33rd Annual International Conference of the IEEE EMBS
Boston, Massachusetts USA, August 30 - September 3, 2011

# A web services-based exergaming platform for senior citizens: the Long Lasting Memories project approach to e-health care

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*Abstract*— **This piece of research describes an innovative e-health service that supports the cognitive and physical training of senior citizens and promotes their active ageing. The approach is adopted by the Long Lasting Memories (LLM) project, elements of which are discussed herein in the light of the functionalities provided to the users and the therapists. The aim of this work is to describe those technical elements that demonstrate the unique and integrative character of the LLM service, which is based on a modular Web service architecture, rendering the system available in different settings like the homes of seniors. The underlying database as well as the remote user interface empower therapists to set personalized training schemes, to view the progress of training sessions, as well as, adding new games and exercises into the system, thereby increasing the services sustainability and marketability.**

## I. Introduction

With the improvement of living standards and health care quality standards, the world has witnessed a steadily rising life expectancy. A United Nations population division report shows the changes of the age structure [1]. The global potential support ratio (the number of people age 15-64 per one older person aged 65 or older) has decreased from 12 in 1950, to 9 for today and is estimated to become 4 in 2050. The number of persons aged 80 or older is 1.6% of the population worldwide for today and is estimated to be 4.4% in 2050.

In addition, one may expect to see a substantial increase in demand for social care over the next 10-20 years, as the population grows older. We can also expect to see substantial increases in demand for health care to older people. To this extent, one can expect a strong demand for Assistive Living Technologies - both to lower the unit costs of home care and to ease the tasks of informal carers, and sometimes to replace the latter with ICT artefacts and e-home-care. Moreover, it is also expected that a growing proportion of Assistive Living Technologies will be funded privately rather by the state.

Population ageing consists an unprecedented challenge for human societies, which may be moderated by recent advances in information and communication technology (ICT), aim at assisting the independent living of aged people, while keeping up quality of their life and their self-confidence. Examples of such ICT systems and/or services include those supporting the training of either mind (mental/cognitive), or body (physical), or other activities and/or raising certain alerts. However, recent research evaluating cognitively stimulating lifestyles and the effects on cognitive function in older adults of interventions targeting cognitive training, physical activity, social engagement, and nutrition supports overall positive effects of cognitive and physical activity, social engagement, and therapeutic nutrition in optimizing cognitive aging. However, the strength of such evidence is limited by either the appropriateness of available systems with respect to the intervention context, or the research designs and the execution of pilots [2].

In the context of the Long Lasting Memories (LLM) project funded by the European Commission, the approach of combining physical and cognitive training within an independent living platform named ehome was adopted [3]. In previous work [4] we have described parts of the technical design of the integration process of the LLM service, which is based on a Web service architecture, and focused on the description of the main technical features of the web service itself.

The aim of this paper is to complement the previous descriptions with updated information of the underlying database structure which forms a kind of a web based health record for the involved seniors, allowing for their body and mind training results, as well as, everyday life alerts of fall to be registered, thereby conforming to the very notion of e-health and home care. So, the emphasis of this piece of work is to present the logic behind the envisaged service from both a senior's and a therapist's point of view; this is done in an effort to support the future sustainability and marketability of the service.

Manuscript received April 15, 2011. This work is partially funded by the LLM Project. ICT Policy Support Programme (ICT PSP) as part of the Competitiveness and Innovation Framework Programme by the European Community.

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## II. Material and Methods

As mentioned above, the core of the LLM is an integrated ICT platform which combines state-of-the-art cognitive exercises against cognitive decline with physical activity in the framework of an advanced ambient assisted living environment. Thus, the LLM service is comprised of three independent components (i) CTC, Cognitive Training Component; (ii) PTC, Physical Training Component and (iii) ILC, Independent Living Component, as well as, common (and supporting) infrastructural components on the server side system, like the LLM database, the LLM web service and the LLM decision making system called Central Management System (CMS). Each of the latter elements is described in brief below.

