International Journal of Multidisciplinary and Current Research

Research Article

ISSN: 2321-3124
Available at: http://ijmcr.com

Progressive Transmission Techniques in Medical Imaging

Archana J.N

Department of Computer Science and Engineering, Atria Institute of Technology, Bangalore.

Accepted 02 September 2013, Available online 01 October 2013, (**Sept/Oct 2013 issue)**

Abstract

Progressive Transmission of an image permits the gradual improvement in the quality. When the size of the image has to be more the progressive transmission helps in restoring the actual quality of the image. This can be used in Medical Image transmission in order to maintain the quality of the image transmission. Also it can be used for picture archiving and communication systems (PACS).It can be used to achieve high effective compression ratio by eliminating the need to transmit the unnecessary portion of the images when the transmission is interrupted. This technique is particularly useful where the bandwidth of the channel is limited and the amount of data is large. In order to send image data progressively, the data should be organized hierarchically in the order of importance, for example from the global characteristics of an image to the local detail. In this paper the various methods used in the progressive transmission of medical images are analyzed and a Haar wavelet –based image transmission scheme which uses the discrete wavelet transform to transform a digital image from spatial domain into frequency domain done. The concurrent computing used here has significantly reduced the computation time overhead as well as the transmission time to a great level.

Keywords: *Progressive Transmission, HEDI, Discrete Wavelet Transformation, Haar wavelet*

1. Introduction

Due to the advances in multi-media applications and digital imaging technology, obtaining high-resolution digitized images from databases over a computer network is becoming more popular than ever. This has led to a growing need for compressing images, both for archival and transmission. In general, lossy compression techniques provide an order of magnitude compression ratio (20:1 to 30:1) than that of lossless compression (2:1 to 4:1). Nevertheless, some applications such as telerdiology do not tolerate any loss of fidelity when images are sent or accessed over a network interactively for the purpose of viewing and analysis. Since the typical resolutions of such images ranges from 1K x 1K to 4K x 4Kwith 8 to 12 bits per pixel, it takes from several minutes to an hour to send one complete image even with dedicated data phone lines. A hybrid method based on a combination of lossy and loss less techniques has been suggested to utilize merits from two techniques: a higher compression ratio from the first and a perfect reconstruction from the latter. The method, however suffers from two major disadvantages. First, depending on the compression technique employed, it requires two different data formats for each method: one for lossy compression and the other for residual error image between the original and the reconstructed image using lossy compression technique. Second, the compression ratio of the combined method tends to yield higher entropy than that of the loss less only case. Recently as the technology and the quality of medical imagery such as MRI and CT improves continuously, so does the need for a system from health care professionals to share the benefit of telemedicine with patients. To satisfy these demands, several schemes that combine medical techniques with network technology have been suggested and studied. However, despite of amazing advance of network technology, network techniques alone cannot provide enough bandwidth to satisfy all the practical demands. To compensate these limits of network techniques and to improve the efficiency of image transmission, compression algorithms are widely used in this area. Compression algorithms used for this purpose must have some properties according to the characteristics of medical image as follows: First, the algorithm should reduce loss as much as possible. Because the quality of medical image links directly to the quality of the service that the patient receives, loss of information in medical image may cause a fatal misdiagnosis. Second, the algorithm should have high compression efficiency. Medical image has vast information in it, so its size generally gets over 10 MB, sometimes more than 100MB. Assuming these large images are to the transmitted from the emergency room to doctor's residence via 56K modem, 10MB image takes 3~5 minutes, 100MB image takes more than 30 minutes to transmit. So, reducing the size of image data is desirable. Third, progressive transmission is needed. Because of aforementioned image size problem, it may take some minutes that doctor can recognize his miss-selection. This miss-selection of image may cause much miss-penalty time according to image size. To solve this problem, user should be able to browse image database with partially transmitted data. This service can be accomplished by progressive transmission. Algorithms that satisfy these requirements are suggested by several researches. It includes low-bandwidth channels for long-distance switched communication, as in PACS applications [1].

