ISSN : 2347 - 8446 (Online)
ISSN : 2347 - 9817 (Print)
Vol. 2, Issue 3 (July - Sept. 2014)
International Journal of Advanced Research in Computer Science & Technology (IJARCST 2014)

Wavelet Sub-Band Block Coding Based Lossless High Speed Compression of Compound Image

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Abstract
Compression of compound image is essential for remote control software, such as real virtual network computing (VNC), which allows a person at a remote computer to view and interact with another computer across the network, as if sitting in front of the computer. A smart display device acts as a portable screen with 802.11b wireless connection to a nearby desktop PC, enabling people to surf the web or browse pictures that are stored on the desktop PC. The challenge is that the huge amount of real-time computer screen video data should be transmitted over the cable or wireless networks. One 800×600 frame of true colour screen image has a size of 1.44 MB and 85 frames/sec produces more than 100 MB data. In this paper, wavelet sub-band coding based lossless compression of compound image is discussed and the implementation shows excellent visual quality of text in compressed computer screen images.

Keywords
Compound image, Computer screen image, Image compression, Wavelet sub-band coding, Image segmentation

I. Introduction
Digital Image Processing is the use of computer algorithms to perform image processing on digital images. Digital image processing has many advantages over analog image processing. It allows a much wider range of algorithms to be applied to the input data and can avoid problems such as the build-up of noise and signal distortion during processing. Since images are defined over two dimensions, digital image processing may be modelled in the form of multidimensional systems. It allows the use of much more complex algorithms for image processing and can offer both more sophisticated performance at simple tasks, and the implementation of methods which would be impossible by analog means.

II. Compound Image
A compound image is an image that contains data of various types such as text, graphics and pictures. Each of these data types has different statistical properties and is characterized by different level of distortion that a human observer can notice. The sensitivity of human eyes for natural image and text is different. The quality requirement of compound image coding is different from general image coding because users cannot accept the quality if text is not clear enough to recognize. Most of the efforts in image compression until now have been in developing new algorithms that achieve better compression at the cost of considerable increase in complexity. Class room setup with wireless projectors and presentation computer providing the flexibility to site anywhere in the room without cable connection to the laptop is another important application of compound image compression.

III. Image Compression
The objective of image compression is to reduce irrelevance and redundancy of the image data in order to be able to store or transmit data in an efficient form. There are two types;

1. Lossless compression
2. Lossy compression

A. Lossless compression
Lossless compression is preferred for archival purposes and often for medical imaging, technical drawings, clip art, or comics. This is because lossy compression methods, especially when used at low bit rates, introduce compression artifacts. Lossless data compression is used in many applications. For example, it is used in the ZIP file format and in the UNIX tool gzip. It is also often used as a component within lossy data compression technologies. Typical examples are executable programs, text documents and source code. Some image file formats, like PNG or GIF, use only lossless compression, while others like TIFF and MNG may use either lossless or lossy methods.

B. Lossy compression
Lossy methods are especially suitable for natural images such as photographs in applications where minor loss of fidelity is acceptable to achieve a substantial reduction in bit rate. The lossy compression that produces imperceptible differences may be called visually lossless. The procedure aims to minimize the amount of data that needs to be held, handled, and/or transmitted by a computer. Typically, a substantial amount of data can be discarded before the result is sufficiently degraded to be noticed by the user. Lossy compression is most commonly used to compress multimedia data (audio, video, still images), especially in applications such as streaming media and internet telephony. By contrast, lossless compression is required for text and data files, such as bank records, text articles, etc.

IV. Block Classification
Bandwidth is a very important limiting factor in application of image segmentation. Several segmentation schemes require morphological analysis of the different regions, and multiple passes over the image being segmented. However, each pass normally requires loading memory data from slow to fast memory, which is a slow process. Segmentation solutions based on multiple passes are much slower or costly than what can be expected by, for instance, counting the number of operations. Thus, an ideal solution would use a single pass to decide on the type of image region. Such solution would be very difficult with arbitrary shapes of segmentation regions, but it is feasible if consider only a pre-defined shape. For example, rectangular blocks decide the image type based only on the properties of the pixels inside the block. Such techniques are called block classification. This technique is theoretically sub-optimal, since it must classify all pixels in the block in the same manner, even if the block contains the boundary between two regions. Another potential problem would be the fact that it does not consider the pixels in the block's neighbourhood.

