Medical image Compression Algorithm Based on Wavelet Transform

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ABSTRACT

With rapid development of electronic imaging and multimedia technology, the telemedicine is applied to modern medical servings in the hospital. Digital medical image is characterized by high resolution, high precision and vast data. The optimized compression algorithm can alleviate restriction in the transmission speed and data storage. This paper describes the characteristics of human vision system based on the physiology structure, and analyses the characteristics of medical image in the telemedicine, then it brings forward an optimized compression algorithm based on wavelet zerotree. After the image is smoothed, it is decomposed with the haar filters. Then the wavelet coefficients are quantified adaptively. Therefore, we can maximize efficiency of compression and achieve better subjective visual image. This algorithm can be applied to image transmission in the telemedicine. In the end, we examined the feasibility of this algorithm with an image transmission experiment in the network.

Keyword: Telemedicine, HVS (Human Vision System), Wavelet Transform, EZW (Embedded Zerotree Wavelets Encoding), Adaptive Quantification

1. INTRODUCTION

In the Telemedicine, the medical image is very important in the process that the clinical doctor and experts carry on diagnosing the disease. To assure the demand of telemedicine serving, the software of image processing in grayscale degree is limited in 256 —4096 and the space resolution should attain the 1 K—4 kdpI. This gives rise to high precision and vast data of the medical image, which induces difficulties in the communication and data storage. By virtue of the optimized compression algorithm, we will have chance to solve the signal delay in the process of image transmission and alleviate the restriction of transmission speed and data storage.

It is the technical characteristics in the compression of new generation image that low encode ratio under the condition of super compression and transmission according to the pixel accuracy and level resolution. Current JPEG standard under the condition of the high bit rate can offer good ratio of distortion performance. But under the condition of low bit rate, usually, it provides the quality of subjective image we can't accept[1]. However, based on wavelet transform we can attain comparatively good compression efficiency and insure the image to transfer in the lower bandwidth. According to the characteristics of human visual system and the characteristics of the medical image. This paper puts forward a kind of image compression algorithm based on wavelet transform, which can be applied to transmit images in the network. Moreover, the feasibility of this algorithm is examined with an image transmission experiment in the network.

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2. BACKGROUND

2.1 Human visual system

The devisers who answer for the design of the image processing algorithm and the system of display image must think over the Human Vision System (HVS). The human vision is a complicated physiology and mental processes. Be known from the physiology anatomy, the outside ray focuses on the retina through a cornea, iris and crystalline lens, and forms sense of vision after delivering to many parts vision of the axis of optic nerve. Having to the observer the important meaning of the image information has been decided by a mental physics parameter, including contrast, contours, structure of texture, shape and color. According to the results which we research to the human visual system, person's eyes has the lower sensitivity to the pattern between quick variety and slow variety. However its resolution in the space mid-frequency is very best. The direction is different, the sensitive degree is also different. In particular, it is not too sensitive towards the diagonal direction[2]. The contrast sensitive function(CSF) was used to describe the contrast sensitive of different frequency in the Human Vision System, we find that characteristic of the CSF resembles a bandpass filter. On the other hand, the human visual system still has the masking effect. For even grade of the image, its some small piece image seems to be a little darker while close to little brighter in adjacent area, while close to the little darker it seems to be a little brighter. This is result in masking effect of the vision in the space frequency.

From the above analysis, it is known that the behavior of the human visual system conforms characteristic of bandpass filter, when we identify details of the image. Consequently, the characteristic of the person's vision can synthesize the independent mechanism of vision. Therefore we can aim at the sensitive band of every kind of the mechanism of vision and use a set filter to simulate. Those filters can separate images into a group limited bandwidths subbands in a set of different directions, the space frequencies and time frequencies. Each filter only makes response in space frequency and directions of the certain area in the adjacent center-frequency. Usually, the space frequency of the grayscale images will be decomposed 4-6 bands with 4-8 directions. But the color images have wider direction bandwidth, generally only it be decomposed 2-3 directions subbands. This characteristics conforms data structure of image after wavelet transform.

