Mobile Applications for Independent Living of Isolated Elderly

Taxiarchis Tsaprounis, Katerina Touliou, Konstantinos Kalogirou, Konstantinos Agnantis, Evangelos Bekiaris
Hellenic Institute of Transport
Centre for Research and Technology Hellas
Thessaloniki, Macedonia, Greece
e-mail: Taxiarchis.Tsaprounis@certh.gr, tuliouk@certh.gr, kalogir@certh.gr, kagnantis@certh.gr, abek@certh.gr

Abstract-**REMOTE aims at an open and innovative reference architecture, based upon ontologies and semantic services that allow plug and play of existing and new services in all domains required for the independent and autonomous living of the elderly and their Quality of Life enhancement. It utilizes ICT and other key technologies in order to provide holistic services to the elderly to support their physical, social or psychological engagement and foster their emotional well being. This paper is strong evidence that telemonitoring applications may ensure maximum gain for patients as long as they are properly designed and implemented.**

Keywords-Symbian OS; Java ME; Elderly; Independent Living; Guardian Angel; Nutritional Advisor; Personal Calendar; Environmental Home Control

I. INTRODUCTION

The older population is growing at a considerably faster rate than that of the world's total population. In absolute terms, the number of elderly persons has tripled over the last 50 years and will be more than triple over the next 50-year period. The percentage of the ageing population using Information and Communication Technologies (ICT) is also rising every year [1]. Hence, future elderly users will have high ICT literacy compared to the elderly populations using similar systems to improve their overall wellbeing. The necessity of creating a platform that contains applications in all relevant domains for the benefit of the elderly user is clear and evident. REMOTE (Remote health and social care for independent living of isolated elderly with chronic condition) [2] is a Collaborative Project within the AAL (Ambient Assisted Living) joint programme which revolutionises the interoperability, quality, breadth and usability of services for all daily activities of the elderly [3].

The REMOTE approach is simple and straightforward. The core concept is direct re-usability of information across heterogeneous services and devices. The REMOTE solution is to provide foundational ontology [4] components, specifically tailored to the requirements of the applications to be covered and the services provided.

The structure of this document complies with the following description. The second section provides a general description of the project, a short state-of-the-art overview of the most crucial and relevant to the project domains and focuses on innovations over the state-of-the-art.

The third section is about REMOTE system's architecture. An overview of the functionality and the role of each module are presented.

The fourth section analyses the internal architecture of a very important component in REMOTE's architecture named Ambient Intelligence Framework.

The fifth section analyses the methodology used in the early stages of the project in order to derive REMOTE system's use cases. The sixth section presents technical specification details that a device should follow in order to be applicable for REMOTE applications' installation.

The following five sections give a detailed description of four applications which have been developed and integrated on Symbian OS platform to ensure remote access to various services related to the independent living and support of the specific target user group. Specifically, the following Java ME applications, which were developed for Symbian OS [5] mobile devices are presented:

(1) *Guardian Angel* [6] includes wearables and sensors for detecting body temperature, blood pressure, heart rate, human posture and motion/acceleration recognition and sends alerts to the healthcare professional in case an abnormal measurement is detected.

(2) *Nutritional Advisor* [6] offering everyday tips on nutrition, weekly menus and recipes according to the user's needs and preferences.

(3) *Personal Calendar* [6] for scheduling/managing daily tasks for the elderly (concerning nutrition, medication and to-do lists) under the unobtrusive supervision of their carers.

(4) *Environmental Home Control* [6] for interacting with home appliances and monitoring the house's status remotely.

All the above applications are interoperating with each other by the use of the user profile mechanism and store patient's monitored data to remote servers which can only be accessible by the professional healthcarers with the use of web applications.

The pre-last section presents the evaluation phase results at determining the usability and acceptance of four of REMOTE's applications and the last section is about conclusions that were gathered during the evaluation phase of the project.

II. REMOTE CONCEPT, STATE-OF-THE-ART AND INNOVATIONS

REMOTE EU project can be divided to REMOTE ontology, REMOTE platform and REMOTE applications.

