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The Role of Users in CAALYX

John NELSON[1], Pepijn VAN DE VEN[1], Alan BOURKE[1], Gearóid ÓLAIGHIN[2], Marco ANTOMARINI[3], Claudio SDOGATI[3], Manuel Escriche VICENTE[4]
[1]*University of Limerick, Limerick, Ireland*
Tel: +353 61 202358, Fax: + 353 61 202572, Email: john.nelson@ul.ie
[2]*National University of Ireland, Galway, Ireland*
Tel: +353 91 492685, Fax: +353 91 494511 Email: gearoid.olaighin@nuigalway.ie
[3]*COOSS Marche, via Saffi n° 4, 60121 Ancona, Italy*
Tel: +39 07150103211, Fax: + 39 07150103206, Email: c.sdogati@cooss.marche.it
[4]*Telefónica Investigación y Desarrollo, Parque Tecnológico de Boecillo, 118-120, 47151 – Boecillo, Valladolid, Spain*
Tel: +34.91.312.99.72, Fax: +34.983.36.75.64, Email: mev@tid.es

Abstract: This paper introduces the Complete Ambient Assisted Living Experiment project (CAALYX), the progress so far and what remains to be done. A lot of what the project is doing is guided by extensive user participation and feedback. Hence, an overview is given of the many user aspects of the project and the associated challenges, strengths and weaknesses, and the lessons learned, in particular from the Phase I trials. A more realistic view of the technology role is discovered as a result of comprehensive verification and validation. Some of the many other aspects to be addressed before such systems can be widely and effectively deployed are identified.

Keywords: Ambient Assisted Living, Elderly, Users, Vital Signs, Fall and Mobility, Sensors

1. Introduction

CAALYX – Complete Ambient Assisted Living Experiment, is a two-year project supported by the European Commission (EC) under the Sixth Framework Programme (FP6) and is active throughout 2007 and 2008[1][2]. The project group comprises eight organisations, located in six European countries. CAALYX's main objective is to develop a wearable light device capable of measuring specific vital signs of the elderly, to detect falls, and to communicate automatically in real time with his/her caregiver in case of an emergency, wherever the elderly person happens to be. The emergency information, containing geographic position and the elder's health information, can be directed to the personal caretaker and/or the Emergency Service to initiate and direct an early and appropriate response. The project philosophy is user-centric with early and continuous user involvement, and a "demand pull" approach is adopted, as opposed to a "technology push".

CAALYX features and integrates mobile geo-positioning and dynamic 'plug-and-play' wireless sensor network technologies, and is developing intelligent clinical bio-signal pattern detection and fall detection algorithms, among other technologies and innovations. The incorporation of largely non-intrusive new sensors for fall detection and highly sensitive geo-positioning is expected to address many of the elderly people's concerns about adopting the technology.

The monitoring device for the caretaker can range from a mobile phone to a more complex Web hosted system, so that an integrated caretaking service can be created to look after groups of elders. When monitoring the elder at home, the system will be complemented with other devices such as cameras and TV to deliver personal services.

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The project has two distinct iterations, known as Phase I and II, aligned with the calendar years 2007 and 2008, respectively. Each phase begins by identifying scenarios, defining requirements, completing technical research and development, performing trials involving elderly end-users, and finally gathering user feedback from all stakeholders. The stakeholders include the elders, their families, carers, doctors, geriatricians, technical staff etc. Following the trials, both verification and validation is undertaken to understand the usability of the constituent components and the system interfaces.

Figure 1 outlines the CAALYX system architecture. In Phase I, a range of sensors are supported and controlled using a mobile application (prototyped on a Nokia N95 device). In the currently active Phase II the sensors are being integrated into a single wearable light device (WLD), which can alternatively be controlled from the home system when the user is at home and the mobile system while roaming. The Caretaker Site gathers all the sensor information, maintains profiles for each user, and presents this information in context specific views for the elder, the carers, the families and the medical personnel.