2.2 Medicinal Image in Telemedicine

The telemedicine is mainly applied in clinic consultation, examining a patient, health care, guiding the cure, medical research, medical communication, medical education, observational learning to the surgical operation etc. It is important to transmit quickly various medical images in the telemedicine. For example, the doctors can make elementary diagnosis to the patient in clinical consultation. According to the high quality transmitted image, all datum in clinical consultation, are delivered the other side, including summary of the case history and the results of assay, and image data including the scanned medical images, pathology slice, X radial, MRI, ultrasonic, gastroscope, isotope, electroencephalogram or cardiogram etc. We can provide source image or amplified images for the experts who participate in consultation. Here it contains a lot of static images which are transmitted to those experts to diagnose diseases. In practical application , generally 1024 bits is called the "1 K"; to store a 2k× 2k×12 Bytes sternum (regard 2 Bytes/ word as the unit),so we need 8MBytes capacity. Only the high compression ratio algorithm can alleviate restriction in the transmission speed and data storage. What’s more, there still exists delay problem in real-time transmission, to shorten the delay time.It is necessary to be encoded before medical images are transmitted.

Digital medical image is characterized by high resolution, high precision and vast data. Making up of multi-resolution, hierarchical structure and texture, those characteristics are in accordance with the information processing process of human visual system. The structure and texture of the image are represented respectively in different resolution level, among them. The contours can be acquired at the edge under the low resolution. The texture information can be attained under the high resolution. The edge information influences mainly to the sense of vision, so image compression should keep the edge information, direction and details of resolution and dimensions. It is very obvious that image datum are very applicable to do multi-resolution in the telemedicine.

It is clear that wavelet transform is very appropriate tool to imitate HVS. Wavelet analysis has become a powerful tool in the analysis of functions and applications in signal processing[3]. What's more, we know that transmitted image also suits to multi-resolution analysis[4]. But if wavelet transform encoding is adopted purely, we can't make good use of the characteristics of coefficients from wavelet decomposition. However, after the CSF is adopted, which is a characteristic of the HVS based on characteristic of person's vision, we can obtain the better subjective impression. According to discrete wavelet transform (DWT), Lai has ever given an model of HVS which is created by himself based on a psychology experiment to realize image codec[5]. According to the characteristic of CSF, this paper bring forward a codec algorithm based on wavelet transform, which is used to transmit static images transmission in the telemedicine. At the same time, the encoding based on wavelet transform can enhance compression ratio, and eliminate noise under the condition of debasing quality of single unremarkably.

3. COMPRESSION ALGORITHM

3.1 Compression Algorithm Framework

The Embedded Zerotree Wavelets Encoding(EZW) is a very effective and computationally simple algorithm[6]. In the EZW algorithm, zerotree quantification is composed of position coding and gradual quantification. Via gradually quantify important coefficients, zero coefficients will appear in the high-frequency area, and form zerotree. Zerotree can't be formed by nonzero coefficients which describes the edge, contours and texture of the image. It has been known that the efficiency of EZW algorithm is decided by the quantity of zerotree, the quantity of the zerotree is more many, efficiency of algorithm is more high[7]. According to the above discussed characteristics about the EZW algorithm, we bring forward this text algorithm. To appear more zero coefficients in the high-frequency area after wavelet transform, in this paper, we propose a pre-processing method that image is smoothed before wavelet transform. The metric of this way can eliminate a part of noise and break in adjacent pixels of image. Then image is decomposed with the discrete haar wavelet and wavelet coefficients are quantified adaptively. To get rid of redundance of signal, here we adopt arithmetic encoding. Therefore, we can enhance greatly compression ratio under of obtain finer subjective vision. The framework of codec is shown in Fig.1.

