ROBUST COLOUR IMAGE WATERMARKING USING HYBRID TRANSFORMS AND EDGE DETECTION

Satyanarayana Murty.P[1] and Rajesh Kumar.P[2]
[1]Research Scholar & [2]Associate Professor,
Department of ECE, AU College of Engg, AU, Vishakhapatnam, India

ABSTRACT

Three robust and semi-blind hybrid colour image watermarking algorithms have been proposed in this paper. These algorithms are based on hybrid transforms using the combination of Discrete Cosine Transform and Singular Value Decomposition (DCT - SVD), Discrete Wavelet Transform and Singular Value Decomposition (DWT- SVD), Discrete Wavelet Transform, Discrete Cosine Transform and Singular Value Decomposition (DWT- DCT - SVD). The original RGB colour image is divided to three colour channels, R, G and B channels. Then each colour channel is embedded with watermark image. The colour channel is divided into number of blocks. A reference image is formed by using these blocks. The process is to make the reference image have two ways. One is finding the spatial frequency of each block. Second one was finding the number of edges in each block. Keep a threshold on number of edges in each block or spatial frequency of each block. Then form a reference image with those blocks having edges greater than threshold or blocks having spatial frequency less than threshold. Then the above three algorithms are implemented on reference image to embedded the watermark. The performance of the proposed algorithms was evaluated with respect to imperceptibility. The three algorithms are provided almost good imperceptibility and the robustness has varied against various attacks.

KEYWORDS: *Colour Image, DWT, DCT, SVD, Edge Detection, spatial frequency & Reference Image*

I. INTRODUCTION

Due to the rapid and extensive growth of network technology, digital information can now be distributed much faster and easier. However, according to the insufficient cognizance of intellectual property, the condition of illegal copies and spread of copyright reserved information are growing serious. To protect the copyright of multimedia information and to decrease the impulse to copy and spread copy right reserved multimedia information. There are immense technical challenges in discouraging unauthorized copying and distributing of digital information. Fortunately, digital watermarking technique has been proposed as a method to embed an invisible signal into multimedia data so as to attest the owner identification of the data and discourage the unauthorized copying and distributing of digital information. In digital image watermarking the inserted watermark should not degrade the visual perception of an original image. This information of digital data can be extracted later for ownership verification [1]. Digital watermarking can applied to a variety of fields like text, image, audio, video and software. A lot of techniques are available for protecting the copyrighted material. The first method for hiding watermarking is by directly changing original cover-media. The advantages are simple and fast calculated but cannot protect itself from varied signal processing attacking [2, 3]. The most of watermarking techniques embed the information data in the coefficients of transformation domain of the cover image, such as Fourier transformation, discrete cosine transformation, wavelet transformation and singular value decomposition. Image watermarking algorithms using Discrete Cosine Transform (DCT) [4], Discrete Wavelet Transform (DWT) [5], and Singular Value Decomposition (SVD) [6] are available in the literature. Domain transformation watermarking schemes, in general, first use DCT and DWT and then transforms the image into the spatial domain. Watermarking schemes usually focus on watermarking black and white or gray scale images. The data hiding capacity is high in spatial domain and frequency domain algorithms based on

DCT, SVD. However, these algorithms are hardly robust against various attacks, prone to tamper and degrade the quality of the watermarked image. Hybrid domain transforms are also available in the literature DCT- SVD [7] and DWT-SVD [8]. In the literature some colour image watermarking algorithms are also available [9- 20]. These algorithms can be used either individual transforms or hybrid transforms.

In this paper we proposed three semi - blind colour image watermarking algorithms using DCT- SVD, DWT-SVD and DWT-DCT-SVD schemes. The rest of the paper is organized as follows: Section 2 provides our proposed algorithms, section 3 experimental results and in section 4 conclusions follows references.

II. RELATED WORK

Authors proposed a hybrid algorithm for colour image watermarking [11]. They tested their proposed method for binary, gray scale and colour watermark images. They used contour let transform and singular value decomposition to embed the watermark. They divided the colour image into RED, GREEN and BLUE colour planes. The singular values of mid frequency sub-band coefficients of colour watermark image are embedded into singular values of mid frequency sub-band coefficients of host colour image in Red, Green and Blue colour spaces simultaneously based on spread spectrum technique. The robustness of watermark is improved for common image procession operations by combining both the concepts of contour let transform and singular value decomposition.

Authors propose [12] a digital watermarking method for colour images based on wavelet transform. In the proposed method, the authors embed a watermark into both the luminance component and the chrominance component by using two different algorithms. In luminance component the watermark embedded by dwt, while in chrominance component by relations between neighbouring coefficients.

Authors present [13] a more secure method for copyright protection. In this scheme colour image is decomposed into R, G, B channels and then DWT and DCT transformations are applied on these channels separately. The bits of watermark image are embedded into middle frequency coefficients of transformed R, G, B channels.

Basically here also the authors proposed [14] a colour image watermarking using DWT-DCT. The colour image was decomposed into YIQ format. The security levels are increased by using multiple pn sequences, Arnold scrambling, DWT domain, DCT domain and colour space conversions. Since pixel values are highly correlated in RGB colour spaces, the use of YIQ colour space for watermark embedding is beneficial for improvement in results. The PSNR and NC values for Q channel are better than PSNR and NC values for Y and I channels.

