PERSONALIZED ELDERLY CARE SCHEME: PROVIDING PERSONALIZED SERVICES BASED ON CONTEXT AND BEHAVIOR ANALYSIS

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ABSTRACT

Elders who live alone generally have rich care networks—support networks of people who provide the elder with care. Such networks provide assistance ranging from day-to-day activities to social support and often include people of varying ages and skills, which have significantly different roles in the elder's care and may or may not be professional caregivers (family members, friends, neighbors, medical staff, etc.).

Clearly, the support network's major objective is to keep the elder physically healthy. However, it must also consider the person's mental and emotional states and overall well-being. In many circumstances, the network is dealing with a person who is slowly losing his or her independence [1]. Care requirements for elders change over time. Some are predictable, such as the well-understood progressions of diseases and conditions. Others are unpredictable, brought on by sudden changes such as a fall or variations in emotional status [1].

Perhaps the greatest challenge for providing effective elderly care is for the Care Network to immediately identify such events that occur in the user context and adapt to the individual features and user behavior patterns.

This work focuses on using technology to aid the elder himself as well as his entire support network. It addresses the creation of a Personalized Care Scheme that meets the individual and altering needs and preferences of the elder to provide targeted, efficient and effective care services.

The scheme is based on a pervasive platform that persistently records information from the user's context in a mobile environment and analyzes the activities of the elderly with the objective of detecting emergency situations, trends and deviations from what might be considered normal behavior. The identification of sublet changes in the social and physical activity can signal to the caregivers' trends indicative of psychological deterioration or progression of a health condition.

Special attention is paid to personal preferences and needs of the users kept in personalized profiles updated dynamically based on information learned by observing the user's interaction with the system. Personalization algorithms ensure that information stored in profiles is reflected in the content provided to the services. The profiles are managed directly, without the need of a centralized server, through a personal mobile device which users carry.

The technology-supported Personalized Care Scheme is highly user-centered and context-aware. Smart devices with pervasive sensors and personalized databases together with care takers improve the quality of life of the elderly by facilitating social interactions, reducing limitations imposed by physical and mental conditions, location and time, and increasing personal control.

APPROVAL PAGE

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LIST OF ACRONYMS & ABBREVIATIONS

AAL	Ambient Assisted Living
ADL	Activities of Daily Living
BVP	Blood Volume Pressure
CHF	Chronic Heart Failure
GPS	Geostatic Positioning
ICT	Information and Communication Technology
OLAP	Online Analytical Processing
RSS	Really Simple Syndication
SVM	Support Vector Machine
UML	Unified Modeling Language

Chapter 1

Introduction

1.1. Problem Statement and Motivation

The burden of future care for older European citizens is described as a major time aggravated thread to the European societies. A clear shift has been witnessed from 1960 up to now regarding the proportion of older people (65 years and over) [2]. As the following figure shows, in 2020 the proportion of older people in Europe (EU15) will be almost doubled compared to 1960.

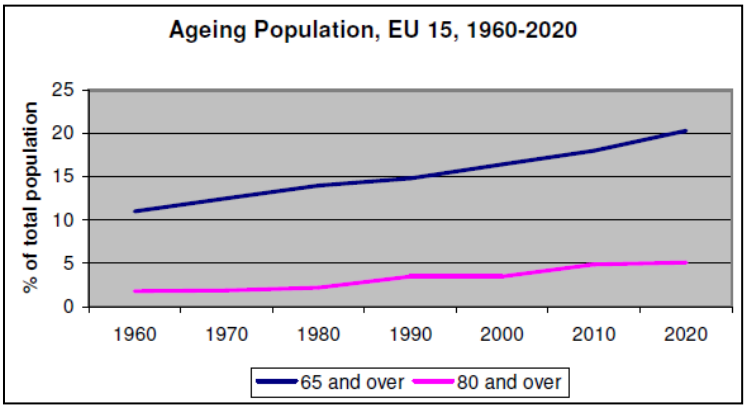

Figure 1: Ageing population, EU 15, 1960-2020 [3]

This steady increase of older age groups in national populations, both in absolute and relative numbers, will have enormous economic and social implications. However, this demographic change and ageing in Europe, implies not only challenges but also opportunities for the citizens, the social and healthcare systems as well as industry and the European market.

State-of-the-art technologies can play an important role in addressing the challenge to support the elderly to live autonomously, improve their quality of life and remain active and included in the society for longer.

Currently, in the European, and international, research field different efforts have been undertaken regarding the development of ICT (Information and Communication Technology) solutions supporting the elderly. The objective of such projects is double: to enhance the quality of life of older people and at the same time, strengthen the European industrial base through the use of ICT.

1.2. Scope of This Work

The presented research, which is a collaboration among academia and elderly care providers, builds an innovative Personalized Elderly Care Scheme for senior citizens, at very early stages of capability degradation. The target group is the big group of healthy elderly or with light physical or psychological health problems which are self-supporting, able to move around, and can still contribute actively[1].

The main aim is the development of a novel, technologically supported, care community (Virtual Care Network) enabling effective management and collaboration of the various members involved in elderly care. The elder himself is placed in the center of the care community, becoming at the same time a receiver and producer of assistance.

The community is supported by an ICT (Information Communication Technology) based platform which integrates various state-of-the-art technologies and mobile wireless devices to improve the quality of life of each of the related stakeholders.

Through seamlessly integrated Pervasive Sensors the platform monitors the user behavior and interaction with the system and uses this information to structure personalized, dynamic user

[1] As per WHO those are the "young old" who are over 63 and under 75 years old.

profiles which take into account the user's preferences, context and special needs or disabilities that may affect the use of the system.

This repository of user information is made available to Personalization algorithms that transform the system into a custom-made, unique user experience, including contents and interfaces adapted to the disabilities and abilities, special needs and preferences of each user.

Additionally, the data in the user profiles provides a rich input for Behavioral Analysis techniques that monitor sequences of patterns in user behavior (social and physical) to allow for a proactive and early detection of age related changes.

The platform offers innovative personalized ICT services to the elderly addressing well documented age related needs such as socialization, mobility, information and cognitive support. Furthermore, it provides reliable, accurate and timely care related information to the associated caregivers. In an attempt to stimulate and prolong the independent and active living of elders in outdoor environments an additional feature was added to the platform. The Fall Detection module that detects possible emergency situations and immediately alerts caregivers.

1.3. Scientific Contributions

This work develops of a virtual, service-oriented Care Network model that places the elderly person in the center of the system, making him both a consumer and producer of assistance. A main achievement is the integration of the Virtual Care Network with pervasive sensors in a cost-effective and portable platform that emphasizes the value of mobility and does not impose any restrictions on the end-user (i.e. remain in the home environment, carry special equipment, etc.).

The results provide new insight in the area of personalized support and on how ICT services supported by pervasive monitoring and behavioral analysis can support day-to-day activities and improve quality of life for each one of the related stakeholders, including not only the elderly but also their families, friends, caregivers, etc.

In particular, in the research carried out scientific contributions emerge in two different categories, including contributions related to the social aspect of elderly care provision as well as technology oriented contributions related to ICT solutions in the care sector.

1.3.1. Contributions in the Technological Domain

- Design of the ICT services that goes beyond simple computer interaction and 'technology push' focusing on the identification of elderly particular wishes and needs in terms of what factors, relationships, communication issues and roles are meaningful and generate the greatest impact on their ability to self-actualize and live independently.
- The system transforms the ordinary elderly care group, consisting of family, friends and care givers, into a virtual, dynamic and collaborative Care Network of members who can interact with each other to assist and provide effective care to the elderly without being together physically.
- Give new insight in the area of personalized support by the development of personalized, dynamic user profiles taking into account the user's preferences and context and special needs or disabilities that may affect the interaction with the system. User preferences are defined as long-term and temporal and context is defined by location, weather data and time of the day.
- Development of personalization algorithms that rely on the information stored in the personalized profiles to transform the system into a personalized user experience, including contents and interfaces adapted to the disabilities and abilities, special needs and preferences of each user.
- Use of state-of-the-art mobile wireless technologies, and pervasive sensors to monitor activities in user behavior, with minimal intrusion and without restricting the user's mobility, and apply analysis for a proactive and early detection of age related changes.

- Provide realistic results displaying the potential of the Personalized Care Scheme based on an extended and complete pilot trial conducted in collaboration with elders and their caregivers[2].

1.3.2. Contributions in the Social Aspect Domain

- Give an answer to the research challenge of how ICT technologies can support in an efficient and effective manner the socialization and daily activity monitoring needs of the elderly at any time in any environment.
- The Virtual Care Network improves the quality of life for each one of the related stakeholders:
    - Enable a rich stimulating social environment around the elderly people that supports them to live independently and actively for longer. This impacts positively their well-being and quality of life.
    - Improving the workload of the elderly families and care takers by prolonging the time the elderly can live autonomously, supported by their Care Network, thereby reducing the demand for care and the associated care cost.

1.4. Publications

Below is a list of publications stemming from the work in this thesis. A complete list of publications and submissions, by other authors, related to ideas of this work can be found in [4].

1. E. Christodoulou, G. Samaras, E. Polydorou, C. Tsiourti, M. Belk **Building Virtual Care Communities Supporting Elderly Socialization and Independent Living by integrating**

[2] Special credit must be given to the staff of "Polidinamo Center" and the Social Services Department of the municipality of Agios Dometios for their indispensable support and effort during the preparation and execution of the trials.

mobile wireless ICT-based services , Conference Proceedings of Med-e-Tel 2010, Luxenburg 14-16 April 2010 (accepted for publication and presentation)

2. E. Christodoulou, J. Dias, E. Polydorou, C. Tsiourti, G. Samaras **Virtual Mobile Elderly Living Communities Supporting Socialization and Independent living in an outdoor environment** , Conference Proceedings of AAliance European Conference on Ambient Assisted Living, Malaga, 11-12 March 2010 (accepted for publication)

1.5. Structure of This Document

The structure of the thesis is as follows:

Chapter 1 is a general **Introduction** to the topic including the Problem Statement and Motivation, Objective and Scientific Contributions of this work.

Chapter 2 presents the **State-of-the-art** focusing on European projects addressing the subject of ICT in Ageing and highlighting a comparison with this work.

Chapter 3 introduces the concepts of **Personalization, User Behavioral Analysis** and **Pervasive Computing in the Care Sector**, which are the main research areas lying at the foundation of the developed platform.

Chapter 4 introduces the reader to the **Context of Elderly Users** including an analysis of the challenges and issues in designing IT systems for the elders as well as their needs regarding independent living.

Chapter 5 presents a thorough description of the proposed **Virtual Care Community** to be built around the elderly users. Details include participating members and their roles, organizational structure and benefits of this concept.

Chapter 6 gives the overall description of the **Personalized Care Scheme** in which ICT-based services are developed on smart devices, with pervasive sensors and personalized databases, to provide personalized assistance to the elderly in maintaining their independence and high quality of life.

Chapter 7 includes a thorough analysis of the end-user requirements and the design of **Use-Case Scenarios** driving the implementation of the ICT services provided by the Care Scheme.

Chapter 8 discusses the **Architectural Design and Development** of the platform presenting the details of all components of the final system. In particular, the various sub-sections present technical information about the database design, the structure of the personalized user profile, the personalization algorithms and the behavior analysis and fall detection processes.

Chapter 9 describes the **Evaluation** process followed to validate if the purpose of the project is successfully achieved. A specific test protocol is applied and a pilot trial is carried out using a prototype system. A questionnaire assessment follows.

Chapter 10 is an **Epilogue** summarizing the results and conclusions resulting from this work. It includes a discussion on how these can be applied in the related areas and presents future trends in the domain if ICT and Ageing.

Appendix A gives documents related to the pilot trials including among others the Evaluation Questionnaires.

Appendix B includes a selection of the most important Source Code files developed for the implementation of the system.

Chapter 2

Overview and Comparison of State-of-the-Art

2.1 The Ambient Assisted Living (AAL) Joint Program

ICT can help older individuals to improve their quality of life, stay healthier, live independently for longer and remain active at work or in their community. Different efforts have been undertaken in the last years at an international level regarding the development of technological solutions, platforms and tools for the delivery of care to the elderly. Innovative solutions are emerging to help counteract problems related to memory, vision, hearing, and mobility, which are more prevalent with age.

The Ambient Assisted Living (AAL) Joint Program is implemented by funding authorities of several European countries with the objective to enhance the quality of life of older people and strengthen the industrial base in Europe through the use of ICT.

The core of the AAL Joint Program is the funding of R&D projects to provide innovative ICT-based solutions to older persons, which means innovative products, systems or services addressing identified wishes and needs of the end-users. This section presents some of the recently finished or ongoing European projects funded by AAL and highlights their similarities, differences and drawbacks in comparison with this work. In particular, four classes of AAL projects are presented and prototypical system examples are given for each:

2.2 Technological Solutions for Home Automation

This class includes solutions for persons in advanced disabilities state, unable to lead an independent or active life outdoors. These solutions are mostly focused on sensor and network infrastructures and are mainly interested in providing technologies for “independent living”

within the home premises of the elderly person. Examples for research projects in this area are the presented in Table 1. In comparison to these solutions, this work addresses the requirements of a wider target group of healthy elderly, who are still able to move around, and provides services that are mobile and thus applicable apart from the highly controlled and constrained home setting also in outdoor environments where the users move and interact.

Project Name (Duration / Start Date)	Short Description
H@H: Health at Home (24 months /1.02.2009) **Website:** www.health-at-home.eu	Design, realize and demonstrate a complete and integrated model of **home care** of the **chronic patient**. Aim at solving problems related to the provision of healthcare services for elderly citizens affected by **Chronic Heart Failure** (CHF), providing them with wearable sensor devices for monitoring of pathophysiological cardiovascular and respiratory parameters and, at the same time, enabling the medical staff to monitor their situations at distance and take action in case of necessity by the involvement of the public and private health organizations.
HMFM : HearMeFeelMe (24 months / 1.07.2009) **Website:** www.hearmefeelme.org	The project is designed for older people with visual impairments providing an easy, simple and intuitive way to access information and digital services in their **home environment**. The services allow users to locate and identify medicine packaging, listen to medication information and dosage instructions through audio, and receive instructions and reminders through electronic medication plan.
HOPE: Smart Home for Elderly People (24 months / 7.07.2009) **Website:** http://www.hope-project.eu/	An integrated, smart platform that uses the Zigbee technology in order to enable the elderly people with **Alzheime**r's disease to use innovative technology for a more independent life, easy access to information and for monitoring their health. Major purposes are to extend the time people can **live at home** by increasing their autonomy, self-confidence and mobility and security, to prevent social isolation and to support maintaining the multifunctional network around the individual, to support carers, families and care organizations etc.

Table 1: Technological Solutions for Home Automation

2.3 Technological Solutions for Prevention and Management of Chronic Conditions

A great number of solutions are focused on elderly patients in early stages of chronic conditions such as dementia or Alzheimer's decease. In this category of systems the specific condition is studied and a technological support solution is provided. Thus, these are rather isolated technological solutions applicable to users with specific characteristics and their caregivers.

On the contrary; this work does not impose strict restrictions on the characteristics of the end-user target group. It is a solution targeting the general elderly audience and it can be customized to the special needs of the users who might be healthy or with light physical or psychological health problems. Examples for research projects in the area of Prevention and Management of Chronic Conditions are the following:

Project Name (Duration / Start Date)	Short Description
eCAALYX: Enhanced Complete AAL Experiment (36 months / 1.05.2009) **Website:** http://ecaalyx.org	A health monitoring solution that addresses **chronic conditions** of elderly people and provides reliable long-term, maintenance-free operation in a non-technical environment to improve the elder's quality of life by assessing their health risk, monitoring and controlling their health status and by teaching them how to **manage their chronic conditions** to continue to live independently at **home**. It includes a Home system, Mobile system, (Wearable Body Sensors) and a Caregiver site for medical professionals to monitor the patient and provide assistance if needed.
ROSETTA (36 months / 1.06.2009) **Website:** www.aal-rosetta.eu	Help people with progressive **chronic disabilities** to retain their autonomy and quality of life as much as possible and support (in) formal carers. The system includes three modules: -Advanced Awareness and Prevention Service (including e.g. smart cameras for activity surveillance and positioning by wireless beacons) - Early Detection System for monitoring patterns of behavior for detecting changes in chronic **long-term conditions**.

	-Elderly Day Navigator (including e.g. reminders of activities of daily living and appointments, visual phonebook, and simplified digital communication facilities).
HELP: Home Based Empowered Living for Parkinson's disease Patients (36 months/ 1.02.2009) **Website:** http://www.help-aal.com	A system able to administer drug therapy in a controlled, and either continuous or on-demand manner, to **manage disease** progression and to mitigate symptoms in **Parkinson's disease** patients. This device is a removable implant loaded with a configurable cartridge to administer a concise amount of drug which will be absorbed efficiently to the body for a constant basal.

Table 2: Technological Solutions for Chronic Condition Management

2.4 Agent-based Technological Solutions

Such systems are characterized by autonomously acting devices or "agents" such as robots, avatars etc. that have their own intelligence and interact with the user to offer services. These systems are restricted in indoor premises and usually require expensive equipment that must be mounted in the user's environment.

Apart from having a high cost, such solutions face the risk of being rejected by the elderly users as they might be considered as intrusive or invasive. On the contrary; this work presents a highly cost-effective and unobtrusive platform. The only requirement imposed on the user is to carry a personal mobile device of moderate cost. All data gathering is performed by pervasive sensors seamlessly integrated in this device without any actions required to be performed from the elders.

Examples for research projects in this area are the following:

Project Name (Duration / Start Date)	Short Description
DOMEO: Domestic Robot for Elderly Assistance (36 months/ 1.07.2009) **Website:**	Develop an assistive robotic system that would allow cognitive and physical stimulations, helping elderly and disabled people to remain autonomous as long as possible and to stay longer and safer at **home.** Two robotics **platforms** are evaluated, RobuMate for cognitive

http://www.aal-domeo.org/	stimulation and daily life assistance, and RobuWalker for walking assistance. They are connected with a remote medical center through web interface helping caring personal and relatives to better assist the person.
ALIAS: The Adaptable Ambient Living Assistant (36 months / 1.07.2010) **Website:** http://www.aal-alias.eu/	A mobile **robot platform** that has the capacity to monitor, interact with and access information from on-line services, without manipulation capabilities. The goal is to provide assistance in daily life, keep the user **linked to the wide society** and in this way to improve her/his quality of life by combating loneliness and increasing activities.
ExCITE : Enabling Social Interaction Through Embodiment (36 months) **Website:** www.excite.org	Examine social interaction between elderly in their homes and remotely located persons through **robotic telepresence**. Learn how to improve the quality of life for elderly **living at home** by enabling social connection through **telepresence embodiment**. The prototype is a mobile, human height **physical avatar** integrated with a videoconferencing system. It utilizes a general hardware that is specifically designed for rapid modification by allowing many modifications to be implemented in software. The methodology is focused around a strong user inclusion process.

Table 3 : Agent-based technological solutions

2.5 Technological Solutions Focused on Socialization and Personalization

All the projects presented so far tackle similar issues with the presented work however the majority either completely disregard or pay little attention to the overall social environment of the user, thus the socialization and personalization aspects of elderly care are not considered as a priority.

In the framework of AAL, and under the recent call titled: “ICT-based solutions for Advancement of Social Interaction of Elderly People” a number of projects have shown special interest in the socialization of senior citizens through assistive technology and highlighted its importance. The majority of these projects are at beginning stages nevertheless among them several stand out for their similarities to this work: The **HOPES** project aims at developing a multimedia platform

providing a network dedicated to social interactions of the elderly to enhance socialization, quality of life and autonomy. The platform focuses on personalization and will use web and databases crawling and intelligent structuring (Text Mining), techniques which are not considered in the scope of this work. The goal of **ELDER-SPACES** is to enable seniors to benefit from social networking especially in terms of their social activation, active living and overall quality of life. It is deployed over the existing iWiW network and other popular platforms such as Facebook and runs on devices such as TV and interactive surfaces. Instead the presented solution is an autonomous platform running on mobile phone device. The **V2me** project addresses social relationships with friends and partners as well as professional contacts through social networks; however the platform is based on a user avatar. More projects focusing on the socialization needs on the elderly are the following:

Project Name (Duration / Start Date)	**Short Description**
Go-myLife: Going social: my social life (30 months /1.07.2010) **Website:** http://gomylife-project.eu	A mobile **social networking platform** connected to disparate social networking sites allowing interactions with peers and families, as well as easy access to relevant geographically based information. A middleware addresses **personalization**, security and integration-related requirements, with an easy and accessible interface. Guiding principles include: **-Inclusiveness:** make it easier for older people to participate in mainstream activities and feel a part of the **whole** of society. **-Focus on social interactions:** give higher priority to assistive technologies facilitating social interactions **-Rapid rate of change and progress of technologies:** reflect future trends and enable the incorporation of future technologies.
SilverGame (26 months/ 1.05.2010) **Website:** www.silvergame.eu	Attractive and stimulating game-based multimedia applications that foster the social connection and interaction of elderly people with society and help them improve their physical and mental abilities with the system providing sensor-based feedback. A central platform and virtual environment that allows elderly to share their hobbies

	such as singing and dancing and helps them to stay in touch with other community members - the goal being to transfer these virtual interactions into real relationships and social inclusion.
WeCare (30 months /11. 02. 2010) **Website:** www.wecare-project.eu	Encourage older people to create, participate in and continue their social networks in order to prevent isolation and loneliness. The service integrates communication, coordination and information, and helps people to participate and cooperate within and between social networks. It includes easy-to-use online calendars and activity planners, video communication, blogs and forums. Special care will be given to privacy and authorization. The service will be built using readily existing applications and prototypes.
ELDER-SPACES (30 months)	A novel ICT-based social networking platform with a range of applications that will be delivered over this platform. key innovations: -Integration of web semantics data and techniques (i.e. ontologies, knowledge bases, data mining) to conventional Web2.0 platforms enabling customization of social networks to elderly requirements. -Novel ergonomic interfaces with proven acceptance by older adults -Customized applications, addressing the needs, interests and preferences of the elderly.
HOPES **(**30 months)	Network dedicated to **enhance socialization**, quality of life and autonomy of elderly persons by preventing isolation and loneliness, and generating positive social experiences and behavior. Provides ICT-based solutions for: -Managing existing e-information by exhaustive search of existing information (web and databases crawling) and intelligent structuring (TextMining) in the HOPES repository. -Transforming selected information into personalized solutions -Providing validated solutions as "e-Social Best Practices" with recommendations about how and when they can be best used during the elderly person's daily life.
PaeLIFE (24 months)	Focused recently retired individuals with some technology knowledge. The goal is to empower these elderly users with a

	Personal (Virtual) Life Assistant , a virtual presence who supports **social communication,** learning and entertainment, fighting isolation and exclusion and thus allowing them to be more productive, independent and to have a more social and fulfilling life. The system is **home based**, since elderly suffer impairments caused by age, which reduce their mobility.
PeerAssist (30 months) **Website:** www.cnl.di.uoa.gr/peerassist/	Peer-to-Peer platform, to allow elderly , not familiar with IT, to build **virtual communities dynamically**, based on interests and needs they share with friends, family, neighbors, volunteers, service providers, etc. Supported applications include : -Peer-driven organization of social activities -Soliciting peer help with housekeeping activities -Support organizations "push" relevant content of interest -Caregivers and family receive alerts to respond to emergencies.
V2me (36 months) **Website:** http://www.v2me.org	Cost-effective solution combining off-**the-shelf technology** to initiate and mediate **social relationships** with friends and partners as well as professional contacts through **social networks**. A **User Avatar** provides personalized and adaptive means to integrate elderly in social networks and meaningful activities, enhancing physical and mental fitness, empowering reciprocal assistance and help.

Table 4 : Technological solutions focused on Socialization and Personalization

The approach of this work goes beyond the state-of-the-art by addressing both care and socialization needs of the elders through a cost-effective and portable technology that emphasizes the value of mobility and does not impose any restrictions on the end-user(i.e. remain in the home environment, carry special equipment, etc.). By integrating pervasive sensors with socialization and daily monitoring services the platform aims at stimulating and prolonging independent and active living of the elderly persons. The novel Social Community model pays special attention to personal preferences and needs of each user leading to personalized care.

Chapter 3

Background and Basic Concepts

3.1. The Personalization Problem

Personalization is a multi-dimensional and complicated area. To this date, it has not been given a concrete definition. According to [5], personalization is the provision to the individual of tailored products, services, information or information relating to products or service. Similarly, most of the definitions [6-9] converge on the description of delivering to a group of individual's relevant information that is retrieved, transformed, and / or deduced from information sources in the format and layout as well as specified time intervals. [10]

Initial attempts at achieving personalization have been limited to check-box personalization on the Internet where portals allowed the user to select the links they would like on their "personal" page. However, this had limited use since it depends on the users knowing beforehand the content of interest to them. As a next step many solutions offering personalization features met an abstract common goal: to provide users with what they want or need without expecting them to ask for it explicitly [5] .

Recent studies have made a great attempt to develop frameworks describing and utilizing various kinds of user related context information to support personalized services. Initially the majority of such systems were restricted just to the level of recommending the expected user-desired service. That is, they did not support personalized services in which details such as service properties or contents are able to be adaptively changed according to the identified user preferences [11].

Today, personalization technology involves software that learns patterns, habits, and preferences [5] .There are many approaches, each one focusing on a specific area, including among others,

profile creation, machine learning and pattern matching, data and web mining or personalized navigation.

3.1.1. Related Works

There has been a great attempt in recent studies to develop frameworks describing and utilizing various kinds of user related context information to support personalized services. To achieve personalized services a unified context is needed that describes user's situation as who, when, where, what, how, and why based on environment data related to both the emotional and physical behavior. Several kinds of contexts have been identified, such as environment contexts, user contexts, computing resource contexts etc.

A number of frameworks for personalized services in pervasive computing environments have been developed so far. These allow the application services to continuously monitor sequences of patterns in user behavior and to manage the aggregated user profiles on databases. The data is used to provide users with context-aware, personalized services.

KDDI cooperation in Japan has developed a client-server architecture framework for aggregating, updating and disseminating personalized user profiles related to user activities from mobile terminal devices [11]. Wear-UCAM [11] is a framework which offers personalized services to users according to service-specific user preferences by analyzing various kinds of contexts obtained from sensors in an environment or sensors worn by users. It is innovative because is supports personalized services in which details such as service properties or contents are dynamically updated by a learning process.

Researchers have also been exploring on the use of various techniques to analyze emotion-related bio-data and deduce a user emotional state and provide personalized services directly based on human emotions.

An example is presented in [12].The core idea behind this work is to present a model for providing personalized services and products based on an analysis of the user's current emotional state. The system consists of a sensing device for emotional data acquisition, a mobile phone device for collecting the data and a server for storing. Emotion categorization is achieved using an emotion recognition engine. The model determines the current emotional state of the user and depending on that decides what type of personalized service should be offered. Picard's work in [13] proposes the measurement of physiological parameters like: skin conductance, skin temperature, heart beat rate, blood volume pressure (BVP), respiration, electroencephalography (EEG) and muscle tension in correlation to change in emotion.

3.1.2. Personalization Techniques

In an attempt to expose capabilities and limitations of personalization the work of [9] examines various techniques used today for personalization. These are summarized next:

- **Lookup of personal records in a database/file**

A database of personal records of users is maintained, and keywords (e.g. name or ID) for a given user are used to identify the record in the database and extract relevant information. This information about the user may be stored in a single record, or in many records in several tables. Relevant information is different from application to application.

- **Lookup of a rule base or a profile database**

A rule base or a profile database is maintained and is searched based on given characteristics (e.g. age, area of residence, ethnicity, etc.) of a user. The rule base or profile database may have been created through use of data mining, weblog mining, text mining, and Online Analytical Processing (OLAP) techniques. Such techniques may be applied either offline or online

depending on application requirements and performance and scalability limitations of the algorithms and available computing resources.

- **Data mining (of numerical and string data in formatted tables/files)**

Most existing data mining techniques are designed to process numerical ata, and short-string data [14]. The techniques serve a variety of purposes, including clustering (grouping of data based on similar characteristics), classification or categorization (placing new data into one of the existing categories), association rules generation (determining the likelihood of events following certain other events), etc. Data mining algorithms may be run on a large number of records to segment or classify these records.

