Active Life Coach: Towards a Framework for Holistic Care of Citizens as They Age

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ACTIVE LIFE COACH: TOWARDS A FRAMEWORK FOR HOLISTIC CARE OF CITIZENS AS THEY AGE

Completed Research

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Abstract

The continuous demographic change, recorded in recent EU and USA reports, clearly indicates that there will be a growing mass of senior citizens who will enjoy good health and will be able to play an active part in the modern workforce and the society. Undoubtedly this requires a more active and healthier status so that the risk of health and wellbeing problems, including cognitive decline is minimized. A combination of different factors such as proactive lifestyle changes, physical and cognitive exercise, and social interaction may play an important role for achieving the aforementioned goal; however, compiling a holistic masterplan that sets specific measurable objectives for achieving these factors requires not only the senior citizen’s active engagement but also the collaboration of a diverse set of healthcare specialists as well as the support of the citizen’s family and close friends. Furthermore, the coordination of this diverse group of people, the real-time monitoring of the masterplan ensuring to the best possible extent that the objectives are met, the continuous adaptation of the objectives in case some or all the objectives are not met, present significant challenges.

This paper introduces the Active Life Coach, a framework that paves the way for holistic care of senior citizens in order to allow them to maintain their independent living, health status and functional effectiveness as well as preserve their physical, cognitive, mental and social well-being. Through a thorough investigation of literature and state-of-the-art health care frameworks in different domain areas, we identify critical functional requirements that should be realized by our framework. We then describe the architectural design of Active Life Coach, justifying its design choices by taking into account the requirements drawn from the investigation.

Keywords: Health and Wellbeing, Proactive Interventions, Collaborative Care, Virtual Coach.
1 Introduction

The continuous demographic change recorded in recent European (EU Demographic Report 2014) and US reports (The Next Four Decades report) clearly predicts that there will be a growing mass of senior citizens (65+) who will enjoy a good health and will be able to play an active part in the modern work force. Quoting J.W. Vaupel’s words ‘While the 20th century was the century of redistribution of wealth, the 21st century may be the century of the redistribution of work to older age groups’. Maintaining an active, social and healthier status can play an important role for this age group (Stine-Morrow E. A. L., et al. 2008) as it can minimize the rate of cognitive decline and the risk of unwanted emergency situations thus enabling senior citizens to efficiently contribute to the economy by continuing to be part of the active workforce.

Maintaining functional effectiveness has been shown to be associated with a number of physiological, psychological and behavioural factors (Stine-Morrow E. A. L., et al. 2008, Williams, K. et. Al, 2010, Warburton, D.E. et al., 2006) including the level of physical, mental and social activities but also medical markers and emotional status. Our investigation has revealed that several research and innovation activities have proposed systems that offer unique features aiming to improve different aspects of the senior citizens’ care; however they usually isolate specific factors and neglect the others. For example, [BeatHealth, DAPHNE] aim to increase the physical exercise, [eHealthMonitor, MyHealth Avatar] aim to collect and share medical data, [RELIEF] concentrates primarily on pain management, etc. Instead, tackling all factors using a holistic approach unveils the opportunity for minimizing the risk of health related emergency problems, or prevention or decrease of the progression of cognitive decline, facilitating more efficient and effective care of senior citizens.

Senior citizens, living semi-independent or in residential long-term care facilities often are recipients of such holistic care provided by a number of health care professionals (e.g., nurses, doctors, physiotherapists, psychologists, etc.) as well as from their family, relatives and friends. However, orchestrating multiple types of activities entails unique challenges as it involves the coordination and collaboration of these actors as well as the senior citizens themselves. This process becomes even more complex when some of the objectives suggested by these actors are conflicting or present unique constraints (e.g., privacy). For example, a physiotherapist may require the senior citizen to rest in order to allow him to heal from a specific injury while a psychologist may suggest more outdoor activities to increase social interaction. Additionally, compiling a holistic “masterplan” that satisfies all objectives without any conflicts is not only improbable but also costly if the coordination of all actors is not aided by multiple ICT technologies. However, even if such masterplan was feasible, it may not be sufficient if the senior citizen remains “static” and does not show advancement towards meeting his objectives.

