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Comparative Study of Various Lossless Compression methods of Medical Images and Enhancing its Security

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Abstract*—The digital image processing is exponentially increasing in today's world which leads to storage and transmission problems. Many methods have been introduced in last decay that focuses on lossy and lossless compression. Medical images should be subjected to loss-less compression that use variable length codes, proposed by Huffman (David Huffman, 1952).Compression ratio and storage space are inversely proportional. Hence effective compression technique results in a reduction in storage space, thereby improving the bandwidth and speed of transmission of medical images with no added complexity and resources.*

Keywords:*—Image Compression, Lossless Compression, DICOM (Digital Imaging and Communications in Medicine), SEGC-N-D Compression, CSPIHT, Wavelet transform using Matlab, Security Enhancement of Medical Images.*

1. INTRODUCTION

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.

Our aim is to design an application to provide lossless compression of DICOM images by applying Daubechie's wavelet and run-length encoding. This helps in better bandwidth utilization of the networks. At the same time, also aims at providing the security mechanism for DICOM images by removing the textual elements of the medical image.

2. LITERATURE REVIEW

The study on the relevant papers related to the topic would not have been possible if the researchers did not routinely place their code and papers on the Internet for public access. Through various sources like books and papers available on Internet, library, digital library relevant papers were surveyed. Some of them are listed below.

Abdullah Al Muhit [1] :

This paper gives the idea about the system for high-quality image transmission applications over error-prone wireless channels requiring low transmission power. LDPC coder admits low-complexity encoding and decoding. The system has an attractive feature, which enables it to optimize channel protection for a source compressed at less than, equal to or greater than available transmission rate. The novelty lies in its ability to discard the less important source layers to accommodate optimal channel protection to more important ones.

Dr. J. Janet, Mohandas Divya, S.Meenalosini [2] :

This paper reveals about the importance of Telemedicine and Medical Image compression scheme based on contourlet transform with Huffman coding which gives PSNR value ranging from 32.8-35.61 dB for various 256×256 CT,MRI Medical Images.

Lalitha Y.S, Latte M.V [3] :

This paper discusses a medical application that contains a viewer for digital imaging and communications in medicine (DICOM) images as a core module. The proposed application enables scalable wavelet-based compression, retrieval, and decompression of DICOM medical images and also supports ROI coding/decoding. The methodology involves extracting a given DICOM image into two segments, compressing the region of interest with a lossless, quality sustaining compression scheme like JPEG2000, compressing the non-important regions (background, et al.,) with an algorithm that has a very high compression ratio and that does not focus on quality (SPIHT). With this type of the compression work, energy efficiency is achieved and after respective reconstructions, the outputs are integrated and combined with the output from a texture based edge detector. Thus the required targets are attained and texture information is preserved.

3. EXISTING SYSTEMS

Keynotes on SEGC-N-D Compression

The proposed algorithm is used to compress bench mark images. Convert the given medical image into array of pixels. Using 2-D Maximum entropy threshold method, the threshold value is defined. The original image is segmented with the threshold value. The pixel coefficients are quantized into nearest integer values. Vector Quantization is implemented in this step to increase the accuracy of quantization mechanism. Run length encoding is applied to get compressed file data. The decoding and Decompression steps are applied to get the reconstructed image that is similar to the original data.

Keynotes on CSPIHT

In a wavelet-based still image coding algorithm known as Contexual set partitioning in hierarchical trees (CSPIHT) is developed that generates a continuously scalable bit stream. This means that a single encoded bit stream can be used to produce images at various bit-rates and quality, without any drop in compression. The decoder simply stops decoding when a target rate or reconstruction quality has been reached. In the CSPIHT algorithm, the image is first decomposed into a number of sub bands using hierarchical wavelet decomposition. The sub bands obtained for a two-level decomposition are shown in Figure 1.

