

# A Study of Digital Image Watermarking for JPEG and PNG Images using Discrete Wavelet Transform

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## Abstract

**Objectives:** To emphasis on digital image watermarking techniques and its applications using Discrete Wavelet Transform (DWT). **Methods:** We propose two watermarking algorithms for embedding and extraction process and use two images as cover image and watermark image of same format as input image. We have considered two image formats JPEG (Joint Photographic Experts Group) and PNG (Portable Network Graphics) of different resolutions for analyzing the performance of the proposed algorithm. **Findings:** The proposed research work is compared with the existing works on the basis of compression percentage, MSE (Mean Square Error), PSNR (Peak Signal to Noise Ratio) and Normalized Correlation (NC) values and the result has been carried out using DWT in Matlab 7.12. All the existing watermarking techniques referred in this paper have some limitations at somewhere. The PSNR values of all the existing research works is not more than 50 dB for the entire traditional image processing images. But in this proposed research work, the PSNR value is more than 66 dB for all the twenty test images we have taken. Higher the PSNR value means the quality of the watermark image is better. If the PSNR value is good then the MSE value will automatically be good because one is inversely proportional to other. **Improvements:** In the previous research works, common values of PSNR were between 30 dB to 50 dB. If the PSNR value of the watermark image is more than 50 dB then it will be tough to detect the difference between the cover image and the watermark image by the common Human Visibility System (HVS). The NC value 1 means that the correlation between the extracted watermark image and the original watermark image is almost similar in a particular point.

**Keywords:** Compression Percentage, Discrete Wavelet Transform, Mean Square Error, Normalized Correlation, Peak Signal to Noise Ratio

## 1. Introduction

Digital watermarking is the process of embedding the text or images in any digital media like images, videos and audio data to protect the information from the hackers or intruders. Now days, the most common complication is to protect the digital media from the unauthorized users. It is mainly used to verify the authenticity and ownership or copyright of digital media from a person or any organization. In this case, digital watermarking prevents any kind of attacks from any unauthorized person or organization. Digital image watermarking was first proposed in 1993<sup>1</sup> to hide the watermark data into the images. Digital image watermarking is basically divided into two categories:

1) Visible image watermarking and 2) Invisible image watermarking<sup>2</sup>. In this proposed research work, we focus on invisible image watermarking using Discrete Wavelet Transform in frequency domain method.

An improved reversible image watermarking has proposed based on different groups and is compressed and embedded into the original image through the expansion process<sup>3</sup>. A new multiresolution image watermarking method in digital images adding pseudo-random codes at the high and middle frequency bands using DWT has proposed<sup>4</sup>. A new watermarking method has introduced based on Qualified Significant Wavelet Tree (QSWT) to get the robustness of the watermarking and used to verify JPEG, image cropping, image sharpening median filtering

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and various attacks<sup>5</sup>. A novel image watermarking algorithm of 2-D DWT to decompose an image into various frequency channels has introduced<sup>6</sup>. This paper also described an algorithm that inserts a binary image watermark into a mid-frequency channel of an image's three level 2-D wavelet transform. The digital image watermarking technique using DWT based on PSNR (Peak Signal to Noise Ratio) value and MSE (Mean Square Error) has explained<sup>7</sup>. They have used alpha blending technique to add the low frequency contents of the two images. For embedding the watermark they have taken the value of scaling factor  $k$  which varied from 0.002 to 0.0002 and kept the  $q$  as constant. And for recovering the original image from the watermarked image they have taken the value of  $k$  which varied from 0.0035 to 0.0012 by keeping  $q$  constant at 0.0009. A new blind watermarking algorithm has proposed which inserted a binary watermark into blue portion of a true color image in the spatial domain for copyright protection<sup>8</sup>. For inserting the watermark they have used the Direct Current (DC) coefficient to modify the values of pixels in the spatial domain. An improved DWT-SVD based invisible robust digital image watermarking in YCbCr color space has proposed<sup>9</sup>. They have proposed a non-blind digital watermarking algorithm and compared the values of PSNR and NCC (Normalized Cross Correlation) with the existing results. A reversible fragile watermark method has proposed and shown the limitations of irreversible and reversible schemes at different parameters<sup>10</sup>. A new LSB based digital watermarking system has proposed with combined LSB and inverse bit technique<sup>11</sup>. According to the transform domain of the cover image, the existing methods of image watermarking in frequency domain have been introduced by<sup>8,12,13</sup>. Two watermarking algorithms based on DWT were presented in his PhD thesis<sup>14</sup>. The first one is additive watermarking which needs original image to detect watermark. But the second algorithm does not require original image to detect watermark. He used grayscale image as cover image and binary image as watermark image and showed the results on the basis of PSNR value against different attacks. A 3-level DWT based image watermarking technique has described<sup>15</sup>. They have used both the cover image and the watermark image as grayscale image. An image watermarking technique using DWT-SVD in low frequency band has proposed and evaluated the performance of the proposed method on the basis of PSNR and NCC value<sup>16</sup>.

We have studied various work done in the past few years and proposed a modified algorithm based on digital

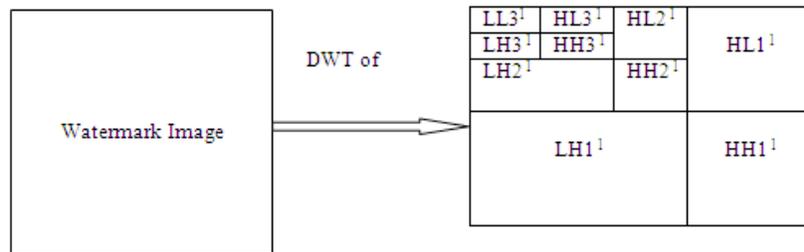
image watermarking for JPEG and PNG image formats and compared with previous results with respect to PSNR, MSE and the Compressed size of each images using DWT. The proposed research work also focuses on Normalized Correlation (NC) between the Watermark image and extracted watermark image and shows the NC value as 1 which means both the images are highly correlated.

