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Lossless Compression Techniques for Medical Images in Telemedicine

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1. Introduction

Telemedicine is telecommunication technology integrated with the advancements in information technology. The main purpose is to enhance health care delivery to a wider population. This telemedicine technology supports the transfer of pathological and imaging reports of patients across the telemedicine networks, so as to provide consultation by specialists located in geographically different locations. The integration of mobile communication and biomedical instrumentation technology plays an important role in Telemedicine as doctors away from the system can also get the health status of their critical patients (AlfredoI.Hernandez et al., 2001).
Advances made in the field of biomedical engineering, has lead to the development of more accurate biomedical instrumentation to measure vital physiological parameters and the development of interdisciplinary areas to fight the effects of body malfunctions and disease.
The chapter is organised as follows. Subsections under 1 describe the application of telecommunication technology to health care and the necessity of telemedicine in India. The challenges pertaining to telemedicine have also been identified and addressed accordingly. Section 2 briefs on the concepts of effective medical image compression. The effectiveness of Huffman Compression in telemedicine and related work is presented in Section 3. Section 4 describes transform based image compression. The basics of contourlet coding and global thresholding based on Otsu's method is described in Sections 4.2 and 4.3 respectively. The algorithm steps of Contourlet based Joint Medical image compression is presented in 4.5.Section 5 gives the results obtained on applying the algorithm. The conclusion is presented in Section 6.

1.1 Applying telecommunications to health care

The term telecommunications generally means electronic transmission of information over a distance. We can use modern telecommunication and information technologies for the provision of clinical care to individuals at a distance. This application is very efficient since patient records, stored electronically, can be made available through the Internet, resulting in the elimination of the need for physical storage and transfer of records. Furthermore, images and video can be included and transmitted as part of a computerized file. Hence, the patient's history can include previous examinations, lab test results, X-rays, etc. in addition to textual descriptions of the results from previous health care. Records on remote sites can also be accessed. This will greatly enhance the chances of correct diagnosis of a particular illness and possibly suggest courses of treatment. Health information of the patient, collected in digitized form, can be easily transmitted without requiring his/her physical presence for the examination. The support of video conferencing through the Internet allows a health care professional to observe and interact with the patient who is not in the same physical location. E-mail or Video Recording could be used for asynchronous discussions. Patient records, lab results and images from detailed examinations can be stored in computer file format, making them easier to search and transfer to distant locations when needed.

E-mail and Internet access for regional and rural medical centres and hospitals could be extremely useful. The benefits from connecting as many hospitals and medical centres as possible to the medical information system would be:

- Improved standard of medical practice
- Improved epidemiological and other reporting
- Educational benefits for doctors and medical staff in distant medical centers, continuous medical education.

Therefore, the telecommunication partners of these telemedicine projects will be a key factor for the future extension of telemedicine services. Successful introduction of telemedicine services require more than just the delivery of the right equipment to the users.

The Internet is already changing the way in which telemedicine is deployed and the extent to which it becomes widely available. The focus should be on low-cost, low-bandwidth Internet applications that facilitate discussion and the transmission of text, data and images (AlfredoI Hernandez et al., 2001, J.A.Mockzo et al., 2001).

Telemedicine can help to develop new ways to deliver medical and health education to professionals and to the community and improve the continuing medical education.

1.2 Technology behind telemedicine

Most of the telemedical applications use one of the two widely available technologies. The store and forward technology transfers digital images from one location to another. The other popular technology is the two-way interactive television (IATV). This is used when a 'face-to-face' consultation between the health expert and the patients become mandatory. It is usually between the patients and their provider in one location and a specialist in another location. Videoconferencing equipment at both locations allows a 'real-time' consultation to take place (K.Hung, YT Zhang 2003). The technology has decreased in price and complexity over the past five years, and many programs now use desktop videoconferencing systems. This includes transfer of basic patient information over computer communication networks, exchange of images such as radiographs or pathologies among geographically separated specialists, remote patient interviews and examination through activities. A telemedicine system enables 'virtual consultation' wherein the local doctor plays the role of a remote medical expert and implements effective decision making and treatment. Telemedicine bridges gap between specialist doctors and patients, thereby overcoming the barriers of distance and time. Health care in isolated areas are improved by enhancing continuing care.

Modern telecommunication and information technologies could be used for the provision of clinical care to individuals at a distance. Patient records, lab results and images from detailed examinations could be stored in computer file format, making them easier to search and transfer to distant locations when needed.

Thus telemedicine technology offers the following benefits:

- Reduction in time and cost incurred in travel
- Easy and quick access to specialist
- Cost effective post treatment consultation
- Efficient use of medical resources.

The major areas of telemedicine technology are

- Tele-consultation
- Tele-diagnosis
- Tele-treatment
- Tele-education
- Tele-training
- Tele-monitoring
- Tele-support

Figures 1 and 2 depict the scenario in a telemedicine setup (Anunay Nayak et al.)

1.3 Necessity of telemedicine in India

The geographical set up of India provides an ideal setup for telemedicine to be implemented in the sub-continent. India's huge population makes it difficult for health care facilities to be made available for everybody and at any place.
India is characterized by low penetration of healthcare services. 80% of secondary & tertiary healthcare facilities lie in cities and towns, distant from rural India where 70% of the population resides. Primary health care facilities for rural population are highly inadequate.