REMOTE ontology basis is a set of existing ontologies related to each application, which was initially planned to be developed for the needs of the project, i.e., health monitoring, physical activity, mental exercise, nutrition,

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communication and calendar tasks. After its finalization the ontology was evaluated by the use of the "Competency Questions" process [7]. REMOTE platform is a framework that allows integration of single services using ontological layering. Services are integrated into the system through a "service-ontology alignment" process. Specifically, the service alignment is realised by the service provider through an alignment and anchoring tool, which is provided through REMOTE and semantically matches (aligns) ontological concepts to web services structural components, i.e., their I/O (input/output) parameters. REMOTE applications, which are invoking the integrated services, are provided to the elderly through the main menu.

Because of the fact that any service following certain specifications may be integrated in the system, REMOTE is considered to be an open reference architecture that allows data and (external) services fusion.

Primary users of REMOTE are the elderly with specific user conditions, especially those living in rural and isolated areas. Secondary users are the professional health carers with tools for continuous monitoring run-time and history patient data. Tertiary end-users are the service providers who are integrating their services into REMOTE platform with the use of the alignment tool.

Taking into account all previous research projects REMOTE's applications have used and further developed results from, i.e., for elderly people: ASK-IT [8] and MAPPED [9], for mobility issues: COGKNOW [10] and EMPOWER [11], to foster daily activities: SOPRANO [12], INHOME [13], OLDES [14] and AMIGO [15]. The most significant innovation in REMOTE is the multi sensor approach, i.e., body and home environmental sensors, performing a data fusion of their various inputs, combined with expert knowledge and individual user information. Particularly, new mechanisms have been defined to hide the complexity of the various sensor network environments and user interface adaptation algorithms have been created that take into account the users' needs and preferences in order to adapt the user interface according to situational and technical context of interaction. The use of ontologies in REMOTE is an innovative feature that gives added value to the platform. The ontologies assist in sharing common understanding of the structure of information among people or software, they enable reuse of domain knowledge and make it easier to analyze it.

A fundamental aspect of REMOTE system (sensors, devices, software, etc.) is its scalability, flexibility and adaptability "characters" that help to be easily integrated into existing set-ups and contexts. REMOTE prototypes and technology-based solutions are well-adapted to the respective diagnosis, prevention and treatment opportunities that can be attained while allowing the elderly to stay "at home" (detecting signs, symptoms, and risk factors; monitoring cure processes; etc.). The REMOTE system developed new elderly-oriented human-machine interaction paradigms, new systems for monitoring users at home, e.g., Dehydration level measurement and/or when they are on the move, e.g., Guardian Angel application. Moreover, the system detects important events (health risks, daily activity and behaviour).

III. REMOTE'S ARCHITECTURE OVERVIEW

The most important components of the REMOTE architecture are briefly described in the following list (Fig.1).

A. *Ontology Repository (OR)*

It is the technological layer that supports the Ontologies storage and management [16].

B. *Common Ontological Framework (COF)*

The COF defines a formal specification of ontology modules, and how they relate. The COF defines a methodology and best practice for ontology construction. It makes possible to define an ontology and facilitate and optimize the integration of new emerging ontologies.

C. *Content Anchoring and Alignment Tool (CAAT)*

This tool aligns the functionality of the provided web service through its Web Service Description Language (WSDL) [17] file with the ontologies stored in the OR. The concepts of the same or different application areas, after being aligned with the appropriate ontological concepts are ready to be used seamlessly through the CCM. The purpose of the Concept Anchoring and Alignment tool is to allow service providers insert their web services into the REMOTE framework.

D. *Content Connector Module (CCM)*

CCM receives a request for service by the end-user (client) application via the Ambient Intelligence Framework (AmI) and invokes the appropriate service that returns the requested content to the client [18].

E. *Ambient Intelligence Framework (AmI)*

The role of AmI framework [18] in REMOTE system is to provide seamless interactivity between REMOTE applications and the Content Connector Module. The Content Connector Module exposes its functionality as a web service and it is invoked by the AmI through a web service client.