Authors [15] proposed an algorithm in RGB colour space. The cover image is decomposed into three separate colours planes namely R, G and B. Individual planes are decomposed into sub bands using DWT. DCT is applied in HH component of each plane. Secret images are dispersed among the selected DCT coefficients using a pseudo random sequence and a Session key. They used only selected high frequency components are modified for the hiding method; therefore there must be a constraint on the secret image size

In [16], Colour Image Watermarking algorithm based on DWT-SVD is proposed. The scrambling watermark is embedded into green component of colour image based on DWT-SVD. The scheme is robust and giving PSNR up to 42.82 db

III. PROPOSED ALGORITHMS

A semi-blind colour image watermarking schemes using DCT - SVD, DWT-SVD and DWT-DCT-SVD have been discussed here. The cover image is a RGB colour image. These three algorithms separately implemented on each colour channel. The watermark can be embedded into Red, Green and Blue channels respectively. Block diagram of proposed watermarking schemes are shown in figure 1. Each colour channel of original RGB image is segmented into blocks of size $p_1 \times p_2$ via ZIG_ZAG sequence denoted by F^l, where l is the number of blocks. There are two ways to form the reference image. One way is find the spatial frequencies of each block and is stored in descending order. Then make a threshold on spatial frequency. Those blocks, which have spatial frequency less than or equal to threshold, are considered as significant blocks and are used for making reference image, F_{ref} which is a size of n × n (Method A). Second way is finding the numbers of edges in each block and is stored in descending order. Then make a threshold on the number of edges in each block. Those blocks, which have number of edges greater than or equal to threshold, are considered as significant blocks and are used for making reference image, F_{ref} which is a size of n × n (Method B).

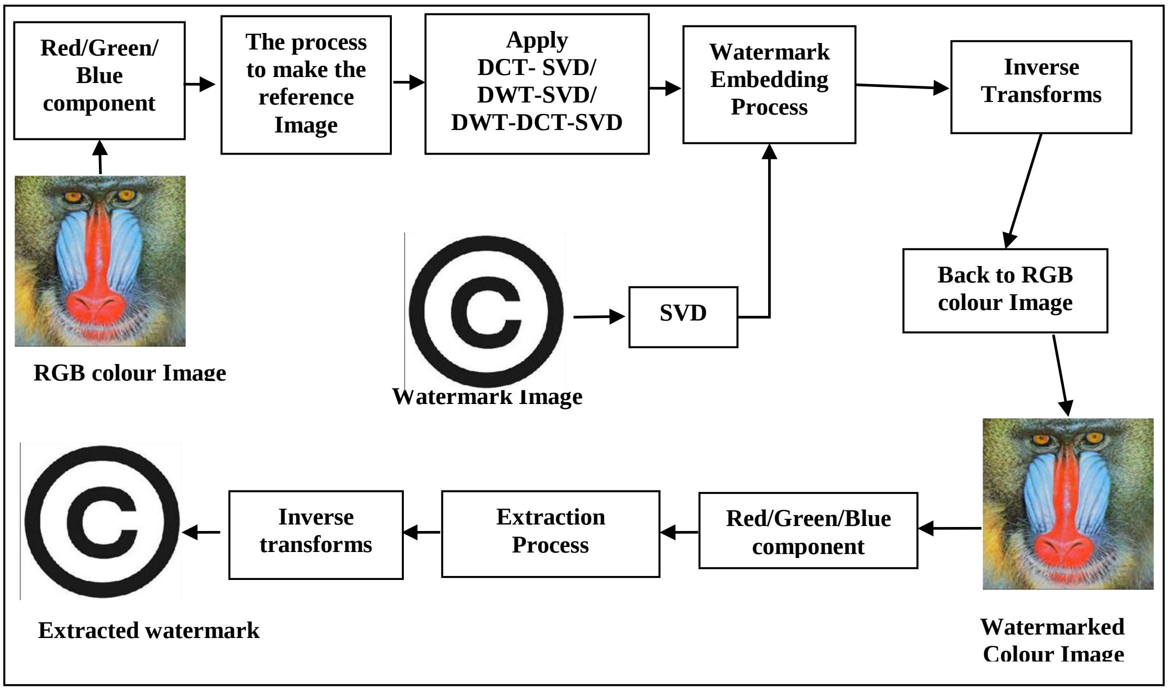


Fig 1: General Embedding/ Extraction Process

3.1. Watermarking Algorithm Using DCT-SVD

3.1.1. Watermark embedding procedure

Step1: Perform DCT on the reference image, which is denoted by f_{DCT}

Step2: Perform SVD on f_{DCT}, which is denoted by

$$f_{DCT}^{SVD} = U_{DCT} * S_{DCT} * V_{DCT}^{T} \quad (1)$$

Step3: Perform SVD transform on watermark image W, which is denoted by

$$f_{W}^{SVD} = U_{W} * S_{W} * V_{W}^{T} \quad (2)$$

Step4: Modify the singular values of reference image with the singular values of watermark as

$$\left(S_{ref}\right)^{*} = S_{DCT} + \beta * S_{w} \quad (3)$$

Where, β gives the watermark depth.

Step5: Perform inverse SVD,

$$f_{isvd}^{*} = U_{DCT} * S_{ref}^{*} * V_{DCT}^{T} \quad (4)$$

Step6: Perform inverse DCT to construct the modified reference image, denoted by. F_{ref}^{*}. Again F_{ref}^{*} is segmented into blocks of size $p_1 \times p_2$ and mapped onto their original positions for constructing the watermarked image. We save the positions of the significant blocks and reference image for the extraction process.