The proposed research work has been classified into the following modules. Section II shows the Digital Image Watermarking using DWT, Section III describes the proposed Digital Image Watermarking embedding and Extraction Algorithm. In Section IV, the Experimental Results and Discussion are shown. The Conclusion of the study followed by References is described in Section V.

## 1.1 Limitations of Existing Watermarking Techniques

All the existing watermarking techniques referred in this paper have some restrictions or conditions at somewhere. A blind watermarking algorithm was proposed where they have embedded the binary image into the blue component of RGB image in spatial domain<sup>8</sup>. In this paper, the PSNR value is less than 50 dBs for lena, baboon, airplane and peppers. A novel blind watermarking algorithm have described in DCT domain using the Normalized Correlation (NC) coefficient between the watermarked image and the extracted watermark image and found the PSNR value below 45 dBs for lena, baboon, airplane and peppers<sup>12</sup>. They have used binary image as watermark image. A digital image watermarking technique has explained for color images in frequency domain<sup>13</sup>. They have shown the results against multiple attacks on images and have evaluated the performance of the proposed algorithm on the basis of PSNR in decibels. Their PSNR value was more than 30 dBs but less than 45 dBs for lena, baboon, airplane and peppers. Also, they have used binary images as watermark image in their experiments. Two watermarking algorithms have proposed using DWT and used grayscale image as cover image and binary image as watermark image and the results have shown on the basis of PSNR value 44.46 dB, 40.18 dB, 41.49 dB and 42.7 dB for barbara, lena, house and boats respectively<sup>14</sup>. A 3-level DWT based image watermarking has described and used cover image as color image but the watermark image as binary or grayscale image<sup>15</sup>. The results have shown on the basis of PSNR and NCC value against different attacks. The PSNR value has evaluated

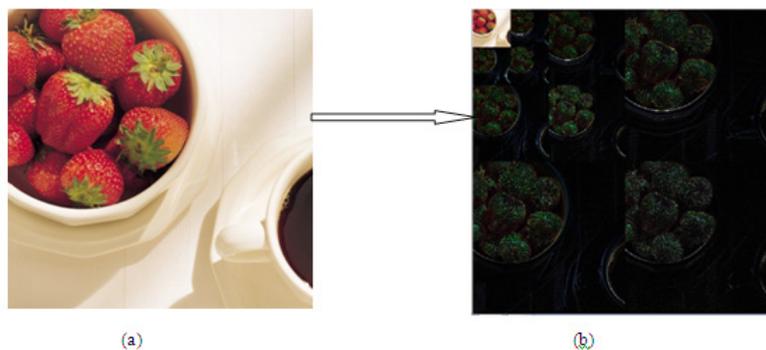
**Figure 1.** Three level DWT decomposition of Cover image and LL3 shows the lowest frequency subband and HH1 shows the highest frequency subband.



**Figure 2.** Three level DWT decomposition of Watermark image and LL3<sup>1</sup> shows the lowest frequency subband and HH1<sup>1</sup> shows the highest frequency subband.



**Figure 3.** Three level DWT decomposition in Matlab. (a) The original Cover image Red Rose of resolution 512X512. (b) Its corresponding DWT decomposition.



**Figure 4.** Three level DWT decomposition in Matlab. (a) The original Watermark image Strawberry of resolution 512X512. (b) Its corresponding DWT decomposition.

for a particular image cameraman ranging from 31.45 dB to 42.41 dB against different visibility factor. An image watermarking method has explained using DWT-SVD in low frequency band and evaluated the performance of the proposed algorithm on the basis of PSNR and NCC value<sup>16</sup>. They have used cover image as color image but watermark image as grayscale image using 2-level DWT and the results have shown using two particular images Lena and Baboon. The PSNR and NCC value have calculated on the basis of visibility factor.

## 2. Digital Image Watermarking Technique using DWT

In this section, we first try to represents the basic process of digital image watermarking for JPEG and PNG images using DWT domain. The wavelet transform shows the identical sub and sand it is used in both the cover image and the watermark image before the embedding process is started. We take two images of two formats and apply three level 2-D DWT decomposition on both the images for each category. An image is first decomposed into four parts in high, middle and low frequencies that is LL1, LL1<sup>1</sup>, HL1, HL1<sup>1</sup>, LH1, LH1<sup>1</sup>, HH1 and HH1<sup>1</sup>subbands respectively. Figure 1 and 2 shows the DWT decomposition of a cover image and watermark image in three level decomposition. The HL1, HL1<sup>1</sup>, LH1, LH1<sup>1</sup>, HH1 and HH1<sup>1</sup> represent the best scaled wavelet coefficients. LL1 and LL1<sup>1</sup> are again decomposed into four more subbands to get the next level of rough wavelet coefficients. This

method runs recursively, which gives us the results at our hand. Here we have shown Figure 1 and 2 how an image is decomposed into ten subbands using DWT.

Using the same process the original image can be reconstructed from the above wavelet coefficients and this reconstruction process is known as Inverse DWT (IDWT). If  $I[x,y]$  indicates a two dimensional image, then the DWT and IDWT for  $I[x,y]$  may be categorized by implementing the DWT and IDWT on each dimension  $x$  and  $y$  separately. A cover image of resolution 512X512 and the corresponding DWT decomposition are shown in Figure3 and the watermark image of resolution 512X512 and the corresponding DWT decomposition are shown in Figure 4.

## 3. Proposed Watermarking Algorithms

### 3.1 Proposed Watermark Embedding Algorithm

In the Figure5, we have shown a normal watermark embedding process. The algorithm to embed a watermark image in the cover image is given below.