In order to meet the objectives, set by the masterplan, the senior citizen must be continuously monitored in a non-intrusive manner (e.g., by using wearables, sensor networks, 3D cameras) in order to infer the user’s behavioural patterns and dynamically adapt his plan in order to meet his growing needs and demands that may change dramatically over time. To this end, a number of interventions must be delivered that stimulate, motivate and promote engagement of activities affecting all factors set by the objectives of the plan. These interventions can be roughly classified in: i) proactive, which identifies risks that may prevent some objectives from not being met; and ii) reactive, which takes action after an objective is not met or a dangerous situation has been detected.

Inspired by concepts arising from coaching and gamification, this paper introduces the Active Life Coach, a framework that paves the way for holistic care of senior citizens in order to allow them to maintain their independent living, health status and functional effectiveness as well as preserve their physical, cognitive, mental and social well-being. Additionally, ActiveLifeCoach treats end-users as players and attempts to positively influence the behaviour towards accomplishing their objectives.
The Active Life Coach conceptual framework: A team (healthcare professionals, family, friends) and the end-user collaborate together to develop a plan, which includes a collection of activities and their associated objectives, that will enable the end-user to improve his health and wellbeing. The plan is set to motion, continuously monitoring the health status of the citizen, analysing his behaviour and possible risks. Possible deviations from the plan or identified risks may trigger interventions of multiple sorts (e.g., motivational activities, medical interventions, etc.). This results in the dynamic adaptation of the plan.

As it can be seen from Figure 1, Active Life Coach, first forms an alliance, coined the “coach” between a diverse set of actors, including the senior citizen, who collaborate to develop and monitor the masterplan. Then, it allows members of the “coach” to collaborate in order to develop a personalized holistic masterplan for the senior citizen by setting specific objectives and their corresponding activities but also identify conflicting objectives when they exist. Finally, the plan is set to motion, enabling continuous real-time monitoring of both the user and its environment, attempting to identify and infer behavioural patterns and then dispatching appropriate interventions in case it discovers that some objectives are not met or a potential risk has been identified.

In summary, the contributions of this paper are:

1. It performs a thorough investigation of literature and current state-of-the-art health care systems in different domain areas and identifies important requirements and opportunities for improvement.

2. It describes the architectural design of Active Life Coach, justifying its design choices by taking into account the requirements drawn from the investigation.

The remainder of this paper is organized as follows: Section 2 describes the related work investigating multiple healthcare frameworks. Section 3 presents a requirements analysis for Active Life Coach and its architectural design. Finally, Section 4 concludes the paper.

2 Background and Related Work

This section first discusses previous work related to health management/monitoring systems. It then performs an in-depth analysis of important requirements that should be incorporated in any framework that attempts to provide holistic care to senior citizens or patients in order. These are then used for justifying the design choices of our framework presented in the next section.
2.1 Previous work on Health Management/Monitoring Systems

Since the 1990s, there have been various efforts to develop biomedical systems for monitoring and managing health. A review report in 1993 (Mora et al., 1993) presented the various factors that take part in the design of intelligent patient monitoring and management systems with regards to the acquisition, fusion and analysis of health-related information. All the efforts (Varady et al., 2002) were initially focused on bedside monitoring solutions which were useful when the patients were lying on the bed in the hospital. The need to monitor mobile patients but also the introduction of wearable technologies led to the development of solutions which monitor and manage patients’ health as they move around a hospital or a nurse home. For example, Hsu and Lu-Pei (2005) have developed a wearable-biomedical health-care system which incorporates wearable technology with a multi-agent software architecture to provide a mobility-enabled solution to medical care centres and detect health emergency events and triggered alarms once these events occur (reactive intervention). However, the need has shifted to more home-based care solutions with less expensive resources. For example, in 2002, a home telecare system has been proposed (Lovell et al., 2002) for remotely monitoring patients whereas the authors of (Yao, 2005) have proposed a wearable plug-and-play point-of-care system for home use which builds upon IEEE1703 Medical Information Bus (MIB) standard and the Bluetooth standard as the wireless technology. Another example of an effort to provide home- and computer-based health interventions for senior citizens, facilitated by a professional coach was the work in (Jimison et al, 2008) which included modules to assess the health behaviour goals, motivations, barriers and readiness to change. The architecture design also facilitated collaborative care by involving family-members and other caregivers in the health-care team.

