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DELIVERABLE D 8.4
White paper on project results.
First release

Document Type:	Deliverable
Dissemination Level:	PU
Editor:	UMAN
Document state:	Final
Document version:	1
Contributing Partners:	All
Contributing WPs:	All
Estimated P/M (if applicable):	10
Date of Completion:	28/08/2013
Date of Delivery to EC:	05/09/2013
Number of Pages:	16

The project is co-funded by the European Community under the Information and Communication Technologies (ICT) theme of the Seventh Framework Programme (FP7/2007-2013). Grant Agreement n°288940.

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Document History

Version	Date	Comments	Editor(s) and Contributor(s)
V0.0	12/08/2013	Draft version circulated to all partners	UMAN (CT, HHH, LB), EPFL, ASF, UNIBO, RBMF, NTNU, DSHS.
V0.1	28/08/2013	Final version submitted to the coordinator	UMAN (CT, HHH, LB), EPFL, ASF, UNIBO, RBMF, NTNU, DSHS.
V1	05/09/2013	Final version submitted to the EC	UNIBO

Executive Summary

This document presents the results of the deliverable D8.4 "White paper on project results: first release" for work package eight of the FARSEEING project. Work package eight aims to:

- Make the results of the project known to the scientific, health and social care, commercial, policy, and general public communities, and create interlinking communities of interest.
- Disseminate project idea and results within target groups (e.g. health professionals)
- Create a sustainable platform for the dissemination of best practice information to target groups

The white paper will be made available on the project website and distributed to professional communities and target groups. It is one of the deliverables which fulfils task 8.3 (M1-M36), 'raising public participation and awareness'. The white paper presents a series of issues which the FARSEEING project aims to tackle and then provides the recommended solutions for these issues if available or the work that has been done so far by the project to respond to each issue. The key issues are:

- Having the correct infrastructure to collect data on real-life falls and therefore establishing what real-life falls look like.
- Establishing the longitudinal risk factors for falls.
- Establishing effective telemedicine models to enable effective intervention.
- Establishing how we encourage older adults to take-up and maintain use of technologies.
- Establishing how we can we use technologies to challenge older adults and prevent falls.

The FARSEEING project is currently able to provide recommendations relating to data collection and data storage on real-life falls, as well as providing information on the infrastructure and design of interventions using technologies to predict, monitor and prevent falls and promote healthy active ageing.

Introduction

Falls are an important public health issue. Each year, 35% of over-65s experience one or more falls. About 45% of people aged over 80 who live in the community fall each year. Between 10 and 25% of such fallers will sustain a serious injury (DH, 2009). This has implications in terms of independence, quality of life and also cost to the health service (DH, 2009). Hip fracture is the most common serious injury related to falls in older people and death rates are continuing to rise (Centers for Disease Control and Prevention, 2010). Each year approximately 10% of the elderly population (65+) will be treated by a doctor for an injury and approximately 100,000 older people in the EU27 and EEA countries will die from injury from a fall (Eurosafe, 2013) .

FARSEEING is a collaborative European Commission funded research project with 10 partners distributed in 5 EU countries. It aims to provide a thematic network focusing on the issue of promoting healthy, independent living for older adults. FARSEEING aims to promote better prediction, identification and prevention of falls with a focus on ICT devices and the unique proactive opportunities they can provide to older adults to support them in their own environment. FARSEEING technologies include the use of a smartphone, smarthome and exergames and virtual reality. This white paper provides an update on the findings from the project so far and where possible gives recommendations useful for researchers, engineers, health and social care and the third sector (e.g. charities).

