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Comparison of Wavelet Based Watermarking Techniques for Various Attacks

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Abstract— **Digital watermarking is a technique for copyright protection. Thus Copyright and security of multimedia contents becomes a vital issue and there is a need in protecting the digital content against counterfeiting, piracy and malicious manipulations. Digital watermarking is the procedure whereby secret information (the watermark) is embedded into the host multimedia content, such that it is: (1) hidden, i.e., not perceptually visible; and (2) recoverable, even after the content is degraded by different attacks. The two basic requirements for an effective watermarking scheme, imperceptibility and robustness, conflict with each other, this is solved using the DWT-DCT based algorithm which is better than previous algorithms.**

Index Terms— ***watermarking; wavelet-tree; wavelet transform; copyright protection; colour space.***

I. Introduction

Digital watermarking has been developed since 1979, but it did not gain a large international interest until 1990. The rapid increase of interest in watermarking technique is most likely due to the increased concern over copyright protection of content for digital multimedia data, because there are many advantages of using digital multimedia data, it is easy to create, edit, reproduce and distribute; however, these advantages can facilitate unauthorized uses as well, such as illegal copying and unapproved modification of the content.

Current digital image watermarking techniques can be grouped into two major classes: spatial-domain and frequency-domain watermarking techniques. Compared to the spatial domain techniques, the frequency-domain watermarking techniques proved to be more effective with respect to achieving the imperceptibility and robustness requirements of digital watermarking techniques. The existing frequency based techniques such as Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT) are more robust against signal processing attacks like compression, filtering, rotation, scaling cropping etc.

Nowadays, along with the flourishment of Digital multimedia technology, the piracy issue are becoming important factors for the creation and development of products of commercial use and copyright is one of the most important issues for content providers to protect their intellectual properties.In literature survey, it has been found that many watermarking methods for images have been presented [1]-[4].MENG and YU developed a method based on Joint DWT-DCT transform [1].This algorithm embeds a binary logo into the colour images according to DCT and DWT characteristics. Before embedding the watermark, the DCT is applied to low frequency sub-images of DWT to get rid of coefficient correlation. The watermark is embedded in middle frequency DCT coefficient. By doing this we can achieve a better balance between robustness and invisibility. Al Haj developed a method based on combination DWT-DCT transform [2], here they embedded the watermark in middle frequency coefficients in DCT domain of three level DWT of LL band of original image using uncorrelated PN sequences. This combination shows little improvement in PSNR and also robust to attack. To improve PSNR more and make it more robust to attack, a wavelet-based blind watermarking scheme is used which is proposed by Run et al [5].They embedded each watermark bit into the maximum and second maximum coefficients of a wavelet tree. However, we found that for some cases their algorithm might suffer a problem that the values of coefficients are over-adjusted and the quality of watermarked images is degraded. In addition, their algorithm might suffer another problem when too many watermark bits “0” are embedded. In [6], Liang and Wang presented an improved wavelet-tree algorithm to embed a binary watermark into the low frequency and medium frequency component of the wavelet decomposition in the Chrominance Cb domain. In [7], Rawat and Raman presented to embed the watermark into all the frequency-sub bands of the image in each colour component of RGB space and YCbCr space. However, the methodology of choosing one of the three components of a colour space for watermark embedding is not sufficiently investigated. The aforementioned problems are solved by an adaptive colour image watermarking based on wavelet-tree structure [9]. Also this algorithm shows better improvement in the PSNR value than other methods.

This paper is organized as follow: Section I deals with importance of digital watermarking techniquesand gives a literature survey of the existing digital watermarking techniques. Section II briefly introduces the DWT-DCT based Watermarking Algorithm. Section III describes the wavelet-tree based watermarking algorithm and two rules for choosing a color component. Section IV describes the improved wavelet-tree based watermarking algorithm and two rules for choosing a color component. Section V shows the experimental results to validate the effectiveness of the method. Section VI followed by the conclusions.