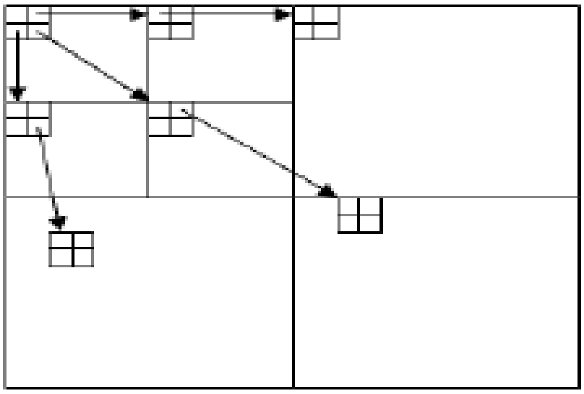

Figure 1. Level wavelet Decomposition with Spacial Orientation Tree

The sub band coefficients are then grouped into sets known as spatial-orientation trees, which efficiently exploit the correlation between the frequency bands. The coefficients in each spatial orientation tree are then progressively coded bit-plane by bitplane, starting with the coefficients with highest magnitude and at the lowest pyramid levels. In practice the number of possible levels can be limited by the image dimensions since the wavelet decomposition can only be applied to images with even dimensions. The use of arithmetic coding only results in a slight improvement for a 5 level decomposition. The information that we know about the image file that is produced from wavelet transformation is that it can be represented in a binary tree format with the root of the tree having a much larger probably of containing a greater pixel magnitude level than that of the branches of the root. The algorithm that takes advantage of this information is the Contexual Set Partition in Hierarchical Tree (CSPIHT) algorithm. The architecture of CSPIHT is shown in Figure 2 and Figure 3.

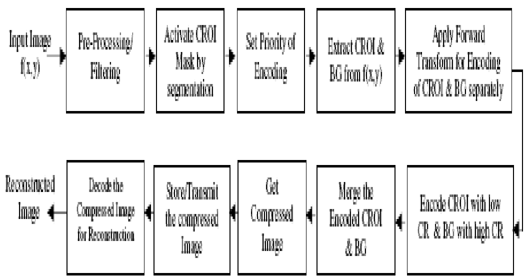

Figure 2. Architecture of Contexual (CSPIHT) Compression System

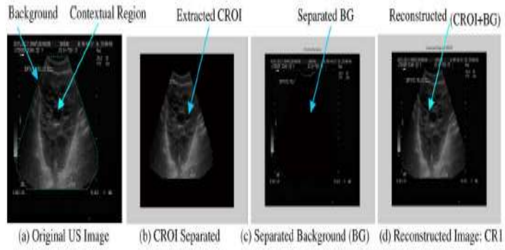

Figure 3. Seperation of CROI and BG from the US (ultra sound) image and its reconstructed Image

4. PROPOSED SYSTEM

With the DICOM standard, it is easy to eliminate textual information such as patient name and ID. 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. We use Daubechies' wavelets and analysis techniques to detect the high frequency variation in the diagonal direction that is indicative of text. 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 real world medical images many with superimposed text.

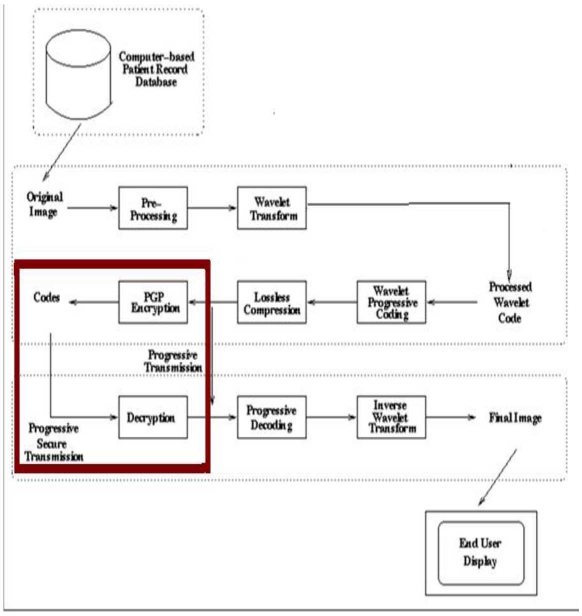

Figure 4. Architecture of the Proposed System

5. TRANSMISSION OF MEDICAL IMAGES

The DICOM Standard is an evolving standard and it is maintained in accordance with the Procedures of the DICOM Standards Committee. Proposals for enhancements are forthcoming from the DICOM Committee member organizations based on input from users of the Standard. These proposals are considered for inclusion in future editions of the Standard. A requirement in updating the Standard is to maintain effective compatibility with previous editions.

6. SECURITY ISSUE IN TRANSMISSION

PS 3.15 of the DICOM Standard specifies security and system management profiles to which implementations may claim conformance. Security and system management profiles are defined by referencing externally developed standard protocols, such as DHCP, LDAP, TLS and ISCL. Security protocols may use security techniques like public keys and "smart cards". Data encryption can use various standardized data encryption schemes.

Choosing Lossless Compression Technique for Medical Images

Medical images are compressed due to their large size and repeated usage for diagnosing purposes. Certified radiologists and doctors assess the degree of image degradation resulting from various types and amounts of compression associated with several different digital image file formats. A qualitative, rather than a quantitative approach is normally chosen because radiologists typically evaluate images qualitatively in their day-to-day practice and, also, because common metrics used for comparing images pre- and post compression, e.g., mean pixel error, root mean square error, maximum error, etc., may not correlate well with visual assessment of image quality.BMP (bitmapped picture) is Microsoft Windows device-independent bitmap standard for loss-less format. Users of this format can depend on images being displayed on any Windows device.

