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Mobile Web Application Development to Access to Psychiatric Electronic Health Records

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1. Introduction

Mobile communication systems in clinical routine have the potential to greatly improve communication, facilitate healthcare information access (e.g. to Electronic Health Records (EHRs)), and increase the quality of patient attention (Ammenwerth, et al., 2000). Even more important with the advantage of mobility in the pocket, patients and physicians are able to carry with them their personal health records as they move across states or countries. Mobile health management seeks to extend the benefits of mobility to patients who are geographically mobile (Chan, 2000), but the development and use of mobile devices in health care is still rare; studies evaluating prototypes have revealed that the acceptance of such tools was rather low, although physicians principally would like to use a mobile EHR system (Reuss, et al., 2004). Mobile EHRs with high usability as outlined here would make a substantial contribution to reach this aim. Moreover, the development of mobile medical information systems is having significant impact on remote medical monitoring, home healthcare, outpatient service, and patient safety making healthcare more flexible and convenient. Mobile medical care services are gradually spreading in hospitals and with the maturity of mobile technology, the time has come for employing mobile healthcare in different school-based health centers (Jen, 2009).

In this context, EHRs system contains information about the type of treatment that a patient has received from a healthcare provider, such as the patient's medical history, etc. They are not just record-keeping tools but also play an important role in quality improvement and data exchange (Esper, et al., 2010). One major barrier to the adoption of such systems is the concern that EHRs may take longer for physicians to use than paper-based systems (Pizziferri, 2005). But, as the authors showed, EHRs did not require additional physician time during a primary care clinic session. Moreover, an EHR is a fundamental part of health information technology and its use is growing quickly. It can be defined as a set of relevant patient data stored in digital format that allows adequate medical assistance delivered to the patient even in different places and scenarios (Furuie, et al., 2007). It can be organized either on a document-based backbone, or on a structured database system. EHRs system fall under the purview of health informatics. It is a combination of computation, computer science and medical record keeping. In recognizing the advantages of EHRs, health information systems are being rapidly deployed. Some recent technological advances have enabled the introduction of an important number of e-health applications in healthcare computing (Hung and Zhang, 2003). Moreover, EHRs are increasingly being implemented by care

providers in order to streamline processes and improve quality of care (Edwards, et al., 2008). Some potential advantages of an EHR over a traditional paper-based patient record involve: distributed and simultaneous access, fast information retrieval, better quality, high availability, higher confidence, etc. (Furuie, et al., 2007). In spite of these advantages, there are several barriers to their adoption such as training, costs, complexity and lack of a national standard for interoperability (Gans, et. al, 2006).

Hence, a crucial question is the standardization, it is a very important aspect to exchange health information as it allows the integration of different healthcare services and it facilitates clinical trials. There are several international organizations concerned with EHR standardization, and the Health Level 7 (HL7) authority is influencing in this process. Its development has also been of great benefit in telemedicine applications. The standard proposed by HL7 is employed for many different medical environments. It is the XML-based international standard more commonly-held for storing and exchanging EHRs. HL7 Document is intended to be the basic unit of a document-oriented EHR. According to HL7 standard, there are mobile clinical information systems which use HL7 to integrate the patient data (Choi, et al., 2006). In May 2005, Clinical Document Architecture (CDA) Release 2 became an ANSI-approved HL7 Standard. A CDA document is defined as a complete information object that can include text, images, and other multimedia contents (Dolin, et al., 2006). Extensive use of HL7/CDA standard is very desirable for all fields present in medicine (Marcheschi, et al., 2004).

Moreover, EHRs systems are subjected to security and privacy issues. This is crucial in EHRs since they involve very important private data, as important as banking information. Slamanig & Stingl (2010) defined security and piracy objectives and explain that they play an important role in the context of Web-based EHRs. Since it is considered that current deployed solutions present clear weaknesses in terms of security, it is explained that a holistic system, whose functionalities cover all the aspects of EHRs, can overcome the drawbacks of already existing solutions. Many studies conclude that in order to obtain the full potential of EHRs, patients should be able to access them anywhere and anytime (Sadan, 2001). This can be achieved by making EHRs portable, turning them into Personal Health Records (PHRs); a solution is to keep PHRs in portable storage media, such as USB flash drives. This portability adds an additional mobility feature whose security needs to be covered; it is necessary to prevent the data from being exposed.

In this paper, we present a mobile Web application, EHRmobile, to store and exchange EHRs in the Psychiatric field. It has been built using Java Servlet and Java Server Pages (JSP) technologies. Its architecture is triple-layered and EHRs are stored in the open-source XML database, eXist 1.2.6, according to HL7/CDA Release 2 standard. We chose this database according to the results shown in (De la Torre, et al., 2010a). EHRmobile verifies the standards related to privacy and confidentiality. Nowadays, the application has been tested by specialists from Fundación Intrás, Spain, managing records from 87 patients with cognitive disabilities from Castilla y León (Spain).

The remainder of this paper is organized as follows. Section 2 presents related works, Section 3 describes the methodology to develop the platform, Section 4 focuses on the results achieved (EHRmobile platform), and Section 5 presents conclusions and future work.

2. Related works

Accessing to EHRs through mobile devices provides a number of advantages both for health centers and clinical staff, and for patients. Among these advantages are: accessing to

patients' information in real time (from wherever and whenever), resource savings, improving the information management, and reducing the delay in health care. In the field of mental health, there are important epidemiological studies releasing relevant information about types and rates of the more frequent disorders. However, a significant number of people with mental diseases remain unnoticed due to the incorrect identification of the symptomatology, the resistance to seek either help or information regarding these services, among others. Mobile technologies can offer their full potential for helping people with cognitive problems and their supporting staff.

