Blind Watermarking Using Hybrid Dwt-Svd Domain On High Frequency Band

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Abstract- *Digital watermarking finds vast applications in the modern era of internet and digital data exchange, specifically, in medical image processing, satellite images and related fields. Here, a blind and robust watermarking approach using DWT and SVD based transformations is presented. A given color image partitioned into RGB color planes and the entropy of each of the plane is computed for choosing the optimal plane for watermark embedding. The chosen plane is then segmented into non-overlapping blocks and watermarking bits are embedded into each of the blocks separately, considering the human visual system (HVS) characteristics. In Blind Watermarking technique, the original image is not required at the receiving end for the detection of the watermark. In almost all the applications of Blind Watermarking, a custom watermark is not used. Instead, an image file is extracted from the features of the original image and embedded in the same image as a watermark. This image is then extracted at the receiving end to provide a proof of ownership of the image. In almost all the commercial applications, blind watermarking is used. The HH band from DWT method is chosen to provide a robust watermarking as it contains most of the information contained in the original signal. To embed the watermark bits, the U matrix values are suitably modified to embed binary bits (0 or 1). As compared to the S matrix of SVD transform, the embedding of the watermarking bits into the U singular matrices gives a much robust watermarking and hence, is preferred when robustness is critical issue. The simulation results established have better robustness and imperceptibility is achieved as indicated through PSNR..*

Keywords- Discrete Wavelet Transform, Singular Value Decomposition, Human Visual System.

I. INTRODUCTION

Watermarking refers to placing a mark on an object with intent to provide a proof of copyright or ownership. The watermark derived its name from the copyright symbol included in the currency note. Digital watermarking refers to embedding digital data object inside another digital data. It is the process that embeds data or information called a watermark into a multimedia object such that watermark can be detected or extracted later to which may be used to verify its authenticity or the identity of its owners without changing its perceptual quality. Object may be an image, audio or video. The embedded information is usually smaller and lightweight than the cover object. Depending on the type of cover media/object, the watermarking can be classified as image, audio or video watermarking. Depending on the requirement of the extraction process, the watermarking may be classified as blind or non-blind watermarking. Watermarking is a concept which is closely related to steganography [1], because both steganography and digital watermarking conceal a message inside a digital signal. However, in-spite of this, their goals are different. In watermarking, a message is embedded with an intent to provide copyright or authenticity information. In contrast, steganography uses communication in which there is no relation between the digital signal and the message and the cover object is only used to hide the existence of the secret information.

Digital watermarking is an area of active research, and the primary motivation behind the research is largely market driven rather than scientific. This is because with the advent of hardware technology, thousands of copies of the digital data files can be created over CDs or flash drives even with the cheapest commodity computers. This results in million dollars of revenue losses to the industries based on digital data distribution business model.

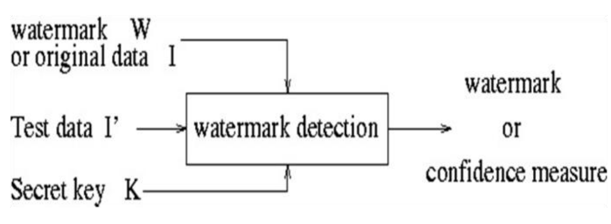


Figure 1: Watermark Embedding Scheme

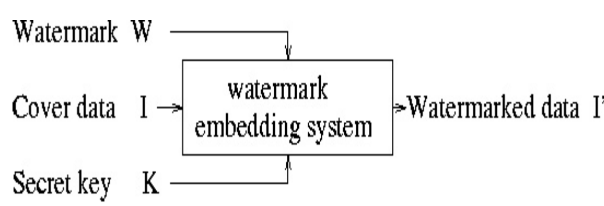


Figure 2: Watermark Recovery Scheme

This paper focuses upon the watermarking techniques on color images. The benchmark techniques for watermarking of color images are studied in details and compared on standard parameters. It is important to note that every watermarking system must possess certain desirable characteristics as follows:

a. Watermarking capacity should be high.
b. Watermarking Embedding and Extraction must be computationally less complex
c. Watermarking must be robust to image processing operations.
d. Watermarking must be robust against attacks. The technique used to embed the watermark into the host data must be designed in such a way that it is nearly impossible to remove the watermark from the host data.
e. Watermarked data must have low Fidelity.
f. Watermarking technique should be preferably blind.
g. Security: It is the ability of the watermark to resist the invasive attempt from the unauthorized user to remove it using crypto analysis while video it not modified.

