A Three Level Discrete Wavelet Transform for Digital Image Watermarking

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Abstract: **In today's world of digitized documents, providing the security to the data is an important task. In the research field it gained a considerable interest towards providing the security and maintaining the ownership of the digital document. Digital watermarking has proven successfully in providing a security to copyright of digitized data. In this paper, proposed a digital watermarking using Discrete Wavelet Transformation (DWT) to embed the watermark image in the cover image. Transformation is applied on cover image; watermark image is inserted into selected coefficient blocks of the cover image. To check the visual quality of the watermarked image and also to evaluate the extracted watermark image, Inverse DWT (IDWT) is applied on host image to extract the watermark image. Parameters, Peak signal to Noise Ratio (PSNR) measured between host image and the watermarked image, Normalized Coefficient (NC) calculated between input watermark image and extracted watermark image. Watermarking process is performed using Matlab software to obtain the result PSNR=44.975 and NC= 0.9987.**

IndexTerms: **Inverse Discrete Wavelet Transformation, Imperceptibility, Gray Scale Image, Copyright, Authentication**

I. INTRODUCTION

Historically, everyone always hide their valuable things from the theft. The major perception is security. Proving a security to valuables plays a significant role in the age of information. A various technology or methods are developed to avoid the illegal copying or providing security [13]. The advance technology called digital watermarking. Digital watermarking is way to embed a message to a digital document to provide security and ownership protection [10]. Digital watermarking was introduced by Andrew Tirkel and Charles Osborne in 1992. Digital watermarking and steganography techniques are similar. In steganography embed the secret information into image and it cannot be identified.

Generally, watermarking is a practice of identifying image in the paper that embedded as different shades like lighting or darkening when viewed by transmitted light or viewed by reflection of dark light. In various domains watermark is used such as on postage stamps, currency, and number of government documents and frequently used in our daily documentation purpose in MS Word like text editors. Digital watermarking is an idea of embedding information into digitized documents. This helps in identifying the ownership of the digital information.

Digital watermarking can be used in various fields depending on the requirements, such as

- Source tracking
- Copyright protection
- Broadcast tracking, such as watermarked videos from global news organization

I.I Existing watermark image transformation domains

I.I.I Spatial domain techniques

In the spatial domain, the watermark image is inserted into host image directly altering the value of the pixel. The spatial domain techniques include Least Significant Bit (LSB) modification, patchwork, texture block coding, etc. The major drawback of spatial domain is robustness limitation. It is complex for spatial domain watermarks to survive when an attacks like lossy compression, low pass filtering etc, are done on watermarked image, the data to be inserted in spatial domain is limited. But it gives high channel capacity to embed the multiple watermarks in the cover image. LSB technique is one of the spatial domain technique introduce in watermarking. It is a straight forward method in spatial domain [12].

I.I.II Frequency domain techniques

Frequency domain technique watermarking is more robust and compatible with image compression when compare to spatial domain. Thus frequency domain got great attention. To insert a watermark image, transformation of frequency domain is applied to cover image. After applying transformations coefficients are modified. Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT) and Discrete Fourier Transform (DFT) are frequency domain techniques. In the frequency domain transformation, the given image is divided into square blocks of size 8x8 for computation. After dividing the image into blocks, certain blocks are selected. The frequency coefficients are then modified. To destroy the watermark, one has got to add noise with

sufficiently enormous amplitude, which can heavily degrade the scale of watermarked image and be considered as an unsuccessful attack. Now, Let us look into the most frequently used transformations DWT and DCT and then select DWT to experiment on selected images at level three from the image database[15]

A. DWT

DWT is one of the frequency domain transformation techniques. Difference between types of wavelet coefficients are depends on the way the watermark is weighted. The reason for this is to reduce the presence of visual artefacts. When the DWT is applied on cover image, it divides the image into a lower resolution approximation image of four sub bands of LL as well as horizontal HL, vertical LH and diagonal HH detail components. In other words an image of size NxN is divided into N/2 x N/2 of four sub bands. The process can then be repeated to compute multiple "scale" wavelet decomposition [11].