Several research projects have attempted to develop a diverse set of frameworks for managing health and care as well as presented innovative methods for enhancing the delivery of health services. BeatHealth, DAPHNE, eHealthMonitor, MyHealth-Avatar target personal health in general, preventive healthcare and mobile health. Projects such as Nymphia-MD and Nevermind identify and experiment on new models for improving mental health treatment, such as decreasing mood disorders and depression. Relief and Selfback target the management of pain through innovative ICT self-management solutions while REWIRE targets rehabilitation in general. Finally, several other projects tackle specific aspects of health such as neurological disorders like Parkinson's and Alzheimer's disease (Dem@Care, NeuroTremor), cardiovascular disorders (CardioProof, CARRE, Hearten), cancer (BD2Decide, CHIC) and sexual health (EmERGE). It is evident that monitoring is one of the most important requirements of a holistic health management system.

2.2 Coaching and Collaborative Care

Coaching usually refers to the training or development in which a person called a coach supports a learner in achieving a specific personal, professional or any other goal [Wikipedia]. The role of such a coach has been highly explored and utilized in modern health systems and has proven to be very beneficial since it facilitates a healthy, sustainable behavioural change by challenging patients to transform their goals into action. Such goals range from managing and possibly curing their “chronic decease” like quitting smoking or alcohol, improving fitness, etc. Traditionally, this kind of coach is a trained and preferably certified person delivering coaching via conventional methods like face-to-face meetings, over the phone etc. However, a survey conducted in Finland in 2013 (Hiekkanen, 2014) has indicated that 41% of the coaching companies reported that they faced difficulties monitoring whether their customers were actually following their coaching plan and instructions. Additionally, 35% have reported that their customers do not commit to coaching well enough. Overall, the survey indicates that the health coaching market would benefit significantly from enhanced tools to facilitate efficient and effective coach-client communication. Based on this, we propose a solution to specifically address this need by turning the coach into a virtual entity supported by a back-end cluster of collaborative
health-carers (doctors, professional coaches, family, etc.) capable of managing/supervising one’s health remotely and effectively. The responsiveness of the system is enhanced by the continuous collection of data (physiological, behavioural, environmental etc.) using wearables and other sensory devices which report centrally and make this data available to the Active Life Coach. The role of the Coach is to generate a coaching plan (“a masterplan”) for a specific end-user and monitor its proper and effective execution. There were efforts to apply the concept of a virtual health coach in various ways (Siewiorek, 2012). For example, in (Jimison et al., 2015) a virtual coach encourages elderly people to engage in physical activities since their physical functioning is highly correlated with their health condition, cognitive functions and wellbeing. Similarly, Albaina et al. (2009) developed a Persuasive Virtual Coach to motivate elderly individuals to walk. Siewiorek et al. (2012) report that a Virtual Coach architecture usually consists of 5 elements; (1) Sensor Processing; (2) Coaching Model; (3) User Engagement; (4) Prescription; and (5) User Interaction. Active Life Coach further builds upon these efforts, to provide a remote personal virtual health coach which facilitates the remote monitoring, management and coaching of chronic patients while they are in their homes. The architecture is not only able of firing alarms in cases of emergencies but also tries to predict abnormal behaviour or conditions to facilitate proactive intervention or assistance and decrease to the best possible extent the occurrences of such emergency situations. Also, it attempts to correlate real-time biometric/physiological data with data about the patients’ behaviour and their environment, not only to facilitate the detection of an abnormal condition or an emergency but also to infer its causes. This requires a component of Artificial Intelligence/Machine Learning so that the system self-learns about the causing conditions that might lead to possible emergency situations. Rather than passively waiting for an event to happen and reactively take charge of it, Active Life Coach offers mechanisms to proactively intervene and prevent it from happening at the first place.