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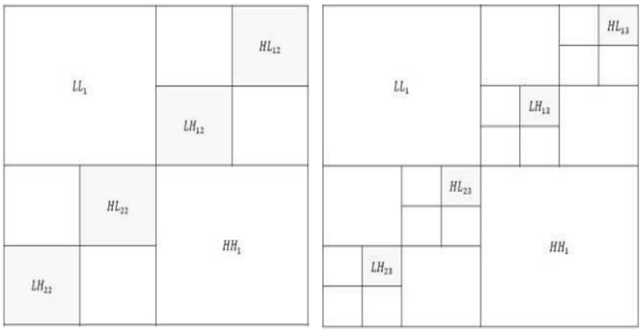
II. DWT-DCT Based Watermarking Algorithm [2]

A. *Embedding Algorithm*

Watermarking process is started by applying 3-levels of DWT on the host image. The agreement adopted by many DWT-based watermarking methods is to embed the watermark in the middle frequency sub-bands HL_X and LH_X is better in perspective of imperceptibility and robustness which is shown in Fig.1.



(a) (b)

Fig. 1 Four multi-resolution DWT coefficient sets of the original image in level 2 to apply DWT to another level; (b) four selected multi resolution DWT coefficient sets of the host image in level3.

The watermark embedding procedure is represented in Fig. 2.

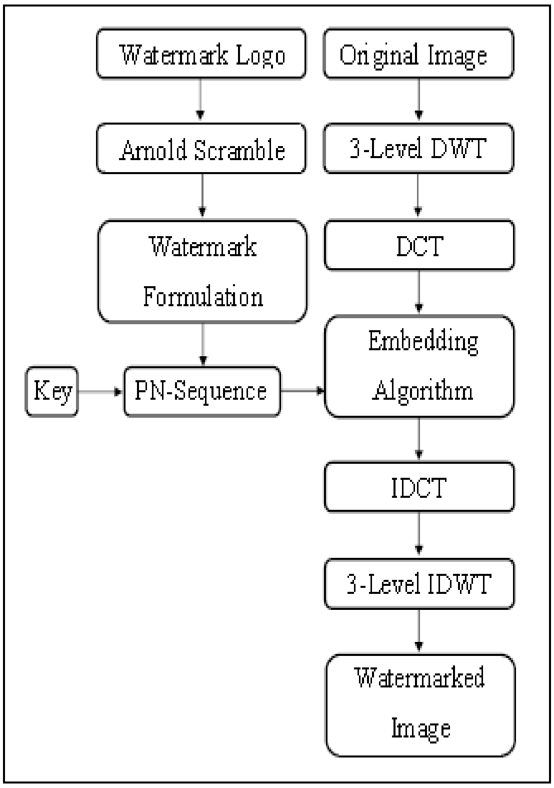


Fig. 2 Joint DWT-DCT watermark embedding procedure.

B. *Extracting Procedure*

The joint DWT-DCT algorithm is a blind watermarking algorithm, and thus the original host image is not required to extract the watermark. Extraction algorithm is the same as embedding one, which is shown in Fig. 3.

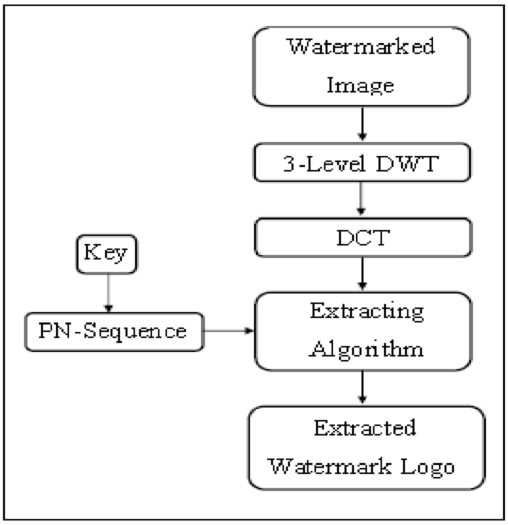
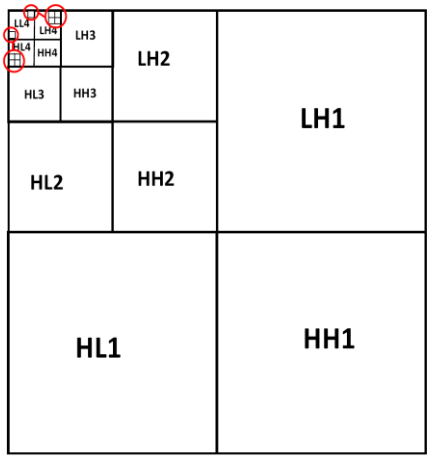
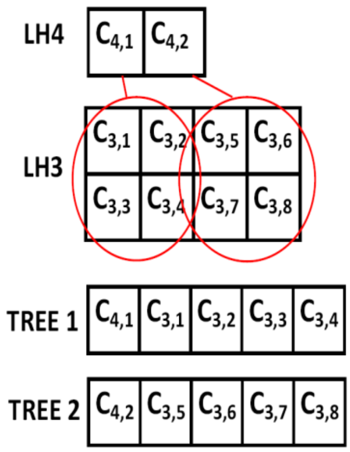


Fig. 3 Joint DWT-DCT watermark extraction procedure.