3.1.2. Watermark extraction procedure

Watermark extraction procedure as follows:

Step1: Using the positions of significant blocks, make the reference image from the watermarked image, denoted by F_W^{ref}

Step2: Perform DCT on reference image, which is denoted by f_{DCT}^{ref}

Step3: Perform SVD transform on f_{DCT}^{ref}.

$$f_{SVD}^{ref} = U_{ref} * S_{ref} * V_{tef}^T \tag{5}$$

Step4: Extract the singular values of the watermark.

$$S_W^{ext} = \frac{S_{ref} - S_W}{\beta} \tag{6}$$

Step5: Obtain the extracted watermark as:

$$W^{ext} = U_W * S_W^{ext} * V_W^T \tag{7}$$

3.2. Watermarking Algorithm Using DWT-SVD

3.2.1. Watermark Embedding Procedure

Step1: Perform DWT on the reference image, which is denoted by f_{DWT}

Step2: Perform SVD on one of four sub bands of f_{DWT}, which is denoted by

$$f_{DWT}^{SVD} = U_{DWT} * S_{DWT} * V_{DWT}^T \tag{8}$$

Step3: Perform SVD transform on watermark image W, which is denoted by

$$f_W^{SVD} = U_W * S_W * V_W^T \tag{9}$$

Step4: Modify the singular values of reference image with the singular values of watermark as

$$\left(S_{ref}\right)^* = S_{DWT} + \beta * S_w \tag{10}$$

Where, β gives the watermark depth.

Step5: Perform inverse SVD,

$$f_{isvd}^* = U_{DWT} * S_{ref}^* * V_{DWT}^T \tag{11}$$

Step6: Perform inverse DWT to construct the modified reference image, denoted by. F_{ref}^*. Again F_{ref}^* is segmented into blocks of size $p_1 \times p_2$ and mapped onto their original positions for constructing the watermarked image.

The positions of the significant blocks and reference image have been saved for the extraction process.

3.2.2. Watermark extraction procedure

Watermark extraction procedure as follows:

Step1: Using the positions of significant blocks, make the reference image from the watermarked image, denoted by F_W^{ref}

Step2: Perform DWT on reference image, which is denoted by f_{DWT}^{ref}

Step3: Perform SVD transform on. f_{DWT}^{ref}

$$f_{SVD}^{ref} = U_{ref} * S_{ref} * V_{ref}^T \tag{12}$$

Step4: Extract the singular values of the watermark.

$$S_W^{ext} = \frac{S_{ref} - S_W}{\beta} \tag{13}$$

Step5: Obtain the extracted watermark:

$$W^{ext} = U_W * S_W^{ext} * V_W^T \tag{14}$$

3.3. Watermarking Algorithm Using DWT – DCT - SVD

3.3.1. Watermark Embedding Procedure

Step1: Perform DWT on the reference image, which is denoted by f_{DWT}.

Step2: Perform DCT on the LH band of DWT decomposition, which is denoted by f_{DCT}.

Step3: Apply SVD on f_{DCT}.

$$f_{DCT}^{SVD} = U_{DCT}^{SVD} * S_{DCT}^{SVD} * V_{DCT}^{SVD^T} \quad (15)$$

Step4: Perform SVD on watermark image.

$$W_{SVD} = U_W * S_W * V_W^T \quad (16)$$

Step5: Modify the single values of reference image with the singular values of watermark as

$$f_{SVD}^{*} = S_{DCT}^{SVD} + \beta * S_W \quad (17)$$

Where, β gives the watermark depth.

Step6: Perform inverse SVD,

$$f_{isvd}^{*} = U_{DCT}^{SVD} * f_{SVD}^{*} * V_{DCT}^{SVD^T} \quad (18)$$

Step7: Perform inverse DCT and DWT to construct the modified reference image, denoted by f_{ref}^{*}. Again f_{ref}^{*} is segmented into blocks of size $p_1 \times p_2$ and mapped onto their original positions for constructing the watermarked image. We save the positions of the significant blocks and reference image for the extraction process.

3.3.2. Watermark Extraction Procedure

Step1: Using the positions of significant blocks, make the reference image from the watermarked image, denoted by F_{ref}^{W}.

Step2: Perform DWT and DCT on watermarked reference image, F_{ref}^{W}. Which is denoted by f_{ref}^{W}.

Step3: Perform SVD transform on f_{ref}^{W}.

$$f_{ref}^{W} = U_{ref}^{W} * S_{ref}^{W} * V_{ref}^{W^T} \quad (19)$$

Step4: Extract the singular values of the watermark.

$$S^{ext} = \frac{S_{ref}^{W} - S_{DCT}^{SVD}}{\beta} \quad (20)$$

Step5: Obtain the extracted watermark as:

$$W^{ext} = U_W * S^{ext} * V_W^T \quad (21)$$

IV. RESULT ANALYSIS

The performances of proposed colour image watermarking algorithms were evaluated with Lena, Mandrill, Home and peppers of size 512 x 512. This has shown in table 1. For the embedding process two gray scale watermark images were used in this experiment. These watermarks were embedded into the three components (RED, GREEN and BLUE) of the RGB colour images. The three algorithms are applied for each colour component for watermarking process. For DCT-SVD algorithm the watermark size was 256 x256, for DWT-SVD and DWT-DCT-SVD algorithms watermark size was 128 x 128. The three algorithms, which are discussed above are implemented on Lena as a cover image and copy as a watermark image. These algorithms are tested against various attacks as mentioned above. This has shown in table2.

The performance of proposed algorithms was carried out with two measures. One is imperceptibility, means that the perceived quality of the colour image should not be distorted by the presence of the watermark. As a measure of the quality of a watermarked image, the peak signal to noise ratio (PSNR) is typically used. Second one is robustness, is a measure of the immunity or resistance of the watermark against attempts to remove or degrade it from the watermarked colour image by different types of digital signal processing attacks. The similarity between the original watermark and the extracted watermark from the attacked watermarked image was measured by using the correlation factor ρ, which is computed using the following Equation:

$$\rho(w, \tilde{w}) = \frac{\sum_{i=1}^{N} w * \tilde{w}}{\sqrt{\sum_{i=1}^{N} w^2} \sqrt{\sum_{i=1}^{N} \tilde{w}^2}} \quad (22)$$

Where N is the number of pixels in watermark, w and $\tilde{w}$ is the original and extracted watermarks respectively. The correlation factor ρ, may take values between -1 and 1.

