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Integration of Cognitive and Physical Training in a Smart Home Environment for the Elderly People

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Abstract

Our research work is towards a service that can support senior citizens towards their independent living and active ageing. As it is suggested, physical and cognitive exercise training can contribute to a significant prolongation of personal autonomy and participation in society across prevailing age-related impairments such as cognitive decline. In the current paper, the approach of combination of both physical and cognitive training - adopted by LLM project - is discussed related to other similar projects that have taken place in the area of elderly home care and training. The aim of this work is to describe the technical design details of the integration process of the LLM service, which is based on a Web service architecture and to discuss alternative interface elements to be included in the LLM platform in terms of enabling user accessibility and acceptance.

Keywords:

Cognitive, Training, Elderly, Assisted, Independent, Mild cognitive impairment

Introduction

Substantial advances have been made over recent years in applying technology to meet the needs of older people. In parallel and in accordance with e-Health solutions, the field of Ambient-Assisted Living (AAL) has been developed, aiming on alleviating the difficulties of everyday life for the elderly or people with disabilities in general [1]. Taking into account the increasing number of elderly population in Europe and the identification of its subsequent social and financial consequences, national and European research efforts have focused on such independent living solutions, trying to make an edge on this quickly arising and expanding market [1]. Condition monitoring of the senior and notification in case of an emergency, comprise the most common features of such systems. This offers a sense of safety and reassurance to the elders themselves and their relatives that they will receive the care required in a time of need, without having to be succumbed to intensive care.

On the contrary, the adoption of technology to elderly healthcare systems is doomed to encounter major problems since the vast majority of this population category is unfamiliarized with the available communication and interaction services [2]. Hence, further attention must be paid to the accessibility and understandability of ICT platforms targeted to seniors, which will provide an innovative solution validated and fitted under realistic scenarios [3].

In the last few years several scientific projects have been conducted concerning the amelioration of senior citizens' overall well being. More recently, a number of solutions have been proposed that make use of sensor networks, from audio and movement to micro- and nano- sensors hand, to detect undesirable situations for elderly, like falls. Projects Netcarity [4], INHOME [5], EMERGE [6] and OLDES [7] fall under this category. AttentiaNet [8] and Seniority comprise two already completed projects which aim at improving the quality of assistance and hence quality of life of elder people in Europe by utilizing advanced technologies for telemonitoring and telecommunications. An alternative framework of tele-assistance services which aims to enhance the security of elderly not only in their home as the previous case, is introduced by the MobilAlarm project, where older people are enabled to initiate an alarm call whenever and wherever they need to do so (using GPS; mobile telephony; body-worn alarm devices; service centres; geographic localisation and alerting software). Another, more recently proposed perspective for a solution to the same problem is offered by Confidence [9] and SMILING projects that utilize wearable tags and non-invasive systems to detect mobility patterns and provide a sense of security in the Third Age.

Apart from improving the physical status of senior citizens, several European projects have been focused on the mental health of elderly people attempting to alleviate the difficulties from certain deficits which are common among this population. In accordance with mainstream e-Inclusion targets, this approach's objective is to retain elderly people socially active and more self-reliant for a wider period of time. An example of such projects is the FP7 HERMES [10] project which aims at providing an integrated approach to cognitive care, based on assistive technology that reduces age-related decline of cogni-

tive capabilities. HERMES offers cognitive training through games, while also supporting them in indoor as well as outdoor environments, when necessary. On the other hand, VM (Vital Mind), provides cognitive training by using related psychology, a TV-set and advanced ICT. The reasoning of VM is to enable elders to exercise actively and autonomously in front of the familiar to them television medium. Support for elderly people with cognitive disabilities, and especially mild dementia or Alzheimer's disease, is provided by COGKNOW [11], which aims to develop a cognitive prosthetic device which will help elder "navigate through their day". Functionalities like reminders and support for communication and anomaly detections are planned to deliver this promise. Finally, the Elder-Games project [12] offers the ability to elderly to train themselves through a series of mixed reality games, whose design is specially adapted to their needs, with particular emphasis on the maintenance of their cognitive skills.