Some factors mitigate the sub-optimal performance of a block-based scheme around region boundaries. First, compound images now have fairly high resolutions. If the block size is small enough, one cannot expect to have the image type changing for every block. Therefore, boundary blocks consist of a small fraction of the image. It is easy to identify those boundary blocks doing a simple analysis on a block level. Such analysis would not require as much bandwidth, because the number of blocks is much smaller than the number of pixels and it is required only when some transition is found. Using those techniques, one can obtain a segmentation that is good enough for image compression, allowing high text quality and with a complexity that is practically the same as required by one-pass segmentation. Furthermore, the resulting segmentation has very attractive features. For instance, many image compression methods are efficient on rectangular regions, but do not work well on arbitrary regions.

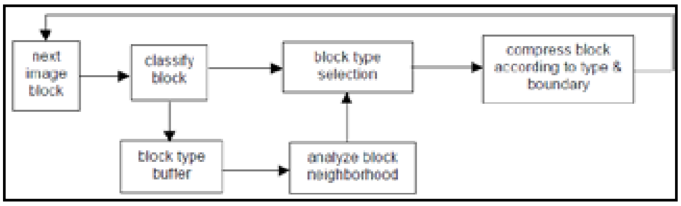

Fig. 1: One pass block classification using neighbourhood analysis

The above Fig.1 shows how the block classification is applied to an individual block. First, the block is classified according to the distribution of its pixels. Next, the class of the neighbouring blocks is analysed. At this stage, identify if a block is in the boundary between two regions, or change the classification if its confidence is low. To avoid adding the burden of analysis to the decoder, the final classification is added to the compressed stream. Finally, the block is compressed according to the identified type. The identification of boundaries is very important because it can change compression parameters for those blocks. For instance, different quantization can be set when moving from a lossy to lossless region. By introducing extra buffering, it is possible to use the block neighbourhood analysis for merging blocks that are classified in the same manner.

V. Segmentation

The goal of image segmentation is to cluster pixels into salient image regions, i.e., regions corresponding to individual surfaces, objects, or natural parts of objects. Segmentation could be used for object recognition, occlusion boundary estimation within motion or stereo systems, image compression, image editing, or image database look-up. In this paper, bottom-up image segmentation is considered. For input, primarily image brightness is considered, although similar techniques can be used with colour, motion, and/or stereo disparity information. Segmentation subdivides an image into it's constitute regions or objects. The level to which the subdivision is carried depends on the problem being solved. That is, segmentation should stop when the objects of interest in an application have been isolated. In the automated inspection of electronic assemblies, interest lies in analysing images of the products with the objective of determining the presence or absence of specific anomalies, such as missing components or broken connection paths. There is no point in carrying segmentation past the level of detail required to identify those elements. Segmentation of nontrivial images is one of the most difficult tasks in image processing. Segmentation accuracy determines the eventual success or failure of computerized analysis procedures. For this reason considerable care should be taken to improve the probability of rugged segmentation. In some situations, such as industrial inspection applications, at least some measure of control over the environment is possible at times. In others, as in remote sensing, user control over image acquisition is limited principally to the choice of imaging sensors. Segmentation algorithms for monochrome images generally are based on one of two basic properties of image intensity values: discontinuity and similarity. In the first category, the approach is to partition an image based on abrupt changes in intensity, such as edges in an image. The principal approaches in the second category are based on partitioning an image into regions that are similar according to a set of predefined criteria. The segmentation approaches used in compound document compression can be grouped into 4 classes;

- Object-based segmentation
- Layer-based segmentation
- Block-based segmentation
- Image-Coding based segmentation

A. Object Based Segmentation

In this case, a page is divided into regions, where each region follows exact object boundaries. An object may be a photograph, a graphical object, a letter, etc. In principle, this method may provide the best compression, since it provides the best match between a data type and the compression method most suitable for this data type. In reality, the best compression may not be achievable for the following reasons. Coding the object boundaries requires extra bits, and the typical algorithms, used for lossy image compression, are designed to operate on rectangular objects. They can operate on objects with non-rectangular boundaries, but the compression performance will suffer. Complexity is another drawback of this method, since precise image segmentation may require the use of very sophisticated segmentation algorithms.