The robustness of the algorithms discussed above section was evaluated against the following image attacks: average filtering, median filtering, Gaussian noise, JPEG compression, rotation, cropping, resize, histogram equalization, pixilation, motion blur, sharpening and contrast adjustment.

Table1: Test Images

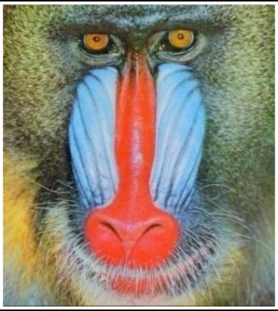
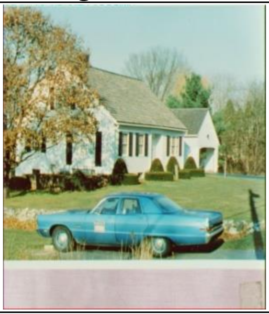
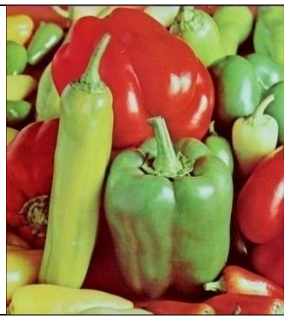
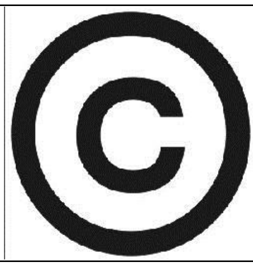
			
(a) Lena	(b) Mandrill	(c) House	(d) Peppers

Table2: Watermark Images

	
(a) Copy	(b) Cameraman

4.1. Performance of proposed method (A) by using Spatial Frequency to form a Reference Image

The three algorithms, which are discussed above are implemented on Lena as a cover image and copy as a watermark image. These algorithms are tested against various attacks as mentioned above. For DCT-SVD algorithm, the attacks median filtering, JPEG compression and resizing are good in red channel. The Histogram Equalization has well in green channel. The blue channel is best for other remaining attacks. For DWT-SVD algorithm, all the attacks are best in blue channel only. For DWT-DCT-SVD algorithm, median filtering, sharpening and pixilation attacks are good in red channel. For remaining attacks the blue channel is best. The corresponding robustness values are tabulated in table-3.

Table3: NCC values of reference image formed by using spatial frequency

Attacks	**DCT-SVD**			**DWT-SVD**			**DWT-DCT-SVD**		
	Red Channel	**Green channel**	**Blue channel**	**Red Channel**	**Green channel**	**Blue channel**	**Red Channel**	**Green channel**	**Blue channel**
Average Filtering (13 x 13)	0.0525	-0.0919	**0.0964**	0.1316	-0.0900	**0.2433**	0.0774	-0.1117	**0.2145**

Median Filtering (13 x 13)	**0.1013**	0.0137	-0.0791	-0.7244	0.5999	**0.9931**	**0.7472**	-0.2194	-0.3464
Gaussian noise **(75%)**	-0.2282	-0.0273	**0.6267**	-0.4111	0.2048	**0.9592**	-0.4342	0.1830	**0.9595**
JPEG (80:1)	**0.9795**	0.4084	0.9057	0.9281	0.9809	**0.9898**	0.9277	0.1830	**0.9896**
Rotation (50^0)	-0.2326	0.4826	**0.9682**	-0.2987	- 0.6588	**0.0914**	-0.3005	-0.6607	**0.0866**
Resizing (512 -> 128 -> 512)	**0.5298**	0.3837	0.5259	0.7756	0.6645	**0.7982**	-0.9515	-0.3915	**0.9823**
Histogram equalization	-0.6635	**0.9596**	0.9599	-0.8744	0.0329	**0.8450**	0.9729	0.9346	**0.9919**
Sharpening (by factor 80)	0.2244	0.3331	**0.4066**	0.2992	0.6180	**0.7588**	**0.6249**	0.3668	0.6143
Pixilation 10	0.2826	0.3514	**0.5925**	-0.7466	0.1969	**0.9961**	**0.5631**	-0.4345	-0.2586
Contrast (-50)	-0.8343	-0.2607	**0.6133**	-0.7470	- 0.0799	**0.8590**	-0.7289	-0.1150	**0.8500**

4.2. Performance of proposed method (B) by using Canny Edge Detection to form a Reference Image

The three algorithms, which are discussed above are implemented on Lena, Mandrill, House and Pepper as a cover image and copy and camera man as a watermark image. The corresponding watermarked colour images and their PSNR values of the watermarked colour images were shown in table4.
Primarily the three watermarked images from three algorithms of red channel have been selected and two filtering masks are imposed (average and median filters). Here DWT-SVD and DWT-DCT-SVD has optimized robustness for the extracted watermark when compared to DCT-SVD. Now noise of type additive Gaussian is added to the watermarked images where the robustness is high for DCT-SVD rather that of DWT-SVD and DWT-DCT-SVD. Now watermarked images are compressed and robustness is calculated which proved that the algorithms DWT-SVD and DWT-DCT-SVD are robust when compared with DCT-SVD. This is followed by the attacks rotation, cropping, resizing, sharpening, wrapping and pixilation were applied to the watermarked images where DCT-SVD is proven less robust to that of DWT-DCT-SVD and DWT-SVD. Motion blur is another attack, attacked on the watermarked images where DCT-SVD and DWT-DCT-SVD weighs less robustness, but DCT-SVD holds good. Contrast adjustment is the last attack given to watermarked images and the NCC of extracted watermarks are compared, which proved robustness of DWT-SVD and DWT-DCT-SVD are appreciable whereas DCT-SVD is moderate. The results were tabulated in table5 and the attacking values have shown in figure2.