B. DCT

DCT is a general orthogonal make over for digital image processing and signal processing, with merits like, as high compression ratio, small bit error rate, good information integration ability and good synthetic effect of calculation complexity [12]. DCT is frequently used mechanism for image transformation and has been adopted by JPEG to compress images; DCT is one of the most common linear transformations in digital watermarking. The DCT_allows an image to be divided into different frequency bands, making it much easier to implant watermarking information into the middle frequency bands_of an image. The middle frequency bands are chosen such that a large amount of visual important parts of the image (low frequencies) is to be avoided without over-exposing it to removal through compression and noise attacks.

One major reason why frequency domain watermarking schemes ar engaging is their compatibility with existing compression standards, particularly, the JPEG commonplace. The compatibility ensures those schemes an honest performance once the watermarked image is subject to lossy compression that is one among the foremost common image process ways nowadays. In consequence, those schemes become significantly helpful in sensible applications on the web

A various technologies are developed to give protection from illegal copyright. There is one way encryption and another is watermarking. During sending information from one to another, however, after delivery and the message are decrypted, the information might available with a distorted image. Watermarking complements encryption by inserting information into host image. Thus, the watermarking always remains present in the information. Traditional watermarking system may be applied to visible media such as images or videos, whereas in digital watermarking, the signal may be audio, picture, video, text or 3D models.

In the proposed system the watermark image is inserted into cover image. Here frequency domain technique DWT is applied to cover image to embed the watermark image for ownership and protection of digital image. PSNR and NC are the parameters considered to calculate the better performance of the system ie with respect to imperceptibility and robustness. IDWT is used to extract the watermark image. There are number of research has been done on the digital watermarking; Here we are proposing a system to evaluate the performance and get the desired result as shown in abstract section, based on dataset [14][15]. Section II summarizes the referred articles, in Section III it describes the methodology for proposed system result is shown in Section IV, Conclusion in section V and Acknowledgement in Section VI.

II. LITERATURE SURVEY

Fre´de´ ric Lusson et al. [01] have presents A novel approach to digital watermarking, exploiting colour spaces. The aim of this presenting a novel hybrid digital watermarking scheme depends on the utilization of both the RGB and the YCbCr colour spaces, using spatial domain techniques. The result shows that hybrid technique can resists typical geometric attacks and processing attacks. The results are compared with the existing techniques, with respect to parameters of security and efficiency, steganography is an inspiration to digital watermarking.

Amit Kumar Singh et al. [02] present an advance strong hybrid multiple watermarking technique using fusion of discrete wavelet transformation (DWT), discrete cosine transformation (DCT) and singular value decomposition (SVD). All transformation is applied one by one in all the traditional methods, here the combination of the transformations are applied like DWT-SVD/DCT-SVD. For authenticating the digital information multiple watermarks are inserted to the single image / multimedia objects simultaneously, this can provide extra level of security with better performance with respect to robustness and imperceptibility. In the insertion of watermark process, initially the host image is decomposed into first level DWT where the lower sub-bands are applied with DCT and SVD. The watermark is also applied to transformation. The S component of the host image is selected for insertion. Watermarked image is reconstructed by inverse transformation. Extraction methods are applied to extract the watermark. The system is tested and analyzed against known attacks and is found to be giving superior performance for robustness and capacity.

Hung-Hsu Tsaia et al. [03] has proposed A zero-watermark techniques with geometrical invariants exploitation support vector machine (SVM) classifier. The geometrical attacks considered here is rotation, scale and translation (RST) operations on watermarked images. The SVM based Zero watermark (SZW) method maintain the quality of the host image after embedding the signature of the owner. In the transformation step, DFT integrates with log-polar mapping (LPM) for finding out RST invariants of image. The SZW technique creates the secrete key for a cover image via performing a logical operation. The proposed SZW method compared with other existing techniques with the attacks of RST. The performance is better than the exciting.

Nasrin M. Makbol et al. [04] has proposed a robust blind image watermarking theme supported Redundant Discrete Wavelet Transform and Singular Value Decomposition. The main task in watermarking is to avoid copyright and protect proof of ownership. The challenge to researcher is to develop an algorithm that withstand to all type of attacks, mainly geometric attacks. In the digital watermarking some parameters are important such as robustness, high imperceptibility, security and capacity. Redundant DWT (RDWT) and SVD are presented in this system. In the host image, unusual values of the RDWT sub-bands value, the grey scale

watermark reflection is inserted. The system achieves smart capacity as a result of redundancy within the RDWT domain and at the same time sealed high imperceptibility because of SVD properties. In the host image coefficients, the pixels values of watermark image are inserted without any changes to provide more security. The performance of the system shows the improved robustness against the image processing and geometrical attacks.