F. *User Profile*

It contains all the context information related to a specific user. If a REMOTE component needs to retrieve some information related to the user context but out of its own scope, it should make a query to this user profile [18].

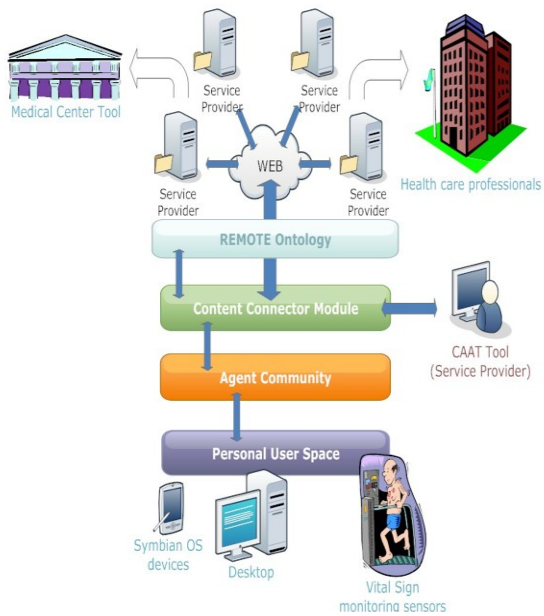


Figure 1. REMOTE Architecture

IV. AMBIENT INTELLIGENCE FRAMEWORK OVERVIEW

The AmI framework consists of four agents [19]. It directly communicates with the Content Connector Module through the Service Provider Agent and with the device through the Dialog Manager Agent. The User Profile Agent is responsible for accessing the User Profile Repository. The AmI internal communication and the user profile repository location are depicted in Fig.2.

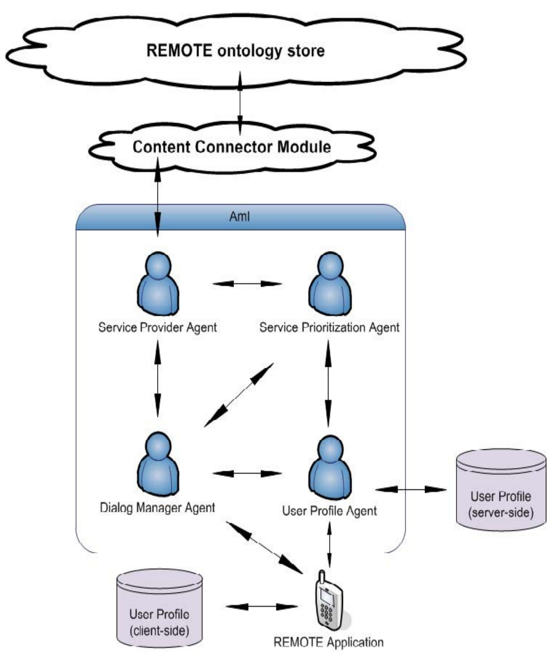


Figure 2. Ambient Intelligence Framework

The **Dialog Manager Agent** role is to contribute to a distinct and clearer AmI internal architecture. It resides on the client side and handles the communication between the mobile and the REMOTE server part.

The Content Connector Module of the REMOTE framework performs semantic search among suitable available web services, in order to satisfy the user request. The results produced as outcome of the search mechanism are then fed to the **Service Prioritisation Agent**, whose role is to provide a ranking of the returned services according to the specific needs, preferences and habits of the user. It actually implements a low-level information filtering process, thus providing the most valuable services to the end user. It prioritizes web services by taking into account meta-data received from CCM. Concerning the meta-data parameters currently used for service prioritization it is important to define that they are distinguished between parameters used for filtering services and parameters used after the filtering process for prioritizing them. In case the meta-data values of a service do not match the filtering parameters the corresponding web service is not taken into consideration in the prioritization process.

The filtering meta-data parameters are the following:

- *Language* (Comparison with the user's preferred languages)
- *Country* (Comparison with the user's country)
- *City* (Comparison with the user's city)

The prioritizing meta-data parameters are stated below:

- *Age Category* (young elderly, elderly, old elderly)
- *Max Accepted Cost*
- *Impaired Category*

The **Service Provider Agent** is responsible for the AmI-CCM communication.