B. Layer Based Segmentation

This approach can be regarded as a simplified version of the full object based segmentation. The original page is divided into rectangular layers, where each layer can have one or more objects, and "mask" planes. A mask plane tells which pixels of a particular layer should be included in the final composite page. Each layer is compressed with a specific compression method. The advantages of this approach are simplified segmentation and a better match between layer boundaries and the compression algorithms. Standard, off-the-shelf compression methods can be easily incorporated into this structure. The drawbacks of this method are: mismatch between the compression method used for a particular layer and the data types, mismatch between the object boundaries and the compressed region boundaries, and an intrinsic redundancy, due to the fact that the same parts of the original image appear in several layers. The layer-based approaches mainly proposed to efficiently compress compound images. They segment an image into foreground layer, background layer and mask. The colours of text are presented in the fore-ground layer and the positions in the mask. Both foreground and background layers are compressed by the approaches similar to those for natural images.

C. Block Based Segmentation

Block based segmentation is a simplified version of the full object segmentation. Each region follows approximate object boundaries and is made of rectangular blocks. The size of the blocks may vary within the same region to better approximate the actual object boundary. The advantages of this approach are: simplified segmentation, better match between region boundaries and the compression algorithms, and the lack of redundancy, which may be present in the layer-based approach. The potential drawbacks are the potential loss in the compression performance compared to the true object-based segmentation and the need to slightly modify the off-the-shelf algorithms to work on non-rectangular regions. Note that the segmentation performed in this case is done with the purpose of optimizing the compression performance and may not be appropriate for other uses, such as OCR, image enhancement, etc. The block-based approaches do not need accurate segmentation. Thus, some simple characters of images such as colour number, histogram and gradient are used for classification. Blocks can then be categorized into different types, such as text, graphics, natural image, and so on. A new method is proposed to represent a text/graphics block by several base colours and an index map.

D. Image Coding Based Segmentation

They adopt the conventional image coding schemes but improve the bit allocation between text/graphics and natural images areas because the text/graphics areas are often blurred after compression. Thus, the quantization steps in text/ graphics areas are decreased and more bits are allocated to them. For a fixed budget, it would correspondingly decrease bits for the coding of natural image areas. Consequently, the overall quality after compression is still not good.

VI. Wavelet Transform

Unlike the Fourier transform, whose basis functions are sinusoids, wavelet transforms are based on small waves called wavelets of varying frequency and limited duration. In 1987, wavelets are first shown to be the foundation of a powerful new approach to signal processing and analysis called multiresolution theory. Multiresolution theory incorporates and unifies techniques from a variety of disciplines including subband coding signal processing , quadrature mirror filtering from digital speech recognition and pyramidal image processing. Another important imaging technique with ties to multiresolution analysis is subband coding. In this coding, an image is decomposed into a set of band-limited components called subbands, which can be reassembled to reconstruct the original image without error.

A. Wavelet Functions

A wavelet function $\Psi(x)$ is given with its integer translates and binary scaling, spans the difference between any two adjacent scaling subspaces, V_j and V_{j+1}

$$\Psi(x) = \sum((h_\Psi(n) * \sqrt{2}\varphi(2x - n))$$

$h_\Psi(n)$ are called the wavelet function coefficients

h_Ψ is the wavelet vector

B. Discrete Wavelet Transform

Like the Fourier series expansion, the wavelet series expansion of the previous section maps a function of a continuous variable into a sequence of coefficients. If the function being expanded is a sequence of numbers like samples of a continuous function f(x), the resulting coefficients are called the discrete wavelet transform (DWT) of f(x). For this case, the series expansion

