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Certain Investigations on Reversible Image Watermarking

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Key words: Reversible watermarking, importance measure model, prediction error, OPSO bi-orthogonal DWT, entropy, PSNR, NC, correlation coefficient

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Abstract: The main objective of image watermarking is to protect secret information in a digital medium without compromising robustness. There are many approaches introduced regarding the importance of utilizing medical, military and natural images for image watermarking procedure. Reversible watermarking is appreciated that the original media can be recovered without any loss of information after extracting stego-data. With an aim to provide higher security and robustness, certain investigations have been done on reversible image watermarking. The scheme proposed in this research not only outperforms other methods with respect to a variety of attacks but still maintains a satisfactory image quality. This research mainly addresses on privacy, reversibility, payload and robustness related goals. Considering these challenges, three parts of image watermarking techniques, namely proposed Bi-orthogonal Wavelet Transform and Importance Measure Model (BWT and IMM), proposed Dynamic Prediction Error Integrated Reversible Image Watermarking (DPEIRIW) and proposed Multi Wavelet Transform and Oppositional Particle Swarm Optimization (MWT-OPSO) are proposed to improve the data hiding performance.

INTRODUCTION

The entrenchment of digital media in whole aspects of everyday life is one of the biggest technological events of the last two decades. Digital data can be stored efficiently with a very high quality and it can be manipulated very easily and effectively using computers. Furthermore, with high quality digital data can be transmitted in a fast and inexpensive way through data communication networks. Digital media hit several distinct advantages over analog media[1-3]. Editing is simple because various locations can be accessed hat need to be changed. Copying is also easy with no loss of integrity and is exact to the original. With digital multimedia distribution over world wide web, authentications are more threatened than ever due to the possibility of unlimited copying. High risk for information creators is established due to the simple way to transmission and manipulation of digital data constitutes. So, the copyright owners want to be compensated every time their research is used. Additionally, they want to ensure that their research is not modified without their permission. For digital data, copyright constraints and content authentication are very tough tasks[4].

One solution is using some encryption techniques to avoid the unauthorized access. However, encryption does not provide overall security. Once, the decryption is done for the encrypted data, they can be freely accessed or modified. The above problem can be solved by hiding some ownership data into the multimedia data which can be extracted later to prove the ownership. Digital watermarking technique has been indicated, so, far as a possible elucidation when in a specific application circumstance (authentication, copyright protection, fingerprinting, etc.), there is the need to embed an enlightening message in a digital document in an imperceptible way[5-7]. Usually, when dealing with sensitive images such as deep space exploration, military research and medical diagnosis, the end-user cannot put up with risk to get distorted information. One example above all: a radiologist who is checking a radiographic illustration to establish if a certain pathology is present or not. It cannot be customary that his diagnosis is wrong both, firstly, to care for the patient's health and secondly to protect the work of the radiologist himself. In such a case, irreversible watermarking algorithms appear not to be viable. Due to this strict prerequisite, another category of watermarking technique has been introduced which is catalogued as reversible where with this term, it is to be anticipated that the original content, other than the watermark signal is got back from the watermarked file such that any assessment can be performed on the original data. Thus, doing the process is zero-impact but allows conveying an enlightening message. The reversible watermarking technique is also named as invertible or lossless and was born to be applied mainly in scenarios where the genuineness of a digital image has to be approved and the original content is peremptorily needed at the decoding side[8-10].

Transferring secure information was a challenging task before the invention of steganography and cryptography. Hackers tend to change the original application either by modifying it or by using the same application to make profits without giving credit to the owner. Thus, privacy techniques need to be well efficient, robust and unique to restrict malicious users. Hence, a very significant watermarking technology emerged.

Digital watermarking is a relatively new field of the last two decades. Digital information can be embedded in data and extracted later. The watermarking information can be texts, logos, handwritten signatures or numbers and have many applications. It is noted that one of the basic requirements for digital watermarking is to maintain the quality of the original data not being distorted when a watermark is embedded into it. Besides, there are other requirements that are necessary for specific applications.

One basic requirement of digital watermarking is the necessity to maintain the original quality of distorted data. Perceptual transparency, robustness[5], capacity to recover data without original, bit rate of data embedding algorithms, secured watermarking, proof of ownership are a few requirements tend to vary with respect to watermarking applications.

