Elsevier Editorial System(tm) for IRBM - Innovation and Research in BioMedical Engineering
Manuscript Draft

Manuscript Number: IRBM-D-15-00125

Title: On the use of XML in medical imaging web-based applications

Article Type: General review

Keywords: XML protocol; Web-based applications; Computational Medicine; Digital databases; Security

Corresponding Author: Mr. Christian Mata,

Corresponding Author's Institution: University of Girona

First Author: Christian Mata

Order of Authors: Christian Mata; Arnau Oliver; Alain Lalande; Paul Walker; Joan Martí

Abstract: The rapid growth of digital technology in medical fields over recent years has increased the need for applications able to manage patient medical records, imaging data, and chart information. Web-based applications are implemented with the purpose to link digital databases, storage and transmission protocols, management of large volumes of data and security concepts, allowing the possibility to read, analyze, and even diagnose remotely from the medical center where the information was acquired. The objective of this paper is to analyze the use of the XML protocol in web-based medical imaging applications, analyzing how this protocol allows indexing and exchanging the huge amount of information associated with each medical case. The purpose of this paper is to point out the main advantages and drawbacks of the XML technology in order to provide key ideas for future web-based applications.

Suggested Reviewers: Olivier Rouviere
Hôpital E. Herriot, Lyon
olivier.rouviere@chu-lyon.fr
Dr. Olivier is a well-known researcher in prostate analysis and he is interested also in the management of the data.

Yago Diez
Tohoku University
yagodiezdonoso@gmail.com
Dr Diez is a well-known engineer in the MRI field and management of data.

Carole Lartizien
Univ. Lyon
Carole.Lartizien@creatis.insa-lyon.fr
Dr. Lartizien is an expert in multiparametric prostate analysis.

Dijon, 09h Dec 2015

Dear Editor-in-Chief,

Find here enclosed the paper

Title: On the use of XML in medical imaging web-based applications

Authors: C.Mata, A.Oliver, A.Lalande, P.Walker, and J.Martí

that it is submitted for publication in the **IRBM journal.**

As already explained by the email of Dr. Alain Lalande, in this paper we review the advances that the XML exchanging information protocol has provided to web-based applications applied to the medical imaging field.

As suggested, we've checked the associated editors list and we think that either Alfredo Hernandez or Frederique Frouin could manage the current submission.

All authors have checked the manuscript and have agreed to the submission. We have no conflict of interest. We think the research topic the paper is dealing with perfectly fits the scope of the journal.

Yours sincerely,

Christian Mata (Corresponding author)
Email: cmata@eia.udg.edu
Phone: +34 972 418178;
Admin Phone: +34 972 418486
Fax: +34 972 418259

Computer Architecture and Technology
University of Girona
Ed. P-IV, Av. Lluis Santaló s/n, 17071 Girona (Spain)

Groupe Imagerie Médicale, LE2I, UMR CNRS 6306
Faculté de Médecine, Université de Bourgogne
7, Bld Jeanne d'Arc, BP 87900, 21079 Dijon, cedex, FRANCE
Tel: (33) 3 80 39 33 91

On the use of XML in medical imaging web-based applications

Christian Mata, Arnau Oliver, Alain Lalande, Paul Walker, Joan Martí

Affiliations:
C.Mata, A.Oliver, J.Martí
Computer Vision and Robotics Institute, University of Girona
Campus Montilivi, Ed. P-IV, 17071, Girona, Spain

C.Mata, Alain Lalande, Paul Walker
Laboratoire Electronique Informatique et Image (Le2I), Université de Bourgogne
UMR CNRS 6306, Dijon, France.

Corresponding author:
Christian Mata
Computer Vision and Robotics Group, University of Girona
Campus Montilivi, Ed. P-IV
17071, Girona, Spain
Tel: +34972419812
Fax: +34972418976
Email: cmata@eia.udg.edu

Acknowledgements:
This work was partially funded by the Spanish R+D+I grant n. TIN2012- 37171- C02- 01. C. Mata holds a Mediterranean Office for Youth mobility grant. Finally, the Regional Council of Burgundy under the PARI 1 scheme sponsored this work.

On the use of XML in medical imaging web-based applications

Abstract

The rapid growth of digital technology in medical fields over recent years has increased the need for applications able to manage patient medical records, imaging data, and chart information. Web-based applications are implemented with the purpose to link digital databases, storage and transmission protocols, management of large volumes of data and security concepts, allowing the possibility to read, analyze, and even diagnose remotely from the medical center where the information was acquired. The objective of this paper is to analyze the use of the XML protocol in web-based medical imaging applications, analyzing how this protocol allows indexing and exchanging the huge amount of information associated with each medical case. The purpose of this paper is to point out the main advantages and drawbacks of the XML technology in order to provide key ideas for future web-based applications.

Keywords: XML protocol, Web-based applications, Computational Medicine, Digital databases, Security.

1. Introduction

Over the past decade, the emergence of large digital volumes of information in medical imaging and the rapid growth of computer-based clinical examinations have increased the number of available on-line web-based medical applications. Moreover, digital imaging technologies have become beneficial to modern medical practices and health care systems, providing powerful tools for diagnosis, treatment, and surgery. Health care consumers have begun to benefit from new web-based applications as tools to guide decision making on treatments and tests [1] or even to enhance empowerment and physical activity in various chronic disease settings [2].

Two principal domains can be defined to describe the development of web-based medical applications during the last decade: medical decision support tools and content-based image retrieval applications. Medical decision support aims to assist physicians to improve their knowledge and reduce decision conflict. On the other hand, the interest in content-based image retrieval (CBIR) has grown due to the limitations inherent in metadata-based systems, as well as the large range of possible uses for efficient image retrieval. The large amount of both visual and data information along with the new on-line tools underlined the need to create thematic accesses that offered more than simple text-based queries or requests based on matching exact database fields [3]. CBIR technology has been proposed to aid clinical care, bio-medical research and education [4, 5]. However, although the initial widespread enthusiasm for CBIR in the engineering research community, its application has still to solve practical problems, including optimization stages in the indexing and retrieval work-flow [6].

Consequently, web-search tools have become a new research topic with the purpose to obtain digital images according to the different attributes used when issuing a diagnosis [7]. In this sense, one of the long standing problems is finding a way to share medical data across a variety of media. XML (eXtensible Markup Language) has emerged as a leading facilitator. Some applications are developed on the integration of frameworks and data management using queries to examine information from multiple data types and large data sets [8]. Although the XML is provided with predefined tags, one of its advantages is its extensible use. Moreover, the inclusion of the XML databases facilitates the management of XML files by storing them in an efficient way.

We present in this review an overview of the most relevant web-based applications in medical informatics that use the XML protocol. Therefore, the main focus of the review is the management of the medical data associated with imaging studies. However, for the sake of completion when developing a web-application, we also briefly review where the data is store (medical databases) and security issues. Encrypted solutions are absolutely necessary in medical applications because of the confidentiality of the personal information.

The rest of the paper is structured as follows. Next section presents different key works concerning web-based applications on which we centered our review. Subsequently, we present a classification and a discussion on the use of the XML protocol in the topics of database management, information exchanging and security, the main aspects when designing and implementing a web-based application. In section 4 the most interesting aspects of this survey and future trends are discussed. The paper ends with conclusions.

2. Methods

2.1. Search strategy

[Figure 1 about here.]

We searched the literature in the following databases: PubMed, Scholar, Embase and Scopus. The main search strategy combined four concepts: Web-based medical applications, XML framework, PACS and security. For each concept, the following search terms were used: web-based applications, XML protocol, computational medicine, digital databases and internet security.

We wanted to identify the main research works for each area in PubMed and in Scopus. As these searches resulted in many duplicates, this dual search strategy was not repeated in Scholar or Embase. To retrieve other relevant publications, we also examined the reference lists of the selected publications and reviews, and we included those works that met the eligibility criteria.

2.2. *Web-based applications*

In this work we reviewed web-based applications developed during the last decade in the medical environment. The final goal of these applications is to help physicians when diagnosing a case. We can classify these applications into two categories according to the way information is provided. On one hand, medical decision support systems aim to analyze multiple data and return to the expert, a ranking probability or even a second opinion about the patient to be diagnosed. On the other hand, content-based retrieval systems aim to provide to the expert similar cases to the one being analyzed. When this data is related to imaging technologies, it is referred to as a content-based image retrieval system. There are recent surveys on both class of applications [1, 3, 6, 9, 10]. In this work, however, we focused on the implementation of web-based applications, independently of whether the goal was as a medical decision tool or a CBIR. From a web-based tool point of view the two approaches are similar.

As illustrated in Figure 2, web-based applications require a web-server to provide the interface between the user-computer and the medical database, consisting of data, but also of images. Web-based applications run on the computer of the user, usually through a small application called applet. From the web-server page, the applet is downloaded to the user machine and it is then executed within an environment provided by the Java Virtual Machine. Notice that once applet is running, it is a process independent of the web browser itself.

[Figure 2 about here.]