Healthcare organizations are increasingly implementing EHRs and other related health information technology. Even in organizations which have long adopted these computerized systems, their employees continue to rely on paper to complete their work (Saleem, et al., 2009). EHR systems have a great potential to improve safety, quality and efficiency in medicine. Previous studies addressing this issue have been done in primary care (Lo et al., 2007).

Before launch effort on developing a system, we performed a deep analysis about web-based EHR systems in specialties like pediatrics (Ginsburg, 2007), urgency (Amouh, et al., 2005), oncology (James, et al., 2001), etc. In the telematic system for oncology, they used a data warehouse as EHR server however the authors did not present an EHR standardization process. Information system for emergency department has been implemented by prototyping a web-based application which makes use of the XML-based openEHR standard. There are other web applications, like CareWeb™, using the HL7 standard (Halamka, et al., 1999). Becker & Sewell (2004) presented an EHR system, InfoDOM, based on web technologies. Siika et al. (2005) described the development and structure of an EHR system for patients with Human Immunodeficiency Virus (HIV) in Kenya. Cho & Park (2003) developed an EHR system based on the Korean beta version of the International Classification for Nursing Practice (ICNP). The system was evaluated by 20 nurses and 57 patients, in 2 Korean hospitals. Karagiannis et al. (2007) implemented a web-based EHR system (pEHR) that was proven by 22 physicians and 150 patients of 3 European hospitals. The system was developed to meet the needs of patients with a congenital heart disease, Parkinson or type 2 Diabetes. Sharda et al., (2006) studied the use of discharge summaries by psychiatrists with experts being given two hypothetical emergency care scenarios with narrative discharge summaries and being asked to verbalize their clinical assessment. The narratives were presented in a more structured form. Other EHRs systems are: PHIMS and CipherMe. PHIMS is a web-based repository of patient health information, which provides interfaces for storing structured and categorized patient information (Kim, 2006). CipherMe architecture enables individual entities to store private information about themselves and to manage access to selected items by other parties (Hansen, 2006). Other authors designed and developed a template based system, called Julius. This system was integrated with existing EHR systems (Chen, 2007). The system has been implemented, tested and deployed to three health care units in Stockholm, Sweden. In the application OpenSDE, authors have expanded the traditional row modeling methodology with additional columns to allow structured representation of medical narrative (Los, 2004). In the EHRs system context, Electronic Medical Records (EMRs) are currently being implemented in psychiatric hospitals throughout Europe (Boyer, et al., 2009a; Boyer, et al., 2009b; Boyer, et al., 2011).

Taking a look at the international scenario, it can be determined that EHRs are not equally adopted in all countries. Whereas the United States and Canada are the most advanced

countries in EHRs integration, in other such as Spain EHRs are not that widespread (Dorr, et al., 2007; Srinivasan, et al., 2007; Cheong, et al., 2009). The authors of the present work accomplished a web-system for ophthalmological EHRs and medical images management, TeleOftalWeb (De la Torre, et al., 2010a; De la Torre, et al., 2010b). This system is in used in the the Institute of Applied Ophthalmobiology (Instituto de Oftalmobiología Aplicada, IOBA) of the University of Valladolid, Spain. TeleOftalWeb complies with the Health Level 7-Clinical Document Architecture Release 2.0 (HL7-CDA) standard for EHRs storage.

Mobile applications offer a chance to improve health services. Most healthcare providers offer mobile service for their medical staff; and few healthcare providers supply mobile service as part of their outpatient service (Jen, et al., 2007). Nowadays there are few applications integrating mobile communications with EHRs. Velde & Brobbel (2001) developed a mobile information system intended for cardiology field. Shyu et al. (2006) performed a mobile EHR system for the family medicine department in the National Taiwan University Hospital (NTUH) from Taiwan. Chan (2000) examines the important need to implement mobile health management systems providing continuous health care delivery even while an individual is on the move. In senSAVE project, authors developed a mobile system for monitoring vital parameters. The user interface and the interaction were specifically adapted to the needs of the elderly. In this paper they described the development of the system and the outcome of an evaluation (Lorenz & Oppermann, 2009). In Spain, the Health Department (Conselleria de Sanitat) from the Community of Valencia allows the opportunity to access to the personal health record through its website, downloading the record updated and ciphered. Hence, patients can be better assisted out of the region. Nevertheless, some barriers still exist to achieve the extended use of this kind of systems: many EHR systems are still in a consolidation phase; information is not shared among different health systems. There is uncertainty in issues related to security and data protection.

3. Methodology

3.1 System overview

EHRmobile is a mobile Web system for performing a complete management of EHRs of patients with mental disabilities providing two different ways of access depending on the device in use, a desktop web and a mobile web. It includes the capability of interoperability with other systems thanks to the use of the standard HL7/CDA Release 2, specifically the version provided by the Department of Health from Castilla y León (Spain) (Consejería de Sanidad, 2010). Fig. 1 shows the schema of the EHRmobile system. It has got three layers: presentation, business and database.

- **Presentation layer.** This layer includes the graphic interface utilized by the user to access the system through the browser. The type of device used is detected to provide the appropriate design and features, when accessing the system either via PC or mobile device. Accessing from a PC allows the complete management of the system, while accessing from a mobile device provides functionalities for browsing and updating clinical data along with additional features related to the terminals used, and always prioritizing information security and privacy. For example, accessing from PC, it is possible to add new EHRs, search in them, update, and delete them. Using a mobile device, data can be consulted, updating those needed, always interacting with a user-friendly interface, considering the possibilities of the device.