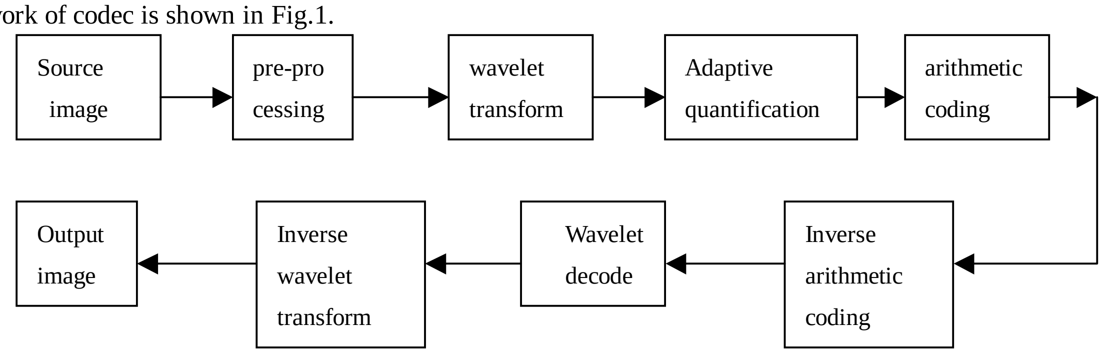
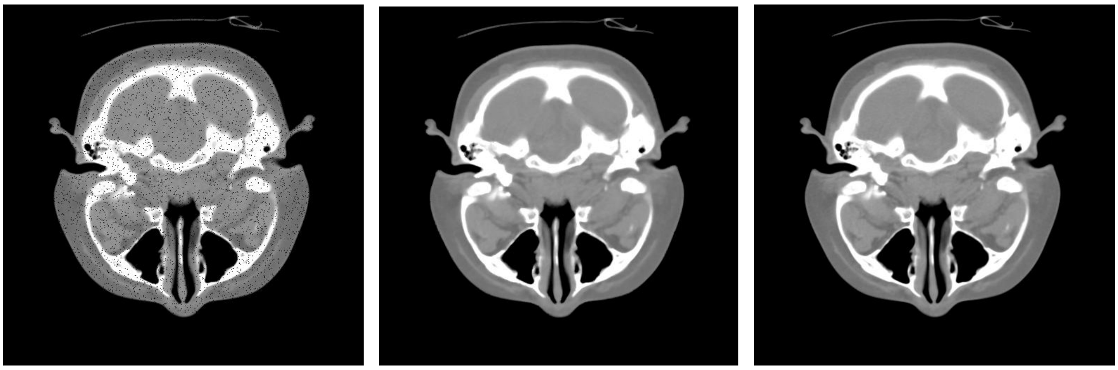


Fig.1 Codec Algorithm Framework

3.2 Smooth Image

In the process of medical imaging, there will be some intuitionistic noise[8]. Therefore, to eliminate the noise of image, we still need to pre-process images before wavelet transform. This pre-processing method by which image is smoothed includes discarding the edge and contours of the image within the receivable extent of the person's subjective vision. The 3×3 medianfilter is adopted here, which can eliminate preferably pulsed noise and scanned noise[9] , in particular, it can get rid of salt noise.

Three head images of CT are depicted in the Fig.2. Fig.2(a) is polluted image by the salt noise , Fig.2(b) is smoothed image by the 3×3 medianfilter, and Fig.2(c) is source image. Form the Fig.3, it is very clear that salt noise has been eliminated in smoothed image, while the subjective vision has no obvious influence on the edges and contours of image. The advantage of this pre-processing is great significance to deal with wavelet coefficients after wavelet transform. It will increase the quantity of the null coefficient after adaptive quantification, and enhance efficiency of encoding.



(a) (b) (c)

Fig.2 head image of CT (a) polluted image by the salt noise (b) smoothed image (c) source image

3.3 Wavelet transform and characteristics of wavelet coefficients

The wavelet transform describes or approaches a certain function f(t) with wavelet function $\Psi_{a,b}(t)$ for base. In the $L^2(R)$ space, arbitrary dyadic function f(t) after wavelet transform is:

