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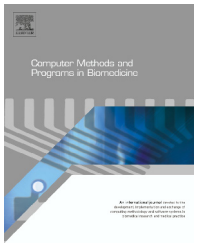

Medical high-resolution image sharing and electronic whiteboard system: A pure-web-based system for accessing and discussing lossless original images in telemedicine

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ABSTRACT

There are various medical image sharing and electronic whiteboard systems available for diagnosis and discussion purposes. However, most of these systems ask clients to install special software tools or web plug-ins to support whiteboard discussion, special medical image format, and customized decoding algorithm of data transmission of HRIs (high-resolution images). This limits the accessibility of the software running on different devices and operating systems. In this paper, we propose a solution based on pure web pages for medical HRIs lossless sharing and e-whiteboard discussion, and have set up a medical HRI sharing and e-whiteboard system, which has four-layered design: (1) HRIs access layer: we improved an tile-pyramid model named unbalanced ratio pyramid structure (URPS), to rapidly share lossless HRIs and to adapt to the reading habits of users; (2) format conversion layer: we designed a format conversion engine (FCE) on server side to real time convert and cache DICOM tiles which clients requesting with window-level parameters, to make browsers compatible and keep response efficiency to server-client; (3) business logic layer: we built a XML behavior relationship storage structure to store and share users' behavior, to keep real time co-browsing and discussion between clients; (4) web-user-interface layer: AJAX technology and Raphael toolkit were used to combine HTML and JavaScript to build client RIA (rich Internet application), to meet clients' desktop-like interaction on any pure webpage. This system can be used to quickly browse lossless HRIs, and support discussing and co-browsing smoothly on any web browser in a diversified network environment. The proposal methods can provide a way to share HRIs safely, and may be used in the field of regional health, telemedicine and remote education at a low cost.

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1. Introduction

Modern medical imaging technology can provide high-resolution images (HRIs) that contain detailed anatomical structure and help doctors to diagnose in clinical practice. HRIs, including radiological photos, clinical images, etc., are important data sources for diagnosis, consultation, and case discussion [1–4]. In the Internet age, doctors wish to conveniently access images and have discussions with other doctors via e-whiteboard communication [5,6]. Additionally, patients wish to access to their radiological examination reports from anywhere for online consultation. These requirements give rise to two technical problems: how to rapidly access lossless medical HRIs in a diversified network environment and in different client devices without installing special software, and how to realize convenient and effective communication online among different client devices.

For rapidly accessing medical HRIs, including DICOM (Digital Imaging and Communications in Medicine) [7], clinicians always try to archive high-quality medical images [8,9], however, there is much limited bandwidth in some remote areas of developing countries and an interface bottleneck in some areas of different countries [10] where HRIs sharing and discussion are most required. Therefore, lossless and rapid sharing of the HRIs is becoming more important. Currently, the main solutions include: (1) Upgrading the existing Internet network platform to meet the regional PACS (Picture Archiving and Communication Systems). This way has high costs, especially in remote and poor areas. (2) Reducing the image resolution and quality while satisfying the needs of the clinical diagnosis, e.g., using image processing technology to compress lossy images [11]. This way may get a risk of losing important information [12,13], or catch a complex process that client needs to be customized for special decoding and reconstruction software. (3) Using new network interactive technologies to change the whole transmission into on-demand transmission [13–18]. For example, [13–16] used JPEG2000, which has been included in DICOM supplement [22] and has very good network transmission characteristics, including *Region of Interest* (*ROI*), *progressivity* and *scalability*. But JPEG2000 has not been directly supported by web browsers and desktop image browsers in the mainstream market. Users must customize decoding and reconstruction programs on the client side. The problems are as follows: first, the client's software products must be independently developed to adapt to different operating systems (OS) and hardware characteristics, which increases the cost of software development, hardware purchasing and deployment. And the limitation of client terminals and OS does not serve the purpose of case discussion at anytime and anywhere. Second, without customized software on the client side, *progressivity* would be unable to play a role. Some solutions deploy the image processing work on the web server [18], which can timely decode and reconstruct what clients request and convert into general image formats that client browsers can accept without installation. But repeatability of transmission may occur, e.g. while zooming or panning an image, and the required data would be entirely transmitted as a new image but not as a progressive superposition. On the other hand, because ROI real-time processing, progressive transmission, decoding and reconstruction all need to take up a certain amount of computing resource, if all of the computing focus is on the server side, a large-scale application to the server load maybe a problem [19]. Here, Shen et al. [17] adopted tile-based transmission to solve redundant transmissions for each fixed scaling resolution, and Lien et al. [18] further reduced the complexity of computing by prestoring tiles according to a basic tile-pyramid without using JPEG2000. Since a household display device with limited size and colors cannot display all the information while focusing on the image details, our study is built on the basis of solution 3, using the idea of tile-based on-demand transmission, to keep lossless large image transmission. However, [17,18] only supported a 4× ratio zooming which was limited by basic tile-pyramid model, which is also the ideal scaling factor of JPEG2000 [20,21]. While 4× ratio zooming does not affect users reading extreme HRIs such as satellite images and microscope images [18,23,24], in practice it may be not convenient to read medical HRIs with such resolutions as 3004×2480. In our study, we should redesign a novel tile-pyramid model named unbalanced ratio pyramid structure (URPS) to adapt to the reading habits of doctors for medical HRIs. Furthermore, to insure client devices compatible, we need to emphasize on "No Installation" on client side, since both JPEG2000 and DICOM cannot be directly presented in web browser, a format conversion engine (FCE) should be built on the server side to manage conversion process and history caches.

On the other hand, for online communication among different client devices, there are many electronic whiteboard systems available for multi-site conferences in telemedicine, such as image co-browsing and synchronous annotation between remote clients, it is important to be clear, effective and intuitive [25–27]. Fromme et al. designed an electronic whiteboard system [25], like what in most hospitals do, but it was restricted to its local-area network because of the data size of HRIs sharing and the structure of P2P (Peer to Peer), and needed independent IP addresses for clients, that may be an issue in countries with limited IPv4 resources [10]. Lim et al. [26] and Zhang et al. [27] respectively designed a web-based interactive medical image processing, yet they need to install a Java Applet or other plug-ins. With a diversity of Internet terminals, such as the IPad, android machines and PCs, a platform with good versatility and which does not require installation is more valuable [28,29].

In this study, we expect to design a set of methods for medical HRIs rapid accessing, presentation, and online communication in pure web environment. For HRIs rapid accessing, we plan to improve tile-pyramid model to adapt to the reading habits of doctors for medical images; for presentation, we plan to build a format conversion engine (FCE) to solve the problems of DICOM tiles browsing compatibility and response efficiency to server-client; for online communication, we plan to design an accurate and clear XML structure to store and share users' behavior. Finally, we hope to set up a medical high-resolution image sharing and electronic whiteboard system that can share medical HRIs and support e-whiteboard discussion in a low bandwidth network.

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