A Personalized Cloud-Based Platform for AAL Support to Cognitively Impaired Elderly People

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Abstract

Population ageing due to declining fertility rates and/or rising life expectancy is poised to significantly transform our societies in the upcoming years. Although a lot of work has been done in the field of AAL for the creation of ICT solutions that will prolong and support the autonomous living of elderly individuals with cognitive impairments, these solutions are unable to meet all user needs and/or to provide an easy to use mechanism for further extension with new services. The present paper presents a cloud-based solution that provides easy, transparent, personalized and contextualized access to all the supported AAL services to the cognitively impaired elderly end-users and their caregivers by also offering a mechanism for easy registration and integration of new AAL services into the platform.

Keywords

AAL services • Ontology • Matchmaking • Cloud based architecture

Introduction

According to the World Report on Ageing and Health [1] released by the World Health Organization (WHO), today the vast majority of people can expect to live into their 60 s and beyond. Cross-sectional comparisons have consistently revealed that increased age is associated with lower levels of cognitive performance [2]. Cognitive loss has an important impact on the capacity to conduct activities of daily living (ADL) in older people, resulting in dependency, distress, and reduced quality of life [3].

The basic infrastructure that supports people with cognitive impairments, such as homes for the elderly, nursing homes, and other care facilities, are becoming insufficient to deal with this increase, thus there is a need to address their unmet needs through the use of ICT [4]. According to Lauriks et al. [5], the elderly have various needs that can be summarized in the following categories: (a) need for general and personalized information, (b) need for support with regard to cognitive decline symptoms, (c) need for social contact and company, and (d) need for health monitoring and perceived safety.

Although, several ICT applications and services have been developed to support people with cognitive impairments, a major challenge is to provide a holistic solution that addresses all the aforementioned needs by also supporting an easy to integrate mechanism of new Ambient Assisted Living (AAL) services.

This paper presents the IN LIFE cloud-based platform developed in the context of the IN LIFE H2020 EU project that aims to lengthen and support the independent living of elderly individuals with cognitive impairments, through interoperable, open, personalized and seamless ICT solutions. The main goal of the platform is (1) to provide personalized and easy access to all the supported AAL services to the elderly cognitively impaired users and their caregivers, and (2) to ensure that external service providers and device manufacturers will be able to register their assets in a user-transparent, open and standards-abiding way.

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Related Work

Existing solutions in the AAL domain can be classified into two main categories: (1) on-premises solutions and (2) cloud-based solutions. Some of the on-premises solutions focus on the establishment of reference architectures for AAL systems, such as the PERSONA project [6], which aimed at the development of a scalable, open-standard technological platform for building a range of AAL services. universAAL [7] reuses many components of PERSONA and it supports non-cloud features by also providing runtime support for software components and services for different types of hardware device. OASIS [8] introduced an ontology-driven, open reference architecture and platform that facilitates interoperability, seamless connectivity, and sharing of content between different services, while SOPRANO [9] introduced an ontology-centered platform for offering AAL solutions through an extensible service-oriented OSGi modular architecture.

All the aforementioned projects are considered to be the most consolidated and well-known AAL platforms, but all of them are based on non-cloud based architectures. However, there are some other AAL solutions that utilize cloud computing features, like the DOMEO project [8], which uses integrated cloud-services for personalized homecare services for tele-presence. The iWalkActive project [10] provides to users with walking disabilities cloud services that make use of indoor and outdoor navigation. The MyLifeMyWay [11] project provides through a cloud platform a Personal Virtual Assistant that can integrate existing and proven technology and home automation appliances. The iCarer project [12] provides a personalized and adaptive cloud-based platform to offer informal carers support by means of monitoring activities of daily care, while the SOCIALIZE project [13] introduced a service-oriented software architecture to supply network services with cloud computing modalities in order to promote elderly social interaction.

Although the aforementioned solutions utilize some cloud computing features, they are not entirely based on a cloud-based architecture for the provision of various types of AAL service. Additionally, some of them try to meet specific user needs like mobility or communication without following a more holistic approach. Moreover, they do not utilize semantic technologies.

The solution presented in this paper goes one step beyond the state of the art by presenting a unified cloud-based framework, enhanced with semantic technologies, based on existing reference architectures, further extended in order to provide advanced functionalities for transparent, personalized and contextualized access to all the supported services as well as easy service registration/integration of new services. The adoption of a cloud-based approach ensures the accessibility of the registered tools/services on demand from everywhere, while the ontology-driven architecture enhances the semantic interoperability between the architectural elements of the platform and takes advantage of well-established health describing ontological frameworks, like ICF [14].