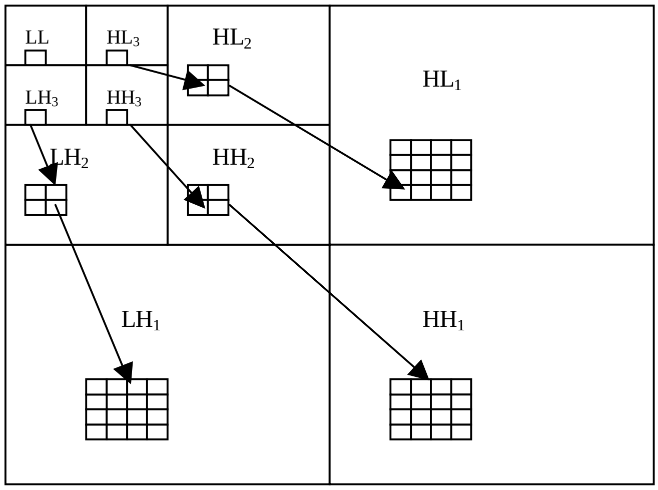
$$C_{i,j}=\int_{-\infty}^{\infty} f(t)\,\Psi_{i,j}(t)\,dt \qquad (1)$$

$$\Psi_{i,j}(t)=2^{-j/2}\Psi(2^{-j}t-i), i,j\in Z, \quad \int \psi(\tau)d\tau=0 \qquad (2)$$

Where we adopt two-dimensional discrete haar wavelet, the definition of $\Psi(t)$ as follows:

$$\Psi(t)=\begin{cases} 1 & 0<=x<1/2 \\ -1 & 1/2<=x<1 \\ 0 & \text{other} \end{cases} \qquad (3)$$

A typical layout of wavelet decomposition obtained by three-level dyadic DWT based on haar wavelet is depicted in Fig.3(a). It has been known that the sign bits form wavelet coefficients exhibit substantial statistical dependencies. There exists relation between coefficients at the coarse level and all four coefficients corresponding to the same spatial location at the next finer level of similar orientation. In Fig.3 (a), each of the rectangular blocks is called the subband. LH1,HL1, and HH1 are called the subbands at the finest level of the wavelet pyramid(also called the highest frequency subbands)which consist of high-frequency components of an image. LL3, LH3, HL3 and HH3 are called the subbands at the coarsest level, which are composed of low-frequency components. In particular, from Fig.3(c), we can know that in LL3 subband, its image resembles greatly source image in substantial statistical characteristic. Most of the energy of an image tends to be packed toward this subband, consist of coefficients are far larger than those in other subbands. Those coefficients have great effect on reconstructed image, so person's eyes are special sensitive in this area. The coefficients that describe varying details in other subbands are mostly very small and zero coefficients emerge here.



(a)

(b) (c)

Fig.3 three-level wavelet decomposition : (a) A layout of the image subbands (b) one-level DWT of CT image (c) three-level DWT of CT image.Each subband is processed for display

From Fig.3(b) and Fig.3(c), we can know that the LH_x and HH_x subbands are composed of coefficients that describe horizontal and diagonal spatial frequency characteristic (e.g. edges ,contours and textures) of an image. The HL_x subbands, called the vertically oriented subbands, consist of coefficients that describe the vertical edges of an image. On the other hand, at the same level, since the covariance of HL_x subbands' and the LH_x subbands' coefficients are larger than those of HH_x subbands and the coefficients of the HH_x subbands describe the edge of image, they are not very important in reconstructed image.

3.4Adaptive Quantification

Wavelet coefficients represent image details such as local maxima, edges, contours and texture. In order to maximize the efficiency of the compression algorithm, we need to prioritize the coefficients in the order of their significance. In this context, according to their effects on the reconstructed image, the coefficients will be quantified adaptively.

(1) Lowest frequency subband(LL): According to the above analysis ,it has about 90% of the original energy of an image, and tends to be packed toward in the lowest frequency subband(LL), representing the basic information of the edge, contours and the texture of the image. Therefore, in the process of reconstructed image, compared with those coefficients of other subbands, the coefficients in the lowest frequency subband are more important. Only lossless encode or almost lossless encode can satisfy the view of the observer. To increase Signal-to-Noise ratio of reconstructed image, here we keep the lowest frequency subband separated from other subbands, lossless compression of DPCM is adopted separately in this subband. Because the pixels in the lowest frequency subband are a small part of all pixels, the DPCM method separately adopted has no influence upon the compression efficiency.