$W_\varphi(j_0,k) = (1/\sqrt{M}) \sum f(x)\varphi_{j0,k}(x)$ approximate coefficient …(1)

$W_\Psi(j,k) = (1/\sqrt{M}) \sum f(x)\Psi_{j,k}(x)$ detail coefficient … (2)

VII. System design

The system design contains two phases

- Segmentation phase
- Coding phase

A. Segmentation Phase

Compound image is split into 8x8 blocks of pixels. Apply 2D DWT on each 8x8 blocks of pixels. Then after applying DWT, four types coefficients such as approximate coefficients (LL subbands), horizontal coefficients (LH subbands), vertical coefficients (HL subbands) and diagonal coefficients (HH subbands) are obtained. Mean and standard deviation for LH, HL and HH subbands are obtained and assigned threshold value for each three subbands (i.e., LH, HL and HH). Standard deviation and threshold values of corresponding LH, HL and HL subbands are compared. The splitted 8x8 blocks of pixels into text/graphics blocks and picture/background blocks are separated.

B. Coding Phase

Wavelet coding algorithm is applied for compressing each text/graphics blocks and then Lossy JPEG coding algorithm for compressing each picture/background blocks is applied. After compression, decompression is performed for each text/graphics blocks and picture/background blocks. The combined decompressed blocks are used to reconstruct the original input image with high visual quality of text as shown in Fig 2.

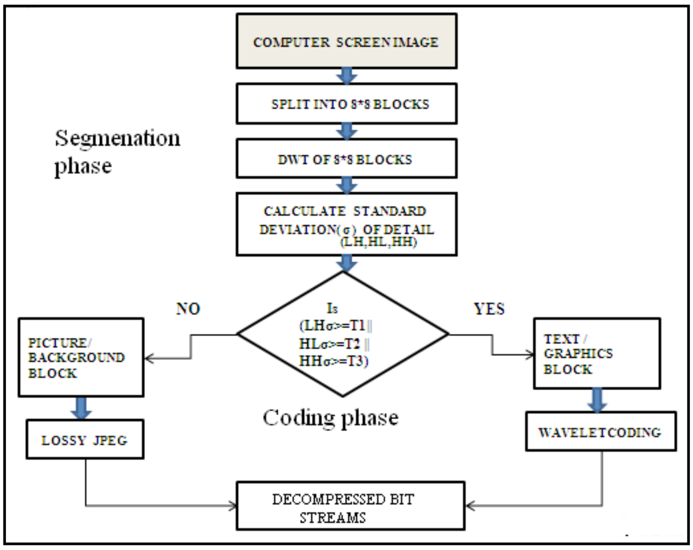

Fig. 2 : System design

VIII. Testing

A. Definition of Testing

Testing can be described as a process used for revealing defects in software, and for establishing that the software has attained a specified degree of quality with respect to selected attributes.

B. Unit testing

The principle goal for unit testing is to ensure that each individual software unit is functioning according to its specification. Good

ISSN : 2347 - 8446 (Online)
ISSN : 2347 - 9817 (Print)

testing practice calls for unit tests that are planned and public.

C. Integration testing
Integration test for procedural code has two major goals such as to detect defects that occur on the interfaces of units and another goal is to assemble the individual units into working subsystems and finally a complete system that is ready for system test.

D. Block Classification Testing
The classified 8x8 blocks of compound image are tested by using precision rate and recall rate. The recall rate is defined as the ratio of correctly detected text/graphics blocks to the sum of correctly detected text/graphics blocks plus false negatives. False negatives are those blocks in the image which are actually text characters, but have not been detected by the algorithm. The precision rate is defined as the ratio of correctly detected text/graphics blocks to the sum of correctly detected blocks plus false positives. False positives are those blocks in the image which are actually not characters of a text, but have been detected by the algorithm as text blocks.