2. Progressive Transmission

Progressive transmission of an image permits the initial reconstruction of an approximation followed by a gradual improvement of quality in image reconstruction. In applications for picture archiving and communication systems (PACS) or multimedia, the concept of progressive transmission is of particular importance in browsing large image files. It can be used to achieve high effective compression ratio by eliminating the need to transmit the unnecessary portion of the images when the transmission is interrupted. This technique is particularly useful where the bandwidth of the channel is limited and the amount of data is large. In order to send image data progressively, the data should be organized hierarchically in the order of importance, for example from the global characteristics of an image to the local detail. There are two types of data structures for progressive transmission depending upon the encoding method employed: transform based encoding and spatial encoding .In a transform-based encoding approach, the image is first divided into a set of contiguous non overlapping blocks. Then each block is transformed into a set of transform coefficients for example using DCT. The coefficients are then quantized appropriately before initiating its transmission. On the other hand, a spatial approach, like pyramidal encoding, generates a set of image frames at different resolutions. An image is successively reduced in spatial resolution and size by sub sampling or averaging. Approximation of an image can be obtained using a single frame or a combination of frames in pyramid from top to bottom level naturally constitutes a progressive transmission.

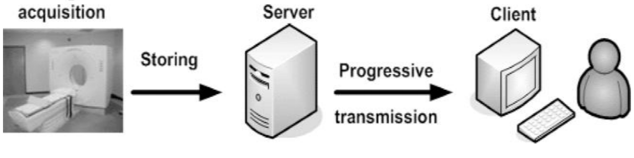


Fig.1. Client–server scheme for progressive transmission.[5]

At the receiving end, progressive expansion from the top level is done using the technique corresponding to that used at the sending end.

The process of progressive transmission (Fig.1)can be described using the following procedure. First the image is acquired and stored in the image server. In the server, the image is decomposed into "pieces", called regions. These regions can be either parts of the original image, parts of some transformation of the image. As the next step a region of the decomposed image is chosen, based on a criteria and then is transmitted to the client. Now the client uses the received data (regions)to make an approximation of the original image, using an adequate reconstruction algorithm. A new region among the untransmitted region is chosen and the server transmits it to the client. Now the client adds the just received region to the already transmitted ones and uses the whole set of received regions to reconstruct a new approximation of the original image with improved quality.The speed or time for compressing and decompressing is another important issue for image archival purposes. In most medical applications, for example, decompression is done more often than compression, since an image is generally compressed and stored in an archive to be used later for clinical purposes.

Progressive Transmission Requirements

The progressive transmission of images is considered as a basic requirement for general public access to obtain digital image details. Hence progressive transmission must meet these requirements[5]:

1. It must provide user the details of the image whenever it is needed, rather than making the user wait until all the data are received.
2. The overall image quality has to be improved with respect to the time.
3. The partially received image must be in proper order with full spatial coverage and lack any objectionable effects due to the incompleteness of the received data.
4. It must allow the user to cancel an image and move on to another image (browse mode),or to ask for more data that will improve the spatial resolution or increase the fidelity of the image in hand.
5. The system must be able to provide a lossless transmission, and the change in image quality as a function of compression factor must be quantifiable for the user.

3. Related Work

The techniques of progressive image transmission (PIT)is divide image delivery into several phases. Progressive image transmission's main objective is to efficiently and effectively provide an approximate reconstruction of the original image in each phase. A review about the various Progressive Transmission Techniques is mentioned in the literature .In [1] a method named HEDI (**Hierarchy Embedded Differential Image)** is used to provide progressive transmission of medical images. In [2] a Haar wavelet based image transmission scheme which uses the discrete wavelet transform to transform a digital image from spatial domain into frequency domain has been explained. In [3] the author proposes a model of concurrent DWT for image compression In [4] In [5] an algorithm for lossy adaptive encoding of digital three-dimensional (3D) images based on singular value decomposition (SVD) is mentioned. In [6] a modified 2D Haar Wavelet Transformation calculation schema is given which aims at developing computationally efficient and effective algorithms for lossy image compression using wavelets techniques.