6. PERFORMANCE EVALUATION PARAMETERS

The effectiveness of lossless compression schemes can be described using following parameters:

Compression Ratio- Its is defined as the ratio of orginal file size to that of compressed file size.

Bit Rate- 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.

Mean Square Error- The cumulative squared error between the original and the compressed image is shown by MSE

$$MSE = \frac{1}{MN}\sum_{y=1}^{N}\sum_{x=1}^{M}[I(x,y) - I'(x,y)]^2.$$

Peak Signal to Noise Ratio- The peak error between the original and the compressed image is shown by PSNR

$$PSNR = 10\log_{10}\left(\frac{MAX_I^2}{MSE}\right) = 20\log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right).$$

7. SYSTEM IMPLEMENTATION

Matlab Software Version 7.0.1 consists of Various Modules:

1. The Input Module to retrieve the Medical Image as input.
2. Provide Security Feature by changing the DICOM unique identifier (UID).
3. Wavelet Decomposition module to provide wavelet compression using Daubechies wavelet of order 2.
4. Compression Module to compress the input image by applying Run Length encoding.

5. Reconstruct original image from compressed image data applying Run Length decoding.

6. Wavelet reconstruction to decompress the image and extract the Original Image.

8. COMPRESSION ALGORITHM

General flow of the Various Modules of Matlab Software is shown by the Algorithm below. Source code of this program is given in Appendix-A.

- Read an image from a DICOM file into the MATLAB workspace.
- Read the metadata from the same DICOM file.
- Remove all the text from the image
- Generate a new DICOM unique identifier (UID) using the dicomuid function
- Set the value of the Series Instance UID field in the metadata associated with the original DICOM file to the generated value.
- Write the modified image to a new DICOM file, specifying the modified metadata structure, info, as an argument
- Apply Wavelet decomposition and Run Length Encoding to provide Lossless compression of Image.
- To verify this operation, view the SeriesInstanceUID metadata field in the new file
- Apply Run Length decoding and Wavelet Reconstruction to decompress the Image

9. SIMULATION RESULT AND DISCUSSION

Simulation: The Images used in this project are shown in the Figure below.The Images for transformation are scanned directly from IPRO GE SYTEC 1800-i CT SCANNER. These Images are in DICOM format and are then converted to .dcm.

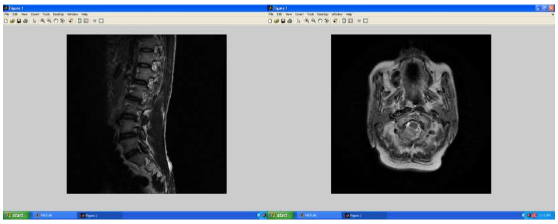

Figure 5. Medical Images

Results:

Step 1: Read an image from a DICOM file into the MATLAB workspace

Figure 6. Original Image

Step 2: Read the metadata from the same DICOM file-Create info as object to retrieve SeriesInstanceUID of the same Image. On applying the below command the following output appears.

info. SeriesInstanceUID

Ans=1.2.840.113619.2.1.2411.1031152382.365.736169244

***Step* 3:** Remove **all the text from the image (Enhancing** Security**)**-Finds the maximum and minimum values of all pixels in the image by using max and min functions. The pixels that form the white text characters are set to the maximum pixel value. The Output screen appears as:

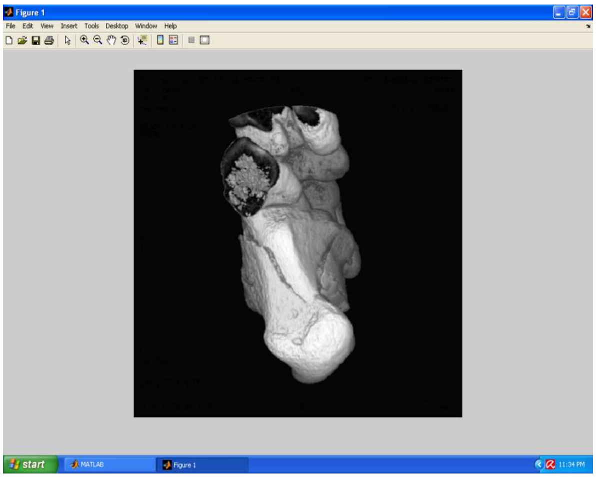

Figure7. Image without Text area

***Step* 4: Generate a new DICOM unique identifier (UID) using the dicomuid function-**Create uid as variable to store the value of new DICOM unique identifier (UID)

uid= 1.3.6.1.4.1.9590.100.1.1.3933169 0911270240817931391323566307755

***Step*5:** Set the value of the SeriesInstanceUID field in the metadata associated with the original DICOM file to the generated value