2.3. *Web-based applications examples*

A number of web-based medical applications have been presented over the last decade. Fernàndez-Bayó et al. [11] presented an approach involving a web server that allowed the query and retrieval of images stored in DICOM format. The images could be viewed within a web browser with use of a small Java program known as the DICOM Java Viewer, which was executed inside the browser. The system, which is still working, supported mainly magnetic resonance and computed tomographic images in a very simple graphical interface. The use of a web-browser user interface allowed access, independently of its hardware and operating system. The application was based on a client-server intranet system and on multi-platform intranet technologies such as Java. The most significant disadvantage of the system was the response speed to obtain images within the web browser. A similar medical web-based application was presented by Deftereos et al. [12] to facilitate clinical work by allowing the communication of patients records between experts. The aim of the work was to share patient records of a particular disease at a national level. The advantage of using an automatic tool is not only the exchange of information but also the standardization of the records. The web-application was implemented with Java technology and was connected to a web server and also with a patients' database using the SQL Language. The use of Java makes possible scalable designs, suitable for the needs of health care units differing in size. However, currently, the application operates on stand-alone computers; therefore the database server is constraint to run on the same machine. These difficulties were encountered because of the lack of more powerful database servers and workstations.

Matsopoulos et al. [13] proposed a web-based medical system developed for the management and processing of obstetrical, gynecological and radiological medical data. The system, implemented in a modular structure, recorded the necessary medical information in terms of patient data, examinations and operations. It also provided to the user, advanced image processing tools for the manipulation, processing and storage of ultrasound and mammographic images using the DICOM protocol. This system ensured the provision to the medical experts of an unified patient management protocol, either in the hospital or outside.

Arnold et al. [14] implemented a well-documented and easily accessible communication loop adaptable to different types of image modalities. Images were displayed in a native DICOM format with a Java applet, along with use of various image manipulation tools. The web-based infrastructure consisted of a server that stored imaging studies and reports, with web browsers that downloaded and installed optional client software on demand. In contrast with previous works, their approach allowed the inclusion of PHP (hypertext pre-processor) as the language to implement the web-application. Application logic consists of a set of PHP modules that were accessible using an application programming interface. The system might be adapted to any clinician-specialist communication loop, and, because it integrated radiological standards with web-based technologies, it could communicate and report data in an efficient way.

On the other hand, Mata et al. [15, 16] proposed an interactive Java applet interface designed as a web-based tool. It aimed to facilitate the diagnosis of mammographic and prostate cases by providing a set of image processing tools that allowed a better visualization of the images and a set of drawing tools used to annotate the suspicious regions. Hualei et al. [17] presented a medical image access and presentation system as a web-based system designed for remotely accessing and presenting DICOM images in a teleradiology operation through the Internet. One of the main advantages of this work is that they provided multiple DICOM image retrieval methods: text-based retrieval, content-based retrieval and combined retrieval, as well as the implementation of on-demand medical image transmission method in a web environment.

A web-based tool for patient-specific consultation in the clinical scenario of breast augmentation was proposed by de Heras Ciechomski et al. [18]. This example shows that the current state of development allows for the creation of responsive and effective Web-based 3D medical tools, even with highly complex and time-consuming computation, by off-loading them to a dedicated high-performance data center. Internet web-based communications tools to guide decision making on treatments and tests were also studied by Schwitzer et al. [1]. They analyzed 4 areas of variability in the use of key web-enabled features in online decision-support tool development. The main features were focused on the presentation of outcomes probability data tailored to the individual user, the use of videotaped patient interviews in the final product to convey the experiences of people who have faced similar diagnoses in the past, the ability to interact with others in a social support network and the accessibility of the tool to any health care consumers with an Internet connection. Recently, Moorhead et al. [19] studied the benefits and limitations of social media for health communication among the general public, patients and health professionals, and identified current gaps to provide recommendations for future health communication research.

CBIR systems have been proposed for a variety of pathologies [6]. For instance, Hsu et al. [20] described the implementation of a web-based CBIR for spine pathologies, consisting of four components: a client applet, a gateway, an indexing and retrieval system, and a database of images and associated text data. It allowed the exploration of a large bio-medical database of digitized spine X-ray images using a combination of textual or even visual queries. In the latter case, a query editor enabled users to pose queries by sketching a unique shape or selecting or modifying an existing shape from the database. Ortega et al. [21] presented a CBIR for retinal image analysis consisting of the web client interface, of the web server that processes the requests and of the service module that performed the image processing tasks.

3. Implementation of medical web-based applications

[Table 1 about here.]

Table 1 presents a compact at-a-glance summary of the reviewed works and their main features. In this review we aim to describe the methodological aspects of a web-based application and how to tackle the features presented in Figure 1. We focus the review on how the database is implemented, using PACS or not, and which images it stores. We also depict how the information is stored and transmitted, using or not the XML protocol, and finally we also illustrated the main security aspects.

3.1. Databases

Web applications typically run on the user's computer and they communicate via standard procedures, i.e. http, to a web server application that usually contains or communicates with another computer that contains the medical data, as is depicted in Figure 3. The web server is responsible for searching within the medical database and for returning the information to the web application. As can be seen in Table 1, in the medical context this database is currently stored under the Picture Archiving and Communication System (PACS) architecture, that allows to integrally store the patient records with their own available digital images acquired at the hospital. Notice that PACS not only refers to a single database but also consists of image and data acquisition, storage, and display subsystems integrated by various digital networks. New digital imaging technologies present a challenge to the management of such large volumes of information, and PACS offers a practical solution. The initial reluctance to PACS has vanished nowadays [58]. Different web-application have described the implementation of a PACS system in their work for the storage, research, transmission, evaluation of medical images [13] and even applied to telemedicine applications [36]. Jorritsma et al. [55] studied the differences in usability terms of PACS with identical functionality, concluding that functional requirements alone are insufficient to determine the overall quality of a PACS. The implementation of the PACS also determines the PACS usability. In the same way, Van der Wetering et al. [59] presented a study based on an integrative model to determine PACS alignment and performance in hospitals, adopting theories and perspectives from the field of information system research and complexity theory.

[Figure 3 about here.]

The advantage of web-based applications is that they allow to easily add newer capabilities to the PACS system. Hastings et al. [32] complemented the PACS by providing an extra management of the information using XML language, allowing a more friendly environment for large biomedical databases. Similarly, Mahmoudi et al. [45] developed a web-application tool connected to a PACS system to allow direct access to the data. The data were uploaded to the application for processing and the processed data saved on the client machine. One of the advantages was that the application supported various DICOM formats. Rosset et al. [25] created an image-based electronic system to print film images directly from a PACS. The benefit of using a PACS in the clinical routine allows for better tools to support teaching and training tasks. Kautelakis et al. [34] developed a web-based interface to the clinical PACS, simplifying the access to the repository and providing a simple mechanism for accessing DICOM objects through the net. Rajala et al. [48] proposed a new system using an integration of PACS in a hospital information system (HIS). It consisted in an alternative implementation to regular PACS systems. Their study described the fusion of a PACS server with a HIS server and their implementation in a large university hospital organization.

3.2. Exchange of information

[Figure 4 about here.]

Once the web application receives the data from the PACS or medical database through the web-server application, it is ready to process it according to its own goal. When the application finishes, the resulting outcomes can be stored, either locally or transmitted to an external database. Since these results usually contain the analysis of the cases, they can be stored in formats compatible with word processor or spreadsheet tools in order to present the information in a structured way. Although there are different formats for information exchange [44, 53, 60], the eXtensible Markup Language (XML) has emerged as a leading facilitator in exchanging structured information between different platforms and storing information in an efficient way and at low memory cost. In the column entitled “Data Exchange“ of Table 1, it is evident that the XML language is also becoming a standard in information exchange in web-based applications. In Figure 4 the common language terms used in XML are depicted: files containing XML information are called XML documents, they are stored databases called XML servers, and used by applications or XML systems.

Hastings et al. [32] addressed the work to metadata and data management issues using a generic, distributed, XML-based data management system. According to the authors, the use of XML schemas and XML documents allowed to manage and publish data models to efficiently store, query, reference and create virtualized XML views into distributed and interconnected databases. Kurc et al. [8] showed one of the best examples of the usability of XML schemes oriented to medical research works. The proposed XML-based data management system supported the integration of data from disparate data sources and large data sets. The system facilitated management of XML schemes and on-demand creation and management of XML databases that conform to those schemes. Recently, Chipman et al. [56] presented a software that can convert local structured data into XML-formatted data. Hence, while clinicians and patients benefit greatly from readily available risk predictions, a large pool of multiinstitutional family history data will be continually gathered.

XML has progressively become a gold standard for accessing, representing and exchanging information, especially in the health care environment. According to Choe and Yoo [40] a key point to allow cooperation among heterogeneous repositories held at various hospitals is the introduction of a common healthcare-record, and XML allows to efficiently store this information. Defteros et al. [12] integrated the use of the XML documents designed to allow the exchange of Electronic Healthcare Record (EHCR) information between different clinical information systems. Complete patient records or record extracts are exported in the form of messages in XML documents. In the same way Zhang et al. [27] used the XML formatted messages to send browser requests or to receive responses from the Web server through the http protocol. Rassinoux et al. [26] also presented an implementation of XML for the electronic patient record (EPR) and discussed more specifically its growing use in two areas of the EPR: firstly, as a format for the exchange of structured messages, and secondly, as a comprehensible way of representing patient documents.