Step 1: Select a 24-bit color image  $a$  as cover image.

Step 2: For every pixel  $p$ ,

Step 3: Decompose the cover image into three sublevels using DWT decomposition.

Step 4: Again decompose each level of decomposition into four subbands LL, LH, HL and HH respectively.

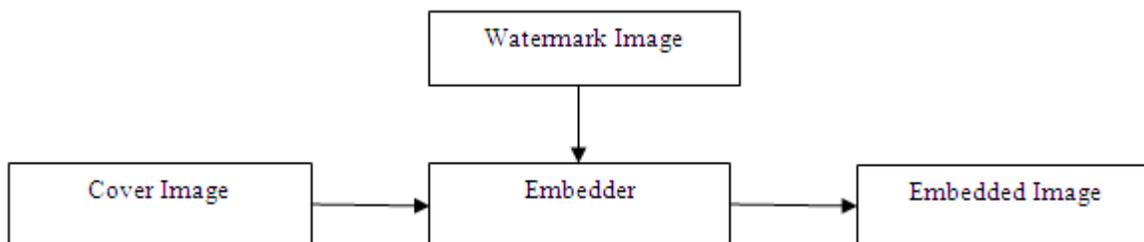


Figure 5. Normal Watermark Embedding process.

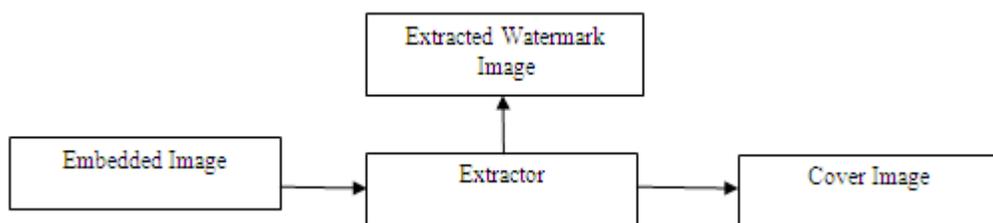


Figure 6. Normal Watermark Extraction process.

Step 5: Apply ‘Haar’ Wavelet to filter the image.

Step 6: The subband pairs like [LL1, LH1, HL1, and HH1], [LL2, LH2, HL2 and HH2]and [LL3, LH3, HL3 and HH3] are used to calculate the low frequency at LL and LL1 frequency bands respectively.

Step 7: Again decompose the color or grayscale watermark image  $b$  into three sublevels using DWT decomposition.

Step 8: The subband pairs like [LL<sup>1</sup>, LH1<sup>1</sup>, HL1<sup>1</sup>, and HH1<sup>1</sup>], [LL2<sup>1</sup>, LH2<sup>1</sup>, HL2<sup>1</sup> and HH2<sup>1</sup>] and [LL3<sup>1</sup>, LH3<sup>1</sup>, HL3<sup>1</sup>, and HH3<sup>1</sup>] are used to calculate the low frequency at LL<sup>1</sup> and LL1<sup>1</sup> frequency band respectively.

Step 9: Apply inverse DWT (IDWT) using the updated subband values to obtain the watermarked image.

Step 10: Repeat step 1 to 9 to obtain remaining outputs.

### 3.2 Proposed Watermark Extraction Algorithm

In Figure6, we have shown the normal watermark extraction process. The algorithm to extract watermark image from the recovered cover image is shown below.

Step 1: Read a color or grayscale watermark image  $b$ .

Step 2: For every pixel  $q$ ,

Step 3: Decompose the watermarked image  $b$  and the original image  $a$  into three sublevels using DWT decomposition.

$C = \text{DWT}(a)$

$C^1 = \text{DWT}(b)$

Step4: Apply ‘Haar’ wavelet to filter the image.

Step 5: The subband pairs like [LL1, LH1, HL1, and HH1], [LL2, LH2, HL2 and HH2]and [LL3, LH3, HL3 and HH3] are used to calculate the low frequency at LL and LL1 frequency band respectively.

Step 6: Again, The subband pairs like [LL1<sup>1</sup>, LH1<sup>1</sup>, HL1<sup>1</sup>, and HH1<sup>1</sup>], [LL2<sup>1</sup>, LH2<sup>1</sup>, HL2<sup>1</sup> and HH2<sup>1</sup>] and [LL3<sup>1</sup>, LH3<sup>1</sup>, HL3<sup>1</sup> and HH3<sup>1</sup>] which is used to calculate the low frequency at LL<sup>1</sup> and LL1<sup>1</sup> frequency band respectively.

Step 7: After accommodating the watermarks  $W$  indexing, we get the extracted watermarks  $W^1$ .

Step 8: To measure the robustness of the watermark and to find the Normalized Correlation (NC) between the original watermark  $W$  and the extracted watermark  $W^1$ , the following formula is used [5].

$$\text{Normalized Correlation, NC} = \frac{\sum_i W_i * W_i^1}{\sum_i W_i^2} \quad (1)$$

The architecture of the proposed work of Digital Image Watermarking method using DWT is shown in Figure 7.

