Error Resilient Transmission and Security Filtering of Medical Images

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Abstract
The increasing adoption of information systems in healthcare has led to a scenario where patient information security is more and more being regarded as a critical issue. Allowing patient information to be in jeopardy may lead to irreparable damage, physically, morally, and socially to the patient, potentially shaking the credibility of the healthcare institution. This demands adoption of security mechanisms to assure information integrity and authenticity. Structured descriptions attached to medical image series conforming to the DICOM standard make possible to fit the collections of existing digitized images into an educational and research framework.

Progressive transmission of medical images through Internet has emerged as a promising protocol for teleradiology applications. The major issue that arises in teleradiology is the difficulty of transmitting large volume of medical data with relatively low bandwidth. Recent image compression techniques have increased the viability by reducing the bandwidth requirement and allowing cost-effective delivery of medical images for primary diagnosis.

General Terms
Transmission of Medical Images, Security Issue in Transmission, Measuring Lossless compression effectiveness ,Compression Algorithm

Keywords
DICOM (Digital Imaging and Communications in Medicine) Image Compression, Lossless Compression, FWT with Daubechie's Wavelet

Introduction

One of the main challenges of the current medical imaging systems is dealing with large amounts of data acquired by the modern modalities. Indeed, new modalities can generate large amounts of high-quality images in a short time. In fact, one of the most important demands toward dealing with large amount of data is to provide a way for fast data transmission between medical imaging applications. The most common approach toward enhancing the speed of data transmission is using compression techniques. This approach is only effective when the speed of the connecting media is not much compared to the compression/decompression computing time, so adding the overhead of compression/decompression times is worth. Hence, as a matter of fact, compression techniques are ineffectual in high-speed networks.

Background

With the DICOM standard, it is easy to eliminate textual information such as patient name and ID.However for digitized films or previous history images, a computerized detection and elimination algorithm is needed. The problem of text identification arises in many applications other than medical security. However, the algorithms used in such systems are not designed to handle superimposed text because it is difficult to differentiate the edges of text from the edges of the medical objects in the image.The security filtering process in our system consists of an efficient and accurate algorithm to distinguish areas with and without textual information in digital or digitized medical images. Areas with text can then be blurred or striped. Because variations in the diagonal directions can be found in almost all Roman characters or Arabic numbers, we use Daubechies' wavelets and analysis techniques to detect the high frequency variation in the diagonal direction that is indicative of text. A mask is used to preserve the losslessness of non-textual areas. With some basic knowledge of the machine used to create the image, we are able to eliminate only sensitive patient identification information while retaining the medical information in the image.Excellent results have been obtained in experiments using a large set of realworld medical images many with superimposed text.

Transmission of Medical Images

Parallel transmission between two medical imaging systems is proposed and assessed. The proposed approach is based on Digital Imaging and Communications in Medicine (DICOM) protocol. DICOM is the standard storage format as well as the transmission protocol, for medical images. It has several advantages such as interoperability, integrity and consistency, which have made it the world wide practical standard for interconnecting medical imaging systems.The proposed method uses parallel connections to carry out the image transformation between two DICOM application entities. These parallel connections are used in the Storage Services in the DICOM protocol. In fact, the method is a way to improve the speed of data transmission in high-speed networks where data compression techniques are not effective.

Security Issue in Transmission

Before digital medical images in computer-based patient record systems can be distributed online, it is necessary for confidentiality reasons to eliminate patient identification information that appears in the images. This requires an automatic security filtering algorithm for on-line medical image distribution using Daubechies' wavelets. With the advancements of the World-Wide Web, the Internet and medical imaging technology, it is becoming increasingly difficult to maintain and retrieve digital health care information. Besides the traditional textual data such as patient reports, health care records are being filled with X-ray images, MRI scans, CT scans, 3-D volume reconstructions and video streams.Efficient security filtering for digital medical images is desirable before medical images (Figure 1) can be transmitted to researchers and external users.

