Important Aspects to Consider When Developing ICTs for Purposes of Fall Prevention in the eHealth Domain

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Abstract. The current paper reviews briefly the eHealth domain, especially fall detection and prevention features, in connection with the developments of ICTs. The timely data signal providing identification of probable fall at early stages as well as its specifics can prevent serious injuries. It is crucial for elderly people living at home alone since it could affect their independent living. Therefore, the specific and contextual characteristics of several related factors are essential to understand in order to be able to diminish or remove the risk of the fall of the elderly at risk. The current paper presents research in progress and its results in the FRONT-VL project part of Celtic plus. The paper highlights essential factors to consider when developing and implementing a semantic database model for purposes, such as fault prevention.

Keywords: fall prevention, fall detection, eHealth, elderly people, ICTs

1 Introduction

The term eHealth was coined in 2000 and since then has widely been used [1]. The eHealth term can be found in several scientific databases, and the area has a broad spectrum of research that has been and is still being performed. In Medline, the eHealth definition differs depending on the functions, stakeholders, contexts and theoretical subjects under consideration. In brief, most of the paper's emphasis is on the communication tasks of eHealth as well as the use of digital technologies, especially the Internet. The formerly mentioned results in differencing eHealth from medical informatics. In addition, regardless of the potential benefits, the public commitment in connection with the eHealth information and communication technologies (ICTs) services diverges. The authors Hardiker & Grant [2] review the factors that influence public engagement in ICT services in the eHealth domain. They identified four type of eHealth services, namely health information on the Internet, custom-made online health information, online support, and telehealth. The public engagement of those services varied and was found to be dependent on the aspects of the user, technical concerns, the aspects of the eHealth services, social aspects of use as well as the eHealth services that are in use. In a review, it was found that 92 per cent of the latest articles in the area of e-health, i.e. the use of information technology to be used in the health sector, were generally positive [3]. Conversely, discontent exists also in connection with the electronic health records as well as due to the fact that there are some patients who are critical to the use of health IT implementation, which might be felt like a barrier to attain its full potential in the domain of interest. The Health information technology (HIT) is, however, important and it is here to stay since its benefits are huge [4]. Buntin, et al. [3] mention that negative findings might be useful, since they provide information on the factors/features to avoid in the design, development and implementation of HIT, i.e. they provide information for a successful HIT. When it comes to falls, they can cause a person's fatal injuries, particularly the elderly people, resulting in severe obstacles for an optimal independent living. In addition, it is also known that one of the primary reasons of injuries are related to death for elderly people in the age of approximately 79 years old or more and the second resulting in death for all ages [5, 6].

The ICTs to support people with risk of falling are, for instance, the fall detection and fall prevention approaches. These systems have many things in common, for instance both use sensor devices to realise their different tasks [7]. In addition, both collect data via the use of ICTs and employ computerized visualization, data mining and machine learning algorithms. Moreover, fall prevention utilises external sensors as well as wearable sensors. Thus, the motion aspects are convenient to use, namely to extract data from the sensors to understand the probability of a fall as well as alert the user in real time. The difference between those approaches is that the fall detection alerts, for example, and the healthcare professional arrives after a fall has occurred. While the fall prevention goes a step further and alerts the user or healthcare professional before a fall occurs.

It is possible to divide the fall detection approaches into three sorts, i.e. wearable device-based, ambience sensor- based and camera (vision)-based [5]. The authors make additional division among these fall techniques, namely into wearable devices-based approaches, such as accelerometer, fusion of accelerometer and posture sensors, inactivity with accelerometry, tri-axial accelerometry, and posture-based,, ambient device-based approaches, such as audio and video, event sensing using vibrational data, ,camera (vision) based approaches, such as spatiotemporal, inactivity/change of shape, posture, 3D head position analysis. One of the major drawbacks with the camera-based approach is privacy concerns, as stated in [8]. When it comes to the wearable device-based approaches, the positive aspects are the low cost and their easy installation as well as the set of the design. However, the main disadvantage is that the devices can easily be disconnected resulting in a non-optimal choice for the elderly. Ambient device-based approaches use pressure sensors for object discovery and tracing. It is a very low-cost alternative and also not so intrusive, i.e. unpleasant or pushy technology for operation of surveillance of the user, its nature of sensing via pressure might create false alarms in the case of fall detection and prevention resulting in a low level of detection. The camera (vision) - based approaches key applications are developed for purposes of surveillance in computer vision methods with the possibilities of real-time implementation. These applications are developed with the use of standard computer platforms as well as with cameras at economical prices. The use of cameras and their image sequences are still in their infancy in several areas; however, in the fall detection, they have not yet been implemented with the use of, for instance, the total optical flow of the image sequence. Certain sensors become very handy to use in connection with a patient's physical activity (PA). PA is viewed as any corporal movement created by a person through his skeletal muscles, which results in energy expenditure [8]. Researchers in the area of epidemiology have studied physical activity for purposes of human activities and their relation to health grade in, for instance the part of cardiovascular illnesses, such as diabetes type 1 vs 2 and obesity. Thus, a deteriorating physical activity level embodies a key cause in several diseases and indications associated with functional deficiency. Accelerometers are sensors that measure the spurts, i.e. acceleration of things in motion alongside reference values [8]. The previously mentioned approach can provide an understanding of velocity and displacement data via the integration of accelerometry data vs time [9]. Any applications developed in the domain of interest need to follow common standards as well as take the opportunity to use open source standards when developing a different kind of applications. The authors Kanter, et al. [10] highlight the importance of using open source technologies and common standards for interoperability when developing and implementing eHealth systems. Currently, with the emergence of new technologies, such as cheap sensors, new concepts and technologies are entering the domain, namely IoT, big data and analytics, promising new opportunities as well as challenges. The current paper presents some of the aspects mentioned above, among others, as well as the characteristics of the FRONT-VL project. The authors present the standards and guidelines in section 2. In section 3 the FRONT-VL and its architecture are highlighted, and in section 4 the database and its analytics aspects of the domain are briefly underlined. Finally, the conclusions are given in section 5.