One of the watermark challenges is to maintaining excellent invisibility qualities. Another fundamental requirement is robustness, the watermark must be resistant to unauthorized detection and decoding. In addition, the watermark must be tolerant to image processing techniques such as compression (lossless and lossy) as well as to intentional attempts to destroy or remove the watermark. Another challenge of watermark algorithm is imperceptibility. An efficient watermark scheme is the one that can balance security and robustness. Another watermark challenge is to implement a watermark system that can handle high data capacity while retaining the quality of the watermarked image. Watermarked images may be subject to a number of common attacks.

In order to meet the above said challenges, it is required to develop and propose novel watermarking algorithms for embedding the images and suitable recovery. Thus, this study focused on developing watermarking algorithms to meet the required challenges.

The objective of this research is to improve current digital watermarking technique and design it for specific applications. It is impossible to design a watermarking system that works in all situations and can resist all attacks. Here, it is aimed to design effective and cost efficient digital watermarking systems for different applications and different requirements.

Recently, various governments have been promoting e-Health programs which collect and store personal health information in an electronic form. These records contain sensitive personal information and should be protected. For medical images, personal information is usually stored in a separate file which can be accessed at the same time with the images. However, this information is usually not protected and can be accessed by intruders.

A recent incident involving accessing patient information for job screening in the University of Health Network in Toronto, raised the alarm on the issue of privacy protection and access control[11]. Digital watermarking can be used to embed sensitive information into the cover files. The advantage of watermarking is that

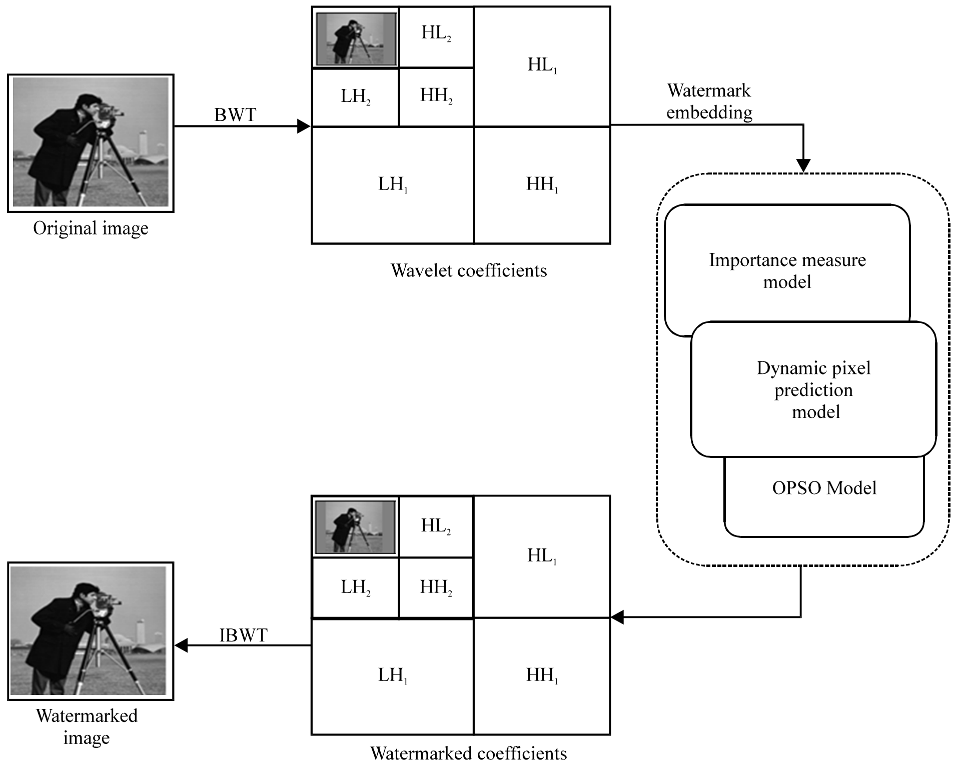

Fig. 1: Block diagram of the proposed scheme with Bi-orthogonal discrete wavelet transform technique

the information stays with the original file which reduces the chance of it being deleted or changed accidentally. Moreover, since, watermarking introduces only small distortions, it will not cause difficulties for physicians who do not have the authority to access the personal file. One disadvantage of digital watermarking is that the original file is changed after the watermark is embedded. For medical images, this change might not be desirable no matter how unnoticeable it is.