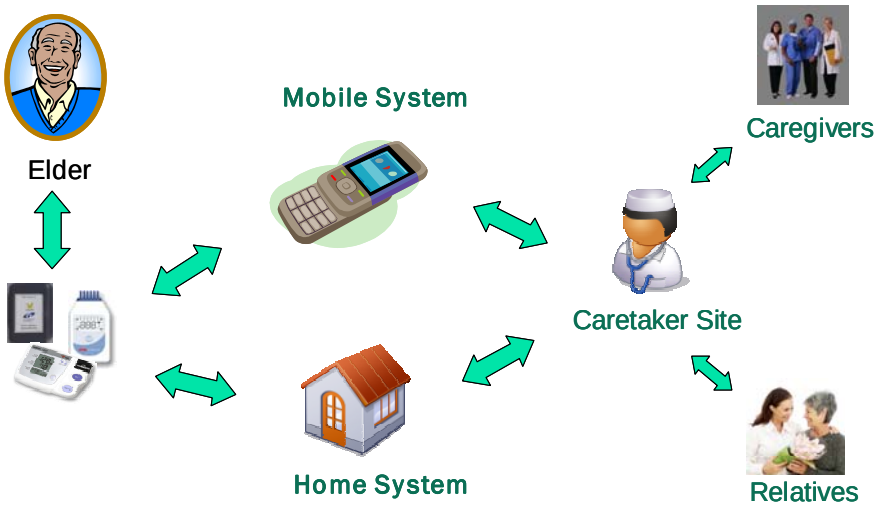

Figure 1 CAALYX System

CAALYX is innovative in a number of respects. From the platform viewpoint, it adopts an adaptive framework, which supports the individual definition of thresholds and diagnostics "scripts" for an elder to reduce information overload and minimise false alerts. The caretaker site supports multiple views for the elder, carer, doctor, and family member. It is reusable in different domains using geographic context awareness where it will act according to the environment. It adopts an open sensor platform, which encompasses the complete definition of the sensor network and allows the association of third party sensors. However, all of this is useless if the end-users don't see value in the system. Hence, a key part of CAALYX is to validate the system through trials involving end-users.

The following sections describe the trial objectives, the first phase trials, the technology used, the verification, the validation, business benefits, and finally conclusions are drawn.

2. Objectives for Trials

Two major trials involving end users were planned at the outset, the first has been completed in the autumn of 2007 and the second will be completed in the autumn of 2008, both at Ancona, Italy. In addition, there are corresponding development trials involving end users taking place in Limerick, Ireland, focusing on the fall and mobility sensing components and on the wear-ability. Each of the two phases involves the following major work activities: Scenario Description, Requirements Specification, System Implementation

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and System Trials. Except for the System Implementation, each activity involves significant stakeholder input and participation.

In particular, the Scenario Definition, adopted the scenario planning steps outlined by Ringland[3]. Social research was undertaken to complete a deeper analysis of the target group with a view to identifying and defining representative scenarios. Six months of interviews and questionnaires were completed in Ancona, Italy looking at issues such as: Economic status, Home location, Living conditions, Health conditions, Assistive needs Information and Communication Technology (ICT) and Assistive Technology (AT) acceptance, Family/friends networks, Social environment and Social services. Again over 100 stakeholders participated including over 50 elders (three elder groups: autonomous at home, day centre users or home care adopters), their families and carers, and representatives from the local administration, experts, national health system staff and policy makers. The "Scenario Definition" deliverables document this significant research carried out to ensure that user opinions were considered in system design from the outset.

The Phase I trials in particular were timed to get early feedback from the elderly end-users, and to address the identified issues in the second phase. Consequently, the major goals for the trials were focused on the elderly users as follows:

1. To get feedback from the elderly on the system usability and acceptability.
2. To get feedback from the nursing home personnel on the system.
3. To get feedback from the "caretaker" on the performance of the system.
4. To test the underlying technology and the system architecture in a real world situation.
5. To better understand the implications of adoption of the CAALYX system.
6. To refine the requirements for the CAALYX second iteration.
7. To determine whether or not CAALYX monitoring affects the user's mobility patterns.
8. To better understand the user interaction needs.

