# Discrete Wavelet Transform (DWT) with Two Channel Filter Bank and Decoding in Image Texture Analysis

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**Abstract:** ***With the expansion of transmission technology over the last two decades, the demand for digital information increases dramatically. The advances in technology have created the utilization of digital image prevailing to an outsized extent. Still images are widely used in application like medical and satellite images. Digital image are comprised of an enormous amount of data. Reduction in the size of image data for both storing and transmission of digital images are becoming increasingly important as they find more application. Image extraction is a mapping from a higher dimensional space to a lower dimensional space. Image extraction play important role in many multimedia application, such as image storage and transmission. The basic goal of image extraction is to extract image data with minimum number of bits of an acceptable image quality. The paper focuses on the Discrete Wavelet Transform (DWT) with two Channel Filter Bank & Decoding in Image Texture Analysis. The work is carried out in MATLAB 13.0 image processing tool and simulated results are tested on colour document images.***

**Keywords:** Discrete Wavelet Transform (DWT), Digital Image Processing (DIP), Texture Analysis

## 1. Introduction

The Discrete Wavelet Transform (DWT) [1, 2] is based on sub-band coding, it is found to yield a fast computation of Wavelet Transform. Discrete Wavelet Transform is easy to implement and reduces the computation time. The foundations of DWT were in 1976 when it uses to decompose discrete time signals [2]. When similar work was done in speech signal coding which was named as sub-band coding. At 1983, and another technique similar to sub-band coding was developed it is known as pyramidal coding, and later many improvements were made to these coding schemes which is used in efficient multi-resolution analysis schemes of image. In Continues Wavelet Transform [6], the signals are analyzed using a set of basic functions which relate to each other by simple scaling and translation or shifting. In the case of DWT, time-scale representation of the digital signal is obtained using digital filtering method. The signal to be analyzed is passed through filters with different cutoff frequencies at different scales.

The advantage of the DWT over Fourier transformation is that it performs multi-resolution analysis of signals with localization both in time and frequency domain. Popularly known as time-frequency localization, and as a result, DWT decomposes a digital signal into different sub-bands so that the lower frequency sub-bands have good frequency resolution and coarser time resolution as compared to the higher frequency sub-bands. Discrete Wavelet Transform is highly used in image compression due to the fact that the DWT supports features like progressive image transmission of by quality and resolution, and ease of image compression coding and manipulation. Because of these characteristics, DWT is the basis of the new JPEG2000 image compression standard [7].

## 2. One Dimensional DWT

Any signal is first applied to a pair of low-pass and high-pass filters [5]. Then down sampling is applied to these filtered coefficients. The filter pair (h, g) which is used for decomposition is called analysis filter-bank and the filter pair which is used for reconstruction of the signal is called synthesis filter bank. The output of the low pass filter after down sampling contains low frequency components of the signal which is approximate part of the original signal and the output of the high pass filter after down sampling contains the high frequency components which are called details (i.e., highly textured parts like edges) of the original signal.

This approximate part can be further decomposed into low frequency and high frequency part. This process can be continued successively to the required number of levels of the process. This process is called multi level decomposition, as shown in Fig. 4, and in the reconstruction process method, these approximate and detail coefficients are first up-sampled [1,14] and then applied to low-pass and high-pass reconstruction filters. Then these filtered coefficients are added to get the reconstructed version of the original image or data.

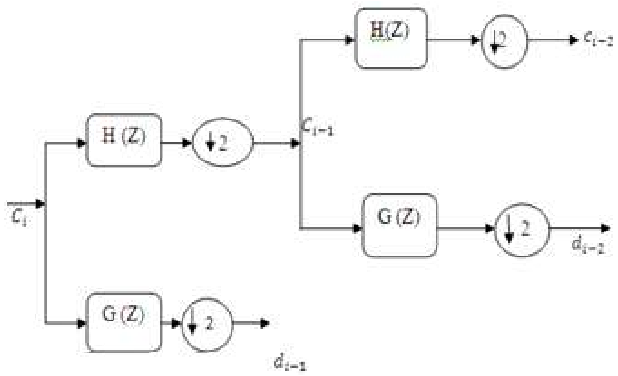



**Figure 1:** One dimensional two level wavelet decomposition

This process can be extended to multi level reconstruction. So that the approximate coefficients of this block have been formed a pairs of approximate and detail coefficients. Fig. 2 shown as below