2.2.1 Sensor Processing: The Wearables and other sensors

The term “wearable” refers to an electronic device or a computer which is comfortably worn on the body (Tehrani, 2015) or in some cases implanted into the body. They can perform many computing tasks like any other computing device, such as provide biofeedback and track physiological functions establishing them as very beneficial for healthcare. Ryokai (2015) investigated the interaction of patients with professional health coaches through the use of a custom-developed interactive visualization tool, which displays data collected from patients using wearable devices. Wearables can usually depict the true story about patients’ health and avoid the fact that patients intentionally or unintentionally tend to be bad historians about their health conditions. The author also presented a way to save time for the doctor by collecting reliable medical records for the patient. It is very important to monitor also the environmental conditions and the human behaviour/activity together with the health indicators so as to be able not only to detect possible health abnormalities, but also to infer their causes.

2.2.2 Coaching Model: The “Masterplan”

Historically, professional coaches used to give standardized plans to their customers in order to achieve their goals, which they slightly adjusted and adapted to the requirements of each customer (e.g., a diet adapted to the personalized dietary requirements). The concept of a plan is also proposed in (Jimison, 2015) which addresses the person’s readiness to change and achieve health goals (e.g. quit smoking, start exercising, eat healthier food etc.) by proposing an approach to first assess the state of the individual, and then generate suggestions (a plan) that are deemed to be most appropriate to affect a change in the patient’s state. Active Life Coach includes an automated generation of a personalized coaching plan (the Masterplan), which will be constantly supervised/monitored using wearable technology and other inputs and will be dynamically adapted based on the monitored progress and on personalized parameters and preferences.
2.2.3 User Engagement/User Interaction: Visualization and Avatars/Rotbots
User engagement and commitment is a big challenge in virtual coaching. Users usually demonstrate low commitment to the coaching plan. Senior citizens need someone to help them, inspire them to reach those goals, and hold them accountable when they just do not feel like making healthy choices or not following the plan. To address this, Ryokai (2015) proposed a user visualization tool that allowed patients to monitor their condition and get an insider perception about their health status. This increased their commitment, since they were provided with insights about how experts interpreted their data and also made personal coach advices and instructions sound more meaningful. It also supported their active participation and understanding of the coaching process and effectively avoided possible demotivation and disengagement from the coaching plan. Additionally, there were efforts to improve human computer interaction in this area and make the overall coaching process more user-friendly and more realistic. For example, Meridou et. al (2015) present the idea of a health avatar as an electronic-representation of a human coach. They conclude that such an avatar promotes a closer doctor–patient interaction to guarantee users the healthiest lifestyle and well-being. In (Gross, et al., 2015) the authors go one step ahead and they present a robot which serves as a companion for domestic health assistance for older people that helps keeping them physically and mentally fit to remain living independently in their own homes. They conducted trials with 9 seniors (aged 68-92) which indicated that a personal robot assistant has high potential to be accepted by older people as both, a useful health assistant and a meaningful social companion. This would potentially increase their engagement and commitment to the coaching plan. A thorough review of the role of Healthcare Robots for older people at home can be found in (Robinson, 2014) where it is established that robotic solutions now seem to be part of the possible future in order to help senior citizens to remain independent.

2.2.4 Prescription: A collaborative system of health-carers
Prescription refers to the requirements set by the care-giver to the virtual-health coach, so that the coaching plan could be defined/adjusted accordingly. In Active Life Coach we define the architecture to support a collaborative system of health-carers which involves the patient, the healthcare professionals and informal carers such as the friends and the family. We believe that this will empower individuals to self-manage effectively their health and will facilitate timely interventions (reactive or proactive) when needed. The objective is to provide a user-centred health care model that facilitates joint-decision amongst all the members of the health-care team. Traditionally, collaborative care programs are the ones in which primary care providers such as doctors, health coaches, and psychiatric consultants work together to provide care and monitor patients’ progress. The recent trend is to include the family into the health-care collaboration equation in order to provide an extra element of care for patients at home. In order to provide continuous and home-based care for the patients, especially those with acute or chronic diseases, a family carer can make informed decisions about the care or provide feedback to the health-care professionals, but to do so, the senior citizen needs sufficient access to the patient’s health information, and supportive care services (Nguyen, 2008).

