The REMOTE AAL Project: Remote Health and Social Care for Independent Living of Isolated Elderly with Chronic Conditions

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Abstract. REMOTE is an AAL project that aims at advancing the state-of-the-art in fields of tele-healthcare and ambient intelligence by enhancing the elderly's home with audio-visual, sensor, motoric monitoring and automation abilities to trace vital signs, activity, behaviour and health condition, and detect risks and critical situations, as well as provide, proactively and reactively, effective and efficient support at home. This paper presents the project objectives, the approach and principles endorsed, and the expected results. Overall, REMOTE is characterised by: a user-centered philosophy and consistent involvement of users; processes for reaching consensus among all stakeholders; strong commitment to ethical and legal issues; sound scientific and evidence-based methods (incl. real context pilots in 6 countries) to measure usability, impact and acceptance of the developments by elderly populations.

Keywords: Chronic conditions, Tele-healthcare, Ambient Assisted Living.

1 Introduction

Chronic diseases are the leading cause of mortality in the world, representing 60% of all deaths [1]. Today, about 133 million people live with a chronic condition, which requires ongoing adjustments by the affected person and long lasting interactions with the health care system. With this number being projected to increase by 2030 by more than one percent per year, resulting in an estimated chronically ill population of 171 million, several challenges arise for modern healthcare systems.

With ICT pervasively affecting all areas of social and economic life, particularly in industrialised countries, several opportunities are there to be pursued through a digital

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revolution for healthcare. Meeting these opportunities will require nothing less than a transformation of healthcare, from a system that is essentially reactive - responding mainly when a person is sick - to one that is proactive and focused on keeping a person as healthy as possible. Applications, such as health telematics [2], can be used in homes to upgrade the way health-related services are conceived and delivered.

Significant research is underway to enable elders and people with disability to use smart assistive technology and smart homes to more easily perform activities of daily living, continue social participation, engage in entertainment and leisure activities, and to enjoy living independently[3]. Today, networks, microprocessors, chips, smart sensors and actuators are faster, cheaper, more intelligent, and smaller than ever.

Current advances in such enabling technologies, coupled with the need to transform the health care delivery system in rural areas, are giving rise to novel applications and services for improving the quality of life for all. In the context of an ageing population, increased burden of chronic diseases, active participation of more demanding patients and ever increasing health expenditure, the realisation and amplification of telemedicine services is important and urgent.

To speed the transition, an AAL[1] project, *REMOTE*[2] ("Remote health and social care for independent living of isolated elderly with chronic conditions", Grant Agreement no. AAL-2008-1-147), was proposed and accepted for funding. REMOTE implements a novel approach, which aims at addressing emerging deficiencies in current tele-healthcare R&D and summarizes the basic elements for improving care in health systems at the community, organization, practice and patient levels.

2 The Project Concept

REMOTE aims at defining and establishing a multidisciplinary and integrated approach to R&D of ICT for addressing, in real life contexts, identified needs of frail elderly, especially of citizens at risk due to geographic and social isolation in combination with chronic conditions , such as hypertension, arthritis, asthma, stroke, Alzheimer's disease, and Parkinson's disease, and the coexistence of lifestyle risk factors, such as obesity, blood pressure, smoking, alcohol abuse, poor eating / drinking habits, stress, and low levels of physical activity.

To this end, the project will advance the state-of-the-art in fields of tele-healthcare and ambient intelligence (AmI) and enhance the elderly's personal environment with audio-visual, sensor / motoric monitoring, and automation abilities for tracing vital signs, activity, behaviour and health condition, and detecting risks and critical situations as well as providing, proactively and reactively, effective and efficient support at home. In particular, scale-up of existing research prototypes and development of new systems for collecting, recording and analysing health- and context-related data will be deployed in the course of the project. These include, on the one hand, wearables and sensors [4] for detecting intra-oral miniature wetness and jaw movements, body temperature, blood pressure, heart rate, human posture and motion / acceleration recognition, etc., and, on the other hand, sensors and actuators to be installed in

[1] Website of the Ambient Assisted living (AAL) Joint Programme: http://www.aal-europe.eu/
[2] Project website: http://www.remote-project.eu/

premises (and vehicles), for providing context information, e.g., air temperature, luminance, humidity, human location and motion, etc.

