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A DICOM viewer with flexible image retrieval to support diagnosis and treatment of scoliosis

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ABSTRACT

This paper presents a medical image viewer implemented in Java whose innovative features are: on the one hand, its capability for visual edition and storage of measurements involved in diagnosis and treatment of scoliosis (a medical condition in which the patient's spine is curved) and performed on digital X-rays; on the other hand, its capability for retrieving images in a flexible way from medical image databases on the basis of those measurements, which are the standard method for diagnosing this pathology. Hence, the viewer is intended to be a useful tool for physicians in diagnosis and treatment of scoliosis.

1. Introduction

Images are a fundamental tool in health care for diagnosis, clinical studies, research and learning. Currently, there are multiple techniques to capture images from patients to help diagnostic tasks such as X-ray images, Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Positron Emission Tomography (PET), and Ultrasonography. The diagnostic task generates a large amount of images which must be archived for future evaluations. Fortunately, most of these techniques produce digital images, which are more efficiently archived and handled, by means of computer systems, than physical ones. In medical imaging these computer systems are called Picture Archiving and Communication Systems (PACS). PACS (Huang, 2010) consist of a network of computers devoted to the storage, retrieval, distribution and presentation of images. The main parts of PACS are: PACS servers, that store and send the images, and PACS workstations, that can use local peripherals for scanning image films into the system, printing them out and interactively displaying digital images. PACS workstations offer means of manipulating the images (cropping, rotating, zooming, windowing and others) through software referred to as DICOM viewers, since the most common format for image storage is DICOM (Digital Imaging and Communications in Medicine). PACS systems solve the problem of storing digital images but do not provide mechanisms to retrieve them based on the pathology's information items they contain. Instead, the single available mechanism is querying the server by patient's name or patient's file number. There are many implementations of DICOM viewers: I Do Imaging (n.d.) provides a tool to find free DICOM and PACS applications. NEMA (n.d.) also contains information about the DICOM format and related resources.

Content-based image retrieval (CBIR) (Lew, Sebe, Lifl, & Jain, 2006) is the application of computer vision techniques to the problem of digital image search in large databases. In Jaime-Castillo, Medina, and Sánchez (2009) we proposed a CBIR system that allows automatically extracting measures of the spine curvature starting from X-rays of patients with scoliosis. These measures are represented and stored into the Fuzzy Object-Relational Database System (FORDBMS) proposed in Cubero, Marín, Medina, Pons, and Vila (2004) and Barranco, Campaña, and Medina (2008b), which provides a flexible way of querying X-rays on the basis of the spine curve measurements stored into it (Medina, Jaime-Castillo, Barranco, & Campaña, 2009).

This paper describes a prototype of DICOM viewer, an important element of the proposed CBIR system. This viewer provides physicians with a tool to visually edit and measure curves and to perform queries to retrieve DICOM images of patients based on the parameters of the spine deformity. The client DICOM viewer has been developed starting from Tudor DICOM viewer (SANTEC, 2009). Because of this, our viewer also includes all features provided by the Tudor DICOM viewer (see Section 4.1).

The rest of the paper is organized as follows. Section 2 introduces the idiopathic scoliosis pathology, its diagnosis and how to perform measurements on X-rays to evaluate the spinal deformity. Section 3 describes the most important modules of the CBIR system to which the viewer belongs. Section 4 describes the viewer, illustrates the use and functioning of the novel features that it provides, and analyzes some aspects that affect the performance of the

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system. Finally, the main conclusions and future work are summarized in Section 5.

2. Idiopathic scoliosis and its X-ray based diagnosis

The proposed DICOM viewer is designed to operate in the CBIR system that will be described in Section 3 to provide physicians with a powerful tool for diagnosis and treatment of idiopathic scoliosis. In this section we will describe the most relevant characteristics of this pathology in relation with our purpose.

Scoliosis is a three-dimensional deformation of the spine that produces vertebral rotation and crushing resulting in lateral curvature. It is typically classified as congenital (caused by vertebral anomalies present at birth), idiopathic (sub-classified as infantile, juvenile, adolescent, or adult according to when onset occurred) or as having developed as a secondary symptom of another condition (such as cerebral palsy, spinal muscular atrophy or due to physical trauma). Depending on the severity and progression of the deformation, treatment may be necessary. Treatment might consists in observation, orthotic treatment (braces) or surgery. About 2–4% of the adolescent population suffer from some degree of scoliosis. Approximately 2.2% of these adolescents require treatment.

