A DYNAMIC PERSONAL HEALTH RECORD WITH SEMANTIC INTEROPERABILITY SUPPORT

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ABSTRACT

The constant growth of life expectancy brought to the focus a challenge for the healthcare systems. The increased longevity of the population directly results in an increased registration of chronic diseases, rising the demand for healthcare. Overcoming this challenge is to change the healthcare model, whose goal is to insert patients as active members in the care of their own health. This new model has generated demand for new information and communication technology solutions that must be able to satisfactorily meet the patient, as solutions in mobile and ubiquitous computing. In this context, this article proposes a model called AllHealthcare, consisting of a Personal Health Record (PHR) solution where patients are able to build a Dynamic Accompanying Profile (DAP) for their healthcare. The profile is defined according to their needs, and changed as either new demands or focus are considered. This dynamism in building a custom profile is achieved because the proposed model is based on openEHR standard archetypes, which also provides the feature of semantic interoperability to this proposal. In a review research focusing on PHR, most of the solutions are designed and focused for treatment of a particular disease or their models do not fulfill a number of important and current operational requirements, such as healthcare mobility and semantic interoperability of information. Finally, to evaluate AllHealthcare , we designed two use case scenarios based on a developed prototype.

KEYWORDS

e-Health. Web Semantics. Mobile Computing. Health Records. Ubiquitous Healthcare

1. INTRODUCTION

Information technology solutions and health-oriented communication have gained strategic strength to combat the rising of health costs at North America and European healthcare systems (Fan and Sui, 2016). Health Information and Communications Technology (ICT) force a change in people's healthcare model, making the patient an active member in the care of own health by making use of software tools, especially in the prevention of diseases (Moraes et al., 2013). Nowadays, the goal of preventive health care is to make people maintain a healthier lifestyle, preventing the occurrence or recurrence of diseases, mainly the chronic diseases, because given their long duration, they require a long-term and systematic approach to treatment; health services must integrate the response to these diseases. More commons chronic diseases are cardiovascular diseases, mainly heart disease and stroke; cancer; chronic respiratory diseases; and diabetes (Lähteenmäki et al., 2015).

The advancements in ubiquitous computing technologies enable better healthcare model, with the patient as an active member in their own health care, which encompasses the use of smartphones, tablets, sensors, which can explore connectivity advantages (Kumar et al., 2013). This scenario makes possible the availability of health care anywhere and anytime with these devices (Hansmann et al., 2001). Therefore, ICT applications in health have become important factor to empower the patient as an agent in their own healthcare. (Gençtürk, 2015).

It is widely accepted that patients with access to their own health status increase control over the care of the body. But the simplicity of the tools and methodologies are factors that can contribute significantly in the patient's level of involvement with the application. In addition to access to your health information, the inclusion of routine data in a PHR, the patient makes it an active member in the care of own health and provides an important step for reducing costs and better health care quality (Gençtürk, 2015).

Some initiatives for integration between PHR and Electronic Health Record (EHR) have been conducted, but, the medical records of patients still in majority, are kept in separate, closed systems, generating medical records sharing difficulties between hospitals, laboratories, PHRs, among others (Belyaev et al., 2013). In order to overcome these difficulties, international standards have been developed for representation of clinical information to enable the sharing of health information of patients between different health service providers. Among these standardizations that promote interoperability of information, it highlights the openEHR[1] and Health Level Seven[2] (HL7). Generally, PHR solutions are using static fragments these standardization in order to offer care to a specific disease. This format is valid, but remains plastered to new possibilities for healthcare or even an improvement in the treatment of a disease.

The use of standardization for clinical knowledge representation favors interoperability between different systems. Interoperability is the ability of two or more systems and components to exchange information and use them (IEEE, 1991). In a study of PHRs led by Bastianen (2015), in 68 analyzed PHRs, only one was integration with EHRs, the most held their own and closed structure without communication with other means, which according Bastianen (2015), is a reality of the situation of systems for available PHRs.

Therefore, we are presenting in this article a model called AllHealthcare model, which is a PHR model that enables the development of DAP for specific healthcare for each user. The profile is compatible with mobile devices, in addition to supporting semantic interoperability, which is the most advanced level of sharing of information between health care providers (Walker et al., 2005). This model is based on openEHR standard, which has a medical and information technology community working on archetypes structures, capable of carrying clinical knowledge of each existing concept in medicine. The main scientific contribution of this work is two-folded: (i) combining the ability for users to build their health care profile in their own PHR, and; (ii) to enable semantic interoperability. The construction of the DAP will have the clinical knowledge base of openEHR standard, as well as interoperability will be based on the same standard. Health standards are gaining adepts by their use's flexibility (Lin et al., 2016).