The effective watermarking should maintain these following requirements:
i. To maintain the original image quality and commercial value, imperceptibility of the embedded data should be there.
ii. It should be robust against hacker attackers.
iii. Ownership of the owner should be apparent.
iv. It should have a secret key in against of unsecure distribution.
v. It should maintain the high hiding capacity and complexity should be at a low glance. To reduce the limitation of the huge amount of stream and non-stream multimedia, we use video summarization. Video Summarization is a process of creating and presenting, an abstract view of entire video within a short period of time. This technique will generate the summaries of the videos which contain maximum information that makes individual more easily.

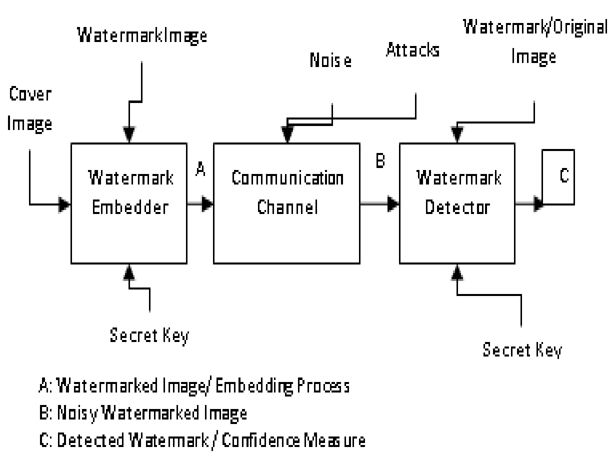


Figure 3: Generic Watermarking Systems

Why frequency domain is better and we have chosen to implement that is explained as follows:
1. High watermark hiding capacity [21] as it allow more bits to be embedded [17].
2. Highly robust and less resist to the attacks as information is spread out to the entire image [16].
3. Gives High PSNR value.
4. Provides security and imperceptibility. [22].

II. WATERMARKING CLASSIFICATION

Following Figure 4 shows the various classifications of watermark based on work domain, host media and human perception.

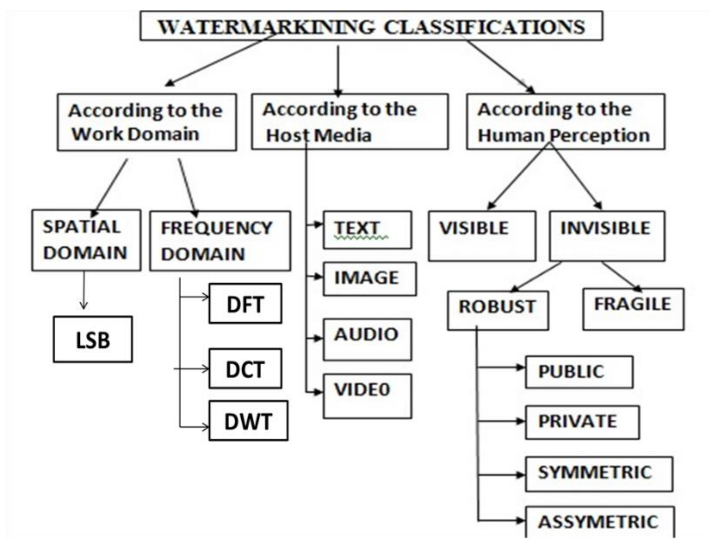


Figure 4: Classification of Watermarking

2.1 Blind and Non-blind Watermarking

Blind watermarking [7] scheme is one in which the detection algorithm itself is capable of detection and (or) extraction of the watermark. In this technique, the original image is not required at the receiving end for the detection of the watermark. In almost all the applications of Blind Watermarking, a custom watermark is not used. Instead, an image file is extracted from the features of the original image and embedded in the same image as a watermark. This image is then extracted at the receiving end to provide a proof of ownership of the image. In almost all the commercial applications, blind watermarking is used.