- **Weblog mining**

Weblog mining is a special case of data mining aiming to determine various access patterns in a website and web pages (i.e. peak periods of access, average visit durations, common navigational patterns across web pages, repeat visits, identities of the websites that frequently lead to the website in question, etc.). Weblog data is stored in formatted simple tables/files that contain only 10-15 fields; however, it can grow very large very fast, because every visit to a webpage is logged.

- **Text mining**

Text mining aims to automatically determine various attributes of a free-form text (e.g., a news article, office memo, technical report, etc.) including key features, frequently occurring words, summary, category, etc.[14]. Key features and keywords are compared against keywords maintained in a knowledge base to determine the category for a text (e.g., Internet taxation, professional basketball, luxury automobiles, social impact of the Internet, etc.).

For the purpose of this work the most appropriate technique to apply personalization is the lookup of personal records in a database. Details on the database records are given in 8.2 . The infrastructure of the Personalized Database Infrastructure where personal records of users are maintained is presented in subsection 8.2 and the Personalization process including the algorithms applied on the personal data is presented in subsection 8.4.

3.1.3. Personalization Challenges

Clearly the problem of personalization is a complex one with many aspects and issues that need to be resolved [15]. New requirements for information and service personalization arise, addressing the handling of an extendable set of user preferences, the definition of multiple user profiles associated with different service usage situations, support for service accessibility to user presence etc. Some of these issues become even more complicated once viewed from a wireless perspective and when focused specifically to a mobile user.

A major goal of this work is to get personalized information "anytime, anywhere and anyhow". As indicated by P. Germanakos et al [10] this is not a trivial task. To achieve it, systems should be tailored to the personal characteristics and needs of individual users and provide them with appropriately adapted information. Furthermore, the system should comply with the fact that the user characteristics and needs differ according to the circumstances and may change over time.

The major issues related to the provision and delivery of adjustable and personalized information in the context of this work is summarized next.

- **Context Awareness**: The basic element used for personalization is the context of a user [16]. Context information can be defined as any information that can be used to characterize the situation of the user. It may consist of many aspects such as the user's needs, preferences, history, and behavior; location-related aspects such as physical coordinates and velocity; and ambient

conditions, technical aspects like bandwidth of the network and capabilities of the terminal, business rules that apply, and so on.

- **Content Selection: How** to decide what to show based on user preferences. Two issues must be addressed. Firstly the need for storing the preferences of the user in a format that is easy to be used and updated, namely a personalized user profile, and secondly how to receive a different system response for each user request based on the stored characteristics of the requestor. As a consequence a personalization process must be applied at the database level.

- **Content Presentation:** Personalized data dissemination and adaptation must be implemented to ensure presentation of content according to the user's preferences. Information must be filtered, showing each time only the details relevant to a specific user.

- **Technology Related Issues:** When moving away from desktop applications and developing for smart devices some new concerns arise. These involve small screen size, lack of processing power, limited interface and data entry, small memory and storage space, and high latency. [10]

- **User Related Issues:** The entire platform, including services and interfaces, is designed and tailored to the special needs of the elderly users group. Age –related changes and disabilities, including memory, cognitive and visual impairment, deteriorate the ability of the elderly to interact with conventional electronic devices and systems. Consequently, the user interfaces must be especially friendly enabling simplistic user involvement, giving the control to the user, providing easy means of navigation and orientation, tolerating users' errors and finally enabling content customization to particular users' needs.

3.2. User Behavioral Analysis

User Behavior Analysis aims to identify sequences of patterns in user behavior, analyze human social behavior or understand utilization of a particular monitored environment. Recent advances in technology, and especially in pervasive computing, made it possible to embed sensors in the environment to gather data with minimal disruption to the user. Various frameworks for context-aware services in a ubiquitous computing environment have been developed so far. Applications include assistive technologies which make use of information produced by behavioral analysis of e.g. residents of a nursing home or elderly patients living alone at home.

In these frameworks, a variety of embedded sensors, ranging from simple to complex sensors or movement tracking systems, is used to extract various environmental attributes and monitor a sequence of patterns in user behavior. The physical or cognitive status of the user/occupant can be inferred from the activity and a decision can be made regarding the health status of the occupant [17].

3.2.1. Related Works

In [18], Shin et al. developed an automated behavior analysis system using infrared motion sensors to assist the independent living of the elderly who live alone and to improve the efficiency of their healthcare. A motion-sensor-based activity monitoring system was installed in the houses of the elderly subjects to collect motion signals and three different feature values, activity level, mobility level, and non-response interval. These feature values were used to classify normal behavior patterns and to detect abnormal behavioral patterns.

Another example is the work of [17] which describes a model-based behavior analysis system for assisted living. In this work, behavior is defined as any pattern in a sequence of observations. To observe behavior a smart home is equipped with embedded sensors that unobtrusively record

various environmental parameters. Model of behavior are generated from the sensor data. The models are analyzed to detect gradual changes in behavior, and atypical behavior.

Physical activity monitoring is another important aspect in user behavior analysis. Abnormal movement behavior might be an indicator for an inappropriate lifestyle, insufficient social inclusion, or generally disadvantageous life conditions which might call for medical treatment [19]. Considerable research has been devoted towards this area.

In the context of activity monitoring , [20] proposes an approach to combine heterogeneous sensor data provided by video cameras and environmental sensors attached to house furnishings to achieve behavior analysis to recognize activities at home. The basic goal is to define a behavioral profile of an individual and capture deviations of activity and posture to facilitate timely intervention or provide automatic alert in emergency cases. For the definition of the behavioral profile two main variables are measured: the duration and the number of occurrence of each daily activity.

The work of [19] presents a mobile technology for identifying movement behavior in everyday life. A three-dimensional acceleration sensor is used to determine physical activity by domain specific feature extraction leading to high quality and robust classification of physical activity.

Computer Vision techniques can also support activity monitoring and offer a relatively high accuracy in tracking people. A large number of systems are focused in automatically detecting physical human activity and interaction events from analyzing video and audio. Such an approach is [21], which proposes a multimodal system for detecting and analyzing human activity and social interaction patterns in a nursing home. The system is able to automatically process surveillance video signals and generate summaries and comprehensive reports of health, activities and behaviors of patients to support the diagnoses of physicians and caregivers.

3.2.2. User Behavioral Analysis in the Scope of this Work

The main aim is to design a component to monitor and analyze behavior of the elderly users with the objectives of detecting trends and deviations from what might be considered normal behavior. Behavior analysis is achieved by gathering information (from sensors and from monitoring the user's interaction with the system) and creating a model to observe gradual changes and trends that might signal anomalous behaviors.

The model monitors sublet changes in the social and physical activity of the user. When these changes are observed and compared over time they signal to the caregivers trends indicative of psychological deterioration or progression of a health condition.

3.3. Pervasive Computing

Today, the evolving concepts of pervasive computing - otherwise known as ubiquitous computing- and ambient intelligence are increasingly influencing the care sector.

In literature, pervasive computing is defined as a post-desktop model of human-computer interaction in which information processing is thoroughly integrated into everyday objects and activities [22]. It is also associated with the spreading of miniaturized mobile or embedded ICT with some degree of 'intelligence', network connectivity and advanced user interfaces [23] .

According to these definitions a pervasive device can be discreetly embedded in an environment, is completely connected, intuitive, effortlessly portable, and constantly available. It can maintain current information about the contexts in which it is being used, and other relevant data about the users.

Some of these capabilities, such as remote, automated patient monitoring and diagnosis, have made pervasive computing a key tool in the care section. Current care solutions rely on automatic

documentation of activities, process control or the right information in specific situations as supplied by pervasive computing to enhance patient self-care and independent living as well as increase the effectiveness and efficiency of care providers.

This section summarizes published research addressing system developments and implementations of pervasive computing in the care section.

3.3.1. Scope of Pervasive Systems

The development and deployment of IT systems in care is usually driven by intentions to improve care provision or workflow. According to an extensive overview of the literature on a broad and heterogeneous range of pervasive computing systems related to care the major functions provided by pervasive systems can be subdivided into six categories: analytical and diagnostic support; alerting; medical treatment; support activities (e.g., reminding or guidance); process automation; and documentation and information [23] .

3.3.2. System Users

Systems users are divided into health care professionals, (i.e. medical personnel, including nurses and professional caregivers, paramedics, physicians), care receivers (i.e. patients) and private caregivers such as family members etc. [23] .

3.3.3. Data Gathering and Transmission

A Pervasive System constantly gathers data from an external environment. The collection can be made by means of mobile components such as conventional mobile devices, wearables, and implanted devices or using computer-enhanced physical environments, such as buildings or furniture.

Depending on the type of data they gather, pervasive systems can be classified into several types:

- Monitoring of persons or objects.
- Localization of persons or objects.
- Manual input or request by the user.

Monitoring of persons is by far the most important type of data gathering. Such systems typically collect physiological or behavioral data for purposes of analytical and diagnostic support, alerting as well as support activities.

Physiological data include measurements like ECG, blood pressure or heart rhythm etc. Behavioral data include monitoring of presence, movements or activities, such as monitoring of 'Activities of Daily Living', medication adherence, social or communicative behavior, or detection of falls.

The second most frequent type of data input is localization of persons. Such systems provide context-aware or location-dependent information. They mostly focus on the localization of patients, residents or medical personnel within facilities or in larger geographical areas by GPS (geostatic positioning).

To serve purposes of data analysis, forwarding, or storage the majority of pervasive systems transmit the gathered data, in most cases to a central server. Other systems do not rely completely on data transmission and are able to perform functions independently and in a decentralized fashion. Examples include wearable devices monitoring health or activity and assisting the user by providing supportive information about the health status or by suggesting certain activities.

3.3.4. Pervasive Computing and Ageing

This review reviles a broad and heterogeneous range of pervasive computing systems related to care. The overall objective is to find innovative means of applying technology in order to extend care beyond the conventional clinical setting to the individual in their own residence within the community.

The goal of this work is to use the technological advances associated with pervasive computing to obtain a clear and accurate knowledge of a person's performance of functional tasks at any time and any place. Based on gathered information it is possible to assess changes in the daily habits and functional abilities of the elderly in order to enhance their well-being by providing needed services in a personalized and timely manner.

Chapter 4

Elderly User Context

4.1. Target Group Definition

For the purposes of this work the target group of end-users is the big group of healthy elderly, aged above 65 years old, who might suffer light physical or psychological health problems however are self-supporting, able to move around, and can still contribute actively.

Technological development has already brought numerous devices and services that facilitate daily life for the elderly and recent studies have shown that the elderly themselves are ready to begin using such technologies as long as these truly facilitate their independent living [24] .

Nowadays electronic devices help elderly people keep in contact with their relatives and friends, allow them to live safely at home, make it easier for them to care of their health, permit them to acquire care and information, and bring new stimuli into their lives.

It is thus clear that the society of the future will have a large number of capable, active elderly users of the new technology. Developed services will give them better living conditions and enable them to cope independently for longer than before.

Nonetheless, the task of providing effective solutions for this large emerging target group is proven to be more challenging than working with any other mainstream group of end-users. As a result of age associated changes elderly people present a particular set of user requirements which standardized technological solutions fail to meet.

Age related changes and disabilities, including memory weakening, cognitive, visual and hearing impairment, all of which vary from day-to-day and over longer time periods, deteriorate the ability of the elderly to interact with conventional electronic devices and systems. Adding to this, psychological aspects affect their attitude towards the latest radical advancements reducing their acceptance of technical systems.

The following paragraphs present related characteristics of older adults and discuss how these affect their relation with technological solutions such as the one presented in this work. These fundamental characteristics served as guidelines throughout the entire development process and mainly during the stages of the design of suitable services and interfaces for the elderly.

4.2. Age Related User Characteristics

4.2.1. Physical Changes

It is generally agreed that old age is associated with a general decline in physiological status which affects among others cognitive and visual skills, restricts hearing and the brains' ability to absorb new information. That is why standardized technological solutions are not sufficient when it comes to the design and development of new devices and services for the elderly. Their particular requirements have to be taken into account in order to ensure and guarantee an accessible, usable and accepted solution.

Age related memory changes and their effects on learning are no doubt at the heart of the difficulties which older people have in using computers and other similar devices. [25] . Research shows that elders are less able to retrace and navigate a route than younger people [26] . This can be seen as analogous to using today's Graphical User Interfaces (GUIs) with multitasking windows and the requirement to build strategies at the interface in order to complete tasks.

Different levels of visual impairment also affect the elder's ability to interact with a conventional device. Good sight is crucial for using today's User Interfaces with small text and multiple buttons. As their vision impairs users can no longer read and require changing the text to a larger font or descriptive symbols to facilitate the interaction. Similar scenarios occur with other sensory impairments such as hearing impairment.

4.2.2. Perceptions and Acceptance of Technical Solutions

The uptake of new technology by users is perhaps one of the greatest challenges faced by a developer. Key factors affecting the acceptance process include the user's awareness, practical experiences, and expectations regarding technology. [27]

Age related psychological aspects affect the attitude of older users towards rapid technological advancements. The perception of the usefulness of the technology weighed against the time taken to learn it plays a major part in the acceptance process. [27]

Added to this is the fear of failure. Learning to use a new technology represents a considerable investment of time and energy, especially in the case of an elder who fears that failure to acquire sufficient skills means a waste of his limited resources.

4.3. Needs Regarding Independent Living of the Elderly

On average, elderly people have an increased demand for support and care in everyday life. [27] Age-specific barriers caused by ageing affect all their different daily activities such as going for a walk, meeting and communicating with people, shopping, feelings of safety as well as contacting supportive civil services.

This entire work is based on one essential principle: Elderly people want to live independently for as long as possible. To be independent means being able to perform all the different activities a person carries out in his or her everyday life despite age-specific constraints.

In order to provide a technological solution assisting the independent living of the elderly it is essential to identify and document their needs and requirements related to care and well-being.

Care requirements for elders change over time. Some are predictable, such as the well-understood progressions of diseases and conditions. Others are unpredictable, brought on by sudden changes such as a fall or an Illness. Such events can immediately change the care needs of the elder. [28]

It is obvious that this problem calls for the definition of a holistic concept focusing on all the aspects of the individuals' life quality. This Chapter identifies and analyses the major user needs

and requirements of the elderly regarding independent living, aiming to highlight their independency and interdependency, as well as their social living framework.

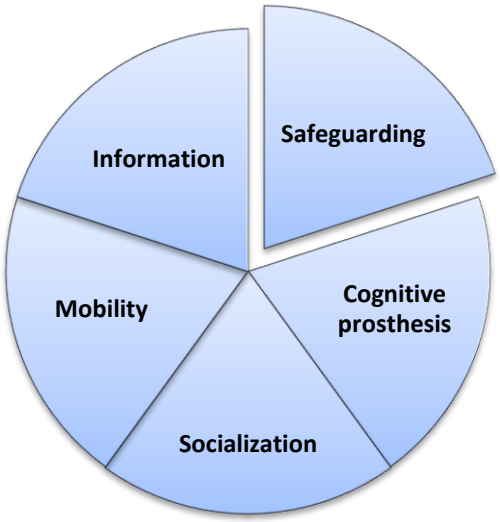

Figure 2: Primary Elderly Needs

4.3.1. Safeguarding

As elderly people become physically and cognitively impaired, accident related risks gain a significant importance. For example, loss of stability is a leading problem for independently living elderly people. Accidents related to falling can have, if undetected by others, severe consequences [29]. By reducing such risks through systematic monitoring and safeguarding, an elder can continue living independently for longer than before.

Such systematic monitoring can also have a positive impact in addressing specific fears of elderly persons. Constant safeguarding increases their particular sense of security concerning typical fears of falling or need for immediate assistance.

4.3.2. Cognitive Prosthesis

A large fraction of the elderly population suffers from varying degrees of memory impairment. In initial stages this could mean regular supervision in carrying out daily activities. However, when

conditions become too severe the inability to remember can have severe consequences. In both cases reminding is an important and time-consuming activity for care takers assisting the elder.

4.3.3. Socialization

Social support has been found to be positively related to well-being in elderly individuals. Engagement in social activities can significantly delay the deterioration and health-related problems. According to studies [27] basic social needs comprise maintaining links to social networks and places people have progressively built up in their lifetime, spending time with family, friends and other important relatives, having real physical contact with people living in the neighborhood, being active participants in different communities .

4.3.4. Mobility

For older people, mobility represents much more than having a means of transportation. It stands as a symbol of freedom, independence and autonomy, offering them a sense of control over their life.

In the case of elders limited mobility is caused by a reduced human motor function, physical capabilities and reduced sensory perception. Restricted mobility is considered as reduction of quality of life as a vast majority of simple daily activities are mobility related.

It is essential for the elderly to maintain their mobility in order to be able to deal with these everyday tasks, such as visiting relatives and friends, participating in social activities or paying their bills. It is necessary to remove physical barriers and to provide solutions that facilitate the mobility of elderly persons.

4.3.5. Information

Maintaining contact with the outer world is particularly essential for the psychological stability of the elderly. To feel connected within society elders wish to continue carrying our tasks such as paying bills, visiting the bank etc. Technology can provide solutions to aid the elderly in contacting supportive civil services and acquiring the necessary information to carry out daily tasks easier and without the need of external assistance.

The various categories of needs mentioned above have led to the design of the fundamental structure of the Personalized Care Scheme provided by the system. A subsequent Chapter will present in detail the structure of the model and explain how technological advances associated with pervasive computing are used to provide the elderly with services that enhance their well-being.

Chapter 5

Virtual Care Community

Elders who live alone generally have rich care networks—support networks of people who provide the elder with care on a daily basis [1]. Often the people involved in these networks are not professional caregivers but merely members of the elder's close environment who provide assistance ranging from day-to-day activities to social support. These can be relatives, friends, neighbors or trained care assistants, of varying ages and computer skills, who depend on timely and reliable information to be able to provide the elder with care.

In such networks it is not guaranteed that all members know each other, that any member will take on any amount of responsibility, that members' skills are the same or that all members share the same motivation to provide care to the elder. Furthermore the network's structure gradually has to change as network members or the elder's needs and priorities change. Depending on their role in the elder's care the daily lives of these members are affected in different ways.

It is obvious that network organization is an important and time-consuming activity for care takers. In fact quite often this type of improvised care networks suffer from coordination problems leading to uneven distribution of responsibility, miscommunication, misunderstanding, unmet care needs, and negative impact on the careers and personal needs of the individuals involved. [28] .

Based on the underlying principle that a care network involves the effective cooperation of a number of different human actors e.g. the elderly people, their relatives and friends, care assistants etc. this work commences with one purpose : to design and develop a Virtual Care Community, operating on mobile agents, supported by pervasive monitoring sensors and focused

on the establishment and successful management of collaborative Care Teams around the elderly to provide personalized care that meets their individual and altering needs.

5.1. Virtual Care Network

Today's fast emerging information and communication technologies have stimulated the growth of virtual communities. As mentioned in [30] "due to the lack of a formal definition, virtual communities are casually defined as distributed online services connecting a group of people that gather to keep in touch, focused on some common interest or purpose ."

An important application context for virtual communities is elderly care. This work intends to prove that if supported by computer networks and adequate assistive tools elderly care networks can evolve towards operating as a virtual organization and the various involved actors become part of a Virtual Community.

Simple technology (smart devices operating on wireless broadband networks) is used to seamlessly integrate the entire care network around the elder in a Virtual Care Community that is described by the following fundamental characteristics:

- **Virtual**: Members can assist and provide care to the elder without being physically present.
- **Dynamic**: Care provision changes dynamically in order to match the elderly person's needs.
- **Collaborative**: Various team members combine their knowledge and work interactively to provide effective elderly care.

5.2. Virtual Collaborative Care Teams

As mentioned above caregivers are organized in an innovative Virtual Care Community. The model places the elder in the center of personalized care provision and promotes around him/her the seamless integration and interaction of different people of different ages (young and old) and

roles (relatives, friends, neighbors, care professionals, etc.). These members can assist, collaborate and actively communicate with the elderly to improve their daily life in an ad-hoc and informal way through the use of mobile wireless technologies at any time and any place.

For purposes of better organization and to better coordinate the care related activities, the Care Community is divided to various teams, each with explicit responsibilities. All the individuals who provide care are eligible community members. It is possible to make various distinct distributions of the network members based on a multiplicity of factors.

The next section discusses how the Care Community is divided into teams and presents the details of each team with special focus on the roles and responsibilities of the involved actors.

The primary members who participate in the Virtual Care Network, each with its own set of needs or responsibilities, are:

- The elderly citizens
- Family members of the elder
- Professional care providers
- Primary Contacts
- Members from the elder's social environment. Friends, neighbors etc.

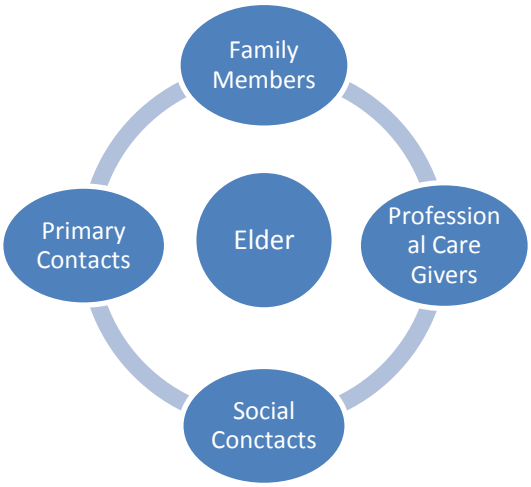

Figure 3: Virtual Community Teams

Friends, family members and caregivers can serve as resources for older adults in two ways. Directly, by helping them accomplish activities of daily living, or indirectly by providing emotional support through personal relationships. Either way these members enhance the elder's physical and psychological well-being.

Each member is assigned a specific role and is allocated to a specific care team. Possible member roles include: Daughter, son, grandchild, friend, social worker etc. Based on their responsibilities and level of participation in the elder's care the members are then categorized into one of the Virtual Care Teams.

- **Primary Contacts**

In each care network, at least one member drastically changes his or her life to care for the elder [28]. These members are the primary contacts of the entire network. They make major, continuous contributions to the elder's care. These members' lives are considerably affected by the role of providing care. In cases of emergency alerts are directly transmitted to this team who is responsible to immediately attend the elder. Periodic trend reports are send to all primary contacts to keep them informed of important developments in the elder's condition.

- **Family Connections**

Family members usually provide older adults with active support. Depending on the functional ability and needs of the elderly members, families provide assistance with everyday activities such as household tasks, transportation (especially when needed on an ongoing basis), companionship, running errands and managing contacts with formal sources of support (health care providers, government agency). Within the family care team two types of relatives are listed. Those who make significant, regular contributions to care for the elder and other members are who peripherally involved. These members might have sporadic social interactions with the elder,

caring has minor impact on their lives, but the interactions with these members still hold meaning for the elder.

- **Social Connections**

The majority of members in this team are other seniors that visit the same facilities, come in daily contact with the elder and wish to get involved in joint leisure activities. Friends serve as companions for each other in a variety of ways such as conversations about everyday events, joint activities, sharing a coffee etc. By maintaining these social relations both ends benefit emotionally. Apart from friends of the same age, other roles that belong into this group include neighbors, that may assist the elder in an emergency or when no one else is available, or younger acquaintances that have infrequent but meaningful social interactions with the elder.

- **Care Professionals**

In several but not all cases the Care Network includes social care assistants, and other health care professionals who monitor the elder on a regular basis. These members are responsible for making drastic changes in the care plan, i.e. assign medication or physical exercise based on the information available on the elder's status.

5.3. Virtual Care Community Benefits

The Virtual Community is especially designed and implemented as an advanced care system that encourages and supports active participation, communication, socialization, mutual assistance and self-organization of the elderly, promoting seamless integration and interaction of different people (family members, caretakers, friends etc.) from all ages and different ICT skills.

The Virtual Community places the elder in the center of a rich stimulating social environment where he is both a receiver and producer of assistance with positive benefits:

- Feel connected to the rest of the world
- Facilitate social interaction and participation in leisure/social activities with others
- Increase feeling of safety, support at any location, any time
- Receive immediate support in unsafe situations or emergencies
- Reduce limitations imposed by physical and mental conditions
- Increase personal control
- Motivate to be more active

With regards to the care givers, the Virtual Community assists them to provide timelier, accurate and personalized care by enabling them to:

- Gain a clear understanding of the type of care that the elder needs
- Stay informed of important developments in the elder's condition
- Receive immediate alerts in cases of emergency

Another important, yet not directly involved, stakeholder how benefits from the Virtual Community is the society of researchers who are engaged in determining how to best use technological advancements to improve the quality and efficiency of care delivery.

Chapter 6

Personalized Care Scheme

This work uses principles of pervasive computing, user behavior analysis and personalization to serve three major purposes in the area of elderly care:

i. Support and stimulate the elderly to remain longer active by detecting unsafe situations or emergencies.

ii. Facilitating independence and functional performance by providing personalized care and support services.

iii. Support caregivers and reduce the care load by facilitating provision of effective and accurate elderly care.

The objective is the creation of a **Personalized Care Scheme** in which smart devices with pervasive sensors and personalized databases together with care takers assist the elderly in maintaining their independence and high quality of life. Embedded sensors monitor physical status and alert care takes to respond to immediate needs in the event of emergencies.

Behavioral analysis techniques applied on the data in the personal databases reveal trends over time which allows care providers to assess the status of the elderly and alter overall care plans.

The scheme leads to better care and greater peace of mind for the elderly and at the same time reduces stress on care takers who must track the details of daily activities of the elderly to detect possible cognitive or physical impairment.

This Chapter discusses in detail the structure of the **Personalized Care Scheme** developed based on the original idea proposed in [31] and modified correspondingly to match the specific needs for personalized care of elderly users.

6.1. The Care-Giving Pyramid

Figure 4 depicts the fundamental structure of the **Personalized Care Scheme**. It is a pyramid based model that describes how data and information are obtained and used to provide the elderly with care services that enhance their well-being.

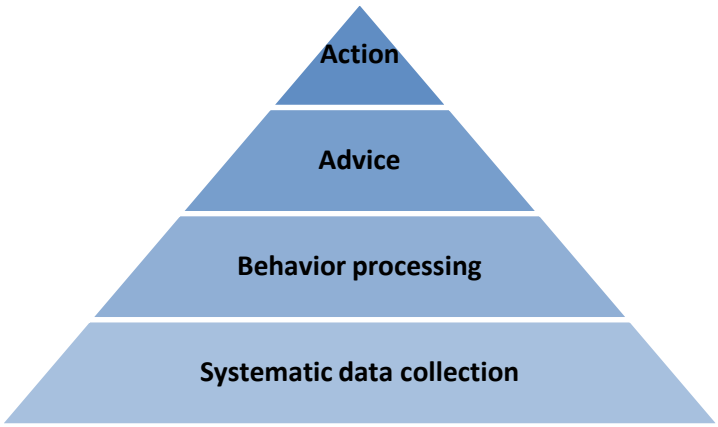

Figure 4: The Care-Giving Pyramid

The four levels: **Systematic Data collection, Behavior processing, Advice and Action** construct a full loop for the care-giving process. At the base of the pyramid physiological and behavioral data are constantly gathered by embedded sensors and stored in personalized databases found on the smart device. The data acquired is continuously interpreted into useful information in level two, both on a daily basis and through trend analysis, to pinpoint changes in behavior that could indicate a problem before it can become a crisis. In the key levels three and four is where information is distilled into advice and then action taken by the caregivers or the system. Reporting of distilled information - behavior deviations, trends and emergency events- takes

place in level three in the forms of advice, alerts and reports for caregivers. Finally at the top level information leads to concrete actions, either direct or indirect, which alter the overall care plan of the elder to deliver an improved personalized care experience.

- **Level One – Systematic Data Collection**

A key problem currently faced in the care sector is the inability to collect data for people living alone. In the elderly user context, the data of interest are relevant to a person's performance on functional tasks in their home or outdoor environment, i.e. walking frequency, falling down incidents, or a person's behavioral tendencies, i.e. participation in social activities. Such details are necessary to obtain clearer and more accurate knowledge of a person's physical and cognitive status.

In classical care-giving models, the only valid information about this data is mainly provided by the person itself, by relatives and friends with various forms of interviewing, or by questioning a caregiver about the elder's behavior. Nevertheless the reliability and objectiveness of these direct data is always a concern because of the relevance and accuracy of the responses.

The purpose of this level is to provide pervasive, continuous and objective monitoring of the daily living activities. Devices embedded in the smart device of elder constantly record physiological and behavioral data based on the user's behavior. The measurements obtained from the geostatic positioning tracker (GPS) and the accelerometer are timely, accurate and reliable. They are instantly stored in personalized databases found on the smart device and are subjected to processing in higher levels.