This article is organized as follows: section 2 will be presented related work and their characteristics; Section 3 will present the proposed model by this work; Section 4 will present implementation aspects; in section 5 will be described the evaluation model through its prototype and finally, in section 6, the final considerations.

2. RELATED WORK

In researching by contributions from studies in PHRs area, six studies stood out because they are concerned about proposals interoperability for sharing information and thus used standardizations for representation of clinical information. Table 1 shows these six studies which were analyzed in relation the standard used, the tool implemented platform and also focused on the particular disease or set of information.

Table 1. Characteristics of related work

Property	(Brugués et al., 2015)	(Peng, 2013)	(Gençtürk, 2015)	(Franz et al., 2015)	(Song et al., 2015)	(Moraes et al., 2014)
Standard	HL7	HL7	HL7	HL7	HL7	OpenEHR
Platform	Mobile (Android) and Web	Desktop	Web	Mobile (Android)	Mobile (Android)	Not specified
Disease and specific care	Diabetes	Diabetes	Rheumatism	Cardiac and vital signs	A limited data group	Only read sensors

Analyzing the options for each study on the use of standardization, HL7 was predominantly more used. This behavior can be explained because of the HL7 be more widespread. The openEHR standard is improving and recently has been integrated as a valid option, especially for having the distinction of clinical knowledge database in archetypes format.

[1] http://www.openehr.org
[2] http://www.hl7.org

Referring to the platform used, the majority of studies has developed in mobile devices or for web. When applicable to mobile devices, the Android Operating System was the choice for all related works. This option was justified by the quantity by the authors because includes most existent mobile devices. The availability of the PHR through mobile devices has been contemplated as one of the requirements that a PHR should provide users according research conducted (Vitaletti and Puglia, 2014). The third examined characteristic is directly related to the main contribution presented in this paper. It indicates the object of PHR tool of the analyzed work. All works propose a specific healthcare to a particular disease or monitoring pre-determined specific data.

Unlike this, not having a disease or treatment as a specific focus, this paper proposes the DAP to healthcare, which consist in a process of construction adding the clinical concepts. Clinical concepts of interest to the user or to help in a specific healthcare situation. Clinical concept refers to a medication or perception of the body such as temperature, weight, heart rate, blood pressure and many others. Thus, this PHR model intends to be the unique PHR solution for any healthcare. Beyond, the model consider too other important resources that a PHR solution needs, like health information's integration with health institutions and the mobile devices compatibility.

3. PROPOSED MODEL

The AllHealthcare model is a PHR solution that utilizes openEHR standard like supplier of clinical knowledge. The openEHR standard contains two main layers, called reference model and archetype model. The archetype model has numerous structures called archetypes where each structure defines a clinical concept containing all the details of possibilities. Are created, reviewed and maintained by an open medical community, the openEHR Foundation, that has an archetype repository, called Clinical Knowledge Manager (CKM). In the purpose model, the archetypes are used by PHR users build their own healthcare profile, only containing important concepts for itself.

The archetypes adoption to the construction of a dynamic PHR is proposed innovation of model. Different from majority of PHR solutions, the objective is not care a particular disease or finite set of information with a static tool. The model was thought to be flexible and adaptable over time, ever supporting the demand of each user or a medical novelty, beyond support for mobile devices and interoperability between different healthcare providers. Interoperability between health institutions is not a novelty, but do it from a dynamic PHR is complex.

The openEHR adoption helps in that problem because the archetype too have the data structure and terminology information, required for data integration. The logic of openEHR for interoperability between different systems is avail the same data structure used, i.e., the same archetypes in both sides of data integration. Figure 1 shows the software architecture proposed by the AllHealthcare model.