## 4. Experimental Results and Discussion

In this research work, the traditional image processing 24-bit true color images for JPEG and PNG formats from the CVG-UGR image database are used as cover image and color or grayscale images are used as watermark image. To evaluate the performance of the proposed

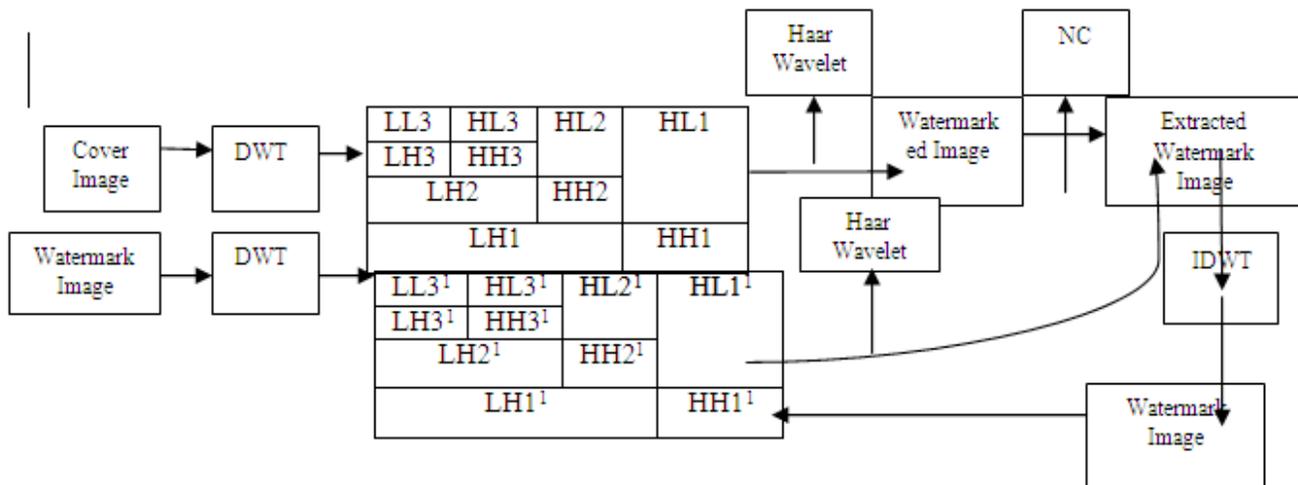
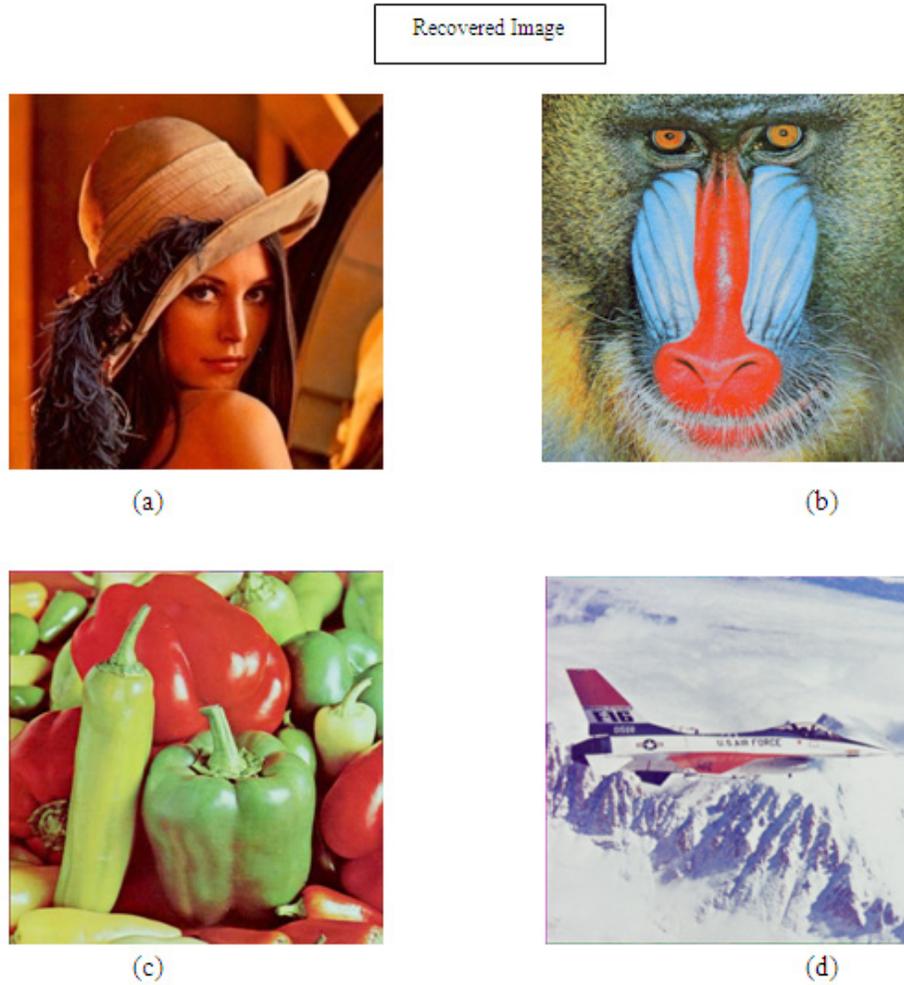


Figure 7. Architecture of the proposed Digital Image Watermarking method.



**Figure 8.** Original Cover Images: (a) Lena.jpg, (b) Baboon.png, (c) Peppers.jpg, and (d) Airplane.png.

algorithm we use Ten JPEG and Ten PNG images of different resolutions. Considering the space complexity of the paper, out of twenty only four 24-bits color images are shown in Figure 8.



**Figure 9.** Original Watermark.

Table 1 and Table 2 shows the experimental results for JPEG and PNG images of twenty test images. In both the tables, image resolution of cover image and watermark image, original image size of cover image and water-

mark image, compressed image size after embedding the watermark image into the cover image and also the compressed image size after applying the DWT on the embedded watermarked image is shown. PSNR, MSE and NC value is measured between the cover image and the watermarked image. The formula for PSNR and MSE<sup>11</sup> is stated below.

$$\begin{aligned}
 \text{PSNR} &= 10 \cdot \log_{10} \left( \frac{\text{MAX}_I^2}{\text{MSE}} \right) \\
 &= 20 \cdot \log_{10} \frac{\text{MAX}_I}{\sqrt{\text{MSE}}} \quad (2)
 \end{aligned}$$

Where MAX=255, for grayscale images, and Where I is the original image and K is the watermark image. Figures 9 to 20 shows the various test results of four watermarked image, original watermark image and extracted watermark image for JPEG and PNG formats.