Reccommendations

THE ISSUE: ICT development
Even though extensive research has been conducted in the area of fall prevention, some of the fundamental factors leading to falls and what actually happens during a fall remain unclear. A number of candidate technologies, products and services are available on the market, or are in a prototypical stage, for managing falls and supporting health monitoring, including: • Wearable systems: Wearable sensor systems for health monitoring are an emerging trend and are expected to enable proactive personal health management and better treatment of various medical conditions. Designing such a system is a challenging task, since a lot of highly constraining and often conflicting requirements have to be considered by the designers. • Smartphones: Today's smartphone not only serves as the key computing and communication mobile device of choice, but it also comes with a rich set of embedded sensors. Although the potential for using mobile phones as a platform for sensing research has been discussed for a number of years, there has been little or no advancement in the field until recently. • Domotics: Home automation systems have been a constantly growing field since the 1990s. Every aspect of the home environment can be monitored and controlled both indoor and remotely through remote controls, touch screen panels, personal computers, tablets, or even smartphones. Even if a myriad of ICT based products or services are in place, trying to satisfy the need of an early intervention in case of a fall, existing solutions still do not have a remarkable social impact or a significant market penetration. Two facts hinder the effectiveness of the existing systems, capping the market demand: bad ergonomics (and hence poor acceptability from older users) and lack of

reliability, due to a poor knowledge of real falls. The FARSEEING project is developing an architecture that makes it possible to collect, store and process data related to mobility and falls in order to overcome the paucity of real fall data.

Recommendations and findings so far:

The complete FARSEEING technological infrastructure includes smartphones, a smart home system, a dedicated wearable unit for high-risk subjects, and a telemedical service model. Smartphone-based solutions are mostly designed for the population scenario while *ad hoc* wearable sensing units are designed for high risk subjects. The smart home system is capable of indoor tracking of the user. It is equipped with environmental sensors and a distributed audio/video system. Both the dedicated wearable sensing unit and the smart home system can monitor the user during the night, while solutions based only on smartphones would not be suitable for nighttime. The following technology has been developed:

A smartphone application: this continuously acquires inertial sensor data for monitoring at home. It is able to record the signals from the embedded accelerometer, gyroscope and magnetometer. The application supports real-time fall/event-detection algorithms that not only can link to telemedical services (the use of telecommunication and information technologies in order to provide clinical health care at a distance) but can also automatically trigger specific devices in the home environment like wall-mounted touchscreens, cameras, or lights. The first version of the FARSEEING fall detection algorithm has been developed and provided preliminary results. Both usability and wearing comfort have been judged positively by the volunteers of a pilot study: the smartphone and the belt used for wearing it have been considered easy to manage and their form factor and weight have been considered satisfactory. Additional features are under development for exercise guidance and for supporting the intervention and motivational strategy for fall prevention. The smartphone can also provide instrumented versions of standardized functional tests of mobility to be used as tools for fall risk assessment (e.g. Timed up and Go Test).

Wearable sensing unit: A unit for long-term monitoring has been released. The system is made of three main components: (i) a small wearable sensing unit with a battery lifetime of 72h designed to be worn directly against the skin; (ii) a docking station, used for connecting the wearable unit to a PC for downloading data and for charging the battery; (iii) the management software. The compliance of the sensing unit with the Communitarian Directive 2004/108/CE based on the standard CEI EN 61326-1:2007-03 has been assessed by an independent laboratory. The wearable unit passed technical and clinical validation. It is expected a second release of the wearable sensing unit whose features will be decided on the basis of user feedback and of a Consensus process.

Smart-home: This consists of a number of sensors and actuators distributed in the home environment. A local unit integrated with the home automation system acts as data collector, gateway, and processing unit. A radio frequency identification (RFID) system is also integrated in the smarthome architecture which is used to identify and track the location of specific users (or objects). Every home automation system is equipped with a Scenario Programmer, a device used to define and manage up to 300 scenarios. The execution of a scenario can be triggered by the user but also by external events like the opening of a door, a detected movement, a temperature change, or a detected fall. It is possible to define and compose a set of conditional rules defining "what", "when", and "if" perform specific actions. Scenarios have been developed for supporting the intervention incorporating a motivational strategy for fall prevention.

The FARSEEING architecture is designed in a way that is maximally transparent to end users, through the flexible and innovative integration of different ICT solutions. System components are used as both monitoring and stimulation tools for providing motivation to restore/enhance healthy functioning of the older persons involved. The tight integration of sensing, smartphone and home technologies will provide the ground for novel intervention programs for fall prevention, aiming to stimulate different aspects of the subject's behaviour.

