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Improving Quality of Medical Service with Mobile Health Software

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Abstract

An increasing number of m-Health applications are being developed benefiting health service delivery. In this paper, a new methodology based on the principle of calm computing applied to diagnostic and therapeutic procedure reporting is proposed. A mobile application was designed for the physicians of one of the Portuguese major hospitals, which takes advantage of a multi-agent interoperability platform, the Agency for the Integration, Diffusion and Archive (AIDA). This application allows the visualization of inpatients and outpatients medical reports in a quicker and safer manner, in addition to offer a remote access to information. This project shows the advantages in the use of mobile software in a medical environment but the first step is always to build or use an interoperability platform, flexible, adaptable and pervasive. The platform offers a comprehensive set of services that restricts the development of mobile software almost exclusively to the mobile user interface design. The technology was tested and assessed in a real context by intensivists.

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1. Introduction

Information Technology (IT) in the area of Medicine and Health has been the focus of many researches nowadays. Their importance has been increasing in the healthcare area, since it leads to the improvement of the quality, safety and efficiency in healthcare [1]. The Mobile Health (m-Health) discipline is constantly being developed and this technology allows interaction between health professionals and their patients, resorting to a mobile device to support medical decision of the caretakers in their duties [2]. The m-Health includes ubiquitous and mobile devices such as mobile phones, tablets, PDA and laptop computers, as well as a variety of technology infrastructures such as 3G and Bluetooth [3]. The m-Health applications are developed for various target audiences, such as healthcare professionals, patients, managers, among others. They can have several functionalities such as portables systems for monitoring personal health's status, detection and prevention of diseases, monitoring systems in the patient's own home, and many others [2,3,4].

The healthcare area has several and heterogeneously associated systems integrating medical equipment. Those are constantly used by different people with different goals in the health organization. These systems have to respond to information demands of health professionals flawlessly [6]. Therefore, the presentation and collection of information for mobile technology allows professionals to access the required information more easily and remotely. Nowadays, m-Health begins to play an important role in the healthcare facilities [7] and the use of this technology has greatly improved the communication between systems, the healthcare, both in the hospital and at home [8] and in the medical decision-making of diagnostics [4,5]. It has been proved that handheld technology has several advantages facilitating patients' medication and data management and accessibility [9].

Motivated by the presented advantages of such technology, this paper proposes a new methodology for improving the medical decision-making of the health professionals by providing, in calm computing [10], reports about the clinical review of patients in a secure and confidential way in a mobile device. The most interesting change and the biggest challenge of ubiquitous computing is calm technology, which tries to provide information to the user without requiring all his attention. Ubiquitous computing aims to increase the use of computers in everyday life, providing a large number of computers in the environment, but they have to be effectively invisible to the user. This is where the calm technology appears, transmitting the required information without requiring much attention of the individual. Weiser (1991) [11] introduced the concept of calm technology and says that the most profound technologies are those that disappear as they engage in everyday life as well as to become indistinguishable from this. It should be taken in consideration that the computers are present everywhere but it is important for people to remain calm and serene, which it is a complicated task when they are constantly addressed by electronic devices [12].

From the necessity of having the information available where physicians need it [9], it is proposed a methodology to develop applications for mobile devices, such as smartphones and tablets, which enables a novel secure mobile access to medical information about patients in a particular hospital. Also, it was designed and here presented a system that allows physicians to have access to all the clinical history of the patients in terms of complementary diagnostic and therapeutic procedures.

As the first step for this study, it was selected the diagnostic and therapeutic area and the procedure reports of one of the Portuguese major hospitals in Oporto. This work is framed in INTCare[13] project and the artefact developed was tested in the Intensive Care Unit of Centro Hospitalar do Porto. Intensivists had the possibility to use and assess the platform developed.

The sections of this paper are organized as follows: section 2 presents the related work, which concerns the existing applications for mobile devices in the medical and healthcare areas. Section 3 describes the AIDA platform and its close relation with the mobile system. The proposed application is presented in the section 4, and its implementation and utility, in section 5, are described as well as its limitation, in the section 6. Finally, in section 7, conclusions and future work are presented.

2. Related Work

The utility of m-Health applications in healthcare facilities has been increasing and many applications were developed over the last years, and the potential of these applications for health systems is well-documented in the literature [14,15]. Many health professionals are beginning to resort to mobile technology, in order to make their

procedures more accurate and efficient, as well as reducing the risk of medical errors. The m-Health applications have different types of technology infrastructures and are developed for devices such as laptop computers [16], Web-based applications [17], agent-based applications [18], applications for mobile phones or tablets [19], among others.