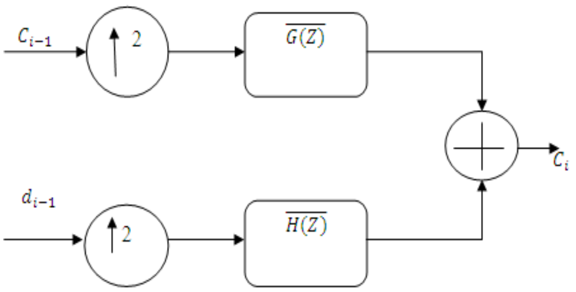



**Figure 2:** One dimensional inverse wavelet transforms

## 3. Two-Dimensional DWT

One dimensional DWT [4, 8] can be easily extended to two dimensions which can be used for the transformation of two dimensional images. A two dimensional digital image can be represented by a 2-D array X [m, n] with m rows and n columns, where m and n are positive integers of 2-D image. First process of a one dimensional DWT is performed on rows to get low frequency L and high frequency H components of the image. Again a one dimensional DWT is performed column wise on this intermediate result to form the final DWT coefficients such as LL, HL, LH, HH. They are called sub-bands.

The LL sub-band can be further decomposed into four sub-bands. This process can continue to the required number of levels. It is known multi level decomposition. The three level decomposition of the given digital image is as shown Fig. 3. High pass and low pass filters are used to decompose the image first row-wise and then column wise. So that similarly, inverse DWT is applied this is just opposite to the forward DWT, to get back the reconstructed image of the compression process, shown in Fig. 3. Various architectures have been proposed for computation of the Discrete Wavelet Transform [1, 7]. These can be mainly classified as either Convolution Architectures [11] or Lifting Based Architectures. So that the number of computations required finding the DWT coefficients by the filter method is large for higher level of decomposition process. This leads to the implementation of new technique called lifting scheme for computing DWT coefficients. Because, this scheme reduces the number of computations and also provides in-place computation of DWT coefficients.

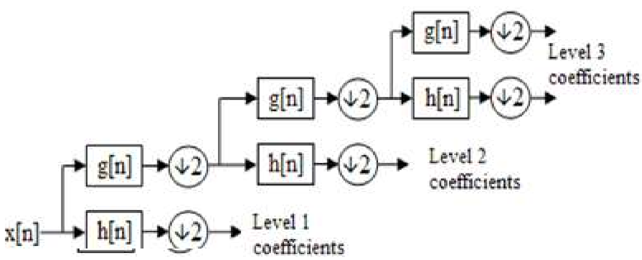
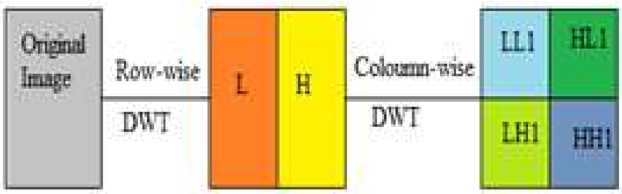
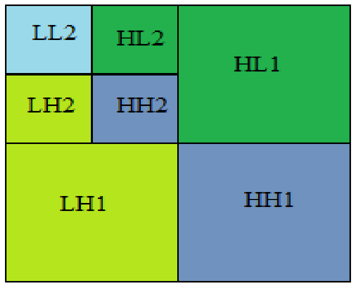