From a technology viewpoint, the purpose is to understand better the usability and appropriateness of the constituent components and the system interfaces, resulting in eight additional technological objectives.

3. The Phase I Trials

The first phase of CAALYX has now completed [4]. The resultant Phase I system consisted of three main components: the caretaker site, the roaming system with integrated sensors and the home system, as shown in Figure 2. For Phase I, the major stakeholders involved were the elders, their caretakers and the administrator. Although technically supported, the family members, medical practitioners and emergency service integration will only be formally incorporated in Phase II trials.

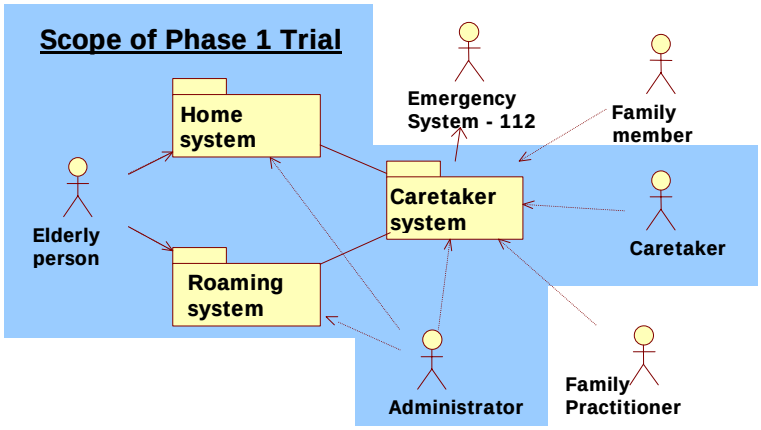

Figure 2 CAALYX Phase I Subsystems and Actors [4]

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The Phase I system trials at Ancona directly involved ten elders using CAALYX over a period of four weeks, and resulted in significant feedback through formal questionnaires, interviews and recorded observations by all the participants (elders, carers, nurses, technical staff and medical practitioners). Important matters such as ethical approval and data protection were strictly addressed resulting in a detailed list of initiatives to inform the participants, their families and the public authorities. This resulted in very strong participation and engagement with the project. A key aspect of the ethical issues was to safeguard the privacy of the older persons throughout the project activities.

In addition, the technology, in particular the fall and mobility sensor was comprehensively tested early at Limerick, using two ethically approved studies "Evaluation Of Fall Detection And Mobility Monitoring Algorithms Using A Wireless Kinematic Sensor" and "Accelerometer-Based Monitoring Of The Elderly While Performing Activities Of Daily Living (ADL) In Their Own Home". The fall evaluation alone involved ten healthy young people performing 480 simulated falls and 300 ADLs. The elderly were monitored while performing typical ADLs. As a consequence of direct observation of users, a wearable garment was developed to hold the sensors and mobile phone.

In parallel, a comprehensive medically led transversal study in Spain is currently being completed by the CAALYX project aimed at understanding normality for the elderly of the monitored vital sign parameters. The study involves 500 persons older than 79 years, as well as 300 persons in the 64-79 age band. The parameters being statistically analysed include: respiratory rate (at rest and during mild exercise), peripheral blood oxygen saturation (at rest and during mild exercise), temperature (at rest and during moderate exercise), postural blood pressure changes and gait parameters.

4. Technology Description

The CAALYX Phase I trial system consists of vital signs sensors (blood pressure and ECG), a fall and mobility sensor, a roaming system, a caretaker system (server and client) and an initial version of the home system. Figure 3 illustrates some of the devices.