Then, in order to focus on the specific risks and problems experienced by elder individuals with chronic conditions because of living on their own (about 1 in 3) or due to the growing gap between urban and rural areas, the project is aimed to enable professional carers to access remotely such real-time and past activity and medical data of their patients at anytime and from anywhere, and to promptly diagnose and react to health and life risks. The project introduces an innovative, ontology-driven, open reference architecture and platform to enable interoperability, seamless connectivity and content sharing among different applications and services.

3 Target Users

REMOTE focuses on the particular needs of elderly with specific chronic conditions, especially those living in rural and isolated areas (**primary users**), by designing automated and multi-user controlled home environments that offer the comfort, security and safety required. Aiming at autonomy, self-confidence, mobility and well-being, elderly-oriented applications and services will be designed to enhance their self-care, social interaction, and skills maintenance ability. Overall, the elderly will be supported in learning to understand their condition and live successfully with it. Thereby, elderly people will be supported in: managing their risk factors; performing self-healthcare, such as dietary management, medicine management, etc.; maintaining communication and interaction with families, friends and other caregivers; and going out for everyday activities or even on long trips and vacation.

Building on its integrating approach, the project will provide professional health carers (**secondary users**) with tools for continuous monitoring run-time and history patient data and, thereupon, implementing patient-centric tele-healthcare, while reducing paper work and travel required from both ends. Through the professionals front-end of the system, doctors will be able to get access to electronic medical records, real time data (transmitted through wireless and wired links) and records of the patient's condition (body temperature, blood pressure), activity (physical activity, medication, food and water consumption), and life environment (i.e., house) changes. Professionals will be further supported by decision support tools aiming to facilitate patient-data reviewing tasks and the generation of personalised, disease care plans and every-day feedback to the patients. All of these modules will be Web-based to enable professionals to access them at anytime and from anywhere.

Ultimately, accumulated knowledge and lessons learned throughout the project will be turned into appropriate forms for serving as guidelines to developers and feeding into standardisation processes, thus satisfying the cost reduction, interoperability, and standardisation requirements of **tertiary end-users**.

4 Progress Beyond the State of the Art

The state-of-the-art of REMOTE encompasses an enormous domain of related applications and services for the elderly, architectures, ontologies and standards for their inter-connection, integration, etc. We will focus here on discussing REMOTE's breakthrough against major limitations of other approaches.

First of all, most efforts so far have a focus restricted on health-related issues [2], failing to see the person as a whole entity of a dynamic and complex nature with, often, multiple conditions and social and psychological aspects playing a major role in individual well-being and quality of life. For elderly, these aspects are even more important because of natural decrease of abilities and skills and the progressive limitation of social life. This implies the need for integrated, scalable and adaptive care solutions for all stages of life, acute care, chronic care, preventive services, rehabilitation services and end of life care.

REMOTE, recognising isolation -both geographical and social- as a common multiplying risk factor, aims at overcoming these limitations by both changing the focus of the research, and by adopting an approach whereby ICT and AmI-based applications and services are part of holistic strategy to health care and management as well as to subjective well-being of the elderly.

Regarding REMOTE's progress beyond the state-of-the-art in integration of technologies and products, the following areas are notable.

Open reference architectures and ontologies: REMOTE moves substantially beyond the state-of-the-art by relating ontology development to a mature and well-defined set of best practices available in software engineering. Principles basic to software engineering will be applied here and the resulting high quality, well-structured ontology will result to a new interoperability standard that will be deployed and evaluated across a broad range of applications for the elderly.