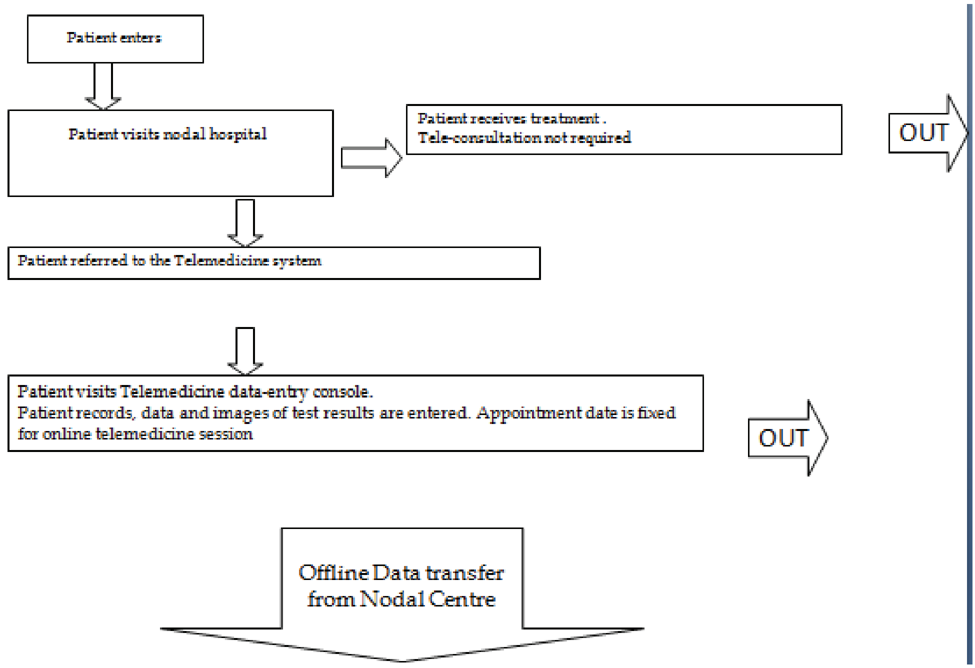


Fig. 1. Day 1 of a Telemedicine consultation (Anunay Nayak et al.)

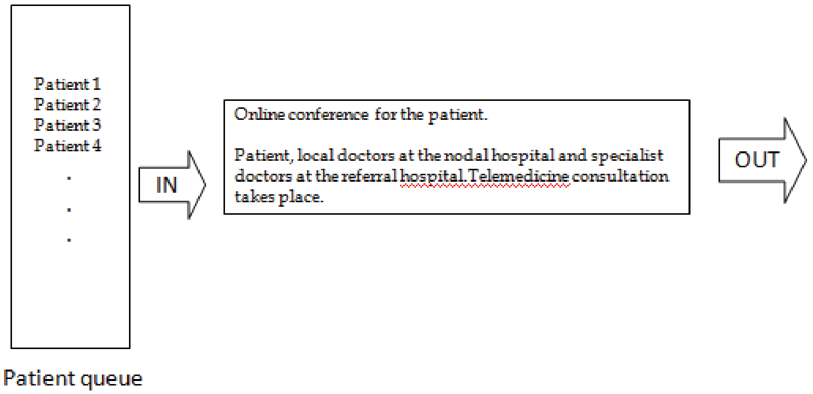


Fig. 2. Day 2 of a telemedicine consultation

Studies reveal that the rural population, though with the same disease than their urban counterparts faces twice the risk of death, due to inexperienced and poor medical facilities in the rural areas. Despite several initiatives by the Government and private sectors, the rural and remote areas continue to suffer from absence of quality healthcare. Telemedicine attempts to narrow the gap underlying urban and rural counterparts, in terms of quality health care.

India has begun to make remarkable progress in the fields of telemedicine and e-health. Indian Space Research Organization ISRO and the Department Of Information Technology provide the infrastructure to support tele applications. One of ISRO's first successful ventures to implement telemedicine in the country was in the year 2001, linking Apollo Hospital in Chennai to a rural hospital in Aragonda village in Andhra Pradesh. Later, in March 2002, Karnataka Telemedicine project linked a super speciality hospital in Bangalore to a small district hospital. The successful implementation of these pilot projects was ISRO's initial steps contributing to the growth of telemedicine in India.

Fig.3 shows the Telemedicine link provided by the Indian Space Research Organisation. These projects are implemented through the State Governments (S.K.Mishra). There is active participation from the Government and Private sectors to bridge the gap in the quality of health care facilities between the urban and rural Indians, through setting up of telemedicine networks.

ISRO has established a telemedicine network for 300 hospitals. A total 257 remote/rural district hospitals and health centres have been connected to 43- super specialty hospitals located in major states. Ten mobile tele-ophtamology units are also present. A majority of the State Governments have collaborated with the Department of IT, in setting up telemedicine networks with the state specialty hospitals and smaller district centres (Saroj Mishra et al., 2008)

The growing need of telemedicine in India can be traced back to the works of (Amrita Pal et.al 2005), where a telemedicine setup in India is absolutely essential.

There has been a number of situations in which telemedicine has been successfully implemented. The Online Telemedicine Research Institute OTRI provided telemedicine links for teleconsultation in Bhuj during the earthquake in Gujarat in the year2001.Asia Heart Foundation has been successfully practising tele-cardiology between Bangalore and cities in Eastern India.The last decade witnessed many more success stories (S.P.Sood, 2002).