The **User Profile Agent** is the agent who has direct access to the User Profile Repository in order to obtain data that will be used for filtering the returned services and optimising the result returned to the user. It is responsible for the storage and retrieval of all these profile properties of the user that are needed by REMOTE applications.

V. METHODOLOGY

Use Cases were created early in the project and the process for finalising them followed several adjustment phases. Firstly, a State-of-the-Art search for identifying relevant systems and services in the domain of Telemedicine applications was carried out. Secondly, an online survey-via REMOTE website - was conducted in eight European countries and a set of interviews has been carried out in five of them for the extraction of user needs and requirements. Based on these findings, the initial Use Cases were developed. Both face-to-face interviews and online surveys were conducted in order to gather as much information as possible about the needs of end users.

A total of 266 individuals from 6 countries (Spain, Israel, Greece, Germany, Norway and Italy) were surveyed via face-to-face interviews, as well as through online questionnaires. As a result of the whole process, 41 use cases have been defined. These use cases were the cornerstone of the architectural design and development of the REMOTE system, which has been continuously improving by taking into consideration each one's of the evaluation phases' results.

VI. DEVICE TECHNICAL SPECIFICATIONS

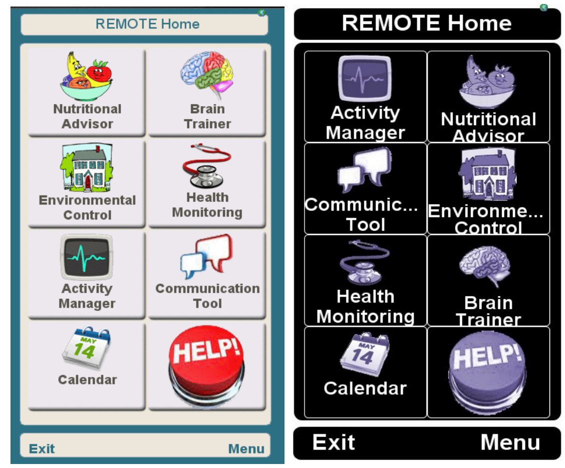
In terms of application development for Symbian OS devices, Java ME (Java Mobile Edition) technology [20] has been used. The Lightweight User Interface Toolkit (LWUIT) [21], which is a versatile and compact API for creating attractive application user interfaces for mobile devices, has been applied for the implementation of the REMOTE mobile user interface.

REMOTE application can be downloaded to CLDC (Connected Limited Device Configuration) 1.1 [22] and MIDP (Mobile Information Device Profile) 2.x [23] devices.

The devices that may be used for REMOTE installation should support JSR (Java Specification Request)-75 (specification that standardizes access in Java on embedded devices -such as mobile phones and PDAs- to data that resides natively on mobile devices), JSR-179 (GPS-Global Positioning System- functionality), JSR-135 (extends the functionality of the JME platform by providing audio, video, and other time-based multimedia support) and JSR-172 (enables Java ME devices to be web service clients). The use of a Wi-Fi enabled mobile device is recommended because of the faster responses the user receives when invoking a service through a WLAN (Wireless Local Area Network) rather than 3G/GPRS/UMTS connection and the fact Wi-Fi can often fill-in some of those dead spots or signal losses (i.e., inside the house).

VII. MAIN MENU OVERVIEW

When launching the REMOTE application, the user is prompted to insert his/her username on a login screen. The initialisation of user profile is taking place in the Medical Contact Centre (administrative web application) and its medical details are filled with face-to-face communication with the health care professionals. Main Menu (Fig. 3) displays only the registered applications of the logged-in user, which are also defined during the user profile initialization process (Medical Contact Centre). Personal preferences acquired by the user profile are taken into account for the automatic selection of the appropriate theme, font size and language. REMOTE supports eight different languages (i.e., English, Greek, Romanian, Spanish, German, Norwegian, Italian and Hebrew), four different themes for different user chronic conditions and three font sizes.