There have even been attempts to change traditional binary data to XML format, arguing that XML files are human readable, searchable and provide a better form of semantics. For instance, Bond et al. [49] studied the encoding of Electrocardiogram (ECG) data using XML format, while Biternas et al. [61] introduced in their work a simple and general XML format for spin system description in magnetic resonance imaging. The aim is to unify under one unique format the principle spin interaction specification conventions.

The XML standard is also used in CBIR systems as a way to link the retrieval machine to the web-based application, as in Ortega et al. [21] for retinal images or in Hsu et al. [20] for spine images. This latter work provided a simple interface between both systems. The information was transmitted between systems using just three XML primaryevents. The first one was used to determine whethera desired service was available and to obtain a list of currently available services. The second one contained information about the features of the query, while the their done returned the matching images along with the similarity scores. Coiera et al. [33] proposed a similar architecture, where XML was used to represent the queries obtained from users in a consistent way.

In fact, XML schemes can be useful for much more complex query languages, like the ones related to DICOM files. For instance, Marcos et al. [38] in their work the advantages to represent DICOM header information using XML and to store their data in a XML database. In the proposal of Arnold et al. [14], XML documents included annotations and descriptive text related to DICOM images. Authors argued that this capability allowed a more efficient exchange of templates and would represent a step toward standardization. In a similar way, Tahmoush et al. [36] also affirmed that the incorporation of DICOM 3 capability was necessary in medical image systems and that XML support should also be included. Indeed, it has become the preferred method for uploading data that was not already in DICOM format. Finally, Hualei et al. [17] remarked the advantages to represent DICOM header information within a XML file, highlighting the importance of extracting and storing in a XML file the semantic attributes of DICOM images (one XML file per DICOM image). Besides, Wang et al. [43] analyzed the use of XML in a PACS workstation managing DICOM images. The advantage is that all the information is embedded in the XML document, thus knowledge on the structure of the PACS workstation is unnecessary. Notice that the necessity to store additional information related to the images stored in a PACS systems has becoming crucial, and new applications are appearing in this direction. An example of this is proposed by Mata et al. [15, 16], who store in XML files the analysis of the images provided by different experts. The files are kept in a external database that manage the files, thus preserving the information integrity of DICOM images.

3.3. Security

Security and privacy protection are essential aspects in web-based medical applications. Figure 5 depicts the main aspects in security areas that web-based applications have to deal with, including authentication of the user and encryption and anonimization of the data. Under the column “Security“ of Table 1 there is a summary of the efforts made in the following aspects: authentication, encryption, anonimization and the security architecture proposed. Notice that aspects related to security and data protection of Internet are out of the scope of this review, as well as aspects related with the way the patients’ information is stored (recent surveys on this topic are [64] and [65]).

[Figure 5 about here.]

Sucurovic [39] presented in his work an authorization policy system based on XML schemas to define the user role in the system. The implementation of a web service security between the clinical and central server and a secure transmission between the central server and a client was previously defined. Furthermore, an extra security algorithm was chosen for signing and performing the encryption during the transmission of medical data. A similar approach was recently proposed by Hualei et al. [17], where the role-based access control was also applied to protect the medical data and the patient privacy. Finally, Mahmoudi et al. [45] claimed that the use of a standard XML-based communication framework allows to reduce the implementation overhead which made their communication well-defined. In addition, by using this combination, the security settings on the client machine were solved.

Regarding data anonimization, Zhang et al. [27] proposed a security model based on multi-purpose internet mail extension message to transfer medical data between servers and clients. The browser sent the request to the server and decoded the XML formatted messages. Subsequently, it looks into its local database and returned the results including patient and study information. This strategy allowed to decode anonymized data information provided from DICOM files. Differently, Neubauer et al. [50] proposed a methodology for the anonymization of medical data that stores health data decoupled from the corresponding patient-identifying information, thus allowing privacy-preserving secondary use of the health records in clinical studies without additional anonymization steps. This approach allowed the unlinked storage of medical data and related patient-identifying information, while still making it possible to reestablish the patient/health data relationship for authorized users. Notice that anonymized data can allow to protect confidential information from unwanted connections [63]. The approach of Bos et al. [66] was different. They implemented a prediction service running in the cloud that takes private encrypted health data as input and returns the probability for suffering cardiovascular disease. The service uses homomorphic encryption, and is able to make the prediction handling only encrypted data. Therefore, the submitted confidential medical data is not necessary. A similar idea was followed by Rossi et al. [67], where different clinical centers share data for one year. The anonymity of the data was preserved by unique identifiers associated with the patients in each center. Only the rellevant clinical information was uploaded to the web-based application that shared the data.

4. Discussion

This paper presents a summary of the current status and trends in web-based medical applications linked to PACS databases, to the use of XML protocols and to security systems. The main observation is the fact that no format currently exists that seeks to satisfy the needs of all potential users. Therefore, as researchers continue to find gaps in current web-based medical informatics applications, they propose their own solutions. A list of web-based medical application research works have been presented in this review. It has brought together a diverse group of works drawn from imaging, computer science, informatics and clinical disciplines. In general, the majority of web-based applications have used their own web server with a combination of Java applet tools. Note that although we focused the review in web applications implemented in Java, new web technologies are appearing such as HTML5, with its powerful and flexible image canvas, or WebGL, that are being used to redefine how users can interact with medical images through a browser. Basically, the inclusion of web technologies in web-based medical applications has been a solution to aid in the diagnosis and visualization of medical images.

Web-based applications have benefited from the inclusion of the XML protocol in the areas shown in Figure 1: databases, information exchanging and security systems. The PACS system is the most common medical database used in medical applications (Table 1, section Database). The inclusion of the DICOM format as the standard medical image protocol was the key to the use of PACS. The support of CBIR, CAD, and Hospital Information Systems (HIS) / Radiology Information System (RIS) architectures have demonstrated the power of PACS as a common image data model. Progress in the related areas of PACS and image processing will certainly impact strongly on imaging informatics. The simultaneous management of several image modalities are also present in all the research works. Indeed, we can find the appropriate tools to manage these different image modalities, the standard DICOM being the most commonly used. Despite DICOM is an old standard that does not adhere to many current best-practices, XML allows integration and easy interface to represent the DICOM header. Different software tools exit for the bidirectional DICOM Header - XML document conversion [68, 69]. However, the main issues in imaging informatics are indexing and context-specific organization of imaging data and the increment of a large DICOM repositories provided by the acquisition systems. Thus, some research works use as a solution parallel architectures (e.g. mini-pacs, GridPacs, etc.) to improve the management of medical data in an efficient way [34, 32, 35].

On other hand, the exchange information has benefited from the inclusion of the XML protocol, a language that is easily accessible and extensible. Moreover, XML is capable of supporting a rich set of features as validation, indexing, query, retrieval and visualization methods developed using open software and standards like the CDA/CCD (Clinical Document Architecture / Continuity of Care Document) (Table 1, section Data Exchange). The relatively quick and easy implementation of XML for transfer information is a major asset. In order to improve the performance to transfer the information such as messaging system, various strategies have been implemented. It is important to remark how the XML files can be stored and related to DICOM images. Hualei et al. [17] proposed the use of an open source package to manage XML files. In addition to this, in their research work a basic attribute and a semantic attribute of DICOM image are extracted and stored in XML file (one XML file per DICOM image). Although other standard exists, such as the imaging domain in caBIG, non-PACS research applications such as XNAT and Midas, the future in medical data exchange, specially in multicenter applications, seems to be the use of XML and DICOM protocols linked with web-based medical application [70, 71, 72].

Finally, the necessity to create security systems in web-based medical applications in order to protect the privacy of medical data have been incremented over the last decade (Table 1, section Security). The main goal is to create security architectures that have been mainly designed for providing authentication and authorization services in web-based distributed systems. Most of the recent contributions are focused on authentication and data encryption but few works are focused in the anonymization of the medical data [27, 50, 63]. It is evident that most of the anonymization systems are applied directly to the DICOM protocol after the acquisition process. However, the muse of anonymized information in web-based medical applications is not present in recent works and this aspect could be improved in future works.

5. Conclusion

This paper presented a summary of the most relevant research works in computational medicine applied to digital databases and digital imaging. It has dealt with the current status and trends in web-based medical applications linked to PACS and databases, the use of XML protocol and security systems in the medical field. The aim of this literature review is to address several of these issues and to have conveyed to the reader that it is a growing field which needs to benefit from future improvements on information storage, exchange and security.

Acknowledgements

This work was partially funded by the Spanish R+D+I grant n. TIN2012-37171-C02-01. C. Mata holds a Mediterranean Office for Youth mobility grant. Finally, the Regional Council of Burgundy under the PARI 1 scheme sponsored this work.

References

[1] Schwitzer G. A review of features in internet consumer health decision-support tools. J Med Internet Res 2002;4(2):e11.

[2] Kuijpers W, Groen W, Guld N, van Harten W. A systematic review of web-based interventions for patient empowerment and physical activity in chronic diseases relevance for cancer survivors. J Med Internet Res 2013;15(2):e37.

[3] Müller H, Michoux N, Bandon D, Geissbuhler A. A review of content-based image retrieval systems in medical applications-clinical benefits and future directions. Int J Med Inform 2004;73(1):1–23.

[4] de Oliveira J, de Albuquerque Arajo A, Deserno T. Content-based image retrieval applied to bi-rads tissue classification in screening mammography. World J Radiol 2011;3(1):24–31.