4. Progressive Transmission Techniques

1. A.Hedi (Hierarchy Embedded Differential Image)

Pyramid Structures

Progressive transmission is a method of data transmission that provides a coarse to fine description as the data flows into the system. This is done by sending the global shape information of the image first, then followed by sending the detail information later to complete the image. Pyramid structure is a data structure, which arranges data in levels. There are several types of pyramid structures: mean-pyramid, difference pyramid, and reduced difference pyramid, etc. Among these, reduced difference pyramid is superior to others in the viewpoint of transmission and compression efficiency. Mean pyramid is a structure whose higher-level value is only mean of lower level blocks. Since this structure adds only mean image data to original image, the overall size increases. Reduced Difference pyramid (mean sampling) is a structure whose higher-level value contains a mean value and lower level value contains a difference between original image and mean image. This structure can reconstruct the original image without any additional data space. One of the most important characteristics of HEDI is its capability of progressive transmission. HEDI can be recognized as superset of this reduced difference pyramid. In HEDI algorithm, pyramid like Fig 2 is constructed by an initial value and residual value for this initial value.

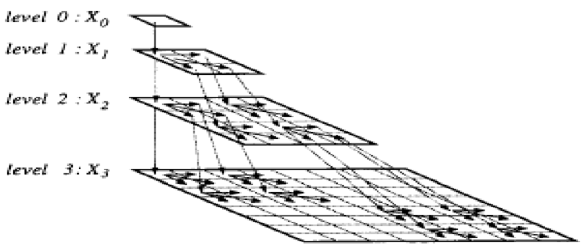


Fig 2: Hierarchical Representation of an Image

The procedure for embedding hierarchical data structures in an image plane of the same size is described below. In these structures, its predictor represents each block.

2.Hedi For 2D Images (2D Hedi)

Sub-sampling Method

Let (X1) be a set of image frames in a conventional pyramid form, as shown in Fig, 2.1. The number of pixels in an image frame, x1 is s1 x s1. Here / denotes level number, with the lowest resolution level 0 at the top; and level L with the highest resolution same as the original image, XL. As the level increases, so does the resolution of the image frame Xl at level l, forming the pyramid structure.Fig 2.1 depicts a 2 x 2 subsampling method for a complete image of size 8 x 8. In this figure, frame X0 in (a) is the shaded pixel, and X1, in (b) has four shaded pixels in this subsampling method, the predictor of a block is defined as the first pixel of the block. Initially the predictor of the hole image XL is the first pixel in raster scan (shaded pixel in Fig. 2.1 (a). Then the image is decomposed into 4 equal quadrants of size 2 L-1 x 2 L-1 each , and the next frame of image is then formed from predictors of these 4 blocks. The predictor of the first block at level 1 is the same as that of level 0, and it becomes the parent node for the remaining three blocks. To construct HEDI, the residual error which is the difference between the parent node and predictor's own pixel value at this level, is computed and stored at the same location in YL. These difference values are illustrated by solid arrows in Fig. 2.3. At any level 1, only three children nodes of each block in YL are computed, and the number of blocks grow by (2x2)l-1, Therefore, the actual number of values stored in YL at each level 1 is 3 x (2x2)l-1. Here 1 is larger than 1 since there is only root node and no children nodes at the top level, This process is repeated until we reach the bottom level where the block size reduces to 1 x 1

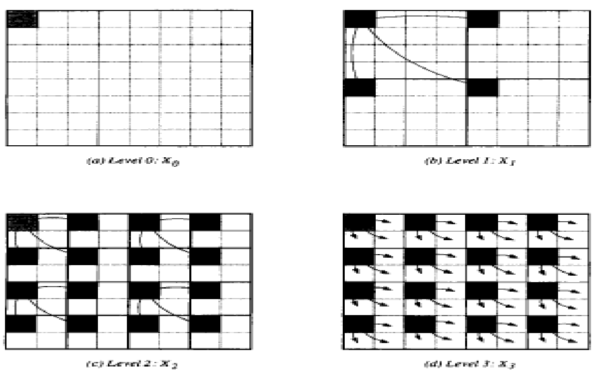


Fig. 2.1. 2 x 2 method on an 8 x 8 image(2D HEDI-Sub Sampling)