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THE ISSUE: Establishing what real-world falls look like

Existing knowledge and assumptions about falls in older people are mostly based on patient or proxy reports. Less than 20% of all falls are observed by others and patient reports are often biased by recall problems (Hauer et al, 2006). Therefore, the understanding of falling in older people is still modest.

To bridge this knowledge gap objective data is needed. With the rapid development of body-worn sensor technology during the last decade, small wearable devices are available to measure physical activity and kinematic parameters of human body movement. However, it is still very cumbersome to record real-world fall data. This is due to limited measurement periods of about one week because of restrictions of battery lifetime and data storage.

Consequently, reasonable numbers of measured real-world fall events are not available. The FARSEEING consortium strongly argues that a sufficient dataset of real-world falls can only be achieved by a pre-planned collaboration of many research groups willing to share their data. Therefore, the major aim of FARSEEING is to build up a large real-world fall meta-database to facilitate the structured collection, analysis and processing of data related to falls, physical activity, clinical parameters and physiological factors.

Recommendations and findings so far:

The literature underlines the shortage of real-world fall data and shows very heterogeneous approaches. Obviously, standardization is needed, which is also essential to build up the FARSEEING meta-database of real-world falls.

Consensus processes have led to the development of a standard fall data format and includes recommendations for a fall definition, fall reporting, a minimum clinical dataset, a sensor configuration and variables to describe the signal characteristics.
Based on these recommendations, a prototype of the FARSEEING meta-database was set up, including a web-frontend for user interaction. Several international recruiting centers have started the recording of participants from high-risk populations and from population-based community-dwelling cohorts. Up to mid 2013, 111 falls were measured in different settings (community dwelling, rehabilitation clinic, nursing home), in different disease groups (healthy, Parkinson's disease, stroke, hip fracture, multiple sclerosis), in Germany, Italy, Norway, and New Zealand. The recorded signals include data from accelerometers, gyroscopes and magnetometers from different types of devices (McRoberts Dynaport, activPAL, uSense) including smartphones (Samsung Galaxy SII).

Bagalá et al (2012) showed that the performance of published fall detection algorithms was insufficient when applied to real-world fall data. Using the recorded real-world falls, a new fall detection algorithm has been developed based on pattern recognition techniques to improve the detection quality. The algorithm will be ported to an Android App. As a result of the consensus process, a five-phase fall model was developed, which may help to better classify and analyze fall events and to improve the development of new fall detection algorithms. Algorithms for long term activity monitoring, 'gait and turn' analyses, and functional testing (iTUG) were developed for smartphone and sensing unit data.

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THE ISSUE: Establishing a predictive model of mobility and risk of falls

There is a lack of longitudinal information on the physiological, clinical, functional, behavioural and environmental correlates of mobility issues which can lead to falls in older people during their daily life. The information collected and analysed are generally motion analysis in a laboratory setting and does not include multi-day recording in an ecological setting.

We aim to use data from the longitudinal InCHIANTI study to broaden our knowledge and to develop a predictive model of mobility and risk of falls in older people. InCHIANTI is a representative population-based study of older persons living in the Chianti geographic area (Tuscany, Italy).

Recommendations and findings so far:

This part of the project started with a retrospective analysis of data aimed at identifying the main risk factors associated to falls and mobility disability in the InCHIANTI population. We found that similarly to the literature, the most common factors associated with falls in elderly are age, female gender (Moyer, 2012), impaired gait and/or balance and muscle weakness (Ganz et al, 2007), ability to perform activity of daily living and physical inactivity (Stuck et al, 1999), history of falls (Tinetti & Williams, 1998; Sekaran et al, 2013), depressive status (Korpelainen et al, 2006), cognitive disorders (Graafmans et al, 1996), drugs (Ensrud et al, 2003), vitamin D deficiency (Bischoff-Ferrari et al, 2006) and sleep disorders (Lehtola et al, 2006).