Extract using {Key}

Non-blind [8] watermarking scheme is one in which the original unmarked image is required at the receiver for detection and extraction of the watermark. This makes the design of detector, relatively simple as the differences in the pixel values need to be computed for the computation of the change in the pixel values and thus the watermark can be detected and extracted. However, it is sometimes difficult to provide the original unmarked image, especially in the large commercial application and this gives a limit to the applications of this category of watermarking.

Extract using {Data, Key, Watermark}

III. DISCRETE WAVELET TRANSFORM (DWT)

DWT decompose original image into 4 sub bands:

a) LL- Low frequency band. It is a approximation low frequency sub band which contain the important information about original image. Most of the information of host image is suspended in LL band [43].

High frequency bands

b) HL It extract the vertical features of original image.

c) LH It extract the vertical features of original image.

d) HH It contains the diagonal information.

In our proposed work 2 level DWT is applied on the blue plane of cover image, we can also increase the number of decomposition levels bet higher the level will come out with some loss of information. Second & third level DWT gives better compression ratio (term used to quantify how good the data size is reduced by applying any compression algorithm) but extracted image will not same as the cover image. If DWT is applied more than 1 level good MSE is obtained [28].

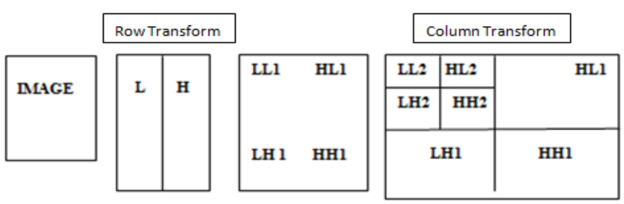


Figure 5: Taxonomy of Discrete Wavelet Transform

Figure 5 describes the taxonomy of discrete wavelet transform showing the different frequency bands. When original signal is passed through the series of low and high pass filter to analyse low and high frequency non overlapping multiresolution, DWT hierarchically decompose the image to provide spatial and frequency description of image.

3.1 Advantages of DWT over other Domain

- Allows good localization both in frequency and time domain, tell at which time which frequency occurred in signal.
- Take less computation time as it does not introduce blocking artifact, entire image is not affected if there is any change in transform coefficient.
- It gives high compression ratio while maintaining the quality of image without losing more information of image [30].
- Introduce the property of multi resolution (analyzes the signal at different frequencies with different resolutions).
- Good for signal denoising, it reduce/remove unwanted signals which contain less information about the image
- It help to find discontinuous and irregularities of signal [25].

IV. SINGLE VALUE DECOMPOSITION (SVD)

Singular Value Decomposition is a very powerful technique in matrix decomposition, used to obtain algebraic features of image. It was introduces by Beltrami and Jordan in 1870 for square matrix and later it is extended to work on rectangular matrix by Eckart and Youd in 1936 [45]. It is mainly used for image processing applications such as image compression, noise reduction, and image watermarking and image steganography. SVD of original image is taken and then singular values of matrix are modified by introducing singular values of watermark. SVD decomposition of the matrix I, split the matrix into three matrices U, S and V, in such a way as to satisfy the following equation:

$$I=U*S*V^T$$

Singular Value Decomposition is an effective tool to analyze the matrix which factor any m*n matrix I in USV^T matrix, where

1. U is a m*m orthogonal matrix, the columns of U matrix is called the left singular vectors of I image. U matrix represents the horizontal detail of an image and is unitary.
2. V is n*n orthogonal matrix where determinant of both U and V matrices is ±1 and it is called right singular vectors of I matrix. V matrix represents the column detail of an image. The V^T is a transpose of V matrix.
3. S is the m*n rectangular diagonal matrix in which all except the diagonal elements are zero and non-negative real numbers and the diagonal values σ_i of S matrix are called singular values of I.
4. U and V describe the geometric property of an image and S matrix describes the luminance or brightness of an image.

$$A = USV^T$$

$$=[u_1, u_2, u_3,.., u_N] * \begin{bmatrix} S1 & 0 & 0 & 0 \\ 0 & S2 & 0 & 0 \\ 0 & 0 & S3 & 0 \\ 0 & 0 & 0 & S4 \end{bmatrix} * [v_1, v_2, v_3,., v_n]^T$$

Where $\mathbf{u}_1$, $\mathbf{u}_2$ ...un are orthonormal basis for the column space of A and **v**1, **v**2 ...vn are orthonormal basis for the row space.