Intelligent agents and AmI framework: Innovation in relation to previous efforts, exploited in REMOTE (i.e. ASK-IT, IM@GINE-IT, etc.) is identified in the following issues: (a) REMOTE adopts a rather light multi-agent architecture of flexible and efficient agents, to ensure a high performance AMI framework; (b) REMOTE agents undertake the process of low-level information filtering using real-time data - information filtering operations are not undertaken by the previous projects' agents; (c) agents of the REMOTE framework act in a more deliberative function compared to the SoA agents - from a technical perspective this is realised by the development of specific techniques for learning and decision-making, such as Bayesian belief networks, and rational decision making abstract models.

Wearables, sensors and health/activity monitoring: The most significant innovation in REMOTE is the multi sensor approach, performing a data fusion of various sensor inputs (body sensors, wearable and mobile/portable sensors), combined with expert knowledge and individual user information in the REMOTE framework.

Independent living applications: Taking into account all previous research, REMOTE proposes an innovative approach of integration of many AAL-enabled Independent living applications through the use of a common set of interconnected ontologies.

Social support applications: Development of advanced social networking visualisation engines; Increase the scope of devices and networks supporting social applications; Address needs of wide range of user groups (55, 65 and 75+).

In-home and domotic sensors and localisation systems: To address sensors diversity and facilitate their integration, quality-aware sensor abstraction and sensor fusion will

be established in a common framework between the high-level application and the low-level communication infrastructure installed at home.

User interfaces and adaptive systems: In a parallel line of work to user-oriented adaptivity, UI research has recently addressed the identification of, and adaptation to, the situational and technical context of interaction although, most of the time, user- and context- oriented adaptivity are combined. This includes systems that adapt: to the user's device's form factor, the actual interaction devices available to the user, the user's geographical location, etc. In the context outlined above, REMOTE aims to provide high-quality, ambient user interfaces, by effectively addressing diversity in the following dimensions: target user population and changing abilities due to aging; categories of delivered services and applications; and deployment computing-platforms (i.e., e.g., PDA, smart phone, desktops, laptops) and input devices. To this end and towards increasing accessibility, usability and subjective satisfaction, an innovative design approach that guarantees device and modality independence will be employed and enhanced by device-, user- and context- adaptation facilities.

Tele-healthcare products and services: Another problem that this project aims to cope with is that of elderly people not wanting to, and/or not being able to buy new apparatus or equipment. One of the most important points is that the REMOTE technology (sensors, devices, software, etc.) will be scalable, flexible and adaptable in a manner that it can be easily integrated into existing set-ups and contexts.

5 Methodological Approach

The REMOTE uses cases (UC) and scenarios of use will be defined in detail early in the project (see Fig.1), based on a thorough literature review, user surveys, interviews and field work, technological benchmarking and iterative consensus building among key stakeholders, including user representatives; all of which are already present in the REMOTE consortium and will be significantly increased through the complementary involvement of external ones (e.g., the User Forum for primary users, while a Health professionals Forum will be considered for enhancing the project's access to independent secondary users).

The UCs constitute a fundament tool towards the success of the project as it offers, among others, the opportunity to present concepts and development plans to all interested parties in comprehensive way and at early stages the project, and ultimately receive thereby extremely valuable feedback regarding the usefulness, ease of use, ethical issues and overall acceptance levels of the envisioned developments.

The approach of REMOTE is simple in conception: direct re-usability of information is to be provided across heterogeneous services and devices. Much of the individual components of such advanced re-usability are already in place. Various service providers currently provide or are interested in providing health-related assistive services for the elderly. Much of the complexity that arises for providing monitoring-based, intelligent assistance then revolves around issues of effective and efficient communication between the user and their assisting devices, as well as communication between different elements of the assistive service. In all cases, to achieve efficient services, it is necessary to ensure a 'common understanding' of contextual information about different services and objects [5]. Such common understanding and sharing

of contextual information can only be achieved by enabling the interconnection of heterogeneous data models used by each service (i.e. by each service provider) or even module of service. This will in turn enable the integration of the plethora of diversiform services into a common platform in order to provide not only improved but also new services for the elderly. In order to achieve interoperability of services and sharing of contextual information between different services and objects, it is necessary to model them first, by extracting each service's individual structure up to its most primitive level. In current approaches, this can lead to more or less ad hoc solutions.