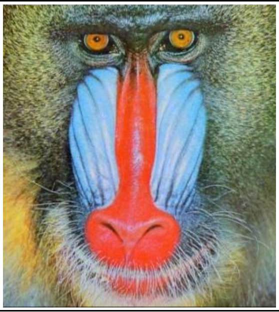
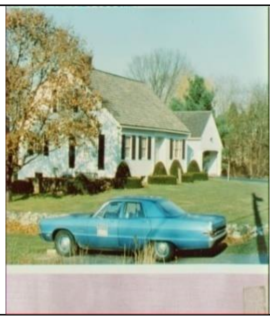
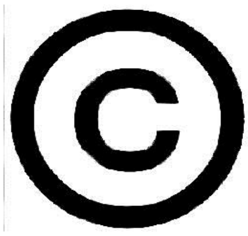
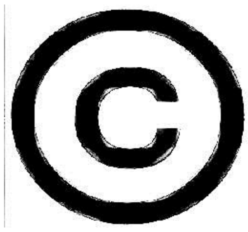
Table4: Watermarked and Extracted watermark images for DCT-SVD method in Blue component			
Watermarked images and PSNR values			
			
(a) Lena (41.70)	(b) Mandrill	(c) House (40.71)	(d) Pepper (43.50)
Extracted Watermark Images (without attacks) and NCC values			
			
(e) Copy (0.9858)	(f)Copy (0.9755)	(g)Camera (0.9567)	(h)Camera (0.9819)

TABLE5 : RED COMPONENT			
ATTACKS	DCT-SVD	DWT-SVD	DWT-DCT-SVD
Average Filtering (13 x 13)	0.9572	**0.9999**	**0.9999**
Median Filtering (13 x 13)	0.9327	**1.0000**	**1.0000**
Additive Gaussian noise (75%)	**0.8843**	0.8696	0.8195
JPEG compression (80:1)	0.9659	**0.9983**	**0.9983**
Rotation (50^0)	0.9902	**0.9978**	**0.9978**
Cropping (25% area remaining)	0.9678	**0.9999**	**0.9999**
Resizing (512 -> 128 -> 512)	0.9748	**0.9981**	**0.9981**
Histogram equalization	0.9027	**0.9863**	0.9493
Sharpening (by factor 80)	0.9092	**0.9983**	**0.9983**
Wrapping	0.9347	**1.0000**	**1.0000**
Pixilation 10	0.9572	**0.9997**	**0.9997**
Motion blur	0.9846	**0.9991**	0.9985
Contrast adjustment(-50)	0.9572	**0.9999**	**0.9999**

Now the three watermarked images from three algorithms of green channel have been selected. The attacks on watermarked image carried out by average and median filter showing that DWT-SVD and DWT-DCT-SVD has appreciable robustness for the extracted watermark when compared to DCT-SVD. Now additive Gaussian noise and Histogram equalization were added to the watermarked images, where the robustness is optimum for DCT-SVD rather than DWT-SVD and DWT-DCT-SVD. Image compression is another attack followed with a compression ratio of 80:1 and the extracted watermarks showed that DWT-DCT-SVD has good normalized cross co-relation. This is followed by the rotation, cropping, resizing, sharpening, wrapping and pixilation are applied to the watermarked images where DCT-SVD is proven to have less robustness to DWT-DCT-SVD and DWT-SVD. Motion blur is another attack, attacked on the watermarked images where DCT-SVD and DWT-DCT-SVD bags less robustness, but DWT-SVD holds good. Contrast adjustment is the last attack given to watermarked images and the robustness of extracted watermarks are compared, which proved robustness of DWT-SVD and DWT-DCT-SVD are appreciable whereas DCT-SVD is moderate. The results were tabulated in table-6 and the attacking values have shown in figure3.