(a) (b)

Figure 3. REMOTE Main Menu: (a) blue theme, (b) high contrast theme

VIII. GUARDIAN ANGEL

Guardian Angel application aims to support the users on the move via monitoring technologies based on state-of-the-art wearable and mobile systems, throughout their daily activities. For this purpose, sensor-enhanced devices are incorporated for the unobtrusive monitoring of various vital parameters such as heart rate, breathing rate, posture and activity, skin temperature, blood pressure, weight, etc. According to the definition of personalized monitoring schemas, appropriate alerts can be generated so as to assist the patients in avoiding or overcoming hazardous health conditions or situations, i.e., arrhythmia, high blood pressure and fall. The system is primarily targeted at patients with chronic diseases such as hypertension and Parkinson's disease.

The Guardian Angel Mobile Application is mainly consisted of five distinct services, deployed on the user's mobile device: a) The sensors communication, b) the sensor data handling, c) the emergency management, d) the vital signs management, and e) the proximity.

The sensor-enhanced devices can communicate via Bluetooth with the patient's mobile device, forming in this way a body-sensor network around the user for health monitoring purposes. Guardian Angel mobile application utilizes the multi-sensing wearable strap Zephyr BioHarness [24]. BioHarness is a device particularly suited for monitoring the heart rate, breathing rate, activity, posture and skin temperature.

The patient is provided, by the initial application screen, with instructions for wearing the strap properly, since this is a critical requirement for the efficient monitoring of his/her health status. Clicking on "What is measured" button, the patient can view his/her measurement values as well as their corresponding thresholds. If a measurement is out of range then proper alerts are generated.

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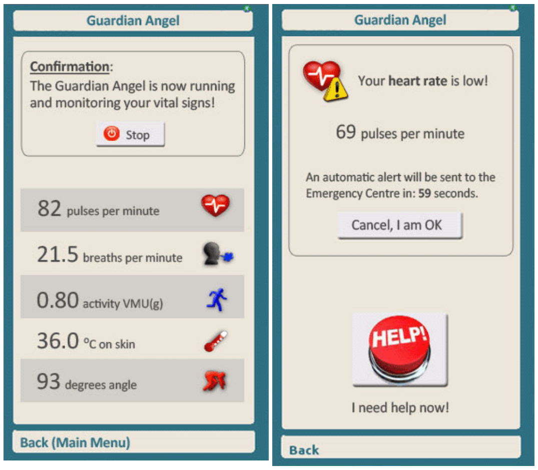


(a) (b)

Figure 4. REMOTE Guardian Angel: (a) Vital sign measurement, (b) Emergency alert

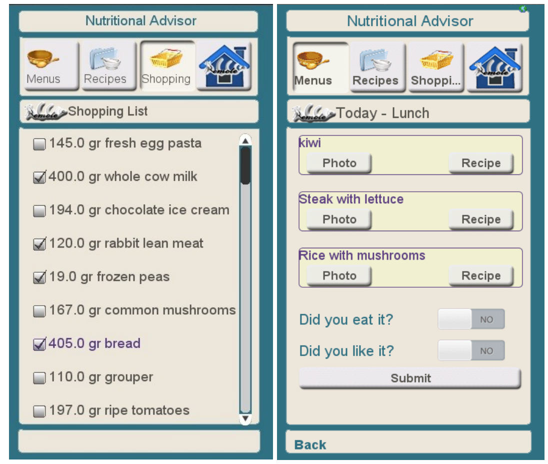
After pressing the "Start" button, communication with the BioHarness sensor is initialized and the patient's parameters - heart rate, breathing rate, skin temperature and posture (i.e., controlling for fall detection) start being monitored (Fig. 4a).

In case of alert (Fig. 4b), the user is notified and an orange alert is transmitted to the emergency service of the Medical Contact Centre. If the alert persists for a period of 55 seconds, a red alert is triggered and sent to the Medical Centre so that appropriate actions are routed. The patient will be notified when the measurement value is back to safe levels. The patient's monitoring values (received by the BioHarness device every second) are sent to the back-end system periodically and health professionals are informed of his/her current health status. The patient is notified in case of loss of internet or Bluetooth connection.