In our proposed work hybrid SVD based watermarking scheme is approached where image is divided into non overlapping blocks of size n*n and each block is transformed to give U, S, V matrix, where in singular values of U matrix, watermark is embedded rather than S matrix as these watermarks are vulnerable to attack and it increase the invisibility, security, noise reduction. Block with lower magnitude value (low informative block) are used as best region for embedding watermark. It is the property of SVD decomposition that when the small signal is added to the cover image it doesn't give much signal variation. U and V matrices remain almost unchanged with the change in values of the individual pixels up to some extent. However, singular matrix S consists of values which are large in order of magnitude and decreases rapidly with row order as compared to the elements of other matrices and thus change proportionately to the magnitude. The watermarking scheme proposed in this dissertation can be more appropriately understood by analyzing the consequences of matrix manipulation over its SVD decomposition.

V. SIMULATION RESULTS OF THE PROPOSED MODEL

LL		HL	
183.50	**179.00**	**-0.50**	**0**
181.00	**176.50**	**0**	**-0.50**
LH		**HH**	
1.50	**1.00**	**-0.249**	**-0.433**
1.00	**0.500**	**-0.433**	**-0.249**

Table 1: 2*2 Matrix of 4 Sub Bands After Performing 2 DWT

The DWT Transform divides the image into 4 sub bands. The Table 1 shows the LL, LH, HL, HH coefficients of 4 sub bands after performing the 2 DWT using Haar wavelet. Each bands consist of 2*2 matrix.

Step 1 In the proposed work watermarking is implanted on the HH band of the DWT transform of the 4X4 segments of the Blue color plane of the original image. The original image used for watermark embedding is color image of dimensions 400*400 Figure 6 shows the simulation result of the original image using MATLAB tool

Step 2 RED, GREEN and BLUE planes of the original image is shown in Figure 7, 8, 9.
Step 3 Generation of the Watermark: The green color planes are used for NVF Generation. The computation of NVF function first performs averaging using a sliding window scheme. The window, typically of size 3X3 is positioned over the image and moved horizontally and vertically one pixel at a time. The pixel value is replaced by the average value of pixels in the window. For more severe smoothing we use larger window 5*5, 9*9 but reducing the high frequency detail by reducing the intensity variation between the neighboring pixels which result in obtaining the less noise in the image and making the image blurred. As all the R, G and B planes consists of values in the range 0-255. Taken individually, these represent the grayscale color values. The subsequent image represents the grayscale versions of the GREEN color plane chosen for NVF Generation. Fig 10 shows the image obtained after averaging operation using sliding window of size 3*3.

Step 4 The figures 11 and 12 shows the image obtained after performing the NVF by differencing the original pixel value by the averaging value. The image shows the edge and border becomes stronger as compare to flat areas.

Step 5 Reduced the size of NVF image into 100*100 dimensions using averaging operation.

Step 6 The binary copyright image or watermark of size 100*100 used in the simulation is shown in figure 13.

Step 7 It is important to note that both Fig 12 and 13 are converted to binary images using the mapping procedure of grayscale image pixel values to {0,1}. Generally, the pixel values below 125 are mapped to 0 and 126 to 255 are mapped to 1.The watermark image to be embedded in the Blue color plane of the cover image is obtained using the bitwise EX-Or of two matrices of dimension 100X100, images 12 and 13 to produce custom watermark. The resultant binary image is shown in figure 14. In proposed scheme, the NVF image is generated from the GREEN color plane which remains unchanged in the watermarking process. Thus, NVF is obtained at the receiver end and when it is operated with the extracted binary pattern, givens the watermark image.

Step 8 Watermarking is done on non-overlapping blocks of size 2*2 U matrix of HH band of the original image. After embedding the custom watermark the figures 15, 16, 17 shows the watermarked image in grayscale and in color image after performing the inverse DWT and inverse SVD.