In the top-down approach discussed above the construction of the image hierarchy at different levels and its transmission can occur simultaneously while accessing pixels of image to process. On the other hand, in the bottom-up approach, an image XL of size 2L x 2L is first decomposed into spatially contiguous, non over lapping blocks of 2 x 2 pixels Then a new frame of image at next level with half the resolution of the original image is formed by the predictors of each block of 2 x2 pixels. The same process is repeated recursively on the reduced resolution image formed by the predictors to yield a new image at one quarter of the resolution where the block size increases by 2 (i.e., image at a level l is obtained from its proceeding level unlike XL in a top- down approach). This process is repeated until the block size, becomes the size of the original image. Notice that in this approach, the whole hierarchical structure is constructed before the transmission commences because the top level of the pyramid initials the transmission. Therefore, while building the, while building the HEDI, the communication channel remains idle and the system becomes less efficient in utilizing the computational resource

Mean Sampling Method

The subsampling method described yields poor quality images suffering from the blocky effect at the intermediate levels of transmission. One way of reducing the effect is to use a low pass filter such as averaging. Therefore, in a mean sampling method, the predictor of a block is the mean of the block.A 2 by 2 mean- sampling method was originally described by Wang et al. In this method, for every 2 x 2 block of image at any level l., we compute the mean and difference values by going around the window as shown by arrows in fig 2.3 (b). In this figure $y_{r,c}$ is the mean of the block, and $y_{r,c+s}$, $y_{r+s,c}$ and $y_{r+s,c+s}$ are the corresponding errors .The algorithm described above builds HEDI using 2 x 2 block with the mean- sampling method with circular differences HEDI-CM2.Once the HEDI is constructed, the progressive transmission begins by transmitting the mean of the image obtained at level 0. Then for each level l, the errors are transmitted for all the blocks at that level when the mean value is transmitted, it is sent as an integer, hence $y_{r,c}$ has to be rounded before sending . Fig 2.3 represents the 2-D HEDI applied to an 8 x 8 image with mean sampling approach.

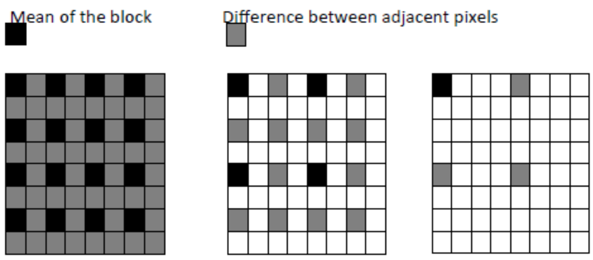
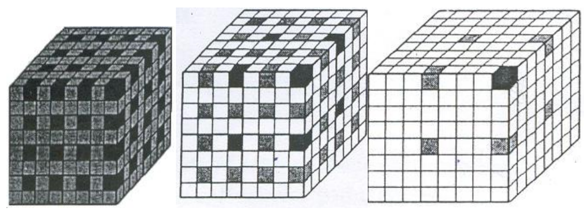


Fig. 2.3 2D HEDI applied to an 8x8 image (Mean Sampling)
(Solid line indicates the border of the block):(a)Level 2 (b) Level 1 (c) Level 0

One drawback of the circular difference method is that during reconstruction, the four have to be computed sequentially because of the circular differences. The drawbacks of the above mean scheme can be avoided by using the radial difference scheme described earlier As before, the mean value is rounded and transmitted as an integer. However, in this case, the transmission is lossless because it is possible to recover the original image at the receiving end. Hence the RM2 method described above is a lossless method for progressive transmission. HEDI's constructed by RS and CS methods are different, but the intermediate image frames at the receiving end are the same. In other words, the set of intermediate image frames reconstructed at the receiving end using RS method is the same as those of using CS method. Similarly, the set of reconstructed image frames using RM is the same as those using CM method. Thus four hierarchical structures (RS2, CS2, RM2, CM2) were constructed using the 2-D HEDI

3. Hedi for 3D Images (3-D Hedi)

As aforementioned, medical image has two major characteristics. Generally, it has a large size. Because medical doctors want to hold every one little bit of analog source image, one medical image might have more than 100,000,000 pixels. Some defects from lossy image compression may confuse medical doctors. This might cause a serious situation, therefore, lossless compression methods are usual for medical image. Lossy compression methods can commonly provide higher compression efficiency about 10 times than lossless methods. For this reason, attempts to introduce lossy compression method into medical field are continuously made using near-lossless scheme. When the amount of data is very large, as a 3-D medical image, the progressive transmission plays an important role in viewing or browsing the image. The data structure takes into account of inter frame correlation as well as intra frame correlation of 3-D images. This type of data structure has been termed as the 3-D hierarchy embedded differential image(3-D HEDI) as was derived from the earlier HEDI structure.