- **Business layer.** This layer accomplishes the processing required for attending the user requests, hence, it includes all the system logic, completely developed under JSP using Apache Tomcat 6.0 Web server. This layer has been divided into different modules according to their functionalities:

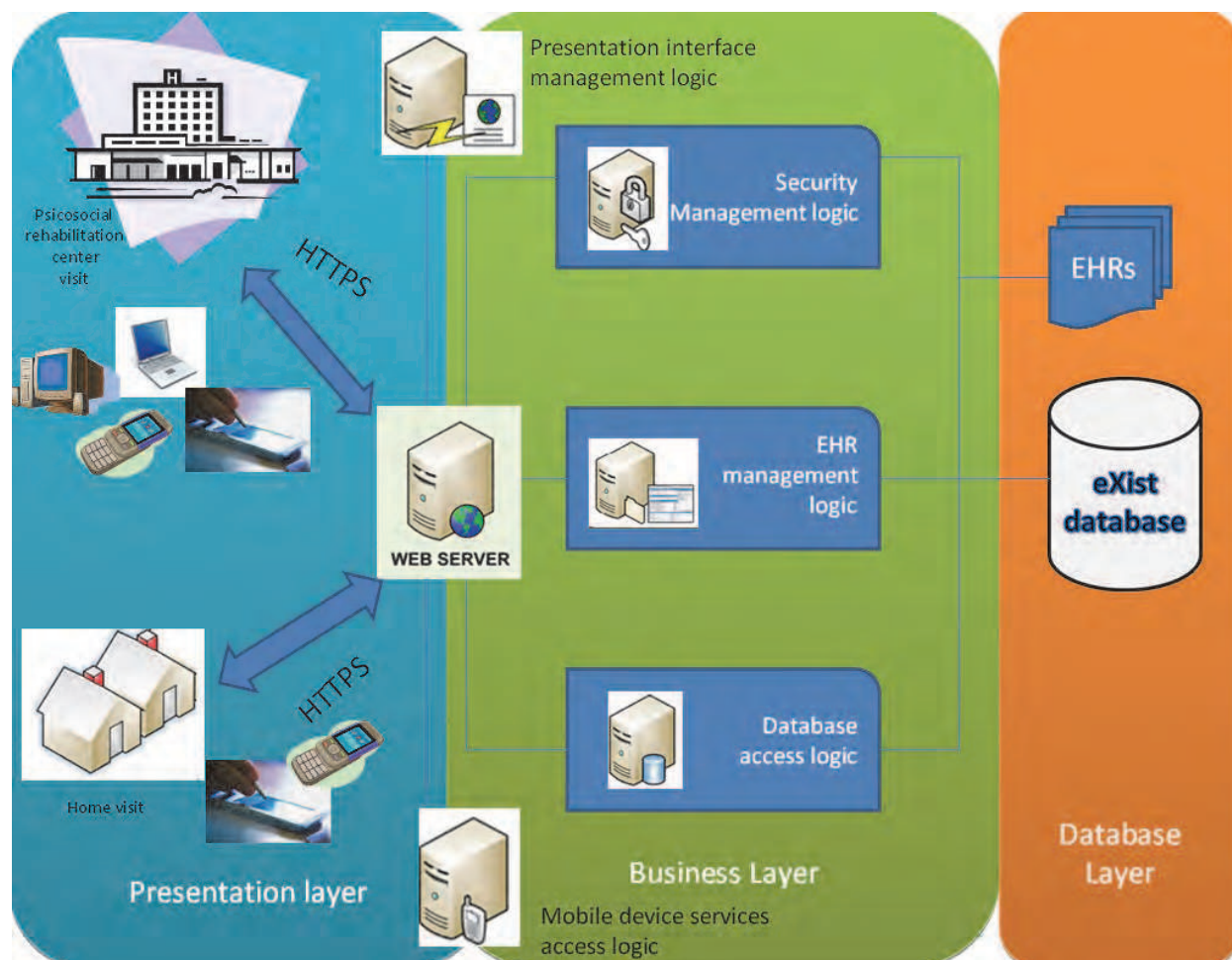


Fig. 1. Shema of EHRmobile.

- Security management logic: Among the security measures taken are in this platform are: user identification determining a privilege level within the system, securing the communication established within the system, physical security. Personal identification is performed every time when trying to access the system, providing information according to the privilege level assigned to each user by Fundación Intrás. In order to provide communications security we use OpenSSL, which implements the Secure Socket Layer (SSL) protocol. All the system communications use the Hypertext Transfer Protocol over Secure Socket Layer (HTTPS) protocol which includes a SSL based ciphering.
- Presentation interface management logic: It undertakes the task of detecting the device requesting access to the system in order to show the interface better fitting its features. As it was previously said, detecting the device is not only important at design level providing a more compact and light web to the mobile terminal, but also at a functionality level, as from a desktop browser it is possible to access to the entire application, allowing inserting new EHRs, delete them, and administration the system.