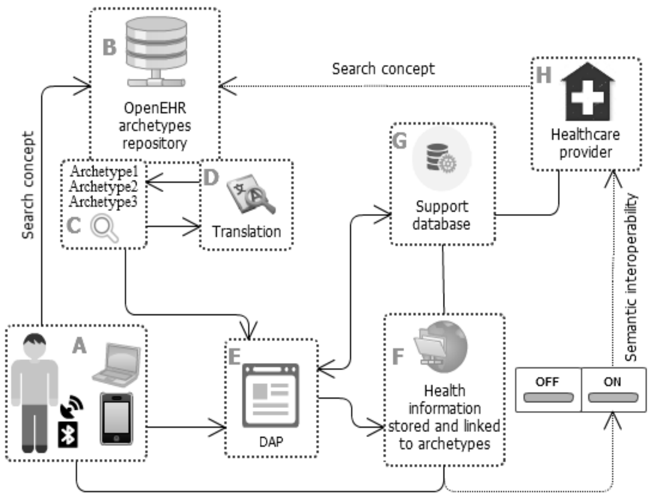

Figure 1. AllHealthcare software architecture model

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Explaining the model in Figure 1, initially, to build the DAP the user enters a keyword for the desired clinical concept to the accompanying in the PHR. Sample keywords are "weight", "respiration", "pressure" and "temperature". For each clinical concept informed, a search is performed on the openEHR archetypes repository (B). The research in archetypes repository applies a scan on file archetype available (C), exploring its information represented in formal language Archetype Definition Language (ADL) or Extensible Markup Language (XML). The scan process explores the following fields of the file structure, in this exact sequence: keywords, purpose and use. Figure 2 illustrates the search being performed successfully, with the clinical concept "fever".

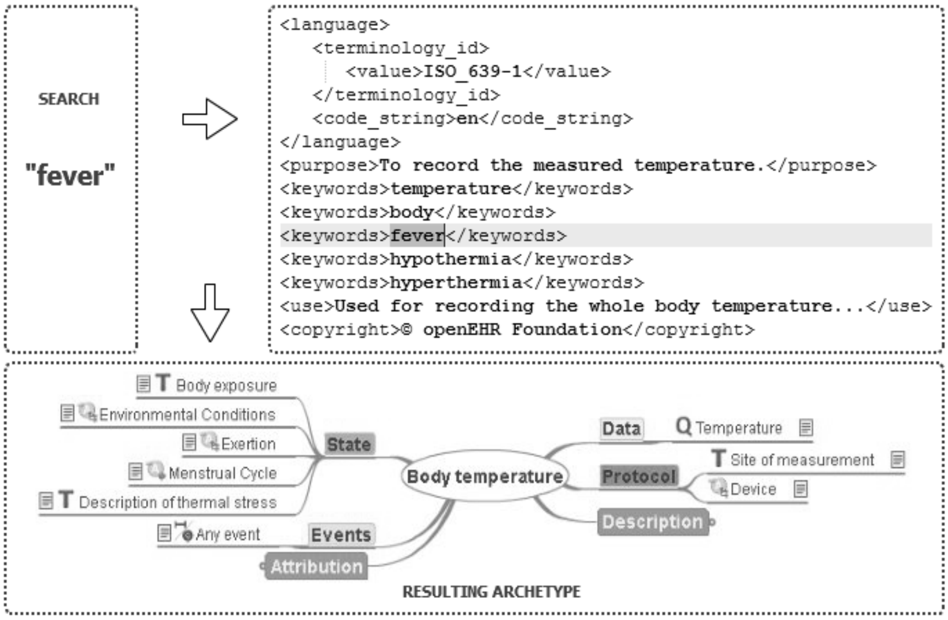

Figure 2. Archetype search in AllHealthcare demonstration

In the search process, if a clinical concept entered by user is not found, the search term is translated from the user's origin language to English (D), and the search is performed again (C). The translation is necessary because most of the openEHR archetypes are in english language. In the proposed model, the translation uses an Application Programming Interface (API), like Google Translate API. The resultant archetypes that corresponded to the user search are send back to the user. If there is no result that matches the search, even after translation, then nonexistence is informed to user.

After adding all the desired clinical concepts, the user can customize them, removing data fields from each archetype in according to their needs. Initially, the archetypes have several detailed fields, that can exceed information needs of their users. The body weight archetype, for example, currently presents seven fields for their clinical representation, but only one is required. Thus, for customization of an archetype, the model purposed uses the archetypes, especially the section containing the data fields description. This section specifies all the fields of personalized archetype, including which ones are mandatory and which are optional, also including possible measurement units for each attribute.

The proposed model allows that the healthcare provider (H) performs the DAP construction. This feature has been thought to be easy to use for elderly people. The DAP construction from by the health provider is not a mandatory option in the model, thus, in the Figure 1, this bind is show by dotted line.

The health information entered by the user in the PHR are stored using a specific database (F). The support database stores the utilized archetypes, personalization made in the archetypes and connection details from PHR with the health institutions for integration of information PHR-EHR within an interoperability scenario. The interoperability proposed by this model, showed in Figure 1, perform the sharing of patient's information with healthcare institutions (M) without losing any semantic meaning of the data, enabling the destination institution immediately use the information. In an environment of semantic interoperability between different systems, communication occurs through structured and coded messages, standardized data, causing the system to exchange information with the same vocabulary.