(2) According to the Mallatde's research results, the person's eyes is comparatively sensitive to the distortion in the horizontal direction and vertical direction, while it dulls to the distortion in the diagonal direction [10]. To make full use of this characteristic of the human visual system, based on the above characteristics of wavelet coefficients, we adopt the different thresholds for different direction of subbands. In the same level, we take the smaller threshold to quantify these coefficients in the LH_x and HL_x subbands. But in the diagonal (HH_x) subband , we adopt a bigger threshold to quantify. Thus, under the condition of the same Signal-to-Noise ratio, compared with EZW of Shapiro algorithm, the above quantification algorithm can attain higher compression ratio and acquire the higher efficiency of image compression.

According to the above requirement of selecting threshold, we define the adjustment parameter of threshold as follows : $\beta = T_{k1}/ T_{k0}$, $\beta >1$, where, T_{k1} represents the threshold of the k level in diagonal direction, T_{k0} denotes the threshold of the k level in horizontal and vertical direction.

4. EXPERIMENT AND RESULTS

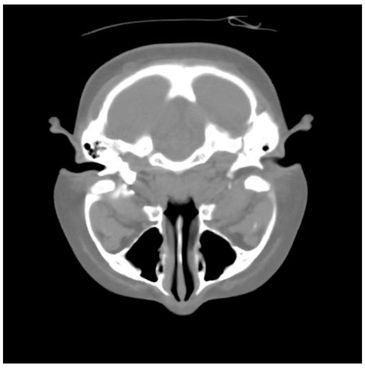
Based on the Ethernet, we simulated a part of Home Health Care system with an image transmission experiment. In the experiment, the medical images acquired via scan, including summary of case history and CT images, are encoded as static images with the above algorithm at the sending port. At the receiving port, the compressed images are decoded to display immediately. While the dynamic images in the home health care system are delivered to the care center as MPEG2 format.

Table.1 compress ratio result compare

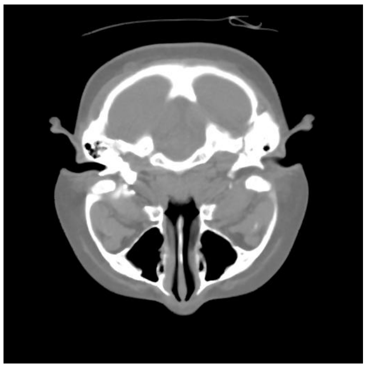
T_0	4	8	16	32	64	128
EZW	10.5	17.6	26.3	31.9	39.7	52.5
This algorithm	18.6	26.7	35.1	43.5	54.3	67.8

(a)

(b)



(c)



(d)

Fig.4 diverse images in the experiment: (a) noise image (b) reconstructed noise image form EZW algorithm (c) smoothed image (d) reconstructed image based on this algorithm

To deal with the static image, experiments of this algorithm are performed on the 512×512 grayscale image such as CT about human head, using a four-level wavelet decomposition based on the haar filters. The adjustive parameter (β) is the threshold of adaptive quantification ,which is set to 2 here. Table.1 and Figure.4 are the results from the comparison between this algorithm and Shapiro’s EZW, where T0 is set to 4.

It is reported that some of medical images such as CT and MRI images. When its comparison ratio achieves as follows: 16:1, reconstructed image has no effect on the subjective vision, and holds 99% of the original energy of medical images[11]. Form the comparison of the quality of images, we can see that the subjective quantity of the image is not remarkable after being smoothed and adaptive quantificationcompression. However, given the same PSNR, compression ratio of our algorithm rise very much when we compare it with that of EZW algorithm. The advantage is also embodied in the delay time of real-time transmission. The reconstructed image delays 150ms in receive port based on the EZW algorithm, while reconstructed image based on our algorithm delays only 85ms.

5. CONCLUSIONS

The ideal image compression algorithm would achieve state-of-the-art results on every type of image, no matter what its characteristics are. In reality, however, this is very difficult to achieve[12]. The compression ratio of image data greatly rise by this compression algorithm. However the image is a little blurry, so it is applicable to the lower resolution medical images. Our next step work is to develop smoothing algorithm to attain better visual effect. With further research and application, the processed medical images based on wavelet transform are adopted to clinical diagnosis by the doctors and experts. It is possible that they can make earlier period or small pathological diagnosis for the patients in the future. At the same time, with the quickly developing multi-media technique in the telemedicine, home health care will be a very important cost-saving method of treatment in this century.

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