Liujuan Cao et al. [05] has presented a unique lossless watermarking scheme for two dimension vector maps supported a novel recursive embedding algorithm. In the proposed algorithm, the feature points are ground into united, the points which are highly correlated are chosen as a cover data for further recursive modification of its indicated highest point coordinates. This system provides lossless compression with good payload capacity. The system results shows effectiveness, efficiency on numerous two Dimensional real-world vector map.

Charu Agarwal et al. [06] have proposed an optimized watermarking scheme based on DWT and SVD. The binary image of watermark image is inserted into the singular value of LL3 sub-bands coefficients of the cover image with the help of multiple scaling factors (MSRs). The firefly optimization technique is used to MSFs to optimize. The performance parameter PSNR is considered for visual quality of the signed and attacked images is good. The system shows the improved performance over similar methods with well optimized and robust.

Mashruha Raquib Mitashe et al. [07] has presented a novel adaptive digital image watermarking model based on modified Fuzzy C-means Clustering (FCM). To embed the watermark image, transformation o f the host image is required. A segmentation technique XieBeni integrated FCM (XFCM) is used to segment the host image to choose the proper place to embedding. The cover image is pre-processed using PSO to lend a hand to the clustering. The main aim of the segmentation is to choose a suitable location to embed watermark, watermarked image can withstand against general image processing attacks. PSNR, MSE, CC are the performance parameters considered to measure. The performance is calculated with and without attacks. Impartibility and robustness is improved when compared with exciting systems.

Luis Rosales-Roldan et al. [08] has projected a two watermarking methods for image data authentication with localization and recovery capability of the attacked regions. The halftone version of the original grey scale image is used as an approximated version of cover image which is then embedded as a watermark sequence into given transformation domains of the cover image. Integer Wavelet Transformation (IWT) is used for watermark embedding which is denominated WIA-IWT (Watermark based Image Authentication using IWT), in the 2nd method, DCT based. WIA-DCT. Structural Similarity Index is used to find tampered region during authentication stage. A Multilayer Perception (MLP) neural network is used to inverse half toning to get better recovered image quality. Both methods show the improved robustness, effective authentication and recovery capability.

Anshul Kanchan Khanna et al. [09] has presented optimal image watermarking method to avoid copyright and also to withstand to general attacks on watermarked image. Genetic algorithm has been used in this system. The main aim of the system is to reduce copyright, ownership verification. The main needs for watermarking are invisibility; less computations and resistance to any attacks have to be dealt with robust method for having successful watermarking. The results show improved PSNR and NC even after applying attacks such as resizing, average filtering and Gaussian noise. Genetic algorithm has proved that it is a strong tool to choose an optimal values of embedding strength of watermarking such that a balance is maintained between PSNR and NC values.

III. METHODOLOGY

Figure 1 shows the Block diagram of proposed system architecture. The information in the digital form can be copied, attacked or it can modify during transmission, hence it is mandatory to provide a security to the digital documents. In the proposed system effective digital watermarking is used to protection to digital data, and also to reduce copyright and to provide ownership benefits. The standard images are considered as a cover image and binary images are considered as a watermark image. DWT is used to embed the watermark image to cover image.

In watermarking maintaining the quality of the image is difficult. The main task in watermarking is maintaining a quality of the image after watermark image is inserted. PSNR (Peak Signal Noise Ratio) is calculated to measure the image quality after watermark image is inserted. IDWT is used at extraction procedure. NC (Normalized Coefficients) is measured between input watermark image and the extracted watermark image.