In Life Platform

The main functionalities supported by the IN LIFE platform are the following:

(a) Monitor user activities and preferences in an unobtrusive way.
(b) Support elderly people with cognitive impairments in a variety of indoor and outdoor activities by providing easy and personalized access to the IN LIFE services and applications.
(c) Provide help and instructions to care givers.
(d) Enable service/application providers to easily incorporate their products in the IN LIFE framework.

In order to support them a cloud infrastructure was set, where the heart of the system is an OSGi/universAAL-based platform [7]. A knowledge base consisting of three ontologies (i.e. User Ontology, Service Ontology and Sensor Ontology) described in detail by Konstantinidou et al. [15] is used for storing information regarding the registered users, the supported AAL services, as well as data coming from monitoring in a semantic manner. Figure 1 illustrates an overview of the platform's architecture, while its main functionalities are presented in detail in the following paragraphs.

User Clustering and Modelling

Different kind of users have different needs, should be the target of different interventions, and possibly of more granular monitoring indicators. Using the user's capacity to function in terms of daily life activities or of disability-free status, and his/her Socio-Economic Status (SES), the personal information of the cognitively impaired individuals is used by the platform's matchmaker in order to cluster the user according to a user taxonomy. The 4 supported taxonomies (i.e. dependent, assisted, at risk and active) represent 4 archetypes of users with different needs [15].

For the described functionality, the information stored in User Ontology is used. The User Ontology defines in a

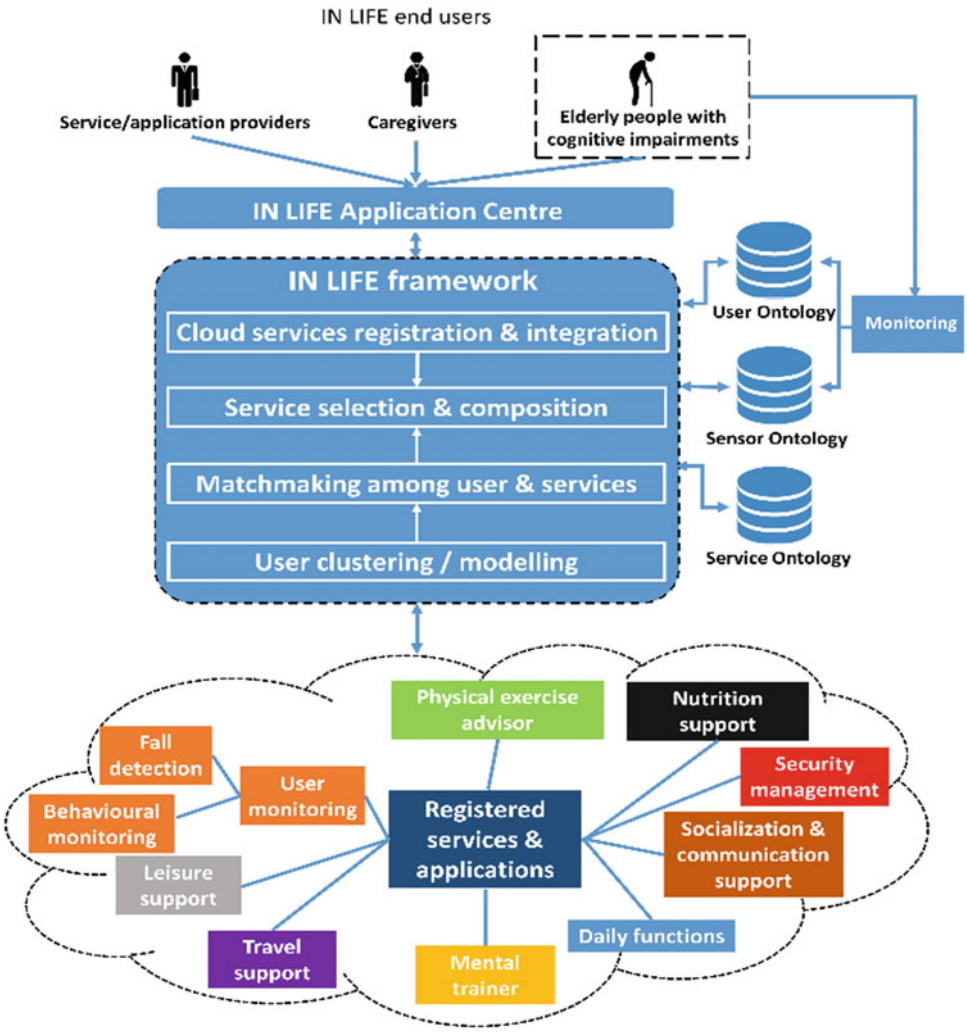

Fig. 1 INLIFE architecture

semantic way all users of the IN LIFE Platform and more specifically assisted people, their informal and formal carers and service providers. It is based on the ontology of the ACCESSIBLE project [16] that was based on ICF [14], thus making it suitable for describing health and health-related states, and the Profiling Ontology of universAAL [17], which models AAL user profiles and their characteristics.