- **Level Two – Behavior Processing**

All the data gathered in the care-giving context are subject to Behavioral Analysis. In this level data is translated into information which will ultimately be distilled into some form of advice to the elder himself or the immediate care givers.

Behavior processing consists in extracting useful information concerning the user's physical and emotional status based on the raw data gathered by the various pervasive sensing devices. The processing methods employed in this level are the following:

i. Situation interpretation, detect high risk situations such as falls.
ii. Detection of behavior trends i.e. preference in activities, locations etc.
iii. Compare performance in physical and cognitive activities with pre-recorded behavior patterns to detect deviations.

- **Level Three – Advice**

The constant monitoring from the previous levels leads to the identification of various behavior trends, deviations and emergency events. These facts serve to produce valuable advice, for both the elder and the care giver, on the type of care the elder requires.

The scheme includes three basic forms to report the information to the elders or care providers:

i. Direct **alerts** to the care givers. Such alerts are issued directly to the designated care giver in the case that information is of urgent nature i.e. when a fall has occurred or an emergency situation has been detected.
ii. Periodic **trend reports** to the care givers. These can be issued on a weekly or monthly basis and report behavior deviations, evaluation and identified trends in the elder's behavior over prolonged time periods.

iii. **Suggestions** for the elderly. The system prompts to the user's screen in regular time intervals suggestions in order to motivate him/her to participate in social or physical activities. The decision of which activity to prompt is based on the analysis of the data gathered during monitoring. For example, it may be effective to prompt a user to attend an event of a type of activity that he or she frequently attended in the past. Another example is to suggest a visit to a location that the user visits on a regular basis according to his documented history.

- **Level Four – Action**

At the top lever of the pyramid the general or specific information extracted is translated into action taken by the care givers responsible for the elderly. These actions can either be direct, i.e. an immediate visit in the case of a fall or indirect, or indirect i.e. if low physical activity is detected adjust the elder's daily schedule to increase mobility.

It is important to notice that a direct dependence relationship exists between all four levels of the Care Scheme. If the data at the base of the pyramid is not reliable the final action taken by the caregiver may not be appropriate, the timing may be inappropriate or the caregiver taking the action may not be the most appropriate person for the required action.

An example of invalid information is an alarm generated indicating that there is a fall when no fall has occurred. This is a false positive and is both expensive and dangerous, given that frequent such false positives could result in the assumption that there is no emergency and thus lack of response.

The Care Scheme is specifically designed to collect reliable and well-timed data and to effectively and efficiently translate this data into valid information compared to the data gathering methods employed in other care-giving models. Actions can be taken because the caregiver is confident in the advice, the advice is regarded as accurate because the information on which it is

based is valid, and the information is valid because the data provided by the sensors is reliable accurate and well-timed [31] .

6.2. Alerts and Behavioral Trends

As discussed in the Care-Giving Pyramid, the system provides two types of information for caregivers: alerts and trend reports. Both are based on the use of SMS messages. Alerts notify a caregiver instantly once an emergency situation is detected, for example in the case of a fall. They allow for action to be taken to address the indicated problem almost immediately.

On the other hand trends are based on the analysis of behavioral data from a much longer period of time. They allow for more subtle changes in physical status and behavior to be observed. These are the type of gradual and slight changes that are difficult, if not impossible, for the individual themselves to notice or even for a caregiver to detect. [31]

The monitoring system generates two different types of alerts:

- Emergency Alerts in the event of fall detection or other urgent situations.
- Non-emergency Alerts to inform for requests made from the elder.

In both cases, emergency and non-emergency, the information is delivered to responsible care givers by SMS messages which are sent directly from the elders' smart device. In order to show how the monitoring system generates alerts, one example each of an emergency and non-emergency alert is discussed in detail.

1. Emergency Alerts

In the case of emergency alerts, an SMS is send to the designated caregiver immediately at the time the system records the alert regardless of the time of day. Such alerts are generated upon fall detection or in the case of urgent situations where the elder requests immediate help.

A fall alert is generated when the embedded accelerometer sensor detects a value that surpasses a predefined threshold value. Instantly the device attracts the elder's attention on the screen, and displays two buttons: a green button with the message "I am ok" and a red button with the message "I need help". The sound is repeated until the user selects one of the two buttons. In the case that the green button is pressed then a false alarm is assumed and no alert is transmitted. If the red button is pressed then a fall alert is issued and an SMS with the appropriate content is send instantly to all designated caregivers. If within one minute the user fails to respond pressing one of the buttons then an alert is generated and send.

The care giver receives an SMS indicating that a fall has occurred, including the exact time of the incident and is asked to contact the elder immediately in order to evaluate the gravity of the situation.

2. Non-emergency Alerts

A non-emergency alert is generated in the case that the elder requests to be picked up by car from his/her current location. Similar to emergency alerts an SMS is send to the designated caregivers as soon as the elder places the request. In this scenario the embedded GPS device can trace the exact location of the user and include it in the content of the message to facilitate the caregiver.

3. Behavioral Trends

Unlike alerts, behavioral trends are the result of the analysis of data over a much longer period of time [31]**.** Data collected during prolonged monitoring are periodically presented to responsible members in the form of reports. At the sight of this information they can determine whether the changes in the elderly person's behavior may mean the beginning of a cognitive decline or just a casual deviation from previously recorded behavior. The same applies for changes related to the elders' physical status.

Trend reports monitor the user's behavior evolution and allow for subtle changes in physical status and behavior to be observed. These are the type of gradual and slight changes that are difficult, if not impossible, for the individual themselves to notice or even for a caregiver to detect.

Details on the Behavior Analysis process are given in section 8.5 where the Behavioral Modeling Component is described. Three categories of behavior are monitored and analyzed by the system:

- Social Activity: i.e. Degree of participation in socialization events, preferences of activities etc.
- Physical Activity: i.e. walking activity levels.
- Abnormal Activity: i.e. Number of falls per week/month.

The system automatically generates reports summarizing the results of the analysis for a chosen time period—one week, two weeks, monthly. Consequent values can then be compared and deviations from pre-recorded values are revealed to facilitate timely intervention in cases of subtle changes.

Even when no striking deviations are generated between two given time periods, the full sequence of values illustrates the magnitude of the change in the number of event occurrences over time or the total distance covered and as a result, allows for gradual and steady changes in behavior to be observed.

Chapter 7

System Requirements Specification

7.1. Use-Case Scenarios Modeling

The careful survey of user characteristics, surroundings, activities and accurate documentation of needs lead to the phase of the Service Scenarios Modeling. The main objective of this phase is to provide service concepts that meet the needs of the users as closely as possible, are mobile and are as easy to use as possible for the special group of elderly users. The results will be used to guide the platform design and the development of the ICT services.

During the identification of user needs, special attention was given to the importance of maintaining and developing social relationships and the necessity of health and safety services. The importance of mobility and providing reminders was also emphasized. Six service concepts are designed during the Services Creation phase.

In order to capture the detailed user needs and requirements and to determine which ICT services to implement the software modeling process of Use-Cases is being used. In this process the specifications are expressed independent of platform and technology. Unified Modeling Language (UML) methodology is used ensuring that the specifications can be further instantiated / implemented in any particular technology.

Each Use-Case focuses on describing how to achieve a specific goal or a task needed by the system users. It describes the interactions with the system, including system responses, as these are perceived as from outside the system.

7.2. Environment Actors and Components

As an introduction to the Use-Case diagrams the following figures present an overview of the main actors and components involved in the system environment.

- **System actors** interact with the system either as produces or consumers of services.
- **Environment components** include assistive systems, sensor systems, database systems etc. supporting the system.

Details about the interactions of each element in the system are provided in the following scenarios.

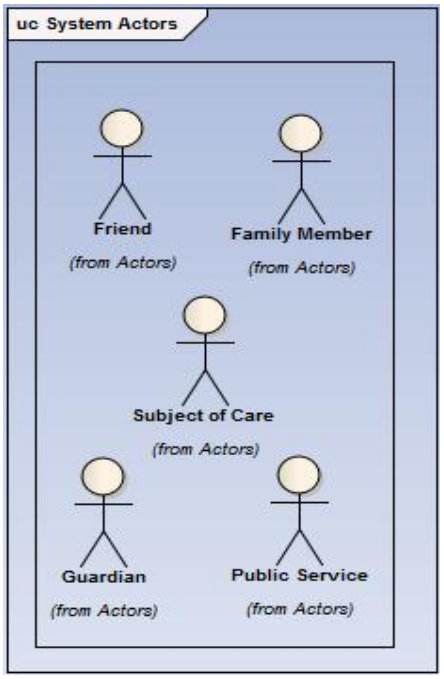

Figure 6: System Actors

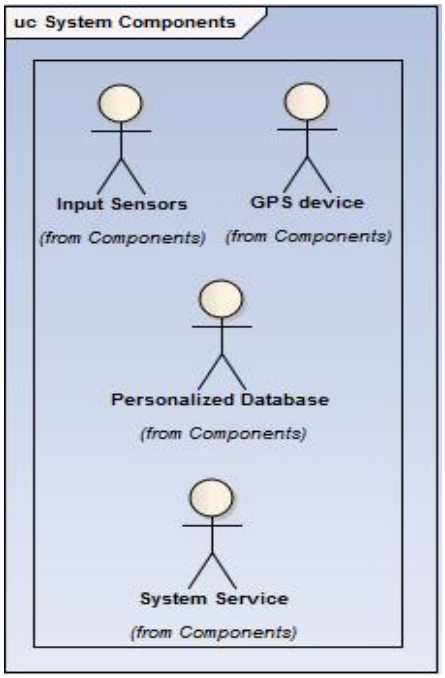

Figure 5: System Components

7.3. Scenario I: Emergency Monitoring

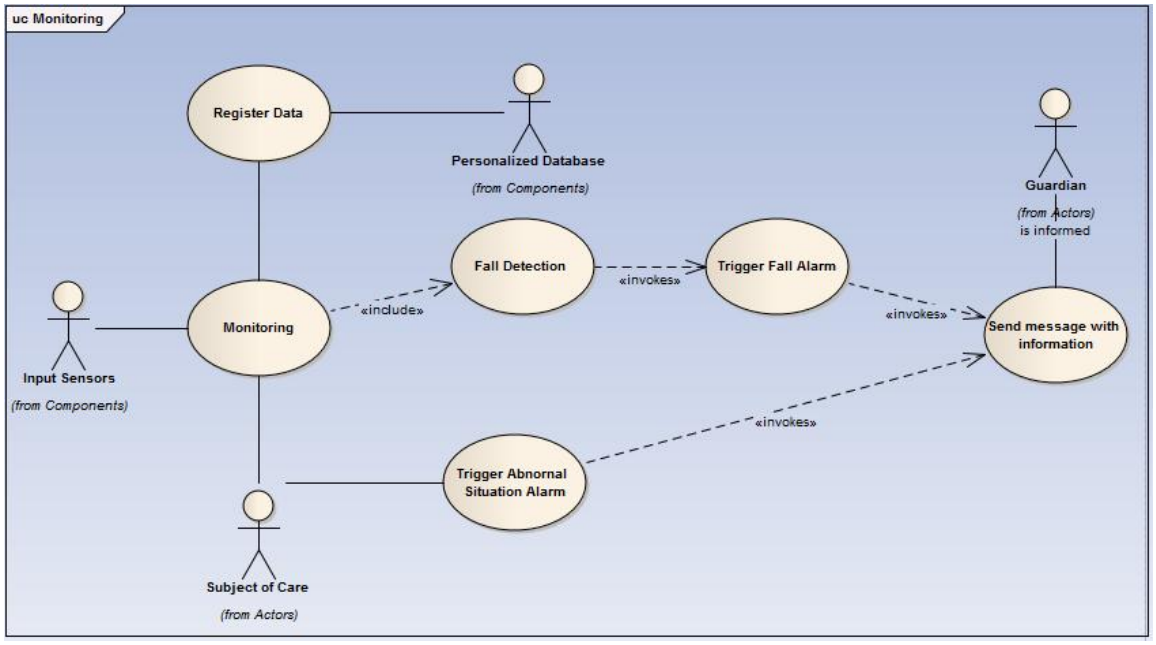

Figure 7: Use-Case Emergency Monitoring

The idea behind this concept is to offer constant safeguarding to the elderly to ultimately reduce accident related risks. With systematic monitoring and automatic alarm transmissions the users can receive help regardless of their location even though they are unable to send an alarm. The concept covers two basic scenarios. Immediate alerts are generated upon:

i. Automatic Fall Detection

For the first case, measurements from the embedded accelerometer device are monitored and compared against a predefined threshold value in a constant loop. Measurements below the threshold value are discarded but if a measurement surpasses the threshold value then a fall is identified. Instantly the device emits a loud prolonged noise, to attract the elder's attention on the screen, and displays two buttons: a green button with the message "I am ok" and a red button with the message "I need help". The sound is repeated until the user selects one of the two buttons. In the case that the green button is pressed then a false alarm is assumed and no alert is

transmitted. If the red button is pressed then a fall alert is issued and an SMS is instantly send over the mobile phone network to all the designated caregivers.

Nevertheless in the case of a fall it is very likely that the mobile device falls out of reach or that the elder is unable to respond by pressing any buttons. To cover this plausible scenario a one minute waiting period is set. If within this time frame the elder fails to respond by pressing one of the buttons then an alert is generated and send.

The one minute waiting period can be adjusted during pilot training to accommodate the specific conditions of particular users. For example it can be reduced to 30 seconds for an elder who has of greater risk of falls. However, it is not recommended to accept a further delay as the slightest delay could have severe consequences in an actual case of emergency.

The origin of the alarm can be traced with the help of the mobile terminal's geographic positioning system and be included in the content of the SMS along with the time of fall.

ii. Direct help request

The second case covered by the scenario allows the elder to physically request help at any time. This case is similar to a panic button scenario except that an innovative interaction method is employed. By a sharp movement of the device, generating the same motion that a fall would cause, the user can trigger the emergency mechanism. Once initiated the scenario continues to flow exactly like the first case. This service is intended to cover cases where the elder needs immediate help, either because he/she is feeling unwell, is lost or in any other emergency situation.

As an improvement of the concept it is determined that a mobile security bracelet could be added to the system in a way that the fall detection measurements will be more accurate and reliable. The bracelet will work as a transmitter linked to the mobile terminal using Bluetooth technology.

7.4. Scenario II: Motivation and Reminding

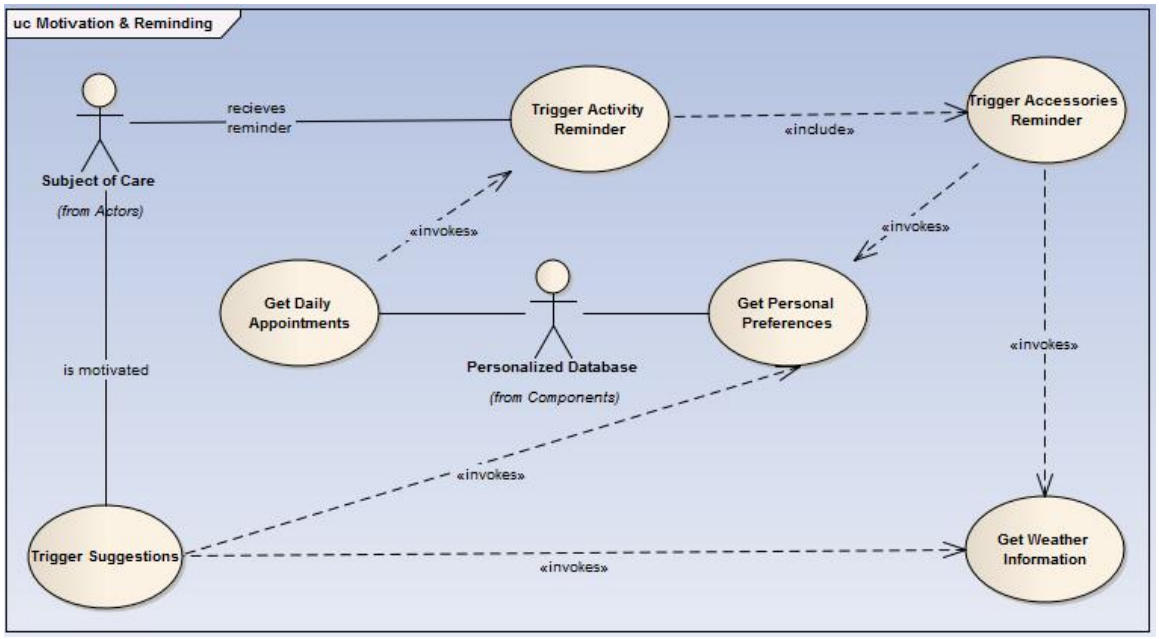

Figure 8: UC Motivation and Reminding

A lot of information is gathered by the system concerning the user's daily habits. The idea behind this concept is to utilize the collected data as input to a service that gives personalized real time "prompts" to users, reminding or suggesting them to participate in social and physical activities that may be of their interest.

i. Motivation

This service prompts suggestions to the user's screen in regular time intervals in order to motivate him/her to participate in social or physical activities. This way it promotes the maintenance of the social network of family and friends and also encourages the elder to stay physically fit.

Nevertheless, the prompts must maximize the likelihood of user response, and must be designed so as not to appear irrelevant, and, hence, annoying. The decision of which activity to prompt the user for is entirely based on the personal preferences and history of each user.

The service selects an activity from the user's personal profile, associates it with the most appropriate location and prompts a suggestion on the user's screen. The location is selected in two possible ways: the list of preferred locations is scanned to locate the closest possible match based on the user's current location or the location associated in the past the most with the specific activity is chosen.

The information is also cross-referenced with external factors such as the time of day or the current weather forecast. For example in a case of rain forecast the system will propose an indoor activity.

As a future improvement information gathered from the history of various members can be joined together to promote new social relationships. Members who have common points of history, such as having attended the same activities or regularly visit similar locations can be prompted with the same suggestions in order to be eventually integrated into common clusters.

ii. Reminding

Similar to the motivation scenario is the reminding case. Two types of reminders are provided:

i. Related to activities in which the elder planned to attend
ii. Related to accessories that the elder needs/wants to carry (i.e. stick, glasses)

Reminders are displayed on the screen the same way as the suggestions. The database is queried searching the user's schedule for activities in the near future. If an activity is coming up then the system prompts an audio signal and displays the relevant information on the screen. Reminders

for necessary accessories are incorporated in the suggestion or reminding prompts. For example, if the user is suggested a walk to the park he is also reminder to carry his walking stick.

7.5. Scenario III: Mobility

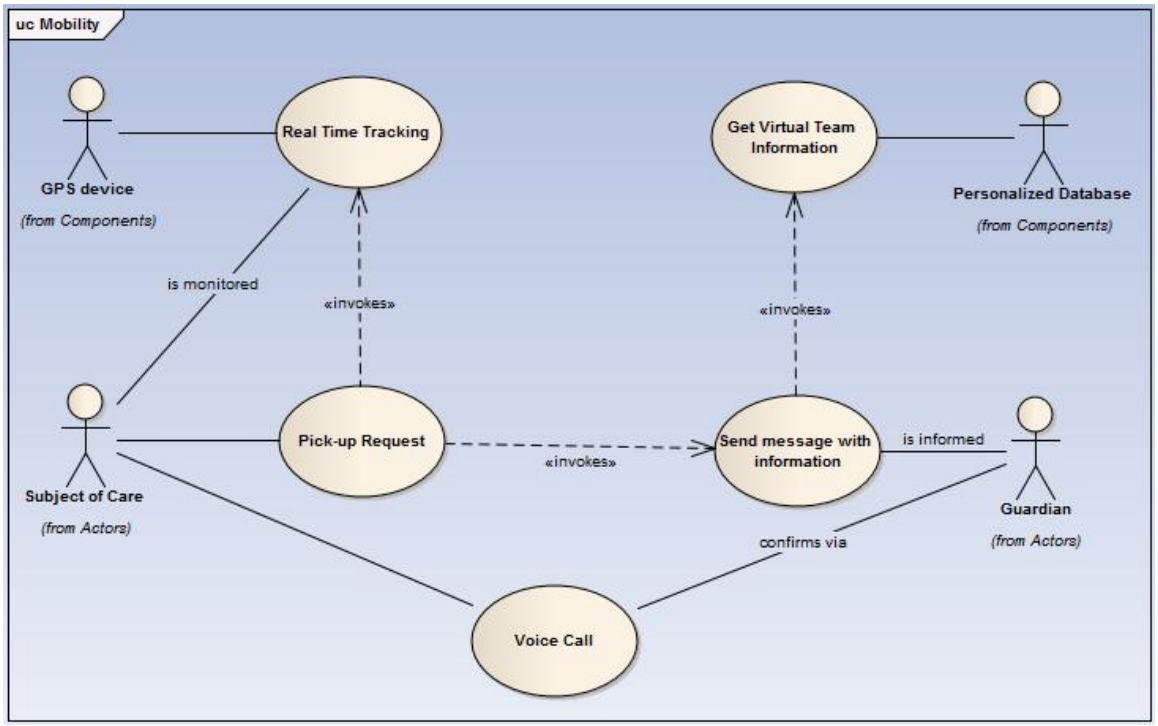

Figure 9: UC Mobility

By reassuring the elder that a caregiver will be able to locate and pick him up at any given moment then he feels more confident getting out of home and moving independently in outdoor environments.

This service enables the elder to request to be picked up from his/her current location at any moment. In ideal circumstances the system's GPS receiver will identify the coordinates of the elder and match them to the closest location found in the user's profile. This way the elder only has to confirm his location and select the member he prefers to inform. In the case that no matching location is found then all of the locations associated with the user are displayed on the screen and the user is asked to select his current location among them or select an unknown

position. Before the pickup the designated caregiver is asked to contact the elder to confirm the details i.e. location, time, destination etc.

7.6. Scenario IV: Socialization

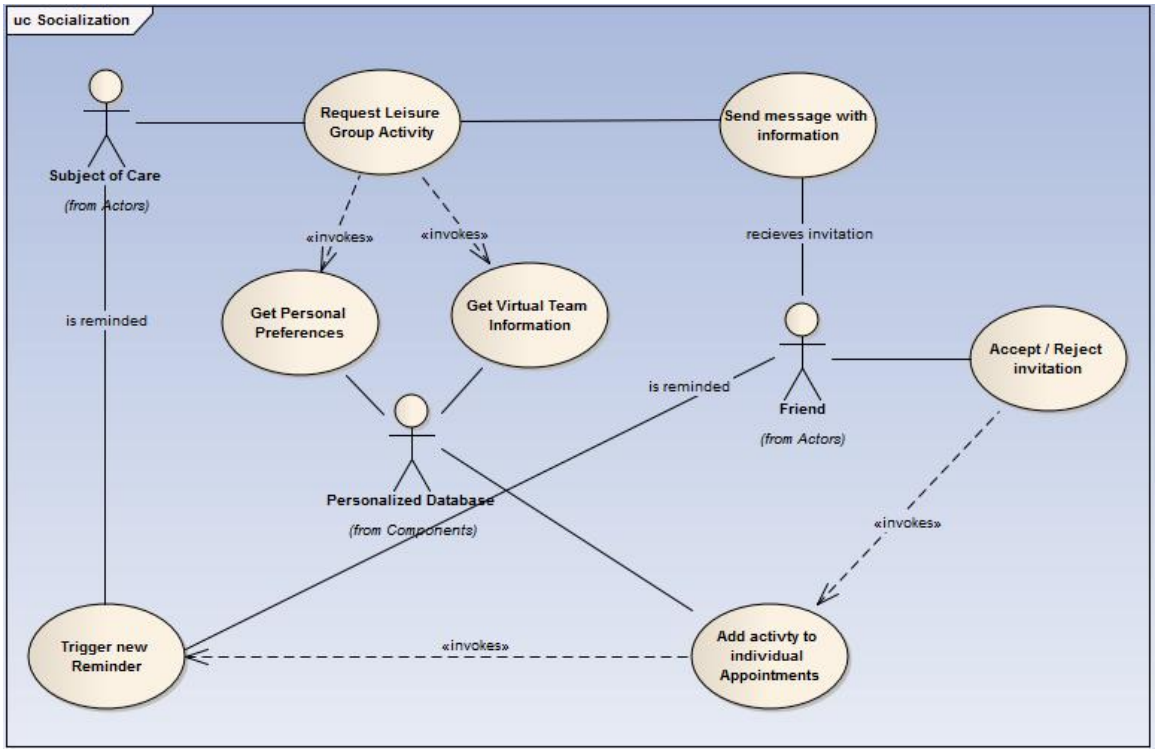

Figure 10: Use-Case Leisure Group Activities

In Concept IV the user is assisted in the organization and participation in leisure activities with other members. A basic description of the scenario is the following: The elderly user can invite members of his virtual group to share common activities. The user creates an invitation for the activity and members are invited to join. Based on their response an activity group can be created. This service is highly personalized. All the information displayed on the interfaces is adjusted to match the unique preferences of each user and thus simplify interaction with the system. All the necessary data are extracted using personalized queries from the user profile and are displayed after being ranked by order of preference according to the classification of the user. This process is presented in detail in Chapter 10– Section 10.1.

As a first step the user is asked to select an activity. All the activities included in the profile are displayed starting from the most interesting for the user. Once the activity is selected the procedure proceeds as follows: the personal profiles of all the members of the elder's network are filtered aiming to locate users with both the right role (friends) and who are interested in the activity chosen. Only the members matching this description are displayed on the second screen and the user is asked to select the guests. This way no user can receive invitations to join activities which do not interest him/her.

Subsequent screens include location selection, also displayed with order of preference, and time/date selection. Once all the information is given invitations are sent to the guests via SMS messages over the mobile phone network. They can either accept or decline the invitation with a YES or NO response.

7.7. Scenario V: Communication

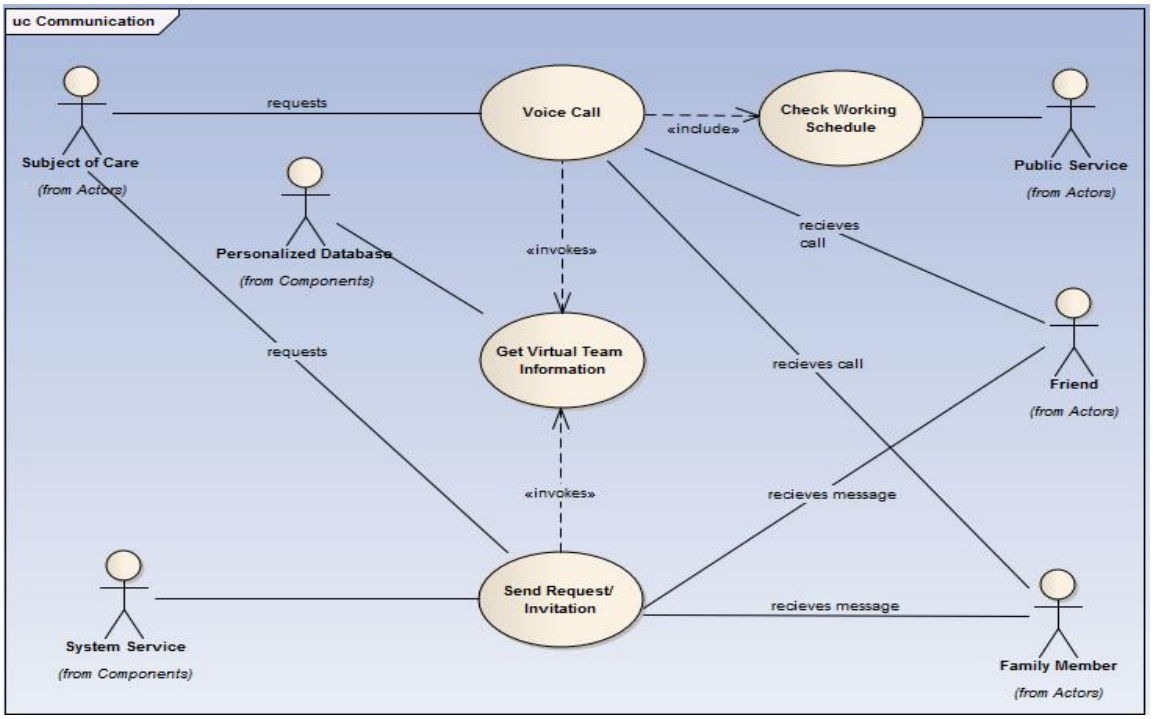

Figure 11 : UC Communication

The specific service facilitates the phone communication with relatives, friends and service providers. The interface is especially simple, picture based with no need for number dialing. Initially the three categories are displaced on the screen and the user selects one. In the next screen all the contacts belonging to the selected category are displayed, one image per contact. If the user has selected the "family" category then images of all the registered relatives will be displayed. Once the user selects an image a phone call is initiated.