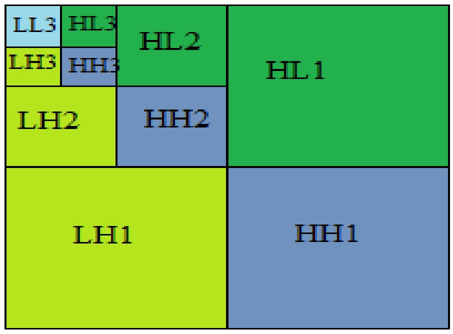

**Figure 3:** Two channel filter bank at level 3[3]




(a) First level Decomposition




(b) Second level Decomposition




(c) Third level Decomposition

**Figure 4:** Row-column computation of 2-D DWT

So that in the discrete wavelet transform, the image signal can be analyzed by passing through an analysis filter bank followed by decimation operation. This analysis filter banks consist of a low-pass and high-pass filter at each decomposition stage of the process. When the signal passes through these filters such as Low-pass and High pass, it split through two bands. The low-pass filter of the filter bank, which corresponds to an averaging operation of the image sample, extracts the coarse information of the signal or image. The high-pass filter performed corresponds to a differencing operation, and extracts the detail information of the signal or image. Then output of the filtering operation is decimated by two. The tow-dimensional transformation is accomplished by performing two separate one-dimensional transforms. The first, image is filtered along the row and decimated by two. Then it is followed by filtering the sub-bands image along the column and decimated by two. So this operation splits the image into four bands, such as, LL, LH, HL, and HH respectively as shown in fig.4

### 3.1 Extension to Two-Dimensional Signals

The two-dimensional extension of DWT is essential for transformation of two-dimensional signals, such as a digital image. A two-dimensional digital signal can be represented by a two-dimensional array X$[M,N]$ with M rows and N columns, where M and N are nonnegative integers of 2D image array. The simple approach for two- dimensional implementation of the DWT is to perform the one-dimensional DWT row-wise to produce an intermediate result and then perform the same one-dimensional DWT column-wise on this intermediate result to produce the final result. This is shown in Fig. 4(a). This is possible because the two-dimensional scaling functions can be expressed as separable functions which is the product of two-dimensional scaling function such as$\Phi_2(x,y) = \Phi_1(x)\Phi_1(y)$. The same is true for the wavelet function $\Psi(x,y)$as well. Applying the one-dimensional transform in each row of image, two sub-bands are produced in each row. When the low-frequency sub-bands of all the rows (L) are put together, it looks like a thin version (of size $M \times \frac{N}{2}$of the input signal as shown in Fig. 4(a). Similarly put together the high-frequency sub-bands of all the rows to produce the H sub-band of size$M = \frac{N}{2}$, which contains mainly the high-frequency information around discontinuities (edges in an image) in the input signal. So that applying a one-dimensional DWT column-wise on these L and H sub-bands (intermediate result), four sub-bands LL, LH, HL, and HH of size $\frac{M}{2} \times \frac{N}{2}$ are generated as shown in Fig.4$(a)$ LL is a coarser version of the original input signal. LH, HL, and HH are the high frequency sub-band containing the detail information of the image. It is also possible to apply one-dimensional DWT column-wise first and then row-wise to achieve the same result. Fig. 5 comprehends the idea describe above.

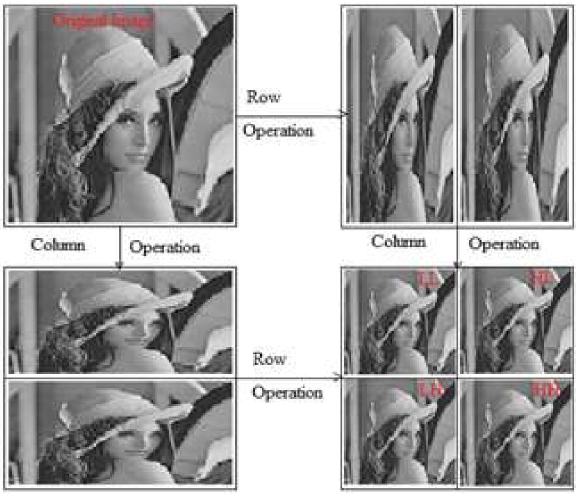


**Figure 5:** Extension of DWT in two - dimensional signals

The multi-resolution decomposition approach in the two-dimensional signal is demonstrated in Fig 4(b) and (c). After the first level of decomposition, it generates four sub-bands LL1, HL1, LH1, and HH1 as shown in Fig. 4 (a). Considering the input signal is an image, the LL1 sub-band can be considered as a 2: 1 sub-sampled (both horizontally and vertically) version of image. The other three sub-bands HL1, LH1, and HH1 contain higher frequency detail information. These spatially oriented (horizontal, vertical or diagonal) sub-bands mostly contain information of local discontinuities in the image and the bulk of the energy in each of these three sub-bands is concentrated in the vicinity of areas corresponding to edge activities in the original image.