Image	Colour based Classification		TCL based Classification		Proposed DWT based classification	
Size of Image 800x1280	Precision Rate	Recall Rate	Precision Rate	Recall rate	Precision Rate	Recall rate
Web page 1	60.87	60.91	71.43	87.40	75.00	89.35
Web page 2	85.45	97.92	75.00	78.50	88.89	98.40
ppt 1	59.00	100.00	93.40	96.80	96.70	98.89
ppt 2	90.62	100.00	94.00	95.40	97.73	99.46
Average	73.99	89.71	83.46	89.53	89.58	96.53

Table 1: Precision rate and recall rate obtained using the three block classification schemes for the images

E. Compression Testing
The compressed and decompressed text/graphics blocks and picture/background blocks can be tested by using compression ratio. In digital image processing, the compression ratio is defined as the ratio of size of original image in gray scale to the size of decompressed image. The proposed system provides competitive compression ratio.

Compression ratio = (Size of original image) / (Size of compressed image)

The peak signal-to-noise ratio, often abbreviated PSNR, is an engineering term for the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Because many signals have a very wide dynamic range, PSNR is usually expressed in terms of the logarithmic decibel scale. The PSNR is most commonly used as a measure of quality of reconstruction of lossy compression codec's (e.g., for image compression). The signal in this case is the original data, and the noise is the error introduced by compression. When comparing compression codec's it is used as an approximation to human perception of reconstruction quality, therefore in some cases one reconstruction may appear to be closer to the original than another, even though it has a lower PSNR (a higher PSNR would normally indicate that the reconstruction is of higher quality). Mean Squared Error (MSE) is two m×n monochrome images I and K where one of the images is considered a noisy approximation of the other is defined as:

$$\mathbf{MSE = (1/(m*n)) \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} [I(i,j) - K(i,j)]^2}$$

The PSNR is defined as:

$$\mathbf{PSNR = 10*log_{10}((MAX^2_I) / (MSE))}$$

Here, MAX_I is the maximum possible pixel value of image.

F. Functional testing
Functional tests at the system level are used to ensure that the behaviour of the system adheres to the requirements specification. Functional tests are black box in nature. The focus is on the inputs and proper outputs for each function. Improper and illegal inputs must also be handled by the system. System behaviour under the latter circum-stances tests must be observed. All functions must be tested.

IX. Conclusion and Future Enhancement

A. Experimental Results
The proposed algorithm is implemented on an Intel Core 2 Duo 1.66GHz using MATLAB 7.0, and several gray and colour computer screen images of various sizes to demonstrate the performance of the proposed algorithm. First, the results of block classification and then results of computer screen image compression have been discussed.

B. Future Works
For the proposed DWT based algorithm, the average precision rate is 89.58% and average recall rate is 96.53%. Hence, it leads to effective coding for text or graphics blocks as well as picture or background blocks. Wavelet coding provides excellent visual quality of text in computer screen images when compared with other compound images. In future, work is to be done to improve the efficiency of the lossless coding of text/graphics regions.

Images	Original size (KB)	Compressed size (KB)	Compression ratio	PSNR
compscreen1.tif	109	17.1	7.4:1	28.86
compscreen2.tif	122	15.9	7.7:1	27.39
text.tif	134	17.1	6.8:1	19.25
picture.tif	157	14.9	5.5:1	24.42
compound.tif	160	14.3	7.2:1	27.13

Table 2 : Compression ratio and PSNR of various images

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Fig. 3: Computer screen image