***Step* 6.** Write the modified image to a new DICOM file, specifying the modified metadata structure, info, as an argument

***Step* 7. Apply Wavelet based Lossless Compression Technique-**Apply Wavelet transform and Run length encoding. Output appears as:

Figure 8.Original and Compressed Images

Discussion: On the basis of parameters of image, the following calculations and results are shown:

Table 1. Calculation of Bit Rate, Compression Ratio, Mean Square Error, Peak Signal To Noise Ratio

Image	Bit Rate	Compres-sion ratio	Mean Square Error	Peak Signal to Noise ratio
Image1	0.58	17.3	0.19	103.63
Image3	1.00	10.0	0.0000038	150.51
Image4	0.81	12.3	0.04	86.70
Image5	0.25	14.2	0.57	74.68
Image6	0.50	18.2	0.25	102.35

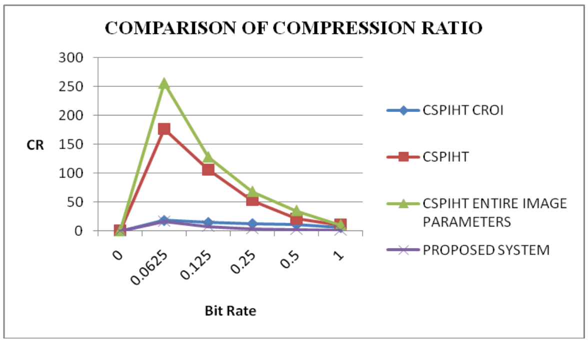

Figure 9. Comparison of Compression ratio

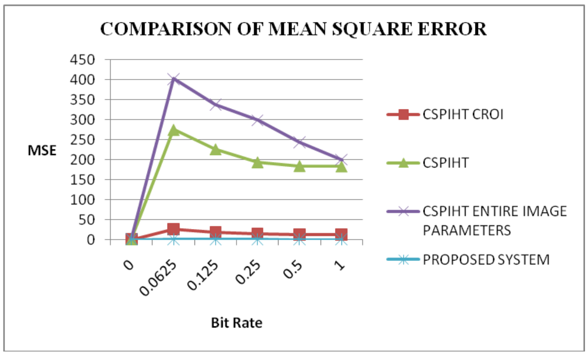

Figure 10. Comparison of Mean Square Error

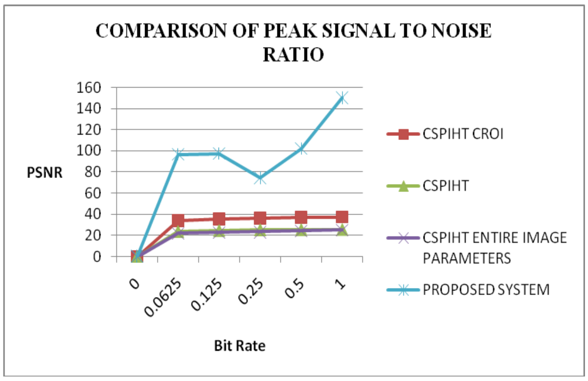

Figure 11. Graphs showing comparison of various parameters for existing (CSPIHT) and proposed system (Wavelet transform with run length encoding)

Table 2. Comparative Study of Different Compression Algorithms for Various Parameters

PARAMETER	CSPIHT	SEGC-N-D	PROPOSED METHOD DWT
BIT RATE	0.56	0.612	0.58
COMPRESSION RATIO	10.81	13.456	17.3
MEAN SQUARE ERROR	12.42	1.123	0.19
PEAK SIGNAL TO NOISE RATIO	36.99	44.235	103.63

10. CONCLUSION

In this paper we have developed a technique for wavelet transforms. With Run Length coding algorithm. Wavelet transform making it attractive both in terms of speed and memory needs and enhancing security features also. It is found that the proposed method gives high reduction in Mean square error with a better quality of the reconstructed medical image judged on the basis of the human visual system (HVS).

So, finally we can conclude that as compared to CSPIHT, SEGC-N-D the proposed Wavelet based method is very suitable for low bit rate compression, high compression ratios, can perform lossless coding, high PSNR, low MSEs as well as good visual quality of the reconstructed medical image at low bit rates. It can also maintain the high diagnostic quality of the compressed image and hence can reduce heavily the transmission and the storage costs of the huge medical data generated every day.

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