E-Health application: Development of a Web Framework for the creation and application of metric systems to the digital medical image

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Abstract: - The purpose of this work is to present the design and implementation of a secure web framework that allows the creation and application of customized metric systems related to diagnoses based on medical images. The image studies are obtained from a Picture Archiving and Communications System (PACS) that was developed at the Medical Informatics and Radiological Diagnosis Centre (IMEDIR Research Centre); the web application is designed with the architectonic design pattern Model View Controller (MVC); and we opted for Java Server Pages (JSP), Servlets and Java DataBase Connectivity (JDBC) as implementation technology and deployment platform. Extensible Mark-Up Language (XML) is used to store the information related to the composition of the metrics, and to save the results of the application of these metrics to each image. The X-Rays were selected at random and proceed from patients at the Orthopedic Surgery Service of the Juan Canalejo Hospital and the Modelo Hospital at A Coruña. The system was validated by a comparative study, in which we used our tool, as well as an already validated software application, to apply the same metric system to a series of 29 digitalized total hip X-Rays.By testing our framework against previously validated methods, we obtain a measurement method that is not only in concordance with preceding software tools, but presents the advantages of secure access through the web, flexibility in the development of new metric systems, and integration with a PACS.

Key-Words: - Tele-heath, E-Health, Telemedicine, Medical Applications, Internet applications, Web Systems, XML, MVC, JSP

1 Introduction

Medical diagnoses are more and more frequently based on images. The image is the tool that allows a medical expert to obtain very valuable and precise information in a fast and inexpensive manner, and which helps him to detect and analyze certain illnesses.

The breakthrough of the digital medical image has lead to the development of analysis and processing techniques that generate the largest possible amount of useful data for the medical expert. Computerized metric systems, for instance, are used to obtain measurements that quantify information which otherwise would be assessed according to the experience and intuition of the expert. Many scientific studies are based on the detection of pathologies through radiological metrics. The follow-up of knee and hip arthroplastia, for instance, applies measurement methods to determine migrations and loosening or wear of the polyethylene[1]; the rotational study of the lower limbs uses an applied measurement protocol[2]. Traditionally, the values of each metric element were measured with the ruler, carpenter's square, triangle, and compass.

2 Problem Formulation

Measurement systems that use software tools improve the precision and speed of the radiological analysis because they simplify the measurements, obtain a better definition, and provide selective amplification. A clear example hereof is the patented "Sistema de Seguimiento a Distancia de Pacientes con Prótesis de Cadera (SSAPRO) tool"[3] (Long distance follow-up system for patients with hip prosthesis), a validated application that by implementing a metric method for hip prostheses reduces the manual execution time of fifteen minutes to a total of two minutes.

The limitations of the available commercialize tools have lead us to develop a framework that allows us to obtain medical images with different modalities from a DICOM PACS, and that provides utilities for the creation and application of customized metric systems that can be adapted to any type of study.

We propose a system for metrics management that provides the medical expert with the necessary elements for the creation of new protocols and allows him to add, eliminate or modify different types of measurements (reference points, distances, angles, etc.) with respect to the existing protocols. Each area of expertise can as such design the metrics according to the information it wishes to reflect in its clinical series, and the medical experts use these metrics to analyze the selected images. The data are stored with a standard labeling language that exports them to practically all the existing calculation applications.

The images that are used in the studies are extracted from the studies database of a secure pre-existing DICOM PACS[4][5]. This set of tools can be safely accessed over the web from the intra-hospital network[6] as well as from outside.

We collaborated with the Juan Canalejo Hospital to do the follow-up of patients with total hip prostheses: we established a measurement protocol for the post-operational stage in order to determine whether the prosthesis was correctly placed and to check the wear of the polyethylene and possible misaligning of the prosthesis

Materials and Methods

1)   Requirements specification.

The implementation of the development platform is preceded by a process of analysis and design, and by a recompilation of the requirements of the specialists at the Juan Canalejo Hospital in the course of personal interviews[7].

The main purpose of these interviews is to gather sufficient information to analyze the problem and conceptualize the application field: identify, analyze and shape all the measurements that are currently used in radiological studies, describe the functionalities that are required by the potential software users, and establish the interface preferences.

There are other requirements that proceed from the legislation on medical information, the norms established by the Autonomous Government of Galicia, the amount of handled information, and the integration needs with respect to already existing image archiving systems.

At this moment, Spanish law protects medical data with the highest security level and seriously restricts the access to these data through communication networks[8]. Since our system is going to be introduced into hospitals that belong to the Galician Health Service (SERGAS), it must abide by the the Resolution of the Technical Consulting Commission for Equipment in Image Diagnosis and Radiotherapy[9], which establishes that all the hardware and operating systems that are implanted must be entirely independent. This naturally affects the selection of the technology and the approach to the design.

2) Selection of the technology

After considering all these requirements, we select the most adequate set of technologies. We opt for Java as programming language because of its portability and independence. Also, Sun Microsystems1 provides an applications development kit, Java 2 Standard Edition (J2SE) and defines, by means of Java 2 Enterprise Edition (J2EE), a specification oriented towards the development of business applications that provide scalable, secure and efficient web services, thanks to an infrastructure that guarantees security, distributed transactions control, and connections control.