The main goal of this research is to propose lossless watermarking or reversible watermarking scheme to address these problems. A reversible watermarking is a method in which both the original copy and the watermark can be recovered without any losses. Bi-orthogonal discrete wavelet transform based techniques are used in the proposed schemes due to its superior performance over other transforms and the block diagram is shown in Fig. 1.

Literature review: In the area of digital watermarking, image watermarking predominantly has engrossed a lot of interest in the research community. The majority of the research is devoted to image watermarking as compared to audio and video. Some of the reasons are described below:

- The test images are readily available
- Images carry sufficient redundant information, so that, watermarks can be embedded easily
- It may be assumed that any successful image watermarking algorithm may be upgraded for the video also

Images are represented in spatial domain as well as in frequency domain. The image in the transform domain is represented in terms of its frequency coefficients and in spatial domain, it is represented by pixels. Simply, transform domain means the image in the form of multiple frequency bands. To represent an image in the transform domain, reversible transforms like Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT) or Discrete Fourier Transform (DFT) can be used. Each of these transforms has its own features and represents the image in its own ways. Watermarks can be imposed within images by changing the transform domain frequency coefficients. In case of the spatial domain, simple watermarks could be imposed in the images by modifying the pixel values or the Least Significant Bit (LSB) values. However, more robust watermarks could be imposed in the transform domain of images by changing frequency coefficients. Cox and Miller[12], proposed a study titled “secure spread spectrum watermarking for multimedia" and after that most of the research is carried out based on this research. Even though, the spatial domain based approaches cannot sustain most of the common attacks like compression, high pass or low pass filtering, etc., many spatial domain based schemes have been presented. After that, transform domain watermarking schemes has emerged and now, it is reversible watermarking.

A review of literature suggests that the challenge remains in the field of digital watermarking in designing schemes suitable for both grey scale and color images that are more robust against a broad range of attacks and maintain reasonable image quality, especially in medical and military data. Most of the schemes underperform especially when image distortion or compression ratio is high. Since, in the multimedia digital communication, tamper detection has more serious commercial implications than the copyright control, it has been decided to go with robust watermarking. Out of all the multimedia contents such as image, audio and video, any image watermarking algorithm which is lucrative can be extended as video watermarking, hence, image watermarking is intended. With future augmentation in mind, the cover medium chosen is an image.

In the first part of this investigation, a reversible image watermarking algorithm by applying bi-orthogonal discrete wavelet transform is proposed. Initially, the image is resized and disintegrated into frequency sub bands. The best band and ideal locations in the best band those are suitable for embedding is found with the help of entropy measure. Subsequently, the proposed watermark embedding procedure is carried out to embed a watermark in the cover image.

In the succeeding parts of this investigation, a reversible image watermarking scheme based on dynamic prediction error and oppositional particle swarm optimization is proposed. Wherein watermark embedding is carried out by the calculation of prediction error and fitness value. In addition, multi wavelet transform is developed for the selection of optimal location for embedding. The performance efficiency of proposed image watermarking schemes is examined in terms of peak signal to noise ratio and normalized correlation values. From the experimental results, it is clearly inferred that this proposed scheme has obtained better results when compared to other approaches available in the literatures.

BWT and IMM: In this proposed research, a reversible image watermarking algorithm using bi-orthogonal wavelet transform and importance measure model is proposed. The two major steps include in the watermarking algorithm is watermark embedding and watermark extraction. In the embedding process, initially bi-orthogonal discrete wavelet transform is employed to decompose the original input image into different bands and the best band is elected based on the entropy. Subsequently, the selection of proper location is carried out using importance measure model. After finding, the best band and the location for embedding, the proposed embedding process is carried out where binary image is used as a watermark.

Selection of band: The procedure for selecting the band is explained below. Initially, the original image is resized to pre-defined standard size. Let the original image after resizing is represented by G of size m×n. After resizing, 2D DWT using bi-orthogonal transform is carried out to have a Coefficient Approximate (CA) and detailed coefficient bands (Coefficient Horizontal-CH, Coefficient Vertical-CV, Coefficient Detail-CD). Here, CA band coefficients are getting neglected as these cannot be taken for the watermark embedding process. From the detailed band, subsequently, the ideal band is selected using the entropy value. The entropy values are found out for the CH, CV and CD bands and are represented by E_{ch}, E_{cv} and E_{cd}, respectively. Based on the entropy, the best band (x) is selected for further processing.