(a) Level 2 (b) Level 1, and (c) Level 0

The concept of 2-D HEDI can be extended to any multidimensional image. An M.dimensional (M-D) image is successively reduced in spatial resolution and size using mean–sampling (or) sub-sampling. In the HEDI encoding step, the M-D image is decomposed into a set of non-overlapping 2M blocks , ie., 2 x 2 pixel blocks in a 2-D case, and 2 x 2 x 2 pixel blocks in a 3-D case, as illustrated in fig 2.6. In a 2-D image, the parameter l is used to index levels and r,c to index row and column numbers of blocks, respectively, and k to index pixels within a block.

In a 3-D image, another parameter s is used to index the depth numbers of blocks (third dimension), Therefore y r,c,s(k) represents the pixel value of the kth pixel in the row r , column c, and depth s block.In the encoding step, the pixels of each block are converted into two types, the first pixel of each block is replaced by the rounded mean of the block (in the case of mean- sampling) and the first pixel of the block itself (in sub- sampling approach), and the rest of the pixels of each block are replaced by the differences between adjacent pixels. To build a hierarchy without additional space, the first pixel of each block (the rounded mean of the block) is reused as a pixel to the upper level. In the decoding step, the original image can be reconstructed recursively and losslessly. Similar to that of the 2D HEDI procedure, RS3, CS3, RM3 and CM3 were constructed for the transmission of 3D medical images.

B.The Haar Wavelet based Discrete Wavelet Transformation

1.Haar Wavelet Technique

The Haar wavelet is the simplest type of wavelet .In discrete form, Haar wavelets are related to a mathematical operation called Haar transform. The Haar wavelet's mother wavelet function ψ(t) can be described as

$$\psi(t) = \begin{cases} 1 & 0 \le t < 1/2, \\ -1 & 1/2 \le t < 1, \\ 0 & \text{otherwise.} \end{cases}$$

s scaling function $\phi(t)$ can be described as

$$\phi(t) = \begin{cases} 1 & 0 \le t < 1, \\ 0 & \text{otherwise.} \end{cases}$$

Properties of Haar Transformation

1. Haar transform is real and orthogonal.

Hence Hr = Hr* ------------(1)

$Hr^{-1} = Hr^T$ -------------(2)

Haar Transform is a very fast transform.

2. The basic vectors of Haar matrix are sequency ordered.

3. Haar Transform has poor energy compaction for images.

4. Orthogonality:The original signal is split into a low and a high frequency part and filters enabling the splitting without duplicating information are said to be orthogonal.

5. Linear Phase: To obtain linear phase, symmetric filters has to be used.

6. Compact support: The magnitude response of the filter should be exactly zero outside the frequency range supported by the transform. If the property is satisfied, then the transform is energy invariant.

7. Perfect reconstruction: If the input signal is transformed and inversely transformed using a set of weighted basis functions and the reproduced sample values are identical to those of the input signal, then the transform is said to have the perfect reconstruction property. If in addition no information redundancy is present in the sampled signal, the wavelet transform is stated as ortho normal[6].

Advantages of Haar Wavelet Transform

- Best performance in terms of the computation time.
- Computation speed is high.
- Simplicity.
- HWT is an efficient compression method.
- Memory efficiency is more.

In case of image transformation there exist three types of detail

images for each resolution: horizontal (HL), vertical (LH) and diagonal (HH). The operations can be repeated on the low low (LL) band using the second stage of identical filter bank. Thus, a typical 2D DWT generates the hierarchical structure. A one Filter Stage in 2D Discrete Wavelet is illustrated in fig 3.