- EHR management logic: It is the module in charge of standardizing the EHRs observing the standard HL7/CDA.
- Database access logic: It is the module in charge of performing the database (eXist) accessing. Database includes all the information required about patients such as: anamnesis, clinical observation, medication, and clinical appraisal. Moreover, it contains data about clinical staff and system administration information.
- Mobile device services access logic: As HTML5 standard is not yet finished, which it is supposed to provide a complete accessing to the mobile devices services. Meanwhile, to complete the access to the camera, we used Adobe® Flash®, JQuery, and JSP.
- **Database layer.** This layer is in charge of managing all the information in a persistent way, storing and supplying the data to the business layer. It includes information about the clinical staff, and the complete EHRs following the HL7/CDA Release 2 standard.

3.2 Data modeling and architecture

EHRmobile has been built on Java Servlet and Java Server Pages (JSP) technologies. The EHRs are stored in an open source native XML database, using the engine eXist 1.2.6. In Fig. 2, the web manager interface for eXist database is shown. We have different collections such as “records” and “users”. One of the main advantages of using a XML native database is data format interoperability and the interface for data input is determinant to achieve this objective (Mabanza, et al., 2006). Combining Java and XML leads to the attractive dual portability of code and data (Fan, et. al, 2005). Wherever Java programs can run, it is also possible to access to the XML files, this enables Java and XML information to interoperate efficiently and effectively on different platforms (Fedyukin, et. al, 2002).

Furthermore, HL7/CDA uses XML and has three different levels of granularity as shown in Table 1, where each level iteratively adds more markups to clinical documents, although the clinical content remains constant at all levels (Eichelberg, M, et. al, 2006). A HL7/CDA structure may include texts, sounds, pictures and all kind of multi-media contents; it can refer to external documents, procedures, observations, and acts. It includes information about authors, authenticators, custodians, participants, patients, and so on (Treins et al. 2006). The HL7/CDA used format in EHRmobile is shown in Fig. 3.

CDA specification prescribes XML markup for CDA Documents: CDA instances must valid against the CDA Schema and may be subject to additional validation. Its development methodology is a continuously evolving process that looks forward to carry out specifications that facilitate interoperability between different healthcare systems. There is a Document Type Definition (DTD), CDA Level One, for all types of clinical documents. A HL7-CDA document is comprised of a header, referred to as the CDA Header, and a body, which at CDA Level One is referred to as the CDA Level One Body. A CDA Level One schema is shown in Fig. 4. CDA Level One is specified by three components:

- **CDA Header.** It identifies and classifies the document and provides information on the document authenticator, the patient, the encounter, provider and other service actors. Document-related information includes the id, set id, version, type, and various timestamps. The id element uniquely identifies the specific clinical document. The type and version elements identify the clinical document template. Encounter data include the id, code, timestamps, service location and local header. The id and code elements uniquely identify the relevant encounter and its type in the regional network, while attribute-value pairs in the local header facilitate interoperability with the EHR system (Paterson, et al., 2002)..

- **CDA Level One Body.**
- **Reference Information Model (RIM) data type DTD.** RIM data type DTD is an XML implementation of the abstract data type specification. It used by both the CDA and the HL7 Version 3 message specifications.

CDA R1	CDA Level One
	CDA Level Two
	CDA Level Three
CDA R2	Unconstrained CD specification
	CDA specification with section-level templates applied
	CDA specification with entry-level templates applied

Table 1. Levels of document granularity in CDA R1 and CDA R2.

