in order to highlight differences emerged during the studies in the three countries. Result of this effort is a list of user requirements with an associated level of *priority* and a set of preferences on different mockups of a component of the system that can be both used to influence the future architecture definition and functional specification of the GiraffPlus system. This comprehensive list of requirements is not only of interest for the specific GiraffPlus system, but also outlines general preference of primary and secondary users with respect to technological solution. The complete list is available at the GiraffPlus website (www.giraffplus.eu) in deliverable D1.1 in the "Project" tab.

3.2 User Expectations

The project's guiding principle is that it should be driven forward by user centered design. In this case, it means active involvement during the entire development of cycle ranging from the initial prototype in the laboratory, the intermediate version installed in the homes and the final complete system.

In the first year, efforts were made to create a group of older users that serves as test subjects throughout the project. This was based on earlier experiences that such a strategy creates more engaged participants willing to serve as proactive users and being partly responsible for the result compared to being merely objects for testing. The advantage for the project manager is a secure process that creates stability and prevents drop outs and problems in case of projects delays.

Initially several workshops were organized inviting potential elderly users to proactively elaborate on the concept playfulness and its bearing on inviting telehealth systems and its artifacts into the home. The results showed the importance of considering cultural differences both in terms of design and in terms of monitoring the contacts between patients and caregivers. Minimalist design was more desirable in Sweden since it was experienced as discrete and stylish and possible to personalize. In Italy and Spain users preferred furniture like design that was experienced as offering more functionality. The knowledge of the variation in health care systems was found important to facilitate adjustment of telehealth care services to national and local conditions.

The next step was to test a preliminary GiraffPlus version in three separate evaluations. First with eleven elderly users in a test flat in Sweden, second, with six professional nurses in Italy, and third, installing a pilot in one real life setting – a home of an elderly user in Italy.

The main aim in the test flat was to identify users expectations and identify problems to facilitate the adoption process and pave the way for the next step i.e. installation of the system in homes of elderly users. Telehealthcare research most often has a technological focus without any chance to understand the user's point of view. Such an approach neglects the experiences of users which in turn limits the ability to implement new products and services in a meaningful way in their everyday lives. Based on the user requirements derived from the initial literature study and focus groups described above elderly users were exposed to three scenarios: the situation of de-hospitalization; daily activity monitoring by a care giver; and monitoring a physiotherapy protocol. The analysis of the expectations was guided by Rogers´s diffusion of innovation theory [Roger 2003] which helped to understand the adoption or rejection of the GiraffPlus system. An innovation is likely to become successfully adopted if it is perceived as better than the idea/product it succeeds – *relative advantage*; if it is perceived as being consistent with exciting values, past experience and the person's needs – *compatibility*; if it is perceived as easy to use – *complexity*; and if the use of the innovation is visible and liked by others – *observability*. The result shows that the crucial factor for adoption of telehealthcare systems is not usability but the system's ability to really support autonomy in everyday life. Results from the user lab tests indicate that a telehealthcare system needs to: (a) be customized to the individual's needs, (b) be reliable, (c) be easy to use, (d) consist of as few devices as possible, and (e) offer training and education throughout the usage. The relative advantage of the system with respect to possible alternatives depends on how well integrated the telehealthcare system can become with the current healthcare system.

The assessment of the prototype in Italy involved nurses as secondary users. They were exposed to the same scenarios as the elderly users in the test flat in Sweden. They also assessed the first version of the interface for the Interaction and Visualization Services, see figure 4. Their main concern was how to integrate the system in their daily work. The means through which GiraffPlus is accessible is crucial in this respect: it needs to fit into their daily work routines and it challenges the way health care is organized. An additional aspect outlined is that to serve the patients the information need to be contextualized; a holistic perspective requires patient information that is beyond singular data, but considers a more general context. For instance, a blood pressure value can be influenced by the activities the person has done before.