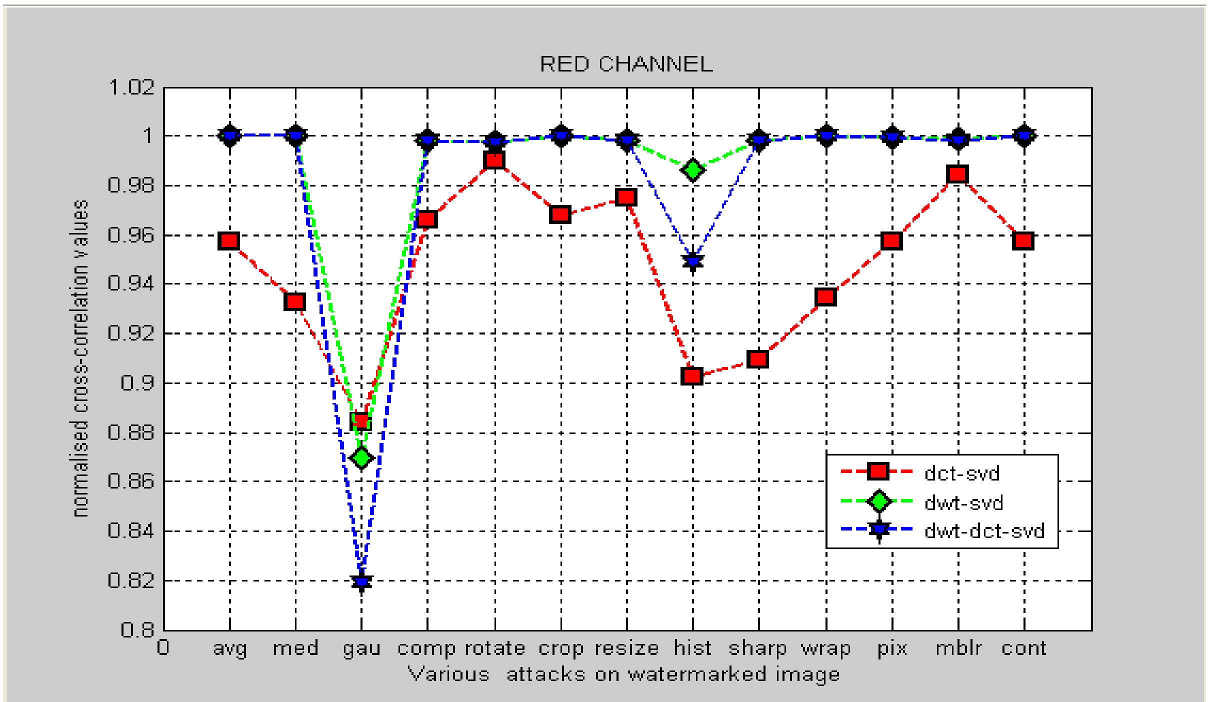


Figure 2: attacks on red channel watermarked image

TABLE 6: GREEN COMPONENT			
ATTACKS	DCT-SVD	DWT-SVD	DWT-DCT-SVD
Average Filtering (13 x 13)	0.9978	**1.0000**	**1.0000**
Median Filtering (13 x 13)	0.9974	**0.9999**	**0.9999**
Additive Gaussian noise (75%)	**0.9174**	0.8681	0.8681
JPEG compression (80:1)	0.9949	0.9972	**0.9976**
Rotation (50^0)	0.9894	**1.0000**	**1.0000**
Cropping (25% area remaining)	0.9976	**0.9998**	**0.9998**
Resizing (512 -> 128 -> 512)	0.9946	**0.9948**	**0.9948**
Histogram equalization	**0.9903**	0.9846	0.9800
Sharpening (by factor 80)	0.9891	**0.9978**	**0.9978**
Wrapping	0.9979	**1.0000**	**1.0000**
Pixilation 10	0.9980	**0.9995**	**0.9995**
Motion blur	0.9985	**0.9989**	0.9988
Contrast adjustment(-50)	0.9978	**1.0000**	**1.0000**

Now the triplet of watermarked images of three algorithms of same blue channel has been selected and attacked with average and median filtering masks and the results showed that only DWT-SVD has optimized robustness for the extracted watermark when to DCT-SVD. and DWT-DCT-SVD. Now additive Gaussian noise and sharpening attacks are given to the watermarked images where the robustness is optimum for DCT-SVD rather than DWT-SVD and DWT-DCT-SVD. Image compression and image rotation were another attacks followed with a compression ratio of 80:1 and rotation angle of 50^0 respectively. The extracted watermarks showed that DWT-DCT-SVD has good normalized cross co-relation against rotation attack while compression against DWT-SVD algorithm. Resizing, Histogram equalization, wrapping were the attacks succeeded and were applied to the watermarked images where DWT-SVD is proven to have high robustness to DWT-DCT-SVD and DCT-SVD. Motion blur, cropping, pixilation and Contrast adjustment are the remaining attacks, attacked on the watermarked images where DWT-SVD and DWT-DCT-SVD have good robustness when compared with DCT-SVD algorithm. The results were tabulated in table7 and the attacking values have shown in figure4. The corresponding attacked watermarked images and extracted watermarks from blue channel were shown in table-8.