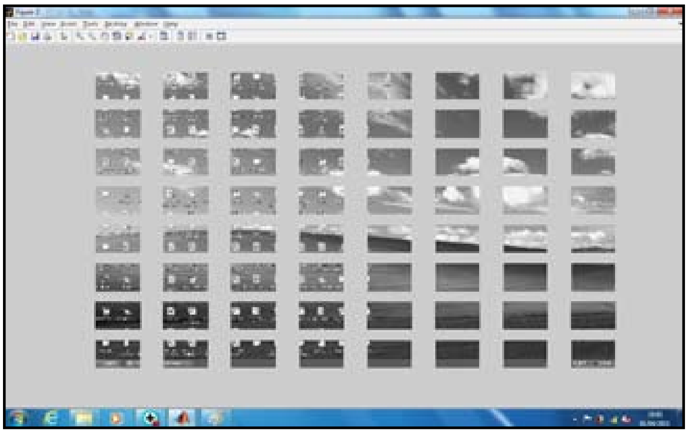

Fig. 4: 8x8 blocks of Computer screen image

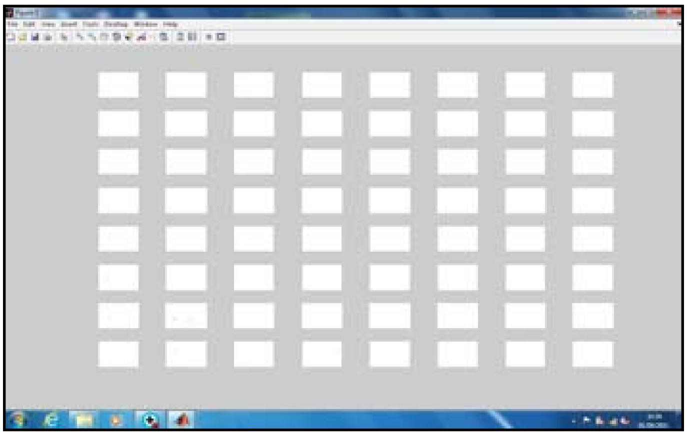

Fig. 5 : Approximate coefficients (LL subbands) of Computer screen image

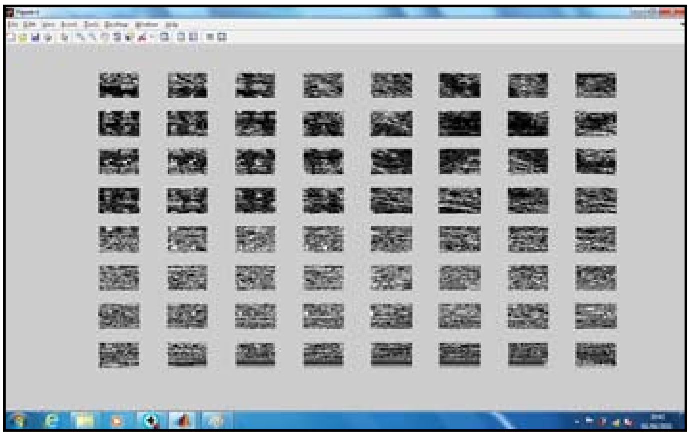

Fig. 6 : Horizontal coefficients (LH subbands) of Computer screen image

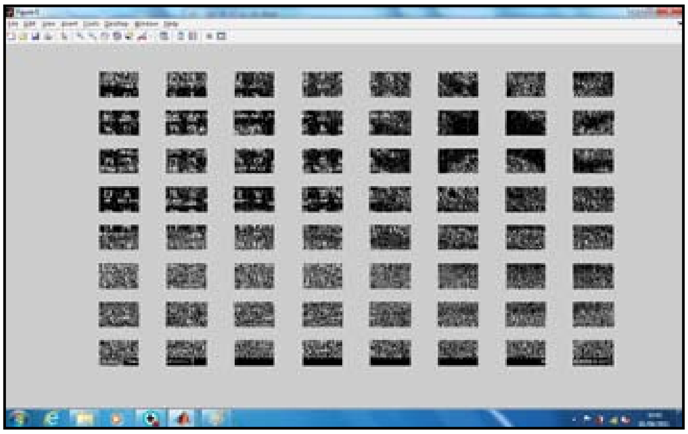

Fig. 7 : Vertical coefficients (HL subbands) of Computer screen image

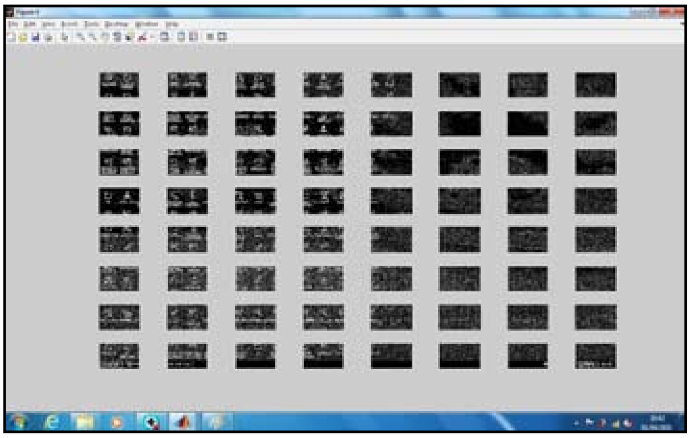