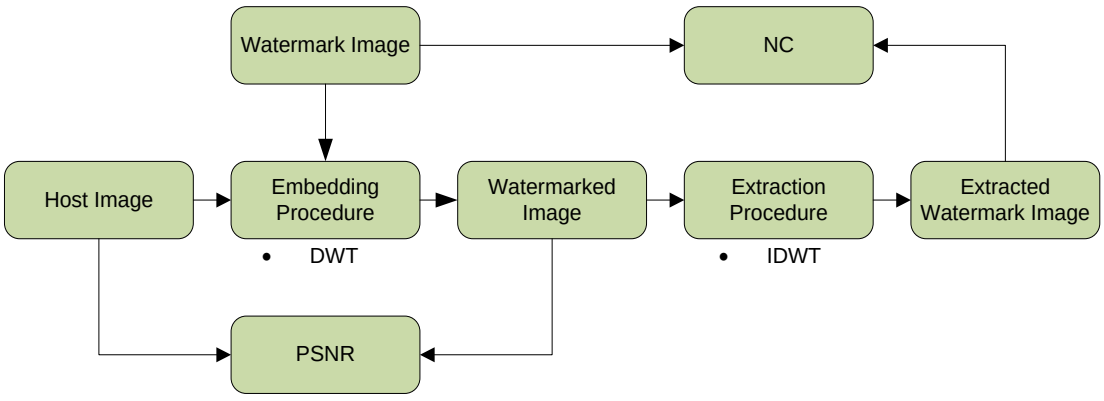


Figure 1: Block diagram of proposed system architecture

III.I Host Image

Every the image has its own gray data and texture features, and also contains complex and smooth regions most of the cover images (Host images) are considering in the watermarking method. Every block has chances to join the embedding technique. Depends on the human visual system's characteristics, the human eyes have various sensitivity to noise in areas with different luminance and texture. High luminance and complex texture areas of image have good visual mask effect. If the secret data is embedded into these areas, it means more imperceptibility. It is necessary to analyze the host image before embedding the watermark image.

III.II Embedding procedure

III.II.I DWT

Frequency domain watermarking techniques gives greater effective with respect to achieving the imperceptibility and robustness parameters of digital watermarking when compared with spatial domain. Generally DCT, DWT and DFT are the regularly used transformation techniques in frequency domain. However, DWT provides outstanding localization and multi-resolution characteristics hence in frequency domain transformation it is used more frequently. The performance improvement of DWT in digital watermarking could be obtained by increasing the level of DWT.

In DWT the wavelets are sampled discreetly. It is useful for pre-processing of non-stationary signals. Generally in wavelet transformation two types of wavelets are seen, small waves and limited duration waves. Small waves are called wavelets of varying frequency and limited duration is used as mother wavelets. Mother wavelets are created by translation and spatial description of an image. Frequency and spatial description of an image is provided by wavelet transform. DWT is the multi resolution description of an image the decoding can be processed sequentially from a low resolution to the higher resolution. The edge information of an image consists in the high frequency of the transformation coefficient, the low frequency of the image is divided again into high and low frequency. The human high is less sensitive to the edge coefficients of an image.

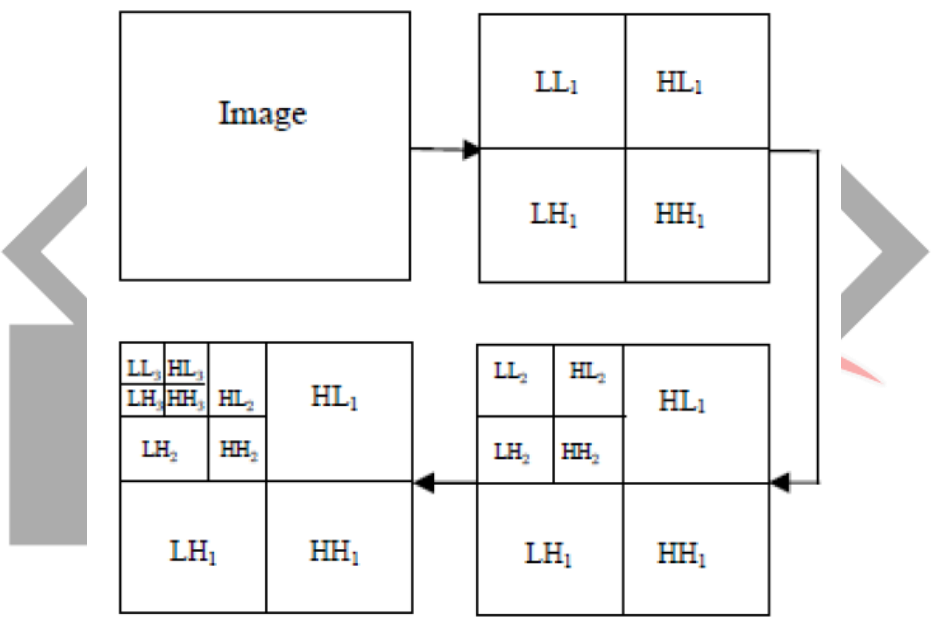


Figure 2: Model of DWT decomposition.

