Abstract. This paper describes the creation process of an electronic medical records (EMR) application in the Juan Canalejo University Hospital Complex (CHUJC). From the knowledge acquired through the observation of the traditional processes of managing the Patients medical records on paper a tool was developed which in principle was thought of to classify electronic documents associated to a patient and to which different functions of medical work have been subsequently added: visualizing clinical documents of patients, creation of new documents and following the development of patients.

Keywords. Health professional workstation, Archival-repository systems for medical records- EPR-CPR-EMR, Knowledge-based systems, HIS management.

Introduction

People working in a hospital need to have access to clinical information of those patients who are under their responsibility. This information must be shown in a structured way so that work on it becomes easier, allowing a quick access to documents needed for a diagnosis, treatment and monitoring of patients.

In 2001, in the CHUJC clinical information was kept on paper, Word documents stored in the network directories and DBASE IV applications. All those resources had no link to relate clinical documents to the patient. The means used by health workers to diagnose a patient and to follow the development of illnesses and diseases was paper.

The need for the integration of the different documents and clinical reports of a patient under the same control has arisen. It is necessary to offer health workers a way of electronic access to patients’ records which previously only existed on a digital format, without being necessary to open the large number of departmental applications and searching for the data that the patient had in any of them.

1. Materials and Methods

1.1. Objectives

The objective was to develop software which would become the only portal for the hospital's staff to obtain information about patients’ health. Information has been
classified according to different criteria, allowing the staff to have access to it in a faster and more intuitive way than if they were visualising it on paper or through different applications.

On the other hand our intention was to facilitate the creation of new medical reports under a homogeneous format for the whole organization: the use of a single corporate tool, the classification of reports according to types, the production of useful types of reports which will represent all the medical information of the patient, the same templates for identical types of medical reports.

It was necessary to develop a tool for the hospital’s staff which could be adapted to the manner in which they work and that would make it easier tracking the diseases and illnesses of the patients and the communication among the different specialists, in short, keeping a well-structured of Electronic Medical Records.

The information to be managed by the new system of information is confidential, classified as High-level, the maximum level, by the Spanish Royal Decree 994/1999, 11th June on Security Measures for Computer Files Containing Personal Data. Such regulation is in force as well the LOPDCP (Organic Law 15/1999, on the Protection of Personal Data), and according to which access to personal data is regulated to guarantee the right to privacy which every person is entitled to. The system was designed to meet the requirements specified by those regulations and to establish two basic objectives:

1. Users should only have access to the information necessary for carrying out their work. In case they required access to another kind of information, their reasons for doing so should be justified.
2. Every time they have access to the personal data of the patients, this must be recorded. This register must be accessible to those people who are responsible for the security of the information services.

1.2. Technical Design of the Solution

1.2.1. Architecture of the System

To obtain a system that would fulfill the policy of software development in our organization and that at the same time was strong, had a high level of performance and was able to endure a high number of users having access at the same time, we used a multilayered architecture based on JEE technology:

- Data were stored in a relational database capable of storing binary documents and enduring a high transactional charge.
- The layer of access to data and the logic of business were implemented using EJB’s technology according to the requirement of JEE 1.4.
- The layer of presentation was implemented by using standalone client technology. The platform on which the client should run was Microsoft Windows, since one of the requirements of the system was that the production of new medical reports had to be made by using the tool Microsoft Word™.

The first problem which had to be solved when using a of non-web client’s architecture was the installation of the software in every workstation and the distribution of the revisions that would be made with the evolution of the product. Two solutions were adopted:
1. The installation of the client application in Citrix servers.
2. The use of JNLP (Java Network Launching Protocol) for the distribution of
   the revisions. The first task done by the application is to connect itself to a web
   server by using this protocol and checking the existence of changes in the
   software packages. That being the case, the new packages are downloaded to
   the local system and normal execution continues.

For the communication of clients (presentation layer) with the “Business Layer”
protocol RMI/IIOP is used. This protocol transmits data in binary system between
client and server, which allows a more efficient communications compared to a
solution based on Web Services.

The organisation has at their disposal a repository of users with access to those
information systems registered in Microsoft Active Directory. LDAP (Lightweight
Directory Access Protocol) is used to delegate the authentication of the users in the
system and the policy of use of passwords in the organization.

In order to increase the performance of the system, especially the communications
between client and the application’s server and in the access to data, the following
patterns of design were implemented:

- Data Access Object (DAO), for the access to databases.
- Data Transfer Object (DTO), for the encapsulation and transmission of data
  among the different layers of the system.
- Session Facade, for establishing the remote interfaces which are available and
  isolating the clients from the implementation of access to data.
- Service Locator, for efficiently locating from the clients the remote resources
  of the business logic.