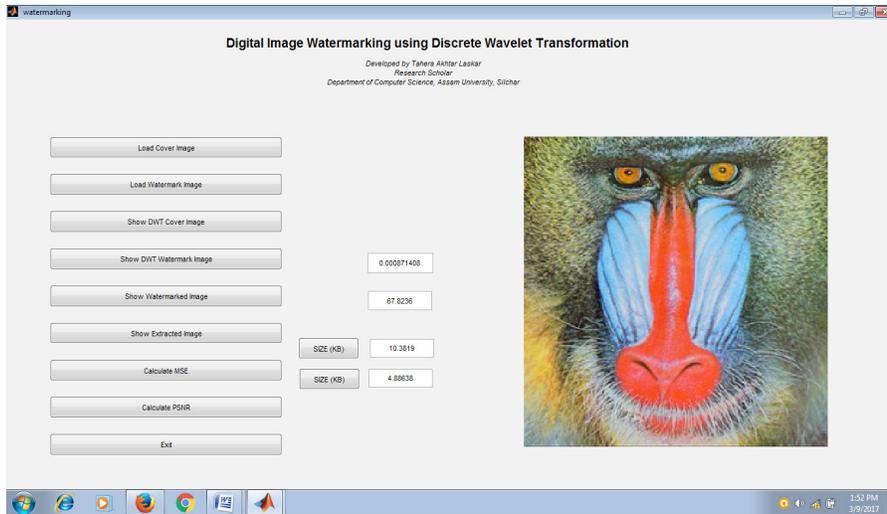


Figure 10. Watermarked Image of Baboon.jpg

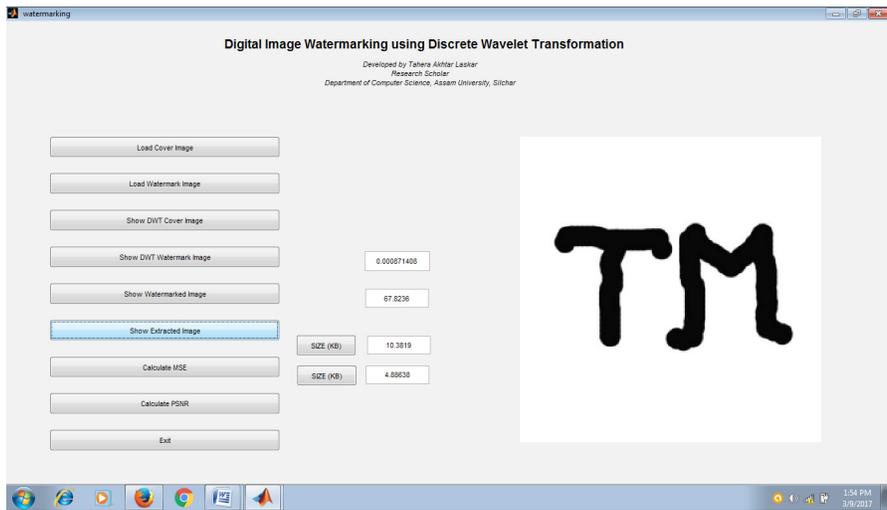


Figure 11. Extracted Watermark Image of TM.jpg

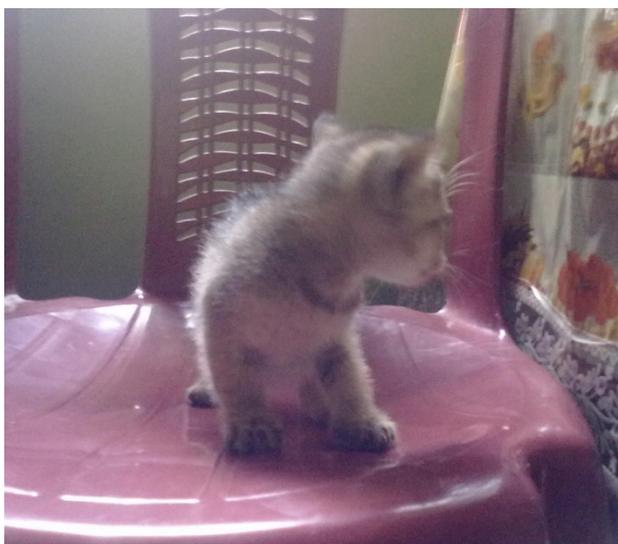


Figure 12. Original Watermark Image of cat.png

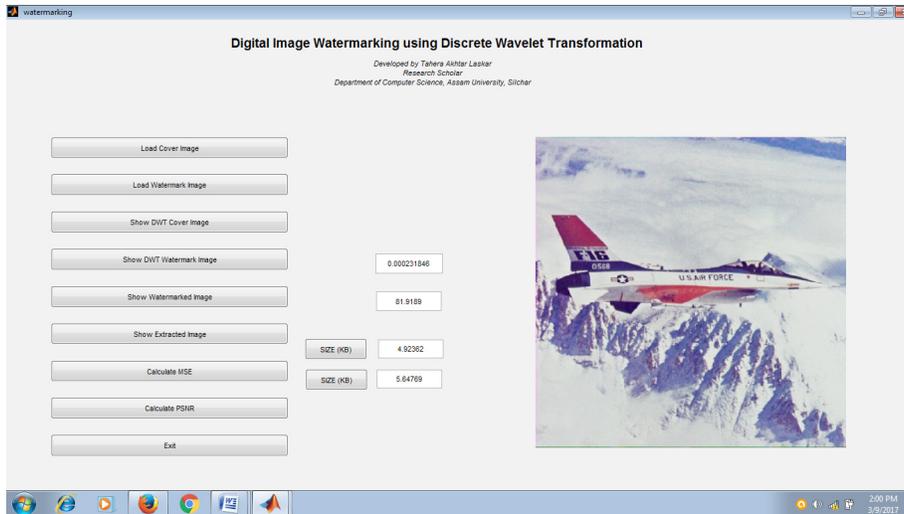


Figure 13. Watermarked Image of Airplane.png.