To diagnose and treat scoliosis it is necessary to measure the spine's deviation. There are physical examinations to initially detect it, but precise diagnosis and treatment need the help of radiological techniques. The most accurate technique to measure spinal deformity is Computed Tomography (CT), which provides a three-dimensional view of the spine. However this technique is expensive and exposes the patient to high doses of radiation. Taking into account that a patient having scoliosis may need observation and treatment for many years and many radiological tests, the frequent use of this technique may be inappropriate. X-rays expose the patient to lower doses of radiation and, because of this, full-length standing spine anteroposterior (AP) X-rays are the standard method for evaluating the severity and progression of scoliosis. The standard method to quantitatively assess curvatures is the measurement of the Cobb angle on AP X-rays, where spinal deformities are projected as curves.

The Cobb angle (Cobb, 1948) can be manually measured by calculating the angle between the lines respectively drawn along the upper endplate of the superior end-vertebra and the lower endplate of the inferior end-vertebra, as shown in Fig. 1. Using this measure, each curve present in the spine is characterized by means of four parameters: the side of the curve's convexity (right or left), the superior end-vertebra, the inferior end-vertebra and the numerical value of the angle. Also, it is important to identify the apical vertebra associated with the adjacent disc interspaces that have the greatest segmental angulation of all interspaces in the curve. This vertebra occurs at the horizon or apex of a curve (T9 in Fig. 1).

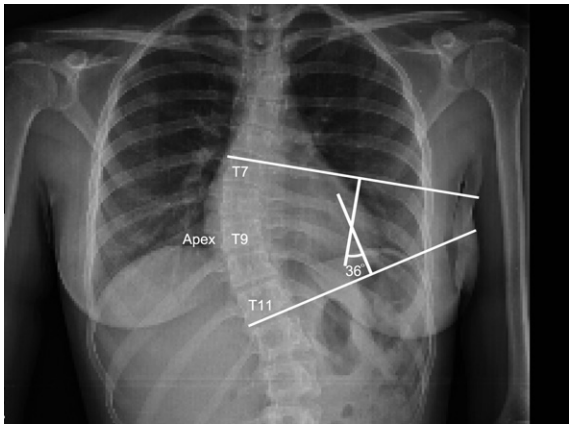

Fig. 1. Cobb angle measurement.

Manual measurement of Cobb angle depends on experience and personal judgment. Errors are due to selecting different end-vertebrae and estimating different slopes of the vertebrae. The standard measurement error is from 3° to 5° for the same observer and from 5° to 7° for different observers.

The use of AP X-rays is useful for diagnosis, clinical studies and training health professionals. To help these purposes, it would be interesting to be able to easily retrieve the images from PACS on the basis of the parameters of the curves present in the spine. Also, for the sake of simplicity and usefulness, queries should be flexible. The proposed DICOM viewer, when interacting with the spine description database created into our FORDBMS, provides such functionalities.

3. Architecture of the CBIR system

The proposed DICOM viewer belongs to a CBIR system that permits the user to perform flexible queries that search for images of patients who present a similar curvature pattern or Cobb angle measure (Cobb, 1948) to a given one (Section 4.3 will provide a description of this measurement). To achieve this functionality, the system integrates a module that can perform automatic spine measurements starting from X-rays. These measures together with their X-rays references are stored into the FORDBMS, for later flexible retrieval.

Fig. 2 shows the general schema of this CBIR system. It is organized in a three tier architecture, although some of the tiers could operate into the same computer. Each tier includes several modules, whose roles are described below:

- **FORDBMS**: It is into the server tier. The FORDBMS, proposed in Cubero et al. (2004) and Barranco et al. (2008b), is a general purpose database server extended with fuzzy data handling capabilities built on Oracle® DBMS. It stores references to DICOM X-rays images, the vectorial description of the spine extracted by the IFME module and the spine measures processed by this module. The FORDBMS can solve flexible queries on this kind of content using an extension of the SQL dialect of the Oracle® DBMS. It is important to mention that the FORDBMS does not store any DICOM image, but their DICOM IDs, that permit retrieving them from a standard PACS server that can run on any server on the network.
- The **IFME** (Image Feature and Measure Extractor) module is in the middle tier and implements the algorithms needed to automatically extract the Cobb measures from X-rays. Also, this module generates the DML statements to store these measures into the FORDBMS and to perform queries based on them. Finally, a vectorized representation of the extracted spine and vertebra shapes is generated by this module and stored into the FORDBMS for display purposes.
- The **Image Server** is an application server that processes the requests of the clients to the FORDBMS. It invokes the IFME module when the client requests the extraction of the spine measures for an X-ray image to perform a query based on an image prototype, or to insert it into the FORDBMS together with its DICOM ID. The image server can generate dynamic HTML pages and can serve Java applets for browser based clients.
- The **client application** is a modified PACS workstation capable to visualize and handle DICOM images. It can be implemented into the middle tier; in this case, the image server provides the application to the browser, or it can be a Java applet/