III. Wavelet Trees Structure Based Watermark Scheme [5]



(a)



(b)

Fig. 4 (a) Decomposition of Host image;(b)Wavelet tree structure

A. *atermarking Embedding strategy*

Step 1: Apply 4-level DWT to host image and make tree structure is shown in Fig. 4.

Step 2: Calculate the global average significant difference (ε) for N-tree

$$\varepsilon = \left\lfloor \left(\frac{1}{N} \sum_{i=1}^{N} (Max_i - Sec_i) \right) \right\rfloor$$

Step 3: Make the coefficient value of Max_i to be zero if Max_i is negative.

Step 4: Calculate the significant difference Δ_i of N-tree, Where $\Delta_i = Max_i - Sec_i$.

Step 5: Modify the coefficient value of Max_i depending on watermark bit 1 or 0. If the watermark bit is 1,

$$Max_i^{new} = \begin{cases} Max_i & if(\Delta_i \geq Max(\in, T)); \\ Max_i + \beta & if(\Delta_i < Max(\in, T)) \text{ and } Max_i \text{ is in } LH4 \text{ or } HL4; \\ Max_i + \beta * \gamma & if(\Delta_i < Maxi(\in, T)) \text{ and } Max_i \text{ is in } LH3 \text{ or } HL3; \end{cases}$$

If the watermark bit is 0,

$$Max_i^{new} = \begin{cases} Sec_i^{new} = 0, & if Sec_{i,} < 0; \\ Sec_{i,} & otherwise \end{cases}$$

Step 6: Apply IDWT to modified coefficient get Watermarked Image.

B. *Watermarking Extracting strategy*

Step 1: Apply 4-level DWT to Watermarked image and make tree.

Step 2: Calculate threshold y for tree, it is defined by,

$$y = \left\lfloor \frac{1}{N * \alpha} \sum_{i=1}^{N*\alpha} \varphi_i \right\rfloor$$
$$where, sort(\varphi_i = Max_i - Sec_i)$$

Step 3: Extract a watermark bit is given by.

$$Watermarkbit = \begin{cases} 1, & if(Max_i' - Sec_i') \geq y; \\ 0, & otherwises \end{cases}$$

Step 4: Get the watermarked logo.

Step 5:

IV. ADAPTIVE COLOUR IMAGE WATERMARKING SCHEME [9]

It is known that RGB colour space does not fit human visual system and is mainly used for computer display. Therefore; we transform a RGB colour image into the YCbCr colour space. The transformation is as below. Now, use the following two rules for watermark embedding and extraction.

Rule 1: To obtain a higher image quality, the watermark is suggested to be embedded in either Cb or Cr component not in Y component. In addition, it is embedded in the domain with lower standard deviation. That is, if the standard deviation of Cb component is smaller than that of Cr component, the watermark is embedded in Cb component; otherwise, it is embedded in Cr component.

Rule 2: To obtain a higher robustness, the watermark is suggested to be embedded into the component with a lower average value of the coefficients in HL4, HL3, LH4, and LH3 sub bands.

A. *Watermarking Embedding strategy*

Step 1: Apply 4-level DWT to host image and make tree structure is shown in Fig. 4.

Step 2: Calculate the global average significant difference (ε) for N-tree

$$\varepsilon = \left\lfloor \left(\frac{1}{N} \sum_{i=1}^{N} (Max_i - Sec_i) \right) \right\rfloor$$

Step 3: Calculate the significant difference Δ_i of N-tree, Where $\Delta_i = Max_i - Sec_i$.

Step 4: Modify the coefficient value of Max_i depending on watermark bit 1 or 0. If the watermark bit is 1,

$$Max_i^{new} = \begin{cases} Max_i + \beta & if(\Delta_i < Max(\in, T)) \text{ and } Max_i \text{ or } Sec_{i,} \text{ is in } LH4 \text{ or } HL4; \\ Max_i + \beta * \gamma & if(\Delta_i < Maxi(\in, T)) \text{ and both } Max_i \text{ or } Sec_i, \text{ is in } LH3 \text{ or } HL3; \end{cases}$$

If the watermark bit is 0,

$$Max_i^{new} = \begin{cases} Sec_i^{new} = 0, & if\ Max_i \geq 0 \text{ and } Sec_i < 0; \\ Sec_{i,} & otherwise \end{cases}$$

Step 5: Apply IDWT to modified coefficient get Watermarked Image.