Fig. 8 : Diagonal coefficients (HH subbands) of Computer screen image

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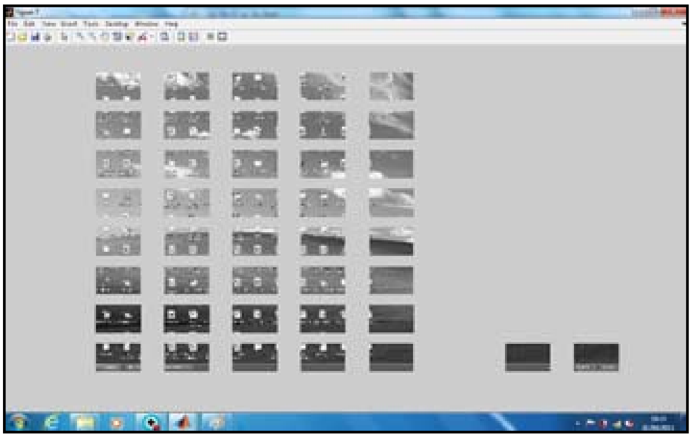

Fig. 9 : Text/graphics blocks of Computer screen image using DWT

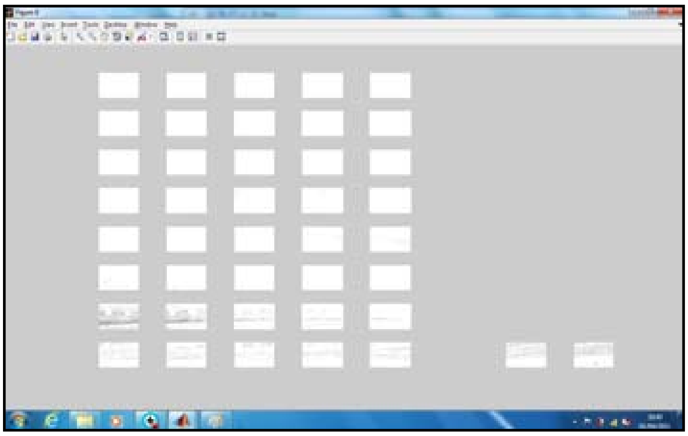

Fig. 10 : Compressed text/graphics blocks of Computer screen image using Wavelet coding

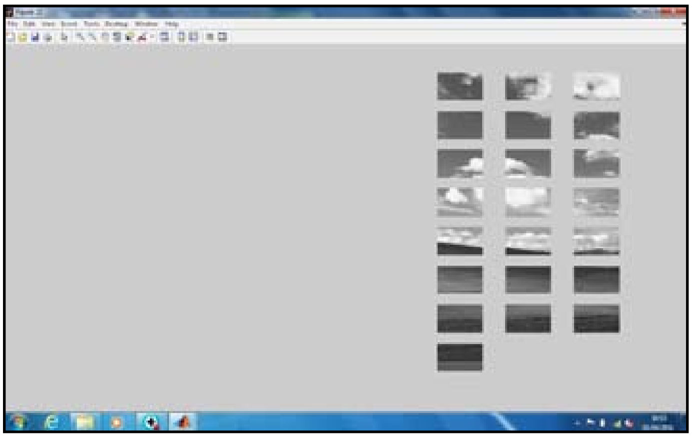

Fig.11 : Picture/background blocks of Computer screen image using DWT