2 Standards and guidelines

Interoperability is crucial when it comes to being able to integrate different data and system successfully. Therefore, the standards and recommendations become key aspects when developing a large ICT system. There are some standards and recommendations connected with the e-health sector. One of those is the PCHAlliance, which stands for Personal Connected Health Alliance. The PCHAlliance issues and supports the use of global adoption of the Continua Design Guidelines (CDG). The following aspects are highlighted, such a secure end-to-end ICT framework for connected personal health and care with the use of open standards with the aim to increase its use. The increased use of the standard results is a secure and possible integration, i.e. interoperability of the personal health data exchange (www.pchalliance.org).

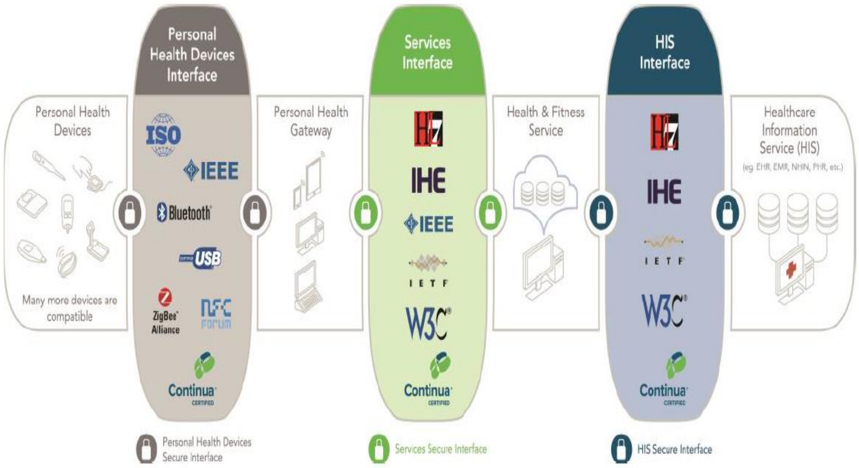

Fig. 1. High-level architecture (www.pchalliance.org).

The Continua Design Guidelines (CDG) provides defined interfaces with the aim to give secure data stream between the different sensors, gateways as well as end services to secure a consistent and interoperable e-health ecosystem.

In addition, the CDG recommends the use of the following transport technologies, i.e. NFC, USB, ZigBee and Bluetooth (Basic Rate / Enhanced Data Rate and Low Energy) for purposes of data transmission on the Personal Health Devices (PHD) Interface. The reason to endorse these technologies is because of their increased popularity in the consumer electronics. Other parts of the Continua Design Guidelines (CDG) is the Services Interface, which recommends standards part of the, for instance, message exchange and security issues. The data part of the message exchange framework is obtained/received through the message package in SOAP and its security with authentication is provided via the use of different technologies. The Healthcare Information System (HIS) Interface agrees on the use of electronic health record using clinical document architecture and other recommendations, which meet future requirements because of its acceptance in health record community.