## 4. DWT Two channel Filter Bank

The wavelet transform decomposes an image into a set of different resolution sub-image, corresponding to the various frequency bands. Sub-band coding is a procedure in which the input signal is subdivided into several frequency bands. Sub-band coding can be implemented through a filter bank. A filter bank is a collection of filter having either a common input or common output. When the filters have a common input, they form an analysis bank and when they share a common output, they form a synthesis bank. The basic idea in a filter bank is to partition a signal dynamically at the frequency domain. First, let us analysis the perfect reconstruction criteria for a tow channel filter bank for a one dimensional signal, and the same concept can be easily extended to a two-dimensional signal, if the two-dimensional signal is separable.

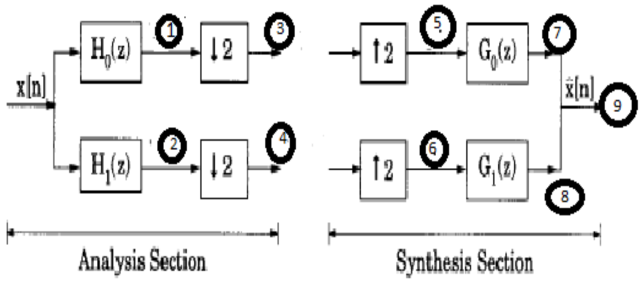


**Figure 6:** Two-band analysis-synthesis filter bank [3]

The tow-channel filter bank is composed by two section, analysis section and synthesis section, as shown in fig.6. The analysis section decomposes the signal into a set of sub-band components and the synthesis section reconstructs the signal from its components. The sub-band analysis and synthesis filters should be designed to be alias-free and are also required to satisfy the perfect signal reconstruction property. The simultaneous cancellation of aliasing as well as amplitude and phase distortion leads to perfect reconstruction filter banks which are suitable for hierarchical sub-band coding and multi-resolution signal decomposition.

The analysis filter bank splits the original image signal two equal frequency bands. Here the filters $H_0[z]$and $H_1[z]$act as low-pass and high-pass filters respectively. After filtering, the signal outputs at 1 and 2 are given in Eqn.(1) and (2) respectively.

$$\text{At node (1) :- } X[z]H_0[z] \quad (1)$$
$$\text{At node (2) :- } X[z]H_1[z] \quad (2)$$

After filtering, the signal's sampling frequency is too high, and hence half the samples are discarded by the down-sampling operation. After decimation, the Z-transform is given in Eqn. (3) and (4) respectively.

$$\text{At node (3):- } Y[z] = \frac{1}{2}\left\{X\left[z^{1/2}\right] \cdot H_0\left[z^{1/2}\right] + X\left[-z^{1/2}\right] \cdot H_0\left[-z^{1/2}\right]\right\} \quad (3)$$
$$\text{At node (4):- } Y[z] = \frac{1}{2}\left\{X\left[z^{1/2}\right] \cdot H_1\left[z^{1/2}\right] + X\left[-z^{1/2}\right] \cdot H_1\left[-z^{1/2}\right]\right\} \quad (4)$$

The synthesis filter bank reconstructs the signal from the two filtered and decimation signals. The synthesis procedure involves expending the signals in each branch by two which is termed expansion or interpolation. The interpolation is achieved by inserting zeros between successive samples. After interpolation, the Z-transform of the signal at node 5 and 6 are given in Eqn. (5) and (6) respectively.

$$\text{At node (5): } X[z] = \frac{1}{2}\{X[z] \cdot H_0[z] + X[-z] \cdot H_0[-z]\} \quad (5)$$
$$\text{At node (6): } X[z] = \frac{1}{2}\{X[z] \cdot H_1[z] + X[-z] \cdot H_1[-z]\} \quad (6)$$

The above Eqn. (6) and (7) can be written in matrix form as given below;

$$\frac{1}{2} \times \begin{bmatrix} H_0[z] & H_0[-z] \\ H_1[z] & H_1[-z] \end{bmatrix} \begin{bmatrix} X[z] \\ X[-z] \end{bmatrix} \quad (8)$$