7.8. Scenario VI: Trend Reports

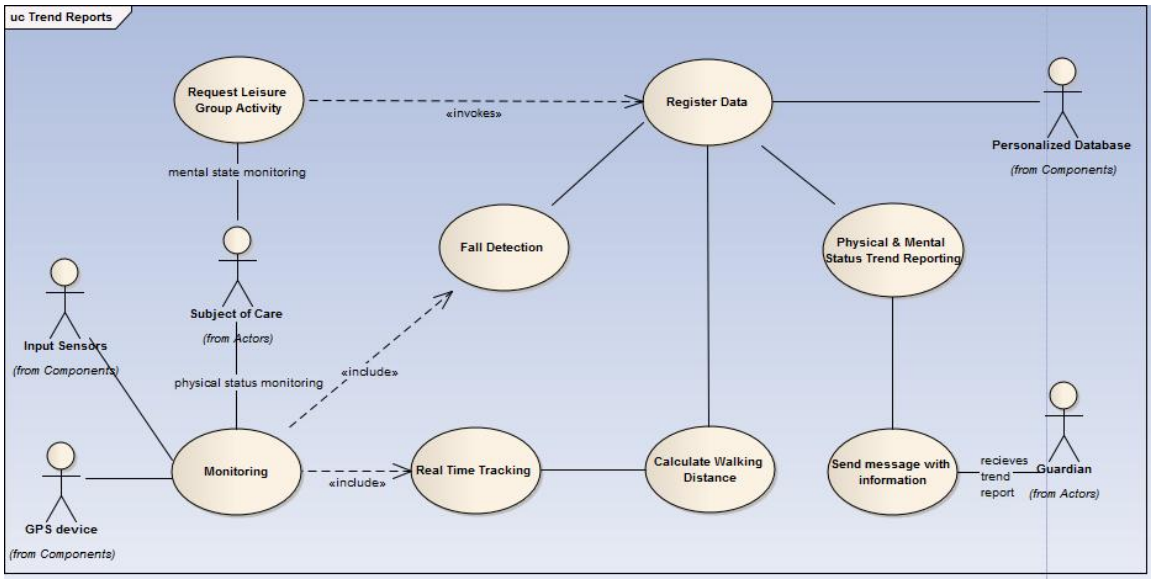

Figure 12 : UC Trend Reports

The goal of this service is to use data collected during monitoring to keep the care givers informed about the effects of the elder's lifestyle choices and changes.

The service does not involve any participation from the elder. Trend reports are automatically generated and provided to the care givers in the form of short SMS messages on a daily, weekly or monthly basis.

The information is generated by processing the data stored in the databases and includes conclusions about the elders' physical or cognitive status. More details on the information motored are included in Table 1: Trend Domains of Chapter 8.

Chapter 8

Platform Design and Implementation

8.1. Overview of the Personalized Care Platform

For the Use-Case Scenarios designed during the System Requirements Specification phase to be transformed into actual technological ICT services it is necessary to design a monitoring and analysis platform consisting of economically deployable mobile smart devices and embedded pervasive sensors.

The objective is to permit automatic and non-intrusive gathering of rich personal datasets of behavioral and physical information. This data will be analyzed and used as input for the different ICT services to provide improved personalized care.

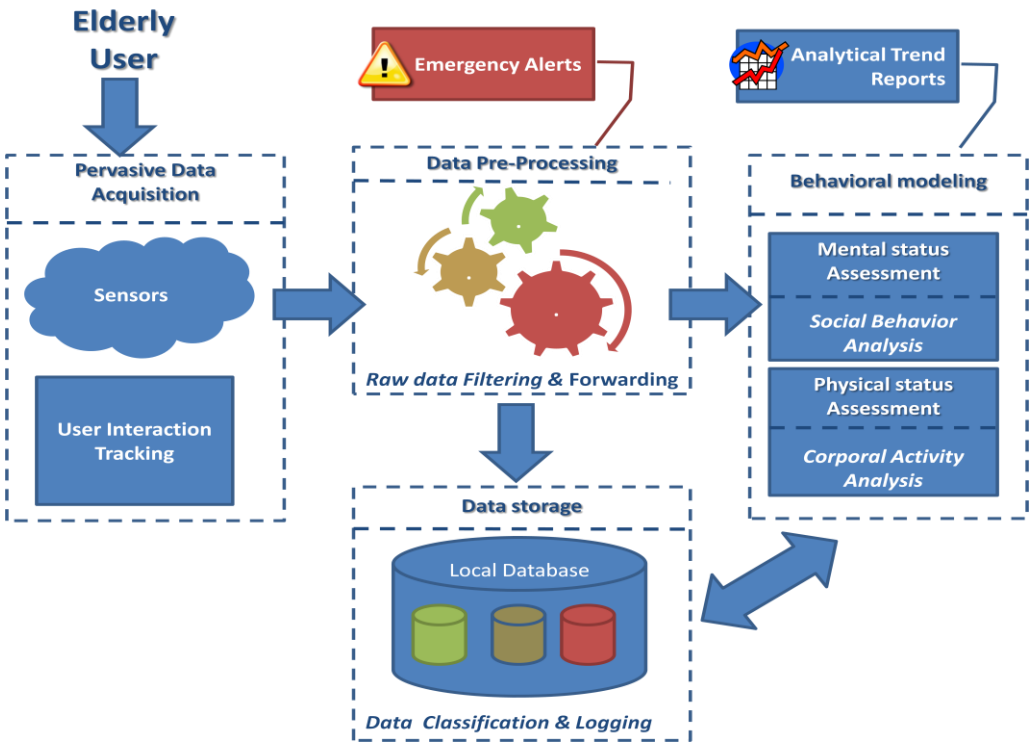

Figure 13: Platform Architectural Design

Figure 13 presents the overall architecture of the Personalized Care Platform. The system is designed to be highly interoperable (usable across many hardware devices) , transparent to the user and researcher for ease of extensibility with further services, and plug and play on any suitable smart device for ease of installation.

At a conceptual level, the platform consists of four components, as seen in
Figure 13. First, the "**Pervasive Data Acquisition Component"** is constantly capturing raw data in a form that is quickly accessible for manual interpretation or automatic analysis. It is divided into two major modules: the "**Sensor Enabled Tracking"** module contains a set of pervasive sensors that capture data related to the physical health of an individual and the "**User Interaction Tracking"** module monitors the user's response and handling of the system. Second, the "**Data Pre-Processing Component**" accepts the raw data streams generated by the sensors in the first component. These data are continuously filtered and pushed into the third component, "**Data Storage Component**" which performs classification and direct storage in personal databases embedded on the smart device. Fourth, the "**Behavioral Modeling Component**" includes an assessment module which produces analytical reports with relevant information and recommendations concerning the health and behavior of the elderly. This component can assist social and healthcare caregivers to monitor the elderly, perform domain specific analyses, and provide more effective care based on the unique identified needs of each user.

- **Component 1 - Pervasive Data Acquisition**

Human behavior reflects the emotional and physical health of a person. The basic goal of the first component of the architecture is to measure variables related to physical and social behavior during the daily activities of the elderly. All the raw data are captured in a form that is quickly accessible for manual interpretation or automatic analysis. The component is divided in two modules:

- **Sensor Enabled Tracking**

The module contains components that capture data related to the physical health and setting of an individual. It is a fully automated data acquisition system consisting of two commercially available off-the-shelf wireless sensors, namely an accelerometer and a location-tracking device (GPS receiver). These components act as monitoring units gathering in real time on a daily basis a great amount of data concerning the geospatial location, walking speed and movement of the user.

As the entire scheme is designed based on the principles of pervasive monitoring the sensors are effortlessly embedded in the smart device that hosts the software. Therefore, the individual is not required to wear any special equipment and can continue to undertake her/his normal activity as if the system were not in place.

- **User Interaction Tracking**

The purpose of this module is recording the ways in which elders respond to each other and to the system. All the data gathered compose the user's personal history. The other components use these personal records to automatically extract relevant information and detect social interaction patterns as well as interface interaction patterns.

Every time the user employs the system to attend a social event with other members the episode is detected by the module and forwarded along with all relevant details (activity, time, location, participants etc.) to the "Storage Component" where it is logged in a personal database.

Changes in interface interaction patterns can reflect changes in the emotional status of a patient. If the elder suddenly shows no interest in using the device then a possible change in his emotional status can be inferred. If the user uses some services more often that others then emphasis should be given on those services to match the user's specific personal needs.

- **Component 2 - Data Pre-Processing**

A significant amount of raw data is generated daily by the sensor devices and by tracking the user's interaction with the system. The pre-processing component continuously collects readings from the separate modules in component one and is responsible for filtering and pushing selected raw data to the right software component for further processing, storage or direct handling.

Data received from sensor tracking module, namely from the accelerometer device, is monitored and compared against a predefined threshold value in a constant loop. If the current measurement surpasses the threshold value then a fall is identified. This critical information must be immediately reported back to the caregivers in order to assist the elder and evaluate the gravity of the situation. An alert is directly generated and send to the designated users before the measurements are pushed to the following layers for logging and analysis. Measurements below the threshold value are discarded. Location-tracking measurements (geographical coordinates) and data relevant to system usage, coming from the User interaction tracking module, are automatically forwarded to the following layer to be logged and analyzed.

- **Component 3 - Data storage**

The purpose of the component is the production of a behavioral record that could subsequently be subjected to trend analysis. All the data that reach this level are date/time stamped, classified and logged in individualized user databases on the smart device. Periodically data logs should be transferred from the smart device to a secure central data server through an Internet connection. The local databases store timely and accurate information composing the user's personal history record.

- **Component 4 - Behavioral Modeling**

Care providers usually do not have the time or expertise to interpret large volumes of data generated by smart sensors. For this reason, the Behavioral Modeling Component of the system is

responsible for extracting useful information concerning the user's physical and emotional status based on the available records.

This can be characterized as the "analytical component". Here data from the individual databases are translated into information resulting to clear and easily understandable trend summaries for the care givers including the effects of the elder's lifestyle choices and changes. Furthermore the system reports back to the elderly real time feedback on their behavioral habits.

Human behavior reflects the mental and physical health of the subject. [32] Two behavioral assessment schemes are designed. The one provides insights relevant to the elder's emotional/mental status and the other relevant to physical health.

Daily habits and social behavior reveal information about a person's mental condition. Tracking an individual's participation in daily socialization activities, i.e. interaction with group members, allows the system to judge cognitive and psychological well-being.

The assessment component counts daily the number of events specified as "socialization activities" and produces average values for designated time periods—daily, weekly, monthly. Constant comparison of these value over measurements of the past day, week, and month expose deviations in a person's behavior. Trend reports are provided to the care givers in the form of short SMS messages including all the information. Similar reports are generated for physical status including daily/monthly walking distance etc. The Chapter "The Care-Giving Pyramid" includes more details on how the output of the assessment modules is generated.

8.2. Personalized Database Infrastructure

This section describes the database design of the platform, implemented to cope with the user requirements identified in section 4.3. Apart from storage point the database serves as a rich repository of user profiles providing data for personalization algorithms and behavior analysis.

The main storage components are local databases kept on each user's smart device. These are designed to store timely and accurate information composing a personal history record for each

user. Raw measurements coming from the sensor devices and data gathered by the software system are immediately date/time stamped, classified and logged in the local individualized databases.

Access, management and processing of all data related to user's desires, needs, and preferences for services, is made locally, through application code running on the personal mobile device which users carry. As a result mobility of the user is not restricted in any way.

This model guarantees constant availability, meaning that the platform can function continuously in an "offline" environment independent of any sort of network connections linking it to a centralized server since all data are available locally. Lack of connectivity does not affect the operation of critical real time applications like Fall Detection that requires a 24/7 operation[3].

However, due to the restricted memory capacity of the end-user devices and for safety purposes all data logs should be periodically transferred from the smart device to a secure central data server where they are backed up.

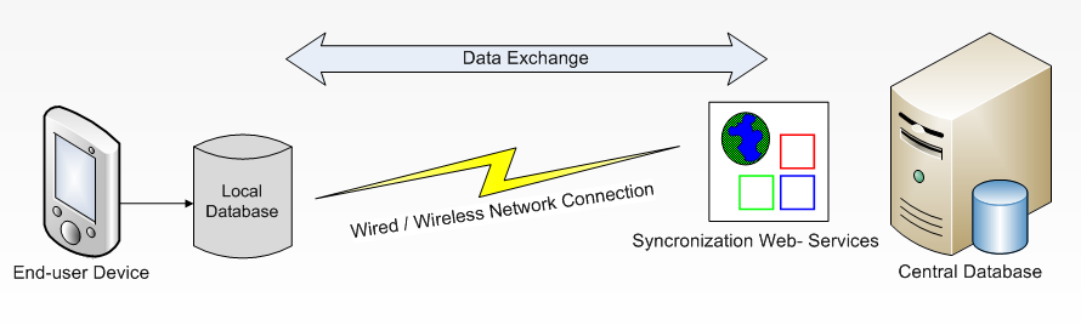

Figure 14: Data Synchronization

Synchronization of the local database with the centralized database is made through Web Service applications. These are stored in the central database and are access through an Internet wired or wireless connection. The application code handles the update of all the data tables. The exchange of information is two-directional meaning that new data can inserted in the central database to

[3] However the Fall Detection Service does rely on availability of a GSM network.

update the profile of the user and during the synchronization process these will be transferred to the local database on the device.

All the code developed for the Database Synchronization component is available in Appendix B.

8.2.1. Database Schema Definition

This section includes an individual description of all the modules used by the system in order to cover the several Service categories identified in earlier stages. Figure 15: Database Schema Definition presents the complete Database Schema.

User Profile: The User Profile module is responsible for the administration of all users in the system. The two existing user types are either an Elderly user or a member participating in a Virtual Team of the Care Community. The module, which is described in detail in a subsequent section, ensures that each individual will have a unique personalized profile of disabilities and abilities, special needs and preferences such as activities, and visiting locations promoting thus personalized care provision. The module consists of the following tables:

- **PERSON**

This table stores all personal details regarding the users.

- **PREFERENCES**

This table includes a list of all possible preferences the user might have. These may include notification preferences, system usage details such as preferred details of the screens etc.

- **PERSON_PREFERENCES**

The table keeps records of the many-to-many relationship between the Person and Preferences table. This states the unique personal preferences of each system user.

- **ACCESSORIES**

This table includes a list of all possible accessories used by the elderly system users. These may include glasses, walking stick etc.

- **PERSON_ACCESSORIES**

The table keeps records of the many-to-many relationship between the Person and Accessories table. This states the unique personal accessories carried by each system user.

- **SKILLS**

This table includes a list of all possible skills that the system users –elderly of team members- might care have. These may include profession or other specialized skills that users care to share with their team member

- **PERSON_SKILLS**

The table keeps records of the many-to-many relationship between the Person and Skills table. This states the personal skills each system user cares to offer to the rest of the Virtual Team members.

- **ACTIVITIES**

This table includes a list of all possible activities found to be of interest to the group of elderly people. This include chess, backgammon etc.

- **PREFERED_ACTIVITIES**

The table keeps records of the many-to-many relationship between the Person and Activities table. This states the unique and personal selection of activities in which each system user is interested in.

- **SERVICES**

This table stores details of various public services which are of interest to the elderly. The user can view information and be directly connected by phone during working hours.

- **WEATHER**

This table stores daily weather information such as temperature, weather forecast details etc.

Localization: The Localization module covers monitoring services developed for the early detection of limitations in mobility of the elderly, the fall detection service, and the service providing transportation of the elder to and from various locations. Necessary tables include: geographical information such as longitude, latitude and address of all the locations that interest the person (i.e. parks, supermarket, local church etc.), geographical locations and timestamps from continuous GPS readings, records of recorded falls associated with location and time etc.The module consists of the following tables:

- **GPS_LOCATIONS**

This table keeps geographical information such as longitude, latitude and address of all the locations that interest the systems users. (Parks, supermarket, local church etc.)

- **GPS_LOG**

This table keeps a list of geographical locations and timestamps. Each time a new GPS reading is made for a specific user it is added to the table, updating the log with the latest information of the user's location.

- **PREFERED_LOCATIONS**

The table keeps records of the many-to-many relationship between the Person and GPS Locations table. This states the unique different locations that interest each user.

- **FALL_HISTORY**

The table keeps records of any recorded sudden fall of a user. Based on the GPS measurements a fall can be detected and details such as location and time are registered in this table for observation purposed.

Appointments: The Appointments schema covers the Socialization service. It includes a table to store details of messages exchanged between members of the Virtual Teams and serve as invitations for various types of activities. Another table stores details of appointments set by system users. After an invitation is accepted a concrete appointment is set up including the attending user, date, time, location of the meeting, activity and other relevant information. The records serve as a personal schedule. The module consists of the following tables:

- **MESSAGES**

The table stores details of a message send by one member to other individual users or entire Virtual Teams. The same entity can be used as an invitation for various types of activities since the basic functionality is the same, deliver the message to the recipients and wait for a response.

- **APPOINTMENT**

The table stores details of appointments set by system users. After an invitation is accepted a concrete appointment is set up including the attending user, date, time, location of the meeting, activity and other relevant information. The records serve as a personal schedule since if a user is bound to an appointment then he is unavailable to attend any other activities simultaneously.

Virtual Teams: The Virtual Teams schema is responsible for the organization of the members of the Virtual Community in to teams. It includes tables that hold information associating members to specific roles and teams. A user may be included in various Virtual Teams and is assigned a different role in each (Elderly, neighbor, daughter, son etc.).The module consists of the following tables:

- **VIRTUAL_TEAMS**

This table stores registration information about a Virtual Team built around an elderly center user.

- **VIRTUAL_TEAM_MEMBERS**

This table implements the many-to-many relationship between the VIRTUAL_TEAMS and PERSONS tables. A user may be included in various Virtual Teams and possibly have a different role in each.

- **ROLES**

This table holds a list of possible Roles a user can obtain in the system. (Elderly, neighbor, daughter, son etc.)

- **VT_TYPES**

This table holds a list of possible team types built around the elderly. (Family, Social workers, Friends, Neighbors etc.)

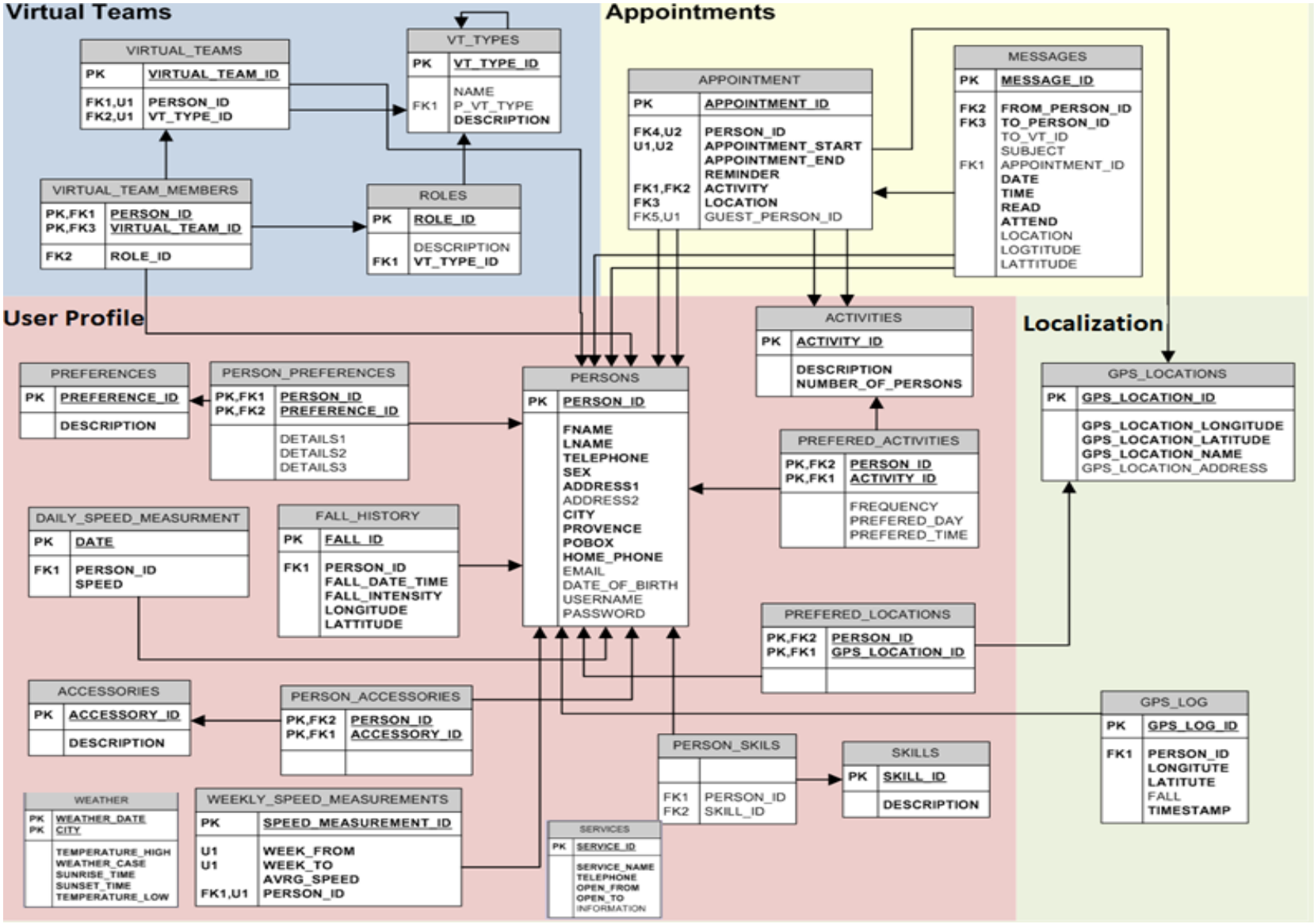

Figure 15: Database Schema Definition

8.2.2. Virtual Care Team Database Organization

As described in detail in Chapter 1, each elderly user has a Virtual Care Community around him including all the members involved in their care cycle. These people and may or may not be professional caregivers (family members, friends, neighbors, medical staff etc.).

Figure 16: Virtual Care Team Organization depicts the structural organization of the Virtual Teams in the system database. All the entities presented here correspond to actual data tables in Figure 15: Database Schema Definition.

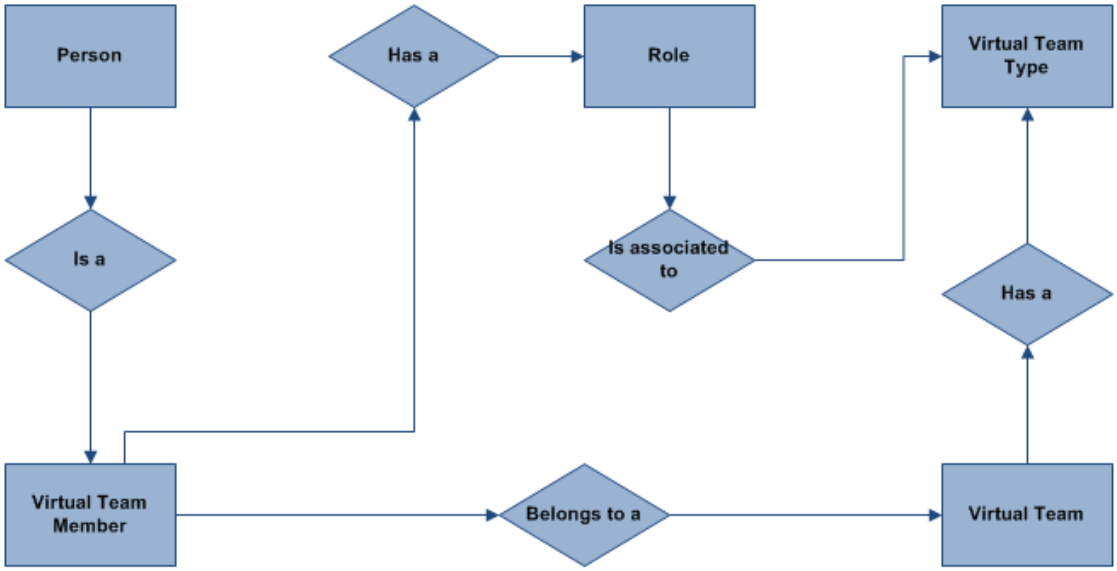

Figure 16: Virtual Care Team Organization

All the individuals who provide care are eligible team members. Apart from the elder himself, each team member is represented by an entry in the PERSONS table where all the personal information is kept. Each person is registered as a VIRTUAL TEAM MEMBER belonging to a VIRTUAL TEAM. A user may be included in various teams and have a different ROLE in each. Each VIRTAL TEAM TYPE has specific ROLES associated to it. For purposes of better organization and to better coordinate the care related activities, the general community is divided to various smaller teams, each with explicit type and responsibilities. Therefore every time a new

VIRTUAL TEAM entry is added to the system it must be associated with a VIRTAL TEAM TYPE.

The most common sub-team types (VIRTUAL TEAM TYPE entries) and their associated ROLES are presented in Table 5: Database Entries Related to Virtual Teams. The presented team types are described in detail in section 5.2. Each of the ICT services of the system is associated with one (or more) specific sub-team. As an example, the scenario presented in Figure 10: Use-Case Leisure Group Activities is associated only with the sub-team of "Social Connections". If fact specifying even more this service only considers members belonging in this sub-team and also have the specific role of "friend". This way the retrieval of information from the database is more efficient as the queries do not consider the entire Virtual Care Community records to retrieve the appropriate members (i.e. Care professionals are of no interest for this service).

VIRTUAL TEAM TYPE	**ROLE(S)**
Primary contacts	Daughter, Son
Family connections	Daughter, Son , Grandson
Social connections	Friend, Neighbor
Care professionals	Care Center Employee

Table 5: Database Entries Related to Virtual Teams

A basic characteristic of the Virtual Care Community is the fact that it is dynamic. Virtual teams can be created or updated or new team members can be added to existing teams at any time. To create or edit existing teams of the Virtual Community an elder it is necessary to update in the database all the data tables included in the Virtual Teams schema (see Figure 15: Database

Schema Definition). These tables are: VIRTUAL TEAM, VIRTAL TEAM TYPE, VIRTUAL TEAM MEMBER, and ROLE. In the case of adding to the teams members that are new to the system a new entry in the PERSONS table, from the Users Profile schema, is also necessary.

8.3. The Personalized User Profile Model

The approach of this work to personalization is based on maintaining a repository of user information, including for every person a private profile whose structure includes all the attributes describing the context of a person.

User profiles have been broadly used for information retrieval and filtering [33-35] of text-based data items [36]. Preferences and wishes are key components of personalized applications [38]. Therefore, apart from traditional user characteristics (demographic information etc.) a personalization system requires a carefully dealing with the user's wishes and preferences [37].These can be either provided explicitly by the user or are collected implicitly by monitoring the user's behavior.

In typical user profiles it is possible to identify various representation types for preferences. They can be stored as single or multiple keyword vectors, unconditional or conditional fields etc. Systems based on traditional SQL treat preferences as hard constraints [36] meaning that they are either satisfied or not satisfied at all. On the other hand, if preferences are treated as soft constraints, they should be fulfilled as closely as possible and may be associated with a number indicating user satisfaction depending on how close a value is to the preferred one[36].

In this work a user profile model is developed that contains all the information related to the user's preferences. All the data are represented as unconditional, single or multiple-value fields expressed as hard constraints (i.e. a user either likes playing cards or doesn't). Furthermore, each preference is associated to a number, named "Degree of Interest", which indicates the user's interest in this preference (see section 8.3.2 for details).

8.3.1. User Profile Contents

In real life a set of a user's preferences may hold in general, whereas others vary due to different situations. For instance, a user may have different activity preferences depending on his location or on the time of day. In order to integrate such situations into preferences a generic user profile model is developed. Four types of components are identified which define a user's personal state - and consequently his preferences- at any given moment:

- Long-term explicit preferences
- Temporal preferences
- Surrounding Influences
- Special needs

Such values for an actual situation can be queried from the system, gained from user input, Internet sources or calculated via sensor devices such as GPS trackers or accelerometers.