We select XML for the storage of user data because it is a portable language that was defined by World Wide Web Consortium (W3C) and allows us to represent complex data structures.

Finally, we follow the architectonic Model-View-Controller pattern (Figure 1) because it has proved its validity and is ideal for he development of scalable development with a graphic interface[10].
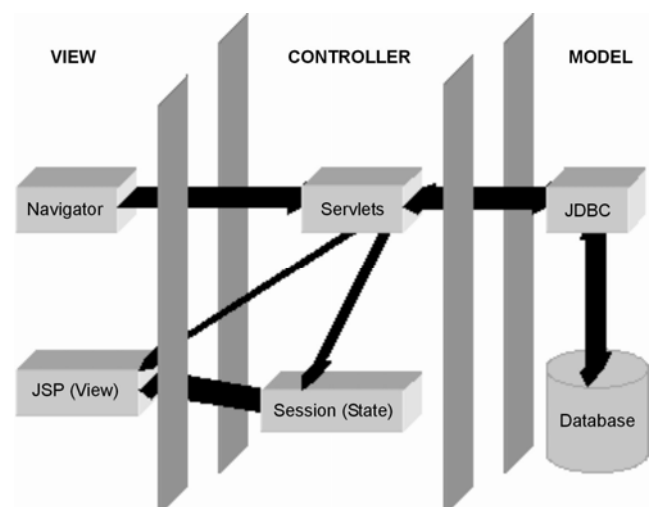

Fig. 1. Scheme of the application of the MVC pattern

3) Description of the System's Operation

The purpose of this application is to carry out epidemiologic studies with different protocols and customized metrics systems, created by the "Protocol Administrators". They are the only persons who are authorized to create, modify and eliminate the protocols and metrics systems.

The users of the protocols are in charge of selecting the best metrics system for each study and applying it to all the images of that particular study. They can only choose the metrics systems for which they have an authorization.

The "Protocol Administrator" disposes of the options to create new metrics or to see a list of existing metrics. When a new metric is created, the user must fill out a form (Figure 2) in which he specifies the metric data, the user groups (roles) that are allowed to use it, and the modalities for which it was designed. Then all the components are defined.

Fig. 2. Creation of a new metric

The components of that a new metric can have are different types of measurements: point, straight line, angle, and midpoint. After choosing the type, the user is taken to a different form on which he specifies the characteristics of each.

We can insert as many elements into the metrics as we like. As soon as the measurement is added to the metric, it can become part of some other composed measurement. When a metric is completely designed, it can be applied to the images of the PACS to generate a metrics study.

When a "Protocol User" visualizes an image, he can access the metrics for which he was authorized and that correspond with the modality of the visualized image (Figure 3). He can also see other already completed studies.

When a study type is selected, the application requests the user to provide the data of that study by means of a form and switches over to the drawing screen (Figure 4). Left from the drawing area is the measurements bar that composes the metric. The user can zoom in an out on the image and store the

performed measurements or see the results in a summary table. If the manipulation is manual, only the points will be located; the midpoints, straight lines and angles become automatically visible when all the necessary measurements are introduced.

Once defined, the study can be consulted and modified.

Fig. 3. Page that visualizes the image that corresponds to a study. We can observe the metrics available for this image
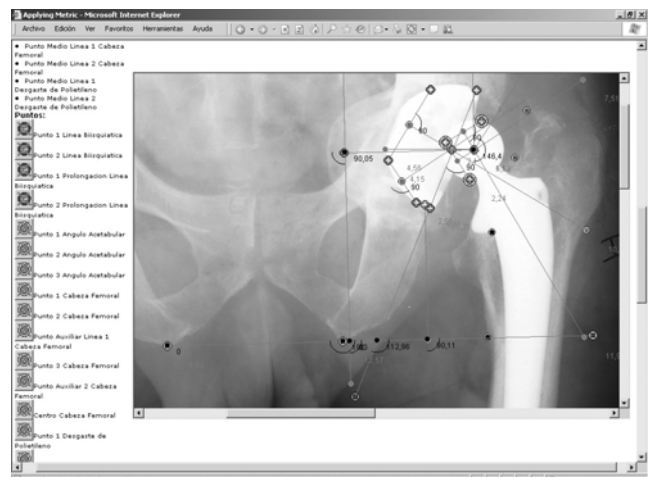

Fig. 4. A new metric system applied

4) Validation: Comparing the results with those of an already validated software tool (SSAPRO).

The Long distance Follow-up System for patients with Hip Prosthesis (SSAPRO) application was developed for the storage of clinical records of patients with total hip prosthesis. The level of accuracy of this tool has already been validated[3].

In the new framework, we copy the metrics system that was used in SSAPRO for the follow-up of patients with total hip prosthesis. The same metrics system is then applied from a new web application to a series of 29 digitalized X-Rays of total hip prostheses, which were implanted at the Orthopedic

Surgery Service of the Juan Canalejo Hospital and the Modelo Hospital in A Coruña.