Figure 1-Text and Non-Text areas in Medical Images

Compression Techniques

LOSSY VS. LOSSLESS COMPRESSION

Despite advances in lossy compression, lossless compression remains useful for many medical imaging applications.It is still unclear in what situations lossy compression is appropriate for short or long term archival or for transmission for diagnostic interpretation.

LOSSY COMPRESSION

Lossy compression reduces a file by permanently eliminating certain information, especially redundant information. When the file is uncompressed, only a part of the original information is still there but the user may not notice it . Lossy compression is generally used for video and sound, where a certain amount of information loss will not be detected by most users. The Joint Photographic Experts Group (JPEG) image file, commonly used for photographs and other complex still images on the Web is an image that has lossy compression. Using JPEG compression, the creator can decide how much loss to introduce and make a trade-off between file size and image quality.

Of course, with lossy compression, we can't get the original file back after it has been compressed. One get stuck with the compression program's reinterpretation of the original. For this reason, we can't use this sort of compression for anything that needs to be reproduced exactly.

LOSSLESS COMPRESSION

With lossless compression, every single bit of data that was originally in the file remains after the file is uncompressed. All of the information is completely restored. This is generally the technique of choice for text or spreadsheet files, where losing words or financial data could pose a problem. The Graphics Interchange File (GIF) is an image format used on the Web that provides lossless compression. This is used in software applications, databases and presidential inauguration speeches,Diagonistic problems.

Measuring Lossless Compression Effectiveness

The effectiveness of lossless compression schemes can be described using a relative measure, "Compression Ratio" or by describing an absolute measure the "Bit Rate" of an image. The Bit Rate is the average number of bits (fractional) required to encoded a pixel and is computed from the total number of bits encoded divided by the number of pixels. Such a value is useful when comparing different schemes applied to one image or multiple images with the same bit depth which in the case of this study they do not. Accordingly, a relative measure, the compression ratio is used here. Compression Ratios are computed from different metrics of size.One approach common in the literature is to compare the ratio of the number of bits in the uncompressed image to the number of bits in the encoded image. In the case of eight bit images common in non-medical applications this is straightforward and provides a meaningful comparison. Unfortunately, the number of bits in an uncompressed medical image may be hard to determine. Most DICOM images contain a description of bit depth that may be considered as the “nominal” bit depth, but this may be artificially large for computing compression ratios. For example, most MR images have a nominal bit depth of 16, though the actual pixel values may be encoded in fewer bits.

The System

The architecture of the system is shown in Figure 2.

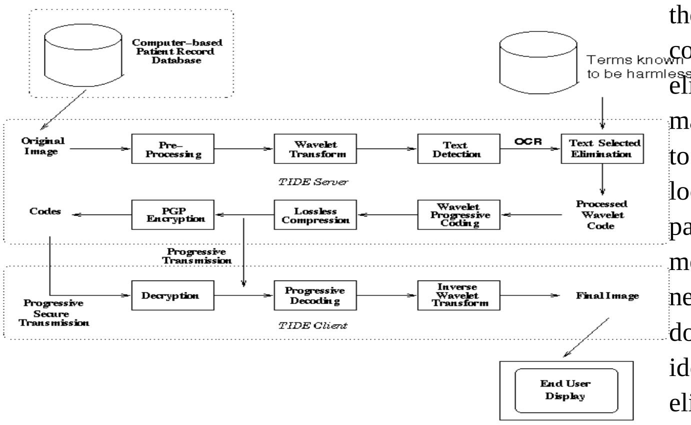

Figure 2-Architecture of the System

We apply an N-level fast wavelet transform (FWT) with Daubechies wavelet to each medical image where N is determined adaptively by the image size as depicted in Figure-3. If the image is of DICOM standard, we may eliminate the patient identification information without processing the image content.