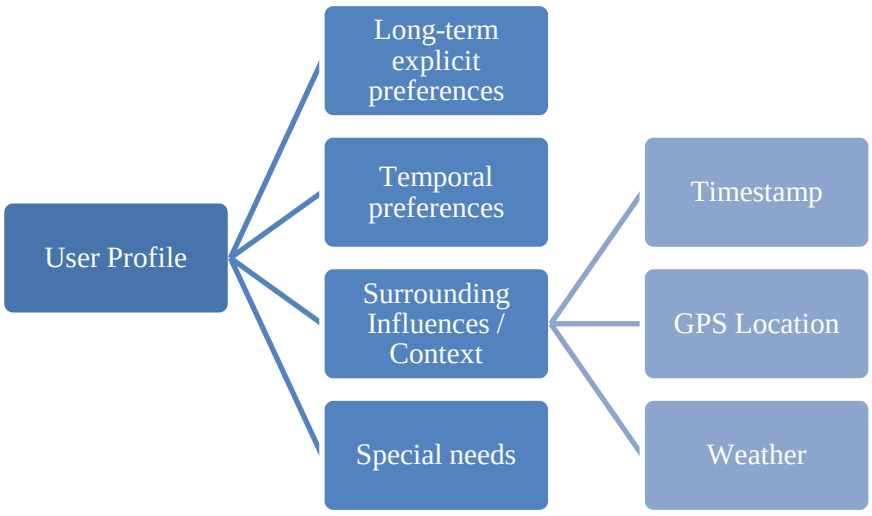

Figure 17: Generic User Profile Model

As seen in

Figure 17 the abstract **User Profile** model contains all the attributes describing the context of a user. Long-term explicit preferences, temporal preferences, Surrounding Influences and Special needs are sub-entities.

- **Long-term explicit preferences**

In general each person has a set of preferences which are typically changeless over long periods of time. In a social context these include favorite activities (i.e. cards, theater) meeting locations (i.e. park), and group of friends. In terms of daily living, long-term preferences include a selection of public or private services that someone uses frequently. Such preferences can either be explicitly set by the user himself or be extracted implicitly by monitoring user interaction with the system. In the database tables, explicit preferences are represented in terms of a single or multiple keyword vectors and are associated with a "Degree of Interest" value (see section 8.3.2 for details).

- **Temporal preferences**

Temporal preferences are usually application-specific and hold in exactly one situation. For example a user decides to participate in a group activity. Among his permanent preferences he selects a specific one, i.e. a card game. The system has to respond according to this temporal preference which is not guaranteed to be the same the next time the user organizes a new activity.

- **Surrounding Influences**

Outer influences relevant to a person's current state like the physical location, time of day, or current weather. Location is given in the form of global positioning system coordinates provided by the embedded GPS tracking sensor. The spatial information can be used to track other people currently located near the user or to deliver regional related information (i.e. weather) etc. Exact time and date help to present the right information at the right time. They are described by SQL data types relevant to timestamp. Weather condition is used to provide appropriate suggestions

concerning activities a user can perform or necessary accessories when going out. It is downloaded from online providers.

- **Special needs**

It is common for people of old age to suffer from various disabilities and thus have specials needs. For example physical disabilities relevant to walking may force an elder to carry a walking stick, visual impairment means wearing glasses etc. Special needs of such type have a serious impact on a person's status and must consequently be appended in each personal profile.

8.3.2. The "Degree of Interest" value

As stated above, user preferences stored in the user profile are accompanied by a "Degree of Interest" associated with each preference to expresses the interest of the user to it. This value is represented by an integer number in the range [1, n] where 1 corresponds to the lowest preference and bigger values indicate higher preference. The value changes dynamically.

In practice, all explicit preferences in a newly created user profile are associated with a "Degree of Interest" value of one. For example the preferred activities of cards and walking are given the value of one. Each time the user selects the activity cards, the associated "Degree of Interest" value is incremented by one. As a result activities performed frequently by the user have higher values to indicate that the user is more interested in these activities. The same holds for preferred locations, and can be applied for a variety of other preferences. Examples of how this is displayed in the database tables can be seen in Figure 23of section 8.6. The "Degree of Interest" value corresponds to the field PRIORITY of the data table.

8.4. Personalization Process

Having defined the structure and contents of the "User Profile" the next section turns to describe how this element can be used to achieve individualized user requests for the personalization of all

the services provided by the care platform. The personalization process is applied at the database query level by two types of algorithms.

The Services of the system rely on content from the database selected by issuing queries. The whole process is independent of any changes taking place in the user characteristics as the inputs of the algorithms are dynamically extracted from the user's profile and context at execution time.

8.4.1. General Query Personalization Concept

The general concept of the personalization algorithms in this work is inspired by the Query Personalization Framework presented by Koutrika G. et al. According to [36] Query Personalization is the process of enhancing a query with user-specific preferences stored in a profile.

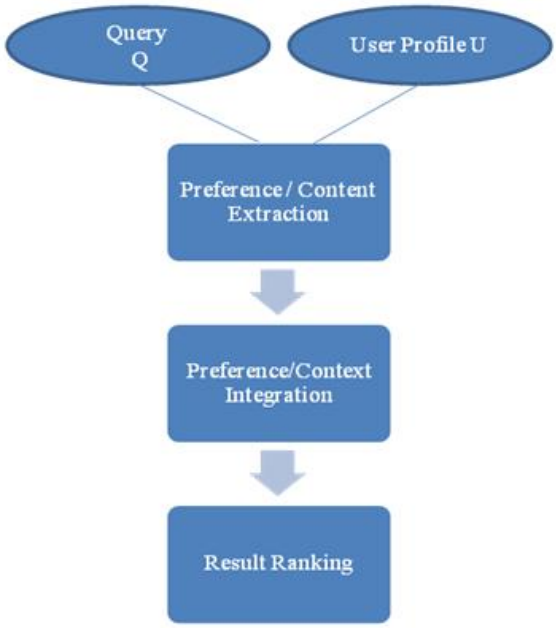

Figure 18: General Query Personalization Concept

Given a query Q, relevant to the service that is being personalized, and a user profile U, of the end user, the personalization algorithm structure proceeds in three phases:

1) **Preference / Content Extraction**

The set of preferences relevant to the given query are identified and extracted from the user profile or the context information is obtained from an external source.

```
SELECT * FROM PERSON_ACTIVTIES

SELECT * FROM WEATHER WHERE  WEATHER_DATE= @TODAY
```

2) **Preference/Context Integration**

The derived preferences or context are integrated logically into the default query producing a modified, personalized one, which is actually executed and generates personalized results for the user, i.e. results that satisfy his/her preferences. The following example integrates a temporal preference of the user (a selected activity) in a default query to return the members that are interested in this activity.

```
SELECT PERSONS.PERSON_ID,
       FNAME,LNAME
FROM   PERSON_ACTIVTIES JOIN PERSONS
       ON PERSON_ID
WHERE PERSON_ACTIVTIES.ACTIVITY_ID=@ACTIVITY
      AND PERSONS.PERSON_ID <> @USER_ID
```

At this step is it also possible to perform logical combinations of user preferences with other related fields. Using the Boolean operations ‘and’ and ‘or’ it is possible to construct complex conjunctive or disjunctive queries. The following example is an extension of the previous one, that returns again the members that are interested in the activity selected by the user but also

ensures that these members are the preferred friends of the user (the input value @ROLE is 'Friend').

```
SELECT  VIRTUAL_TEAM_MEMBERS.PERSON_ID,
        PERSONS.FNAME, PERSONS.LNAME,
        PERSONS.PERSON_MOBILE_PHONE
FROM    VIRTUAL_TEAM_MEMBERS
JOIN    PERSONS  ON PERSON_ID
JOIN    PERSON ACTIVTIES ON PERSON_ID
WHERE  ROLE_ID=@ROLE_ID AND
       PERSON_ACTIVTIES.activity_id=@ACTIVITY
```

3) **Result Ranking**

Execution of a personalized query returns a ranked list of results, where most interesting results (based on their estimated "Degree of Interest" value) come first followed by results that are less interesting to the user. It is easy to rank the results obtained in step 2 based on the "Degree of Interest" using an appropriate *order by* SQL clause.

```
SELECT  PERSON_ID,DESCRIPTION,
        NUMBER_OF_PERSONS, ACTIVITY_ID,
        PREFERED_DAY,PREFERED_TIME
FROM    PERSON_ACTIVTIES
WHERE   PERSON_ACTIVTIES.PERSON_ID=@USER_ID
ORDER BY PRIORITY DESC
```

This process of query personalization assembles a query using the various user preferences derived from the user profile. The results are returned ranked based on their "Degree of Interest" and can be presented on the User Interface in a personalized manner. For example, the activities

that interest the user the most will be displayed foremost on the screen, followed by other activities of less importance. This way there is a higher probability that the elder will not have to spend time searching for the desired selection. This process facilitates interaction and thus implicitly to encourages the elder to continue using the services since this is an easy task.

8.4.2. Preference-based Personalization Algorithm

The algorithm, presented in Figure 19, is directly related to and follows the steps of the scenario presented in Figure 10: Use-Case Leisure Group Activities. It takes as input a user profile U. The first step of the personalization process deals with the extraction of the queue A including the preferred activities from the user profile (table PREFERED_ACTIVITIES). Each activity element in this table includes apart from the activity description field to describe the "Degree of Interest" of the user. This is an integer number in the range [1, n] and is used to rank the preferences of the user. For example a value of 1 in the field "Degree of Interest" of the row of activity "Cards" indicates this as the activity of lowest preference. Bigger values indicate more preferred activities. In the second step the elements of the queue PA are ordered in descending order based on the "Degree of Interest" value meaning that the activities that most interest the user go to the head of the queue. Next the user selects one activity from the elements from PA. The selection A is then integrated into a new complex query to obtain the members of the Virtual Team of user U that have the role of friend and have the activity A in their preferences (tables PREFERED_ACTIVITIES, VIRTUAL_TEAM_MEMBERS). The results are extracted in queue F. The user selects one or more elements added to a new list F'. The next step is the extraction of the preferred locations from the user profile. These can also be ordered by the "Degree of Interest" and the user selects one of the queue elements L'. Finally the outputs of the algorithm are the three selections of the user: the activity A, a group of members F' and a location L'.

Preference- based Personalization Algorithm		
Input:	User profile U	
Output:	Activity A	
	Set of friends F’	
	Location L’	
1.	Retrieve PA←Preferred activities in user profile U	**[Query]**
2.	PA ← Order PA queue (by descending “Degree of Interest” value)	
3.	Display PA	
4.	A ← Selected activity from PA	[User Input]
5.	Retrieve F ← Friends interested in activity A	**[Query]**
6.	Display F	
7.	F’ ← Selected friend(s) from F	[User Input]
8.	Retrieve L←Preferred Locations in user profile U	**[Query]**
9.	Display L	
10.	L’← Selected location from L	[User Input]
11.	Return (A,F’,L’)	

Figure 19: Preference-based Personalization Algorithm

8.4.3. Context-based Personalization Algorithm

The algorithm, presented in Figure 20 takes as input a user profile U. The first step is to extract from the profile information the city of the user. This is used in the second step to get the current weather information form an online RSS source (Yahoo! RSS [39]). The next three steps deal with the extraction from the user profile U of the queue A including the preferred activities (table Prefered_Activities), queue C with the necessary accessories (table Person_Accessories) of the specific user and the queue L with the preferred locations (table Prefered_Locations). In the next step the most appropriate of the personal activities accessories and activities are selected based on the weather

information. For example for rainy weather prediction indoor activities and accessories such as umbrella are included in new queues A', C' and L'.

Context-based Personalization Algorithm

Input: User profile U

Output: Set of Activities A'

Set of Accessories C '

Set of Locations L'

1.	Retrieve L← User Location from profile U	**[Query]**
2.	Retrieve W← Current Weather forecast for location L	[RSS Feed]
3.	Retrieve A←Preferred activities in user profile U	**[Query]**
4.	Retrieve C←Necessary accessories in user profile U	**[Query]**
5.	L'← Selected from L locations related to weather condition W	
6.	A' ← Select from A activities related to weather condition W	
7.	C'←Select from C accessories related to weather condition W	
8.	Retrieve L←Preferred Locations in user profile U	**[Query]**
9.	Return (A',C',L')	

Figure 20: Context-based Personalization Algorithm

The data returned from the algorithm are used by the Service described in Figure 8: UC Motivation and Reminding to display to the User Interface the most appropriate suggestions based on the user's personal preferences and the current context (weather situation).

8.4.4. Performance of Personalization Algorithms

The two algorithms presented above execute queries on the data of the local database. A set of experiments were performed to explore the effect of the User Profile size and the Virtual Care Team size on the execution time of the Preference-based Personalization algorithm.

- Profile Size: represented by the number of rows in the tables PERSON_ACCESSORIES, PREFERED_ACTIVITIES, PREFERED_LOCATIONS.
- Virtual Care Team Size: the number of members of the Virtual Care Team, represented by the rows in the tables PERSONS, VIRTUAL_TEAM_MEMBERS.

The experiments were conducted both with realistic profiles (from the pilot trial data) and synthetic profiles, with varying Profile and Team sizes.

In realistic conditions both these sizes are limited, not exceeding 50 rows even in extreme situations. Consequently the queries, even if complicated, with various joins, do not delay more than 0-3 seconds. An important benefit for the performance of Preference-based Personalization algorithm the is the fact that the data required by these algorithms is available locally on the device therefore there is no additional network overhead to transfer the data from a remote server.

On the other hand, the Context-based Personalization Algorithm faces an important overhead in step 2 (see Figure 20) where an RSS feed must be obtained over the network. Depending on the type of the available connection this step can cause a delay of up to 1 minute.

8.5. Behavioral Modeling Component

The main aim is to design a component to monitor and analyze activities of the elder to allow for a proactive and early detection of age related changes and deviations from what might be considered normal behavior.

The component relies on the rich User Profile information (obtained from sensors and from monitoring the user's interaction with the system) and creates a model to observe gradual changes and trends that might signal anomalous physical or emotional behaviors. The model monitors

sublet changes in the social and physical activity of the user. When these changes are observed and compared over time they signal to the caregiver trends indicative of psychological deterioration or progression of a health condition.

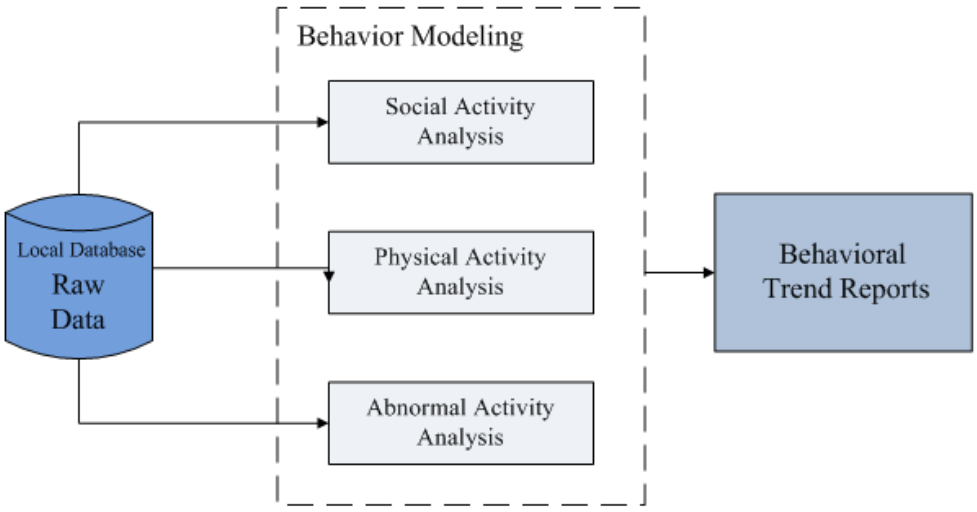

Figure 21: Overall Behavior Analysis component structure

Figure 21 shows the overall Behavior Analysis component structure. In the proposed method three different features are analyzed to extract the user's behavior patterns:

- **Social Activity:** Represents the user's emotional state. The weekly participation in social activities with other members value is calculated and is used to observe deviations across time. Lowering numbers indicate the user is less interested for social interaction. A caregiver is informed to discover the possible causes of this emotional decline.

- **Physical Activity:** Related to the mobility level of the user. Measures the distance covered walking by the user outside home. Deviations and lowering numbers can indicate the user's physical status might be affected. A caregiver is stimulated to find the possible causes.

- **Abnormal Activity:** For the system a fall is defined as an abnormal activity. Monitor how many times a fall incident is captured by the detection module. Frequent or consecutive incidences must be immediately addressed.

8.6. Inputs and Processing

This section describes the raw input data and the processing performed in each of the three Behavior Analysis components.

Table 6 summarizes the conclusions extracted in each component.

Social Activity	**Physical Activity**	**Abnormal Activity**
Participation in socialization events*(per Week/Month)*	Walking distance *(per Week/Month)*	Number of falls *(per Week/Month)*
Preference of activities		
Patterns of activity repetition	Time spent outdoors *(per Week/Month)*	
Patterns of location-activity association		

Table 6: Behavior Modeling Domains

8.6.1. Social Activity[4]

The inputs for this component are taken from the database tables APPOINTMENTS and PERSON_ACTIVITIES. The first keeps a log of all the social events in which the user participates or organizes. Details include the date and time of the event, the activity performed, the location etc. The log also includes any events in which the user was invited but did not participate.

[4] For confidentiality reasons all the database tables presented in this section include synthetic data for demonstration purposes only.

Database: \Internal Storage\REVIEW\localDB-APPOINTMENTS.sdf
Table: APPOINTMENT

ORGANIZER_PERSON_ID	APPOINTMENT_END	ACTIVITY_ID	GPS_LOCATION_ID	APPOINTMENT_ID	APPOINTMENT_DATE	ATTEND	APPOINTMENT_START
ΦΟΙΝΙΚΟΥ	21:39	4	5	34	9/05/11	(null)	2139
ΦΟΙΝΙΚΟΥ	21:39	1	5	33	9/05/11	(null)	2139
ΦΟΙΝΙΚΟΥ	19:4	1	1	23	30/10/10	0	194
ΜΑΡΟΥΛΑ	18:35	1	1	25	30/10/10	(null)	1835
ΜΑΡΟΥΛΑ	18:24	1	1	24	30/10/10	(null)	1824
ΦΟΙΝΙΚΟΥ	14:00	1	5	31	14/02/11	(null)	1400
ΦΟΙΝΙΚΟΥ	13:22	1	5	27	1/11/10	1	1322
ΦΟΙΝΙΚΟΥ	12:25	1	1	26	1/11/10	1	1225
ΦΟΙΝΙΚΟΥ	12:00	1	5	28	29/01/11	(null)	1200

Figure 22 : Raw data from table APPOINTMENTS

The table PERSON_ACTIVITIES keeps a list of all the activities that interest each user. The activities are also prioretized based on each user's personal preferences by the field PRIORITY that represents the estimated "Degree of Interest" (see details in section 8.3.2) of the user to each activity. The value of one corresponds to the lowest preference and bigger values indicate higher preference. The value changes dynamically ,and activities performed frequently have higher values. The column NUMBER_OF_PERSONS corresponds to the minumum number of members needed to perform a specific group activity. In this example a group of two peope is sufficient for all the activities.

Database: \Internal Storage\REVIEW\localDB-APPOINTMENTS.sdf
Table: PERSON_ACTIVTIES

PERSON_I...	DESCRIPTION	NUMBER_OF_PERSONS	ACTIVITY_ID	PREFERED_DAY	PREFERED_TIME	PRIORITY
ΧΡΥΣΩ	ΚΑΦΕΣ	2	1	(null)	(null)	2
ΧΡΥΣΩ	ΧΑΡΤΙΑ	2	2	(null)	(null)	1
ΧΡΥΣΩ	ΘΕΑΤΡΟ	2	5	(null)	(null)	1
ΦΟΙΝΙΚΟΥ	ΚΑΦΕΣ	2	1	(null)	(null)	11
ΦΟΙΝΙΚΟΥ	ΒΟΛΤΑ	2	4	(null)	(null)	1
ΦΟΙΝΙΚΟΥ	ΧΑΡΤΙΑ	2	2	(null)	(null)	4
ΜΑΡΟΥΛΑ	ΚΑΦΕΣ	2	1	(null)	(null)	2
ΜΑΡΟΥΛΑ	ΧΑΡΤΙΑ	2	2	(null)	(null)	1

Figure 23: Raw data from table PERSON_ACTIVITIES

After analysis a number of conclusions can be extracted from this information:

- The weekly or monthly social activity of the user can be monitored counting in how events he/she participated. A high number of events organized by the user can indicate a good

health state and stable emotional mood. On the other hand a big number of rejected or unanswered events can signal a possible psychological decline. A monthly report is generated.

- The preference of the user concerning activities can be observed. In the table PERSON_ACTIVITIES the field PRIORITY represents the estimated "Degree of Interest" of the user to each activity. Initially the field is set to have a value of one for all the activities in the table. The value of one corresponds to the lowest preference and bigger values indicate higher preference. The value changes dynamically, every time the user performs a specific activity the value is increased by 1. As a result activities performed frequently by the user have higher values. This information is used by the Preference-based Personalization Algorithm described in section 8.4.2.

Apart from the implemented analysis other conclusions that can be extracted from the above inputs include:

- Patterns of repetition can be identified, i.e. a specific user frequently performs the same activity on the same day and time of the week. Information can be stored in the fields PREFERED_DAY, PREFERED-TIME. Over time the system can learn the user's habits and use this information to provide suggestions encouraging the user to perform the most appropriate activities at the most appropriate time.
- Patterns of location-activity or activity-invited members association can be identified. I.e. the activity "Cards" is frequently performed in location "Park" or with the specific group of people. These can be used to personalize the interfaces. When the user creates a new event and selects the activity "Cards" the "Park" can be displayed first in the possible locations.

8.6.2. Physical Activity and Abnormal Activity

For the Physical Activity and Abnormal Activity analysis the inputs are provided by the GPS and tri-axis accelerometer (g-sensor) sensors which are embedded in the user's device and simultaniously record data in a constant loop. The measurements are inserted in the GPS_LOG database table. The exact fields of the table and some sample data recorded for a specific user (PERSON_ID) over a short period of time can be seen in Figure 24. The GPS readings are stored in the two values of LONGITUDE and LATITUDE which indicate the user's exact location in coordinates, with a sampling rate of 10 seconds as seen at the TIMESTAMP column. The field FALL (of type Boolean) is related to Abnormal Activity analysis. A positive value indicates that a fall has been identified based on the accelerometer measurement. The date/time and exact location (in coordinates) are available.

The data sampling is tested on an HTC Diamond device and to get the readings of the embedded g-sensor the HTCGSensor API is used. All the code developed for the component is available in Appendix B.

Database: \Program Files\sync\localDB-GPS_LOG.sdf
Table: GPS_LOG

PERSON_ID	LONGITUTE	LATITUTE	FALL	TIMESTAMP	GPS_LOG_ID
ΦΟΙΝΙΚΟΥ	33	35	false	2008/09/25 14:32:39	4
ΦΟΙΝΙΚΟΥ	33	35	false	2008/09/25 14:32:49	5
ΦΟΙΝΙΚΟΥ	33	35	false	2008/09/25 14:32:59	6
ΦΟΙΝΙΚΟΥ	33	35	false	2008/09/25 14:33:09	7
ΦΟΙΝΙΚΟΥ	33	35	false	2008/09/25 14:33:20	8
ΦΟΙΝΙΚΟΥ	33	35	true	2008/09/25 14:33:29	9
ΦΟΙΝΙΚΟΥ	33	35	false	2008/09/25 14:33:30	10
ΦΟΙΝΙΚΟΥ	33	35	false	2008/09/25 14:33:40	11
ΦΟΙΝΙΚΟΥ	33	35	false	2008/09/25 14:33:50	12
ΦΟΙΝΙΚΟΥ	33	35	false	2008/09/25 14:34:00	13

Figure 24 : Raw data from Sensors with Date/time stamp, GPS coordinates and fall flag

Due to the GPS sensor's sensitivity the geospatial coordinates can only be sampled when the device is in an outdoor environment. The accelerometer samples there values constantly. The x-axis, y-axis and z-axis measurements (Figure 28) are represented in terms of "g", where 1 g represents the force of gravity. These are processed to get a vector that describes the direction of gravity/acceleration in relation to the phone device screen. The vector values are not registered

but instead are processed directly by the fall detection algorithm (see Figure 27). If a fall is detected the field FALL (of type Boolean) of the table GPS_LOG gets the value of True.

After analysis a number of conclusions can be extracted from the raw data of the table GPS_LOG:

- The field FALL seen above is related to Abnormal Activity analysis. A positive value indicates that a fall has occurred and the date/time and exact location (in coordinates) are available. Apart from the immediate alert send to the caregivers this data are used to send monthly or weekly reports indicating if the number of falls increases or decreases.

Further analysis could be done to monitor the exact locations and time of fall and observe if any patterns appear. However, an important technical issue blocks the way of this analysis. The location measurements are sampled form a GPS device that only receives signals in outdoor environment. If a fall occurs inside the user's home it will be detected and handled appropriately, however it is most likely that the location will not be registered in the log. As a result analyzing the logged data will not produce realistic concussions. Furthermore during a real pilot study the possibilities of a fall occurrence are considered low and therefore data gathering is rare and not sufficient to perform the necessary analysis.

- The analysis related to physical activity also obtains inputs from the above database table. This time the columns LONGITUTE and LATITUDE are of interest. The coordinates recorded here are processed and transformed into a vector measured in meters (code available in Appendix B). The data is processed (daily or weekly) and generate a report showing if the distance covered by the user increases or decreases. If the distance covered by a user drops significantly between consecutive weeks this could reflect a general physical degradation of the elder that affects not only the walking ability but his general health.

- Another conclusion that could be extracted from the above raw data is the total time the elder spends in outdoor environments. This can be calculated based on the timestamp data recorded in the log.

8.7. Fall Detection Component

The Use-Case Scenario of Emergency Monitoring (Figure 7) is designed as an attempt to stimulate and prolong the independent and active living of elders in outdoor environments guaranteeing their constant safeguarding. It includes an Automatic Fall Detection module that detects possible emergency situations and immediately alerts caregivers.

8.7.1. Approaches of Fall Detection

Many efforts have been made in fall detection for elderly and a series of technologies have already been developed in recent years. Xinguo Yu [40] presents a complete survey of existing fall detection methods in products and in literature and analyzes the merits and demerits of each. The author also builds a classification tree of the various detection methods separating the different approaches in three categories according to how fall is detected: wearable device, ambience device and camera or vision based. The class hierarchy of fall detection methods according to [40] is depicted in Figure 25: The hierarchy of approaches and classes of fall detection.

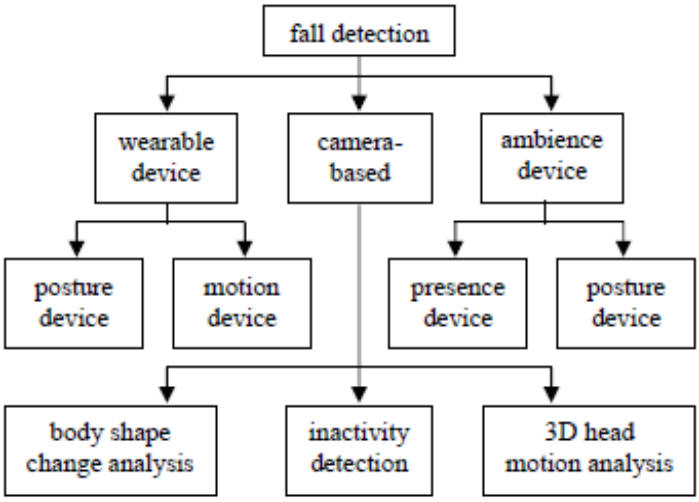

Figure 25: The hierarchy of approaches and classes of fall detection [40]

Wearable devices are further divided into the two classes of posture device and motion device. Ambience devices are further divided into presence device and posture device. Camera-based methods include three classes according the used principles: inactivity detection, 2D body shape change analysis, and 3D head motion analysis.