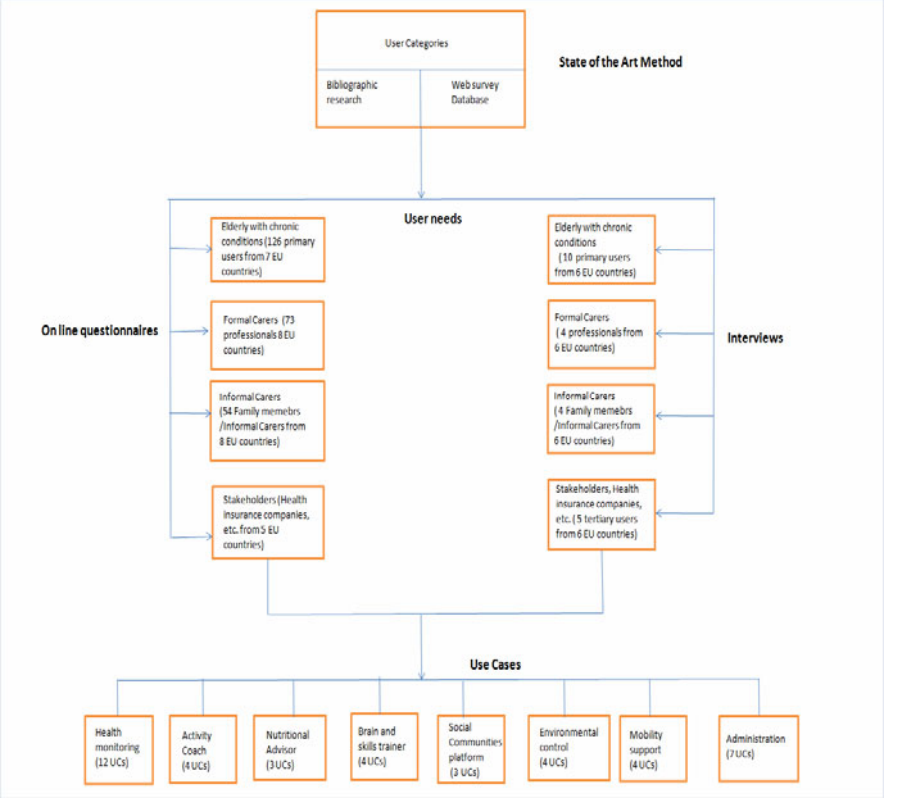

Fig. 1. Overall Methodology of extraction of the REMOTE Use Cases

The REMOTE solution is to provide foundational ontology components, specifically tailored to the requirements of the applications to be covered and the services provided. Overall, the implementation of the REMOTE platform will be based on an AmI framework which integrates healthcare applications, content and services, as well as health-monitoring hardware sensors. From a technical perspective information gathering capabilities where applicable will rely on an ontology-driven service-oriented environment whose purpose is to interact with the users and provide real-time invocation of the appropriate services either on user demand or in an autonomous fashion when necessary (e.g. in case of emergency).