The existing m-Health applications have various fields of application, such as mobile assistance for patients with certain diseases [19,20], mobile access to medical knowledge and support for medical decision [5,21], mobile access to medical information concerning a patient [22,23] and mobile communication [24,25].

Other client applications to visualize medical records such as lab results and medications like PatientKeeper Mobile Clinical Results and MEDITECH are integrated with the same company's software for registering medical records [26]. The proposed application uses the data stored in AIDA but can quickly and easily be modified to allow its use at another Hospital as it relies on a Service Oriented Architecture layer to retrieve the information.

According to the literature review, the application presented in this paper can be considered an innovation in the area of healthcare, providing mobile access to clinical information concerning a patient using mobile devices that, currently, integrate the daily lives of health professionals - the smartphones and tablets - which provide a quick, secure and remote access to confidential information of patients.

3. INTCare and AIDA

Information storage and management is extremely important in hospital facilities, which make the integration and application of new information technologies an imperative task, in order to provide a greater efficiency and accuracy in healthcare. For a proper information management, it is noted that the information sources are aplenty in the health facilities. In addition, the sources are heterogeneous, complex and have to be integrated with the medical equipment. Beyond those difficulties, the department systems are customized by companies that use their own languages and hardware and are used by professionals aiming different goals [27]. In order to overcome these difficulties an interoperability platform was developed, the Agency for the Integration, Diffusion and Archive (AIDA) of medical information uses different interoperability protocols to allow the integration of different sources of information under a dynamic framework [28].

With the same goal arises INTCare, a research project with a particular focus in intensive care. INTCare is also a pervasive intelligent decision support system to monitoring patient condition and predict clinical condition online and in real-time. Behind of the main goal of using intelligent agents[29] to collect, process and create new knowledge in real-time it is the possibility of presenting the information in mobile devices[30]. Taking advantages of interoperability with AIDA platform a new solution is being developed and tested in order to turn some of data used by INTCare available anywhere and anytime.

The suite of AIDA tools results of a research partnership between the University of Minho (the biomedical Informatics research group) and some Portuguese hospitals. AIDA is an agency that provides intelligent electronic workers, called pro-active agents, which are responsible for the communication between heterogeneous systems, managing and saving the information and answering requests, on time and with accuracy. The AIDA platform is the core system for electronic health and medical records, clinical business intelligence and group decision support systems. It is the first step for the so-called free paper hospital. AIDA also provides services and applications, including diagnostic and therapeutic procedures, a service oriented architecture, a Monitoring Information System, work management and organization and Ambient Intelligence. The structure of the AIDA platform is represented in Fig. 1 and shows the connections that AIDA establishes with: the Electronic Medical Record Information System (EMR), the Administrative Information System (AIS), the Medical Support Information System (MIS), the Nursing Support Information System (NIS) and the Information Systems (DIS) of all the departments or services, the laboratories (LIS - Laboratory Information System) and the Services of Medical Imaging (PACS - Picture Archive and Communication System), RIS - Radiology Information System and emergency. In addition, AIDA enables message sending via mobile phone or e-mail [6,31]. This paper focuses in improving the Diagnostic and Therapeutic Procedure (DTP) area.
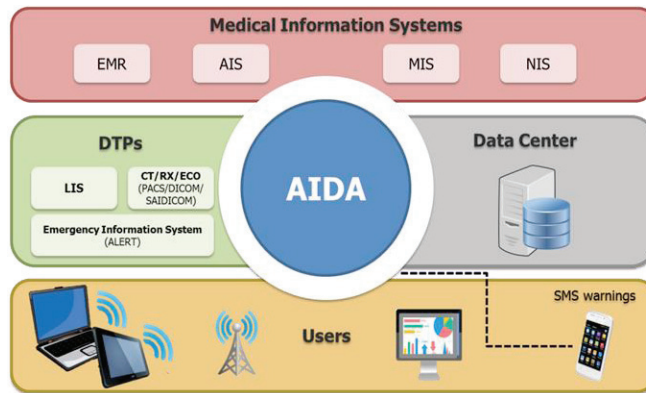
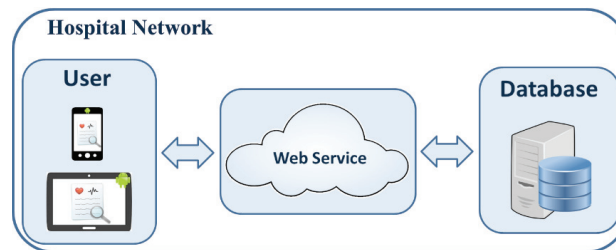**Fig. 1.** AIDA structure. (Adapted from AIDA [6]).