8.7.2. Fall Detection General Framework

Despite the principal differences across the three categories all existing fall detection devices and systems share a general framework. The difference lies in the complexity of each component. For example, data acquisition can vary from single simple sensor to sense one indicator to multiple different sensors and different cameras to work together to collect signal and video data. Fall detection can vary from comparing one sensed indicator with a threshold to a complicated image processing algorithm including background subtraction, shape detection, and shape change analysis.

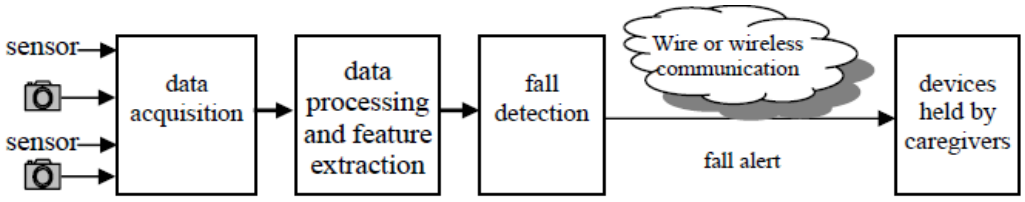

Figure 26: General framework of fall detection and alert [40]

The fall detection service of this work follows the general framework presented in Figure 26: General framework of fall detection and alert [40] and belongs in the category of wearable device according to the classification tree presented above. According to [40], the wearable device approach is to hold some devices or to wear some devices or garments with imbedded sensors to detect the posture and/or motion of the body of the wearer and use classifiers to identify suspicious events including fall

In particular, in the scope of this work the device used is personal mobile phone with an embedded tri-axial accelerometer for data acquisition. The mobile device carried by the users is used to perform data processing and to send fall alerts in the form of SMS messages to the elderly caregivers.

The wearable device approach has its advantages. In general wearable devices for fall detection are cheap (except wearable garments). Also such wearable devices are easy to be set up and operate. A number of wearable fall detection systems exist. Among them various are also based in data acquisition through accelerometers. Some examples include:

- Clifford *et al* [41]patented a system for human body fall detection. The system includes a monitoring unit, including a plurality of accelerometers, a processor and a wireless transmitter.
- Doukas et al [42] developed a wearable device to detect fall of patient, which uses plural accelerometers to collect data and uses a SVM (support vector machine) to distinguish fall from non-fall.

- Noury et al [43-45] developed a fall device called actimeter, which collects three types of data: the vertical acceleration shock obtained from a piezoelectric accelerator, the body orientation monitored from a position tilt switch, and the mechanical vibrations of body surface.
- Petelenz et al [46] patented an elderly fall monitoring method and device that uses accelerators to collect motion data. The difference is that this device also targets to distinguish the health from threatening fall.

However, the wearable device approach also has multiple disadvantages. To get accurate results the detection device must be permanently attached to the user and this condition is easy to be broken. Another big disadvantage of the wearable device is that it is intrusive. In all the fall detection systems mentioned above, accelerometers must be bind to human body. However, this is not the case for the approach of this work. The mobile phone is a device of daily use that the users normally carry. However, anther disadvantage rises. Movements made while using the phone as a calling device might affect the activity detection. Movements like to put the phone in the pocket quickly, to throw the phone onto a sofa are often very similar to a real fall. As a result, this approach is prone to have a high rate of false alarm and a specific approach must be developed to handle this events.

With regards to fall detection algorithms, Kangas M. et al in [47] evaluated different fall detection algorithms using body attached accelerometers from intentional falls and activities of daily living (ADL). The results indicated that fall detection using a waist or head worn tri-axial accelerometer is efficient, even with quite simple threshold-based algorithms. The same authors, in [48] showed that when the simple threshold-based detection , based on measurements from the waist and head ,was combined with posture detection after the fall, the sensitivity and specificity of fall detection were up to 100 %.

8.7.3. Fall Detection Approach in this Work

Drawing on these conclusions the fall detection service of this work uses a simple threshold-based detection algorithm and the users are advised to keep the mobile device in their waist pocket whenever not using it as a calling device to maximize the accuracy of the results. Although the results are not fully precise, they are accurate enough to enables us to observe and document the reactions and opinions of the elderly users and their caregivers in relation to an unobtrusive fall detection service.

Figure 27 : Fall Detection Algorithm shows the flowchart of the fall detection algorithm. Input samples are drawn from the tri-axial accelerometer every few seconds in a constant loop. Raw input values (TiltX, TiltY, TiltZ) are processed to get a vector that describes the direction of acceleration in relation to the device screen. The vector returned has length measured in the unit meters per Second Square. Ideally when the device is in a motionless state, the vector would be of length 9.8.

This vector is compared against a predefined threshold value. Measurements below the threshold magnitude are discarded but if a measurement surpasses the threshold value then a possible fall is identified. After trial and error the threshold magnitude was set to a length of 25.

The next step is included to control the false alarm probability. The user is asked to confirm if a fall has occurred. If a positive response is given then a fall alert is triggered, the data are registered in the database and appropriate actions are taken. The user has a given time frame to declare a false alarm (default one minute waiting period). If that expires without any response then a fall alert is issued. An optional step is to trace through the GPS system the location of the device during the fall and include it in the alert.

The service is tested on an HTC Diamond device and to get the readings of the embedded accelerometer the HTCGSensor API is used. All the code developed for the component is available in Appendix B.

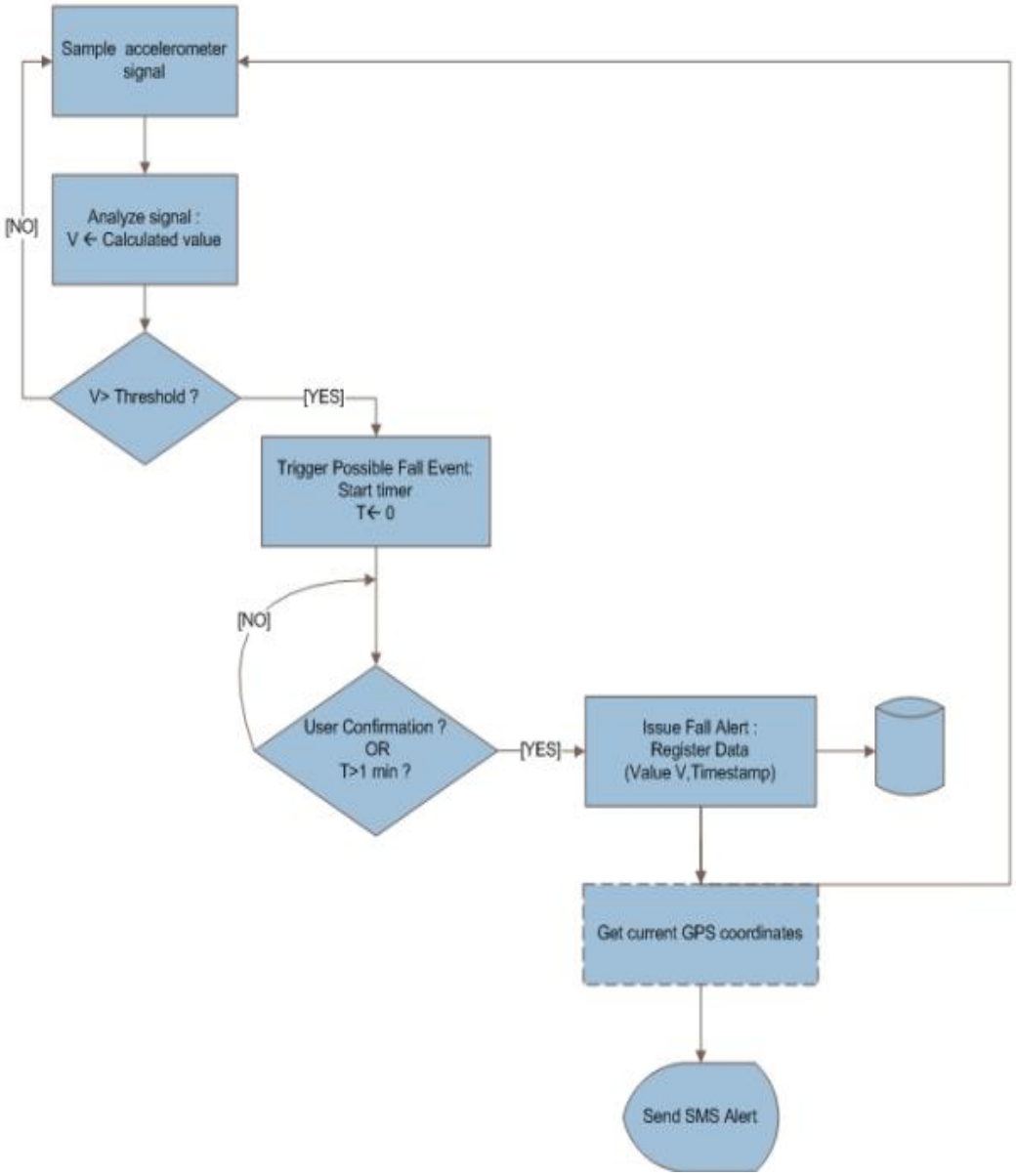

Figure 27 : Fall Detection Algorithm

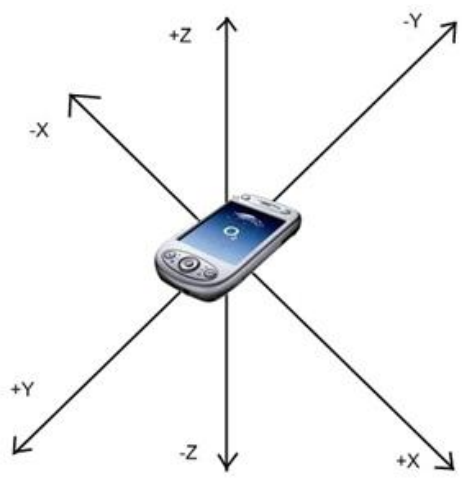

Figure 28: Accelerometer Input Data (TiltX, TiltY, TiltZ)

8.7.4. Fall Detection and Thresholds

A main difficulty was encountered during the development phase of the Automatic Fall Detection Module. As indicated in the service description a fall is detected if the accelerometer measurement surpasses a specific threshold value. No acceleration database of actual falls of elderly subjects was available in literature; therefore this module has been tested using simulated intentional falls performed under supervised conditions and activities of daily living. Based on these observations a mean threshold value was identified. However, the exact value of the threshold determining a fall may often vary from person to person as it is closely associated with physical characteristics.

As a solution to have a generalized solution was to set a range of values found to be associated with fall detection. Then when the calculated value from the accelerometer data is checked and if it falls within this range a possible fall is detected. During the pilot study valuable results can be gathered related to the individual threshold values of each user however the possibilities of a fall occurrence are considered low and therefore data gathering is rare.

8.8. Security and Privacy Infrastructure

Personal data is the core resource that the system services build on. When designing ICT systems designers must remember that privacy is a fundamental right of the users. Information privacy, also known as "data protection", involves the establishment of rules governing the collection and handling of personal data. Therefore an important task in the system development is to investigate the Use-Case Scenarios to identify the security and privacy requirements and design an appropriate Security and Privacy Infrastructure.

Much of the information handled by the platform services is sensitive personal data or other types of information which have requirements to confidentiality and integrity (e.g. information on calendar items and sensor data). The fundamental principle lying behind any security and privacy mechanism is that users should feel that the system does not allow unwanted privacy intrusions, does not interfere too much with their private lives and ensures that they are in control of the services offered to them.

8.8.1. Security and Privacy Requirements

In particular, in this work, according to the identified Use-Case Scenarios the main security and privacy requirements of the end-users are related to the following questions:

- *What type of data, and how much data, should be stored?*

The amount of sensor data that is stored by the system needs to be just enough to accomplish the tasks related to the care services. Any extra information may compromise the individual's privacy.

- *Where should the sensitive data be stored?*

Centralized versus decentralized storage. In the case of remote monitoring, should the raw sensor data reside only locally or should it also be stored at the central monitoring station?

- *Which data are considered sensitive and who has read/write access on them?*

The user should to authorize partial viewing of his/her personal record to certain members. However, there are situations in which the user's information needs to be disclosed to people other than the previously authorized users. For example, in the case of remote monitoring, an emergency might require disclosure of personal data without the user's consent in order to receive immediate care.

- *Should all users have access to the same information?*

Do all users have the same authority as the data owner, or are their rights narrower? What level of privacy and security protection must be maintained when data is transferred to a third party.

- *How is the protection of sensitive user information ensured as it is exchanged between the services and as it travels through the web?*

Sensitive data may pass across the network and must be protected from disclosure during transfer. A third party can gain access to sensitive data whenever it leaves a secure area, such as a protected local storage, or crosses a non-secure communication line such as a public network.

8.8.2. Security Requirements: Definition of Terms

As stated above, several security requirements have been extracted from the Use-Case Scenarios in order to ensure a secure and safe environment for the system and the user interactions/activities. In this section, a small definition is given for the security requirements identified to be the most relevant, applicable and of value to the system.

- **Access control**

Access control is the problem of determining the operations (e.g. read, write and execute) that subjects (e.g. users and services) can perform on objects (e.g. database data). Access control is comprised by mechanisms that enforce access rights to resources and hence prevent unauthorized use of these resources. These mechanisms help controlling who has access to a certain resource, under what conditions access can occur, and what those accessing the resource are allowed to do [49]. More specifically, access control involves authentication and authorization - concepts that are defined below.

Authentication: According to [50], identification is what you do when you announce who you are, while authentication is the process of proving your identity [51] . Every user of the system must be definable and recognizable. This means that every user must possess a set of characteristics that distinguish him/her from all the other users. There are three qualities that can be used to confirm a user's identity, and therefore can be used by authentication mechanisms [52]:

-Something the user *knows*; passwords, PIN codes, passphrases etc.

-Something the user *has*; keys, like secret keys or shared keys, certificates and smart cards, special software or hardware are examples of things a user may use to prove his/her identity.

-Something the user *is*; biometrics, based on the user's physical characteristics, may be used; fingerprint, iris scan, voice verification or a picture of the face. Also behavioural biometrics may be used, like keystroke dynamics recognition.

Authorization: Authorization determines/verifies whether an authenticated user has the credentials/rights to perform a certain operation/activity and ensures that only authorized users can access protected resources. In other words, authorization defines an authenticated user's rights and permissions on a system, and determines what that user can do on the system. Therefore, authentication always precedes authorization. The entity is authenticated and then is

determined whether it has the appropriate permissions to perform a restricted operation or access restricted data.

- **Availability**

Availability is the property of being accessible and usable upon demand by an authorized entity [53]. Lack of availability can affect the operation of critical real time applications like those in the healthcare sector that require a 24/7 operation, and such a problem may have fatal consequences for the patients involved.

- **Freshness**

Data freshness implies that the data is recent, and it ensures that no adversary replayed old messages [54].

- **Secure Communication**

Secure communication refers to the protection of all the information that is exchanged while two parties are communicating as well as the protection of the different components that are involved in this communication. This gives the ability to the user to connect securely to a remote site, perform a secure transaction, store and retrieve data from a secure site.

8.8.3. Platform Security and Privacy Mechanisms

This section describes the security and privacy mechanisms that are utilized in the system. Due to the limited time extend of the project these mechanisms are a small compilation of state-of-the-art security requirements that a complete solution should support. The focus is on providing the best practices which cover the minimum user requirements defined above.

- **Role-based Security**

The Role-based security mechanism is selected to build the Security and Privacy Infrastructure of the platform. This model it is based on identity and roles and resembles the classic

authentication/authorization model used for securing users in any environment. Applications can define their own authentication and authorization, such as by looking up password and list of roles in an application-specific database.

Role-based access control in combination with the Team-based access control were identified to be the most appropriate models to be used. With Role-based access each system user is mapped into high level role and inherits its access rights to the information of the elderly based on that pre-existing role. Team-based access is related to the elderly Virtual Team, where a group of members is collected with specific roles that cooperate to achieve a specific goal or task. Also each process is mapped to some predefined access rights to use specific resources of the system.

In the version of the system developed for the pilot trial, the only role that is able to modify the system data is the role of "Elderly user". The rest of the roles only interact with the system by receiving external notifications containing information. Therefore only the role of "Elderly user" is granted access to the system.

- **User Logon Process for Authentication and Authorization**

As stated above authentication ascertains the identity of the user and Authorization determines whether or not the user should be allowed access. To provide for these two independent actions the application implements a user Logon process (also known as login process, also sign-in process).

The Logon is performed using standard type credentials like name/password and token. The application code can then learn the identity of the current user or query it for a particular role as necessary to perform some privileged operation.

In concrete the Logon process of the platform provides for user identification; it initiates an authentication dialogue between the user and the system. This is the first screen seen by the user

and a correct password must be entered in order to proceed and have access to access the system and the information stored.All the passwords used by the system are static passwords.

Static passwords are the oldest and most widespread form of user credentials [53]. Static passwords are shared between the client and the authentication server, and do not change very often. The system administrator assigns a password to each new system member. This is kept in the PERSON data table of the database (see Figure 15: Database Schema Definition).The model of trust for static passwords is that only the user requesting access and the authentication data tables know the secret password; and even when it changes, still only the two of them are going to know it.

If the Logon process is correct then the user is granted access and the system generates an application-specific structure for the user, referred to as an access token. The access token structure sits in between user authentication and authorization. It is attached to every new process launched by the user, to determine whether the user has or has not been granted access.

- **Availability and Freshness**

Availability and freshness of data are ensured by keeping local copies of the database on the personal mobile devices of the users. This way, even in the event of loss of communication with the central server the system can persist and have access to all the necessary data stored locally. The interaction of the user with the system will therefore not be interrupted at any time guarantying constant availability.

- **Secure Communication**

To provide secure communication many different protocols and security mechanisms can be utilized, among other things encryption, integrity checks, proxy servers, secure transport layer protocols like HTTPS, and communication protocol security mechanisms. However, this requirement is not applicable to the system developed for the pilot trial as it works “offline” that

is without requiring any form of communication over wireless or wired media. All the data are stored and retrieved from the local databases on the devices running the application.

The only time communication occurs is during the synchronization of the local and central databases when the device is connected either wireless or via a wire to the machine hosting the central database. As a future improvement of the system, a secure communication mechanism can be implemented to cover this.

Chapter 9

System Evaluation

9.1. Pilot Study

In order to evaluate the proposed platform, a fully functional prototype system was implemented and used in a pilot study. The goal was to assess the opinions of the elderly regarding the underlying concepts of the developed services. The intention was also to evaluate ease of use and acceptance of the system and to find out which service concept had the most potential in the minds of the users.

9.2. Experimental Setup

The pilot study was held in collaboration with the elderly care services of "Polidinamo Center" of the municipality of Agios Dometios. After a careful selection process, conducted by the professional staff of the center, two pilot groups were assembled. Altogether six elderly people were selected and divided into two groups.

According to the care professionals a gender-wise homogenous team would have higher possibilities of success therefore the first group consisted of four female members and the second included two male members. All the participants attended on their own free will.

The prototype system was deployed on a smart phone device with embedded pervasive sensors (HTC Diamond). Fully functional prototypes of all of the concepts described in the concept definition phase were provided. All the data gathered from the system were stored on the individual databases to be used for further processing and the comments of the participants were recorded by means of questionnaires (see Appendix A).

9.2.1. User Characteristics

All of the participants were active members of the service home and participated in daily activities taking place at the facilities. They were capable of living independently at home alone or together with their spouse. All members had close relationships with members of their family.

The age range was between 65 and 75 years old. The state of health of all members was reported as ‘‘good’’ or at least ‘‘reasonably good’’. All members owned and could operate a mobile phone and usually kept it with them at all times. All of the participants had several hobbies, the most common being card games and theater.

9.3. Pilot Study Protocol

The study was initiated with the female group. The involvement of the second team will follow. As described below the pilot study was realized by means of three sequential steps:

Step 1: Supervised Training in Controlled Environment

At the first step of the pilot study the members participated in weekly training sessions where a skilled social worker explained the purpose of the system and gave them detailed instructions on the functionality of the services. Each member was given his own device and used it to practice the services individually as well as to interact with the other members through the system.

Apart from user training this step also served as a feedback mechanism for documenting the viewpoints and opinions of the users. Taking them into consideration as early in the development process as possible ensures that the results are both desired and hoped for [24] .

This process lasted 12 months during which the users were gradually familiarized with the system concepts. To avoid confusion and to facilitate the learning process the concepts were introduced one by one progressively adding to the functionality of the system. This way the users had sufficient time to practice until they felt confident with the use of all the system features.

Step 2: Involvement and Training of Caregiver(s)

In the second step of the pilot study members from the elder's Virtual Community were asked to take up a more active role. One or more of the close family members was trained with the use of the system and the handling of possible technical problems related to the smart device. Once the members were trained they were able to assist the elder resolve any problems during the use of the system at home.

Step 3: Autonomous Use in Uncontrolled Environment

In the third and final step of the study the members were asked to use the system autonomously and in their own environment. They were encouraged to carry their device with them constantly at home, at the care center etc., and to use the services independently as much as possible.

The system was available at all times, gathering data which could later be used to validate the functionality of the services. The trained member of the Virtual Community was responsible for assisting the elder with any problems.

9.3.1. User Feedback Chain

A robust chain of feedback was set up during the pilot study in order to ensure that any problems, likes, dislikes or requests of the end-user were thoroughly documented.

The trained family member was in direct contact with the elder and was responsible for getting direct feedback concerning his/her opinion of the system.

At regular time periods the team member had to report these comments to the social worker who carried out the initial training. The majority of the problems were solved at this level of the chain. However, issues requiring changes to be made at functionality or interface were documented as requirements for the next version of the system and passed on to the developer.

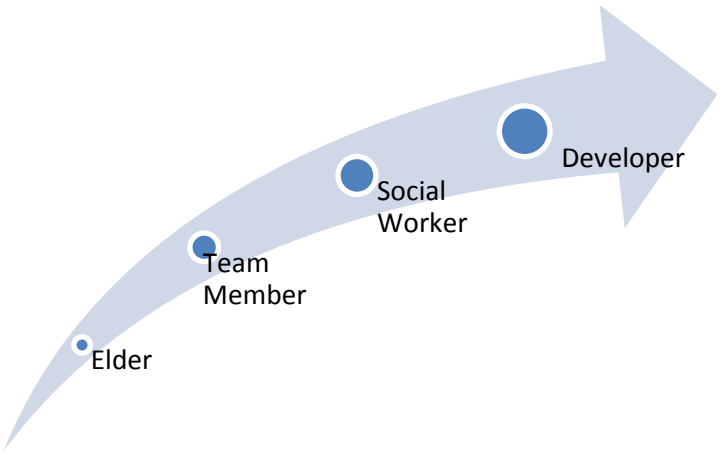

Figure 29: Chain of feedback

9.4. Evaluation Metrics

The goal of the pilot study is to evaluate the system in terms of effectiveness, efficiency, and user satisfaction, addressing issues such as:

- *Evaluate to what extend the system meets the user needs in the care context.*
- *Evaluate to what degree the system enables users to achieve their goals.*
- *Determine whether users find the use of the developed solution acceptable.*

System usability metrics are associated with these issues. The international standard ISO 9241-11 (Ergonomic requirements for office work with visual display terminals) [55] provides guidelines for usability and defines it as "The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use." The context of use consists of the users, tasks, equipment (hardware, software and materials), and the physical and social environments which may all influence the usability of a product in a work system [55].

There are many different ways to measure usability, each way having distinct advantages and limitations. This metrics are essential to improve the elegance and clarity of interaction with a computer program as they can reveal if the needed functionality goals have been achieved,

indicate the aspects of the system that need improvement and set the priority of usability problems. Thomas Tullis et al in [56] define six general categories of usability metrics:

1. **Self-reported metrics relate to what an end-user reports about his experience with the system. Examples of self-reported metrics include satisfaction, ease of use, usefulness, awareness, and expectations.**
2. Performance metrics focus on how effectively and efficiently users perform tasks.
3. Issues-based metrics are based on the identification of specific usability issues and the severity of those issues.
4. Web-navigation metrics are based on how users navigate through a web site, such as click-through rates, abandonment rates, stickiness, and optimal paths.
5. Derived metrics provide a valuable, higher-level view of an entire interface and summarize the usability of more than one task or using more than one type of metric.
6. Physiological metrics focus on phenomena which can be directly or indirectly measured from the human body. These may indicate the usability of a system through behaviors such as eye-movements, stress, and facial expressions.

In the scope of this pilot study self-reported metrics have been selected as the most relevant and applicable usability metric to be used for evaluation. These metrics give important data about the users' perception of the system and their interaction with it.

9.4.1. Self-reported Metrics

Questionnaires have long been used to assess aspects of usability [57]and for a handful of them the validity and/or reliability have been established. The following table includes several such examples, discussed in detail in Chapter 6 of [58]. These references have served as the basis for developing a questionnaire to gather self-reported metrics related to the use of the pilot system.

Acronym	**Instrument**	**Reference**	**Institution**
QUIS	Questionnaire for User Interface Satisfaction	Chin et al, 1988[59]	Maryland
PUEU	Perceived Usefulness and Ease of Use	Davis, 1989[60]	IBM
ASQ	After Scenario Questionnaire	Lewis, 1995[61]	IBM
PUTQ	Purdue Usability Testing Questionnaire	Lin *et al*, 1997[62]	Purdue
USE	USE Questionnaire	Lund, 2001[63]	Sapient

Table 7 : Usability Evaluation Questionnaires

The constructed questionnaire is presented in Appendix A. It is divided in five major parts: Learning Evaluation focusing on “Learnability” and “Memorability”, Interface Evaluation, Usefulness Evaluation, Service Evaluation examining the efficiency of a specific service and Overall Satisfaction, questioning how pleasant is the use the system.

To better evaluate the pilot outcomes the same questionnaire was presented to the elderly users twice. Once right after the end of the Supervised Training session and again during the

Autonomous Use session. All questionnaires were conducted under the guidance of a social worker.

9.5. Pilot Study Results

The results obtained concerning the need for services and the interests of the users were compatible with opinions presented in diverse literature studies.

I. System Learning Evaluation

This section is focused on the "Learnability" of the system, that is it examines how easy is it for users to accomplish basic tasks the first time they encounter the system and how long it takes to feel confident in with its use. Also it focuses on "Memorability", questioning how easy it is for users to re-establish proficiency in the use of the system after a period of not using it.

The elders were asked to comment on the training sessions. Whether they thought the training period was sufficient, if they would like the training to continue in regular sessions.

The users were satisfied with the training process and always attended the meetings with interest. They expressed the wish to maintain less frequent meetings to solve any possible questions or issues.

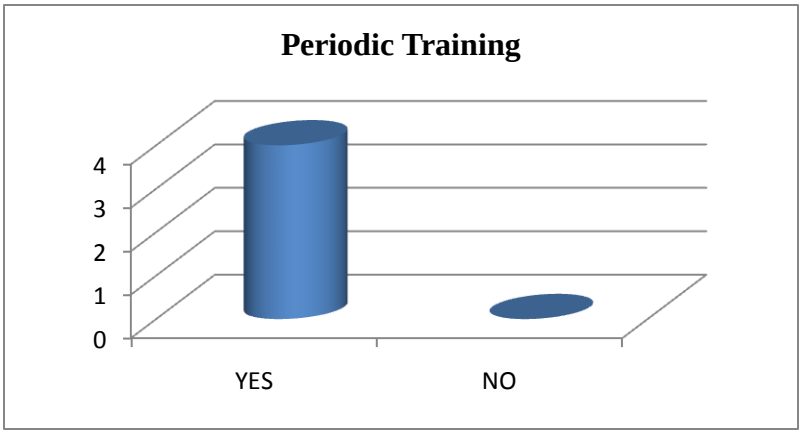

Figure 30: Participants wish to continue having periodic training sessions

Concerning the “Memorability” the users were asked if they found the learning process difficult and if they faced difficulties to remember how to use the various interfaces. It is worth to notice that during the pilot it was obvious that one of the four members was significantly more advanced than the other three and could use the system with greater ease.

II. User Interface Evaluation

The participants were asked to comment the system interface. Questions examined screen layout, text size and color, whether the descriptive symbols used were understandable and if these facilitate interaction.

The majority of the respondents asked for bigger font size and commented that the symbols are useful for navigation although it takes time to memorize their meaning.