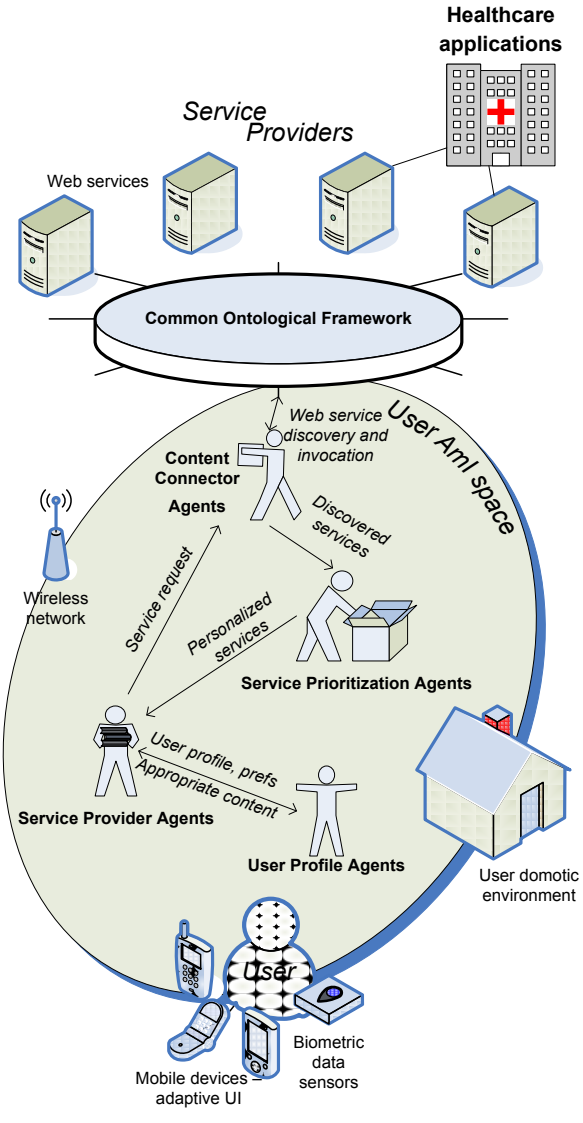

Fig. 2. REMOTE AmI abstract and functional architecture

The main parts of the REMOTE architecture are the following (see Figure 2):

- AmI framework managed by software agents. The AmI framework consists of the software infrastructure and the physical communication network that implements the body-area network that surrounds the user at home. Four types of software agents reside on the AmI. These are the following:
  - User Agents. These agents which belong to the user personal AmI space are in direct interaction with the user and his/her surrounding environment. User

Agents play the role of user representative in the AmI. They are responsible for carrying and handling information about user profile and preferences. This information may include, apart from user-specific attributes, their needs and wants, the type of the end-user device, as well as the attributes of user's physical environment which they conceive through the wireless sensors network. By collecting all user-related info, these agents become capable of synthesising suitable user-profile data, which they store in a local repository. In addition, these agents may perceive events occurring in the user AmI space and take specific actions, such as to invoke a specific service in order to provide real-time context sensitive information to the user or to notify a medical centre in case of emergency.

  - Service Prioritisation Agents. The Common ontological framework which is described later operates as a semantic search engine of Web services, in order to fulfill specific user requests for services. The returned results are received by the Service Prioritisation Agents, whose role is to provide a ranking of the returned services according to user-specific needs, preferences and habits. They actually implement a low-level information filtering process, thus providing the most valuable services to the end user.
  - Service Provider Agents. The real invocation of a requested service is performed by the service provider agents that also take into account user profile-specific information in order to make sure that users receive the appropriate content on the appropriate device.
  - Content Connector Agents. These agents are responsible to interact with the Common Ontological Framework and launch the Web discovery process. These agents take into account user-related information in order to discover those services that best match the user profile. They do this by receiving combined information by the User and Service prioritisation agents.

- Common Ontological Framework. This part of the REMOTE architecture provides a semantics-aware infrastructure that facilitates discovery and invocation of Web services and integrated applications on behalf of software agents. It serves as an ontology-driven middleware infrastructure which receives requests for services and returns the required content.
- Monitoring and tracking infrastructure: The AmI environment is supported by a network of wireless sensor devices. These include biometric data readers and health-monitoring devices. The devices communicate in the body area network with the end-user devices via Bluetooth that the user is equipped with. Additional devices include user location and motion tracking sensors. Monitoring data (at various levels) sets the grounds for implementing intelligent mechanisms (personalised, evidence-based) for automated (at home) and semi-automated (remotely, e.g., controlled by professionals) support provision to health and social care to frail and isolated elderly.
- Service-oriented content management architecture. The required information and content is delivered to the user device in the AmI space via a service-oriented infrastructure. This is comprised by a set of registered service providers as well as customised services whose role is to integrate user-asistive applications, such as healthcare, self-care and medical applications.