Algorithm 1: DWT

Input: *Cover Image and Watermark Image*
Output: *Watermarked Image.*
Step1. Covert the RGB cover image to grey scale image
Step2. Apply 1-level DWT to grey scale cover image and watermark image
Step3. Select low frequency (LL1) sub-band
Step4. Apply 2-level DWT to LL1 sub-band of watermark image and cover image
Step5. Select LL2 sub-band of cover image and watermark image from 2-level DWT
Step6. Apply 3-level DWT to LL2 sub-band
Step7. Select LL3 sub-band from 3-level DWT
Step8. Embed the watermark image into cover image low frequency components
Step9. Reconstruct the cover image with all the sub-bands (Watermarked image)
End algorithm.

$$WMI = K * (LL2) + q * (WM2) \quad (1)$$

Typically in two levels DWT, for every level of decomposition, we apply DWT in the vertical direction, after DWT for horizontal direction of an image. Once first level decomposition is completed, there are sub-bands remains LL1, LH1, HL1 and HH1. For the next level of decomposition LL1 sub-band is used as an input. DWT is applied on LL1 sub-band of first level decomposition. Once the second level decomposition is completed, for third level of decomposition LL2 is used as input. LL2, LH2, HL2 and HH2 are the sub-bands of second level of decomposition. To reach the third level of decomposition LL2 is used as an input, and the result is LL3, LH3, HL2 and HH3 are sub-bands. This shows the 10 sub-bands per components. The LH1, HL1 and HH1 include the higher frequency bands presents in the image tile. While LL3 contains the lowest frequency bands and approximately image as shown in the Figure 2: and Figure 3: shows the flow chart of embedding procedure

Where in Eq. (1) WMI denotes the low frequency component of watermarked image, $LL3$ refers to the low frequency component of the original image by 3-level DWT, $WM3$ refers to the low frequency components of watermark image, K denotes scaling factor of original image and q scaling factor of watermark image. Once embedding the watermark image is completed, 3-level inverse wavelet transformation is applied to the watermarked image coefficient to generate the protected watermarked image.