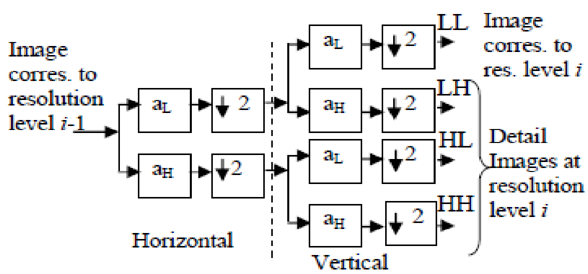


Fig. 3 One Filter Stage in 2D Discrete Wavelet Transform

Two sub-bands refining method is based on wavelet. There are three steps included here which are :decomposition, transmission, and reconstruction. In the first step , the scheme performs Haar DWT on the image. Then the wavelet coefficients are represented by sub-bands. In the next step called transmission, the sender transmits the sub-band along with some selected coefficients in the next sub-band to the receiver for image reconstruction. If the coefficients in the sub-band have been submitted, then the scheme transmits all the coefficients in the next sub-band.

2.Concurrent Transformation of Image

According to the scheme of wavelet transformation, the image data is horizontally transformed first and then vertically. Here in concurrent transformation the image plane is divided into n horizontal sections which are horizontally transformed concurrently. Next the image is divided into n vertical sections which are then vertically transformed concurrently .Fig 3.1 illustrates the process of Image division.

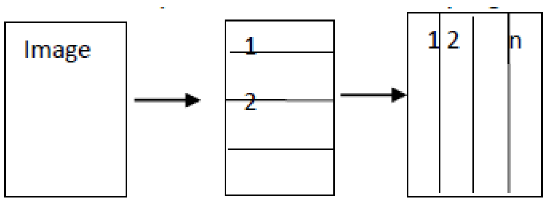


Fig-3.1 Image Division

When considering the concurrency problem in image division certain possibilities has to be considered. According to the Wavelet transformation [4] it lets the possibility for vertical transformation to begin on some vertical sections before horizontal transformation in all section is completed. Vertical sections that are already horizontally transformed can be vertically transformed as illustrated in fig 5.which permits the possibility for threads that completed horizontal transformation to go on to vertical transformation without waiting for the other threads to complete horizontal transformation. The pink color indicates sections of image data that are horizontally transformed. The white color indicates sections of image data that are not yet horizontally transformed. The pink vertical section with line stripes can be assigned to a thread for vertical transformation. Before a vertical section is available for transformation, one condition that must be met is that all horizontal sections transform *n* size data horizontally such that an *n* wide vertical section is available with all data points already horizontally transformed