Fig. 2. Architecture of the application.

The medical reports are stored in the DTP module and can be seen by the health professionals in the Users module (Fig. 1). The system is called from the AIDA platform interface, from the EMR application or from external applications, resorting to a web link using the common patient identifiers as a key. Fig. 2 presents the architecture of the proposed application. The user can access to a mobile device to consult the data. The application installed on this device will connect to the web service in order to answer to user requests. Then the data stored in the database are presented to the user in the form of information / knowledge.

4. Proposed Application

The application presented in this paper was developed for mobile devices that use the Android operating system. The main goal is to visualize DTP reports, in the hospital facility with one mobile device connected to the hospital intranet. The first goal was to provide the same functionalities as the AIDA desktop web interface; i.e., the same input data and the same output information, in particular the final reports. The concept of calm computing was taken into account to design the application as the desired information should appear quickly and without the physician putting much effort into it.

The application was divided into three linked parts, as can be seen in the Fig. 2: the Android application; the Web Service; and the Database. The user inserts the specific search data of the patient and the request of the information is made from the Android to the SOA (Service Oriented Architecture) layer by a Web Service. The Android application requires connection to the hospital intranet to establish the connection with the Web Service which retrieves the information from the AIDA database. The Android application uses the protocol SOAP (Simple Object Access Protocol). The SOAP protocol is widely used due to being platform independent, transport independent and operating system independent [32]. It relies on XML Information Set for its message format. The application uses one type of SOAP request - the document request -, where an XML document is passed to the Web Service. This

exchange of XML documents is made by a SOAP message. In order to apply this protocol, the KSOAP2, which is a lightweight and an efficient SOAP library for the Android platform was used.

The database has stored all patients' clinical data, such as their personal information as well as their complete medical history. The database of a hospital involves a large volume of data and all the information must be safe and comply with the rules of confidentiality, requiring that the database must be reliable and with a high degree of security. Thus, the connection to a database of this level involves some precautions and authorizations from the professionals responsible for its maintenance.

The proposed application requires access to the database to thereby allow the collection of the required clinical information of the patients. This connection to the database could be direct but that would require distribution and maintenance of many drivers in the client-side. For example, modifications in the connection to the database or any change in the queries that allow the achievement of the required information would demand upgrades and/or modification in the code of the Android application. These modifications, in turn, would oblige the client to make a few changes in the application, from uploads to swap for the latest application, which would cause further discomfort to the client. The best option was a web service that would make the connection between the Android application and the database.

A Web Service can be described as a software application with various properties: its interface and binding can be described in XML; it can interact directly with the SOA layer through XML; and it is supported by standard protocols such as SOAP [33,34]. The main reason for the development of a Web Service resides in the fact that performing database operations using Web Service requests provides a secure and controlled way of connecting with the database and the share of the information can be made in a heterogeneous and non-connected corporate intranet. Basically, the main function of the Web Service is to receive the request of information about patients and, in turn, reproduce the request to the hospital database as an SQL query.

The mobile application should perform the following cycle: the user requests for certain information of patients and the Android application sends that request to the Web Service, using the SOAP protocol. The Web Service, in turn, receives the request and performs a query to the database, in order to get the information. The database sends the information to the Web Service, which sends back to the Android application in XML. The Android application receives the XML and performs the required processing, returning the requested information to the user.

Since the designed application is going to be used in a hospital and enables access to confidential information of patients, some requirements were taken into consideration by healthcare staff along with Information Systems specialists. These requirements take into account the necessity of availability of information, the easiness accessing those data, interoperability, safe access and confidentiality, such as:

- The Android application requires user identification.
- The application has to be connected with the hospital intranet, which is a secure and restricted connection.
- There is a log recording each patient form and each reporting viewing.
- When a user request a patient report, the report is downloaded as a temporary file and is removed from the device directory after visualization, in order to prevent the leak of confidential information. The report is always downloaded as an encrypted file.
- The application has an option to read barcodes from the device camera. This option allows a faster access, simply by reading the barcode that usually is near the inpatient bed. This option should be useful in the Intensive Care Unit, where assistance has to be fast and accurate.

The prototype was designed by combining two areas of knowledge: Medicine and Information Systems. During the development, a set of future users (clinicians / intensivists) were consulted in order to develop the most suitable application to their needs.

Taking into account all these requirements, the developed application is ready to be implemented in the hospital and it is expected that it will provide good results, in particular, the improvement of quality of medical service.

5. Deployment

The application proposed in this paper was implemented in one of the Portuguese major hospitals. Their access and use it is exclusive to the physicians who are practicing there.