At node 7 and 8

$$\frac{1}{2} \times [G_0[z] \quad G_1[z]] \cdot \begin{bmatrix} H_0[z] & H_0[-z] \\ H_1[z] & H_1[-z] \end{bmatrix} \cdot \begin{bmatrix} X[z] \\ X[-z] \end{bmatrix} \quad (9)$$

$$\frac{1}{2} \times [G_0[z] \quad G_1[z]]_{1\times 2} \cdot \begin{bmatrix} H_0[z] & H_0[-z] \\ H_1[z] & H_1[-z] \end{bmatrix}_{2\times 2} \cdot \begin{bmatrix} X[z] \\ X[-z] \end{bmatrix}_{2\times 1} \quad (10)$$

Combining both G and H matrices using matrix multiplication:

$$\left[\frac{G_0[z]H_0[z]+G_1[z]H_1[z]}{2} \quad \frac{G_0[z]H_0[-z]+G_1[z]H_1[-z]}{2}\right]_{1\times 2} \cdot \begin{bmatrix} X[z] \\ X[-z] \end{bmatrix}_{2\times 1} \quad (11)$$

$$F_0[z] = \frac{G_0[z]H_0[z]+G_1[z]H_1[z]}{2} \quad (12)$$

$$F_1[z] = \frac{G_0[z]H_0[-z]+G_1[z]H_1[-z]}{2} \quad (13)$$

So that

$$[F_0[z]F_1[z]]_{1\times 2} \cdot \begin{bmatrix} X[z] \\ X[-z] \end{bmatrix}_{2\times 1} \quad (14)$$

$$F_0[z]X[z] + F_1[z]X[-z] \quad (15)$$

In the above equation,$X[-z]$ refers to the aliasing component. This aliasing will spoil the signal. So select the filter co-efficient in order to reduce the aliasing effect of sample, that's make the $F_1[z]$as zero to neglect the aliasing effect. Let,

$$H_0[z] = H[z];$$

$$H_1[z] = H[-z]; \quad (16)$$

$$G_0[z] = 2H[z];$$
$$G_1[z] = 2H[-z];$$

From the above conclusion, we can say that the four filter designs are given by a single filter co-efficient. This is the beauty of sub-band coding.

When we substitute the above assumptions,

$$F_1[z] = \frac{G_0[z]H_0[-z] + G_1[z]H_1[-z]}{2} => 0$$

$$F_0[z] = \frac{G_0[z]H_0[z] + G_1[z]H_1[z]}{2} = \frac{2H[z]H[z] + (-2H[-z])H[z]}{2}$$

$$= H^2[z]+ H^2[-z]$$

So, finally at node 9

$$(H^2[z] + H^2[-z]) \cdot X[z] \quad (17)$$

While transmitting from one place to another, the delay is unavoidable though the delay value may be mille-seconds. For a perfect reconstruction filter bank, the reconstruction signal is the delayed version of the original signal which is given by,

$$(H^2[z] + H^2[-z]) \cdot X[z] = z^{-k} \cdot X[z] \quad (18)$$

$$(H^2[z] + H^2[-z]) = z^{-k}$$

That is, $H[z] = A[z] \cdot z^{-\left(\frac{N-1}{2}\right)}$

Then the signal value at node (9) is given by

$$A^2[z] \cdot z^{-(N-1)} - A^2[-z] \cdot (-z)^{-(N-1)} = z^{-k}$$
$$A^2[z] \cdot z^{-(N-1)} - A^2[-z] \cdot (-1)^{-(N-1)} \cdot (z)^{-(N-1)} = z^{-k}$$
$$A^2[z] \cdot z^{-(N-1)} - A^2[-z] \cdot (z)^{-(N-1)} \cdot (-1)^{-(N-1)} = z^{-k}$$

If k=N-1 (delay is governed by the filter co-efficient)

$$A^2[z] \cdot z^{-(N-1)} - A^2[-z] \cdot (z)^{-(N-1)} \cdot (-1)^{-(N-1)} = z^{-(N-1)}$$
$$A^2[z] - \left(A^2[-z] \cdot (-1)^{-(N-1)}\right) = 1$$

If N is even (for PR condition)

$$A^2[z] + A^2[-z] = 1$$
$$H^2[z] + H^2[-z] = 1$$

Then the condition for perfect reconstruction is given by

$H^2[z] + H^2[-z] = 1$ (19)

### 4.1 Desirable Characteristics of a Filter Bank

The desirable characteristics of a filter bank include (i) maximal decimation, (ii) separable filtering, (iii) polyphase form, (iv) perfect reconstruction, and (v) tree structure.