In the Phase I trials elderly people used the two vital signs sensors daily at the start of each day. During the day the fall and mobility sensor continuously monitored their activity and potential falls. All data, events and alerts were stored on the caretaker server, monitored by a carer, and observed by the consortium technical and medical partners. In addition, an activPAL^{TM} device was to be worn by each subject for the entire duration to determine the impact of CAALYX on mobility. The activPAL^{TM} device is a very compact non-intrusive device (size is 53 x 35 x 7 mm and weighs only 20g including battery) that can record mobility for seven days when worn on the thigh.

Mobile System (N95) Fall and Mobility Sensor ECG Sensor

Figure 3 CAALYX Phase I Devices

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The Caretaker Site applications (both client and server) are responsible for linking all the stakeholders: elders from their mobile and home system, caretakers, doctors, relatives, the mapping server and emergency services. In the case of an event or an alert the computer based in the caretaker site informs the respective user of the nature of the event / alert. The first version of the caretaker system included all the major services and user interfaces, where the focus has been on observation patterns, health observations, alerts with location and communication. Alerts and events contain the GPS position of the elder to allow positioning on maps, and may contain complex observations such as electrocardiograms. Video conferencing is supported.

The Home System fulfilled several of the core requirements to allow the elder access to their medical records through their television using a simple controller (Nintendo Wii Controller), and is able to switch easily between normal TV and CAALYX for health related information and tele-assistance.

The roaming/mobile system, shown in Figure 4, is responsible for continuous monitoring of the elder and liasing with the caretaker system, as necessary. It controls the body area network and associated sensors, and enables communication with the caretaker system. It is based on a mobile phone platform equipped with GPS, Bluetooth and 3G communication capabilities (Nokia N95). The integration of the vital sign sensors was realised by developing driver components that run on the roaming device. The fall and mobility sensor is a custom made sensor developed based on algorithms outlined in [5] and extended as part of the CAALYX project [6,7]. The mobile phone and the fall and mobility sensor were worn in a custom-made sensor vest in Phase I for anticipated ease of wearing.

As a result of the technology breadth, significant project planning and logistics were required to ensure successful trials. An early pre-trial demonstration was arranged in Ancona, Italy to allow the stakeholders and necessary ethical approval committees to understand the scope of the trials. Five separate trials related tasks were adopted to aid the smooth management. The first involved deploying the multi-lingual system to Italy ensuring all hardware and software was available and compatible. The second task ensured the system was configured and optimised e.g. ensuring that the third generation mobile networks and applications were usable. The third task involved formally training the end-users ideally to ensure no intervention by the technology providers during the actual trials. The fourth task was concerned with the execution of the detailed trial protocols. Finally, the fifth task centred on monitoring and analysing the trial outputs.

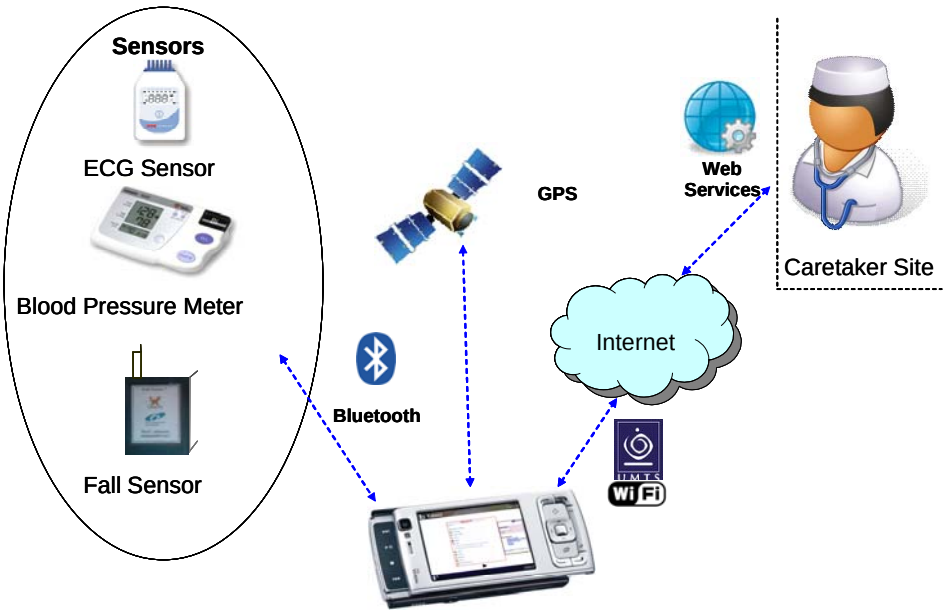

Figure 4 CAALYX Phase I Mobile System [4]