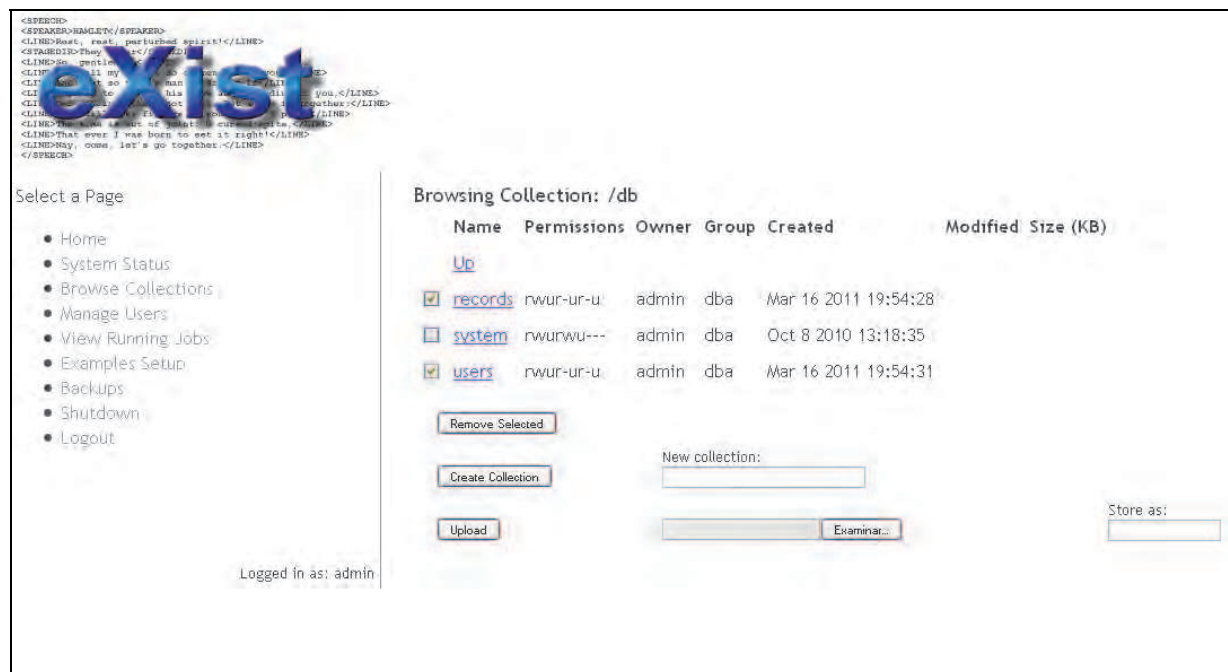


Fig. 2. Web manager interface in eXist database in EHRmobile application.


```

<?xml-stylesheet type="text/xsl" href="cda.xsl"?>
<ClinicalDocument xmlns="urn:hl7-org:v3" xmlns:voc="urn:hl7-org:v3/voc"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="urn:hl7-org:v3 xsd/CDA.xsd">
  <typeId root="2.16.840.1.113883.1.3" extension="POCD_HD000040"/>
  <id root="8694706b-7f87-4928-b190-85ab95ef700b" extension="2406538"/>
  <code code="28634-4" codeSystem="2.16.840.1.113883.6.1" codeSystemName="LOINC"
    displayName="OID de LOINC a nivel mundial"/>
  <title>INFORME GENERAL DE ALTA</title>
  <effectiveTime value="200802221250"/>
  <confidentialityCode code="N" codeSystem="2.16.840.1.113883.5.25"/>
  <languageCode code="es-ES"/>
  <recordTarget>
    <patientRole>
      <id root="91e8b514-6eea-48e6-86ce-63cfc67a96b" extension="56864"/>
      <addr>
        <streetAddressLine>FERMOSELLA</streetAddressLine>
        <city>CALLE GENERAL SANJURJO</city>
        <state>ZAMORA</state>
        <postalCode>49220</postalCode>
      </addr>
      <patient>
        <realmCode code="5/140665/4" codeSystem="6fdf0743-4fd5-4921-9a34-
24298b2941eb"
          codeSystemName="OID de la tarjeta sanitaria a nivel comunitario"/>
        <name>
          <given>ANTONIO</given>
          <family>DE LA TORRE</family>
          <family>PUENTE</family>
        </name>
        <administrativeGenderCode code="F" codeSystem="2.16.840.1.113883.5.1"/>
        <birthTime value="19440708"/>
      </patient>
      <providerOrganization>
        <id extension="0501" root="aea19799-cla4-4a6b-a7c6-5ba778e2d29c"/>
        <name>Complejo Asistencial de Zamora</name>
        <telecom value="980548200"/>
        <telecom value="980512838"/>
        <addr>
          <streetAddressLine>Avda. Requejo, 35</streetAddressLine>
          <city>Zamora</city>
          <state>Zamora</state>
          <postalCode>49022</postalCode>
        </addr>
      </providerOrganization>
    </patientRole>
  </recordTarget>
  <author>
    <time value="200802221240"/>
  </author>
  <component>
    <structuredBody>
      <component>
        <section>
          <code code="yyyyMMddHHmmss" codeSystem="HL7DATE" codeSystemName="Fecha"
            displayName="Fecha ingreso"/>
          <title>Fecha ingreso</title>
          <text>20/01/2009 12:00</text>
        </section>
      </component>
      <component>
        <section>
          <code code="yyyyMMddHHmmss" codeSystem="HL7DATE" codeSystemName="Fecha"
            displayName="Fecha alta"/>
          <title>Fecha alta</title>
          <text>22/02/2009 00:00</text>
        </section>
      </component>
      <component>
        <section>
          <code code="08675-1" codeSystem="LN"
            codeSystemName="OID de LOINC a nivel mundial" displayName="Anamnesis"/>
          <title>Anamnesis</title>
          <text>Texto por defecto</text>
        </section>
      </component>
    </structuredBody>
  </component>
</ClinicalDocument>

```

Fig. 3. A part of EHR in CDA format in EHRmobile application.

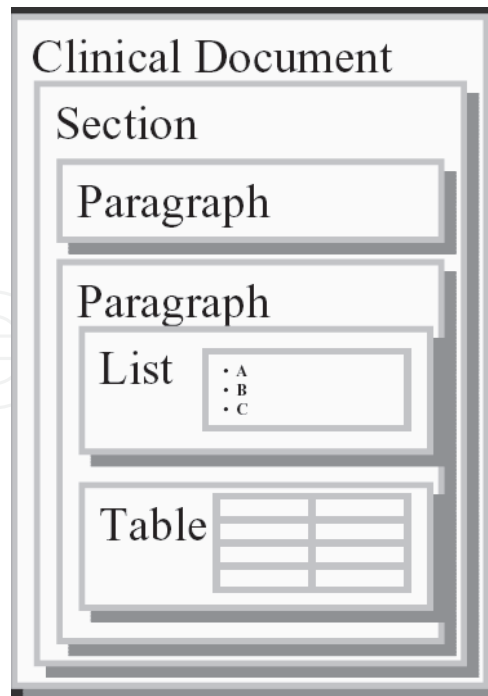


Fig. 4. CDA level one.

Fig. 5 shows the application architecture. The system is platform-independent thanks to the use of XML and Java technologies. XPath and XUpdate languages are used in communication with the used native XML database. XPath is employed to find information in an XML document. XUpdate makes heavy use of XPath for selecting a set of nodes to modify or remove them. The Java servlet inserts the record into the eXist database. It stores and indexes collections of XML documents both in native and mapped forms for highly efficient querying, transformation, and retrieval (Staken, 2001).