- **(i) Maximal Decimation**: The maximal decimation property indicates that the number of coefficients produced by decomposition is the same as the number of input samples. This is also known as critical sampling. This property is associated with computational complexity as it keeps the number of samples to be processed to a minimum.
- **(ii) Separable Filtering:** Separable filtering indicates that two-dimensional as well as higher dimensional filtering can be performed as one-dimensional filtering. For example, two-dimensional filtering is performed as two one-dimensional filtering performed row-wise and column-wise. This property is associated with computational efficiency as separable filtering is more efficient than the equivalent non-separable filtering
- **(iii) Polyphase Form:** Polyphase form is efficient implementation of decimated filter bank where the filtering is performed after the down-sampling, thus reducing the number of components.
- **(iv) Perfect Reconstruction:** Perfect reconstruction property ensures that the reconstructed signal resembles

the original signal without any error. That is, the coefficient produced by the forward transform can be sent through the inverse transform to reproduce the original signal without any error.

**(v) Tree-Structure Decompositions:** Tree structure decomposition sub-divides radically the low frequency region. Such decomposition is well-suited to processing of natural images which tend to have the energy concentrated in radically low-frequency regions.

## 5. DWT Algorithm for Text Extraction

Wavelet analysis can be used divided the information of an image into approximation and detailed sub image signal. The approximation sub signal shows the generally pixel value of image, and three detailed sub signal show horizontal, vertical and diagonal details (changes in image). Otherwise if these detail is very small than they can be set to zero without significantly changing the picture. If the number of zeroes is greater than the compression ratio is also high. There is two types of wavelet is used in image compression. First one is Continues wavelet transform and second one is discrete wavelet transform. The Wavelet analysis is computed by filter bank. This is combination of high-pass and low-pass filters. High pass filter kept high frequency information and lost low frequency information. Low pass filter kept law frequency information and lost high frequency information. So signal is effectively decomposed into two parts, a detailed part (high frequency) and approximation part (low frequency). The Level 1 detail is horizontal detail, the level2 detail is vertical detail and level 3 details is diagonal detail of the image signal. The Flow chart representation of DWT algorithm for image compression using MATLAB is shown in Fig.7, according HAAR DWT algorithm, first applying reset signal is one then run the simulator, so all the value of the previous input and output will be zero. After then applying a clock pulse on the clock signal and the reset signal will be zero, all above condition will be done after then the original 2D image will be convert the set of pixels