2.3 Proactive Intervention
An effective and responsive health system would be the one that not only reacts quickly in emergency situations but also provides those proactive mechanisms that allow health carers to intervene prior to a possible emergency. Historically, medicine offers such mechanisms, for example the monitoring of cholesterol levels in order to facilitate the intervention and avoid possible cardiovascular problems, or the prevention of depression or any other mental disorder (Muñoz, 2009). However, effective proactive intervention is better facilitated when continuous input about patients’ health status is being reported. This presents an inherent difficulty, especially with the elderly people who have to periodically and systematically visit their doctor or health coach to have their health condition regularly evaluated.
Our solution tackles this by providing the means and the technology to continuously monitor physiological and other personal parameters through the use of wearables but also facilitates a personalized risk analysis which will evaluate the need of a health-carer’s intervention. Recent work (Pavel, et al., 2015), reports the need for a computational modelling-based approach to the assessment of behavioural, physical, cognitive, and affective states to revolutionize healthcare delivery, including the provision of effective, timely, and targeted interventions. Active Life Coach tries to identify abnormal physiological patterns in the user-context collected and proactively intervene to revert a potential emergency situation. In addition to that, it monitors behavioural/activity patterns and tries to correlate these behavioural patterns with health related risks/threads. Our vision is in line with that of (Pavel, et al., 2015), as we also try to improve health behaviour interventions using the tools of behavioural informatics, which have the potential to optimize interventions through monitoring, assessing, and modelling behaviour in order to support tailored and timely interventions.

2.4 Intrusiveness, Ethics, Security and Privacy

Undoubtedly ICT-based health monitoring and management systems would be very beneficial for senior citizens’ health. However, there is discussion taking place about the possible controversial effects of this type of telemonitoring. To this end, Mittelstadt (2014) reviewed and examined the ethical issues related to Personal Heath Monitoring (PHM) and has identified eight themes which better describe them; these include: privacy, autonomy, obtrusiveness and visibility, stigma and identity, medicalisation, social isolation, delivery of care, and safety and technological need. Similar findings were also reported by Nordgren (2013) who identified and discussed the values that should be promoted and respected in PHM, and formulated an ethical checklist that can be used by stakeholders and also constructed an ethical matrix that can be used for identifying values, among those in the ethical checklist, that are particularly important to the various stakeholders. Since our work is mostly based on wearable technology we believe that the most important values, which should be respected and promoted are Intrusiveness, Security and Privacy. This is also supported by the work of Ryokai (2015) who conducted a pilot study in which people using wearables that were collecting data for one week and sharing it with a professional Health coach, showed that people were concerned about their privacy and expressed preference to exclude specific data from being recorded (e.g., their whereabouts). Wearables collect personal data ubiquitously and continuously about individual users and their environment, which although it may serve the purpose of the application, (Motti, 2015), it may also pose many privacy challenges, with regards to which information is collected, who has access to it, how it is used, whether it is stored or not, how it is accessed and how long can it be kept until it is destroyed. In conclusion, the aforementioned questions must be taken into consideration when designing any healthcare framework that manages personal and often sensitive data.

3 Active Life Coach

Through a careful study of the health and care frameworks presented in the previous section, this section first identifies the most important requirements that any framework must adhere to in order to provide efficient and effective care to citizens as they age. Based on the identified requirements, it then describes the architecture of Active Life Coach, a framework that encompasses all requirements in a unified manner in order to allow for the provision of holistic care to senior citizens with the goal to enable them to maintain their independent living, health status and functional effectiveness as well as preserve their physical, cognitive, mental and social well-being.

3.1 Requirements Analysis

Section 2 identified a number of works that enable efficient and effective health management. Having studied these frameworks thoroughly, we have identified nine important requirements that are vital for...
delivering care in a holistic manner. These requirements have guided the architectural design of Active Life Coach, which is presented in the next section.

R1 – Monitoring: It is evident that all frameworks require some sort of monitoring, utilizing in most scenarios different types of sensor devices in order to monitor both the status of the end-users and their environment. Additionally, since some frameworks offer activities that the end-users must perform, there is also the requirement for activity monitoring, which is used for behaviour recognition.