5.1 Detection Process

Here the watermark is detected and obtained by X-OR operation (bitwise) between 2 matrices 100*100 each of the watermark bits with NVF image which is generated from the GREEN color plane of watermarked image, which remains unchanged in the watermarking process. To detect the watermark no original image or secret key is used as this approach is blind gives high security & good robust watermarking. Figure 18 gives the NVF grayscale image of green plane of watermarked image and Figure 19 is the original detected watermark.

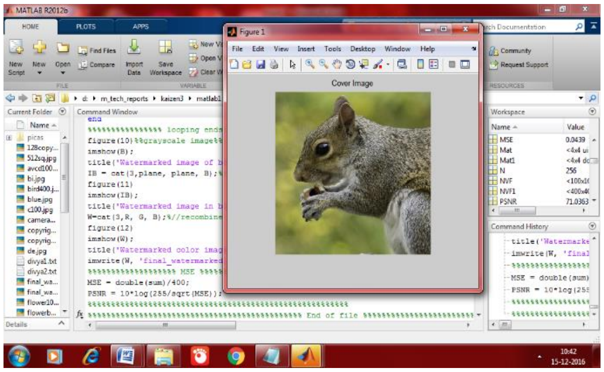


Figure 6: Screenshot of Original Cover Image (400X400)

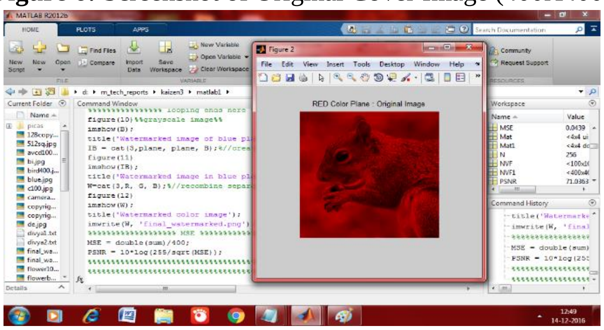


Figure 7: Screenshot of RED Color Plane of cover image

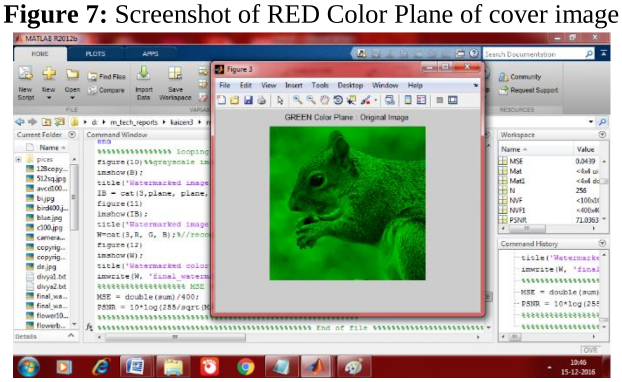


Figure 8: Screenshot of GREEN Color Plane of cover image

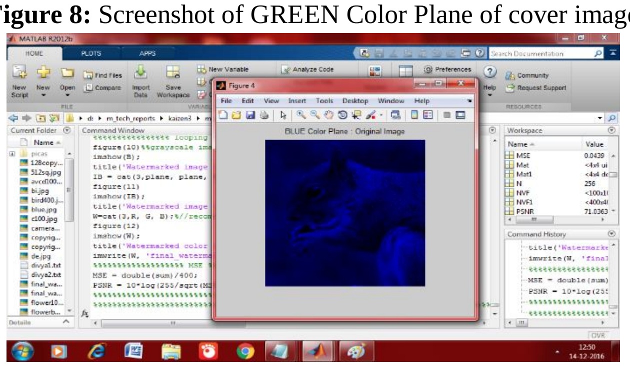


Figure 9: Screenshot of BLUE Color Plane of cover image

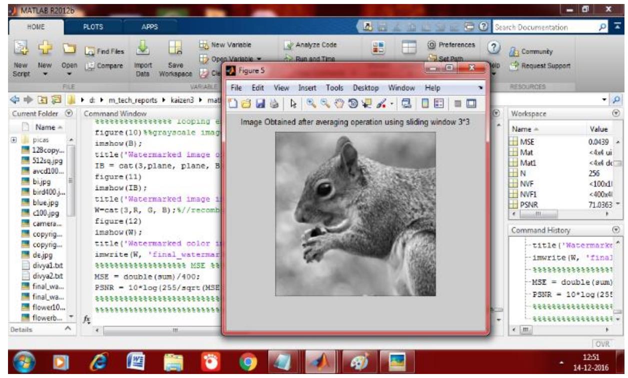


Figure 10: Screenshot of Image after Mean Value Approximation using sliding window