[5] Welter P, Riesmeier J, Fischer B, Grouls C, Kuhl C, Deserno T. Bridging the integration gap between imaging and information systems: a uniform data concept for content-based image retrieval in computer-aided diagnosis. J Am Med Inform Assoc 2011;18(4):506–10.

[6] Long L, Antani S, Deserno T, Thoma G. Content-based image retrieval in medicine: Retrospective assessment, state of the art, and future directions. Int J Health Inf Syst Inform 2009;4(1):1–16.

[7] Flanders A. Next generation web search: augmenting information access for radiologists. Radiographics 2007;27(5):1519–1521.

[8] Kurc T, Janies D, Johnson A, Langella S, Oster S, Hastings S, et al. An xml-based system for synthesis of data from disparate databases. J Am Med Inform Assoc 2006;13(3):289–301.

[9] Akgül C, Rubin D, Napel S, Beaulieu C, Greenspan H, Acar B. Content-based image retrieval in radiology: Current status and future directions. J Digital Imging 2011;24(2):208–222.

[10] Hwang K, Lee H, Choi D. Medical image retrieval: Past and present. Healthc Inform Res 2012;18(1):3–9.

[11] Fernàndez-Bayó J, Barbero O, Rubies C, Sents M, Donoso L. Distributing medical images with internet technologies: a dicom web server and a dicom java viewer. Radiographics 2000;20(2):581–590.

[12] Deftereos S, Lambrinoudakis C, Andriopoulos P, Farmakis D, Aessopos A. A java-based electronic healthcare record software for beta-thalassaemia. J Med Internet Res 2001;3(4):e33.

[13] Matsopoulos G, Kouloulias V, Asvestas P, Mouravliansky N, Delibasis K, Demetriades D. Mitis: a www-based medical system for managing and processing gynecological-obstetrical-radiological data. Comput Meth Prog Biomed 2004;76(1):53–71.

[14] Arnold C, Bui A, Morioka C, El-Saden S, Kangarloo H. Informatics in radiology: A prototype web-based reporting system for onsite-offsite clinician communication. Radiographics 2007;27(4):1201–1211.

[15] Mata C, Oliver A, Torrent A, Martí J. Mammoapplet: an interactive java applet tool for manual annotation in medical imaging. In: IEEE Int. Conf. Bioinf. Bioeng. 2012, p. 34–39.

[16] Mata C, Walker P, Oliver A, Brunotte F, Martí J, Lalande A. Prostateanalyzer: web-based medical application for the management of prostate cancer using multiparametric MR images. Inform Health Soc Care 2015;:dx.doi.org/10.3109/17538157.2015.1008488.

[17] Hualei S, Dianfu M, Yongwang Z, Hailong S, Sujun S, Rongwei Y, et al. MIAPS: A web-based system for remotely accessing and presenting medical images. Comput Meth Prog Biomed 2014;113(1):266–283.

[18] de Heras Ciechomski P, Constantinescu M, Garcia J, Olariu R, Dindoyal I, Le Huu S, et al. Development and implementation of a web-enabled 3d consultation tool for breast augmentation surgery based on 3d-image reconstruction of 2d pictures. J Med Internet Res 2012;14(1):e21.

[19] Moorhead S, Hazlett D, Harrison L, Carroll J, Irwin A, Hoving C. A new dimension of health care: Systematic review of the uses, benefits, and limitations of social media for health communication. J Med Internet Res 2013;15(4):e85.
[20] Hsu W, Antani S, Long L, Neve L, Thoma G. Spirs: a web-based image retrieval system for large biomedical databases. Int J Med Inform 2009;78(1):s13 – s24.
[21] Ortega M, Barreira N, Novo J, Penedo M, Pose-Reino A, Gmez-Ulla F. Sirius: A web-based system for retinal image analysis. Int J Med Inform 2010;79(10):722–732.
[22] Halamka J, Osterland C, Safran C. Careweb, a web-based medical record for an integrated health care delivery system. Int J Med Inform 1999;54(1):1–8.
[23] Papadakis I, Chrissikopoulos V, Polemi D. Secure medical digital libraries. Int J Med Inform 2001;64(3):1–8.
[24] Sinha U, Bui A, Taira R, Dionisio J, Morioka C, Johnson D, et al. A review of medical imaging informatics. Ann N Y Acad Sci 2002;980(1):168–197.
[25] Rosset A, Ratib O, Geissbuhler A, Vallée J. Integration of a multimedia teaching and reference database in a pacs environment. Radiographics 2002;22:1567–1577.
[26] Rassinoux A, Lovis C, Baud R, Geissbuhler A. Xml as standard for communicating in a document-based electronic patient record: a 3 years experiment. Int J Med Inform 2003;70(2):109–115.
[27] Zhang J, Sun J, Stahl J. Pacs and web-based image distribution and display. J Comp Medical Img Graph 2003;27(3):197–206.
[28] van der Haak H, Wolff A, Brandner R, Drings P, Wannenmacher M, Wetter T. Data security and protection in cross-institutional electronic patient records. Int J Med Inform 2003;70(3):117–130.
[29] Müller H, Rosset A, Vallée J, Terrier F, Geissbuhler A. A reference data set for the evaluation of medical image retrieval systems. J Comp Medical Img Graph 2004;28(6):295–305.
[30] Gritzalis D, Lambrinoudakis C. A security architecture for interconnecting health information systems. Int J Med Inform 2004;73(3):305–309.
[31] Kluge E. Informed consent and the security of the electronic health record (ehr): some policy considerations. Int J Med Inform 2004;73(3):229–234.
[32] Hastings S, Oster S, Langella S, Kurc T, Pan T, Catalyurek U, et al. A grid-based image archival and analysis system. J Am Med Inform Assoc 2005;12(3):286–295.
[33] Rassinoux A, Lovis C, Baud R, Geissbuhler A. Architecture for knowledge-based and federated search of online clinical evidence. J Med Internet Res 2005;7(5):e52.
[34] Koutelakis G, Lymperopoulos D. Pacs through web compatible with dicom standard and wado service: advantages and implementation. IEEE Eng Med Biol Mag Soc 2006;1:2601–2605.
[35] Güld M, Thies C, Fischer B, Lehmann T. A generic concept for the implementation of medical image retrieval systems. Int J Med Inform 2005;76:252–259.
[36] Tahmoush D, Samet H. A new database for medical images and information. In: Proc. SPIE - Medical Imaging 2007: Image Processing. 2007, p. 65160G1–65160G7.
[37] Doi K. Computer-aided diagnosis in medical imaging: Historical review, current status and future potential. Int J Med Inform 2007;31(5):198–211.
[38] Marcos E, Acua C, Vela B, Cavero J, Hernndez J. A database for medical image management. Comput Meth Prog Biomed 2007;86(3):255–269.
[39] Sucurovic S. Implementing security in a distributed web-based ehcr. Int J Med Inform 2007;76(6):491–496.
[40] Choe J, Sun K. Yoo S. Web-based secure access from multiple patient repositories. Int J Med Inform 2008;77(4):242–248.
[41] Oster S, Langella S, Hastings S, Ervin D, Madduri R, Phillips J, et al. cagrid 1.0: an enterprise grid infrastructure for biomedical research. J Am Med Inform Assoc 2008;15(2):138–149.
[42] van der Linden H, Kalra D, Hasman A, Talmon J. Inter-organizational future proof {EHR} systems: A review of the security and privacy related issues. Int J Med Inform 2009;78(3):141–160.
[43] Wang C, Ritter F, Smedby A. Making the pacs workstation a browser of image processing software: a feasibility study using inter-process communication techniques. Int J Comput Assist Radiol Surg 2010;5(4):411–419.
[44] Do BH, Wu A, Biswal S, Kamaya A, Rubin DL. Informatics in radiology: RADTF: A semantic search¢enabled, natural language processor¢generated radiology teaching file. Radiographics 2010;30(7):2039–2048.
[45] Mahmoudi S, Akhondi-Asl A, Rahmani R, Faghih-Roohi S, Taimouri V, Sabouri A, et al. Web-based interactive 2d/3d medical image processing and visualization software. Comput Meth Prog Biomed 2010;98(2):172–182.
[46] Gao X, Qian Y, Hui R. The state of the art of medical imaging technology: from creation to archive and back. Int J Med Inform 2011;5:73–85.
[47] Korenblum D, Rubin DL, Napel S, Rodriguez C, Beaulieu C. Managing biomedical image metadata for search and retrieval of similar images. J Digital Imging 2011;24(4):739–748.
[48] Rajala T, Savio S, Pentinnen J, Dastidar P, Kähönen M, Eskola H, et al. Development of a research dedicated archival system (taras) in a university hospital. J Digital Imging 2011;24:864–873.
[49] Bond R, Finlay D, Nugent C, Moore G. A review of ecg storage formats. Int J Med Inform 2011;80(10):681–697.
[50] Neubauer T, Heurix J. A methodology for the pseudonymization of medical data. Int J Med Inform 2011;80(3):190–204.
[51] Haas S, Wohlgemuth S, Echizen I, Sonehara N, Mller G. Aspects of privacy for electronic health records. Int J Med Inform 2011;80(2):e26–e31.
[52] Baltasar A, Gonzlez-Sistal A. Design of a web-tool for diagnostic clinical trials handling medical imaging research. J Digital Imging 2011;24(2):196–202.
[53] Gerstmair A, Daumke P, Simon K, Langer M, Kotter E. Intelligent image retrieval based on radiology reports. Eur Radiol 2012;22(12):2750–2758.
[54] Carrión I, Fernández-Alemán J, Toval A. Are personal health records safe? a review of free web-accessible personal health record privacy policies. J Med Internet Res 2012;14(4):e114.