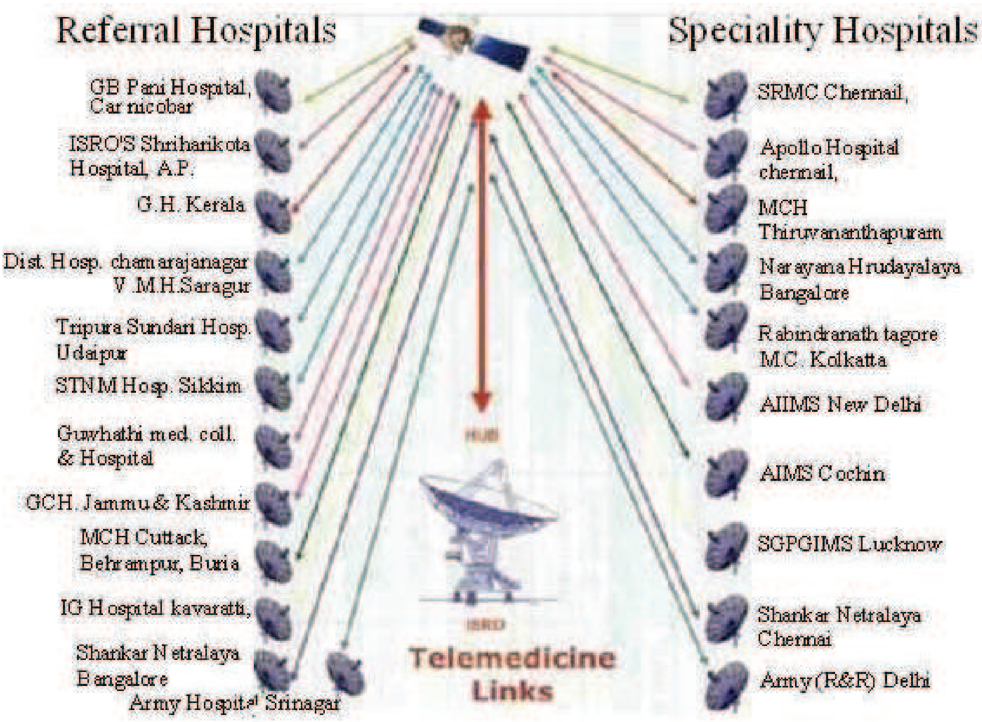


Fig. 3. Telemedicine links provided by Indian Space Research Organisation (ISRO) (S.K.Mishra)

1.4 Challenges identified in telemedicine technology in India

- A multifunctional Telemedicine facility is necessary which would enable the monitoring of the patient through a virtual instrument fed with physiological signals. This enables real time health monitoring of critically ill patients.
- To aid in decision-making, an automated decision support system can be developed which encompasses the principles of artificial intelligence and knowledge based expert system. This system could be of good use as a decision support tool to the physician.
- To improve the quality of decision making, image segmentation algorithms can be developed which take medical images as input and segment them to produce a well-defined area in that image. The same can be transmitted to the remote medical center for effective diagnosis.
- The medical images have to be transmitted across telemedicine network to remote medical centre for diagnosis. In this connection, effective loss-less compression algorithms can be developed which result in saving of storage space and better utilization of bandwidth and speed of data transmission.
- The existing image compression algorithms can be analyzed over several parameters and constraints like noise analysis. The outcome of this research will throw light on the most effective compression technique for various categories of images.
- In the present chapter, specific needs are identified and discussed hereunder. The needs are:

- An automated segmentation of two-dimensional data such as ultrasound images.
- Compression of the above data for quick and reliable transmission.

1.5 Significance of image segmentation in telemedicine

Segmentation of medical images is one of the interesting applications of image processing techniques and has attracted a significant amount of attention in the past few years(Lei Ma et al, 2005). It is a technique for partitioning the image into meaningful sub regions or objects with same attributes, and usually is image and application dependent. Several segmentation methods have been proposed in medical images and especially in ultrasound images (Wy Ma, B.S.Manjunath, 2000). A number of algorithms based upon approaches such as histogram analysis, region growing, edge detection, and pixel classification have been proposed in the past. Generally speaking, these methods make use of local information (i.e., the gray-level values of the neighbouring pixels) and/or the global information (i.e., overall gray-level distribution of the image) for image segmentation. Some algorithms using neural network approach have also been investigated in image segmentation problems (Kuo Sheng Cheng et al, 1996).

A large number of different approaches are employed recently on segmenting images. The methods for ultrasound medical image segmentation rely on five main approaches, namely, thresholding technique, boundary-based method, region based methods, and hybrid techniques that combine boundary and region criteria and active contour based approach.

Ultrasound imaging has been used extensively for detecting cysts. The Radiologist scans the body for detection of cyst and reports the features of cyst.

In general, the diagnosis of illness involves two basic tasks of collection of information about the patient and analysis of that information to arrive at a conclusion about the type of the illness. An automated model that receives information about the cyst and produces segmented output of cyst image will be of immense help in the future. These segmented images can be transmitted through the network to the medical center where the analysis is carried out and suitable medical recommendations provided by the decision support tool at the distant medical center.

Thus, there remains a tremendous need for creation of knowledge based artificially intelligent decision support system for detection and diagnosis of diseases and incorporating this model into telemedicine technology. This is achievable given the advances made in the field of information technology and medical imaging.

1.6 Significance of image compression techniques in telemedicine

1.6.1 Compression techniques

Data Compression is one of the most renowned branches of Computer Science. Over the years, extensive research has been done in this field and many standards have been developed to compress data in several ways (A.K.Jain, 1981).

Data Compression can be defined as reducing of the amount of storage space required to store a given amount of data. Data compression comes with a lot of advantages. It saves storage space, bandwidth, cost and time required for transmitting data from one place to another. Compression can be lossy or loss-less. With a loss-less compression and decompression, the original and decompressed files are identical bit per bit. On the other hand, compression efficiency can be improved by throwing away most of redundant data, without however losing much quality.

There are many loss-less compression techniques such as Arithmetic coding, Run Length Encoding, Huffman Coding and some famous Dictionary based algorithms like Lempel-Ziv-Welch (LZW) coding, though Huffman Coding forms the basis of many compression algorithms. JPEG, MPEG, which are lossy compression methods use Huffman coding. Even the new proposed algorithms like JPEG-2000, Burrows-wheeler transformations (Bwt) and BTTC use Huffman coding in the final stages.