Utilizing openEHR in both sides for data integration, the messages are transmitted in same vocabulary, the use terms and expressions are equals, shared and pre-established. In this format translation or interpretation is not necessary. In the proposed model, the user can PHR utilize without data integration, thus, in the Figure 1, this resource is showed with dotted line.

4. IMPLEMENTATION ASPECTS

The implementation of the prototype to represent the model aims to demonstrate the main contributions proposed in this article, as the construction of DAP along with the integration of health information PHR with an EHR on a mobile platform for the PHR user. The prototype implementation was divided into three modules: client module, service module in a cloud computing, and a health institution module, that is an EHR also based openEHR for integrate health information, through interoperability.

In the client module has been adopted PhoneGap technology, by Adobe, to allows the application to be developed with web solutions such as Hypertext Markup Language (HTML), JavaScript (JS) and Cascading Style Sheets (CSS) and resulting a app compatible with several operating systems available for mobile devices. In the application use, all interactions are performed through web requests, requiring a web server to meet these requests. Figure 3 shows the user interfaces proposed, starting in PAD construction, with search of clinical concepts, personalization, removing fields in necessary cases and information insertion.

Figure 3. Prototype user interfaces

The cloud computing module contains most of the services because receives e send back requests from client module. Also, perform searches for DAP construction and handles all resources. This module have a web server Apache with PHP to answer the requests, handling files, archetypes, databases, translation API and web services for interoperability of health records with a health institutions.

In the DAP build, this module receives the search term of a clinical concept and run the search algorithm, which may involve calling the translation API, trying to find archetypes containing its description in the local language of the user. Contextualizing the three modules, the Figure 4 shows the content of each and the transitions between them.

The data persistence uses two database management systems, each with different structures e characteristics. The first is a MongoDB database that has a NoSQL structure and is used to register user's health information. This structure has advantages for handling large volumes of data quickly. NoSQL databases have no relational structure, but provide better results for speed and scalability. The second is a PostgreSQL database, that has a relational structure and is used to store user's access data, personalized DAP and interoperability settings. Ever that user to start the PHR app to insert information, a requisition is performed in this database to mount the constructed profile and updated. Both database management systems choices were considered by being open source and have extensive documentation available.

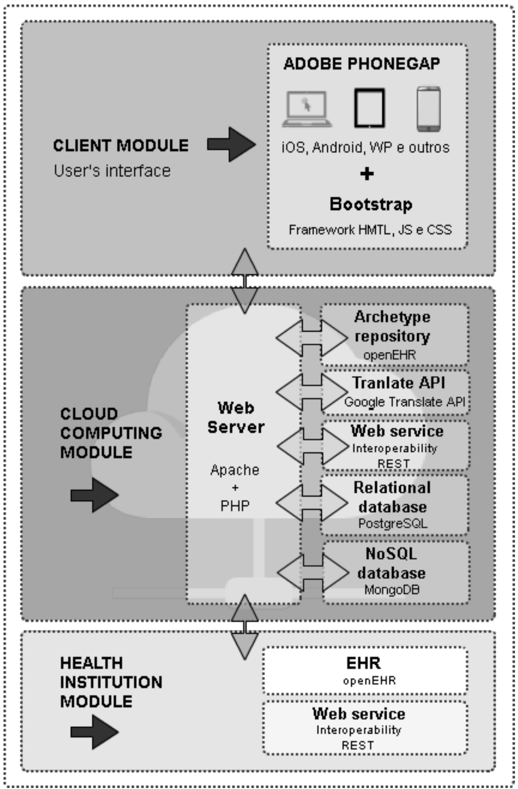

Figure 4. The three modules of the model and their relations

The integration of data between PHR and healthcare providers occurs through web services REST type connection. Due the data leaving the cloud service module and be transmitted to the healthcare provider, the PHR's user do not need to be continuously connected to the Internet. The data are transmitted as according availability of necessary resources. In addition, this integration of health records only occurs with the user's consent. From this, a web service can be configured in the health institution module, pointing to the EHR for transmission of user's health information stored in the NoSQL database in the cloud computing module.

5. EVALUATION AND RESULTS

This section describes the evaluation of AllHealthcare model, in order to assess the proposed PHR using the DAP with interoperability for sharing of health semantic information. The evaluation using scenarios has been adopted by the scientific community on mobile and ubiquitous solutions (Satyanarayanan, 2010; Costa et al, 2015), therefore, a scenario was modeled for evaluation, adding demands that this solution proposed to solve. Two scenarios were proposed.