[55] Hwang K, Lee H, Choi D. Merits of usability testing for PACS selection. Int J Med Inform 2014;83(1):27–36.

[56] Chipman J, Drohan B, Blackford A, Parmigiani G, Hughes K, Bosinoff P. Providing access to risk prediction tools via the hl7 xml-formatted risk web service. Breast Cancer Res Treat 2014;140(1):187–193.

[57] Agarwal R, Anderson C, Zarate J, Ward C. If we offer it, will they accept? factors affecting patient use intentions of personal health records and secure messaging. J Med Internet Res 2013;15(2):e43.

[58] Huang H. Medical imaging, pacs, and imaging informatics: retrospective. Rad Phys Tech 2014;7(1):5–24.

[59] Wetering R, Batenburg R. Towards a theory of pacs deployment: An integrative pacs maturity framework. J Digital Imging 2014;27(3):1–14.

[60] Schweiger D, Trajanoski Z, Pabinger S. Sparqlgraph: a web-based platform for graphically querying biological semantic web databases. BMC Bioinformatics 2014;15(279):1–5.

[61] Biternas A, Charnock G, Kuprov I. A standard format and a graphical user interface for spin system specification. J Magn Reson Imaging 2014;240(0):124–131.

[62] Kammerer FJ, Janka R, Kramer M, Hammon M, Uder M, Schlechtweg PM. Mycases – a portable application for radiologic case collections. J Digital Imging 2014;27(5):557–562.

[63] Sethi N, Lane G, Newton S, Egan P, Ghosh S. Disaster easily averted? ¢ data confidentiality and the hospital desktop computer. Int J Med Inform 2014;83(5):385–391.

[64] Fernández-Alemán JL, Señor IC, Lozoya PO, Toval A. Security and privacy in electronic health records: A systematic literature review. J Biomed Inform 2013;46(3):541–562.

[65] Gkoulalas-Divanis A, Loukides G, Sun J. Publishing data from electronic health records while preserving privacy: a survey of algorithms. J Biomed Inform 2014;50:4–19.

[66] Bos JW, Lauter K, Naehrig M. Private predictive analysis on encrypted medical data. J Biomed Inform 2014;50:234–243.

[67] Rossi E, Rosa M, Rossi L, Priori A, Marceglia S. Webbiobank: A new platform for integrating clinical forms and shared neurosignal analyses to support multi-centre studies in Parkinson's disease. J Biomed Inform 2014;52:92–104.

[68] Zhao L, Lee K, Hu J. Generating xml schemas for dicom structured reporting templates. J Am Med Inform Assoc 2005;12(1):72–83.

[69] Yu C, Yao Z. XML-based DICOM data format. J Digital Imging 2010;23(2):192–202.

[70] Haak D, Page CE, Reinartz S, Krüger T, Deserno TM. DICOM for clinical research: PACS-integrated electronic data capture in multi-center trials. J Digital Imging 2005;28(5):558–566.

[71] McIntosh LD, Sharma MK, Mulvihill D, Gupta S, Juehne A, George B, et al. catissue suite to openspecimen: Developing an extensible, open source, web-based biobanking management system. J Biomed Inform 2015;57:456–464.

[72] Qiao L, Li Y, Chen X, Yang S, Gao P, Liu H, et al. Medical high-resolution image sharing andelectronic whiteboard system: A pure-web-based system for accessing and discussing lossless original images in telemedicine. Comput Meth Prog Biomed 2015;121:77–91.

List of Tables

	Paper		Database			Data Exchange			Security					
		Web-based application	PACS	Database	Image modality	XML documents	XML-server	System architecture	Security	Authentication	Data Encryption	Anonimization	Web-security system	System architecture
1999	*Halamka [22]*	✓	x	SQL-Server	CT	x	x	n.d	✓	✓	✓	x	✓	HL7
2000	*Fernàndez-Bayó [11]*	✓	✓	SQL-Server	CT,MRI	x	x	n.d	✓	✓	x	x	x	n.d
2001	*Defteros [12]*	✓	x	SQL-Server	MRI	✓	x	EHCR	x	x	x	x	x	n.d
	Pappadakis [23]	✓	✓	own DB	n.d	✓	x	R-EHCR	✓	✓	✓	x	✓	CORBA
2002	*Sinha [24]*	✓	✓	own DB	CT	✓	x	HIS.	✓	✓	✓	x	x	HIS
	Rosset [25]	✓	✓	n.d	CT,US	x	x	n.d	✓	✓	x	✓	✓	CBIR
	Rassinoux [26]	✓	x	own DB	n.d	✓	x	HL7	✓	✓	x	x	✓	HL7
	Schwitzer02 [1]	✓	x	Cochrane, DIPEx	n.d	x	x	n.d	✓	✓	x	x	x	n.d
2003	*Zhang [27]*	✓	✓	own DB	CT	✓	✓	IIS	✓	✓	✓	✓	✓	HIS
	Müller [3]	✓	✓	own DB	CT,MRI	x	x	n.d	x	x	x	x	x	n.d
	van der Haak [28]	✓	✓	IS- H*MED	n.d	x	x	n.d	✓	✓	✓	x	✓	HIS
2004	*Matsopoulos [13]*	✓	✓	own DB	MRI,US	✓	x	n.d	✓	✓	x	x	x	n.d
	Müller [29]	✓	✓	own DB	CT,MRI	x	x	n.d	✓	x	x	x	x	n.d
	Gritzalis [30]	✓	✓	n.d	n.d	✓	x	n.d	✓	✓	✓	x	✓	EHR
	Kluge [31]	✓	x	n.d	n.d	x	x	n.d	✓	✓	x	x	✓	EHR
2005	*Hastings [32]*	✓	✓	MAkoDB	MRI	✓	x	GridPACS	✓	x	x	x	✓	OGSA
	Coeira [33]	✓	x	MySQL	n.d	✓	✓	Apache	x	x	x	x	x	n.d
2006	*Kautelakis [34]*	✓	✓	Oracle9iAS	n.d	✓	x	n.d.	✓	✓	✓	x	x	PACS
	Kurc [8]	✓	✓	MySQL	n.d	✓	✓	MakoDB	✓	✓	x	x	x	CAD
2007	*Güld [35]*	✓	✓	GridPACS	n.d	✓	x	n.d.	x	x	x	x	x	n.d
	Tahmoush [36]	✓	✓	MySQL	MRI	✓	x	x.d	✓	✓	✓	x	✓	RMI
	Doi [37]	✓	✓	own DB	CT, MRI	x	x	n.d	x	x	x	x	x	n.d
	Arnold [14]	✓	✓	MySQL	n.d	x	✓	XML-RPC	✓	✓	x	x	x	n.d
	Marcos [38]	✓	✓	MEDIMAN	MRI	✓	✓	OGSA-DAI	x	x	x	x	x	n.d
	Sucurovic [39]	✓	x	n.d	n.d	x	x	n.d	✓	✓	✓	x	✓	EHR
2008	*Choe and Yoo [40]*	✓	x	n.d	n.d	✓	x	HIS-CAC	✓	✓	✓	x	✓	HIS
	Oster [41]	x	x	CaGrid	CT	✓	x	GRID	✓	✓	x	x	✓	GAARDS
2009	*Hsu [20]*	✓	✓	MySQL	X-rays	✓	✓	H IS-RIS	x	x	x	x	x	n.d
	van der Linden [42]	✓	x	own DB	MRI	x	x	n.d	✓	✓	✓	x	✓	EHR
	Long [6]	✓	x	own DB	n.d	✓	x	n.d	x	x	x	x	x	n.d
2010	*Wang [43]*	✓	✓	OsiriX	n.d	x	x	Retinal	x	x	x	x	x	n.d
	Do [44]	✓	✓	MySQL	CT	x	x	x	✓	✓	✓	✓	✓	RIS
	Mahmoudi [45]	✓	✓	n.d	n.d	x	x	n.d.	✓	✓	x	x	x	n.d
	Ortega [21]	✓	x	own DB	CT	✓	x	XML-RPC	✓	✓	x	x	x	n.d
2011	*Gao [46]*	✓	✓	QBE	X-Rays	✓	x	n.d	✓	x	x	x	x	n.d
	Akül [9]	✓	✓	EMR	CT	x	x	n.d	x	x	x	x	x	n.d
	Korenblum [47]	✓	✓	MySQL	CT	✓	x	LibXML.	x	x	x	x	x	n.d
	Rajala [48]	✓	✓	CRDAS	MRI	x	x	n.d	✓	✓	✓	✓	✓	CRDAS
	Bond [49]	✓	✓	ECG	MRI	✓	✓	HL7	x	x	x	x	x	n.d
	Neubauer [50]	✓	✓	SQL-Server	n.d	x	x	n.d	✓	✓	✓	✓	✓	HSM
	Haas [51]	✓	x	own DB	n.d	x	x	n.d	✓	✓	✓	x	✓	EHR
	Baltasar [52]	✓	✓	own DB	X-Rays	x	x	n.d	x	x	x	x	x	n.d
2012	*de Hwang [10]*	✓	✓	own DB	CT, X-Rays	x	x	n.d	x	x	x	x	x	n.d
	de Welter [5]	✓	✓	n.d	X-Rays	✓	✓	HIS-RIS	x	x	x	x	x	n.d
	Gerstmair [53]	✓	✓	RIS	CT	x	x	n.d	x	x	x	x	x	n.d
	Carrión [54]	✓	x	myPHR	n.d	x	x	n.d	✓	✓	✓	x	✓	PHR
	de Heras [18]	✓	x	own DB	n.d	x	x	n.d	x	x	x	x	x	n.d
2013	*Jorritsma [55]*	✓	✓	n.d	CT,MRI	x	x	n.d	x	x	x	x	x	n.d
	Chipman [56]	✓	x	MySQL	n.d	✓	x	HL7	x	x	x	x	x	n.d
	Agarwal [57]	✓	x	own DB	n.d	x	x	n.d	✓	✓	x	x	x	PHR
	Kuijpers [2]	✓	x	own DB	MRI	x	x	n.d	✓	✓	x	x	x	n.d
2014	*Huang [58]*	✓	✓	n.d	CT,MRI	x	x	n.d	✓	✓	x	x	x	n.d
	van de Watering [59]	✓	✓	EMR	n.d	x	x	n.d.	✓	✓	✓	x	x	n.d
	Schweiger [60]	✓	x	n.d	n.d	x	x	n.d.	x	x	x	x	x	n.d
	Biternas [61]	✓	x	n.d	n.d	✓	✓	SpinXML	x	x	x	x	x	n.d
	Kammerer [62]	✓	✓	MySQL	CR	x	x	n.d	✓	✓	x	✓	✓	XAMPP
	Hualei [17]	✓	✓	n.d	CT, X-Rays	✓	✓	eXistdb	✓	✓	✓	x	✓	EHR
	Sethi [63]	✓	x	n.d	n.d.	x	x	n.d	✓	✓	✓	✓	✓	HSM
2015	*Mata [15]*	✓	✓	MySQL	X-Ray	✓	✓	eXistdb	✓	✓	x	✓	✓	n.d