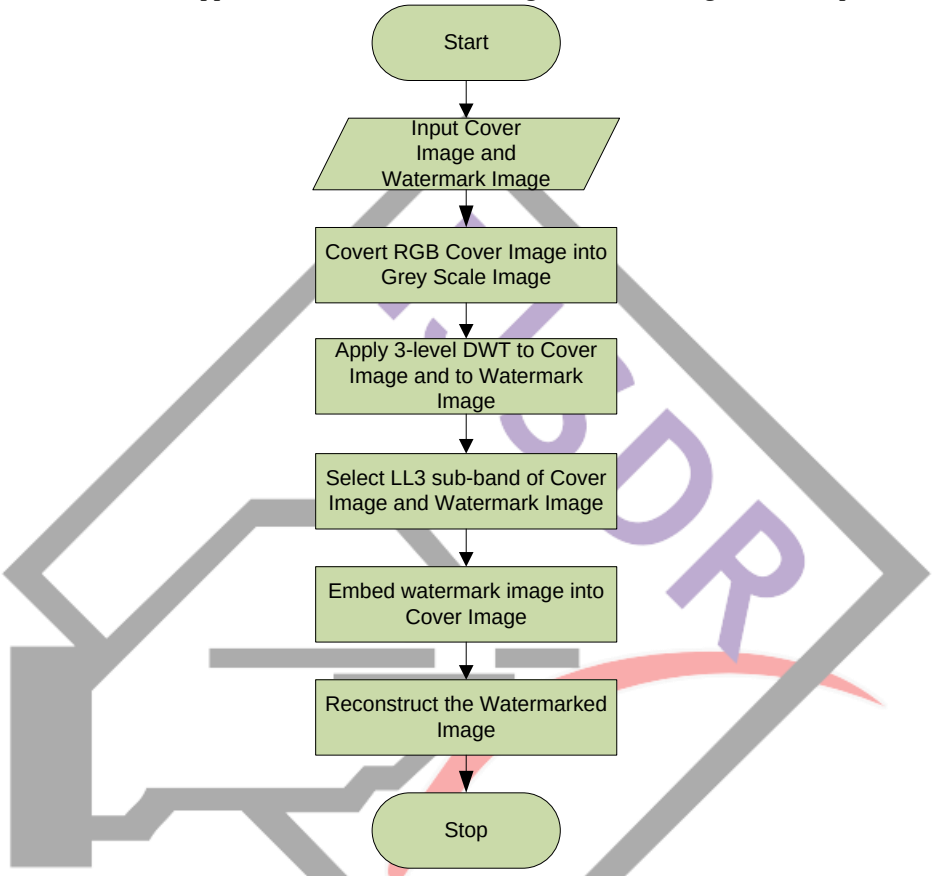


Figure 3: Flow Chart of Embedding Procedure

III.II.II Extraction procedure

Watermark extraction: In the extraction of the watermark image, first 3-level IDWT (Inverse Discrete Wavelet Transform) is applied to watermarked image, which decompose the image into sub-bands. Watermark image is recovered from the inverse DWT.

$$RW = (WMI - K * LL3) \quad (2)$$

Where in Eq. (2) RW represents the low frequency approximation of extracted watermark, $LL3$ denotes low frequency approximation of the original image, and WMI low frequency approximation of watermarked image.

IV. EXPERIMENTAL RESULTS

The implemented of proposed system is based on the DWT. The performance of the system is calculated using the parameter PSNR and NC to check the robustness and imperceptibility of the system. The University of Oulu's Media Team dataset are considered as a standard dataset for cover image [14] and watermark images are considered from dataset [15]. The term imperceptibility define the visual quality the image, host image visual quality should be maintained after the watermark image has been embedded. The imperceptibility of the system is calculated between cover and watermarked image, the cover image must be almost similar after watermarked.

Figure 4: shows the result of proposed system. The grey scale image is considered as a cover image and it is as shown in the figure 4 (a), (b) shows the host image, binary image is considered as a watermark image. 3-level DWT is applied to cover image and the watermark image is as shown in the (c) and (d).

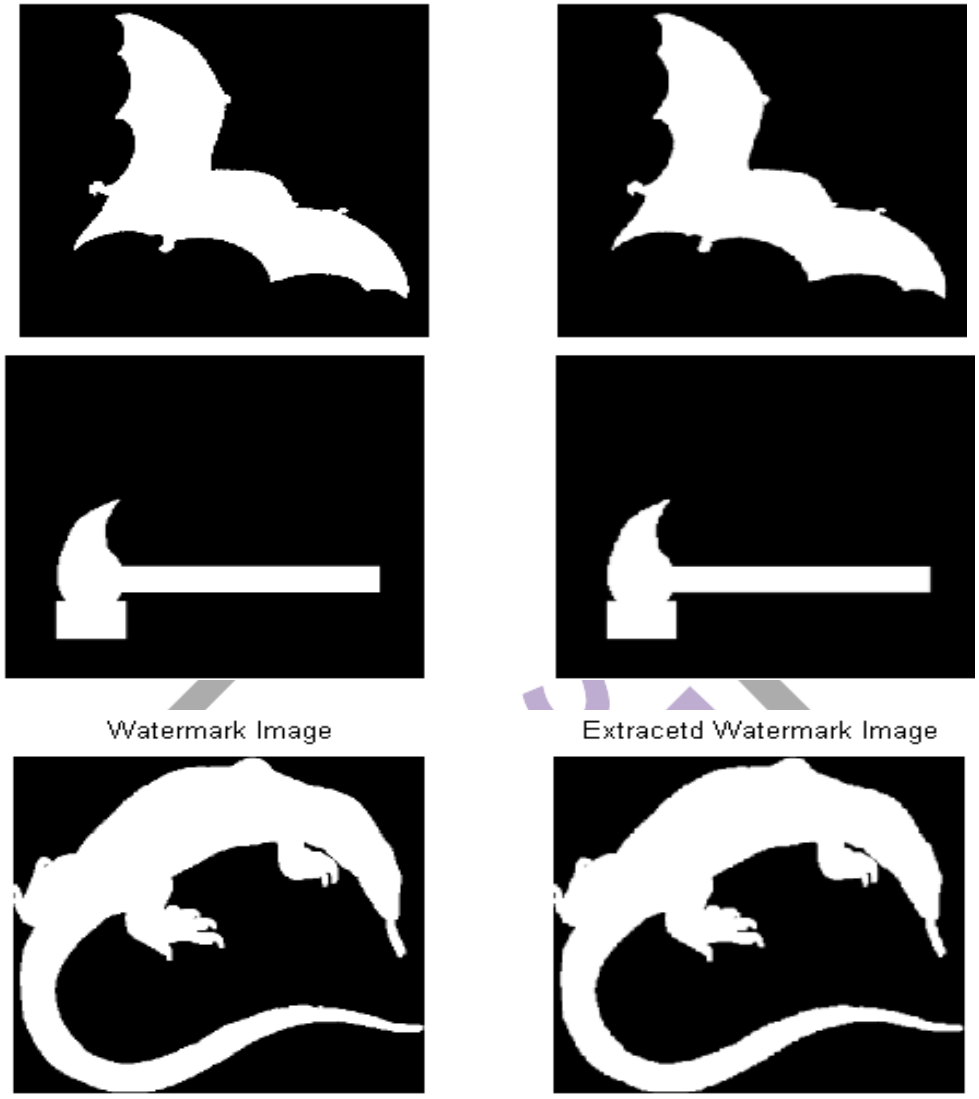
(a) (b) (c) (d)