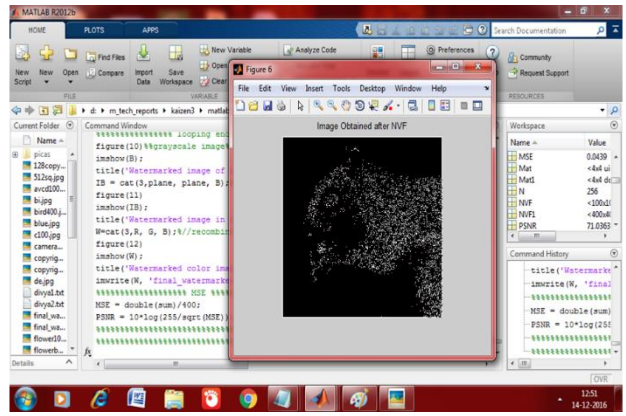


Figure 11: Screenshot of Visualization of the NVF image of GREEN plane of window size 3X3

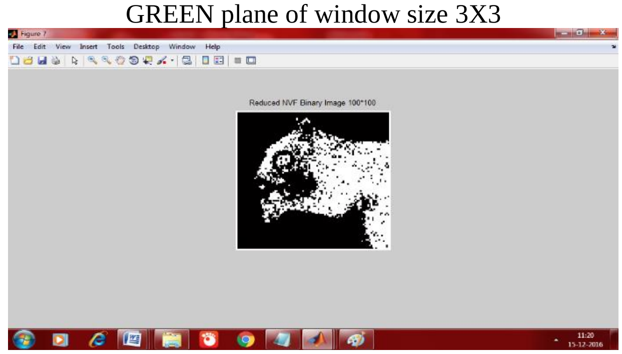


Figure 12: Screenshot of Reducing the NVF image using averaging of blocks

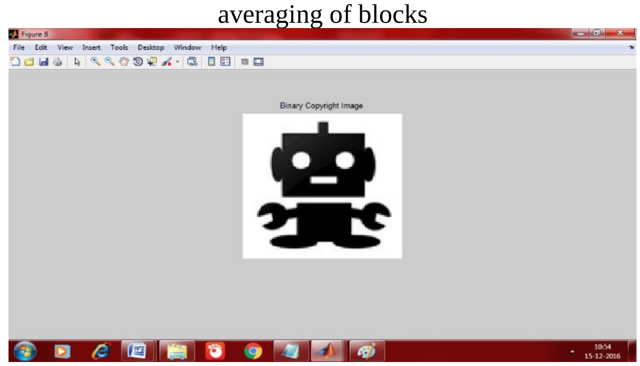


Figure 13: Screenshot of Watermark: To be embedded : Original Dimension 100X100

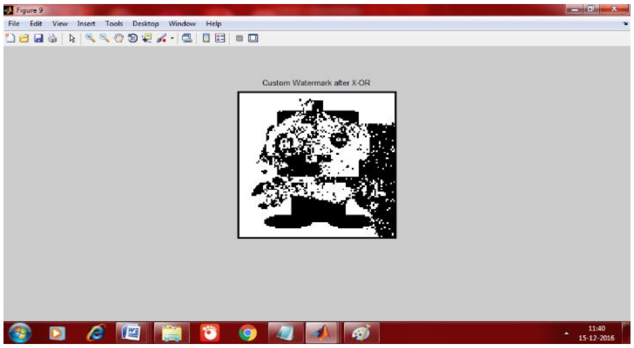


Figure 14: Screenshot of Ex-Or of Watermark and NVF Image

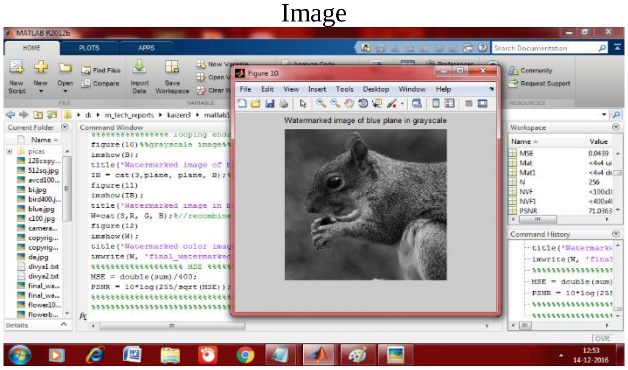


Figure 15: Screenshot of Watermarked Binary Image of Blue plane in grayscale

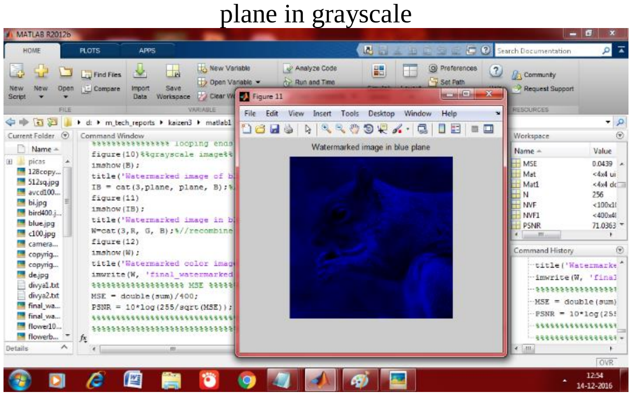


Figure 16: Screenshot of Watermarked Binary Image in blue plane