Furthermore, several programs have focused on the improvement of elderly people physical condition and especially target to the training of their balance, endurance, flexibility and co-ordination. Through the use of interactive technology and virtual reality technology, physical interventions have been successfully applied to seniors. An example of this kind of training is a program called TheraWii. It incorporates the use of Wii Balance Board (four accelerometers are embedded at the four corners of the board and record each step (x, y, z coordinates) of the user), a Bluetooth adapter connected to a PC and a game-like interface, with which seniors are interacting. TheraWii offers seniors the chance to combine exercise and entertainment in order to improve their physical health and quality of life.

Though several other categories for applications for the elderly can be identified like mobility aids or medical implants, the aforementioned ones are those more closely related to the Long Lasting Memories (LLM) project [13]. By enforcing the unprecedented approach of simultaneously inducing neural and corporal stimulation in a safe and controlled environment, this platform will deliver an effective countermeasure against age-related cognitive decline, thus significantly reducing chances of mild dementia or Alzheimer's disease appearance. Moreover, the service will utilize a number of remotely operated screens, which will be embedded in the independent living environment and connected to training equipment (like recumbent bikes, ergometers or treadmills). Light exercise will be combined with a targeted set of cognitive exercises, while the environment's sensors will ensure the safe and enduring application of this training, adjusting, intervening or providing motivation according to each person and situation. The aim of this paper is:

i. to describe the technical design details of the integration process of the LLM service
ii. to describe alternative interface design scenarios to be incorporated in the LLM system

Materials and Methods

As already mentioned, the heart of the LLM service 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 main service is comprised of three independent components:

- CTC, Cognitive Training Component
- PTC, Physical Training Component
- ILC, Independent Living Component

These three independent components will meet the proposed service by means of a server side system, which is comprised of a database and a web service and a decision making system called Central Management System (CMS). The main aim of the LLM system is to offer support not only to elderly people but also to their relatives and families.

Web Service Architecture

The integration aspects of the system are tackled on the basis of a web service and a database. The web service is responsible for providing all methods and functions in order to support the three independent components' and CMS's functions as it is depicted in Figure 1. Moreover, the web service is responsible for the authentication of the system's users according to their role. A database accompanies and supports the web service's procedures. Each of the three components accomplishes a different scope of application and provides heterogeneous data and semantic sources. According to these requirements the proposed architecture must support the integration of the data and the co-ordination of the components' functionalities. One of the major features that the proposed architecture should accomplish is flexibility. The web service's architecture and functionality will be open in order to allow new developments to be integrated and supported by the proposed service in the future developed components (CTC, PTC, ILC). The only prerequisite for the candidate applications to be integrated into the proposed service is to be compatible with the general framework of the service.

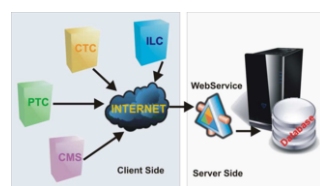

Figure 1- The web service supports the three independent components

The Web Service provides programmatic access to the system's features and services. Developers can build custom applications, tools, and services that correspond to the same services. Typical applications include add/edit and searching for registered seniors, add senior's progress to cognitive or physical training and add information about senior falling or alarms. The Web Service includes the Simple Object Access Protocol (SOAP), Web Services Definition Language (WSDL), and the XML Schema Definition language (XSD). These standards are

supported by a wide range of development tools on a variety of platforms.

The web service provides structures (an example is given in Table 1) as inputs and outputs to all supported methods. All structures and methods are well described by a human readable document which is publicly available. Moreover, each structure is accompanied by an "error" structure in order to facilitate appropriate message exchange with the components.