Figure 4: (a) Host Image, (b) Watermark Image, (c) DWT of Host Image and (d) DWT of Watermark Image

(e) (f) (g)

Figure 5: (e) LL2 of Host Image, (f) LL2 of Watermark Image and (g) Watermarked Image

Figure 5: shows the low frequency components of the cover and watermark image. (e) and (f) shows the LL2 band components after applying the DWT to cover and watermark image, after applying the DWT, the watermark image is inserted block wise into the cover image. Once the embedding is completed IDWT is applied to recover all the sub-band, (g) shows the watermarked image. PSNR is calculated between cover and watermarked image.



(h) (i)

Figure 6: (h) Input Watermark Image and (i) Extracted Watermark Image

Figure 6: (h) and (i) shows the input watermark image and extracted watermark image. After extracting the watermark image, NC (Normalized Coefficients) is calculated between input watermark and extracted watermark image.

There are objective and subjective criteria to measure the quality of the watermarked image, and both should be good. PSNR (Peak Signal Noise Ratio) is one of the objective criteria, to show the imperceptibility degree.

The PSNR can be calculated as follows in Eq. (3) and Eq. (4)

$$PSNR = 10log_{10}\left[\frac{\max(x(i,j))^2}{MSE}\right] \quad (3)$$

Where the Mean Square Error (MSE) between the host image X and the watermarked image Y is defined as

$$MSE = \frac{1}{m+n}\sum_{i=1}^{m}\sum_{j=1}^{n}[x(i,j) - y(i,j)]^2 \quad (4)$$

Robustness is one of the important requirements considered in watermarking. The robustness is calculated using parameter NC; it is calculated between input watermark image and extracted watermark image. It is the comparison between input watermark image and the extricated watermark image.

$$NC_{(w,W)} = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}[w(i,j) - \mu_w][\overline{w}(i,j) - \mu_{\overline{w}}]}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}[w(i,j) - \pi_w]^2}\ \sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}[\overline{w}(i,j) - \pi_{\overline{w}}]^2}} \quad (5)$$

In Eq. (5) where N and M stands for the quantity of pixels in the watermark, $w, \overline{w}$ is the specification to the input watermark and the extracted watermark. μ_w and $\pi_{\overline{w}}$ is specification to the mean of the input watermark and the mean of the extracted watermark respectively. The relationship coefficients between w and $\overline{w}$ can be between −1 and 1. If the NC value is near +1, then the extracted watermark is strongly correlated. If it is near −1, the extracted watermark is also strongly correlated. But, if it is near 0, the extracted watermark is totally uncorrelated. Normally, the NC is considered acceptable if it is 0.75 or above. Table 1: Performance analysis show the PSNR and NC values.