### *A. LLM Web Service*

The architecture of the LLM service is based on a client-server scheme, where the main functionalities of the service are served centrally by the LLM Web Service and LLM Database [4]. The LLM Web Service provides several functionalities such as authentication and authorization of LLM system users, provision of interface methods to the data of LLM Database, LLM Database security and insurance of data integrity. The LLM Web Service supports heterogeneous kind of data and semantics, thereby contributing to the integration of the different subcomponents of the LLM system. Main data structures that are supported by the LLM Web Service and LLM Database (see below) are the following:

- Senior: Senior structure describes the end user who interacts with the three subcomponents of the system, namely PTC, CTC and ILC.
- User: User structure refers to the remaining categories of the LLM system such as Therapists, Administrators and Relatives.
- ILC/PTC/CTC Activity: Describes the semantics of the activities being supported by the three subcomponents of the LLM system.
- ILC/PTC/CTC component: Describes the components being integrated into the LLM system.
- ILC/PTC/CTC Senior's Activity: Training results of seniors and any existing alarms recorded by the ILC.

The currently introduced architecture is characterized by an open and modular structure that enables the integration of third-party applications to the already existing platform. Therefore scalability of the LLM system is feasible using the proposed framework. The only prerequisite for new applications to successfully participate into this LLM service, is their conformance with the general structural and functional framework of the LLM Web Service. Some of the methods that are supported by LLM Web Service are the addition of a treatment, the search of seniors, the storage of training results (physical and cognitive) of each senior, as well as the recording of alarms. The LLM Web Service consists of a number of widely accepted communication protocols such as SOAP, WSDL and XML. These protocols are supported by a wide range of development platforms and application, and they, therefore, offer reliable ways of interchange information among different kinds of applications.

### *B. LLM Database*

The LLM Database composes a valuable part of the LLM service since it provides the semantic schema of the platform and the basic data structures that support the main functionality of the system. The database includes data, such as users, seniors, components, training activities and training results. In addition, information such as the seniors' sessions, configuration properties etc are also available. LLM Database schema is shown in Fig. 1.

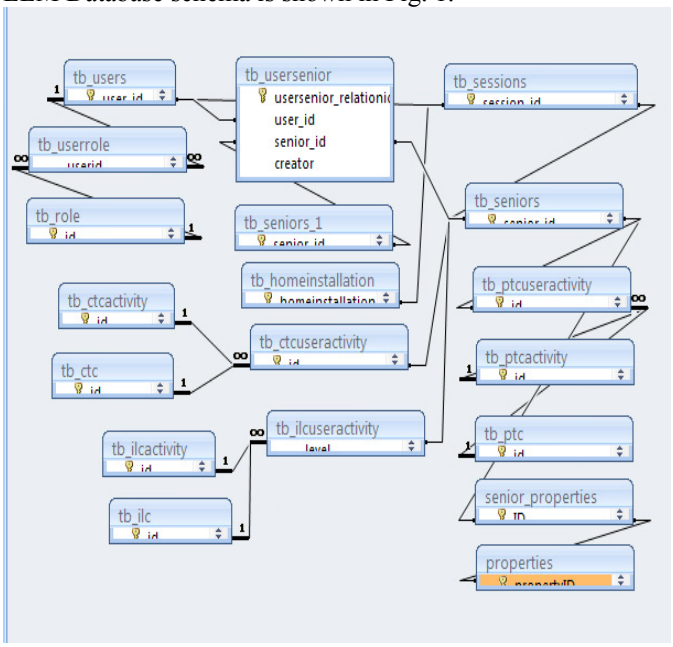


Fig. 1. The LLM database (LLMDB) entity-relationship schema

Apart from the data described above, LLMDB also includes information regarding the assessment tests that are used in order to categorize elderly people as either healthy, or with cognitive impairments, or demented. The list of test results that are stored in the LLMDB includes:

- Digit Span test
- Mini Mental State Examination (MMSE)
- Montreal Cognitive Assessment (MoCA)
- Trail Making Test (TMT)
- Instrumental Activities of Daily Living Scale (IADL)
- World Health Organization Quality of Life Questionnaire (WHOQOL)
- Senior Fitness Test (Fullerton Fitness Test)
- California Verbal Learning Test (CVLT)
- Social Life Questionnaire

A web interface provides access to the results of the tests. Therapists are able to load results of the tests and get data statistics regarding the health status of the senior(s) in question. A future ambition of the LLM service is the

creation of a universal data pool that will give access to cognitive and physical health status of seniors, by integrating intervention and assessment tools [5].

## III. Remote Access

A Remote User Interface (RUI) provides therapists the possibility to check on their patients and track their progress regarding the physical and cognitive training. In addition, there is a possibility to administer several categories of users, such as seniors, therapists and relatives. Each one of the above user categories has access to certain information based on the privileges assigned to them by the central system (LLM Web Service and LLM database). The categories of users that have access to the RUI are the following: (1) Administrators; (2) Therapists and (3) Relatives.