1.6.2 Compression for medical images

Medical images give information of shape and function of organs of human body, this being one of the most important means for diagnosis. An expert physician uses images for diagnosis, together with other information. In most cases it is qualitative and subjective evaluation. The information conveyed by medical images is very difficult to exploit quantitatively and objectively. Increasingly, medical images are acquired or stored digitally. This is especially true of the images that are used in radiology applications.

1.6.3 Reasons for choosing a loss-less technique

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. BMP supports 24-bit images. Loss-less compression is possible, using Huffman algorithm. Images compressed in loss-less manner occupy less space than the originals. No image data are lost during loss-less compression. Decompression restores the original image without loss of fidelity.

We have dealt with the above said concepts and challenges In the present chapter, we address the research issues pertaining to effective compression of medical images.

2. Effective medical image compression

Medical images should be subjected to loss-less compression, a technique that stems from mathematical theory of communication (Shannon, 1948**).** Loss-less compression techniques use variable length codes, proposed by Huffman (David Huffman, 1952). Compression ratio achieved is not very satisfactory in Huffman. Hence modifying Huffman's technique and optimizing it, yields a more effective compression algorithm that increases the compression ratio on medical images. 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.

As far as medical images are concerned, several research processes are reported for effectiveness of loss-less compression. One such paper evaluated the effectiveness of traditional and state of the art approaches of loss-less compression of grayscale medical images. The new JPEG-LS process (ISO/IEC 14495-1), and the loss-less mode of the proposed JPEG 2000 scheme (ISO/IEC CD15444-1), which are new standard schemes that may be incorporated into DICOM, was evaluated. Three thousand, six hundred and seventy-nine (3,679) single frame grayscale images from multiple anatomical regions, modalities and vendors, were tested. For all images, combined JPEG-LS and JPEG 2000 performed equally well. Both out-performed existing JPEG.It was found that the use of standard schemes could achieve state of the art performance, regardless of modality. Further, it was found that JPEG-LS is simple, easy to implement, consumes less memory, and is faster than JPEG 2000, though JPEG 2000 will offer lossy and progressive transmission(D.A.Clunie,2004).

Another interesting paper performed loss-less medical image compression by building a modified S-tree structure to make each block contain similar pixels. The medical images have a very close pixel-to-pixel correlation. In order to preserve this characteristic, a loss-less medical image compression method was developed. It was found that this method could reduce the required number of bits to record those pixels. The experimental results also show that this method is better than other methods in almost all cases (Chi-Shiang Chan, Chin-Chen Chang, 2005).

In another paper, a design of ultrasound data compression in a tele-ultrasound system was presented. It underlines the benefits of tele-ultrasound that may not be available in locations, which lack high bandwidth transmission channels. Because of the importance of speckle structure in the ultrasound image, standard compression algorithms like conventional JPEG are not suitable for ultrasound images. This design of compression was tested on those locations, which has band limited signal channel (R.Mir et al, 2003).

Other approaches for image compression use Wavelet transform-based image compression algorithms, which are recognized as a superior method to compress, archive, and electronically disseminate medical imagery. This class of algorithm is now available to a wider medical system user base with the approval of JPEG2000 as an accepted image compression option by the DICOM Working Group 4 (compression group) (M.A Ansari, R.S. Anand, 2005).

Although, new techniques that provide better compression ratio are developed now, a careful study into the Huffman Compression technique reveals the scope for improvement in terms of compression ratio and computationally simpler code. Such an algorithm is developed which optimizes the existing Huffman's variable length codes and produces an effective compression technique for medical images. This is discussed in 3.2

3. Related work-effectiveness of Huffman compression in telemedicine

3.1 Huffman – A basic compression technique

Huffman codes are digital data compression codes resulted from the excellent piece of work by Prof. David A. Huffman. Huffman codes exploit the entropy of the message to give good compression ratios.

Huffman coding is a statistical coding technique that forms the basis for many compression techniques. Huffman compression techniques consist of techniques guaranteed to generate an exact duplicate of input data stream after an expand cycle. This type of compression is used when storing database records, spreadsheets, or word processing file and image formats. In these applications, the loss of even a single bit could be catastrophic. Huffman algorithm can be used in the case of medical image compression where there should not be any loss of information during compression that will affect proper diagnosis.

3.2 Improved Huffman compression Algorithm (An introduction to the existing work)

The Huffman Coding can be refined to generate a new effective compression algorithm, which will give improved compression ratio and at the same time maintain the quality of the original image like Huffman.

The core concept of the algorithm is based on building up a collection of n-length patterns in the image. The basic model of new compression algorithm is similar to that of the Huffman encoder except for the pattern finder (J.Janet, T.R.Natesan, 2005). The operation of the pattern finder is to find the best pattern, which is the most frequent occurring pattern. Therefore the best pattern will also be an input to the encoder. The output of the encoder will be the code along with footer information.

3.2.1 Working steps for IHC (Improved Huffman Compression) Algorithm

There are four basic considerations for implementing this new compression method. However, they do not impose an added complexity to the existing system.

These restrictions include:

- The pattern is restricted to 3-length patterns.
- The first and last characters in the pattern must not be same as the second (middle) character to be replaced by Footer information.
- The pattern once traced for its positions must not be traced again. (i.e.) Each pattern must be traced only once.
- Positions of the patterns and sub patterns traced must be accurate.