The metrics system consists of various distances and angles that allow us to discover changes in the position of the implant. They are applied to X-Rays that were taken before the hip operation and in the course of the two years that follow the implant1.

In order to study the position of the implant, possible variations in this position, and migrations, the metric system includes the following quantitative measurements: polyethylene wear, horizontal and vertical migration of the colinden tree, position of the implant, and femoral stem depression.

These measurements are based on the following reference points:

- Biischiatic line.
- Acetabular angle.
- Femural Head.
- Sacroiliic Point.
- Upper point of the piston rod, upper point of the femur and lower point of the piston rod.
- Lesser trocanter point: The programmed measures the perpendicular distance between the neck point and the biischiatic line traced from this point.
- Standard measurement taker: By means of this button, and the definition of two points, we can obtain distances between other two locations that may be of interest.

After collecting these measurements (measurement 2) in the web application, we study their level of concordance with the measurements obtained with the already validated method (measurement 1), the SSAPRO application, using the statistic method developed by J. Martin Bland and Douglas G. Altman[11][12]. For each basic reference point of the metric, we graphically represent the difference between the values obtained by the two systems and the arithmetic average of the measurements. This allows us to detect the relationship between the measurement error and the real value. For these methods to be exchangeable, the difference between the values measured with the already validated system and the new system must lie within the interval known as agreement limit. These limits are calculated by applying the formula: $\overline{d} \pm s$, where $\overline{d}$ is the arithmetic average of the differences between measurement 1 and measurement 2, and s is the standard deviation of these differences. The standard error of $\overline{d} \pm s$ is $\sqrt{3s^2/n}$, where n is the number of elements that compose the sample.

3 Problem Solution

The final result is a web application that is designed and implemented in three layers according to the MVC architectonic pattern (Figure 5), and allows us to charge digital X-Rays from a database that is integrated into a pre-existing PACS. The users can design their own metric system to extract quantitative information from the images, while storing the results in a complementary database whose scheme was designed for that purpose.
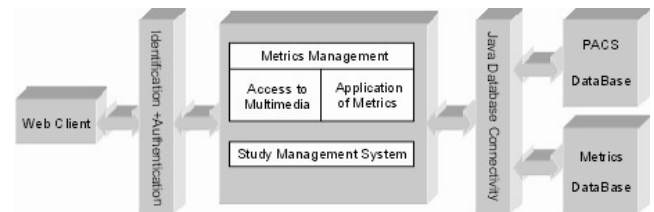

Fig. 5. Architecture of the created Web Framework

To validate the new application, we have taken a series of 29 digital X-Rays and arbitrarily applied the same metric system to the images that compose that series, using both the SSAPRO tool and the here presented framework.

Table I: Assessment of the Acetabular Angle measurements

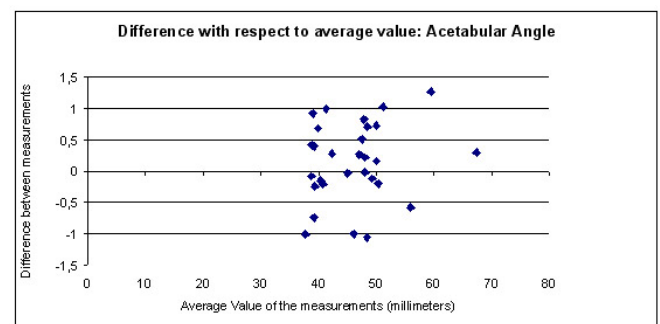| Acetabular Angle	(mm)
Average Difference	0,15
Standard Deviation	0,63
Upper limit of the agreement interval	1,41
Lower limit of the agreement interval	-1,12
Standard error	0,16181598

Fig. 6. Difference with respect to average value. Acetabular Angle

To determine whether the second method is valid, we apply the statistic method for the assessment of concordance between two clinical measurement systems: this method indicates that the system is valid for the values interval if the difference between the values measured with the validated system and those measured with the new system lie in the interval called "agreement limit".

The results of a example of the measurements are shown in the Figure 6 and their corresponding data in table I.

We can observe that the metric system that was introduced in a web context provides a measurement mechanism that can be exchanged with the validated mechanism, and that this new tool can be used for the long distance follow-up of hip prostheses.

4 Conclusion

This work presents improvement to the existing software used for diagnoses based on images. The advantage of this open working environment is the possibility of developing new studies on the basis of fundamental measurement elements: the environment can be adapted to any type of image or study. However, this characteristic also requires the collaboration of the medical staff in the development of the protocols and the metric systems. The clinical staff that have used the tool have requested that help tools and new types of basic measurements be included, such as the possibility to trace parallel and perpendicular lines as well as arcs.

Thanks to the Java plug-in, the tool can be accessed through any web browser and from any Internet Protocol based host, and a standard access interface for the application is established.

At present we are working on a comparative study with another validated measurement tool and in the context of long distance follow-up of total hip prostheses; we are also studying knee and foot pathologies. These studies will be submitted to the same validation process, in order to determine whether the use of this tool is equally adequate in those cases.

8 Acknowledgements

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