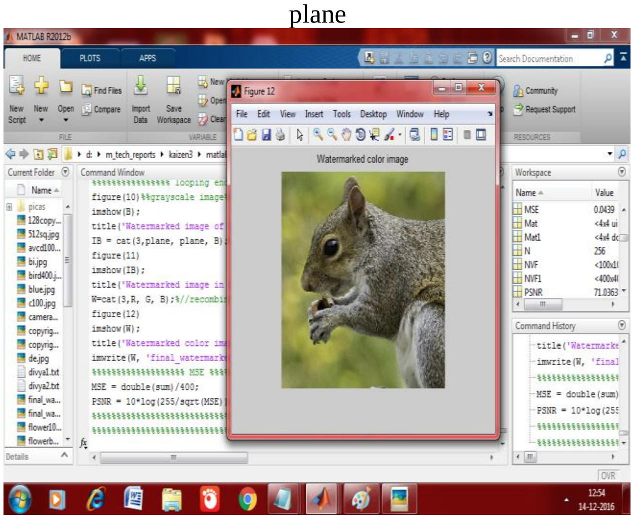


Figure 17: Screenshot of Watermarked Color Image: Obtained after combining RED, GREEN and Watermarked BLUE Plane

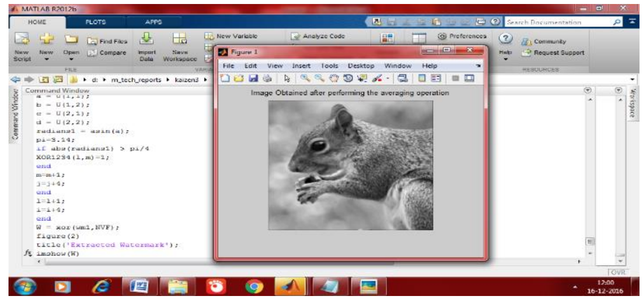


Figure 18: Screenshot of Detected NVF of Green plane of Watermarked Image

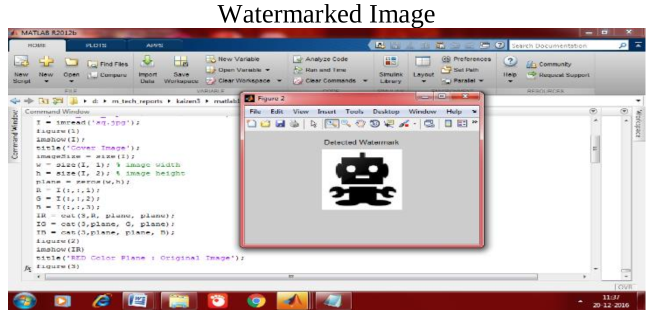


Figure 19: Screenshot of Detected Watermark

5.2 Result Analysis of Proposed Work

It is evident through perceptiveness that the proposed techniques perform well over the color images. The properties evaluated for proposed scheme are imperceptibility and robustness. However, the Quality Metric of the watermarking process has always been the Peak Signal to Noise Ratio (PSNR) and the Mean Square Error (MSE).