3.2.2 Pattern recognition

The idea is based on the redundant nature of character or signals in the data encountered. Consider for example a 3-length pattern commonly occurring in text files say "ABC". Here, considering the sub pattern "AC" of length 2, all 3- length patterns such as "ABC" patterns can be encoded as "AC" in the corresponding compressed version. To differentiate between "ABC"s and "AC"s in order to bring out the exact original file on decoding, the concept of a new feature called "Footer Information" is introduced. Through this footer information bits, "1"s indicate the presence of "B" in "ABC" and "0"s denote the absence of "B" in the sub patterns "AC"s. These bits are added at the last of compressed file after coding other characters in the file. These extra sets of bits are called footer bits, as they resemble the footer note of a word document that is added at the end of a page. Generally to identify the start of Footer bits from the normal compressed bits codes are added for first and third characters found in the pattern being selected (i.e.) codes of "A" and "C" are added in footer information. They also help in the identification of the sub patterns between which the reduced character namely "B" (here) have to be inserted during decompression.

3.2.3 Search of best patterns

The original medical image considered for compression can be of any type namely scans images, or x-ray or MRI etc. As the first step, all the characters are read with an initial note of forming the frequency table. The count for each character is entered in their corresponding ASCII position in the output file. Now the file is searched for 3-length patterns with the initial conditions stated above. This aim for finding the patterns forms the basic differences from original method. The positions of occurrence of each and every pattern throughout the file are stored with their count of occurrence. Each and every pattern has its corresponding sub pattern formed by their first and last character (i.e.) omitting their middle character. These sub patterns are also searched for its occurrence throughout the file. Their positions and their count are stored along with their corresponding pattern's positions and count.

After tracing the patterns, selection is made for the best pattern that can yield the maximum amount of bits that can be reduced. Hence, an array is constructed which holds the total bits that can be reduced for each and every pattern. The total bits that can be reduced are calculated by computing the product of the code length of the middle character of each and every pattern of length 3 that are being stored and their count. Hence a tree data structure is constructed. Based on the codes formed for middle character for the patterns, the maximum bits that can be reduced are noted. Then this large sum is subtracted from the number of footer bits being added to the file. This is obtained by computing the sum of counts of occurrences of the pattern and its corresponding sub pattern. The total number of bits that can be reduced for each pattern is then stored in a new array for each pattern. The patterns are then sorted in the descending order to decide for the best pattern.

Once the best pattern is decided, footer bits are identified. Any footer information starts with the codes for the first and the third character of the chosen pattern. The remaining bits are formed based on the position of occurrences of the selected pattern and its corresponding sub pattern. This is obtained by finding the index of the best pattern from the stored pattern array. Based on this index, 1 is added to the footer information if the first encountered position is from patterns list, else a zero is added if the first encountered position belongs to that of sub patterns.

The normal Huffman method is followed if the best pattern cannot be found. The compressed file is formed by replacing each character with their codes except the middle characters in the chosen pattern, which are checked by their positions already traced. The footer bits are added at the last after adding compressed codes. The set of bytes so formed make up a compressed file. The compressed file includes an extension **".** hff1**"** to the original bmp file. As the compressed file size gets reduced further, the amount of compression done here increases in comparison to Huffman model.

3.3 Optimization

In the optimization part, the new compression algorithm is improved further by selecting out two best patterns each of length three but assisted via a single set of footer information. In simple words it is the extension to one pattern replacement. This part helps in increasing the compression percentage by 2-3% more than the single pattern and by 4-5% than the Huffman method. The research was further extended to search for 3 best patterns, which yield better compression ratios than existing methods (Divya Mohandass, Dr.J.Janet, 2010). The 3pattern Huffman compression algorithm as depicted in Fig. 4.can be applied to all types of medical images namely CT, MRI and ultrasound images. Experimental results indicate improved compression ratios without compromise on image quality.

However, at a particular point in time, as the numbers of best pattern search increases, a slight degradation in the image quality is observed. The threshold value' n' is computed, where there is some complexity in pattern search and image quality. The value of n is found to be 5.