IX. NUTRITIONAL ADVISOR

The main purpose of nutritional profiling is to detect nutritional risks and preferences for users and the nutritionist can determine the best nutritional plan taking into account their health condition. Nutritional Advisor application aims at controlling and influencing the nutritional habits of the elderly. It provides appropriate data that facilitate their nutritional-related daily habits (i.e., grocery shopping and cooking activities). In particular, the shopping list feature assists the elderly in purchasing everything he/she needs for preparing the meals of the day/week and the recipes feature provides everything that the user may need in order to prepare a meal such as meal photos, detailed instructions and precise quantities of each ingredient needed (Fig. 5a).

The system recommends to the user a daily menu (Breakfast, Lunch and Dinner) based on the nutritional plan prepared by the nutritionist, which takes into account the calories of each menu, the user's medical profile and health status (allergies, medications and diseases) and also the user's activity level (Fig. 5b).



(a) (b)

Figure 5. REMOTE Nutritional Advisor application: (a) Shopping List, (b) Lunch menu display – Nutrition telemonitoring

All the nutritional content provided by the Nutritional Advisor service, is customized for each specific user, taking into account their user profile, which gathers the likes, needs and requirements of the elderly user. Due to the fact that nutritional content is totally depended on the service provider, no extra details can be given about it. The exchange of information between the Nutritional Advisor and other REMOTE applications like the Guardian Angel or the Activity Coach improves both the nutritional service, as well as the other applications connected to it.

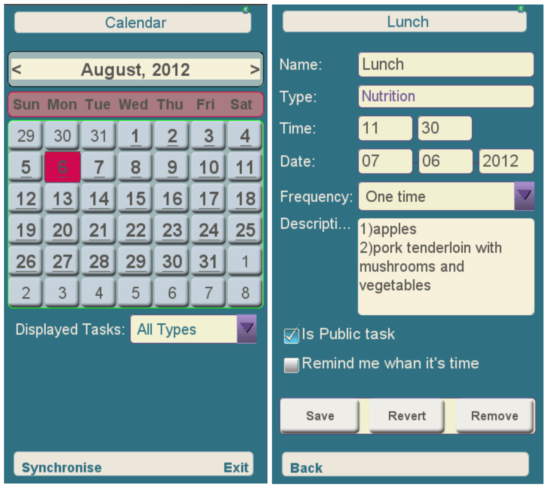
X. PERSONAL CALENDAR

The personal calendar application for REMOTE is used for scheduling and managing the daily tasks of the elderly under the unobtrusive supervision of the caregiver. The application enables the user to keep a good schedule of their life and activities and also serves as a memory aid to assist their memory.

The application offers four different kinds of functionalities: (a) calendar management, (b) task management, (c) notifications and (d) integration with other applications.

Calendar management has to do with the daily schedule of the user. A standard calendar view is provided and the user can check and navigate through days and months (Fig. 6a). The tasks that have been added to the calendar are visible and can be examined in detail. These can be either user-created tasks or notes by the healthcare professional or the caregiver. It contains all entries that are relevant to the current day (e.g., including any suggested activities), medication intake and calendar tasks and notes (Fig. 6b).

Task management has to do with personal or third-party tasks that concern the user. The application can show the list of tasks that have been added to the calendar and offers services for adding or deleting them.



(a) (b)

Figure 6. REMOTE Personal Calendar application: (a) Calendar panel, (b) Lunch stored as nutrition task

(a) (b)

Figure 7. REMOTE Home Environmental Control application: (a) Available rooms, (b) Integrated sensors/devices

These services are also offered to other applications that may need to manage the user's tasks, such as an application for the professional, allowing him to add medicine-related tasks for the user or the nutritionist's application that displays the daily meals of the elderly as calendar tasks.