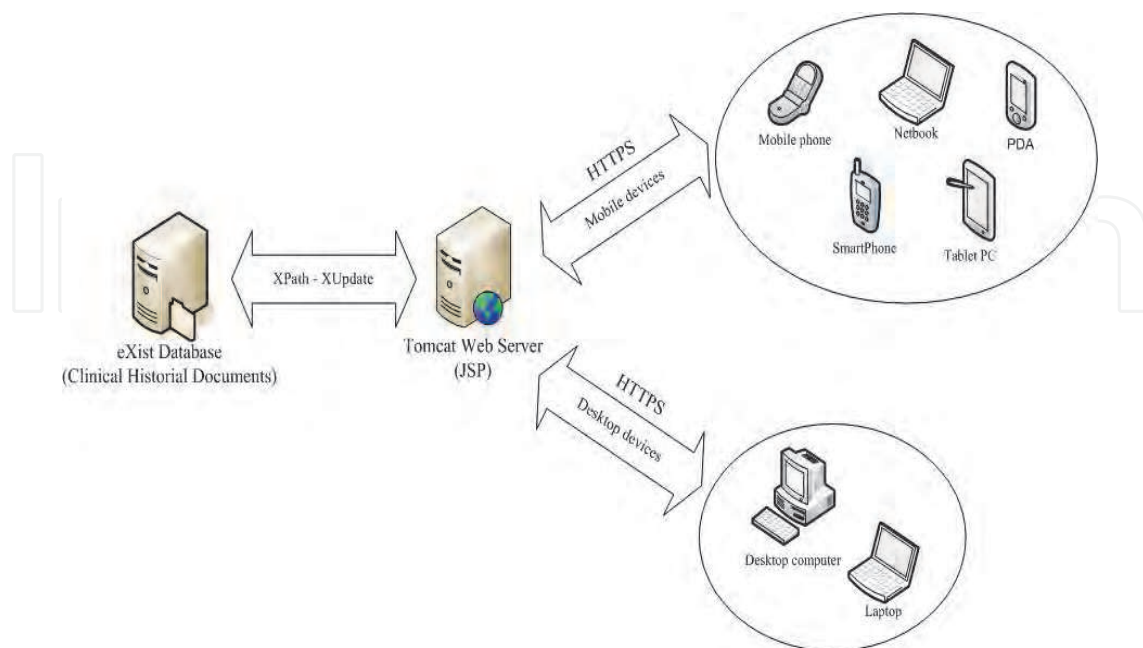


Fig. 5. EHRmobile Architecture.

4. Results

In this section, we present EHRmobile application (desktop and mobile version).

4.1 EHRmobile application

Fig. 6 (a) shows the interface to access to EHRmobile application from desktop version and Fig. 6 (b) from mobile version. All users have to introduce the login and password. The interface includes the following parts:

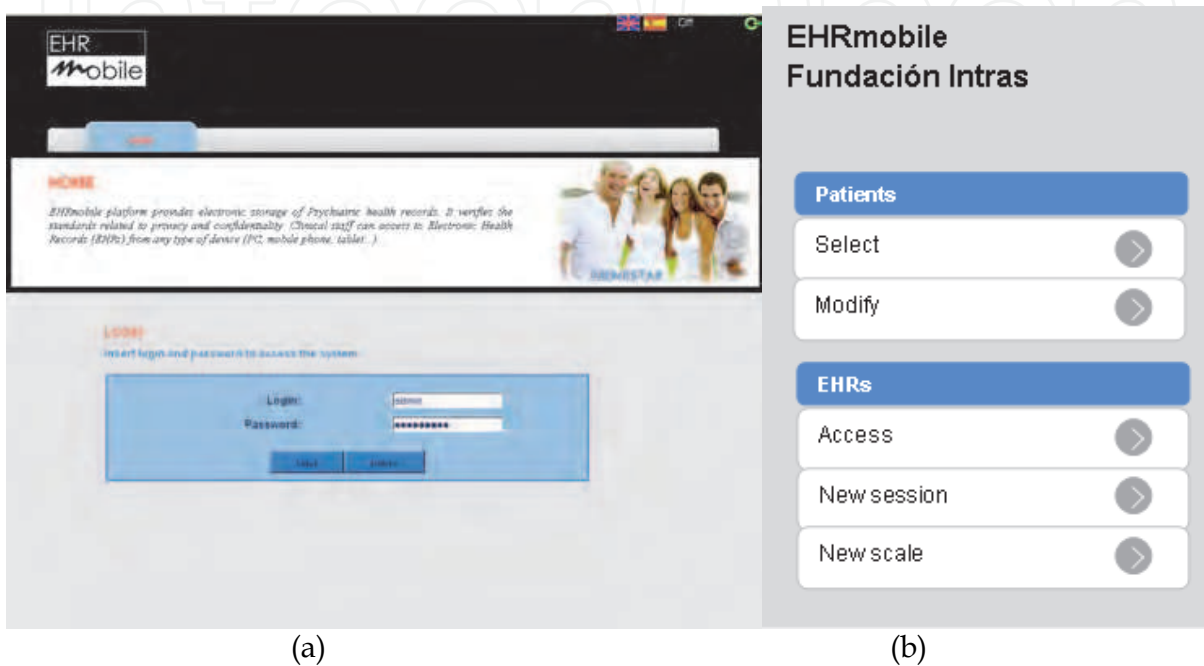


Fig. 6. (a) View from desktop version of platform. (b) View from mobile version of the platform.