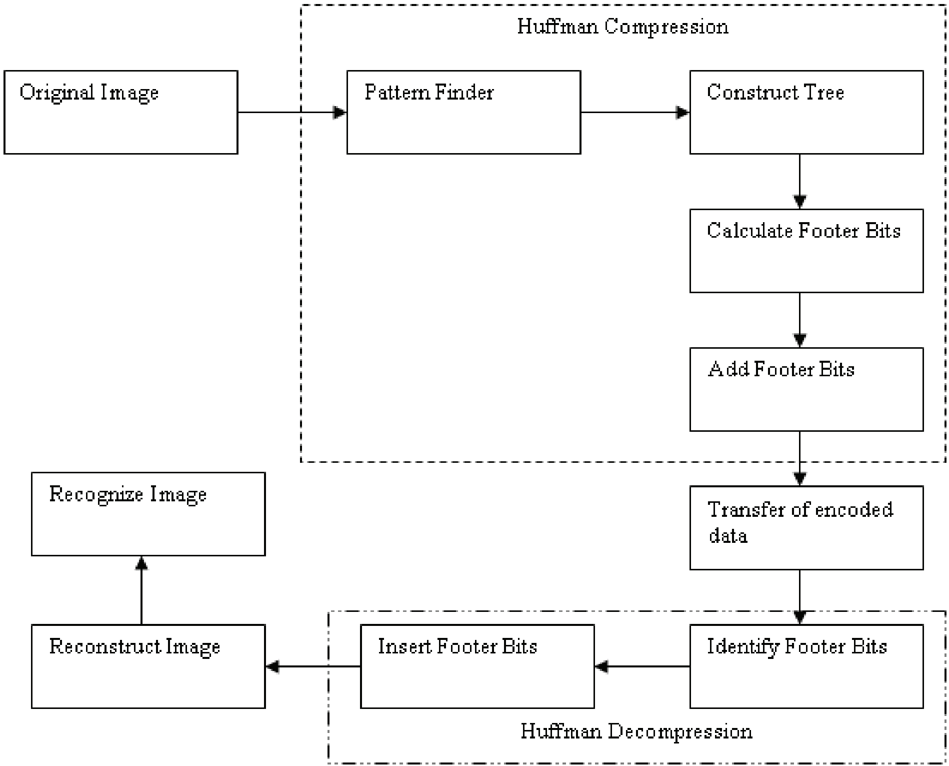
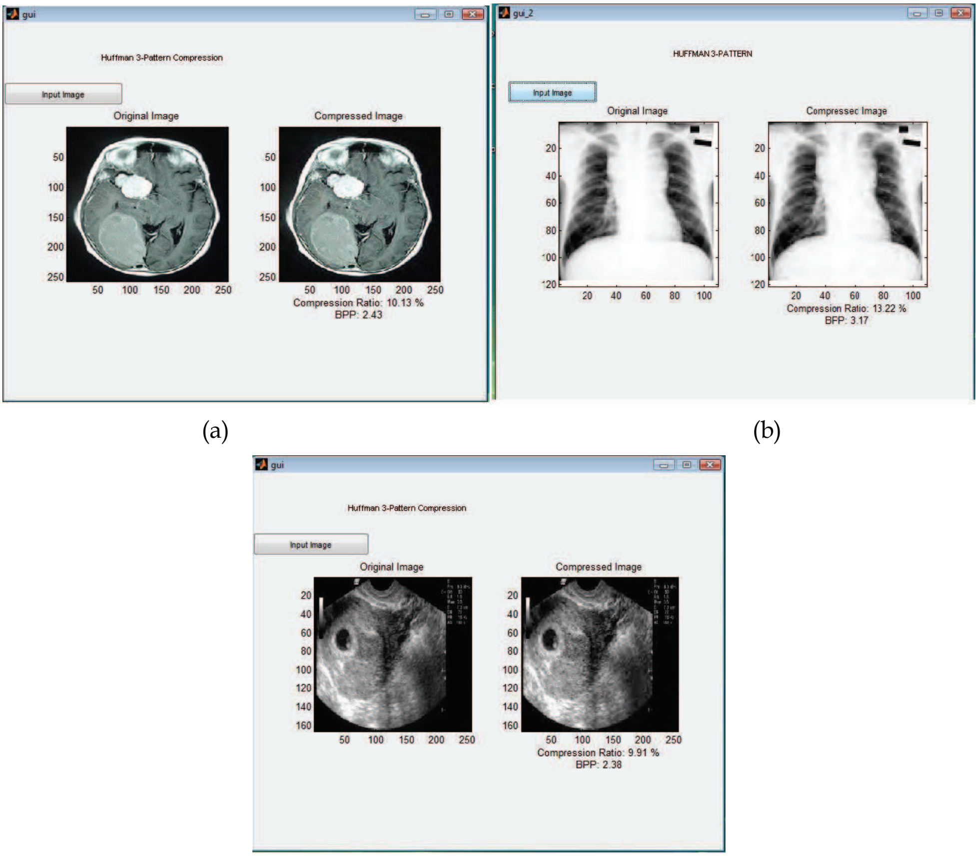


Fig. 4. 3-pattern Huffman compression algorithm

Increasing the value of n to be greater than 5 introduces complexity in computation of footer bits. Increasing size of footer bits causes a reduction in the compression ratio. Hence, it has been observed that the search for best patterns is restricted to 5.

A hybrid compression technique (Divya Mohandass, Dr.Janet,2010) was also implemented. The input to the system was an ultrasound medical image.The image was segmented into ROI and non-ROI using Canny Edge Detction Algorithm.The ROI was compressed using 4-pattern Huffman compression algorithm and the non-ROI was compressed using lossy baseline JPEG algorithm. Another challenge pertaining telemedicine namely image segmentation has been addressed with the design of a hybrid algorithm (Divya Mohandass, Dr.J.Janet,2010).The hybrid algorithm has been tested on ultrasound images with cyst. The input algorithm was introduced to enhance the amount of compression still further.



(c)

Fig. 5. 3 Pattern Huffman Compression results a) MRI Brain image b) X-ray chest image c) Ultrasound abdomen image

4. Transform based image compression

The focus on image compression algorithms lie on the fact that image should be represented with a minimum number of bits while maintaining a desirable quality. A number of methods are available in literature. Transform coding is a widely used method of compressing medical images.2-D images from the spatial domain are mapped to the frequency domain and concentrates vital information into few transform coefficients. The generalized transform-based image compression method works as follows:

a. Image Transform: This operation aims to decorrelate pixels of the image. This operation is reversible and does not cause any loss of information in the image. Examples of such a transform operation are cosine transform, wavelet transform and contourlet transform.
b. Quantization: This operation is irreversible and represents the lossy stage in the compression process. It maps a large set of input image values to a smaller set of quantized values.

c. Encoding: This process removes redundancy of the output of the quantizer. The most common entropy coding techniques are Run-Length Encoding (RLE), Huffman coding, arithmetic coding and Lempel-Ziv- Welsh methods.

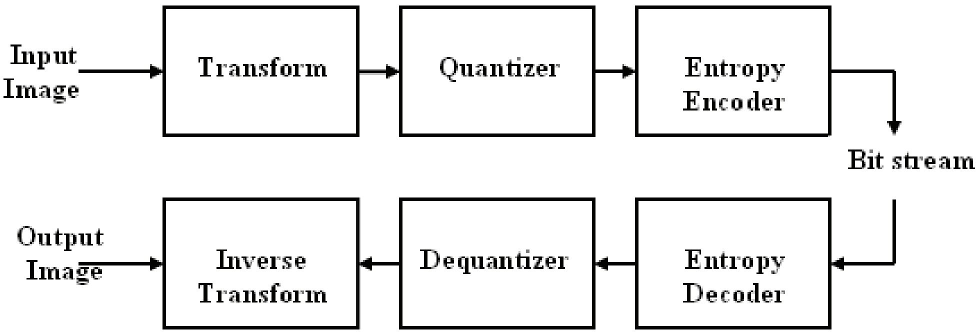


Fig. 6. Transform based image compression

4.1 Proposed strategy

In this chapter, a Joint compression method based on contourlet and built upon the well known Huffman encoding is proposed. The basic characteristics of contourlet transform and the details of the proposed strategy are presented in detail.