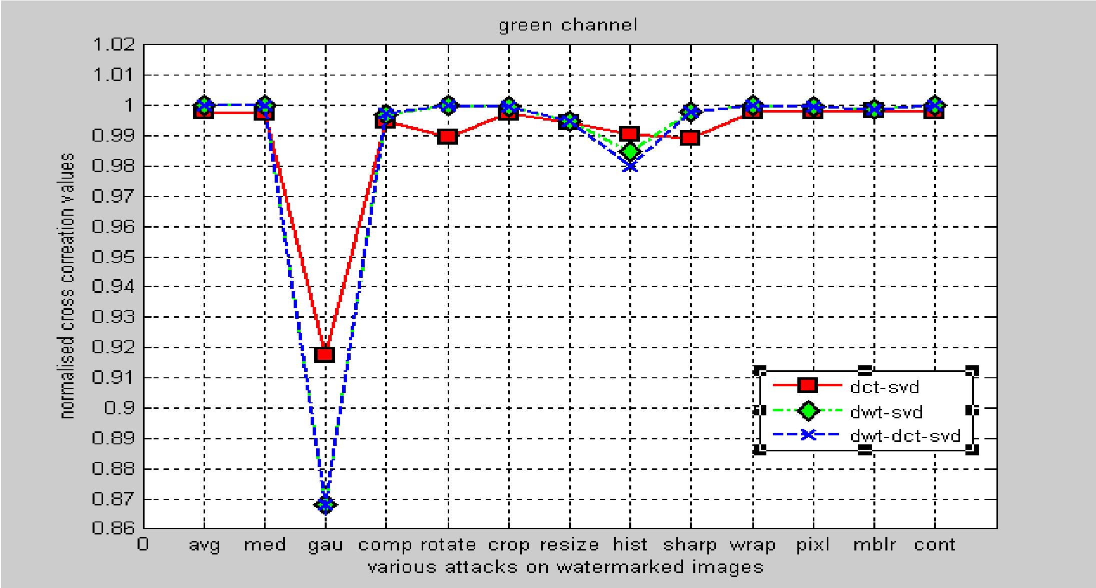


Figure 3: attacks on green channel watermarked image

TABLE 7: BLUE COMPONENT			
ATTACKS	DCT-SVD	DWT-SVD	DWT-DCT-SVD
Average Filtering (13 x 13)	0.9957	**1.0000**	0.9823
Median Filtering (13 x 13)	0.9880	**1.0000**	0.9823
Additive Gaussian noise (75%)	**0.9141**	0.8819	0.8659
JPEG compression (80:1)	0.9935	**0.9987**	0.9787
Rotation (50^0)	0.9902	0.9783	**1.0000**
Cropping (25% area remaining)	0.9783	**0.9992**	**0.9992**
Resizing (512 -> 128 -> 512)	0.9973	**0.9999**	0.9819
Histogram equalization	0.9917	**0.9937**	0.9690
Sharpening (by factor 80)	**0.9943**	0.9879	0.9639
Wrapping	0.9963	**0.9989**	0.9986
Pixilation 10	0.9972	**0.9999**	**0.9999**
Motion blur	0.9974	**0.9998**	**0.9998**
Contrast adjustment(-50)	0.9971	**0.9993**	**0.9993**

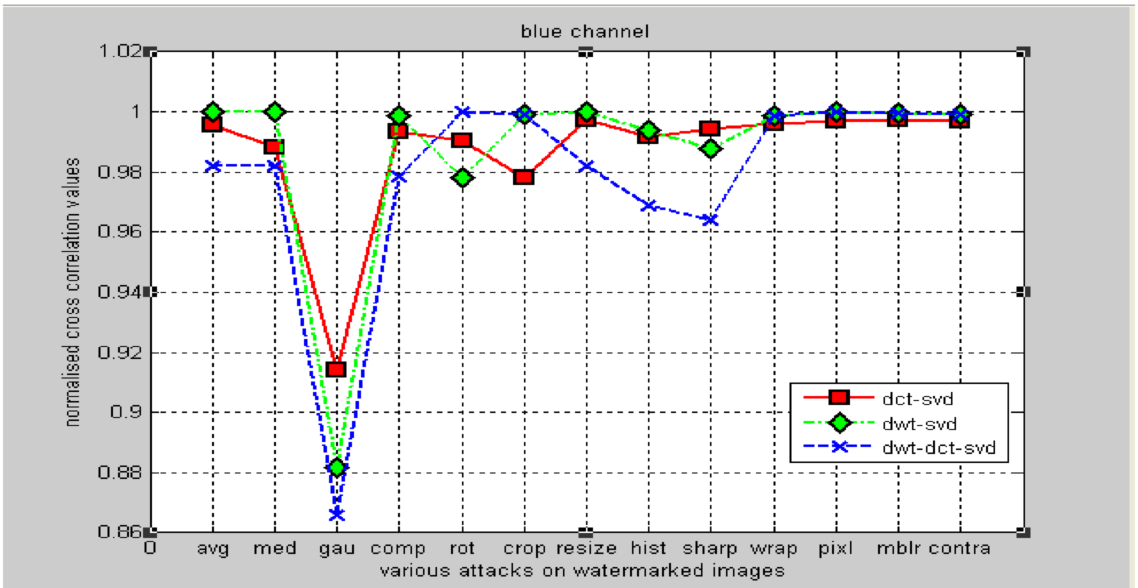
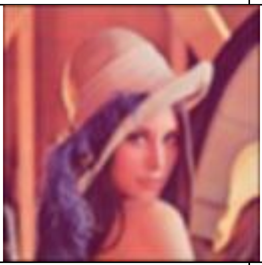
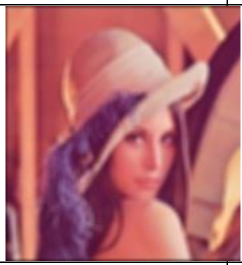
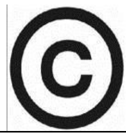
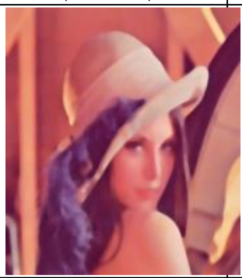
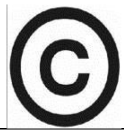
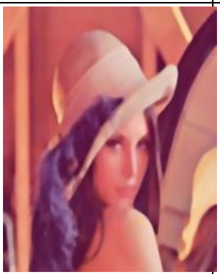
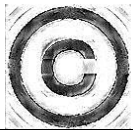
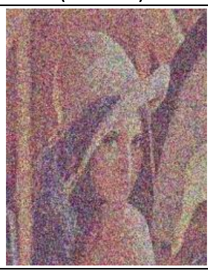
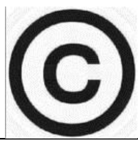
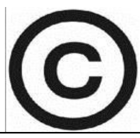
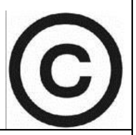
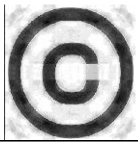
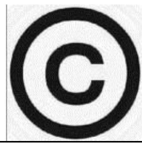
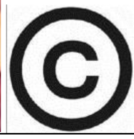
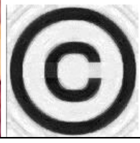
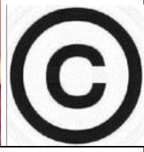
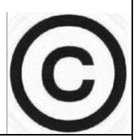


Figure 4: attacks on blue channel watermarked image

TABLE 8: attacks on blue component watermarked image and extracted watermarks					
DCT - SVD		DWT - SVD		DWT-DCT-SVD	
Attack	Extracted wm	Attack	Extracted wm	Attack	Extracted Wm
					
Average filter (13 x 13)	0.9957	Average Filtering (13 x 13)	1.0000	Average Filtering (13 x 13)	0.9823
					
Median filter (13 x13)	0.9880	Median filter (13 x13)	1.0000	Median filter (13 x13)	0.9823
					