B. *Watermarking Extracting strategy*

Step 1: Apply 4-level DWT to Watermarked image and make tree

Step 2: Calculate threshold y for tree, it is defined by,

$$y = \varphi_b$$
$$where, sort(\varphi_i = Max_i - Sec_i)$$

b is the number of watermark bit 0.

Step 3: Extract a watermark bit is given by.

$$Watermarkbit = \begin{cases} 1, & if(Max_i' - Sec_i') \geq y; \\ 0, & otherwises \end{cases}$$

Step 4: Get the watermarked logo.

V. EXPERIMENTAL RESULTS

To evaluate image quality, commonly used measures are Mean-Squared Error and Peak Signal-to-Noise Ratio which are shown below:

A. *Mean-Squared Error*

The mean-squared error (MSE) between two images I_1 (m, n) and I_2 (m, n) is:

$$MSE = \frac{\sum_{M,N}[I_1(m,n) - I_2(m,n)]^2}{M * N} \tag{10}$$

M and N are the number of rows and columns in the input images, respectively. Mean-squared error depends strongly on the image intensity scaling.

B. *Peak Signal-To-Noise Ratio*

Peak Signal-to-Noise Ratio (PSNR) avoids this problem by scaling the MSE according to the image range.

$$PSNR = 10log_{10}\left(\frac{R^2}{MSE}\right) \tag{11}$$

PSNR is measured in decibels (dB).where R is maximum pixel value in image.

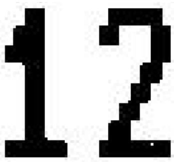
Fig. 5 Test images

The creation of watermark logo is complete defined by user using alphanumeric words which is converted into binary image. As show in Fig. 5 all test images are tested for all algorithms. Fig. 6 shows the original image and logo which is inserted into original image. The watermarked image and extracting logo is shown in Fig.7.

Fig. 6 (a) original image

(b) Inserted logo

Fig. 7 (a) watermarked image



(b) Extracted logo

The performance analysis results for test images are cited in Table I, Table II, and Table III. The DWT-DCT block size=8 method and DWT-DCT block size=4 is compared to the all other method have more PSNR value for no attack, so the visual qualities of the watermarked images are maintained. The watermark can be correctly extracted from the watermarked image under no attack with NC=1.0000 in DWT-DCT method for block sizes 4 and 8. Also Embedding and Extracting time in second are less for DWT-DCT block size=8 than other Algorithm are shown in Table IV and Table V.

Table I PSNR Value of Watermarked image

Test image	PSNR			
	DWT-DCT block size=4	*DWT-DCT block size=8*	*Wavelet tree structure*	*Adaptive color Image method*
Lena	56.9112	56.2681	47.7263	50.0376
Baboon	57.19	56.4743	45.1098	49.4992
Nature	57.3663	56.6398	46.2763	46.558
Plane	56.8467	56.2139	49.047	50.3844
House	56.8777	56.2492	41.0842	48.6638
Boat	55.8835	55.4167	41.848	48.3812
Barbara	55.6843	55.2537	47.1045	49.8729

Table II MSSIM value of Watermarked image

Test image	MSSIM			
	DWT-DCT block size=4	*DWT-DCT block size=8*	*Wavelet tree structure*	*Adaptive color Image method*
Lena	0.99972	0.99967	0.9997	0.99716
Baboon	0.99976	0.99972	0.9996	0.99786
Nature	0.99965	0.99959	0.9995	0.99686
Plane	0.99957	0.99951	0.9997	0.99677
House	0.99965	0.99959	0.99963	0.99734
Boat	0.99964	0.99959	0.99956	0.99743
Girl	0.99952	0.99946	0.99966	0.99676
Barbara	0.99963	0.99958	0.99966	0.99771