Matchmaking - Service Selection and Composition

Towards providing personalized services to the elderly end-users and resolving emergency cases (e.g. the user has fallen), a hybrid matchmaking mechanism has been developed that consolidates the results of a rule-based matchmaker and a statistical matchmaker.

The rule-based matchmaker, in case there is an alarm notification that indicates an emergency for the user, through a set of rules selects the most proper set of services to be called. By applying the *Exact* and *Plug in* OWLS-MX filters [18] in the selected services, it identifies which of them can be combined and called in a sequential way. Moreover, another set of rules selects the most suitable tool categories and tools for the user to be displayed by using his/her current activity and status stored in the User Ontology and the semantic description of the tools stored in the Service Ontology.

The statistical matchmaker tries to improve the recommendation accuracy of the rule-based and recommends tools for the user by creating clusters of likeminded user. Two different clustering approaches are used: a collaboration filtering method that utilizes the tool usages of the users and a demographic filtering method that uses certain personal

attributes like socio-economic status, country, education level, etc.

The tool recommendations of both matchmakers are combined into a hybrid matchmaker that uses user-specific weights in order to combine the results of all techniques into a single recommendation value. The weights are dynamically adjusted in order to optimize the predictions of the system.

Application Centre

The Application Centre is the main interface of the IN LIFE platform and through it cognitively impaired individuals and caregivers can access the AAL services registered in the IN LIFE ecosystem or browse/search/connect with other users and service providers can register new services/applications.

A personalized dashboard with different functionalities for each role is supported. In addition, according to the current activity and status of the user, and by using the matchmaking capabilities of the system, the most suitable set of services is proposed and displayed.

An Alarm Management mechanism has been implemented in order to manage effectively alarm notifications created by AAL tools and services that are integrated into the IN LIFE ecosystem. Each received alarm notification is stored in the Sensor Ontology and it is instantly displayed through the Application Centre to all caregivers connected with the elderly.

An accessible and user-friendly interface, appropriate for cognitive impaired elderly, is provided, based on the guidelines and techniques described mainly in the WCAG 2.0. All pages of the Application Center website have checked by two online web accessibility evaluation tools: the A Checker [19] that resulted a WAI "AAA" classification and the checker of the European Internet Inclusive Initiative project [20] that resulted a 94.015% average compliance.

Finally, due to the multilingual environment of Europe, the following 9 languages are supported: English, Greek, Spanish, Dutch, Slovenian, Swedish, German, French and Italian. The Application Centre, in the context of the IN LIFE project, was tested, evaluated and further refined by large-scale, Europe-wide pilots conducted in Greece, the Netherlands, Slovenia, Spain, Sweden and UK.

Cloud Services Registration and Integration

Application/ service providers can easily register their AAL solutions in a semantic way and also integrate them on the cloud platform. The registration is made through a set of web forms provided by the Application Centre. The semantic description of the services is stored in the Service Ontology, a core component of the IN LIFE platform, that is based on the universAAL Profiling Ontology [17] and supports also the OWL-S standard [21] for the proper technical description of a service.

This ontology was further extended in order to include the technical description of services not only from a syntactic point of view, but also in terms of semantic capabilities in order to indicate different service features and the way to interact with them. Semantic capabilities have been taken into account by specifying a set of terms/classes, to which each service is mapped, creating this way a common dictionary that ensures the use of the same terms when describing same things, thus enabling the use of generic rules by the matchmaker for mapping services and users according to their status by also identifying which of these services can be used in a combined matter.

Conclusions

In the present paper, the IN LIFE platform, a holistic cloud-based ICT solution for supporting the independent living of elderly individuals, was presented. Through its innovative hybrid matchmaking approach it provides personalized solutions to the elderly end-users and resolves emergency cases by selecting and combining the most proper services. Through Application Centre it provides accessible, personalized dashboards that elderlies can use to access the most suitable tools, caregivers can effectively monitor their connected cognitively impaired individuals and service providers can register their assets, building this way a distributed ecosystem of services targeting elderly.

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Conflict of Interest The authors declare that they have no conflict of interest.

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