The first scenario is described as follows: "Lucas started to use PHR application on his smartphone, which allows the creation of a Dynamic Accompanying Profile of several health factors, as needed. To better monitor the progress of his body with the beginning of a routine physical activities, he has created a initial profile. After a few days, and with the constant lack of air during the physical activities, Lucas decided to improve his profile by entering the accompaniment of smoking, to try to reduce the use of cigarettes. Even with the reduction of smoking, their air lacks persisted and he decided to seek help from a physician. Through the PHR application, he authorized the transfer of all the information to the healthcare institution database, facilitating the diagnosis."

The described scenario and the prototype was performed by a person with expertise on smartphone utilization. The PAD construction was analyzed step by step. The user initially searched by two clinical concepts: "weight" and "mass". These two clinical concepts resulted in two archetypes: body weight and body mass index. In the personalization step, the user kept the fields weight and state of dress for the body weight archetype and for the body mass index archetype the user kept only the index field. To add tobacco accompaniment, the user searched by "cigarette". This term resulted the tobacco use archetype. In the personalization, the user kept the follow fields: specified day, tobacco use and form, which specifies the cigarette type. Thus, to execution this first proposed scenario, the prototype achieved openEHR archetypes with clinical knowledge to support the accompaniment requested by the user, including maintenance to add one more clinical concept on time later. The returned archetypes were analyzed as to content quality. The keyword list formation contained six words and the use and purpose fields contained a long description, justifying the search success.

The second scenario explores a different situation, as follow: "Marie has seventeen years old and has headache frequently. In the doctor's appointment, she was recommended monitoring their blood pressure (ever in sit position) and sharing this information with the hospital. The doctor requested the patient return a month later". The second scenario was performed by a young person with basic expertise on smartphones. The user handled the prototype, starting by the DAP construction. The search clinical concept was "pressure". The returned archetype by the prototype was Blood Pressure. The user has accepted and went to the next step, the personalization step. The user has removed some data fields, keeping the data fields diastolic, systolic (mandatory) e keeping too the fields position and sleep status. Has attending for doctor's request, the user does authorization to the blood pressure information sharing with health institution. Thus, the PHR information form, personalized by the user stood with four data fields to shared entries with medical institution for patient's accompaniment e monitoring.

Analyzing the PHR prototype's behavior in this scenario, it was returned the Blood Pressure archetype for user. The search found two correspondent keywords in this archetype's description: mean arterial pressure and pulse pressure. Moreover, the personalization allowed the user to highlight the position for obtaining the blood pressure, in accordance with physician's request. Therefore, the evaluation was considered positive because the user achieved the proposed goals without difficulties. More than dynamic profile construction, the clinical knowledge transported from the openEHR archetypes to the DAP helps user on an unknown area for it, that is the clinical area. The information sharing with healthcare institution met the expectations because the user easily found the sharing resource for authorization. Finally, these evaluated scenarios with PHR prototype's use showed how the solution proposed behaves on a different, but specific user profiles. Another evaluation is planned, which will consist of the prototype free use for ten different users.

6. CONCLUSION

This article proposed a PHR model called AllHealthcare, which enables the user to create a Dynamic Accompanying Profile to healthcare, utilizing the openEHR standard to accomplish this. The openEHR uses archetypes to represent clinical knowledge which were created to improve the interoperability level between different healthcare information systems.

The main scientific contribution of AllHealthcare is combining the ability for users to build their health care profile in their own PHR, also enabling semantic interoperability. In the researched literature, we did not find examples of exploitation of archetype's descriptive content. The majority of PHR solutions are focused in specific diseases treatment. The DAP to healthcare enables user to utilize PHR for their personal and momentary necessity. Beyond the DAP, the model also offers support the semantic interoperability, turning possible to share PHR information with other healthcare institutions, such as hospitals, clinics and laboratories, without the need for data mapping or any kind of conversion.

Considering the evaluation, two scenarios were modeled to define some use situations. Through the implemented prototype, we could execute the two proposed scenarios. The result was satisfactory because the

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user achieves the proposed goals without difficulties in execution. As future works, we aim at suggesting clinical concepts based in user's choices. We also plan to assess the prototype with real users and different types of chronical diseases.

ACKNOWLEDGMENTS

The authors would like to thank to CAPES, CNPq and FAPERGS for partially funding this research.

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