3 The FRON-VL and its ICT architecture

In this section, the authors introduce into the context as well as highlight the conceptual architecture and its components, especially in the case of fall prediction. The context of the FRONT-VL project is connected with the new reality of the Europeans who live longer and have fewer children (front-vl.eu/index.html). It is also believed that the number of working-age people will drop considerably in the next few years. The former mentioned is regarded as one of the major challenges to European economies and welfare systems. FRONT-VL aims, therefore, to develop smart and efficient technical solutions to upturn the prospects for the elderly to live at home without being reliant on children or in-home care. In the FRONT-VL, the use of three use cases was crucial to the understanding of the ICT requirements for the specific needs for the user's part of each case. The use cases used were about rehabilitation, fall prevention and Mental Health. This paper is about use case two, i.e. fall prevention. The objective was to understand the suitability of the use of, for instance, machine learning algorithms, big data analytics as well as IoT based data acquisition for the development sophisticated predictive health-related services for both the users and health care professionals, such as nurses and physicians. Hence, all the data created by the sensors system with the help of these previously mentioned technologies has the aim to develop and consequently implement a learning system. The system is based on the created sensor data so the users (elderly people) and health care professionals can learn from the data created by the sensors and by so resulting in fall prevention procedures can be considered. Figure 2 below highlights as the aspects mentioned above.

Fig. 2. The high level and popular view of the project architectures (modified from front-vl.eu/index.html).

It is also well understood that the FRONT-VL has to ensure a high level of criteria when it concerns the privacy and data ownership of the individuals involved. The innovative aspects of the project are firstly the connection between the end-user services which are defined based on the use cases with the aim to provide ICT grounded home care as well as health services to the users of the system, i.e. the elderly people and healthcare professionals in a customizable as well as flexible way. The second is based on a computerized data collection that permits peer-to-peer learning and knowledge transfer. The use of big data in the previously mentioned system is expected to provide an enhanced the quality of the services provided. More detailed information can be found in the following link (front-vl.eu/index.html). It is central to understand the different services that can be provided by the data created and stored in the framework and its databases. Thus, it enables one to comprehend what kind of analytics and what services can be provided by those, for instance directed to the elderly people and health care professionals so they can learn and prevent a fall by way of the real-time or historical data.

Figure 3 below highlights the data flow and its various processes. Starting from the left is the sensor data which is produced by various connected health devices as well as sensor/s that the elderly people are directly wearing and are attached, for instance to the leg or other suitable parts depending on the capabilities of the sensor/s. The data is later acquired by the system and stored in suitable databases, i.e. relational or non-relational databases like the No–SQL. The data can be stored on a cloud or at home of the different users, to be further sent to the cloud when the user agrees to transfer it. Further, the analytics part performs relevant machine learning algorithms for different decisions that need to be taken as well as learning aspects which are later moved into user interfaces of the health care professionals and/or elderly people. The user interfaces (UI) of the former mentioned users differ, of course, depending on their needs and requirements. It is also possible for different users to perform further ad-hoc queries and analytics into the former layers. In addition, the UI and connected modules provide the elderly people with a learning module so they can learn from their behavior. For instance, in a case of a fall they can try to understand the reasons of it by the support of relevant machine learning algorithms. The algorithms take conclusions based on a comprehensive analytical process where other data, such as medical activity, can be used to learn from the situation, i.e. the reason of a fall.

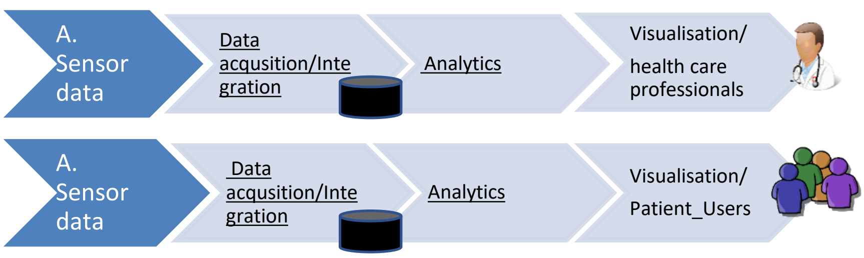

Fig. 3. The data flow and its processes.

4 The database & analytics aspects of the domain

What becomes important when working in the efforts to follow the PCHAlliance and its Continua Design Guidelines is the semantic database model. It is, therefore, crucial to understand how the database/s should be developed to optimize its use. The emergence of new technologies, such as big data, new sensor technologies and IoT, puts specific necessities in the requirements specification of the semantics and its database/s for purposes to be used in the eHealth sector. Thus, database design is normally carried out in two phases. These are the logical and physical database design phases. In logical design, the main activity is to identify the objects, the relationship between the objects, objects identifiers and classes. Before the logical database design is done, a conceptual database model should be designed, [12]. This phase is independent of all implementation details like the underlying model, such as the relational or object data model design or other physical things to take into account. In addition, it has been known for long that the semantic database models are crucial because of the needs of further expressive conceptual data models [12]. Thus, the semantics and its ontologies are important to be able to integrate the data at a lower and a metal lever, i.e. service level.