The pilot study in an elderly home in Italy helped to make the preparations for implementation more realistic and effective. The main factors emerging in the pilot study were technology weaknesses, for example that sensors were more difficult to install than expected. In addition organizational and maintenance issues emerged, for example the previous relation between those visiting the home and the elderly impacted the willingness to regularly use the technology. There was also the need to adapt the expectations of technology reliability between a lab setting and a real life setting where reliability is much harder to achieve. The lessons learnt from this pilot illustrates very well the theoretically based fact that usefulness and meaningfulness is context based.

To conclude, the first evaluation of the Giraffe Plus emphasizing expectations shows the difficulty of assessing the value of innovation outside its context. It demonstrates the need to understand the daily life of the organization or the individual where it will be implemented. It also shows the value of involving users, both elderly and care givers, and not least, to test the system both in a laboratory and in a real life pilot and most important, to understand the difference between the settings and adapt the technology to the real home.

3.3 Deployment of the System in the Test Sites and Evaluation

The GiraffPlus system has been deployed in 6 homes. For each country (Italy, Spain and Sweden) two homes have been selected and a version of the system has been deployed. In Sweden the test sites are the homes of two single men both 83 and 82 years old. In Spain two men 84 and 76 years old. In Italy two women 93 and 94 years old. An example of the sensor deployment in a home in Sweden is shown in Fig. 5.

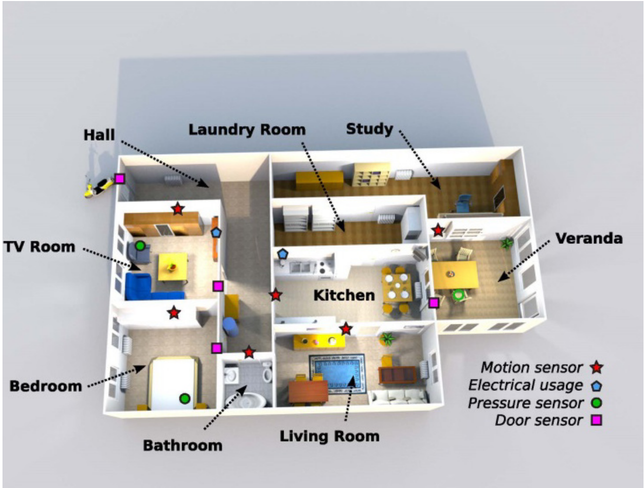

Fig. 5 Sensors deployed in a test site in Sweden

An interview has been performed for each test site to assess the expectation of the person and to decide which sensor to deploy and where depending of what was expected to be monitored. The expectations that emerge from the interviews show the presence of both drivers and barriers with respect to the use of the system. No technological barriers were considered especially significant pointing to the fact that the usability aspects of the system components are satisfactory. One barrier addressed in Spain was worries about the "big brother syndrome" i.e. the surveillance by unknown people. One driver that overshadows the barriers is the positive experience of being involved in a project and their own experiences being taken seriously.

We are in the process of performing additional interviews after an initial period of using the system.

4 Discussion and Conclusions

The GiraffPlus system aims at facilitate a prolonged independent living for elderly in their own home. The system monitors daily activities and physiological parameters and can give a more reliable view of the health status of the person both for the person himself and for health/care personal and family. The system can also give alarms and present long term data that can show health deterioration.

An essential aspect to be considered is a thorough user evaluation both in terms of user expectations and user feedback when using the system. We briefly present in the paper the methodology for acquiring the user requirements and we refer to a report available on-line for the full list of requirements due to space limitations. We also describe the acquisition of user expectations prior of the system deployment. Currently, the system has been recently deployed in 6 test sites where it will be evaluated for one year. 9 additional test sites will be started in February 2014. The system deployed is described in the paper. A first feedback from the users of the system is currently collected and can also be presented in the final version of the paper.

Acknowledgment. The project is supported by the Fp7 EU programme.

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