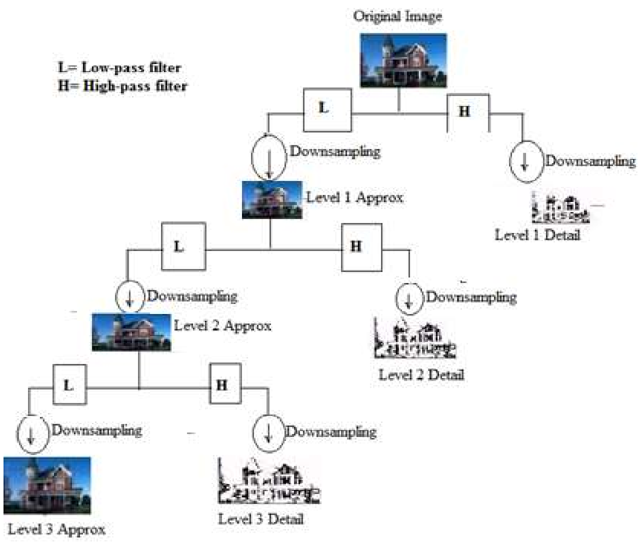



**Figure 6:** Decomposition of an input image using a wavelet transformation using three passes

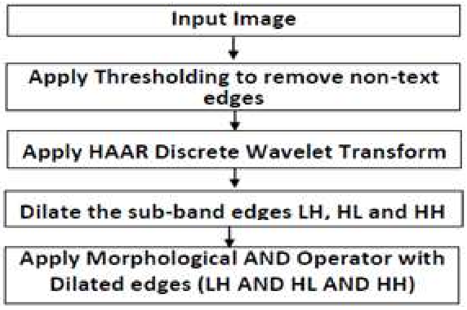



**Figure 7:** Flow chart representation of DWT algorithm for Text extraction

Every pixels of the 2D image have own x-axis and y-axis, so we will represent the image pixels in histogram representation. After then the image will be applying to a filter bank, the filter bank will consist of Low-pass and High-pass filters, then the image signal will be separated high band signal and low band signal, according the HAAR DWT algorithm the low band and high band image signal have four possible combination, such as LL,LH,HL,HH. The LL band is more significant band it contains more information of the original image, so it is most important part of the algorithm process. The LL band again sub divided to lower band till to the desired output will not obtained, this process shown below in the Fig. 8

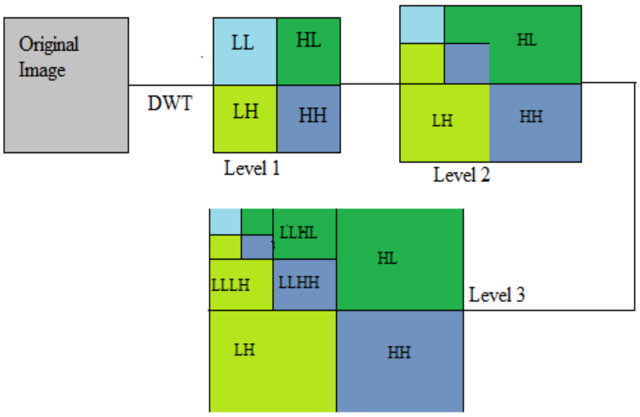



**Figure 8**: Decomposition of wavelet transforms

## 6. Results & Discussion

The MATLAB results for the colour images are shown in figure. 9 (a) & (b), 10(a) & (b) and 11(a) and (b)