Gaussian (0,75)	0.9141	Gaussian (0,75)	0.8819	Gaussian (0,75)	0.8659
					
Compress (80:1)	0.9935	Compress (80:1)	0.9987	Compress (80:1)	0.9787
					
Rotate(50)	0.9902	Rotate(50)	1.0000	Rotate(50)	1.0000

					
Cropping	0.9783	Cropping	0.9992	cropping	0.9992
					
Resizing (512 -> 128 -> 512)	0.9973	Resizing (512 -> 128 -> 512)	0.9999	Resizing (512 -> 128 -> 512)	0.9819
					
Histogram equalization	0.9917	Histogram equalization	0.9937	Histogram equalization	0.9690
					
Sharpening (by factor 80)	0.9943	Sharpening (by factor 80)	0.9879	Sharpening (by factor 80)	0.9639
					
Wrapping	0.9963	Wrapping		Wrapping	0.9986

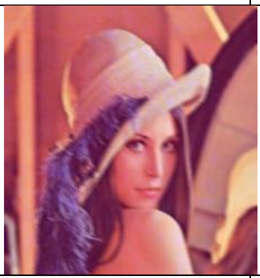
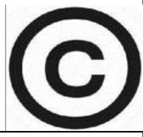
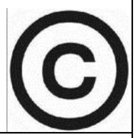
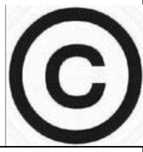
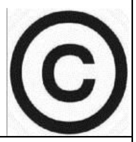
					
Pixilation 10	0.9972	Pixilation 10	0.9999	Pixilation 10	0.9999
					
Motion blur	0.9974	Motion blur	0.9998	Motion blur	0.9998
					
Contrast adjustment(-50)	0.9971	Contrast adjustment(-50)	0.9993	Contrast adjustment(-50)	0.9993

Table 9: comparison of NCC values with ref 19

Attacks	**Existing DWT-SVD (ref 19)**	**Proposed DWT-SVD**
JPEG compression (90:1)	0.9882	**0.9973**
JPEG compression (70:1)	0.9788	**0.9969**
JPEG compression (50:1)	0.9402	**0.9956**
JPEG compression (30:1)	0.8775	**0.9972**
Cropping (25% area remaining)	0.9031	**0.9988**
Median Filtering (13 x 13)	0.8968	**0.9999**
Resizing (512 -> 128 -> 512)	0.8264	**0.9998**
Additive Gaussian noise (75%)	0.7415	**0.8681**

Table10: comparison of NCC values with ref 20

Attacks	**Existing (ref 20)**			**Proposed DWT-DCT-SVD**		
	Read Channel	**Green channel**	**Blue channel**	**Read Channel**	**Green channel**	**Blue channel**
Salt and peppers noise	0.9904	0.9888	0.9942	**0.9974**	**0.9982**	**0.9984**
Gaussian noise	0.9893	0.9911	0.9902	**0.9962**	**0.9961**	**0.9959**
Rotation	0.9060	0.9548	0.9549	**0.9992**	**1.0000**	**1.0000**
Sharpening	**0.9990**	**0.9982**	**0.9977**	0.9905	0.9941	0.9958
Histogram equalization	0.9927	0.9945	0.9908	**0.9994**	**0.9984**	**0.9979**
Gaussian blur	0.9999	**0.9999**	0.9999	**0.9999**	0.9998	**0.9999**

Colour contrast	0.9881	0.9430	0.9430	**0.9997**	**0.9996**	**0.9998**
Resize	0.9963	0.9926	0.9841	**0.9999**	**0.9999**	**1.0000**
Compression	0.9786	0.9952	0.9831	**0.9994**	**0.9993**	**0.9996**

V. CONCLUSIONS

In this paper, three hybrid colour image watermarking algorithms has been implemented based on DCT-SVD, DWT-SVD and DWT-DCT-SVD using either canny edge detection or spatial frequency for preparation of reference image. The cover image is a RGB colour image of size 512 X512. These three algorithms separately implemented on each colour channel. The watermark can be embedded into Red, Green and Blue channels respectively. The robustness of the proposed algorithms was tested against various attacks.

For the three algorithms as mentioned above, the proposed method (A) has good robust against all the attacks in DWT-SVD algorithm. Considering the colour channels, the blue channel has better robustness. Next coming to method (B), here also the DWT-SVD algorithm has well robustness, when comparing with other two algorithms. The embedding and extraction are good in blue channel, when comparing with other two colour channels. Further the results were compared with existing paper references [19, 20]. When results were compared with ref 19, for all the attacks the proposed algorithm has proved too robust. When compared with ref 20, the existing algorithm well against only for sharpen attack. For other attacks the proposed algorithm has good robustness.

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AUTHORS

P. Satyanarayana Murty is currently working as Sr. Associate Professor & Head of the department in ECE Department, GIITS, Engineering College, Vishakhapatnam, Andhra Pradesh, India. He is working towards his Ph.D.at AU College of Engineering, Vishakhapatnam, India. He received his M.Tech from Jawaharlal Nehru Technological University, Hyderabad, India. He has fifteen years' experience of teaching undergraduate students and post graduate students. His research interests are in the areas of image watermarking, and image compression

P. Rajesh Kumar is currently Associate Professor in ECE Department, AU College of Engineering, Vishakhapatnam, India. He received his M.Tech and Ph.D. from Andhra University, Vishakhapatnam, India. He has eleven years' experience of teaching undergraduate and postgraduate students and guided number of post-graduate theses. He has published 10 research papers in National and International journals. Presently he is guiding six Ph.D students in the area of digital signal processing and Image processing. His research interests are in the areas of digital image processing and digital signal processing.