XI. Home Environmental Control

The Environmental Control application enables the users to control household appliances from a remote distance. The user can either be at home controlling devices of a room from another room or from a place outside his house. This interaction is achieved through actuator devices such as switch or dimmer switches. Home monitoring is also possible through the use of sensors which have been installed in different places inside the house. Temperature, humidity, luminance are some of the various measurements that can be monitored in order to make the user feel more secure about the environment s/he lives in. A home automation lab was built at CERTH's (Centre for Research and Technology Hellas) premises in order to demonstrate and validate the functions that are supported by the REMOTE system. The home environment is very heterogeneous composed of different application areas, devices communication standards, user needs and wants. Moreover, many incompatible systems are available on the Market. This leads to many incompatible "communication islands" at home, with no interoperability and no "overall interaction". Therefore, the Home Environmental server should follow a "multi-standard-approach", facilitating to control devices using different communication protocols on various busses at the same time. This defined some technical requirements to the architecture of the server:

- It needs to "know" the busses, its protocols and how to use them.
- Each device has to provide a communication protocol, able to receive commands and/or answer requests.
- The server needs to "know" the devices that should be controlled.

Each device is described by a Device Profile using XML, defining the communication protocols and their parameters and containing the names of the devices and other device properties [25].

All devices are using wireless communication protocols based on 868MHz ISM band, i.e., FS20, HMS, S300.

Clicking on the "Environmental Control" button on the REMOTE main menu displays the Environmental Control menu which consists of a horizontal menu with the "Rooms" and "Home" buttons and a vertical menu where each button represents a room (Fig. 7a) except the last which updates the sensor values and the pre-last one which displays the energy that is currently consumed by the devices which are connected to the system.

Clicking on any of the room buttons (Living room, Kitchen or Bedroom) displays the devices connected to the room and the current sensor values. The living room electrical appliances can be seen on Fig.7b. On the left side of the central panel the user can check the room's temperature and humidity, whether there is any motion inside the house, if the door is opened and if the room is dark or light.

XII. Results

A user-centred approach was adopted early in the REMOTE project aiming to accommodate the needs of patients with chronic diseases that might live in isolated regions. An iterative testing cycle was conducted with experts in the field of usability testing and developing. Overall, applications were regarded as sufficient and accepted. Comments for both functionalities and Graphical User Interface (GUI) were uploaded to the Mantis tool [26] for responsible partners (i.e., developers) to have access. It was necessary- as first rectification step to match experts' prioritisation to developers' prioritisation for pragmatic improvements. Respective bugs, errors and issues were dealt with prior the final evaluation phase with real users. The evaluation phase aimed at determining the usability and acceptance of the mobile applications.

A. Participants

17 female (57.8±6.61 years old) and 13 male (59.8±4.12 years old) users participated in the pilot study. All users were derived by an existing user database. 27 users suffered from chronic diseases (e.g., hypertension, diabetes, arthritis) and 3 were healthy elderly. Most users live with their spouses (25/30). All users are adequately familiar with mobile phones. Participants provided written consent prior participation and received compensation.

B. Main Findings

Evaluation was based on tasks' completion derived by two fictional scenarios. Each session lasted approximately two hours with short breaks and was audio recorded in order to gain as much insight as possible from "think aloud" processes. Users had constant support by two facilitators throughout testing.

Post-task analysis showed that overall success to completed appointed tasks to users was high (Fig. 8) for all mobile applications tested. Task analysis was based on steps and time taken to successfully complete the appointed task. At least three tasks were completed by each user per tested mobile application.

Calculation of task completion success rates was based on both users' and facilitators' ratings. Users had to state if they thought they successfully completed each task and at the same time the facilitators recorded their own rating (i.e., success/partial success/failure). The average score from both facilitators and user was the overall user success rate. Increased success in completing the tasks was found for the health monitoring application. However, fewer steps were required to complete the respective tasks for this application and it might have affected the overall success rate for this specific mobile application. Nevertheless, success rates are all above 90% and are quite impressive taking into consideration that most users (83%) were not acquainted with touch screen mobile phones. These findings support both the easiness and learnability of the mobile applications developed within the framework of REMOTE but also their increased potential for deployment and penetration to existing telemedicine and health mobile applications with minimal instructions and training.