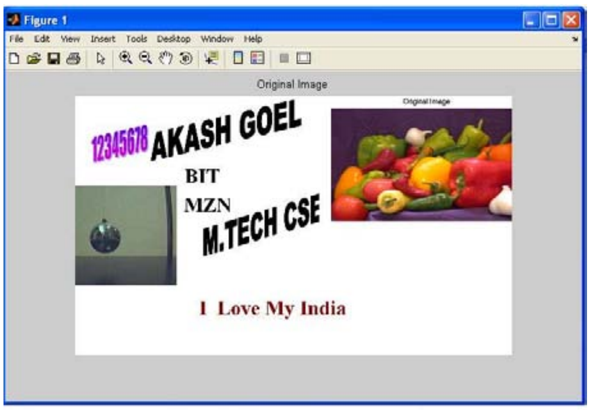



**Figure 9:** (a) Image 1, Original image

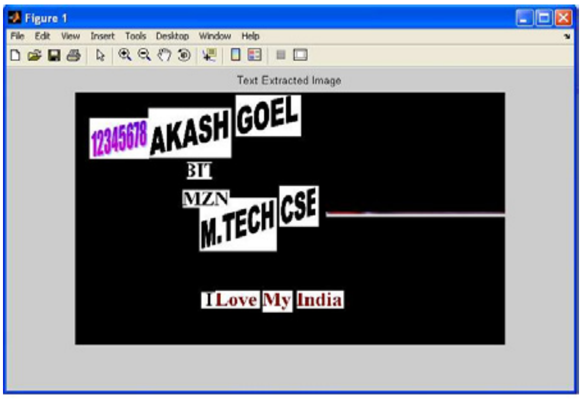



**Figure 9:** (b) Text extracted image from image 1

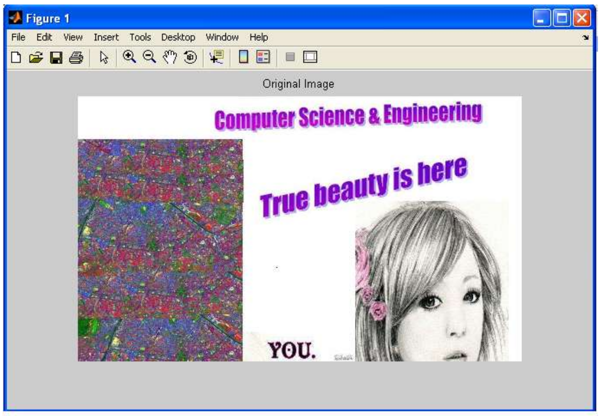



**Figure 10:** (a) Image 2 , Original image

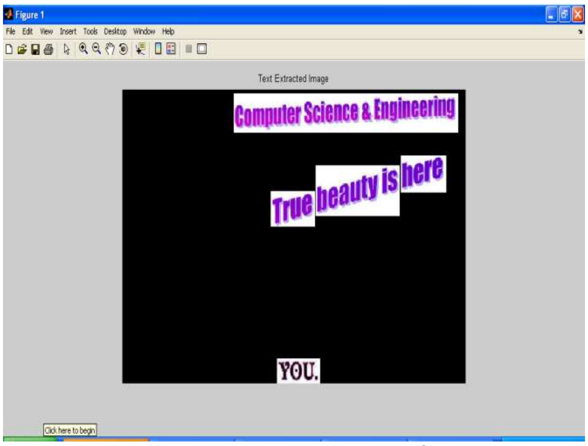



**Figure 10:** (b) Text extracted image from image 2

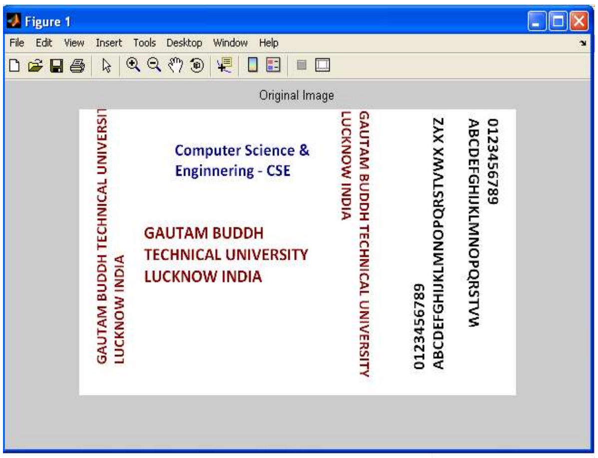



**Figure 11:** (a) Image 3, Original image

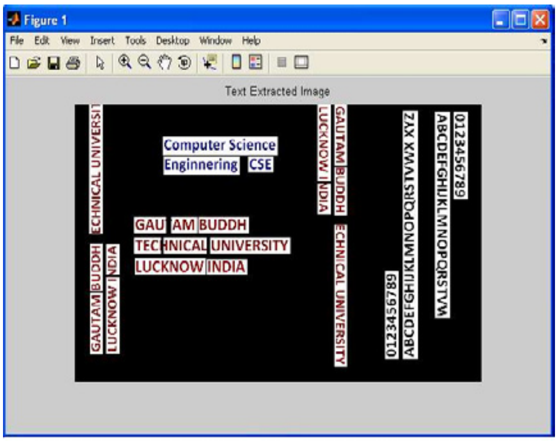



**Figure 11:** (b) Text extracted image from image 3

We have created the templates for the all characters and these templates are used for the edge detection using mathematical morphological operators. These mathematical tools are integrated to detect the text regions from the complicated images. The proposed method is robust against language and font size of the texts. The proposed method is also used to decompose the blocks including multi-line texts into single line text. According to the experimental results, the proposed method is proved to be efficient for extracting the text regions from the images.

## 7. Conclusion

The MATLAB simulation is carried out on the different images with single and multiple texts, multiple text of different sizes, images with uniform and non uniform images. The text extraction is used to produce a violation fine on speeding vehicles, illegal use of bus lanes, and detection of stolen or wanted vehicles. License plate recognition technology has gained popularity in security and traffic applications as it is based on the fact that all vehicles have a license plate and there is no need to install any additional tracking apparatus. The main advantage is that the system can store the image record for future references. The rear part of the vehicle is extracted off the filmed image and is given to the system for processing.

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## Author Profile

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