Table 1 – Structure for senior's demographic data example

```
<s:complexType name="senior">
   <s:sequence>
      <s:element minOccurs="1" maxOccurs="1"
name="senior_id" type="s:int"/>
      <s:element minOccurs="0" maxOc-
curs="1" name="lname" type="s:string"/>
      <s:element minOccurs="1" maxOc-
curs="1" name="birthdate"
type="s:dateTime"/>
……..
   </s:sequence>
</s:complexType>
```

For example, in order to add an activity performed by a senior we use the method shown in Table 2. It behaves as a log file of the senior's progress and activities. The required attributes that must be provided are:

- senior_id: The senior that performs the activity
- ctcactivityid: The CTC Activity that is performed by the Senior
- ctcid: The CTC Component that is used by the senior in order to perform the Activity
- datetimestart: The date and time that the activity started
- datetimeend: The date and time that the activity ended
- score: The score that is achieved by the Senior
- level: The level of difficulty of the performed CTC Activity

Table 2 –C# example using LLM web service method to record user's performance to a certain CTC activity

```
ctcactx = new CTCSeniorActivity();
ctcactx.ID = 0;
ctcactx.senior_id = 16;
ctcactx.ctcactivityid = 1;
ctcactx.ctcid = 1;
ctcactx.datetimestart = new Date-
Time(2009, 6, 21, 10, 00, 00);
ctcactx.score = "16";
ctcactx.level = 8;
ctcsac = AddCTCSeniorActivity(ctcactx,
"username", "password");
if (ctcsac.error.ErrorCode == 0)
ctcactx =
ctcsac.CTCSeniorActivityList[0];
```

A senior has the privilege to use this method only for himself, the Therapist for all of his/her Seniors and the Administrator for all the Seniors. The common scenario is the senior to provide his activities (by LogIn to the LLM system).

Scenarios of Use - Interfaces

Each component, like ILC, CTC and PTC, supports a finite predefined number of activities. These well-described (by the component's providers) activities behave as the elementary entities of the Seniors Interaction. For example, the movement activity in the kitchen may be named "KitchenActivity1", the movement activity in the bedroom may be named "BedroomActivity1". These two activities are different entities. Another example may include the procedure of software that displays 3 screens to the senior (with different multimedia material each time). This may be a CTC Activity. In conclusion, activity is a set of exercises that is treated by LLM system as an Activity. The activity is performed by a Senior and a score for this activity is generated. The proposed system supports a finite number of activities. This number stems from the activities that are supported by the CTC, the ILC and the PTC. These activities are defined by the providers of the components and added to the system once. If a new Activity is available, the administrator is responsible for adding it as a supported activity of the system. Moreover, the term Component is used in order to describe the system that is used by the ILC, CTC and PTC. For example, the Components of the PTC may be a treadmill model1, a treadmill model2, a Wii Balance Board, a Wiimote, etc. Each of the above activities may be available to more than one Component. For example, the "walking" activity may take place at the treadmill model1 or the Wii balance board. If a new Component is available, the administrator is responsible for adding it as a supported Component of the system.

Independent Living Component

The ILC component is based on the eHome system [14], which is comprised of a network of wirelessly distributed operating sensors connected to an embedded system (the e-Home central unit). It includes features such as intelligent learning of normal and exceptional patterns of behavior (dangerous situations or indicators for emerging health or social problems), raising of alarms and controlling of elements which are typical for a smart-home environment. Falls constitute one of the major safety and health risks in older people. For this reason the detection of possible falls plays an essential role in the concept of the sensor technology to be used.

Cognitive Training Component

The CTC is designed to support the cognitive exercising procedure. Any software that is compliant with the web service can be used for this process. Several applications (commercial or not) will participate in the early stages of the service development so as to validate the integration of the system and its usability. The cognitive training procedure contains several kind of exercises that target to specific brain functions, such as memory, attention, etc.