A pilot study carried out to assess mobility ability and the feasibility of smartphone technology recorded mobility during laboratory tests and daily life activity. Different signals recorded by the 3 sensors incorporated in the smartphone were analysed to identify a profile of the participants daily living mobility and technology satisfaction levels were tested with a validated questionnaire (The Telehealthcare Satisfaction Questionnaire-Wearable Technology The Telehealthcare Satisfaction Questionnaire-Wearable Technology, TSQ-WT. Chiari et al, 2009). Participants in the pilot study were positive about wearing the smartphone technology giving high expectations for the next population based scenario study. This work not only helps to provide a 'longitudinal' profile of fallers it is also provides real-life fall data which helps us to understand what real falls look like.

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THE ISSUE: Developing telemedical service models

With the rapid increase in age groups over 60 and over 80 years in society, greater emphasis will be put on technology that aims to prevent functional decline and falls and promote safe living. Telemedicine is the use of telecommunication and information technologies in order to provide clinical health care at a distance. Telemedicine services are designed to eliminate distance barriers and can improve access to medical services that would often not be consistently available in distant rural communities. It can also improve access to services for older home dwelling people from their own home. A service model is a description of how such a service can be delivered to the receiver (Hersh et al, 2006). During the last 15 years, several telemedicine service models have been developed in the areas of handling adverse conditions and assessing health status. However, most of the models have never found their place in routine health care delivery. Reasons for this might be that the services have not been designed from the users' needs and perspective, important stakeholders have not been in focus when developing the service models, and the reliability of the content of the service has not been highlighted.

We are currently developing three service models that will support management of the different aspects of falls, from detection to prediction and prevention. Within the scope of the project, we aimed to develop telemedicine service models for 1) fall detection and management, 2) fall risk assessment, and 3) exercise guidance as part of fall prevention interventions.

Recommendations and findings so far:

Based on the literature on existing telemedicine service models and services a platform was chosen (the framework on which applications run). It is recommended that this platform be user-centered and focused on sharing with other platforms. Based on the literature the platforms agreed for FARSEEING were open platforms (accessible to all) such as Google Android for smart phones, OpenWebnet for home automation and universALL platform for telemedicine service models.

The exercise guidance model focuses on use of exergames. Body worn sensors and smart house technology are used to give feedback on the older user's behaviour in order to increase uptake. The exercise guidance model implements results from fall prevention interventions. In order to develop an exercise guidance service model, three off-the-shelf interactive full body movement exergames for older persons have undergone usability testing in older persons. The games have been chosen because of their focus on stepping, which is seen important for fall prevention. Older people were invited to explore three different video stepping games, all involving full body movement. The step training not only provides an enjoyable exercise alternative for preventing falls in older people, it also improves physical and cognitive parameters of fall risk in older people without major cognitive and physical impairments (Schoene et al, 2013).
Usability tests have provided hands-on usability assessments indicating that older people liked the idea of employing stepping games for exercise counseling in order to increase balance and reduce the risk of falling.

Figure 1: Participants playing The Mole *(left)*, Your shape-Light race *(Centre)* and Dance Dance Revolution: Modified version *(Right)*.

Human movement science experts have analyzed the game play of older people and outlined six success criteria for the use of video games in balance training of older people. These criteria are fun, safety, shifting of body weight, independent use, full-body movement and challenging game-play. In terms of the criteria established, experts found that *The Mole* designed by SilverFit systems (Rademaker et al, 2009) was the most suitable game, although not optimal, due to the limited progression in game difficulty.

The next step in developing telemedicine service models in the field of fall management and prevention is to perform usability testing, using an iterative design and establish proof of concept service models. The fall management service model will be tested in real life in Trondheim (Norway) between months 24 and 30 of the project.

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THE ISSUE: Uptake and adherence to technology use.