*Entering the RUI*

Users may access the RUI via the following url address: https://pilots.longlastingmemories.eu. To ensure maximum protection of the communication channel between the application server and the requestor of the application, the Secure Sockets Layer (SSL) encryption protocol is provided. Each user has to enter his/her personal credentials, so as for proper authorization to take place. After successful authorization, the workspace of the RUI is formed according to the corresponding user role rights.
For instance, a system administrator's RUI workspace has the following menu items: Log Off, Training Viewer, Users, Seniors, Sessions, Terminals, Alarmzones, CTC Components, PTC Components.


Fig. 2. Administration Control Panel

Administrators can manipulate users (therapists, relatives, seniors), terminals and several system components. Therapists can track the training (physical and/or cognitive) progress of seniors over a certain period of time. The following Figure provides a screenshot of the environment in which the therapists work to view the seniors' results.

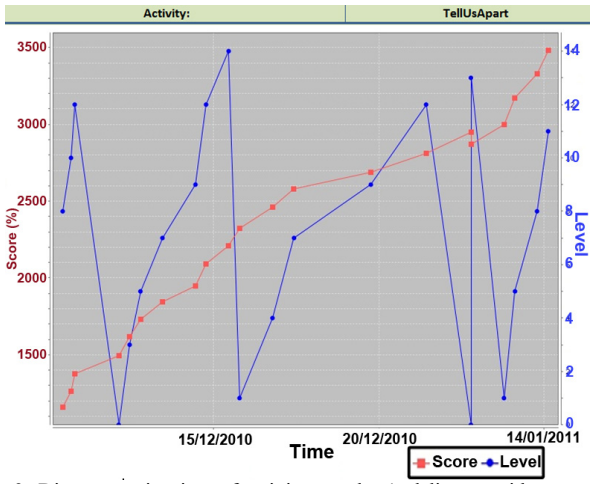


Fig. 3. Diagrammatic view of training results (red line provides progress regarding the score, while blue line provides progress regarding level of difficulty)

## IV. CTC Component: The Brain Fitness Program

The Brain Fitness software [6] employs auditory stimuli that aim to enhance the participant's cognitive status through one hour practice per day. The difficulty level is adaptive in order to motivate neuro-plasticity. It is composed by the following exercises:

1. **Story Teller**. The purpose of the "stories" is to attain more details regarding the everyday discourse. Participants answer relative questions, while stories become gradually more complex
2. **Up or down?** The scope of the exercise is to recognize the direction of the sound (for example, the first sound goes up and the second down or vice versa, or both sounds go up or down).
3. **Match It!** Participants look at some cards projected on the screen and then they listen to some words. For each word they hear, a card is turned to the other side. The purpose is to combine corresponding cards and words. During the practice, the pairs of the words pronounced and written to the cards become more complicated.
4. **Listen and do.** The purpose is to remember the directions in order to follow them by putting the pictures on the screen to the right order. The directions become gradually complicated.
5. **Tell Us apart.** The participants listen to two different words, real or fake, which sound similar. Then, these two words are displayed on the screen and participants are prompted to choose which one they heard. The purpose of the exercise is to remember and differentiate similar sounds.
6. **Sound Replay.** Participants listen to a number of different words. After that words are printed on screen and seniors have to select them in the right order, which is the order they have heard them.

## V. FitForAll

The Physical Training Component of the LLM service is comprised of the exergaming platform [7], [8], namely

FitForAll (FFA)[1] [9], developed by the Lab of Medical Informatics, AUTH. FFA provides actually a semi-virtual environment, where seniors can "physically" interact with game content on the PC screen via body movements, thus enhancing the experience they gain, while they exercise.
In order for the software/games to recognize body movements, several peripheral devices equipped with motion and pressure sensors, are used. Nintendo Wii Remote and Balance Board© are the mainly used devices. After recording of the body movements, sensor data are sent to the PC via Bluetooth communication protocol. These data are read and interpreted using the API of an open source library, namely WiimoteLib by Brian Peek [10]. High level information is then passed as input to games where it is handled properly, according to the game logic.