Physical Training Component

The system is completed by the Physical Training Component (PTC) which is comprised by custom training equipment. The only prerequisite for this equipment is to be able to provide exercise performance output. Sub parts of PTC should offer a variety of physical exercising possibilities according to needs and disabilities of each individual. The system will monitor the user's performance progress and will provide feedback using motivation messages and performance indicators. Possible physical training equipment options are: Ergometer Bikes, Treadmills and Wii Balance Board and Wii Remote

Central Management System (CMS)

CMS offers the end user an intuitive, simple to use graphical interface for interaction with the cognitive training system, the physical training system and the independent living component. Besides this, the CMS will be responsible for providing the appropriate feedback to the interacting senior:

- A humanoid avatar, like in Figure 2, will accompany the individual during his/her activity
- Scheduling daily form activities and plan based on previous data (overall performance, physical training, cognitive training)
- Making use of current and previous performance indicators, avatar acts not only as an instructor but also as a supporter, by motivating the individual to achieve expected targets
- Recognizes individual's presence (ILC) and makes a reception call

A television or a touch screen will host the main graphic user interface (GUI) of the system, thus providing elderly a more user-friendly mean of communication with the LLM system. Although touch screens concerned as user friendly input devices, voice recognition and remote controls (wii remote) may be used as the interaction layer between the senior and the system. Apart from providing an abstract schedule for the senior's daily activities, CMS is responsible for displaying the appropriate GUI of the three components, based on the current activity.

Figure 2- Avatar accompanies senior during exercise

User Roles

The system is able to deal with 4 Member Roles. The Role with the most limited access rights is the Relative (User) who is able to get information about his/her relative (senior). More privileges are attached to the Senior (Senior) who has not only the right to see his/hers progress but also to add information about it (through his/her LogIn action to the ILC, CTC and PTC). The Therapist has the authority to add/edit, delete and get results about all seniors that are under his/her supervision (Seniors that are attached to the Therapist). Finally, the administrator has all the available rights [15].

Prototype testing

For the prototype testing a scenario of home installation was selected, as it is shown in Figure 3.The proposed system and especially the web service were tested by contributions of the components' providers. The system testing concerned the efficiency, efficacy, data encryption, data integration and fusion, versatility, code re-usage and cost savings. During evaluation of the web service development, substitute took place in order to provide us with more conclusions concerning the testing. Moreover, some of the methods were redesigned and redeveloped according to the contributors' comments and ideas. As a result, the proposed system is able to support the components; as it was designed for (ILC, CTC and PTC). Although the data semantic information derived from different data source is different from one component to the other, the proposed integration technique seems to be promising for giving a more enhanced meaning to this kind of data fusion providing CMS with information needed for its decision – support system. Last but not least, data encryption techniques provide protection from privacy vioaltion and preserve anonymity of each senior user across the Internet.

Figure 3- Trial site. At Home installation scenario

Furthermore, the combination of the proposed methods and structures may provide a standard on the integration of different components targeting to elderly people ambient assisted living [16].

Discussion

As discussed in the introduction of this paper, an ICT platform which integrates physical, cognitive training and independent living components may be promising for the improvement of elderly people quality of life. Moreover, continuous brain and fitness exercise are considered as one of the most important methods of prevention in elderly dementia and more specific in Mild Cognitive Impairment – MCI (early stages of dementia) [17]. Although seniors with MCI are able to stay at their home, they often visit day care centers. A system as the one proposed to this paper should be able to be applied in both situations. Furthermore, the LLM system due to its open and flexible architecture design, can meet the needs of a wide

range of elderly population, as it is able to integrate any application or device, which complies with the LLM infrastructure. Therefore installation and implementation costs per home can be dramatically reduced and suit to each end user's financial affordability. Future steps include testing of the proposed system not only to senior's homes but also to day care centers. Moreover, trials to different European countries will contribute not only to the further evaluation of the system, but also to the extrapolation of conclusions concerning the benefits of concurrent usage of CTC and PTC by seniors with MCI.

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