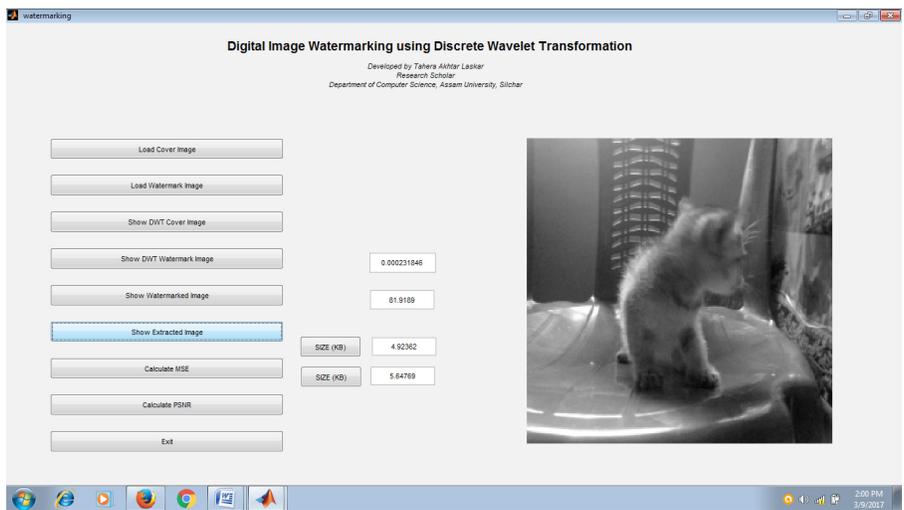


Figure 14. Extracted Watermark Image of cat.png.

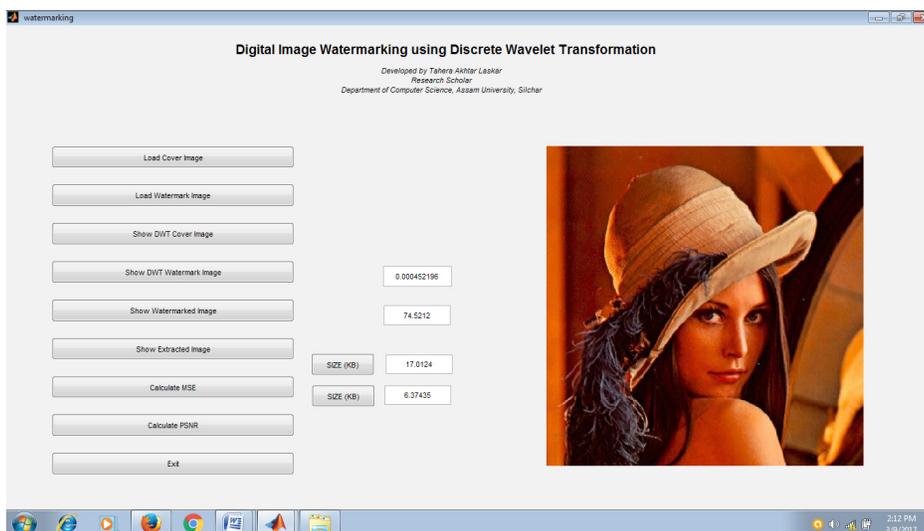


Figure 15. Watermarked Image of Lena.jpg



Figure 16. Original Watermark Image of Strawberry.jpg.