Table 1: Classification of applications using PACS and databases. *(n.d) means not defined.

List of Figures

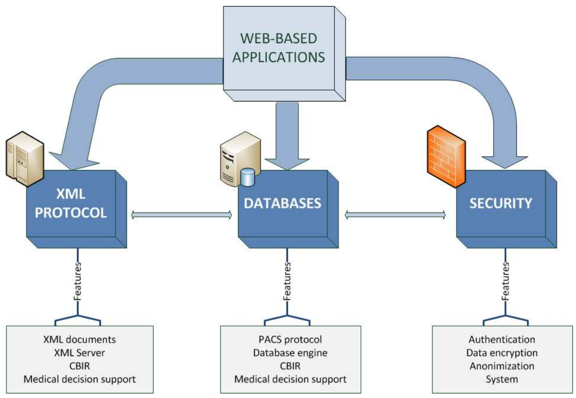


Figure 1: Web-based medical applications links a variety of topics.

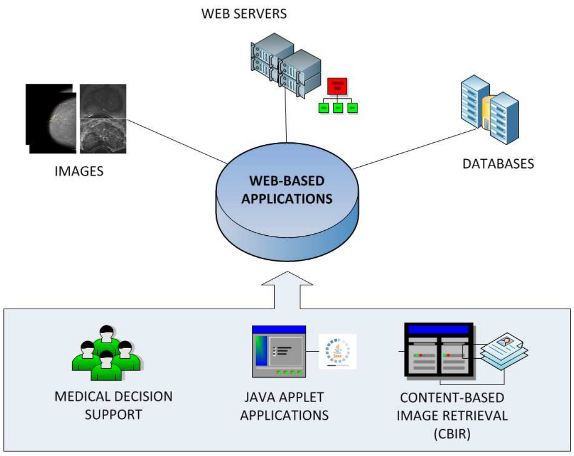


Figure 2: Web-based applications allows to create a (visual) interface between stored medical data and user applications.

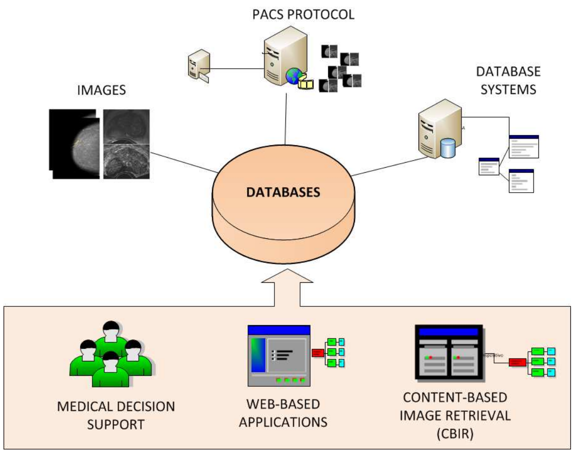


Figure 3: Web-based applications rely on the use of databases. These databases may be categorized according to their architecture and the kind of data/images they contain.

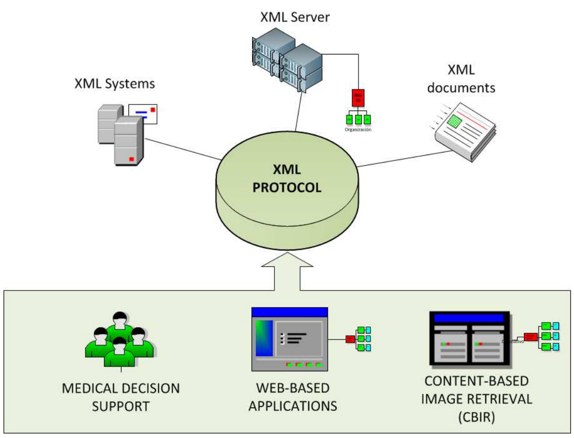


Figure 4: The XML protocol is used by many web-based applications to exchange information. XML documents are stored in XML servers and used by XML systems.

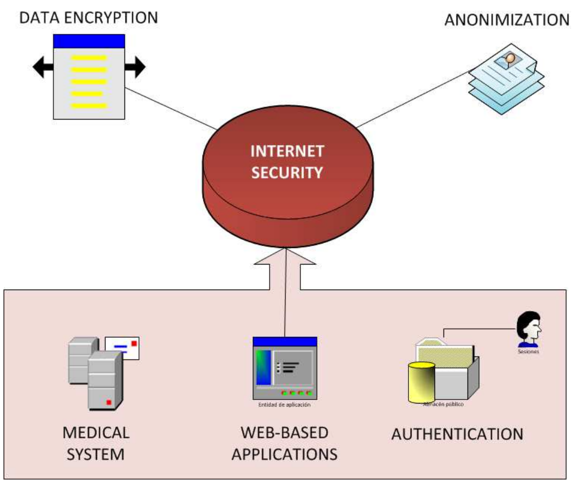


Figure 5: Security in web-based applications relates with the user authentication and the encryption and anonymization of the data.