- Adaptive user interfaces and mobile devices. Users are equipped with multiple front-ends on which a set of personalised, customisable and adaptive user interfaces are installed. These interfaces exploit user and context information to adapt to diverse usage conditions. Adaptations are oriented towards accessibility and increased usability and satisfaction levels.
- Healthcare applications (at the primary user's end). A set of healthcare applications to be developed in the project will be interfaced to the AmI through appropriate Web services provided by the REMOTE SoA.

6 Conclusions

Telemedicine works: For instance, disease management through telemonitoring of heart conditions reduces mortality rates by an estimated 20%. It has also demonstrated the influence on attitudes and behaviour of patients resulting in better clinical outcomes[3]. Elderly people at large, especially individuals with chronic conditions and/or in risk of exclusion, will benefit from REMOTE in terms of an increased level of self-management capacity. The feeling of security and command that aged people 'on the edge' in the European countryside will receive, will strengthen their confidence in leading an independent life at home and delaying, if not fully avoiding, institutionalization [6]. Without being highly intrusive, REMOTE enables continuous health monitoring services, thus allowing health care personnel at hospitals and care institutions to seamlessly supervise, follow-up, treat, and monitor elderly people in their own homes or within elderly homes. Older people will be able to live longer on their own, while in an emergency help can be called for immediately. The REMOTE open Reference Architecture will enable sharing of data and interoperability between various services, thus enabling "*integrated care processes for the ageing population*".

Overall, REMOTE has the potential to contribute to the following areas:

Information extraction and use: The REMOTE project, through its planned activities for investigating user needs (both for the elderly and the health professionals), will identify types and sources of information that, once collected and properly combined, can lead to advanced (combined) information, such as health/disease progress, user activity, habits, behavioural patterns, preferences, etc. The project, in addition to making this information available to personal care giving teams, will investigate and suggest new ways for further exploiting such information within its intelligent mechanisms (decision making support, adaptation mechanisms).

Understanding of (chronic) and age-related conditions: Given the fact that REMOTE will give the chance to health professionals to monitor real-time health data of their patients and thereupon provide personalised tele-health care, the collected data records will give the chance to academics and researchers from the medicine field to further study chronic conditions (signs, symptoms, etiology, and factors / interrelations) in real settings and without interfering biases due to the presence of the doctor. Long term use of the suggested REMOTE system, has the potential of empowering

[3] Systematic Review of Home Telemonitoring for Chronic Diseases: The Evidence Base: J Am Med Inform Assoc. l 14, 269—277 (2007).

academia with data for statistical studies towards achieving deeper understanding and better management of chronic and other age-related conditions.

Patient modelling (the medical perspective): Understanding a chronic condition alone cannot guarantee efficient management unless the deployed care strategy takes into consideration the behavioural and lifestyle aspects of each patient. Through the projects user needs analysis, as well as throughout the pilot studies, significant knowledge in terms of patient patterns, needs and requirements will be accumulated, organised and properly disseminated. Of particular interest will be the information to emerge with regards to individuals in (risk of) isolation, both geographical (e.g., living in rural areas, remote islands, mountains, etc.), as well as social (e.g., lack of partner, family and friends, even when living in urban areas with everything nearby).

Elderly-friendly user interface design & development: REMOTE will enrich the available design knowledge with an innovative design paradigm that focuses on organising the user options in layouts that allow optimised user performances with all potential input modalities through common and assistive devices such as mouse, keyboard-only, joystick, special switches, speech input, etc.).

Guidelines, standards and policy: REMOTE will further elaborate on its findings and outcomes (see SoA advances in previous section) to translate them into useful guidance to developers, into appropriate input to standardisation working groups, and into a R&D roadmap for aging-well that will be disclosed to policy developers, academia and industry.

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