Over recent years a number of Information and Communication Technologies (ICTs) have emerged aimed at falls prevention, falls detection and alarms for use in case of a fall (Brownsell et al, 2004). To date these technologies tend to be reactive, helping to reduce a long lie and allowing help to be brought quickly to the person who has fallen. There are also a range of ICT interventions that have been created or adapted to be pro-active in preventing falls, such as those which provide strength and balance exercise training to older adults in the prevention of falls, e.g. exergames, Wii-fit, Kinect (Miller et al, 2012; Williams et al, 2010). There is increasing evidence that specific strength and balance exercises can significantly reduce falls (Gillespie et al, 2009). Therefore, ICT innovations that can deliver these in the home have the potential to reduce cost to the health service and individual in addition to increasing the amount of exercise older adults carry out.

However, the main issue with the use of ICT devices is related to the take-up and use of systems, especially adherence to the use of the systems. If we know more about older adults' attitudes towards falls interventions that use technologies, then we will be better able to create technologies and interventions which they will use and continue to use regularly.

Recommendations and findings so far:

As a result of work carried out as part of FARSEEING we recommend undertaking the following to engage with older adults:

Ensure that the technology adapts to older adults' needs and relates to the outcomes that they want to achieve. The specific falls technology literature and wider falls and exercise literature suggest that we promote the positive outcomes of an intervention to improve uptake and adherence. It is suggested that technologies focus on promotion of independence, increased safety, increased social opportunities and improvements in function and confidence. It may also be possible to enhance the older person's image of themselves to grandchildren, for example, by reference to technology use. Regular real time feedback related to the individuals' needs and goals has been successful in achieving motivation to continue.

Ensure that usability issues are considered. Specific advice about large buttons, clear screens and both auditory and visual messages are important to meet the needs of all older adults.

Technology must not be obtrusive or define an older adult as a 'faller'. Aesthetic design issues may be as important as the function in ensuring uptake and adherence to technology.

Camera/visual surveillance technologies should only be used in response to an alarm trigger. It needs to be emphasised to participants that this is the only situation in which the cameras will be activated. The option of using blurred our outline images are proposed. There should be very clear indicators when the cameras are activated, so that participants feel reassured that their privacy is not being compromised.

Ensure that older adults feel in control of the technology. For falls alarms, ensure that they have the ability to cancel false alarms, so that they feel that they maintain control. This will also reduce the nuisance for others. However, follow up should be provided to ensure that the person does not require further falls assessment.

The opportunity for a social element and group cohesion is important. Consider creating 'virtual social networks' if trying engaging older adults in pro-active technology e.g. a forum where older people can share their improvements/experiences of working towards their goals.

Cost implications for individual users must be carefully considered. The eventual cost of technologies and whether they can be sustained long term by an individual will be important to long term use.

For further information please see our systematic review. Currently under peer review, a link on the website will be available shortly.

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THE ISSUE: Developing complex interventions to promote independence
The literature highlights that it is now possible to analyze patterns of gait and physical activity over long durations and detect clinically relevant changes or declines. Physiological complexity was found to be important to this. From a physiological perspective, complexity is synonym with a person's adaptability to a changing environmental input. This functional adaptability has been shown to decrease with aging (Lipsitz and Goldberger, 1992). With regard to physical activity; under normal healthy conditions, fluctuations of activity states display a complex structure (high entropy), similar to other physiological signals. Disability and frailty may disrupt these complex fluctuations of activity states. A successful intervention restores these complex activity fluctuations.These conclusions have led to a fresh perspective on interventions for the older population. Complex interventions influence different aspects including physical, physiological, psychosocial and cognitive (effecting physiological complexity). A review of complex interventions suggests the benefits of using virtual reality (VR) and serious games. These interventions have been implemented in the laboratory with camera-based motion capture systems and dedicated visual feedback projections, or at home using commercially available gaming systems such as the Wii or the Kinect. The older person is represented in a virtual environment and can perform a series of exercises in a fun and safe manner. Feedback is given regularly through friendly and constructive messages that keep the elderly person motivated. This is a feasible method of delivering personalized and tailored at-home interventions. Standard exercise interventions (including strength and balance programmes) such as Otago, T'ai chi and FaME) are shown to reduce fall risk and rates, in addition to increasing strength and balance in the older population. However, the user perspective on these interventions still had a major effect on their success and adherence rates are poor (Nyman & Victor, 2012). Innovations which can deliver these in the home are likley to increase adherence and also outcomes for the older adults. A key aspect in successful rehabilitation and fall prevention is the monitoring of activities of daily life (ADL). A limited number of smart home systems have been implemented, using a multitude of sensors, in an attempt to analyze various parameters in ADL. These sensors monitored position inside the house, usage of appliances, temperature, humidity, lighting, gait, physical activity and falls. Feedback was also sent to the older person at home in an attempt to motivate and encourage, while striving to keep the systems unobtrusive and simple to use. Moreover, wearable sensors have also been used in the home setting for ADL monitoring and fall detection. This has further impacted the area of home monitoring, since smartphones now have sensing and fast data transmission capabilities. All of the above interventions have the potential to promote independent living by making the home environment responsive in cases of emergency, as well as making the user more mentally and physically healthy. Within the FARSEEING project, we aim to design and evaluate a self-adaptive home based intervention to restore and enhance the physiological complexity in older adults. This is achieved through the combination of technology embedded in the persons own home environment as well as wearable sensors and devices.
Recommendations and findings so far:
Each smarthome has been fitted with sensors and interfaces in the users own home environment. Users will be able to interact with the smarthome system either through a 10-inch touch screen