User acceptance ratings ranged from -2 (negative) to 2 (positive). The two extremes were defined by the content of each questionnaire item (e.g., unpleasant-pleasant). Mean user acceptance ratings ranged from 1.62 (SD: ± 0.32) to 1.76 (SD: ± 0.26) (mean and standard deviation for Nutritional Advisor and Environmental Control, respectively). Mean user acceptance scores for Health Monitoring and Calendar were similar (1.69 ± 0.41 and 1.72±0.22, respectively). Mean acceptance scores were high for all four mobile applications.

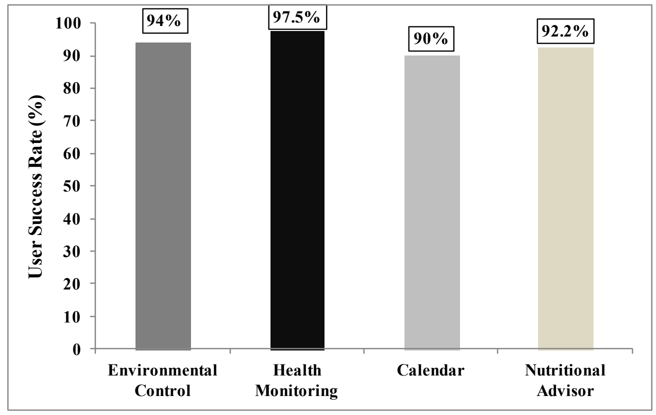


Figure 8. User success rates (%) per tested mobile application

Fig. 9 depicts Usability scores [27] for each application tested. Overall, all mobile applications were perceived as useful with higher percentages found for both Environmental Control (78.5%) and Calendar (77.5%) applications. Lower ratings were recorded for Health Monitoring (67.3%) and Nutritional Advisor (66.6%) applications probably because users were not familiar with these types of applications at all. Hence, the differences might lie in the purpose of usage and content of these applications. In addition, for Environmental Control the results were evident (e.g., they switched on a light and they could see it). On the other hand, they received information about a vital sign (e.g., heart rate) but they did not know if this was true or not. In other words, the trust to the system was higher for some applications when compared to others. Moreover, the content for Health Monitoring and Nutritional Advisor was increased compared to the other two applications for both complexity and appearance (i.e., Information appearing on the screen).

Overall usability (72.5%) is adequate and above average but it also shows that further improvements could be made resulting into an even more usable system. Therefore, decreasing complexity and amount of information displayed at screen might increase usability.

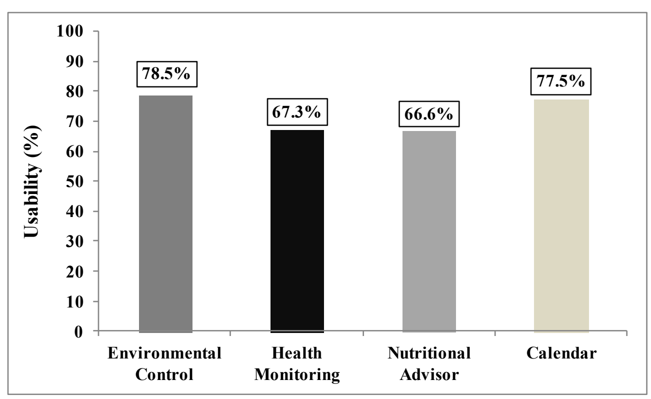


Figure 9. Usability scores (%) per tested mobile application

XIII. CONCLUSIONS

The REMOTE mobile system provides a flexible solution for elder patients for services ranging from health monitoring to environmental control. Technical advancements are required for these services to be available and accessible to the older populations.

The REMOTE system has been developed within a research framework and it is not yet a marketable product. Therefore, its adaptation to the commercial needs should be implemented with the assistance of relevant stakeholders (i.e., telecommunication service providers and mobile device vendors) in order to be optimised when a marketable version will be available.

Overall, all four mobile applications were regarded as usable, easy to learn and desired by most users. The latter is highly dependable to the affordability of this system as it is an important prerequisite for most elder users.

Finally, it is worth to be indicated that research on holistic approaches to providing services to isolated elderly and patients via New Technologies is nowadays an essential research tool that could result into a valuable assistive and supporting product for better quality of life [28].

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