4.2 Contourlet coding

Contourlet transform is an extension to the existing wavelet transform. They use non-separable and directional filter banks. Recent studies reveal the lack of directionality caused by wavelets. (M.Do.and M.Veterelli,2005) have proposed the concept of contourlet in representing contours and other fine details in an image, which was a drawback in the wavelet methods.Moreover,unlike other transforms, contourlet is easily implemented by a filter bank (S.Esakkirajan et al.,2006).

Contourlet transform comprises two blocks, a Laplacian pyramid (LP), introduced by (Burt and Adelson,1983) and a directional filter bank (DFB). The LP decomposition at each level generates a signal by means of a low pass filter and down sampling. This coarse version is then sampled up and filtered to predict the original image. The prediction residual constitutes the detail signal as seen in Fig. 7. This procedure can be repeated iteratively in order to obtain a multiresolution decomposition.

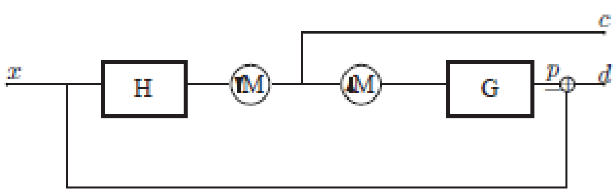


Fig. 7. Laplacian pyramid

In contourlet decomposition, a directional filtering is performed on the band pass versions of input signal. Hence, it needs a decomposition that permits further sub band decomposition of its band pass images. LP has two advantages. First, it generates only one band pass version, second, it does not suffer from the frequencies “scrambling
In contourlet scheme, a structure which implements the dual frame reconstruction has been implemented because it is an optimal choice in presence of noise.

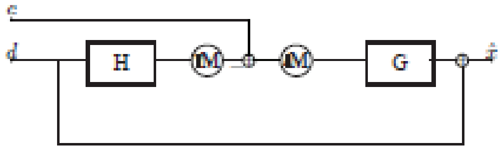


Fig. 8. Directional filter bank

The second block of contourlet decomposition is a directional filter bank that singles out directional components, with a number of directions that can vary as a power of two. Bamberger and Smith introduced a perfect reconstruction directional filter banks (DFB) that can be maximally decimated, implemented via an l-level tree-structured decomposition that leads to 2l sub bands with wedge-shaped frequency partition. Fig.9 shows an example of DFB frequency partitioning with l = 3, the sub bands 0-3 correspond to the mostly horizontal directions, while sub bands 4-7 correspond to the mostly vertical directions.

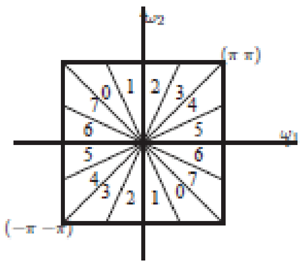


Fig. 9. DFB frequency partitioning with l=3

4.3 Global thresholding and Huffman encoding

The proposed approach involves the computation of threshold using the Otsu’s method. (N.Otsu,1979) proposed the widely used binarisation method. If a binarization method computes threshold for an entire image, it is known as a global method.Local thresholding is more adaptive, by selecting different threshold for each area in the image, according to the image characteristics.
In this method, we can directly calculate the threshold without pre-treatment to histogram. This algorithm is simple and is a remarkable method for selecting the threshold. The fundamental principle is given.

The gray value of a grey-scale map is 0~255.The total number of pixels is defined as N, n_i is the number of pixels which's gray value is i. By normalizing the histogram, the following equations could be obtained.

$$\sum_{i=0}^{255} n_i = N \tag{1}$$

$$p_i = \frac{n_i}{N} \tag{2}$$

p_i is the probability of the pixels which's gray value is i. The threshold of the image segmentation is defined as m, then the probability θ and mean value μ of the background can be obtained through the following equations:

$$\theta_0 = \sum_{i=0}^{m} p_i \qquad \mu_0 = \frac{\sum_{i=0}^{m} ip_i}{\theta_0} \tag{3}$$

The probability and typical value of the target also can be obtained:

$$\theta_1 = \sum_{i=m+1}^{255} p_i \qquad \mu_1 = \frac{\sum_{i=m+1}^{255} ip_i}{\theta_1} \tag{4}$$

The variance between the background and target is defined as σ^2

$$\sigma_B^2 = \theta_0(\mu_0 - \mu_T)^2 + \theta_1(\mu_1 - \mu_T)^2 \tag{5}$$

$$\mu_T = \sum_{i=0}^{255} ip_i \tag{6}$$

By computing the equation (3), (4), (5) and (6), the following equation (7) could be obtained.

$$\sigma_B^2 = \theta_0\theta_1(\mu_0 - \mu_1)^2 \tag{7}$$

Variance is a metric of the uniformity of distribution, the greater the variance yields, the greater the difference between the target and the background. Therefore, the threshold which makes the variance yields maximal is the optimal threshold.

4.4 Contourlet based joint medical image compression

A simple block diagram of the proposed strategy is depicted in Fig. 10. The input to the system is a gray scale image. A 2-dimensional contourlet transform is applied to the acquired input medical image. The image is split into 8 subbands. Global Thresholding and Huffman encoding is applied to the lower frequency sub bands and the compression percentage is calculated.