Table III NC value of Watermark logo after Extracting

Test image	Normalisaton correlation(NC) of Logo			
	DWT-DCT block size=4	*DWT-DCT block size=8*	*Wavelet tree structure*	*Adaptive color Image method*
Lena	0.93203	1	0.91834	0.85455
Baboon	0.95463	1	0.90736	0.83305
Nature	0.95823	1	0.90742	0.8672
Plane	0.93873	1	0.91766	0.85961
House	0.91737	0.99289	0.90087	0.88617
Boat	0.83724	0.97396	0.92456	0.91652
Girl	0.92566	0.99525	0.93523	0.74451
Barbara	0.89901	0.98579	0.92908	0.86973

Table IV Embedding time for Algorithem

Test image	**Embedding time in second**			
	DWT-DCT block size=4	*DWT-DCT block size=8*	*Wavelet tree structure*	*Adaptive color Image method*
Lena	1.1818	0.60865	0.94492	1.2153
Baboon	1.1973	0.63187	0.72863	0.76182
Nature	1.2132	0.59975	0.75605	0.75616
Plane	1.1966	0.60044	0.73722	0.73624
House	1.2176	0.62409	0.71983	0.77478
Boat	1.2008	0.59783	0.73988	0.73938
Girl	1.2014	0.61632	0.72146	0.75545
Barbara	1.2103	0.60766	0.74492	0.77619

Table V Embedding time for Algorithm

Test image	**Extracting time in seconds**			
	DWT-DCT block size=4	*DWT-DCT block size=8*	*Wavelet tree structure*	*Adaptive color Image method*
Lena	1.0067	0.38822	0.37796	0.40765
Baboon	0.9848	0.38981	0.37823	0.39491
Nature	0.98526	0.38248	0.37211	0.38863
Plane	1.0013	0.38961	0.36635	0.39108
House	1.001	0.39185	0.37018	0.40027
Boat	1.0063	0.40209	0.38377	0.39797
Girl	0.9831	0.39499	0.40137	0.40408
Barbara	0.99622	0.38539	0.40285	0.39966

In order to get the measure of the robustness of the algorithm, several image processing attacks are applied on the watermarked image (Lena as host image), including adding Gaussian noise, Salt and pepper noise, speckle noise, JPEG compression and cropping of the watermarked image. The results are shown in the Fig. 8 to Fig.12.