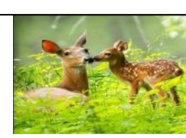
S. No.	Image	Quality Index (Proposed)
1		MSE = 0.043 PSNR = 71.03dB
2		MSE = 0.12 PSNR = 65.75dB
3		MSE = .077 PSNR = 68.21dB

Table 2: PSNR and MSE values of the sampled images

VI. COMPARATIVE RESULT ANALYSIS WITH EXISTING WORK

The result of existing work is comparatively low than the proposed one as work domain is different and watermark is embedded in U matrix of HH band. Therefore these tables conclude that hybrid 2DWT – SVD gives better performance. The parameter for comparison is PSNR and MSE. The below Table 3 conclude that embedding in HH band shows the better PSNR value as it do not degrade the visual quality of an image.

S. No	Domain Used	Embedded region	Cover image	MSE	PSNR
1	**2DWT + SVD RGB plane Proposed**	**HH band of U matrix of Blue plane**	**Lena**	**.0328**	**72.50**
2	DWT + SVD [46]	HH band of S matrix	Grayscale Lena	5.93	40.3
3	1DWT + SVD [26]	LL band, modifying S diagonal matrix	Grayscale Lena	3.72	42.4
4	DWT [26]		Grayscale Lena	5.71	37.3
5	2DWT + SVD [38]	S matrix of HL, LH	Grayscale Lena	0.075	59.3

Table 3: Comparative Performance Analysis in Different Domains

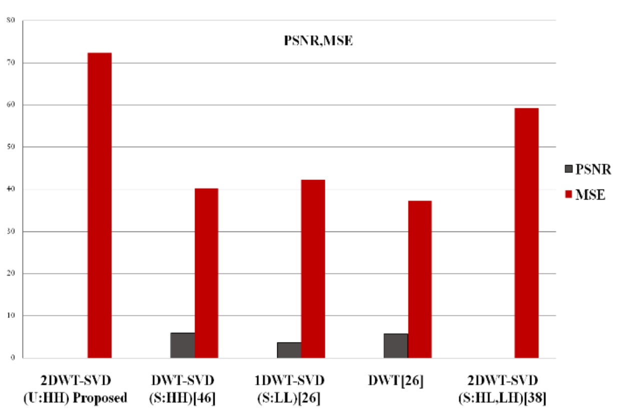


Figure 20: Bar Graph corresponding to different Work Domain

Table 4 shows the output result of various existing research work which depict that proposed work outperforms better than previous one. The proposed watermarking technique is blind and hence more robust against the attacks without affecting the visual quality of the image and hence provides security. Hybrid domain gives better PSNR value as show.

S. No	Domain Used	Embedded Sub Region	Cover image	PSNR
1	**2DWT + SVD (Proposed)**	**HH band of Blue plane, modifying U matrix**	**Color Image Grayscale Lena**	**71.03 72.50**
2	1DWT + SVD [22]	LL band by modifying U matrix	Grayscale Lena	63.31
3	2DWT + SVD + Genetic algo [36]	LL band by modifying U matrix	Color Lena	44.3
4	DCT + SVD [39]	U matrix of lowest coefficient blocks.	Grayscale Lena	61.6
5	3DWT + SVD + Arnold [33]	HL band, modifying S matrix in YUV .	Color Lena	52.3
6	3DWT + DCT [17]	HL band	Lena	63.99
7	SVD, PRNG [15]	U matrix by selecting complex S blocks.	Grayscale Lena	47.6
8	SVD, PRNG [32]	Embed in U matrix by selecting complex S blocks.	Grayscale Lena	46.5
9	DWT + Alpha blending Technique [30]	DWT of each RGB plane of both images & concatenate	Color Image	29
10	1DWT, Acquire LL band to	HH band	Cameraman	59

	generate watermark. [35]			
11	SVD, Arnold Scrambling [44]	Blue plane for embedding	Color Bird	44.65

Table 4: Comparative Result Analysis with Existing Work

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