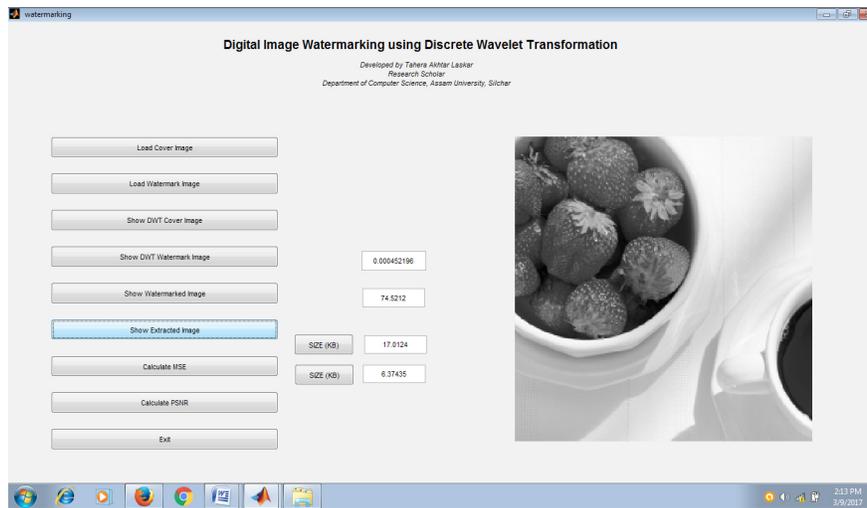


Figure 17. Extracted Watermark Image of Strawberry.jpg

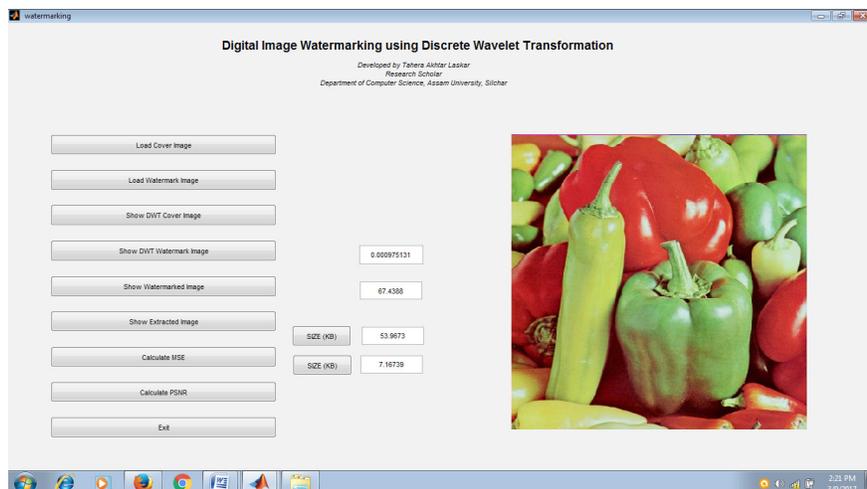


Figure 18. Watermarked Image of Peppers.png

# COMPUTER SCIENCE

Figure 19. Original Watermark Image of Computer Science.jpg

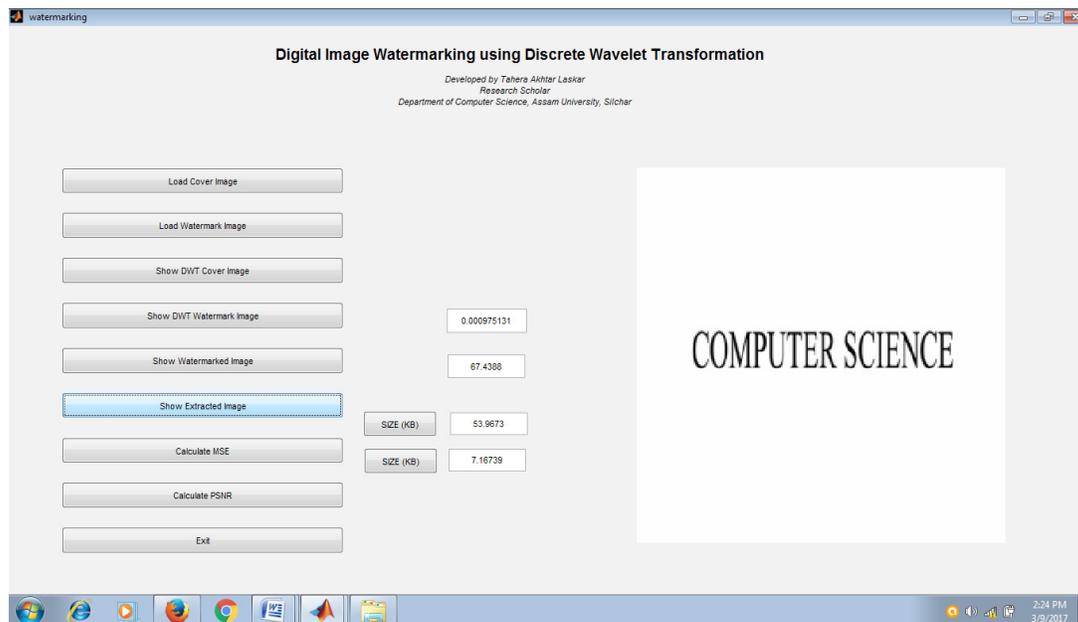


Figure 20. Extracted Watermark Image of Computer Science.png

$$MSE = \frac{1}{m * n} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} [I(i, j) - K(i, j)]^2 \quad (3)$$

## 4.1 Testing and Invisibility of the Proposed Watermark Algorithm

Common values of PSNR are between 40dB to 50dB and if the PSNR value of the watermark image is more than 50dB then it is tough to detect the difference between cover image and the watermark image by the common human visibility system (HVS). A better NC values means that the correlation between the extracted watermark image and the original watermark image is almost similar in a particular point. The proposed method has a higher NC value that is 1, so the method is more robust. We have measured the PSNR values of all the watermarked images of JPEG and PNG formats and the results are illustrated in Table 1 and Table 2. In Table 3, the proposed work is compared with some of the previously worked papers<sup>3, 5, 8, 11, 12, 13</sup> and found to have better results with better invisibility of the watermarked image.

## 4.2 Analytical Treatment

In this research work, we propose a modified watermarking algorithm using three levels DWT taking both the images as color image in frequency domain. The experiments are carried out on the basis of PSNR, MSE and NC value. Higher the PSNR value means the quality of the watermarked image is better. As we know, if PSNR value is good then the MSE value will automatically be good because PSNR is inversely proportional to MSE. In our experiment, cover images are always taken as color image but both color and grayscale images are taken as watermark image for JPEG and PNG images. If we embed any color image as watermark image but the extracted watermark image will be a grayscale image. We have embedded the watermark image into the cover image first and apply loosy image compression technique up to three level of DWT decomposition to compress both the watermarked image and extracted watermark image. At the end of the work, we have found that the PSNR, MSE and NC value is good as compared to the previous work done.