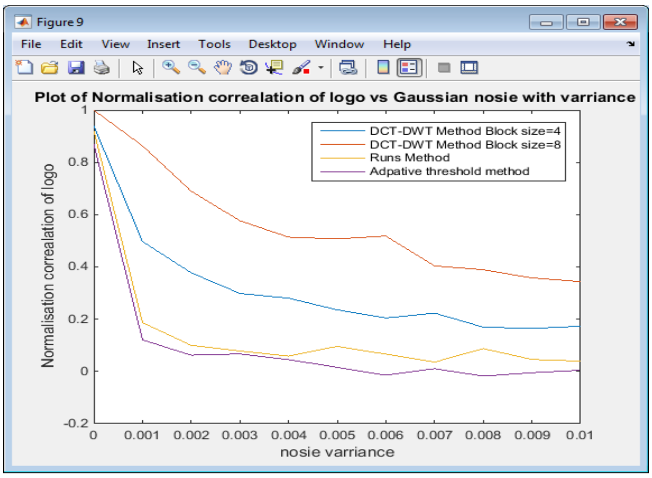


Fig. 8 Gaussian Noise Attack Analysis

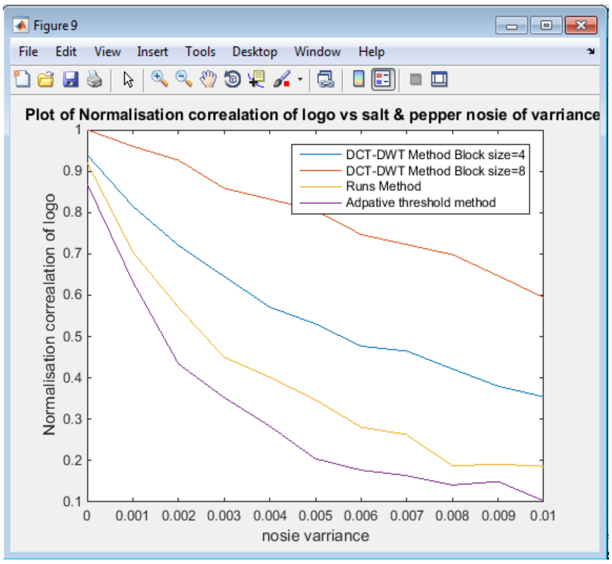


Fig. 9 Salt & Pepper Noise Attack Analysis

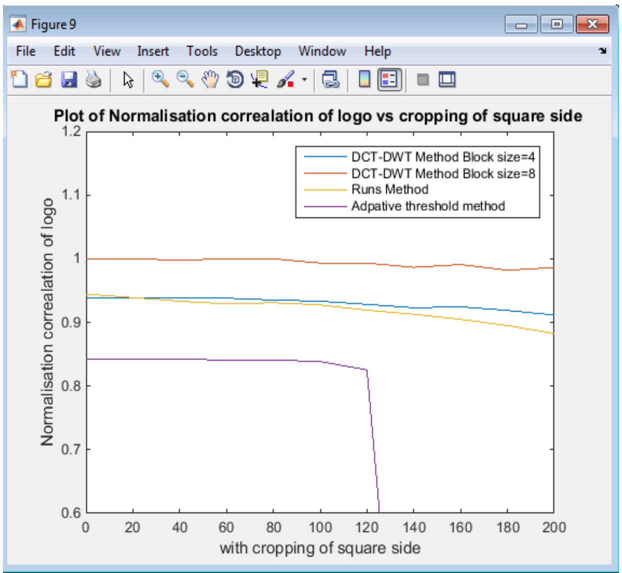


Fig. 10 Cropping Attack Analysis

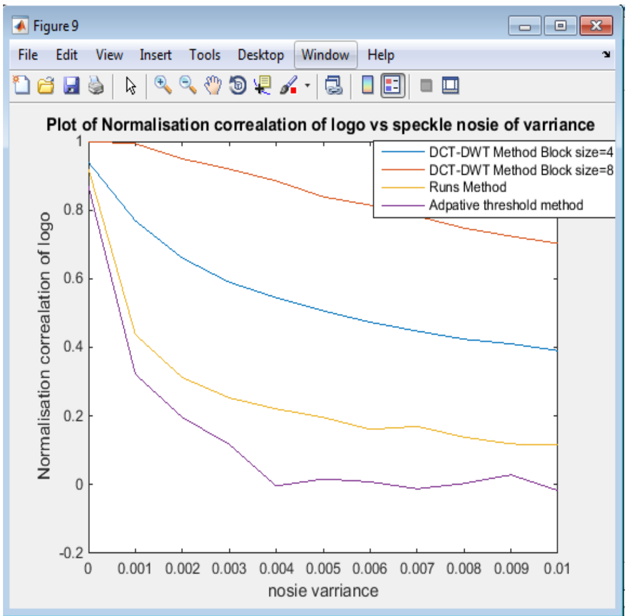


Fig. 11 Speckle Nosie Attack Analysis

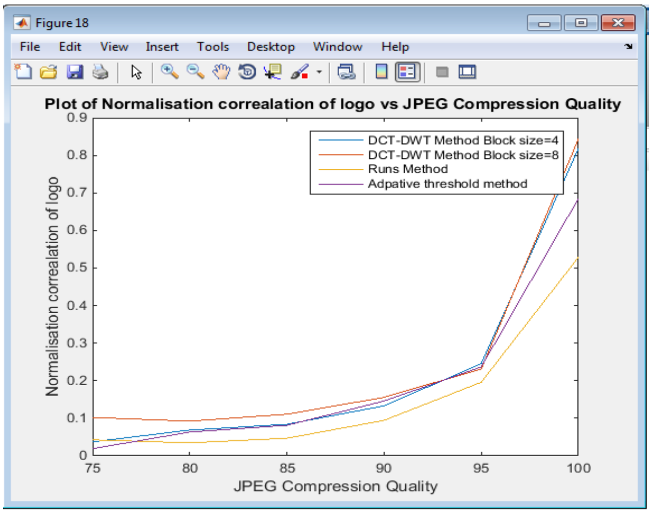


Fig. 12 JPEG Compression Quality Attack Analysis

As Experimental Result for Robustness Analysis shows that the DWT-DCT block size=8 method are more robust as compared to other methods.

VI. Conclusion

This paper presented various methods for evaluation of PSNR, MSSIM value and NC. The best results for these parameters are obtained using DWT-DCT method with Block size=8. This method requires less processing time for Embedding and Extracting the Logo from the watermarked images. This method is also imperceptible and robust, which makes it an effective watermarking scheme as compared to other methods.

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