1.2.2. Tools Used

A great number of tools have been used for the development and production of the
solution:

- Borland JBuilder v.6-v.2006, as integrated development environment (IDE).
- Informix Dynamic Server v9.40 as main Database Management System
  (DBMS) for storing the information generated by the information system. The
  new system should obtain information from other DBMSs which were storing
  the patient’s medical information: Microsoft SQL Server, SyBase.
- IBM Websphere Application Server v5.1 and v6.1, as applications’ server
  J2EE for the display of the business objects (EJB’s) and access to data.
- Sun JDK 6.0 for the production of the user’s graphic interface through the use
  of Swing library.
- JFree Chart, for the production of evolutionary charts.
- Jakarta FOP, for the production of PDF reports from XML documents and
  XSL style sheets.
- Jacozoom, for access through JNI (Java Native Interface) to native elements of
  the Windows platform. Its main use is to operate the tool Microsoft Word
  from a Java application.
2. Results

In 2001 the design of the application was started and the application began to be produced at the end of 2004. The application was called “Gestión Documental” (Document Management) since its function at the beginning was precisely that, to manage the documents of the patients. After 12 revisions and 3 more years of development the application became the medical workstation, electronic medical history tool used by the professionals of the Juan Canalejo Hospital.

The main functions achieved by the application so far have been:

- Doorway of access to administrative data of patients, their medical histories and reports of tests managed by the system or generated by other department systems, such as cardiology, urology, radiology, pathological anatomy, medical tests laboratories, digestive tests, nursing cares, digital medical image… The system does not store the information from other subsystems. When it is required by a client, the system has access to every subsystem to verify the existence of the information required, and that being the case, it can recover it. The information of the patients is not duplicated. Every subsystem stores and keeps the information which it manages.

![Figure 1. Structure of Clinical History and graphical evolutions](image-url)
It supplies a tool for the production of new medical documents. The system allows to produce documents and associate them to the administrative medical case to which are related. To create reports a high integration with Microsoft Word™ (2000, Xp, 2003 and 2007 versions) has been undertaken, since this is the corporate text processor. The system operates the management of the documents: production, edition, closing, printing… Every operation done in relation to a document is managed by the system. Moreover there are other functions:

- The use of documents’ templates stored in the system and classified according to type of report, speciality and, in some cases, pathology. The system manages an unlimited number of templates.
- Automatically-incorporated data into reports utilities have been implemented: the patients’ administrative data and medical cases data, results from medical tests in laboratories, conclusions from radiology or pathological anatomy tests.
- Signature of the document: basic electronic signature (log in / password) and / or acknowledged advanced electronic signature (digital certificate issued by the National Mint- FNMT).
- Documents’ versioning utilities: addenda, new version and new replication.
- Coding of the reports according to the diagnosis and the procedure. The international system CIE-9 is used. This system is used to search for reports according to the pathology.

- Production of graphic elements to help with the diagnosis of the patient and the management of the surgery waiting and medical external consultations list registry.
- Statistical data operating from the production of reports.
- A system of notifications has been incorporated so that the different professionals who use the application can exchange messages. The notifications can be generated manually by the users or automatically by the system to notify events to the users: system stoppages, new versions of documents previously consulted by the user…
- Medical interconsults system of management for hospitalization services. If a professional needs to consult another specialist, he or she could do it through the application: a circuit of demand, reception, reply and tracking of the consultation has been established.
- Module of Subscriptions to medical alerts. Doctors do no longer have to check when new medical information about a patient is available. After subscribing, as soon as new information is available, the system automatically sends a message indicating the new kind of information available. There are three different ways of notification: through the application, by using emails or through a SMS to a mobile phone.
- The system has been provided with a mechanism for controlling errors. When an error is made in any module of the system, an email is automatically sent to the IT department with the details of the error.
Table 1 shows the degree of penetration of the tool in the day-to-day medical practice at the Juan Canalejo Hospital:

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Number of items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well-defined users within the system</td>
<td>2,800</td>
</tr>
<tr>
<td>Users who regularly use the system</td>
<td>2,200</td>
</tr>
<tr>
<td>Users that have daily acceded to the system</td>
<td>965</td>
</tr>
<tr>
<td>% implementation within the organization (consultation mode)</td>
<td>99%</td>
</tr>
<tr>
<td>% introduction within the organization (production of documents)</td>
<td>80%</td>
</tr>
<tr>
<td>System’s concurrent users (maximum)</td>
<td>400</td>
</tr>
<tr>
<td>Medical histories uploaded</td>
<td>6,600 – 7,000 / day&lt;br&gt;approx. 150,000 / month</td>
</tr>
<tr>
<td>Reports produced through the tool</td>
<td>274 / day&lt;br&gt;6,000 – 6,500 / month</td>
</tr>
<tr>
<td>Reports from laboratory medical tests consulted</td>
<td>8,300 – 8,700 / day</td>
</tr>
<tr>
<td>Reports to Pathological Anatomy accessed</td>
<td>525 / day</td>
</tr>
<tr>
<td>Reports to Radiology accessed</td>
<td>600 / day</td>
</tr>
<tr>
<td>Studies of digital medical image accessed</td>
<td>900 – 1,100 / day</td>
</tr>
<tr>
<td>Cases of nursing accessed</td>
<td>600 - 700 / day</td>
</tr>
</tbody>
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Table 1. Use of the tool (average data between 01-Feb-2008 and 28-Feb-2008)

3. Conclusion

The system which has been created provides the health staff in our organization with a global and structured view of the medical history of the patients, allowing an agile and real-time access to the information, avoiding the delays caused if the documentation had to move around on paper or, in some cases, if it went astray or was damaged.

Finally, we would like to indicate that the system continues developing and incorporating new revisions periodically (approximately once every two months). The improvements in the systems are not only technical, but they incorporate new functions demanded by the users as well as documents generated (produced) by new departmental systems which become integrated in the organization.

References