In order to analyze the pros and cons of the implementation, it was developed a SWOT analysis by the same team that identified the requirements, which provides the knowledge of strengths and weaknesses, as an internal perspective of the organization, and the opportunities and threats, as an external perspective of the organization. The SWOT acronym stands for: Strengths, Weaknesses, Opportunities and Threats and, following this section, the various points detected for each of these factors will be properly exemplified.

Strengths of the application:

- Immediate access to clinical information of patients;
- Ease of use;
- Quick access to information;
- Security;
- User-friendly and Intuitive interface;
- Remote access to clinical information;
- Application can be used by all the physicians of the hospital;
- High availability of the AIDA platform;
- The option of reading barcodes.

Weaknesses of the application:

- Requires connection to the hospital intranet;
- Some functions can present some slowness.

Opportunities of the application:

- Use of mobile devices to access medical information;
- Modernization and organizational development;
- Increasing expectation of citizens to obtain faster and reliable responses of clinical services;

Threats of the application:

- Competition/market pressure;
- Economic and financial crisis.

It can be concluded that the proposed application has many positive features for the hospital, endowed with many points such as security, immediate access to clinical information of patients and high availability. On the other hand, the application has some weaknesses, such as the requirement to be connected to the hospital intranet but, despite being a limitation, it ensures the safety of clinical data. It is not possible to access the clinical information outside the hospital intranet for legal reasons. The other weakness is related to the slowness in some functions due to the high number of records in the AIDA database. The slowness is only noticeable sometimes as the network traffic load to the database and Web Service and Database is variable during the day. Some tests are being conducted to evaluate when and why the overload slows down the service.

The SWOT analysis shows two threats that the administration should realize, where the biggest threat is the competition from other applications, since the market of m-Health applications has grown exponentially [3], despite the economic and financial crisis represents a big threat as well.

After the deployment, a technology assessment process is being performed with some users in order to understand the application's usability and utility. The results of this study will be published at the end of the test phase.

6. Discussion

The development of m-Health applications requiring connection to the hospital intranet that will be used by health professionals involves some precautions. It is necessary to take into account the infrastructure owned by the hospital where the application is implemented. It can become an obstacle if a reliable network connection is not guaranteed. Also, another precaution is the lack of acceptance to resort to new technologies by healthcare professionals, leading to a decreased usability of such applications. Some studies defend that the major barriers to acceptance of IT by physicians can be classified into three main groups: personal characteristics of each individual, organizational characteristics and the technology characteristics to be implemented [35]. Lastly, it should be taken into account that the adoption of new technologies, especially mobile technologies, entails costs to the users themselves,

since they need to have mobile devices in order to use the m-health applications, such as smartphones and tablets, which can be costly.

7. Conclusion and Future Work

This paper proposes a new methodology to improve patient's assistance inside a hospital according to the principle of calm computing and comprehensiveness. A mobile application has been developed in order to validate the methodology. In this application, a user-friendly environment able to deal with mobility and interaction between the health professionals and the devices has been developed.

The application has been tested by intensivists in a hospital, in real world context, taking advantage of an interoperability healthcare platform called AIDA.

According to the literature review, there are many mobile applications for the area of health but none of those applications have the functions of the application proposed in this paper.

This application represents an extension of some of the main features of Electronic Health Record and INTCare system as is for example the access to laboratory exams. It allows an easy and quick access to patient data anywhere and anytime.

These functions give some benefits to the health professionals, since it allows them to consult clinical information of a patient, using a mobile device, increasing efficiency and improving the quality of service. In addition to those benefits, the proposed application respects the confidentiality rules of the clinical information of patients and allows a restricted access to the information, since only the healthcare professionals belonging to the hospital have the necessary credentials to ensuring their access.

The SWOT analysis shows some application strengths, which grant an advantageous applicability, such as security and availability, as well as some few weaknesses when working with big data and attending to some problems of insufficient wireless coverage in some hospital areas. Opportunities and threats have been identified. The application is able to improve quality of service in medical practices.

The development of m-health applications can entail some limitations, which may be related to the infrastructure of the hospital where they will be implemented or related with the limitations and characteristics from users themselves, in this case, healthcare professionals.

Different mobile devices require different mobile operating systems. The application was created for devices with the operating system *Android*, which is one of the most popular in the world since it is the one with the highest market share.

Regarding to the assessment technology process in execution the first results are very interesting, motivating a continuous improving of this application.

As future work, this application will be updated and adapted for others mobile platforms, such as *iOS* and *Windows Phone*. At the moment it is being made some usability tests in order to analyze the impact and the acceptance of the application in the daily work.

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