LaTeX Source Files

Click here to download LaTeX Source Files: journal.tex

Figure

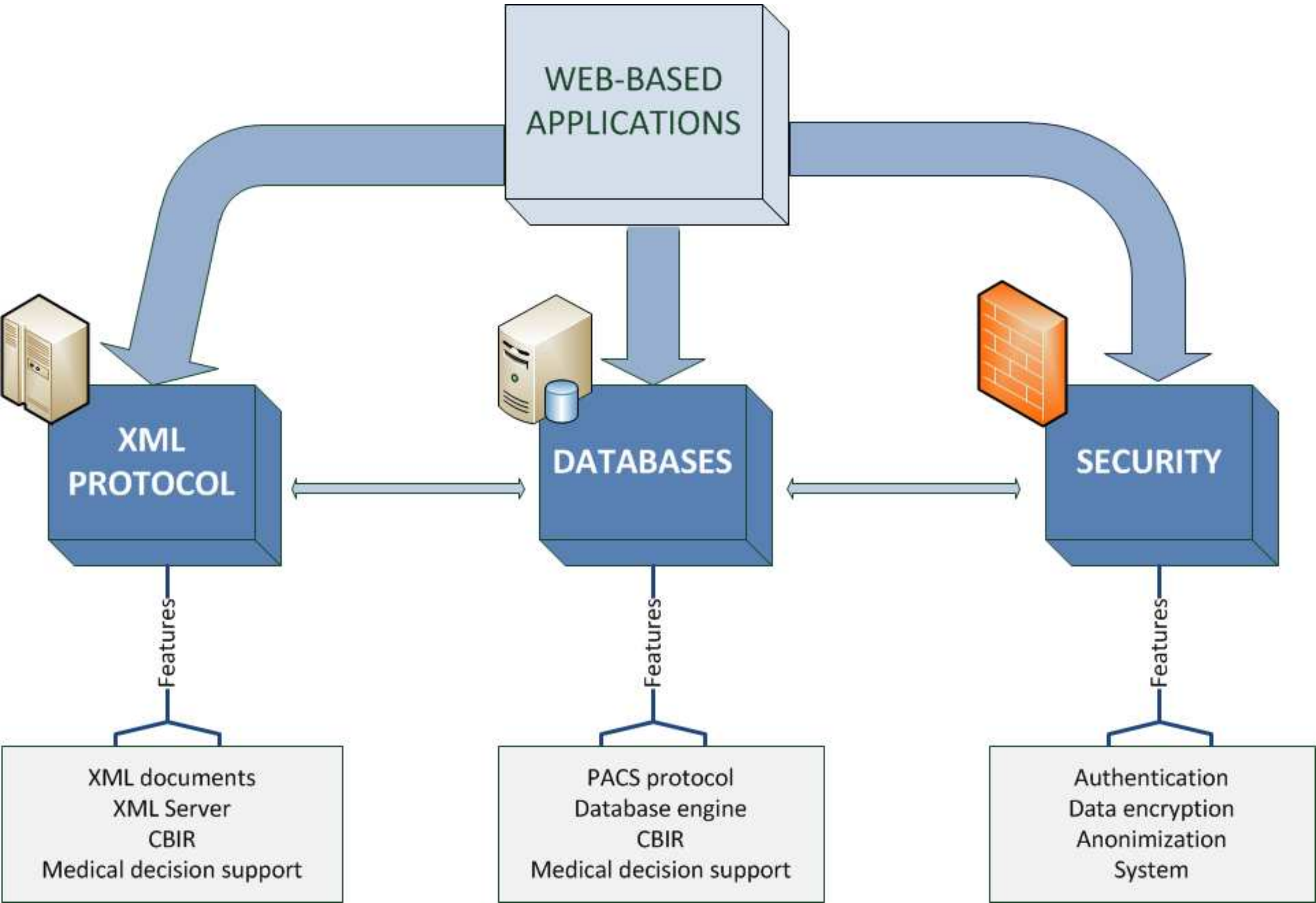

WEB-BASED
APPLICATIONS
XML
PROTOCOL
DATABASES
SECURITY
Features
Features
Features
XML documents
XML Server
CBIR
Medical decision support
PACS protocol
Database engine
CBIR
Medical decision support
Authentication
Data encryption
Anonimization
System

Figure2

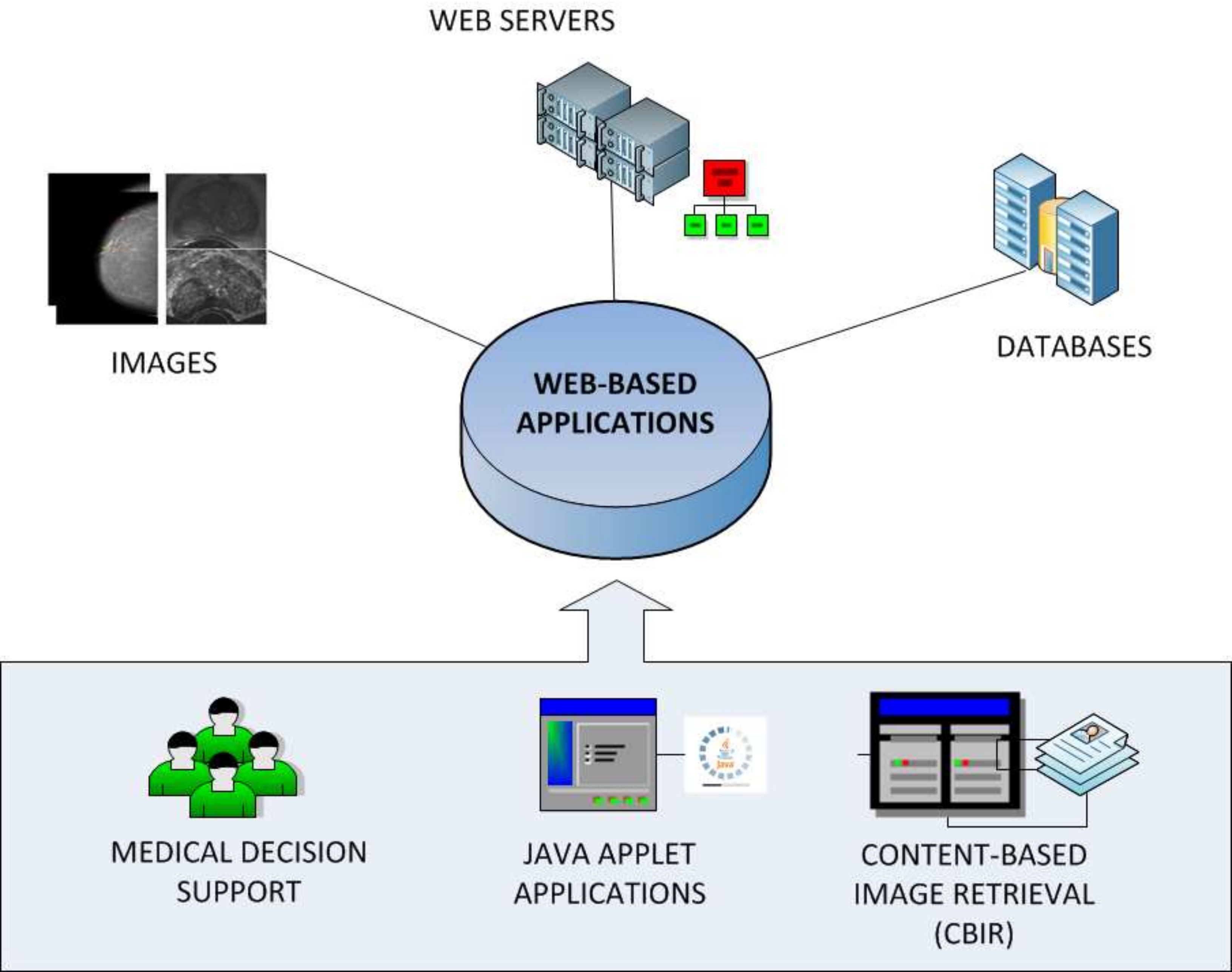

WEB SERVERS
IMAGES
DATABASES
WEB-BASED
APPLICATIONS
MEDICAL DECISION
SUPPORT
JAVA APPLET
APPLICATIONS
CONTENT-BASED
IMAGE RETRIEVAL
(CBIR)

Figure3

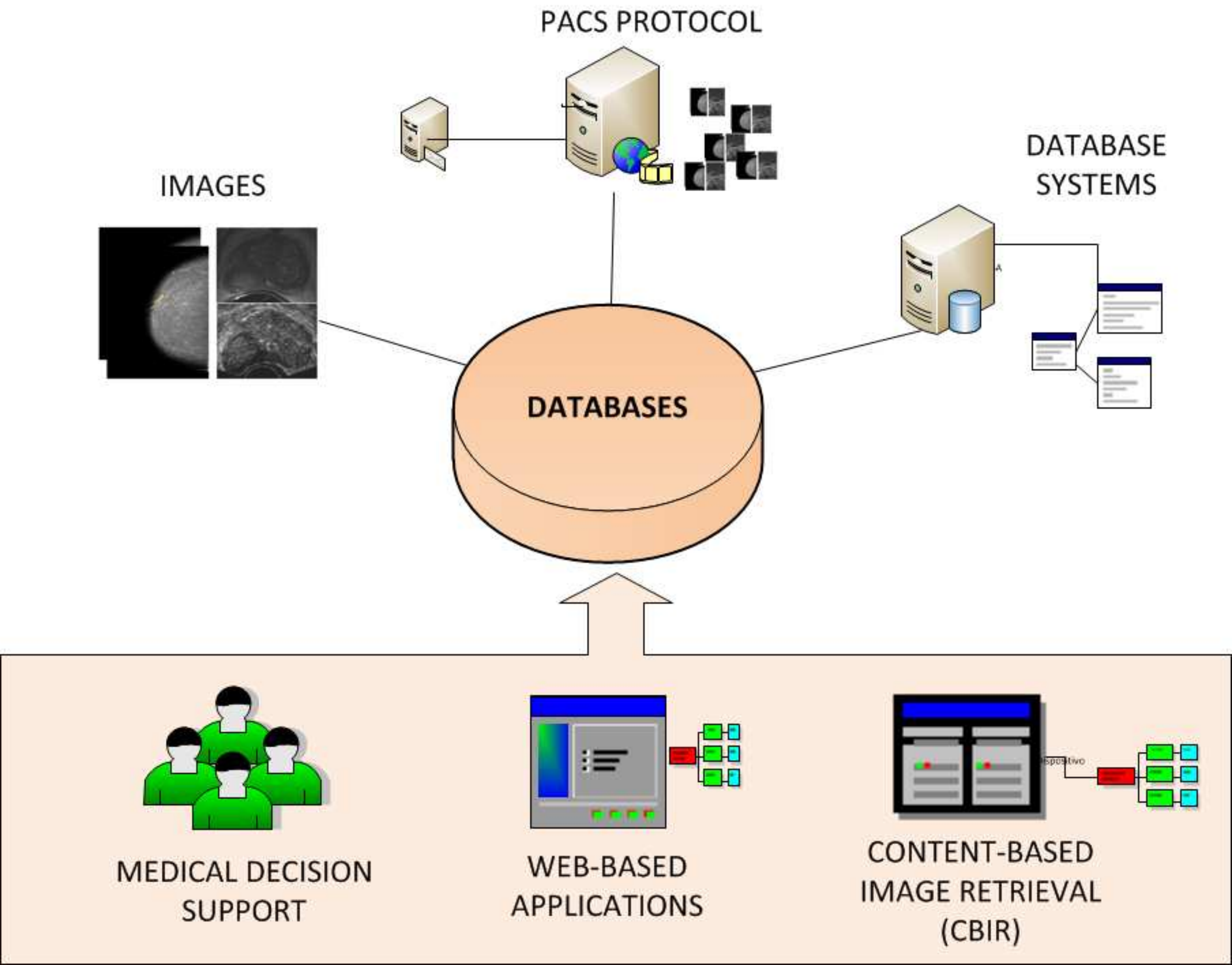

PACS PROTOCOL
DATABASE SYSTEMS
IMAGES
DATABASES
MEDICAL DECISION SUPPORT
WEB-BASED APPLICATIONS
CONTENT-BASED IMAGE RETRIEVAL (CBIR)