Table 1: Performance analysis

Performance / Images	PSNR	NC
Image 1	44.975	0.9987
Image 2	49.266	0.99648
Image 3	48.9942	0.99674

V. CONCLUSION

Recently advance in information technology is digitization. This is occurring worldwide, digital information can be easily copied, attacked or modified during sending. Thus, efficient digital watermarking methods that secure digital information need to be developed. Here we proposed a system to provide more secure digital data by providing watermark to digital information. The watermark image is embedded to host image using the embedding technique DWT, 3-level DWT is applied to watermark and cover image, LL2 sub-bands (low frequency component) of cover and watermark image selected to embed the watermark image. After embedding the watermark image IDWT is applied to cover and watermark image to reconstruct the watermarked image. PSNR and NC parameters are calculated to check the performance of the proposed system and it shows the imperceptibility and robustness.

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Although any errors are our own and should not tarnish the reputations of these esteemed persons.

REFERENCES

[1] Lusson F, Bailey K, Leeney M. and Curran K, **(2013)** "A Novel Approach to Digital Watermarking, Exploiting Colour Spaces", Signal Processing, Elsevier, Vol. 93, Issues 5, pp.1268-1294.

[2] Singh A.K., **(2017)** "Improved Hybrid Algorithm for Robust and Imperceptible Multiple Watermarking using Digital Images", Multimedia Tools and Applications, Springer, Vol. 76, Issues 6, pp.8881-8900.

[3] Tsai H.H, Lai Y.S and Lo S.C, **(2013)** "A Zero-Watermark Scheme with Geometrical Invariants using SVM and PSO against Geometrical Attacks for Image Protection", Journal of Systems and Software, Elsevier, Vol. 86, Issues 2, pp.335-348.

[4] Makbol N.M and Khoo B.E. **(2013)** "Robust Blind Image Watermarking Scheme based on Redundant Discrete Wavelet Transform and Singular Value Decomposition", AEU-International Journal of Electronics and Communications, Elsevier, Vol. 67, Issues 2, pp.102-112.

[5] Cao L., Men C. and Gao Y., **(2013)** "A Recursive Embedding Algorithm Towards Lossless 2D Vector Map Watermarking", Digital Signal Processing, Elsevier, Vol. 23, Issues 3, pp.912-918.

[6] Mishra A., Agarwal C., Sharma A. and Bedi P., **(2014)** "Optimized Gray-Scale Image Watermarking using DWT–SVD and Firefly Algorithm", Expert Systems with Applications, Elsevier, Vol. 41, Issues 17, pp.7858-7867.

[7] Mitashe M.R, Habib A.R.B, Razzaque A, Tanima I.A and Uddin J, **(2017)** "An Adaptive Digital Image Watermarking Scheme with PSO, DWT and XFCM", In Imaging, Vision & Pattern Recognition (icIVPR), 2017 IEEE International Conference, IEEE, pp. 1-5.

[8] Vellasques E., Sabourin R. and Granger E., **(2012)** "DS-DPSO: A Dual Surrogate Approach for Intelligent Watermarking of Bi-tonal Document Image Streams", Expert Systems with Applications, Elsevier, Vol. 40, Issues 13, pp.5240-5259.

[9] Ramanjaneyulu, K. and Rajarajeswari, K., **(2012)** "Wavelet-based Oblivious Image Watermarking Scheme using Genetic Algorithm", IET image processing, IET, Vol. 6, Issues 4, pp.364-373.
[10] Agarwal C., Mishra A and Sharma A., **(2013)** "Gray-scale Image Watermarking using GA-BPN Hybrid Network", Journal of Visual Communication and Image Representation, Elsevier, Vol. 24, Issues 7, pp.1135-1146.
[11] Khalili M. and Asatryan D., **(2013)** "Colour Spaces Effects on Improved Discrete Wavelet Transform-based Digital Image Watermarking using Arnold Transform Map", IET Signal Processing, IET, Vol. 7, Issues 3, pp.177-187..
[12] Lusson F., Bailey K., Leeney M. and Curran K., **(2013)** "A Novel Approach to Digital Watermarking, Exploiting Colour Spaces", Signal Processing, Elsevier, Vol. 93, Issues 5, pp.1268-1294.
[13] Yahya A.N., Jalab H.A., Wahid A. and Noor R.M., **(2015)** "Robust Watermarking Algorithm for Digital Images using Discrete Wavelet and Probabilistic Neural Network", Journal of King Saud University-Computer and Information Sciences, Elsevier, Vol. 27, Issues 4, pp.393-401.
[14] http://www.mediateam.oulu.fi/downloads/MTDB/download2.html
[15] http://www.imageprocessingplace.com/root_files_V3/image_databases.htm