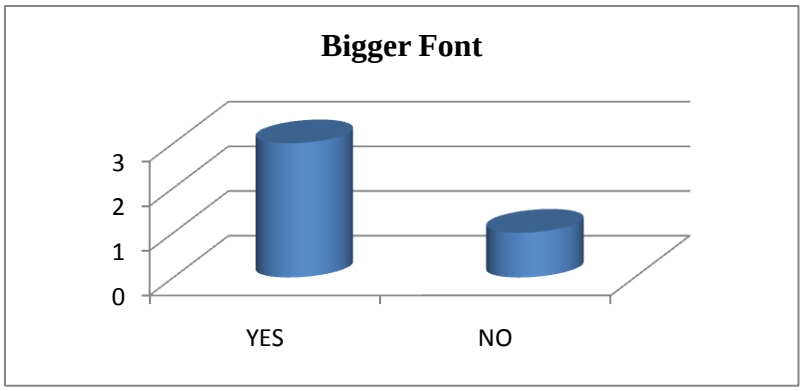

Figure 31: Participants request bigger fonts in interfaces

III. Usefulness Evaluation

An important goal of the pilot study was to ascertain how important the elderly felt the service concepts were to them now and in the future. The participants were asked to rank the concepts based on how significant they found the service to be to them.

Questions examined whether use of the services facilitates execution of daily activities and communication with others. The intention was also to find out which service concept had the most potential in the minds of the users. Apart from the ranking process an additional question asked the user to identify the most useful service. In both questions Concept Communication was found to be the one the users felt was most useful to them. According to comments they best liked the simplicity and ease of use of the service.

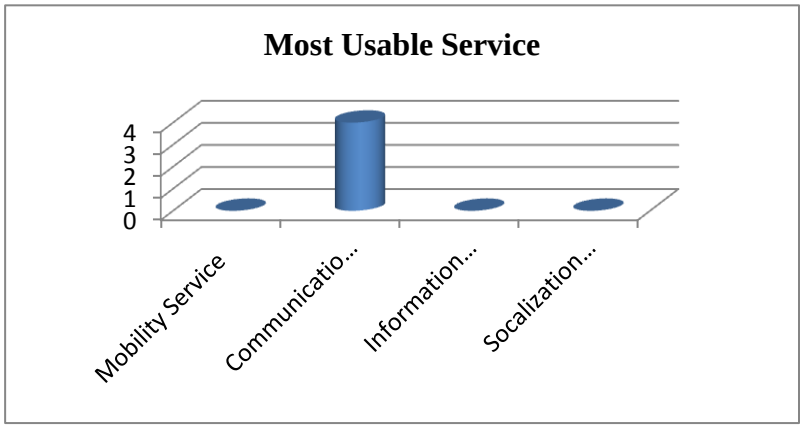

Figure 32: Participants' opinion on which service they find more usefull

IV. Service Evaluation

This section examines the efficiency of a specific service of the system questioning how quickly and easily the users can perform tasks once they have learned the design. The users were asked to specifically evaluate the "Social activities" service, which has the biggest number of interface steps; it consists of five consecutive screens asking for user input.

All participants stressed the fact that the service had significantly more steps than other concepts and thus required longer time to gain ease of use. However, they acknowledged that the process was necessary to complete the task at hand; invite friends for an activity; and therefore were willing to learn how to use it.

V. Overall Satisfaction

The last part examined the overall satisfaction of the user at an abstract and general level. Questions examined whether the interaction with the system was pleasant and if the user feels the need to use the system. It was assumed that a way to determine the user's satisfaction with the system would be to ask them if they would recommend it to other friends.

All users responded positively and indeed had already promoted the idea among their group of friends.

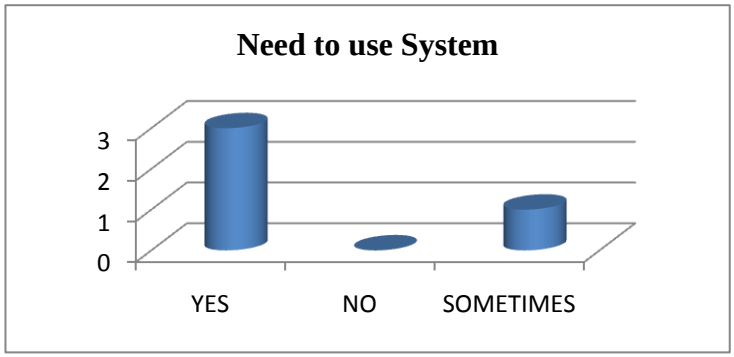

Figure 33: Participants' evaluation of the importance of system

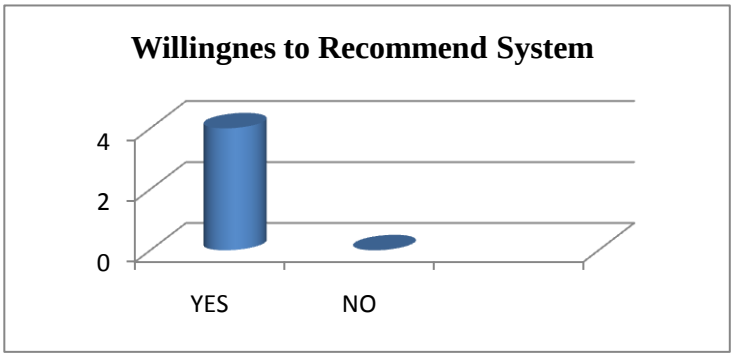

Figure 34: Participants' willingness to recommend the system to others

9.6. Ongoing topics

As the pilot study progresses with the second team more user comments can be extracted and more issues can be explored. Several concepts can only be judged after prolonged use of the system.

One such example is the service “Fall Detection & Emergency Handling”. The users can be asked to say how much they fell using the service increases their feeling of security only after an emergency event occurs and the service is used. It is also important to observe changes over time in the opinions of the elderly people regarding their feelings of security resulting from the use of the service.

As mentioned before a major goal of the pilot study is to determine the participants’ opinion on the importance of the service concepts. One way to clarify this would be by asking the elderly directly whether or not they would be ready to begin using the concept if it were already available and how much money they were ready to pay per month to use a specific service.

Chapter 10

Epilogue

10.1. Conclusions

This work addresses the overall care needs of the senior citizens through a cost-effective, portable, non-intrusive technology that pays special attention to the individual preferences and needs of each user leading to a personalized care experience for each user. The value of mobility is highly emphasized since the solution does not impose any restrictions on the end-user (i.e. remain in home environment, carry special equipment etc.).

A Virtual Care Community model is developed to enable effective and dynamic management and collaboration of the various stakeholders involved in elderly care. The Community is supported by a platform integrating pervasive sensors with socialization and daily monitoring ICT services aiming to stimulate and prolong independent and active living of the elders and at the same time reduce the care load of their caregivers.

The solution targets elderly persons at the very early stages of capabilities degradation and is designed to take a proactive action and report to the caregivers gradual changes and trends that might signal anomalous user behaviors. Behavior analysis techniques are applied to observe facts indicative of psychological deterioration or progression of health conditions.

The entire course of action of this work has confirmed that the development of new technologic solutions for the elderly community is not a trivial task. Contrary to standardized technological solutions that target mainstream end-users, apart from developing services based on various new technologies, it is indispensable to keep in mind the elderly people's unfamiliarity with new

technology and specific age related requirements such as the changing physical and mental abilities.

The study concentrated on finding out the key service needs related to personalized elderly care. Based on a thorough user study, six different concepts of services were developed with the help of mobile communication technology. The developed services reflect a compromise between the needs of the elderly and easy-to-use services used with the help of pervasive sensors and low-cost mobile terminals emphasizing the additional value of mobility.

After sufficient training the services were tested in a pilot study by the group of elderly and their Care Teams. Based on the results, the needs of elderly users could be prioritized and it became clear that the elderly find most beneficial those services which help them maintain their social relationships. Although the specific service would not bring a significant improvement in the independent life of the elderly the users appreciate its simplicity and ease of use and find that it greatly facilitates their communication with their community.

Although ICT is still a barrier for seniors who face difficulty in coping with advances in technology, the overall outcome of the pilot study reveals the fact that the elderly appreciate and accept new forms of help made possible by technology and are ready to begin using the services as long as they are confident that they truly facilitate their daily activities and are easy to use.

10.2. Discussion

10.2.1. Key principles for future developments in ICT and Ageing

An increasing number of older people will need to use computer related systems in the future to assist them to live more independently. The significance of developing services accessible through mobile terminals will also increase since today's working population, who is the elderly of the future, are more accustomed to using new technology.

The entire development cycle of this work has led to important conclusions and to a set of good pointers to high quality design, which can be valuable for future developments in this domain. Important principles, addressing the overall design philosophy for any pervasive monitoring system, especially targeting the elderly user group, were identified:

1. Actual need of the services is an important criterion .The design should be based on a well-conducted user study covering the needs, characteristics, surroundings, activities and tasks of the users as accurately as possible.
2. Sufficient training in the use of the technology is required to avoid confusion caused by the first interaction and most importantly to allow users to feel confident with the use of all the system features.
3. The solution should be software driven so that services could be easily added and removed as the needs of the individual alter.
4. The system must be easy to install and use for all individuals involved.
5. The use of the system should require no change in the normal behavior of the monitored individual; it should be passive rather than active. If a system requires people to change their behavior, or requires major modification of their daily activities it is eventually considered threatening and has less acceptance.
6. In the existence of a marketing plan, the solution should be cost-effective, similar to the cost of a monthly subscription.

10.2.2. Conclusions in the Scope of Behavioral Analysis and Personalization

Over the last years, important research advancements on pervasive, wearable and ubiquitous computing environments have been made allowing application services to monitor sequences of patterns in user behavior with minimum intrusion. All the inputs can be integrated to rich context-aware user profiles stored on servers and exploited to generate systems that trigger

exactly those services that users call for. To achieve this unified context is needed that describes the user's situation as who, when, where, what, how, and why based on environment data related to both the emotional and physical behavior. However, both social and physical behavior analysis in everyday life are complicated tasks. Social interaction one of the most complex human activities to monitor and analyze. As a result it can be a great burden for personalization systems to attend to this rich context information to address the individual desires of the users.

Last but not least, in frameworks applying any form of analysis on sensitive information to provide personalized services it is important that the users are able to enjoy such services without compromising the privacy of their personal data.

10.3. Future work

A substantial and continued effort has been made in the last years on ICT and Ageing. High-speed pervasive broadband connectivity, web-based technologies and advanced sensorial and robotic systems, offer new opportunities for innovative solutions to improve quality of life, facilitate social interaction, and reduce limitations imposed by physical and mental conditions, location and time, thus increasing personal control.

A vision in the domain of ICT in Ageing is the design of context-aware services to support seniors with personalized interfaces and affection-based interactions that can adapt to users' sensory, cognitive and physical capabilities. Progress in sensing technologies, creates the possibility of having more effective monitoring and context awareness reasoning functionalities. Extracting knowledge about the activities of the user and the current situation in the environment from low-level sensor data can allow services to plan appropriate short-term and long-term reactions. Furthermore, data mining techniques are opening new opportunities for personalization and profiling support allowing services to adapt to the user instead of forcing the user to learn specifics of the interface. When equipped with multiple sensors and using those sensors to detect

and predict context, a system can become smarter and more intuitive to use, fostering a wider acceptance of its services in everyday life.

Nevertheless, further research needs to build on these results. Among other issues, the risk of developing technology that is not taken-up by target users raises the need for a careful analysis and a better planned approach towards what concerns new developments. There is a lack of adequate training support for adoption of fast developing technologies by seniors.

Furthermore, these developments raise important security and privacy issues for which users, especially the elderly, might not be aware of. A better combination of context awareness, personalization and profiling features with security and privacy issues is needed. Although a large variety of mechanisms and tools exist for safe communications (including cryptography), user identification and authentication (including biometric systems), access rights definition and control, integration and configuration to ensure security, rights, and privacy on data and used services is still a difficult issue both at technological and regulatory levels.

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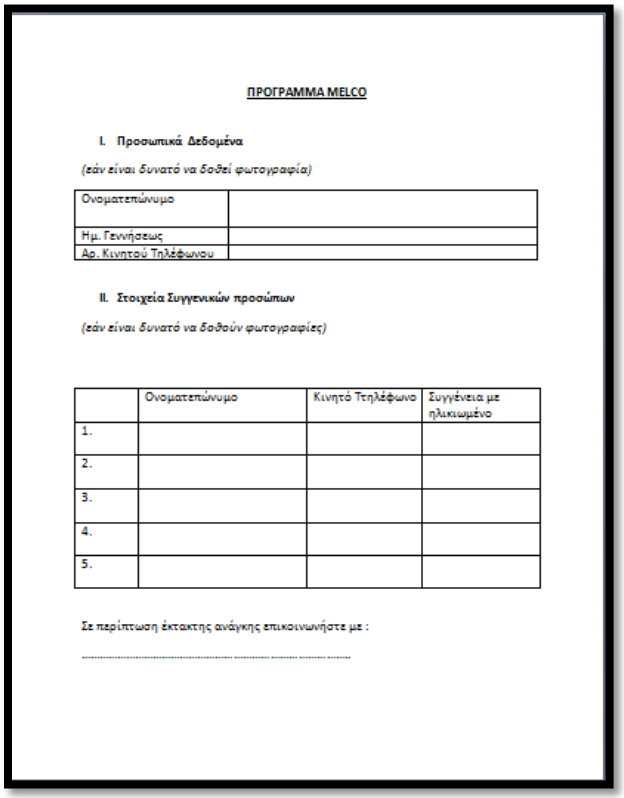
Appendix A

Pilot Trial Documents and Forms

I. Personal Data Gathering Form



ΠΡΟΓΡΑΜΜΑ MELCO

I. Προσωπικά Δεδομένα

(εάν είναι δυνατό να δοθεί φωτογραφία)

Ονοματεπώνυμο	
Ημ. Γεννήσεως	
Αρ. Κινητού Τηλέφωνου	

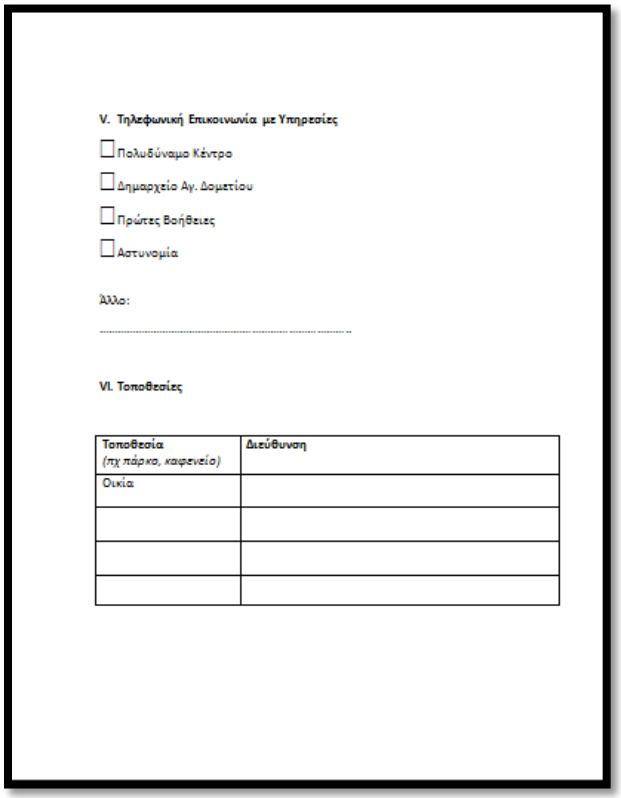
II. Στοιχεία Συγγενικών προσώπων

(εάν είναι δυνατό να δοθούν φωτογραφίες)

	Ονοματεπώνυμο	Κινητό Τηλέφωνο	Συγγένεια με ηλικιωμένο
1.			
2.			
3.			
4.			
5.			

Σε περίπτωση έκτακτης ανάγκης επικοινωνήστε με :

.....



V. Τηλεφωνική Επικοινωνία με Υπηρεσίες

☐ Πολυδύναμο Κέντρο

☐ Δημαρχείο Αγ. Δομετίου

☐ Πρώτες Βοήθειες

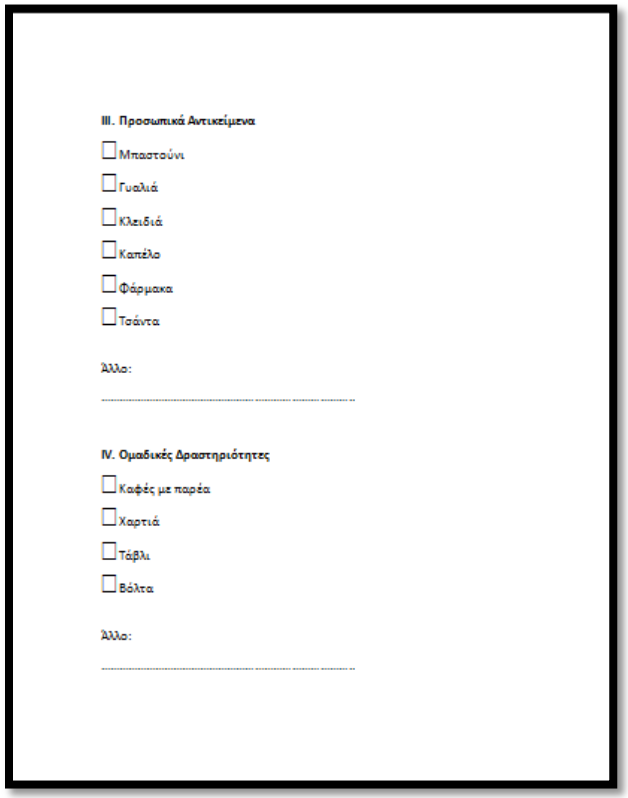
☐ Αστυνομία

Άλλο:

.....

VI. Τοποθεσίες

Τοποθεσία *(πχ πάρκο, καφενείο)*	**Διεύθυνση**
Οικία	



III. Προσωπικά Αντικείμενα

☐ Μπαστούνι

☐ Γυαλιά

☐ Κλειδιά

☐ Καπέλο

☐ Φάρμακα

☐ Τσάντα

Άλλο:

.....

IV. Ομαδικές Δραστηριότητες

☐ Καφές με παρέα

☐ Χαρτιά

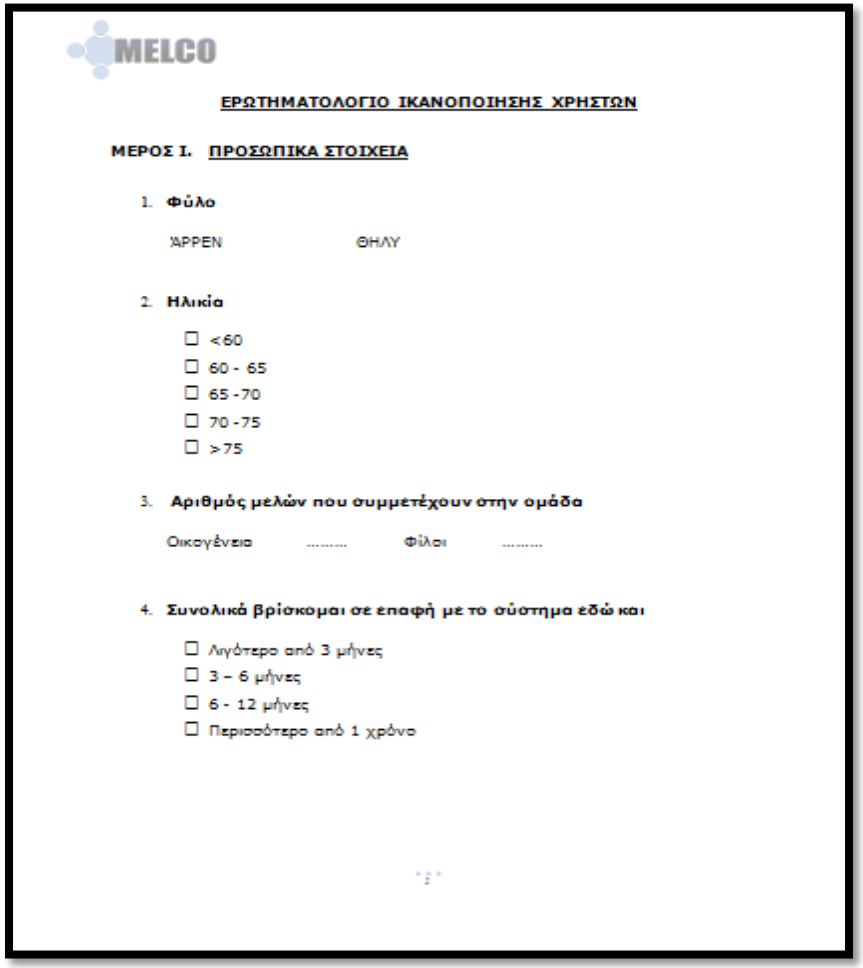
☐ Τάβλι

☐ Βόλτα

Άλλο:

.....

II. Pilot Evaluation Questionnaire



MELCO

ΕΡΩΤΗΜΑΤΟΛΟΓΙΟ ΙΚΑΝΟΠΟΙΗΣΗΣ ΧΡΗΣΤΩΝ

ΜΕΡΟΣ Ι. ΠΡΟΣΩΠΙΚΑ ΣΤΟΙΧΕΙΑ

1. **Φύλο**

   ΆΡΡΕΝ ΘΗΛΥ

2. **Ηλικία**

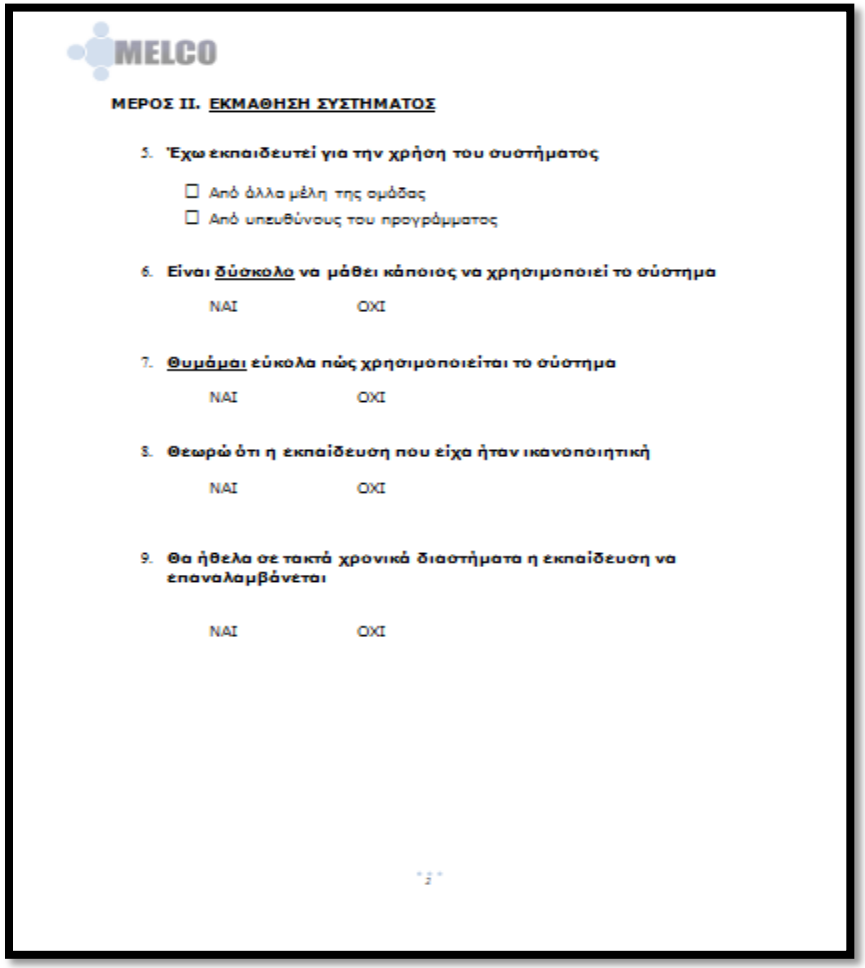
   - ☐ <60
   - ☐ 60 - 65
   - ☐ 65 -70
   - ☐ 70 -75
   - ☐ >75

3. **Αριθμός μελών που συμμετέχουν στην ομάδα**

   Οικογένεια ..... Φίλοι .....

4. **Συνολικά βρίσκομαι σε επαφή με το σύστημα εδώ και**

   - ☐ Λιγότερο από 3 μήνες
   - ☐ 3 – 6 μήνες
   - ☐ 6 - 12 μήνες
   - ☐ Περισσότερο από 1 χρόνο



MELCO

ΜΕΡΟΣ ΙΙ. ΕΚΜΑΘΗΣΗ ΣΥΣΤΗΜΑΤΟΣ

5. **Έχω εκπαιδευτεί για την χρήση του συστήματος**

   - ☐ Από άλλα μέλη της ομάδας
   - ☐ Από υπευθύνους του προγράμματος

6. **Είναι δύσκολο να μάθει κάποιος να χρησιμοποιεί το σύστημα**

   ΝΑΙ ΟΧΙ

7. **Θυμάμαι εύκολα πώς χρησιμοποιείται το σύστημα**

   ΝΑΙ ΟΧΙ

8. **Θεωρώ ότι η εκπαίδευση που είχα ήταν ικανοποιητική**

   ΝΑΙ ΟΧΙ

9. **Θα ήθελα σε τακτά χρονικά διαστήματα η εκπαίδευση να επαναλαμβάνεται**

   ΝΑΙ ΟΧΙ

MELCO

ΜΕΡΟΣ ΙΙΙ. ΑΞΙΟΛΟΓΗΣΗ ΔΙΑΔΙΚΑΣΙΑΣ

Οι παρακάτω ερωτήσεις αναφέρονται στην διαδικασία δημιουργίας μιας ομαδικής δραστηριότητας. Να απαντηθούν αφού εκτελεστεί η διαδικασία.

10. **Είναι εύκολο να ακολουθήσω τα βήματα (επιλογή δραστηριότητας, ατόμων, τοποθεσία, ημερομηνίας)**

ΝΑΙ ΟΧΙ

11. **Ο αριθμός των βημάτων που πρέπει να εκτελέσω είναι**

Ο ΕΛΑΧΙΣΤΟΣ ΑΧΡΕΙΑΣΤΑ ΜΕΓΑΛΟΣ

Θεωρώ αχρείαστα τα βήματα : .....

12. **Χρειάζομαι επιπρόσθετες οδηγίες για να ολοκληρώσω τη διαδικασία.**

ΝΑΙ ΟΧΙ

13. **Είναι εύκολο να <u>μάθω</u> να εκτελώ την διαδικασία**

ΝΑΙ ΟΧΙ

14. **Η διαδικασία με <u>διευκολύνει</u> στην οργάνωση δραστηριοτήτων με φίλους**

ΛΙΓΟ ΑΡΚΕΤΑ ΠΟΛΥ

15. **Θα προτιμούσα να ενημερώσω την παρέα τηλεφωνικώς**

ΝΑΙ ΟΧΙ

MELCO

16. **Αυτή η διαδικασία είναι πιο <u>δύσκολη</u> από τις υπόλοιπες**

ΝΑΙ ΟΧΙ

17. **Η απεικόνιση στην οθόνη είναι βοηθητική**
(κουμπιά μπροστά/πίσω, επιλογή μέρας/ώρας κλπ)

ΝΑΙ ΟΧΙ

Θεωρώ <u>μη</u> βοηθητικό : .....

18. **Θα θέλατε να βελτιωθεί/αλλάξει κάτι σε αυτή την διαδικασία ;**

.....
.....
.....
.....

MELCO

ΜΕΡΟΣ IV. <u>ΧΡΗΣΗ ΣΥΣΤΗΜΑΤΟΣ</u>

19. **Κατά την διάρκεια της βδομάδας χρησιμοποιώ το σύστημα**

☐ Καθημερινά
☐ Μόνο για τηλεφωνήματα

20. **Αριθμήστε τις διαδικασίες ανάλογα με την συχνότητα χρήσης τους *(1-4 , όπου 1= πολύ συχνή χρήση , 4 = σπάνια χρήση)***

..... Τηλεφώνημα σε μέλη της ομάδας μου
..... Οργάνωση δραστηριοτήτων (καφές, χαρτιά κλπ)
..... Ενημέρωση για τον καιρό
..... Αναζήτηση μεταφορικού μέσου

MELCO

ΜΕΡΟΣ V. <u>ΑΞΙΟΛΟΓΗΣΗ ΔΙΑΠΡΟΣΩΠΙΑΣ (οθόνες)</u>

21. **Μου αρέσει η εμφάνιση της οθόνης *(χρώματα, λέξεις , εικόνες)***

ΝΑΙ ΟΧΙ

22. **Τα σύμβολα και εικόνες που βλέπω στην οθόνη είναι κατανοητά *(βέλος μπροστά/πίσω,σπιτάκι κλπ)***

ΝΑΙ ΟΧΙ ΜΕΡΙΚΕΣ ΦΟΡΕΣ

Θα ήθελα να αλλάξουν τα σύμβολα : .....