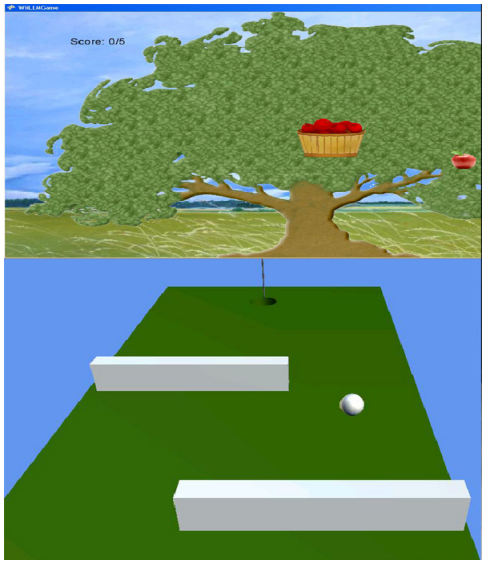


Fig. 4. A FitForAll balance games: apple collection (top) and mini golf (bottom)

The physical training program constitutes of training protocols of different intensity levels, so that exercise suits to the fitness and the needs of each senior. The training load can be assessed based on objective and subjective criteria. The objective criteria are measurements of vital signs such as heart rate and blood pressure, while the subjective criterion is the scale of perceived exertion, introduced by Borg [11]. These indicators provide seniors and therapists an idea of how they cope with the training program and whether trainees have to increase the work intensity or remain at the same intensity level. During the LLM trials, four predefined different intensity levels have been formed based on the actual heart rate of the trainees. The training schedule is a multi component one, since it combines aerobic endurance, flexibility, strength and balance exercises, and it is based on widely accepted guidelines[2].
Accessibility and user acceptance are two aspects seriously considered during the implementation of the game interfaces, since seniors face a number of limitations and impairments. Therefore, the design of a user-friendly interface, that depicts game content in the most convenient way and provides guidance to the seniors, is of utmost importance so to alleviate any physical limitations.

Finally, the implementation of a flexible architecture, allows therapists to intervene in the training process, since they are able to track the seniors' progress and adjust intensity and duration of the training according to each user's health status, thereby providing a totally personalized training program, tailored to the needs of each senior.

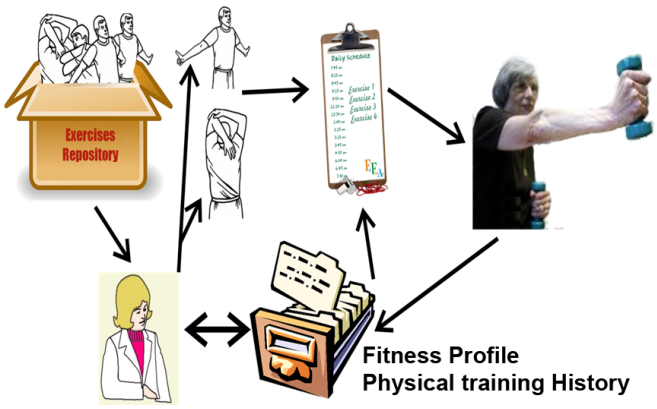


Fig. 5. FitForAll – from a user-centric implementation perspective

## VI. Future Developments - Daily Schedule

One of the major advantages of the LLM service is the central storage of the training results and the possibility that is provided to the therapists to remotely monitor and track progress of seniors, at any time by simply accessing the Internet and logging into the RUI website. This feature allows seniors to train themselves at their own homes without the need of having intensive care and surveillance by a specialist. Therapists can have a summary of the training results of the seniors over a certain period of time and come into conclusions regarding their progress.
Integrating into the service's overall functionality, a daily schedule tool, where therapists would be able to intervene, by prescribing training sessions individually to each senior and checking seniors' compliance with the already prescribed schedule, would seriously enhance the results of the whole training, while it would give seniors the feeling that they get the full attention of their doctor without the need to visit him/her every time they need an advice. It is expected that the above design characteristics together with the already promising results of the currently running trials will render the LLM service both sustainable and marketable.

## Acknowledgment

Authors would like to thank Travis Wade and Henry Mahncke of PositScience Inc for their collaboration in integrating BrainFitness. This work has been partially

[1] http://kedip.med.auth.gr/fitforall/
[2] ACSM (American College of Sports Medicine) guidelines, 2009

funded by the LLM Project (CIP-ICT-PSP-2008-2 - 238904) of the ICT Policy Support Programme as part of the Competitiveness and Innovation Framework Programme by the European Commision.

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