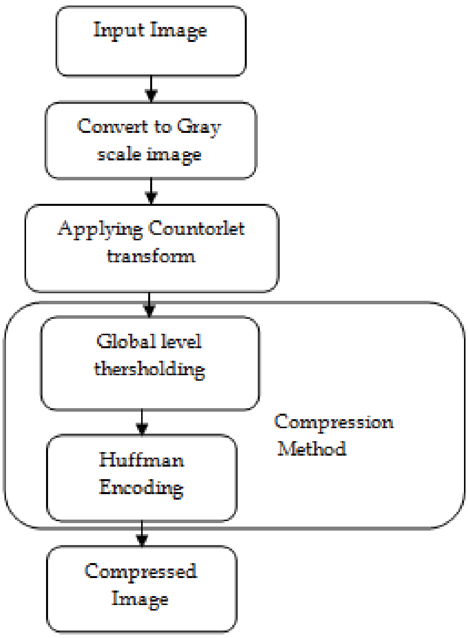


Fig. 10. Block diagram of proposed system

4.5 Algorithm Steps of Joint Contourlet based Medical Image Compression

Step 1. Input Medical image
Step 2. Convert Gray scale image
Step 3. Contourlet transform
Level = 3
Begin contourlet (Input image, Level)
CT = nsctdec (Input image, Level)
for x = 1:2^Level
Add the all contourlet subband images
end
End Contourlet (Input image, Level)
Step 4. Step 4: Compress technique
Method name = ‘gbl_mmc_h'
option = 'c'
Begin Compress (Method name, option, Input image)
1. Calculate size of output image.
2. Calculate compression percentage.
End Compress (Method name, option, Input image)

5. Experimental results and discussion

The proposed algorithm was tested on 256x256 CT, MRI medical images. Simulation results reveal the compression ratios and PSNR values of the tested input images.

$$\text{Compression Ratio} = \frac{\text{Compressed Size}}{\text{Uncompressed Size}}$$

Thus a representation that compresses a 10MB file to 2MB would yield a space savings of 1 - 2/10 = 0.8, often notated as a percentage, 80%.
PSNR expanded as Peak Signal To Noise ratio is a metric used to determine the quality of reconstruction in any compression method. For a considerably good quality image reconstruction, the PSNR ranges from 20 to 40. Experimental results reveal that our method shows good compression ratios and PSNR values.The compression ratio and PSNR values were computed on various test images and calculated.

Test Image	Compression Ratio	PSNR value(db)
Image1	11.78	34.03
Image2	13.84	33.39
Image3	10.76	35.53
Image4	17.93	35.61
Image5	14.27	34.68
Image6	15.2	35.07
Image7	15.53	32.8

Table 1.Compression ratio and PSNR values of test images

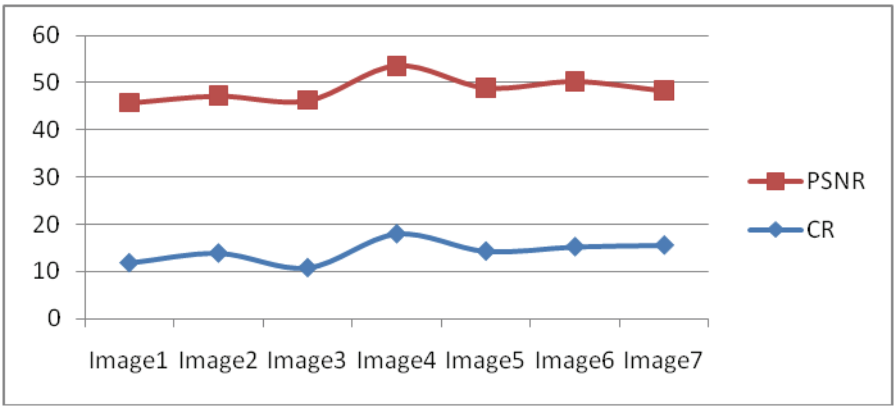


Fig. 11. Graph plot of CR and PSNR of test images

6. Conclusion

In the present chapter, a joint medical image compression scheme based on contourlet transform was proposed. The outcome obtained on applying most of the image processing algorithms is that they give different results when applied to different classes of medical images. The algorithm was applied to various medical images, collected from a database of CT, MRI modalities. Better image reconstruction is possible, on account of the application of the contourlet transform Telemedicial applications require images to be transferred without loss of information.Hence, lossless methods are applied. The proposed system is a purely lossless technique in which the experimental results reveal improved compression percentages, than the existing methods in literature, thereby making it suitable for telemedicine applications and for the medical fraternity. In future, the joint medical image compression technique could be applied on different transforms namely directionlets and curvelets , and the compression percentage could be evaluated.

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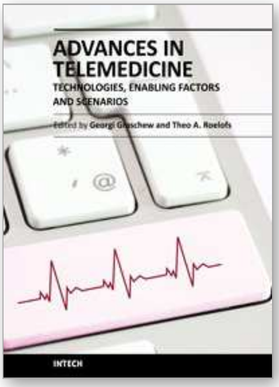

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Innovative developments in information and communication technologies (ICT) irrevocably change our lives and enable new possibilities for society. Telemedicine, which can be defined as novel ICT-enabled medical services that help to overcome classical barriers in space and time, definitely profits from this trend. Through Telemedicine patients can access medical expertise that may not be available at the patient's site. Telemedicine services can range from simply sending a fax message to a colleague to the use of broadband networks with multimodal video- and data streaming for second opinioning as well as medical telepresence. Telemedicine is more and more evolving into a multidisciplinary approach. This book project "Advances in Telemedicine" has been conceived to reflect this broad view and therefore has been split into two volumes, each covering specific themes: Volume 1: Technologies, Enabling Factors and Scenarios; Volume 2: Applications in Various Medical Disciplines and Geographical Regions. The current Volume 1 is structured into the following thematic sections: Fundamental Technologies; Applied Technologies; Enabling Factors; Scenarios.

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