23. **Θα ήθελα το μέγεθος των γραμμάτων να είναι <u>μεγαλύτερο</u>**

ΝΑΙ ΟΧΙ

24. **Το σύστημα χρησιμοποιεί τα ελάχιστα δυνατά βήματα για να ολοκληρώσει μια διαδικασία**

ΝΑΙ ΟΧΙ ΜΕΡΙΚΕΣ ΦΟΡΕΣ

MELCO

ΜΕΡΟΣ VI. ΧΡΗΣΙΜΟΤΗΤΑ ΣΥΣΤΗΜΑΤΟΣ

Κατά την γνώμη μου το σύστημα :

25. **Είναι χρήσιμο στην καθημερινή μου ζωή**

NAI OXI

26. **Διευκολύνει την επικοινωνία με τα μέλη της οικογένειας μου**

NAI OXI

27. **Μου δίνει περισσότερο έλεγχο των καθημερινών μου δραστηριοτήτων**

NAI OXI

28. **Κάνει τα πράγματα που θέλω να ολοκληρώσω ευκολότερα**

NAI OXI

29. **Περιγράψτε εν συντομία τις κυριότερες δραστηριότητες που διευκολύνει για εσάς το σύστημα(*πχ τηλεφωνήματα*)**

.....

.....

MELCO

ΜΕΡΟΣ VII. ΙΚΑΝΟΠΟΙΗΣΗ ΧΡΗΣΤΗ

30. **Το σύστημα λειτουργεί τον τρόπο που θέλω**

NAI OXI ΜΕΡΙΚΕΣ ΦΟΡΕΣ

31. **Η χρήση του συστήματος είναι ευχάριστη**

NAI OXI ΜΕΡΙΚΕΣ ΦΟΡΕΣ

32. **Αισθάνομαι την ανάγκη να έχω το σύστημα**

NAI OXI ΜΕΡΙΚΕΣ ΦΟΡΕΣ

33. **Θα σύστηνα το σύστημα σε φίλους**

NAI OXI

ΜΕΡΟΣ VIII. ΓΕΝΙΚΑ ΣΧΟΛΙΑ ΧΡΗΣΤΗ

Παρακαλώ σημειώστε οποιαδήποτε γενικά σχόλια

.....

.....

.....

.....

~ Σας ευχαριστούμε για την συνεργασία ~

Appendix B

Implementation Source Code

(Selected Modules)

1. Fall Detection Source Code Files

HTCGSensor.cs (C# code)

```
using System;
using System.Runtime.InteropServices;
using System.Collections.Generic;
using System.Text;
using System.Diagnostics;
using Microsoft.WindowsMobile.Status;

namespace GSensorSDK
{
   public struct HTCGSensorData
   {
      public short TiltX;         // From -1000 to 1000 (about), 0 is flat
      public short TiltY;         // From -1000 to 1000 (about), 0 is flat
      public short TiltZ;         // From -1000 to 1000 (about), 0 = Straight up, -1000 = Flat, 1000 = Upside
down
      public short Unknown1;      // Always zero
      public int AngleY;        // From 0 to 359
      public int AngleX;        // From 0 to 359
      public int Unknown2;      // Bit field?
   };

   public class HTCGSensor : IDisposable, IGSensor
   {
      enum HTCSensor : uint
      {
         GSensor = 1
      }

      #region HTCSensorSDK
      // The following PInvokes were ported from the results of the reverse engineering done
      // by Scott at scottandmichelle.net.
      // Blog post: http://scottandmichelle.net/scott/comments.html?entry=784
      [DllImport("HTCSensorSDK")]
      extern static IntPtr HTCSensorOpen(HTCSensor sensor);

      [DllImport("HTCSensorSDK")]
      extern static void HTCSensorClose(IntPtr handle);

      [DllImport("HTCSensorSDK")]
      extern static IntPtr HTCSensorGetDataOutput(IntPtr handle, out HTCGSensorData sensorData);
      #endregion
      IntPtr myHandle = HTCSensorOpen(HTCSensor.GSensor);

      #region IDisposable Members
```

```
        public void Dispose()
        {
            if (myHandle != IntPtr.Zero)
            {
                HTCSensorClose(myHandle);
                myHandle = IntPtr.Zero;
            }
            using (myOrientationState)
            {
                myOrientationState.Changed -= new ChangeEventHandler(myOrientationState_Changed);
            }
            myOrientationState = null;
            myOrientationChangedHandler = null;

            // Once it hits 0, the service is stopped.
            IntPtr hEvent = CreateEvent(IntPtr.Zero, true, false, "HTC_GSENSOR_SERVICESTOP");
            SetEvent(hEvent);
            CloseHandle(hEvent);
        }
        #endregion
        [DllImport("coredll")]
        extern static bool CloseHandle(IntPtr handle);
        [DllImport("coredll", SetLastError = true)]
        extern static IntPtr CreateEvent(IntPtr eventAttributes, bool manualReset, bool intialState, string
name);
        [DllImport("coredll", SetLastError = true)]
        extern static bool EventModify(IntPtr handle, uint func);
        //#define SENSOR_START        _T("HTC_GSENSOR_SERVICESTART")
        //#define SENSOR_STOP         _T("HTC_GSENSOR_SERVICESTOP")

        static bool SetEvent(IntPtr handle)
        {
            return EventModify(handle, 3);
        }
        public HTCGSensorData GetRawSensorData()
        {
            HTCGSensorData data;
            HTCSensorGetDataOutput(myHandle, out data);
            return data;
        }
        public HTCGSensor()
        {
            IntPtr hEvent = CreateEvent(IntPtr.Zero, true, false, "HTC_GSENSOR_SERVICESTART");
            SetEvent(hEvent);
            CloseHandle(hEvent);

            myOrientationState.Changed += new ChangeEventHandler(myOrientationState_Changed);
        }

        void myOrientationState_Changed(object sender, ChangeEventArgs args)
        {
            if (myOrientationChangedHandler != null)
                myOrientationChangedHandler(this);
        }
        #region ISensor Members
```

```
        public GVector GetGVector()
        {
            GVector ret = new GVector();
            HTCGSensorData data = GetRawSensorData();
            ret.X = data.TiltX;
            ret.Y = data.TiltY;
            ret.Z = data.TiltZ;
            // HTC's Sensor returns a vector which is around 1000 in length on average..
            // but it really depends on how the device is oriented.
            // When simply face up, my Diamond returns a vector of around 840 in length.
            // While face down, it returns a vector of around 1200 in length.
            // The vector direction is fairly accurate, however, the length is clearly not extremely precise.
            double htcScaleFactor = 1.0 / 1000.0 * 9.8;
            return ret.Scale(htcScaleFactor);
        }
        RegistryState myOrientationState = new
    RegistryState(@"HKEY_LOCAL_MACHINE\Software\HTC\HTCSensor\GSensor", "EventChanged");
        // #define SN_GSENSOR_BITMASK  0xF

        public ScreenOrientation Orientation
        {
            get
            {
                return (ScreenOrientation)((int)myOrientationState.CurrentValue & 0xF);
            }
        }
        OrientationChangedHandler myOrientationChangedHandler;
        public event OrientationChangedHandler OrientationChanged
        {
            add
            {
                myOrientationChangedHandler += value;
            }
            remove
            {
                myOrientationChangedHandler -= value;
            }
        }
        #endregion
    }

}
```

GSensor.cs (C# code)

```
using System;
using System.Collections.Generic;
using System.Text;

namespace GSensorSDK
{
   public enum ScreenOrientation
   {
      Landscape = 0,
      ReverseLandscape = 1,
      Portrait = 2,
      ReversePortrait = 3, // upside down
      FaceDown = 4,
      FaceUp = 5
   }

   public struct GVector
   {
      public GVector(double x, double y, double z)
      {
         myX = x;
         myY = y;
         myZ = z;
      }
      double myX;

      public double X
      {
         get { return myX; }
         set { myX = value; }
      }
      double myY;

      public double Y
      {
         get { return myY; }
         set { myY = value; }
      }
      double myZ;

      public double Z
      {
         get { return myZ; }
         set { myZ = value; }
      }

      public GVector Normalize()
      {
         return Scale(1 / Length);
      }

      public GVector Scale(double scale)
```

```
        {
            GVector ret = this;
            ret.myX *= scale;
            ret.myY *= scale;
            ret.myZ *= scale;
            return ret;
        }

        public double Length
        {
            get
            {
                return Math.Sqrt(myX * myX + myY * myY + myZ * myZ);
            }
        }

        public override string ToString()
        {
            return string.Format("X={0}\nY={1}\nZ={2}\nMagnitude={3}", Math.Round(myX, 4),
Math.Round(myY, 4), Math.Round(myZ, 4), Math.Sqrt(myX * myX + myY * myY + myZ * myZ));
        }
    }

    public delegate void OrientationChangedHandler(IGSensor sender);
    public interface IGSensor
    {
        /// <summary>
        /// Returns a vector that desribes the direction of gravity/acceleration in relation to the device screen.
        /// When the device is face up on a flat surface, this method would return 0, 0, -9.8.
        /// The Z value of -9.8 would mean that the acceleration in the opposite direction of the orientation of
the screen.
        /// When the device is held up, this method would return 0, -9.8, 0.
        /// The Y value of -9.8 would mean that the device is accelerating in the direction of the bottom of the
screen.
        /// Conversely, if the device is held upside down, this method would return 0, 9.8, 0.
        /// </summary>
        /// <returns>
        /// The vector returned will have a length measured in the unit meters per second square.
        /// Ideally the when the device is in a motionless state, the vector would be of length 9.8.
        /// However, the sensor is not extremely accurate, so this almost never the case.
        /// </returns>
        GVector GetGVector();

        ScreenOrientation Orientation
        {
            get;
        }

        event OrientationChangedHandler OrientationChanged;
    }}
```

AlertFall.vb (Visual Basic code)

```
Imports System.Data
Public Class AlertFall


    Private userid, userName As String
    'Private main As MainMenu
    Private sendSMS As clsSMS
    Private recepient As String
    Private emergency_contacts As LocalDataSets.SELECTED_MEMBERSDataTable
    Private content As String
    Private data As clsLocalServices
    "play sound
    Private sound As GeneralUtils.cSound

    Public Sub New(ByVal id As String)
        InitializeComponent()

        tmr_fall.Enabled = True
        userid = id

        '  main = New MainMenu(userid)

        data = New clsLocalServices()

        userName = data.GetPersonInfo(userid).ElementAt(0).fname + " " +
data.GetPersonInfo(userid).ElementAt(0).lname
        sendSMS = New clsSMS()
        content = "ΠΡΟΣΟΧΗ ! ΠΙΘΑΝΟ ΝΑ ΕΧΕΙ ΣΗΜΕΙΩΘΕΙ ΠΤΩΣΗ ΤΟΥ/ΤΗΣ " & userName & "
ΠΑΡΑΚΑΛΩ ΕΠΙΚΟΙΝΩΝΙΣΤΕ ΤΗΛΕΦΩΝΙΚΟΣ ΑΜΕΣΑ. Μήνυμα απο MELCO"
        emergency_contacts = data.Get_ROLE_MEMBERS(2)  "role number for emergency contacts

        '  MessageBox.Show(content)

        "Handle sound
        sound = New GeneralUtils.cSound()

    End Sub

    Private Sub NOT_OK_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
NOT_OK.Click
        Try
            sound.StartSound("den_ime_kala.mp3")

            If Not emergency_contacts.Equals(Nothing) Then
                If emergency_contacts.Rows.Count > 0 Then

                    sendSMSalert()
                    'emergency_contacts.Dispose()
                    'emergency_contacts = Nothing
                    'sound = Nothing
                    'tmr_fall.Enabled = False
                    Me.Close()
```

```
            Me.Dispose()

          End If
        Else
          MessageBox.Show("no members found")
        End If


      Catch ex As Exception
        MessageBox.Show("FALL-not" & ex.Message)

      End Try

    End Sub

    Private Sub OK_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
OK.Click

      Try
        sound.StartSound("ime_kala.mp3")
        ' main.Show()

        'emergency_contacts.Dispose()
        'emergency_contacts = Nothing
        'sound = Nothing

        If Not tmr_fall.Equals(Nothing) Then
          tmr_fall.Enabled = False
        End If

        Me.Close()
        Me.Dispose()

      Catch ex As Exception
        MessageBox.Show("ok" & ex.Message)

      End Try

    End Sub


    Private Sub sendSMSalert()
      Dim i As Integer = 0

      If Not emergency_contacts.Equals(Nothing) Then

        "SEND ALERT SMS TO RESPONSIBLE MEMBER

        For Each r As DataRow In emergency_contacts
          'recepient = emergency_contacts.ElementAt(i).PEROSN_MOBILE_PHONE
          Dim info As LocalDataSets.PersonsDataTable =
data.GetPersonInfo(emergency_contacts.ElementAt(i).PERSON_ID)
          recepient = info.ElementAt(0).PERSON_MOBILE_PHONE

          '  MessageBox.Show("name " & emergency_contacts.ElementAt(i).PERSON_ID & " phone " &
recepient)
```

```
                Try
                    sendSMS.SendSMS(recepient, content)

                    'emergency_contacts.Dispose()
                    'emergency_contacts = Nothing
                    'sound = Nothing
                    Me.Close()

                Catch ex As Exception
                    MessageBox.Show("FALL-send" & ex.Message)
                    'main.Show()
                    'Me.Close()

                End Try
                i = i + 1
            Next

        End If
    End Sub

    Private Sub tmr_fall_Tick(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
tmr_fall.Tick

        'MessageBox.Show("Timer enabled")

        ' Uncomment HERE & fix time
        sendSMSalert()
    End Sub

End Class
```

2. Physical Behavior Analysis Source Code

cGPS.cs (C# code)

```
using System;
using System.Linq;
using System.Collections.Generic;
using System.Windows.Forms;
using System.Text;
using Microsoft.WindowsMobile.Samples.Location;

namespace GPSMetrics
{    public class cGPS
   {
      private Gps m_GPS = null;
      private double m_latitude, m_longitude;
      private delegate void MessageHandler(Control control, string message);

      #region Property : Latitude
      public double Latitude
      {
         get { return m_latitude; }
         set
         {
            if (m_latitude == value)
               return;
            m_latitude = value;
         }
      }
      #endregion
      #region Property : Longitude
      public double Longitude
      {
         get { return m_longitude; }
         set
         {
            if (m_longitude == value)
               return;
            m_longitude = value;
         }
      }
      #endregion
      #region Property : IsGPSOpened
      public bool IsGPSOpened
      {
         get { return m_GPS.Opened; }
      }
      #endregion
      #region Constructor
      public cGPS()
      {
         m_GPS = new Gps();

         if (!m_GPS.Opened)
         {
```

```
            m_GPS.LocationChanged += new LocationChangedEventHandler(m_GPS_LocationChanged);
            m_GPS.DeviceStateChanged += new
DeviceStateChangedEventHandler(m_GPS_DeviceStateChanged);
            m_GPS.Open();
         }
         else
         {
            m_GPS.LocationChanged -= m_GPS_LocationChanged;
            m_GPS.DeviceStateChanged -= m_GPS_DeviceStateChanged;
            m_GPS.Close();
         }
      }
      #endregion
      #region Method : CloseGPS()
      public void CloseGPS()
      {
         if (m_GPS.Opened)
         {
            m_GPS.LocationChanged -= m_GPS_LocationChanged;
            m_GPS.DeviceStateChanged -= m_GPS_DeviceStateChanged;
            m_GPS.Close();
         }
      }
      #endregion
      #region Method : m_GPS_LocationChanged
      private void m_GPS_LocationChanged(object sender, LocationChangedEventArgs args)
      {
         MessageHandler cu = UpdateControl;

         GpsPosition position = args.Position;

         if (position.LatitudeValid)
            m_latitude = position.Latitude;

         if (position.LongitudeValid)
            m_longitude = position.Longitude;
      }
      #endregion
      #region Method : m_GPS_DeviceStateChanged
      private void m_GPS_DeviceStateChanged(object sender, DeviceStateChangedEventArgs args)
      {
         MessageHandler cu = UpdateControl;
         GpsDeviceState device = args.DeviceState;
      }
      #endregion
      #region Method : UpdateControl
      private void UpdateControl(Control control, string message)
      {
         control.Text = message;
      }
      #endregion
   }
}
```

cgetDistance.cs (C# code)

```
//:::        unit = the unit you desire for results          //:::        where: 'M' is statute miles
//:::             'K' is kilometers (default)                //:::             'N' is nautical miles
//:::

using System;
using System.Linq;
using System.Collections.Generic;
using System.Text;

namespace GPSMetrics
{   public class cGetDistance
   {

 #region Method: CalculateDistance
      public  double CalculateDistance(double lat1, double lon1, double lat2, double lon2, char unit)
      {
         double theta = lon1 - lon2;
         double dist = Math.Sin(deg2rad(lat1)) * Math.Sin(deg2rad(lat2)) + Math.Cos(deg2rad(lat1)) *
Math.Cos(deg2rad(lat2)) * Math.Cos(deg2rad(theta));
         dist = Math.Acos(dist);
         dist = rad2deg(dist);
         dist = dist * 60 * 1.1515;
         if (unit == 'K')
         {
            dist = dist * 1.609344;
         }
         else if (unit == 'N')
         {
            dist = dist * 0.8684;
         }
         return (dist);
      }
      #endregion

      #region Method: deg2rad
      private static double deg2rad(double deg)
      {
         return (deg * Math.PI / 180.0);
      }
      #endregion
      #region Method: rad2deg
      private static double rad2deg(double rad)
      {
         return (rad / Math.PI * 180.0);
      }
      #endregion


   }
}
```

3. Database Synchronization Source Code

SynchronizationClass.vb (Visual Basic code)

```
Imports System.Data.SqlServerCe
Imports System.IO
Imports System.Configuration


Public Class SynchonizationCls
   Dim localConnection As String = "Data Source=\Program Files\sync\localDB.sdf"

   Dim gConnStr As String = String.Empty
   Dim gSourceUrls As String = String.Empty
   Dim gTableNames As String = String.Empty
   Dim gSourceURLArray() As String
   Dim gSiteIPArray() As String
   Dim gTableArray() As String
   Dim gLogFile As StreamWriter
   Dim USER_ID As String


   "CONSTRUCTOR- GET USERID
   Public Sub New(ByVal USER As String)
      USER_ID = USER
   End Sub


   Public Sub ProcessAllSynchOperations(ByVal output As Label)

      ' call routine to fetch the DataSet from the remote Web Service
      Dim oDS As LocalDataSets = FetchTables(USER_ID)

      ' see if there were any errors with the Web Service
      If oDS Is Nothing Then
         Throw New Exception("No DataSet returned from Web Service")
      End If
      If oDS.Tables(0).TableName = "Errors" Then
         Throw New Exception("Error reported by Web Service: " & oDS.Tables(0).Rows(0)(0))
      End If

      output.Text += "Clearing local database..." & vbCrLf
      ' Delete all existing data in database tables
      clearTables()

      ' create Connection, open it and start a transaction
      Dim oConn As SqlCeConnection
      Dim oTrans As SqlCeTransaction
      Try
         oConn = New SqlCeConnection(localConnection)
         oConn.Open()
         oTrans = oConn.BeginTransaction()

         ' iterate through all the tables in the list
```

```
        Dim sTableName As String


        For Each sTableName In gTableArray

          If oDS.Tables(sTableName) Is Nothing Then
            WriteStatus(">> WARNING: no rows received for table ''' & sTableName & """)
          Else
            ' see how many rows are in this table
            Dim iRows As Integer = oDS.Tables(sTableName).Rows.Count
            WriteStatus("Received " & iRows.ToString() & " rows from." & sTableName)
            If iRows > 0 Then

              output.Text += "Updating local database..." & vbCrLf
              WriteStatus("Updating local database...")
              Try
                ' create new Command for SelectCommand within current transaction
                Dim oSCmd As New SqlCeCommand("SELECT * FROM " & sTableName, oConn,
oTrans)
                ' create DataAdapter from Command
                Dim oDA As New SqlCeDataAdapter(oSCmd)
                ' create auto-generated INSERT command with CommandBuilder
                Dim oCB As New SqlCeCommandBuilder(oDA)
                ' get InsertCommand from CommandBuilder
                Dim oICmd As SqlCeCommand = oCB.GetInsertCommand()
                ' attach the current transaction to the InsertCommand
                oICmd.Transaction = oTrans
                ' specify this as the InsertCommand of the DataAdapter
                oDA.InsertCommand = oICmd
                ' update the database table

                Dim iCount As Integer = oDA.Update(oDS, sTableName)
                WriteStatus("Added " & iCount.ToString() & " rows to table ''' & sTableName & """)


              Catch e As Exception
                oTrans.Rollback()
                Throw New Exception("Error updating target table " & sTableName & " - " & e.Message)
              End Try
            End If
          End If
        Next

        ' all OK so commit all of the updates
        oTrans.Commit()
        WriteStatus("Transaction committed" & vbCrLf)

      Catch e As Exception
        ' error encountered so roll back all the updates

        oTrans.Rollback()
        MessageBox.Show("Transaction failed to complete ")
        Throw New Exception("Transaction failed to complete - " & e.Message)

      Finally
        oConn.Close()
```

```
        End Try


    End Sub

    " ADD ALL WEBSERVICES TO GET DATA FROM REMOTE SERVER
    Function FetchTables(ByVal user_id As String) As LocalDataSets

        'MessageBox.Show("Accessing Web Service...")

        ' call Web Service methods to fill DataSet tables
        Dim DS As LocalDataSets = New LocalDataSets
        Dim SERVICES As clsRemoteservices = New clsRemoteservices

        Try

            Dim city As String = "nicosia"
            DS = Synchronization.GetAccessories(user_id, DS)
            'DS = Synchronization.GetSkills(user_id, DS)
            'DS = SERVICES.GetAccessories(user_id, DS)
            'DS = SERVICES.GetLocations(user_id, DS)
            'DS = SERVICES.GetServices(user_id, DS)
            'DS = SERVICES.GetVT(user_id, DS)
            'DS = SERVICES.GetWeather(city, DS)

            Return DS
        Catch ex As Exception
            MessageBox.Show("Web Service Error" & ex.Message)
            Return DS
        End Try

    End Function

    Sub GetConfigurationValues()
        ' get values from application configuration file
        'gConnStr = ConfigurationSettings.AppSettings("TargetSqlClientConnectionString")
        'ConfigurationSettings.AppSettings("TargetSqlClientConnectionString")
        'gTableNames = ConfigurationSettings.AppSettings("SourceTableList")
        'Dim sSourceUrl As String = ConfigurationSettings.AppSettings("SourceWebServiceURLs")
        'Dim sWebSiteIP As String = ConfigurationSettings.AppSettings("SourceWebSiteIPAddresses")
        " check that the required values exist
        'If sSourceUrl = String.Empty Or gConnStr = String.Empty _
        'Or sWebSiteIP = String.Empty Or gTableNames = String.Empty Then
        '    Throw New Exception("Error loading configuration settings from " &
System.Reflection.Assembly.GetExecutingAssembly.Location & ".config")
        'Else
        '    ' display values on Form
        '    SourceWS.Text = "Source Web Service URLs: " & sSourceUrl
        '    WebSiteIP.Text = "Source Web Site IP Addresses: " & sWebSiteIP
        '    TargetConn.Text = "Target Database Connection String: " & gConnStr
        '    gSourceURLArray = sSourceUrl.Split(",")
        '    gSiteIPArray = sWebSiteIP.Split(",")
        '    If gSourceURLArray.Length <> gSiteIPArray.Length Then
        '        Throw New Exception("There are a different number of Web Service URLs and IP addresses in
the configuration file")
```

```
        '    End If

        gTableNames =
"ACCESSORIES,ACTIVITIES,APPOINTMENT,GPS_LOCATIONS,GPS_LOG,MESSAGES,
PERSON_ACTIVTIES,PERSON_SCHEDULE, PERSON_SKILLS, PERSONS, VIRTUAL_TEAMS,
VIRTUAL_TEAM_MEMBERS,SERVICES, VT_TYPES,WEATHER"
        gTableArray = gTableNames.Split(",")

        ' End If
    End Sub


    Public Sub synchronizeNow(ByVal output As Label)
        Try
            OpenLogFile()
            GetConfigurationValues()

            Try
                If IsConnectionAvailable() = True Then
                    output.Text = " Synchronization in Progress..." & vbCrLf

                    WriteStatus(" Synchronization in Progress...")

                    ' main routine to fetch rows and update database
                    ProcessAllSynchOperations(output)

                    output.Text += "Completed at " & DateTime.Now.ToString("yyyy-MM-dd hh:mm:ss")

                    WriteStatus("Completed at " & DateTime.Now.ToString("yyyy-MM-dd hh:mm:ss"))
                    CloseLogFile()
                Else
                    output.Text += "No internet connection available! Please Try Again."
                    WriteStatus("No internet connection available!")
                End If

            Catch ex As Exception
                MessageBox.Show(ex.Message)
                output.Text += "Internet connection Error! Please Try Again."
                WriteStatus("Internet connection Error " & ex.Message)
            End Try


        Catch errMain As Exception
            MessageBox.Show(">>>" & errMain.Message)
            CloseLogFile()

        End Try
        '  If gbAutoStart Then End
    End Sub


    Sub WriteStatus(ByVal sMessage As String)
        ' MessageBox.Show(sMessage)
        Try
            gLogFile.WriteLine(sMessage)
        Catch
```

```
    End Try
End Sub


Sub OpenLogFile()
    Dim sFile As String = "\Program Files\MELCO\logFile.txt"
    'ConfigurationSettings.AppSettings("LogFileFullPathAndName")
    Try
        gLogFile.Close()
    Catch
    End Try
    Try
        If File.Exists(sFile) Then
            gLogFile = File.AppendText(sFile)
        Else
            gLogFile = File.CreateText(sFile)
        End If
        gLogFile.WriteLine(vbCrLf & "----------------------------")
        gLogFile.WriteLine(DateTime.Now.ToString("yyyy-MM-dd \a\t\ hh:mm:ss"))
    Catch e As Exception
        Throw New Exception("Cannot open log file: " & sFile & e.Message)
        Try
            gLogFile.Close()
        Catch
        End Try
    End Try
End Sub


Sub CloseLogFile()
    Try
        gLogFile.Flush()
    Catch
    End Try
    Try
        gLogFile.Close()
    Catch
    End Try
End Sub

Sub clearTables()

    ' create Connection, open it
    Dim oConn As SqlCeConnection

    Try
        oConn = New SqlCeConnection(localConnection)
        oConn.Open()
        ' oTrans = oConn.BeginTransaction()

        ' iterate through all the tables in the list
        Dim sTableName As String
        WriteStatus("Clearing Database...")
        For Each sTableName In gTableArray

            Try
```

```
                ' create new Command for SelectCommand within current transaction
                Dim delCmd As New SqlCeCommand("Delete FROM " & sTableName, oConn)

                ' clear the database table

                Dim iCount As Integer = delCmd.ExecuteNonQuery()

                WriteStatus("Deleted " & iCount.ToString() & " rows from table '" & sTableName & "'")

            Catch e As Exception
                '  oTrans.Rollback()
                Throw New Exception("Error deleting " & sTableName & " - " & e.Message)
            End Try
        Next
        ' oTrans.Commit()
        WriteStatus("Transaction committed" & vbCrLf)
    Finally
        oConn.Close()
    End Try

End Sub

"CHECK IF AN INTERNET CONNECTION IS AVAILABLE
Public Function IsConnectionAvailable() As Boolean
    ' Returns True if connection is available

    Dim objUrl As New System.Uri("http://www.google.com/")
    ' Setup WebRequest
    Dim objWebReq As System.Net.WebRequest
    objWebReq = System.Net.WebRequest.Create(objUrl)
    Dim objResp As System.Net.WebResponse
    Try
        ' Attempt to get response and return True
        objResp = objWebReq.GetResponse
        objResp.Close()
        objWebReq = Nothing
        Return True
    Catch ex As Exception
        ' Error, exit and return False
        " objResp.Close()
        objWebReq = Nothing
        Return False
    End Try
End Function


End Class
```