R2 – Data Storage and Access: Besides all the monitoring measurements, all frameworks require storing of multiple types of data, ranging from user profiles of all actors collaborating within the system to data required to facilitate the provision of care, such as the activities and services. These data can be made available through dedicated APIs.

R3 – Data Fusion: In some scenarios, individual end-user measurements (e.g., heart rate, blood pressure) cannot provide a comprehensive picture of the health status of the end user (e.g., risk of heart attack). Similarly, augmenting data from the end-user’s environment (e.g., room temperature) can lead to more meaningful results. Therefore, data fusion components should be employed in order to combine various stand-alone data in order to provide collective information.

R4 – Analytics: Data fusion is not enough to infer the behaviour of the user. Instead, various ontologies need to be developed that will represent the acquired knowledge about the user including the relationships that exist within the various recognized contexts (e.g., emotions, gestures) related to the end-user. In order to identify changes in behaviour, this process necessitates processing of both real-time and historical data.

R5 – Collaboration/Coordination of Involved Actors: In order to support the collaboration and coordination of the diverse set of actors in the system, various tools that enable team formation and management should exist. Additionally, mechanisms for the communication amongst actors should be made available (e.g., messaging, sharing of data) in order to facilitate effective interaction.

R6 – Health and Wellbeing Plans: All systems define different objectives for the end-users and in the majority of scenarios, specify the actions/activities that need to be performed in order to meet these objectives. In order to incorporate objectives from different actors, there should be appropriate plan management mechanisms that allow all actors to collaborate and formulate a holistic plan for the users. These mechanisms should allow for plan definition and maintenance, specification of their objectives and corresponding activities and when the need arises for conflict resolution.

R7 – Interventions: Similarly, to R6, all systems include some sort of interventions that are employed when a risk has been identified. Through R4 and appropriate models, a system can identify a risk: i) before a problem actually happens (i.e., proactive intervention); or ii) after a problem happens (i.e., reactive intervention).

R8 - Security and Privacy: As in the case of any distributed application that orchestrates multiple services that process end-user data, a controlled environment is required to guarantee security and privacy. A goal of any health and wellbeing framework should be to provide for such guarantees through individual and unified state-of-the-art security and privacy mechanisms.

R9 – Presentation layer: There should be a presentation layer in order to facilitate human-computer interaction with all users i.e., citizens and actors. This layer should provide graphical user interfaces that enable interaction with all modules and services of a framework.

3.2 Architectural Design

Active Life Coach aims at a holistic care framework for senior citizens by combining all the useful characteristics and effective features identified from current state-of-the-art frameworks. As shown in Figure 2, the Active Life Coach framework adopts a layered architectural design that aims to promote extensibility by wrapping functionality into loosely coupled self-contained units. Based on the

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requirements identified, we have organized all functionality into 5 horizontal layers: Hardware, Data Mana, Data Storage and Access, Models and Analytics, Plan Orchestration and Presentation. Furthermore, we adopt a vertical security and privacy layer that spans across all horizontal layers.

**Figure 2.** The Active Life Coach architectural design

### 3.3 Hardware

This layer realises the low-level data acquisition and includes various wearable devices with embedded sensors such as Heart Rate and Galvanic Skin Response, medical sensor devices such as blood pressure sensor and glucometer, as well as various input devices such as microphone and motion camera, and sensors, such as temperature and humidity that are also able to monitor the environment. Since most of these devices feature different APIs, data acquisition queries (e.g., Retrieve Heart Rate every 5 seconds) will be disseminated native sensor libraries for execution. In the case of wearable devices, these may also require mediator devices (e.g., PCs, smartphones) that are paired with the wearable devices. These low level libraries sometimes require registering specific data listeners for events raised by the corresponding sensors when a measurement is generated. In order to ensure a uniform way of query dissemination and data acquisition, a uniform interaction manner will be provided through the Sensor Hardware Abstraction API.