Figure4

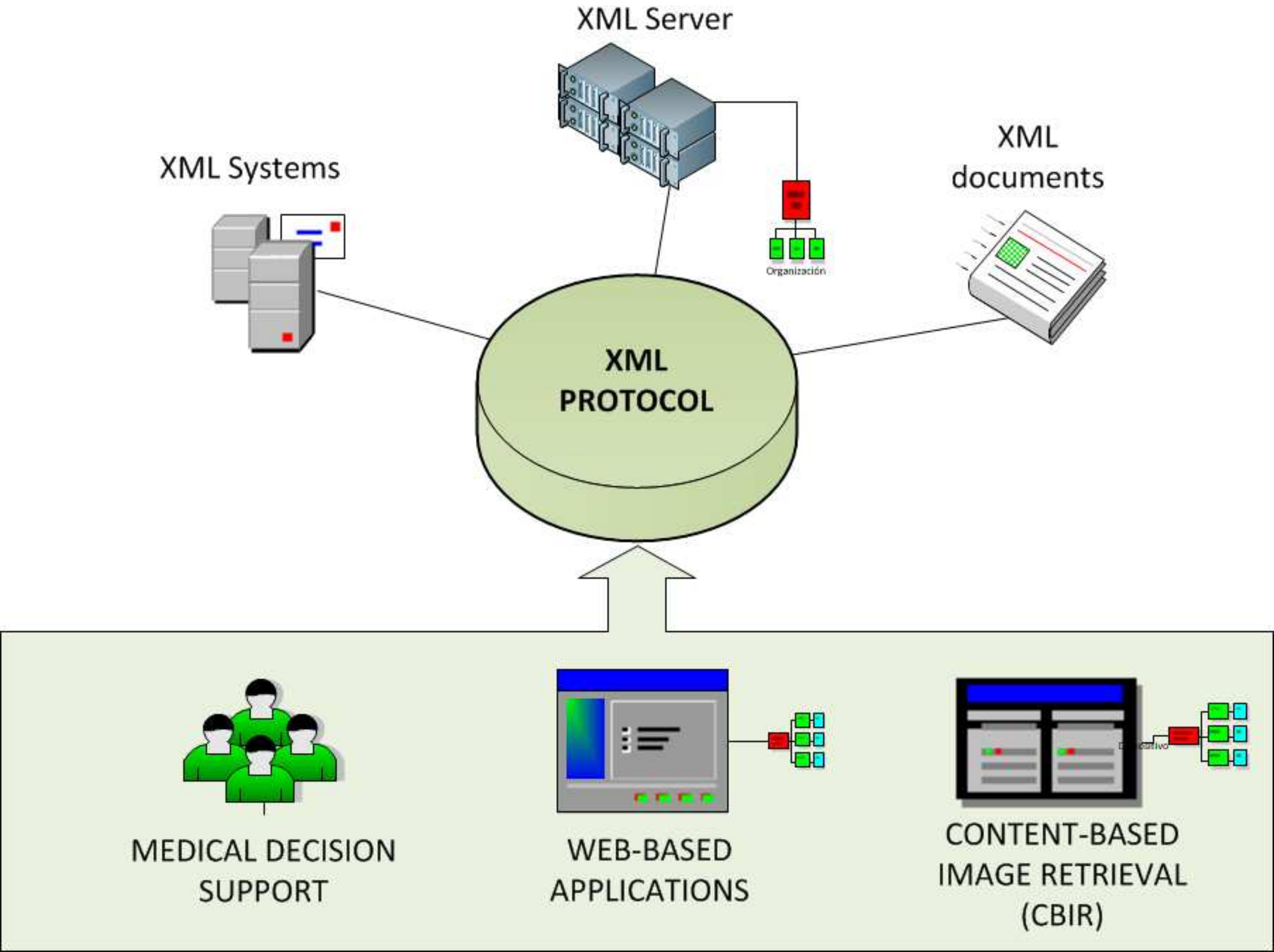
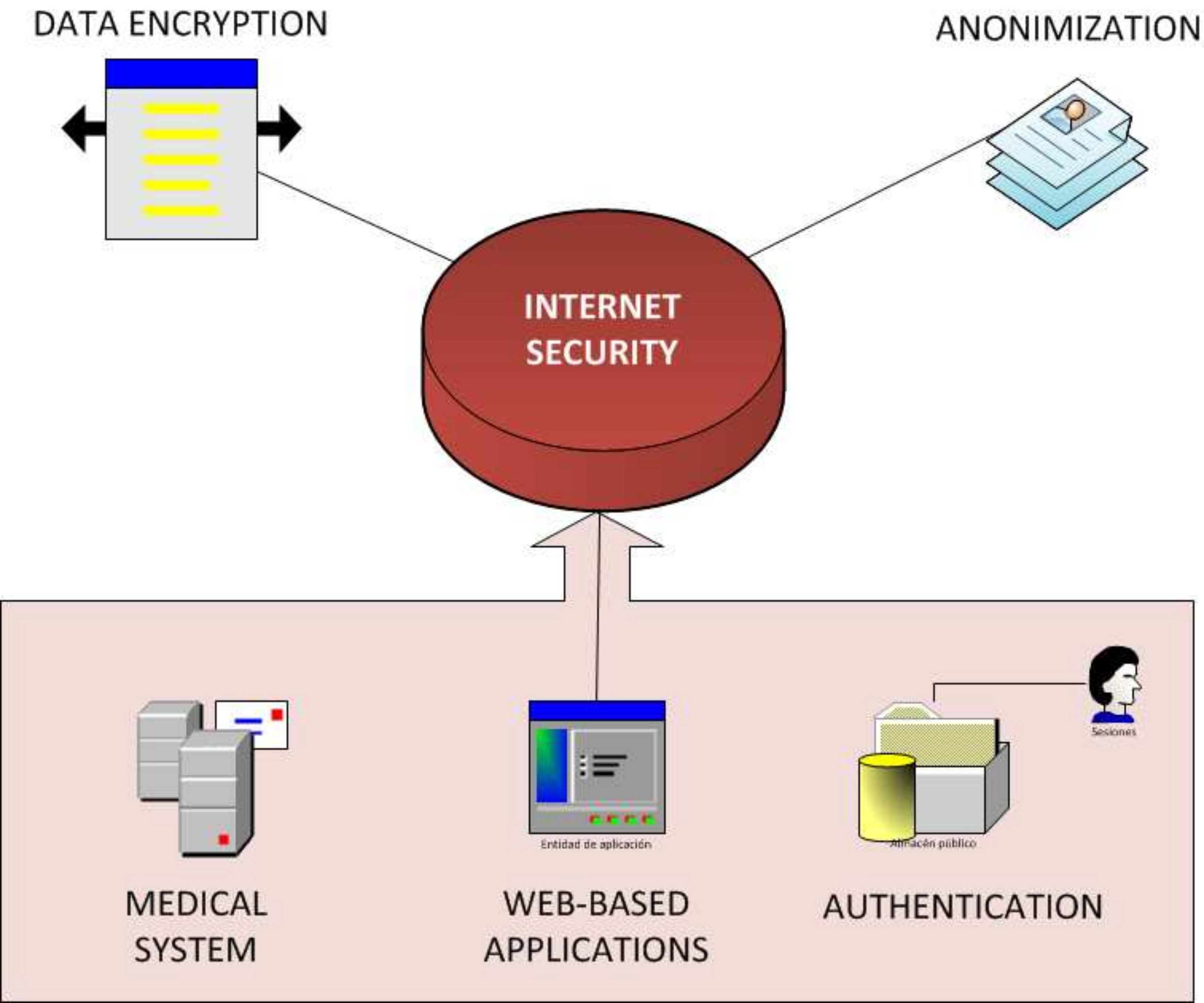

XML Server
XML Systems
XML
documents
XML
PROTOCOL
MEDICAL DECISION
SUPPORT
WEB-BASED
APPLICATIONS
CONTENT-BASED
IMAGE RETRIEVAL
(CBIR)

Figure5


DATA ENCRYPTION
ANONIMIZATION
INTERNET
SECURITY
Entidad de aplicación
Almacén público
Sesiones
MEDICAL
SYSTEM
WEB-BASED
APPLICATIONS
AUTHENTICATION