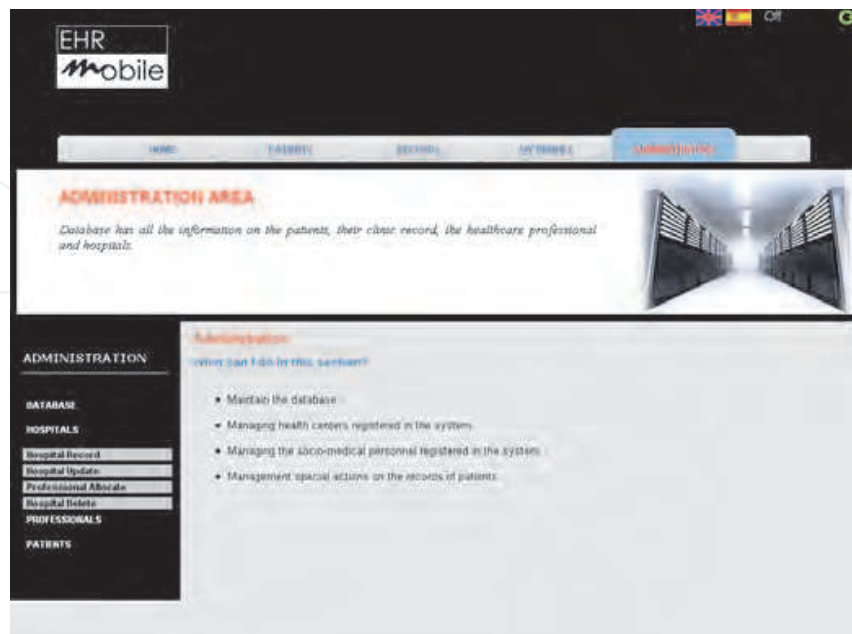


Fig. 7. Home view from desktop version of platform, manager profile.

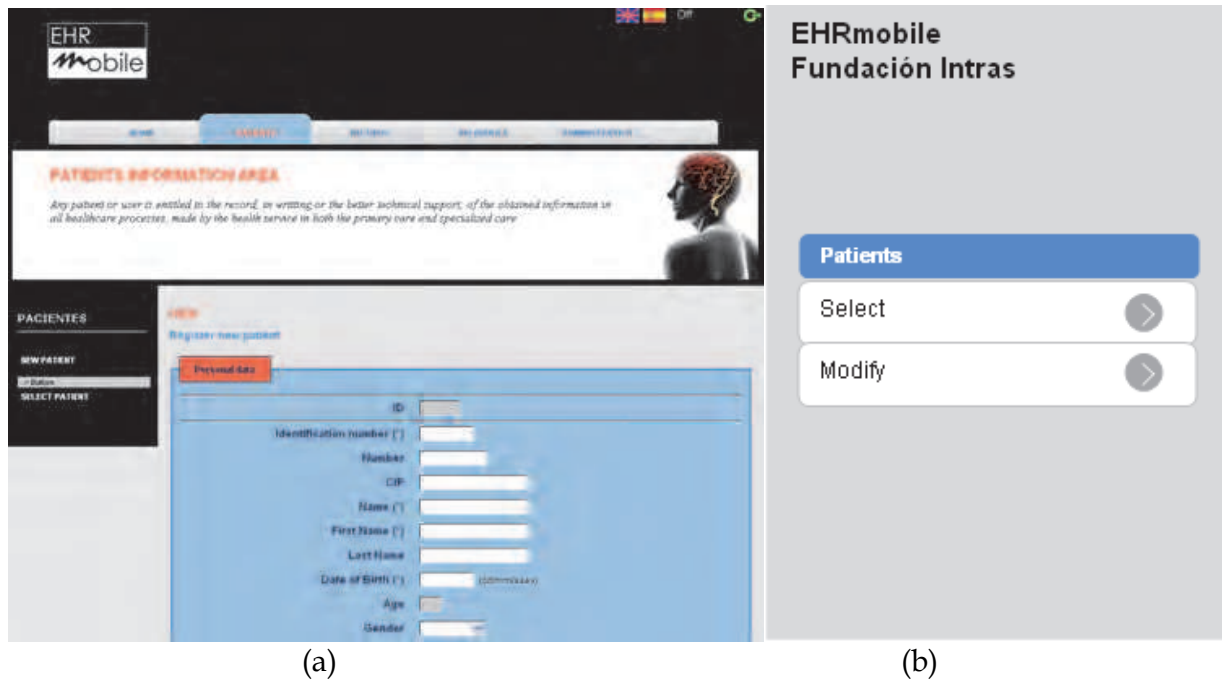


Fig. 8. (a) Patients module in EHRmobile. (b) View from mobile version of EHRmobile.



Fig. 9. My profile in EHRmobile.