interface, a 3.5-inch interface, or through the various buttons and switches normally found within the home. The user interface for the smarthome system has been designed to be suitable for older adult interaction through its tailored colour scheme, button design and layout, as well as through the timing and nature of the promoting strategy and message content. Tailored, person centred feedback will be given, based on information from all elements of the system, to motivate older adults to maintain an active lifestyle.

The 10-inch touch screen interface has been designed with 3 main scenarios in mind. These scenarios include exercise, evaluation and fall-detection. The user is encouraged to exercise through a number of various routines:

Outdoor walking: Recommendations will be given that they should participate in outdoor walking when weather conditions are suitable.

Home exercise: Home exercises will be offered via the smarthome technology. Older adults will be guided through exercise videos specifically designed for older adults, which will make recommendations for incorporating more exercise into a person's daily routine and movements.

Virtual reality exercise game: This will be used to promote and develop the step-recovery response of a user if they become inadvertently unbalanced.

Self-test: The users' improvements will be evaluated through the use of an assessment of gait speed as well as other measurements of physical ability and scripted tests.

Falls detection: The fall-detection scenario is a combination of a fall-detection algorithm running on the smartphone worn by the person, which communicates with the smarthome system. Through a combination of fall-detection via the smartphone application, as well as minimum user interaction via the smarthome touch screen interface, a user-friendly method of fall-alarm control and interaction is achieved. This will allow the user to automatically raise an alarm or, if no interaction is performed following a fall-alarm, help is immediately requested. User-feedback on the performance of the fall-algorithm can later be used to improve the fall-detection algorithm via false-positive reduction.

Along with the user interaction via the smarthome interface directly and the smartphone, users physiological complexity is evaluated though their interaction with distributed switches and sensors deployed about the house, which the user will interact with through the course of their normal daily routine. In parallel with the developed smarthome intervention, a virtual reality exergame, which monitors the stepping movements of a user is also under development with usability testing taking place during 2014. A subset of this platform is the foot-worn sensor, which consists of inertial sensors mounted on each foot, as well as pressure sensors used to measure the distribution of a user's weight during various normal ADL. The aim of these smartshoes is to perform unobtrusive activity classification through feet worn sensors in a ubiquitous manner.

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Conclusions and Remaining Work

The FARSEEING project is currently able to provide a wide range of recommendations relating to data collection and data storage on real-life falls, as well as providing information on the infrastructure and design of interventions using technologies to predict, monitor and prevent falls and promote healthy active ageing. The second part of the project will enable us to build on this work ensuring the usability and effectiveness of the interventions and technologies proposed. It is hoped that the subsequent white paper at the end of the project will provide guidance on best practice for the most appropriate and effective approaches to monitor, understand and prevent falls, as well as providing the wider falls prevention community access to real life falls data.

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