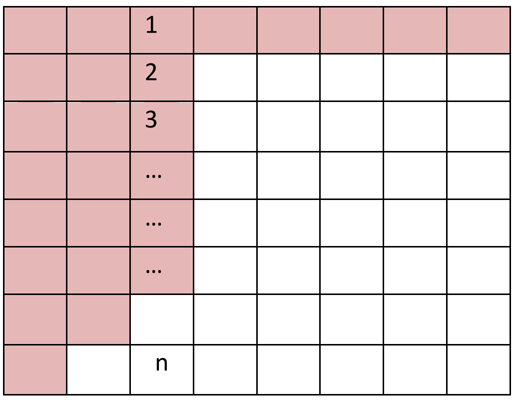


Fig 3.2 Ordering of transformation in DWT

3.Haar Wavelet based Discrete Wavelet Transformation

First of all, the image matrix is mapped from the digital image. The horizontal transformation threads are initialized for horizontal transformation. The separate process for every pair of rows of the matrix is used with a little change with the algorithm of traditional Haar wavelet transform and thus the vertical transformation process is also embedded in the row transformation process to speed up the computation process and to avoid complexity. Separate threads for transforming red, green and blue (RGB) components are used[3]. Thus multiple threads are started at a time. The threads normally transform the rows following the discrete Haar wavelet transformation. But as soon as the pair of elements of the same column is transformed the column transformation for those two components is also done. In the concurrent transformation scheme proposed in [4] vertical transformation starts after first element of last row has horizontally transformed. With our new proposal it speeds up the transformation process as no waiting time required for the column transformation after row transformation has been finished. After completion of encoding process the matrix with detail coefficients and average coefficients is found. Then the required thresholding is applied on it and the final matrix is ready to transmit to the receiver. At the transmission phase we have transmitted the matrix by pair of columns. This is also done by several threads. The decoding process is done as the reverse of encoding. Thus the reconstruction of image requires comparatively lower time. As illustrated in Figure 3(a), threads for horizontal transformation are started for each pair of rows at the same time. The region blue shaded region is horizontally transformed. In figure 3(c) horizontal transformation for the first two elements of the second row is completed. Then the vertical transformation is also done for available elements. The blue shaded region with dotted spots is vertically transformed Fig. 3(d)

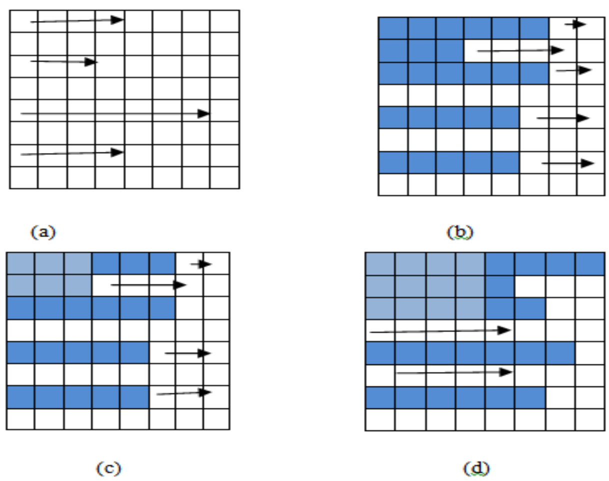


Fig. 3.3 Concurrent transformation a)Threads for each pair of row, b) Row transformation in progress, c) Column transformation done when pair of column elements are ready, d) Row and column transformation are in progress,

This method forms the output image with fractions as illustrated in figure 4. But as the fractions are parts of the original image without modification and it appears very fast the person can identify whether the image is the actual one or not within very short time[3].

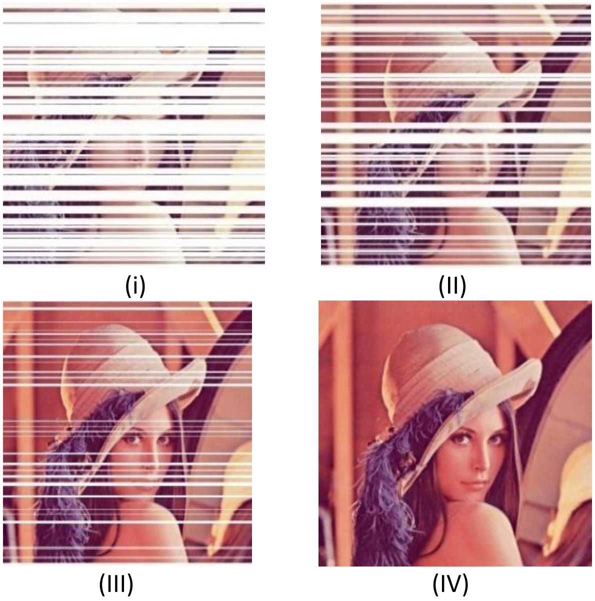


Fig.4. Reconstructed image after receiving pairs of column concurrently, PSNR values (i) 25.2837dB (ii)26.5822 dB (iii) 30.6938dB (iv) Reconstructed image 40.71 dB[4]

Conclusion

In this work the Progressive Transmission techniques used in Medical Imaging discussed. The pyramid structures in HEDI (HIERARCHY EMBEDDED DIFFERENTIAL IMAGE)followed by 2D and 3D HEDI was discussed. An enhanced method for the progressive image transmission has been discussed called Haar Wavelet based Discrete Transform ,which uses concurrent computing on Discrete Wavelet Transformation to get the enhancement and thus it reduces the image browsing time with a very less loss in reconstruction phase and also transmission is completed in very less time duration compared to the other techniques.

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