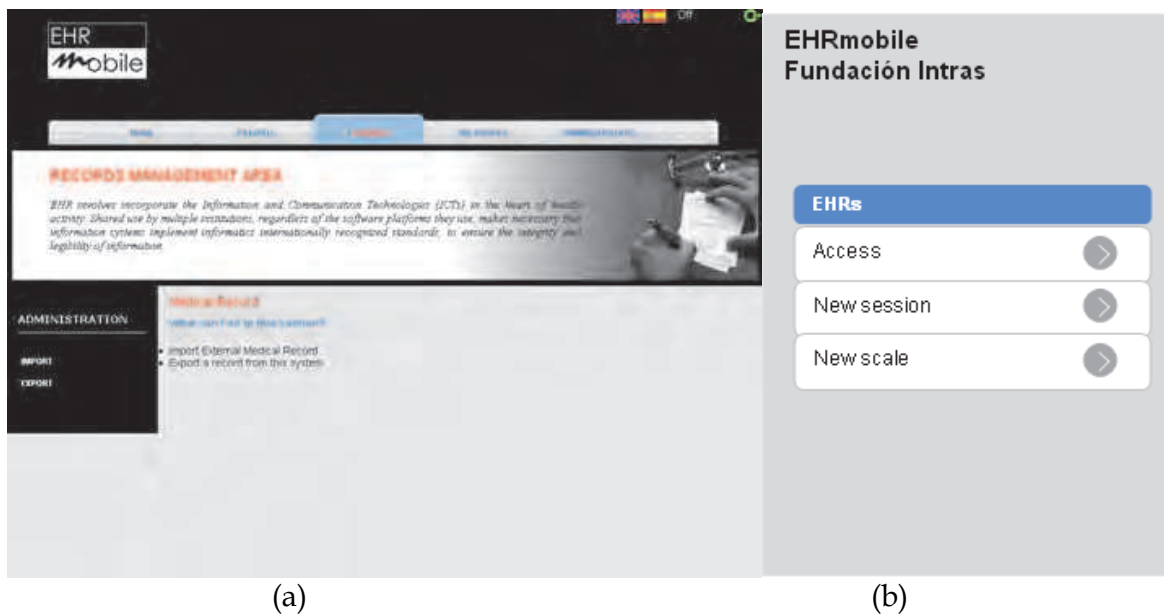


Fig. 10. (a) Records module in EHRmobile. (b) View from mobile version of the platform.

5. Conclusions and future work

Nowadays, applying mobile technologies to health assistance may open new possibilities: better access to relevant information, counseling and cooperation among health professionals, and patient care assistance at home. However, these new facilities must inexorably include security and privacy information issues. Furthermore, the use of EHR management systems, specifically framed in the mental health field which suffers from an ever-expanding perspective, can mean an important support for improving both the treatment quality of these patients and the work quality of the socio-sanitary staff. EHRs will be an important part of the future of medical practice. Behavioral health treatment demands certain additions to the capabilities of a standard general medical EHRs system. An efficient and effective EHRs system will greatly assist the overall clinical enterprise in a number of important areas (Lawlor & Barrows, 2008). The employment of EHRs will contribute to continuity of care across organizations for the growing number of elderly and chronically ill people who need continuous nursing care after an episode of hospitalization (Helleso & Lorensen, 2005). An important number of people with mental diseases remain unnoticed due to the incorrect identification of the symptomatology, the resistance to seek either help or information regarding these services, etc. Mobile technologies can offer a full potential for helping people with cognitive problems and their supporting staff.

In this chapter, EHRmobile system has been developed to access to EHRs in Psychiatry by using HL7/CDA Release 2 standard. The whole system is implemented using open technologies and free software. It has been built on Java Servlet and JSP technologies. We employed eXist 1.2.6 database according to results published in (De la Torre, et al., 2010a, 2010b). It verifies the standards related to privacy and confidentiality. All transactions in the systems are secure. All EHRs systems require a high level of security and privacy control because they can provide great accessibility (whether wireless, local or remote) to the patients' personal medical information. The majority of current systems address these implications in a different form, and even different countries apply their unique policy to their respective e-Health systems. EHRs need to be robust without any open issue;

moreover, EHRs contain data that may decide the life of a person in a critical situation. Since people can attend different hospitals and suffer unpredictable illnesses, EHRs need to be available anywhere and anytime, but that implies more security and privacy.

In summary, we have developed a mobile Web application to store and share Psychiatric EHRs by using HL7/CDA. Our application tries to solve some of the barriers to the EHRs adoption in this speciality. It has several distinct advantages over paper health records. The records are continuously updated and are available concurrently for use everywhere. Nowadays, the system is on a trial basis with the final user (Fundación Intras), managing records from 87 patients with cognitive disabilities from Castilla y León (Spain). The possibility of accessing to the updated information of the patients in the house calls means an important benefit for the Fundación Intras's staff and so, for its patients. Nevertheless, some issues have emerged, like the accessibility to the system from a mobile device, as a usual complaint is to have to type the URL accessing the system and, then, the patient's name. At this point, we pretend to incorporate the QR codes to give access to the patient's information. Moreover, we are working in the process to get from the XML documents to PDF printable documents and statistics from the system.

The future extension of the system will include the integration with Grador, the rehabilitation system used by Fundación Intras and a great deal of associated centers, so as the data about the patient and his/her rehabilitation sessions.

6. Acknowledgments

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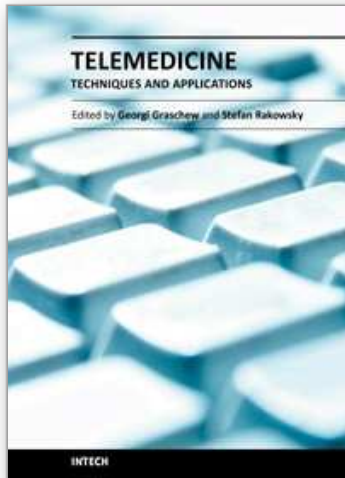
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Telemedicine is a rapidly evolving field as new technologies are implemented for example for the development of wireless sensors, quality data transmission. Using the Internet applications such as counseling, clinical consultation support and home care monitoring and management are more and more realized, which improves access to high level medical care in underserved areas. The 23 chapters of this book present manifold examples of telemedicine treating both theoretical and practical foundations and application scenarios.

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