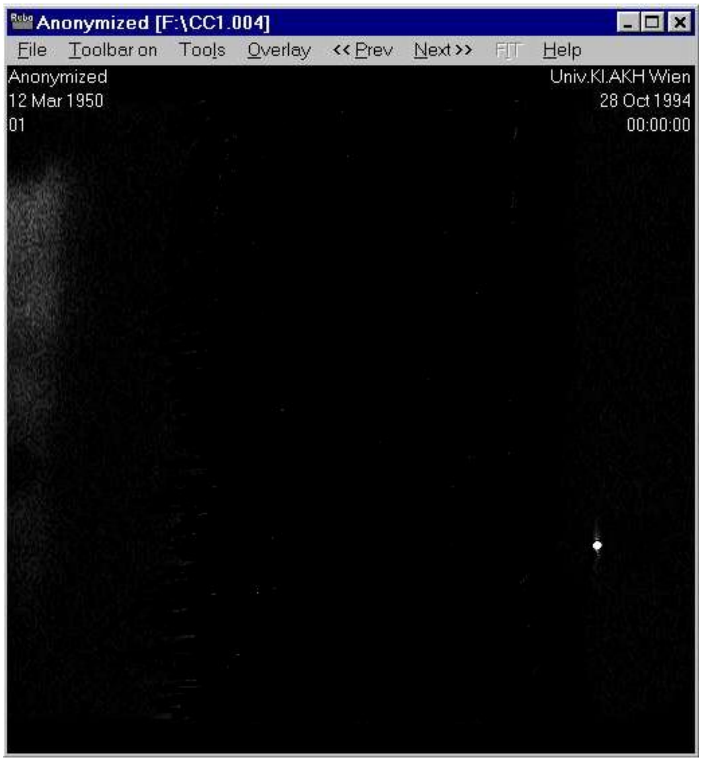

Figure 3-Text pixels extracted after processing the wavelet transform

For non-DICOM images, we extract and analyze the lower right-hand corners of each level of the transform matrix, where the diagonal directional high frequency information is located, to obtain a mask containing only the areas with textual information. Once such a mask is computed, we apply it to all the high-frequency bands to eliminate the text within areas with textual data. Or, we may apply the mask selectively to all the frequency bands to block the areas with text. Knowledge of the rough location (e.g.,which one of four corners) of the critical patient identification information of certain type of medical images is used to eliminate only information needed to be deleted while preserving the rest.When we do not have knowledge of the rough location of patient identification information, we may apply the mask to eliminate all textual information within the medical image as shown in Figure 4.

Figure 4-Patient identification information is eliminated

To achieve secure transmission, we may also apply a Pretty Good Privacy (PGP) encryption to the code segments before sending the data to the client via public network.

Compression Algorithm

In this paper we apply N-level Fast Wavelet Transform (FWT) with Daubechie's Wavelet to each medical image where N is determined adaptively by the image size.
Our text detection algorithm has several immediate advantages-

1. Unlike traditional approaches, such as the neural network, algorithm does not depend on the actual font size, font type and style of the text in the medical image.
2. It is proposed to use Daubechie's Wavelets rather than a traditional edge detector to capture the high frequency information in the images. This reduced the dependence of the results on the quality or the sharpness of the images.
3. The algorithm does not rely on the color of the image or the text. It also has minimum dependence on the contrast between text and background objects.
4. It is faster than other algorithms due to our adaptive multiresolution approach.
5. Wavelet-based algorithm using Daubechie's Wavelets can be easily integrated with cutting-edge image compression, compressed-domain indexing and processing algorithms.
6. Experiments indicate that the algorithm is capable of handling images with superimposed hand-written text and even foreign languages.

Results

In this paper, we have demonstrated an efficient wavelet-based security filtering algorithm for on-line medical image distribution. This algorithm has been implemented by testing about 75 medical images of different modalities,collected from different sources. Some of them are downloaded from the world-wide web and medical imaging newsgroups. The textual information detection and elimination module takes about 1 second of CPU time to process a 12-bit medical image of size 512 x 512. The algorithm is a linear algorithm with respect to the size of the image. Besides the fast speed, the algorithm has achieved remarkable accuracy. It successfully detected and eliminated all of the critical textual information within the corners of the medical images.

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