**Table 1.** Experimental Results of JPEG Cover image and Watermark images using DWT

| Cover Image    | Image size (kb) | Resolution | Watermark Image | Image Size (kb) | Resolution | Compressed Watermarked Image Size (kb) | Compressed Extracted Watermark Image Size (kb) | MSE         | PSNR (dB) | NC     |
|----------------|-----------------|------------|-----------------|-----------------|------------|--|--|-------------|-----------|--------|
| Airplane.jpg   | 89.8            | 512X512    | W1.jpg          | 9.07            | 512X512    | 10.56                                  | 5.17   | .000992548  | 67.3769   | 1      |
| Baboon256.jpg  | 95.5            | 256X256    | W2.jpg          | 114.74          | 256X256    | 18.04                                  | 4.50   | 0.000980937 | 66.6396   | 1      |
| Barbara.jpg    | 108             | 512X512    | W3.jpg          | 5.35            | 256X256    | 89.24                                  | 9.77   | 0.000985855 | 67.6333   | 0.9994 |
| Boat.jpg       | 218             | 512X512    | W4.jpg          | 7.73            | 256X256    | 14.91                                  | 4.34   | 0.000965354 | 68.2031   | 1      |
| Cat.jpg        | 198             | 1600X1200  | W5.jpg          | 46.1            | 512X512    | 112.01                                 | 4.32   | 0.000871408 | 70.6131   | 0.9986 |
| House.jpg      | 23.2            | 256X256    | W6.jpg          | 9.30            | 50X50      | 11.70                                  | 4.92   | 0.000903098 | 68.9871   | 0.9857 |
| Lenna512.jpg   | 99.5            | 512X512    | W7.jpg          | 14.70           | 512X512    | 50.66                                  | 4.21   | 0.000982193 | 66.7645   | 1      |
| Peppers512.jpg | 112             | 512X512    | W8.jpg          | 16.70           | 512X512    | 82.37                                  | 3.59   | 0.000975131 | 67.4388   | 1      |
| Strawberry.jpg | 152             | 666X666    | W9.jpg          | 20.5            | 256X256    | 79.21                                  | 3.31   | 0.000976333 | 69.5349   | 1      |
| Sailboat.jpg   | 132             | 512X512    | W10.jpg         | 10.9            | 512X512    | 14.11                                  | 5.27   | 0.000989108 | 68.1553   | 0.9945 |

**Table 2.** Experimental Results of PNG Cover image and Watermark images using DWT

| Cover Image    | Image size (kb) | Resolution | Watermark Image | Image Size (kb) | resolution | Compressed Watermarked Image Size (kb) | Compressed Extracted Watermark Image Size (kb) | MSE         | PSNR (dB) | NC     |
|----------------|-----------------|------------|-----------------|-----------------|------------|--|--|-------------|-----------|--------|
| Airplane.png   | 624             | 512X512    | W1.png          | 14.2            | 512X512    | 41.33                                  | 4.36   | .000992607  | 67.484    | 1      |
| Baboon256.png  | 206             | 256X256    | W2.png          | 13.6            | 256X256    | 14.32                                  | 8.14   | 0.000981101 | 66.6379   | 1      |
| Barbara.png    | 608             | 512X512    | W3.png          | 11.1            | 256X256    | 40.91                                  | 4.33   | 0.00098612  | 67.7149   | 0.9965 |
| Boat.png       | 606             | 512X512    | W4.png          | 9.13            | 256X256    | 37.52                                  | 3.03   | 0.000965808 | 68.1984   | 1      |
| Cat.png        | 1800            | 1600X1200  | W5.png          | 37.8            | 512X512    | 41.24                                  | 3.71   | 0.000871407 | 70.6131   | 0.9959 |
| House256.png   | 167             | 256X256    | W6.png          | 1.42            | 50X50      | 59.48                                  | 3.22   | 0.000902745 | 68.9124   | 0.9891 |
| Lenna512.png   | 661             | 512X512    | W7.png          | 19.6            | 512X512    | 53.41                                  | 3.52   | 0.000982354 | 66.7629   | 1      |
| Peppers512.png | 732             | 512X512    | W8.png          | 18.9            | 512X512    | 32.02                                  | 4.42   | 0.000975348 | 67.4365   | 1      |
| Strawberry.png | 943             | 666X666    | W9.png          | 7.97            | 256X256    | 38.8                                   | 3.32   | 0.000976333 | 69.5349   | 1      |
| Sailboat.png   | 769             | 512X512    | W10.png         | 13.8            | 512X512    | 23.49                                  | 3.61   | 0.00098921  | 68.0453   | 0.9983 |

**Table 3.** The Invisibility Comparison Results and the Normalized Correlation between the different methods without attacks

| Image        | PSNR (dB)       |                             |                              |                            | NC              |                             |                              |                            |
|--------------|-----------------|-----------------------------|------------------------------|----------------------------|-----------------|-----------------------------|------------------------------|----------------------------|
|              | Proposed Method | Method of Das et al. (2014) | Method of Kalra et al.(2015) | Method of Su et al. (2017) | Proposed Method | Method of Das et al. (2014) | Method of Kalra et al.(2015) | Method of Su et al. (2017) |
| Lena.jpg     | 66.7645         | 41.7801                     | 42.0109                      | 49.9898                    | 1.0000          | 1.0000                      | 1.0000                       | 1.0000                     |
| Baboon.png   | 66.6379         | 40.2446                     | 36.1103                      | 49.8901                    | 1.0000          | 1.0000                      | 1.0000                       | 1.0000                     |
| Peppers.jpg  | 67.4388         | 41.0122                     | 42.6843                      | 50.0839                    | 1.0000          | 1.0000                      | 1.0000                       | 1.0000                     |
| Airplane.png | 67.4840         | 40.7932                     | 39.7644                      | 49.8664                    | 1.0000          | 1.0000                      | 1.0000                       | 1.0000                     |

## 5. Conclusion

We have tried to implement watermarking using DWT to secure our digital media by having a watermarking algorithm and the experiment has been carried out based on PSNR, MSE, and Compression size after applying DWT which has given appreciable results. The NC value between the watermark image and the extracted watermark image for JPEG and PNG formats also gives proper results. The embedding and extraction algorithms based on DWT have been described. Hence, the proposed work has not only the better watermark invisibility but also has a good robustness and the accuracy between the watermark image and extracted watermark image.

In future work, we will try to extend our works taking both the cover image and watermark image as color image of all formats using blending methods in DWT domain.

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