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5. System Verification

The major goals set out for the Phase I trials, outlined in section 2, were fulfilled and the associated technological objectives were achieved. The five sets of devices and ten users over one month were adequate to verify all the underlying technology choices and the customized software developed for CAALYX. In the main, all of the specified complex functionality and associated components worked with some initial but minor issues. The architecture adopted was proven and the system remained robust and available throughout the trials with some minor transient non-corrupting failures. The chosen subset of the vital signs selected was adequate to verify all major components of the system and to enable the users to provide empirical feedback to guide and impact the second phase requirement specification. The continuous fall and mobility monitoring, and the intermittent vital sign sensors are representative of the types of non-invasive sensors necessary for a complete CAALYX system.

The mobile monitoring concept and the defined use cases were technically proven although the end-users clearly preferred a single device with all the sensors integrated. The monitoring while mobile is a key concept for the CAALYX system, which enables the elder to complete their daily activities while seamlessly gathering data from the sensors in their body area network. This data is automatically reported through the care system, as enabled, to their carers, family and medical practitioners. The main requirements were demonstrated including: real time monitoring and alerts, position independence, largely non-intrusive to the user, active logging, and sensor and body area network robustness.

The caretaker system was fully functional and realized its technical specification. The home system was functional and enabled the project to obtain very useful feedback from the elders on their home system requirements.

Overall, the platform remained stable throughout the trials after some initial technical issues. In the first two-week period, minor technical support was required for the care system and the wireless body area network configurations. Throughout the second two-week trial period, the trials required no direct technical support. The users continued to use the CAALYX system for the entire duration of the trials.

6. System Validation

The system was validated by the end-users through the use of questionnaires and interviews. In the trial, three vital signs were recorded and sent to the caretaker site: blood pressure, heart rate and heart electrical activity. Although the time of monitoring and the number of physical sensors were scant for reaching relevant medical conclusions, the system proved to be reliable in recording and transmitting the physical signs information. Analysis of the vital signs recorded were analysed from a remote location at the hospital Comarcal Sant Antoni ABAT, Vilanova i la Geltrú, Spain. Two medical experts analysed the recorded physical signs using the CAALYX Caretaker-Site web application in the “doctor’s role” option. Overall the doctors considered that the system provided useful information regarding the measured physical signs. Nevertheless, further development of results presented at the caretaker-site, increased monitoring time, and a larger number of physical sensors were identified for adequate health monitoring.

The elderly participants in this trial remained interested in being monitored, as they were worried of being alone in case of an emergency. For this reason the elderly were enthusiastic to use and explore the CAALYX system. They expressed strong preferences for a non-intrusive wrist or belt worn system; a wearable garment is not desirable. Device interfaces should be very simple, if necessary. Some elders requested that there be no intervention necessary with the technology. During the round table with the elders, they showed a general satisfaction about their direct experience with the prototype system, and,

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according to their contributions and to their questions, it was clear that they understood the scope of the system and they recognized that there are several circumstances in their lives during which the CAALYX system would represent a usable solution. Elders appreciated the opportunity to monitor their vital signs, and each requested access to the measurements. All of the participants had had a fall in the past, and felt that a fall sensor would improve their confidence while walking.