When it comes to ontologies, an accepted definition of it is the following "what exists", i.e. what exists in the domain or area of discourse in a field [13]. Moreover, the use of ontologies is important, because it provides critical semantic foundations, which support both interoperability between software platforms and data integration [14]. In addition, the use of the Internet facilitates the integration of the different data and its databases because of its use of the common framework like the semantic web and web services [15]. It facilitates the integration of the data at a holistic level, i.e. Meta level by use of services.

There are different approaches or methodologies for the development of ontologies [16, 17, 18]. In addition, there are ontologies that follow the recommendation of the W3C Web Ontology Language (OWL), which is a Semantic Web language (www.w3.org). One of important aspects of the OWL Web Ontology Language is that it is suitable to be used by applications that need to further process the data and information as an alternative to only present the data and/or information to the users as is the case of the FRONT-VL project. In addition, there are many approaches that have been suggested in the semantic web data connection with knowledge discovery in databases (KDD), a survey on the topic can be found in Ristoski & Paulheim [19], other related works are the ones of Zhang et al. [20] and Dou et al. [21]. However, one of the first steps when developing an ontology is to understand various classes existent in the area which describe the different and existent concepts in the domain. In addition, the ontology approach illustrates the importance of the data and information needed for designing successful ICTs and highlights the connection between the data needed for the databases, the software applications and the user interfaces [22, 23].

In Figure 4 below, the important aspects of a database ontology for fall prevention are illustrated. Consequently, in the eHealth, a key part of the database is the user, i.e. elderly people, who in this case are an important part of the database, where a number and location are incorporated so he/she can be identified, etc. The sensors and their measurements are also key part, i.e. the wearable devices such as sensors or ambient devices as well as camera-based ones have their different ways of being measured, as mentioned earlier. All of the different measurements have some reference value that can tell if there has been some deviation from predetermined values, as in this case would be a fall of the person wearing them. The periodicity of the measurements are also important to incorporate because of the different intervals at which the necessary data is sent into the system, i.e. continuously, random or at specific intervals. Moreover, other factors that are of interest to combine with the fall prevention classes are such as the medicines that a person is taking as well as his mental health etc. The user is the central concept connected directly with the measurements and their historical values as well as with other concepts/classes from other uses cases, as mentioned above.

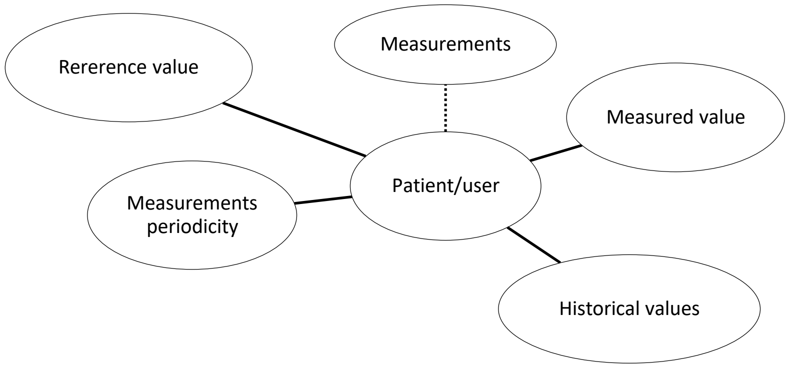

Fig. 4. Important classes/concepts of the conceptual database ontology for purposes of fall prevention.

The data and big data analytics that can be performed for purposes of fall detection and prevention are various. However, they are constrained by the different sensors used and their specific characteristics. For instance, some sensors have embedded the analytics part resulting in the fact that they send only processed results. In addition, other sensors send the data into the system at different intervals, and the reason is that of issues with the battery life, i.e. if they send the data all the time, then the time of them working would be less. In addition, there are matters with the gateways since they can get obscured if a person wearing the sensor gets into a place where the gateway cannot reach the signal. All the above-mentioned are related to the quality of the data, which in its turn needs to be used to perform the analytics. In addition, the user is able to add some data manually, for instance what they have eaten, a kind of activity they have done on a specific day, if they have taken medicine, etc. The former mentioned should have a user interface that is easy to use to insert data into the system, i.e. the user interfaces are crucial to adapt to the people using them to avoid other aspects related to the quality of the data.

5 Conclusions

The eHealth domain is a multifaceted area where several aspects need to be considered to be able to develop and implement the different ICT applications successfully. The development of a semantic database model is crucial for the domain due to its real-time access and analytics, among other aspects, since much of the recommended standards about the integration occurs at a higher level. In any circumstances, the different cases, such as the fall prevention and other related areas, form important guidance on the data and information that is needed and are of key importance in each case of ontology for its further implementation in the semantic database, application software and its user interfaces.

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