### 3.4 Data Storage & Access

This layer forms the data management backbone of Active Life Coach. All data will be stored in dedicated repositories and communicated among the cooperating services and components. In particular, this layer will provide unified data structures for sensor and environmental data including mechanisms for fusing individual measurements to produce more comprehensive information per user. Additionally, this layer will serve as the repository for all information utilized by the system, including specification of the objectives and definition of activities. Additionally, all developed plans will be stored here in order to allow for further analysis and identification of successful plans that can be used as templates for similar users in the future. In order to facilitate data exchange among all components, this layer also introduces a data management API that will enable querying of the repositories in a unified manner thus enabling seamless sharing and distribution of the accumulated data and stored knowledge. Predominant technologies such as Simple Object Access Protocol (SOAP) and REpresentational State Transfer (REST) web services for communication among the services as well as interoperable formats such as JSON and XML for the message structure representation will be considered.
3.5 Knowledge & Analytics

This layer incorporates the intelligence of the framework and realizes the behavior recognition and reasoning, and risk detection mechanisms by modelling the end-users behavioral states utilizing data arising from the end-users recognized, emotions, gestures and motion. This mechanism also incorporates data arising from the user’s profile and preferences but also their daily recorded activities. The knowledge models will be in the form of ontologies written in OWL format. These ontologies will integrate facts inferred from activity monitoring and behavior recognition of any context to provide the knowledge models that underpin the reasoning.

3.6 Plan Orchestration

This layer provides components that realize the high level services of the framework. The collaboration tools allow for defining and maintaining virtual coaches, which are teams of actors that collaborate to form health and wellbeing plans for end-users. Additionally, these tools include communication/messaging tools that allow for efficient coordination of the virtual coach members. Intervention tools provide mechanisms that provide personalized interventions to each user. According to the category (proactive or reactive), these tools provide appropriate templates for defining interventions as well as the conditions that must be satisfied in order for the interventions to be triggered. Plan choreography enables the coach members to formulate health and wellbeing plans for end-users. A plan is formulated as a set of objectives and activities that are required to meet these objectives as defined by the virtual coach members. However, as these objectives may be conflicting, the framework provides tools for conflict detection and resolution. Finally, one of the most important features of this module is that it allows for the plan to be set in motion and coordinated through monitoring all related information (e.g., monitoring of the end-user activities, generated interventions).

3.7 Presentation

The Presentation layer facilitates human-computer interaction with all users (i.e., healthcare professionals, family friends and the senior citizen) by providing interactive graphical tools that generate visualisations of the different aspects of the system. The collaboration dashboard provides a register of the active and past virtual coaches and their individual members as well as the graphical user interfaces to manage them. The User Dashboard allows for registration of users and analysis of their current status, including accomplished or failing/failed objectives as well as interventions performed so far. Finally, the Plan Dashboard allows for plan management but also provides analysis of the plan objectives, assigned and ongoing activities and triggered interventions.

3.8 Gamification Widgets

Active Life Coach employs gamification concepts in order to stimulate and motivate end-users to be actively engaged in accomplishing their plan’s objectives. A number of mechanics are supported ranging from different types of badges, which allow for displaying the end-users accomplishments (i.e., accomplished objectives) in a visual manner, social standings (e.g., number of friends), achievements progress bars, etc. Through this mechanics, Active Life Coach treats end-users as players and attempts to positively influence the behaviour towards accomplishing their objectives.

3.9 Security and Privacy

The security and privacy infrastructure features state-of-the-art protocols and mechanisms that prevent unauthorized access and protect private data.
4 Conclusions & Future Work

In this paper, we have presented a thorough investigation of the current state-of-the-art on ICT-based health care management systems related to virtual coaching, collaborative care and proactive interventions, and uncovered a set of nine important requirements that any healthcare framework must adhere. By taking into consideration these requirements, we have presented the Active Life Coach; a framework that attempts to provide holistic care to senior citizens as they age. We justify how the architectural design of Active Life Coach satisfies the aforementioned requirements by gracefully combining all the identified useful characteristics and key features. Through the proposed layered design, Active Life Coach offers a secure, private, non-intrusive monitoring environment, facilitates collaboration of healthcare professionals with the end user, manages the coordination of the coaching plan in order to ensure that objectives are effectively met and provides proactive and reactive interventions in the cases where a deviation is identified. Active Life Coach will enable senior citizens to live independently and autonomously as they age, keep them physically, cognitively and mentally fit to efficiently contribute to the economy by continuing to be part of the active workforce.

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