The opinions of the nurses and the caregivers involved in the trials who assisted the elders were similar: they appreciated the aims and the scope of the system. The nurses agreed that the different sensors should be reduced to one only, and most of them suggested a bracelet as a final solution given that all the elderly wear a watch. There was experiential feedback on the high frequency of falls and subsequent admissions to hospital, and hence there was emphasis on the importance of fall monitoring and fall prevention. They also provided feedback on the sensitivity settings for the fall detection algorithms. They recognized CAALYX as a strong solution for those elderly who have no help from relatives or friends and live alone, although it cannot completely substitute the "human role".

Concerning the Home System, the nurses stated that it is potentially the most innovative component of the system. In particular, they indicated that more functionality should be considered, for example integration with social networking, informing the elderly about the social events of their town or about the social and care services available to them; as the nurses experienced a lack of such information among the elderly. There was feedback on the remote control, which they suggested should be as simple as three coloured buttons with specific functions. The feedback on the activPAL^{TM}s was generally negative as the elders did not wish to wear it on the thigh and removed it within days.

The Caretaker Site worked well: the server was easily accessible for those who had permission. The client application showed all the alerts and the alarms sent by the fall-sensors through the mobile phones; the operators managed each single case easily, according to the agreed procedure listed in the Trials Protocol. Alerts arrived in real time as expected, including various false alerts from the fall sensor. The alerts were shown in the Caretaker Site in "real time", sometimes just a few seconds after the event, and so the operator was able to react and intervene in a very short time. There was lots of good feedback for the caretaker developers as the operators had previous experience with tele-control systems. They suggested reorganization of the data display and requested inclusion of specific data on the person's home environment in particular about getting access. Overall, the operators all agreed that CAALYX represents the future of the Tele-Control, and they appreciated to learn more about the technical aspects of the system. They identified the capability of the system to ask for help by sending an alert to the Caretaker Site without user intervention, the main point of strength of the system as a whole.

A detailed summary of all the Phase I suggestions and comments was documented for Phase II consideration. The system was validated; the prototype of CAALYX System as a whole worked and from the user's perspective it was really effective.

7. Business Benefits

The project has a dedicated work package for dissemination and exploitation. Commercial partners are responsible for the various subsystems, each of which is actively investigating commercial exploitation. In particular, Phase II will result in significant improvements such as the creation of a single wearable light device incorporating heart-rate/heart rhythm, ECG, blood oxygen saturation (SpO2), blood pressure, body temperature, respiration rate and fall and mobility sensing. These physiological parameters among others were prioritised using a recently completed evidence based study [8].

In addition, the care, home and roaming systems are being significantly enhanced, taking account of the Phase I feedback and additional requirements e.g. for system

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diagnostics and to realise stronger synergy. The overall system provides integrated end-to-end functionality at competitive cost. Well-defined interfaces exist for the sensors, to allow easy adoption in other systems, and standards conformance is targeted. The system is built using reusable components and uses relatively low cost robust wireless communications.

8. Conclusions

In summary, apart from some anticipated minor technical issues, the entire CAALYX system performed as expected and Phase I trials enabled project partners to gather useful feedback to improve their understanding and set requirements for the next phase. All users were very positive and motivated, and provided deep insight into how an ideal system should operate. It is clear that the success of such systems is not just about technology.

The trials went better than anticipated, where the elders continued to use and interact with the system for the entire duration even when the technology was sometimes more awkward than it needed to have been. Hence, the adoption of an early end-user based trial in the first year, supported by technology centred studies, was vindicated based on the resultant feedback. An important factor was obtaining and communicating the trial goals and ethical approvals, to all the stakeholders.

It became clear that further work was necessary on the selection of the vital signs to be monitored and on incorporating symptoms. There are technical issues on battery life/recharging and ensuring rural network connectivity. Personalisation for elders, especially as they age requires attention.

The specification for the CAALYX 2nd phase iteration is currently being finalised taking consideration of the detailed feedback from the first phase. The technical challenge is a comprehensive wearable light device that can be adopted by the targeted users to enhance autonomy, safety and security. More comprehensive user trials are currently being planned for later this year.

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