That is, the band having the maximum entropy value is taken as the best band and is selected for further processing and represented as in Eq .1:

$$E_x = \text{Maximum}\,(E_{ch}, E_{cv}, E_{cd}) \quad (1)$$

Here, E_x is the entropy of the selected band x. After the input image is resized to a standard size, then bi-orthogonal DWT is applied and found out the best band for embedding with the aid of entropy measure.

Selection of location: Once the best band is selected, the next task is to find the optimal location where the embedding can take place. For this, the importance measure model[13, 14] is used. The model takes into consideration five parameters of intensity, contrast, location, edginess and texture. For each parameter, respective importance measures are calculated and finally squared sum is taken to have the overall importance measure.

The image is initially split into blocks and the importance measure is calculated for each of the blocks. And those blocks having a good overall importance measure are chosen as the location for embedding. Let, image input for finding the location is represented as H of dimension m×n. Let the number of blocks be y and each block (B_i; $0<i<y$) is with dimension p×q. That is m×n = y×p×q. Subsequently, the importance measure (D; $0<i<y$) corresponding to each block is computed. The individual importance measure of parameters is computed based on the level of interest that a human eye could have to that region.

In the extraction process, initially inverse discrete wavelet transform is applied and then the proposed extraction procedure is done in the location chosen. While investigating the performance of BWT and IMM, this proposed technique obtained good results having an average PSNR value of 39.8606 and maximum NC value of The robust feature of the proposed watermarking scheme is evaluated with the aid of a variety of filtering techniques and good results were achieved in all cases. The processing time elapsed for the run of the proposed algorithm with respect to the considered image datasets is 84 sec.

MATERIALS AND METHODS

DPEIRIW Model: In this proposed research, Dynamic Prediction Error Integrated Reversible Image Watermarking (DPEIRIW) is developed and implemented for the considered image samples from the database. The proposed approach consists of four calibres, namely pre-processing module, pixel prediction module, embedding module and extraction module. The block diagram of the modelled approach is as given in Fig. 2.

Pixel prediction module: In this module, the pixel values are predicted based on the position and making use of mathematical operations. The prediction is carried out based on the neighbouring pixel values and the median is found out. The process of prediction depends on the position of the pixel and is classified accordingly. The classes include four kinds of pixels based on the position termed as initial set, first derived set, second derived set and third derived set. Based on the prediction fault, embedding and extraction can be carried out.

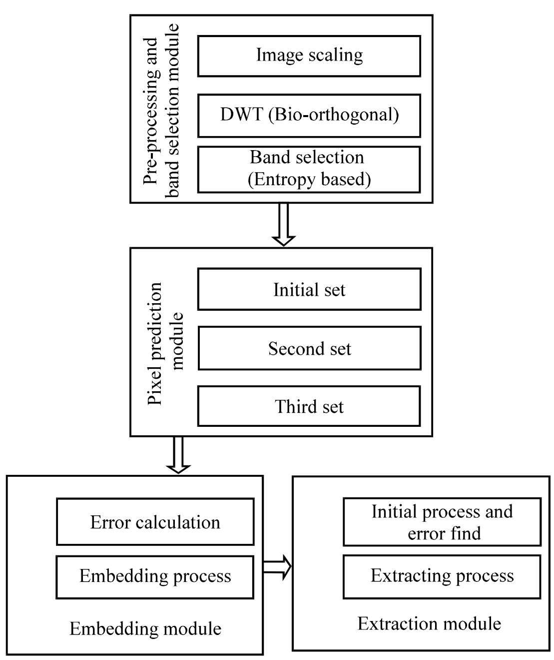

Fig. 2: Block diagram of proposed DPEIRIW scheme

Once the image is predicted, the prediction fault is found out by correlating the predicted image to that of the original value and embedding is carried out based on the error value. Owing to a high correlation between the adjacent pixels, error would be small and pixels having lower errors are preferred for embedding process. For extraction, the prediction error is the difference between the predicted pixel value and the watermarked pixel value. This error value is compared with a set threshold to extract the watermark.

The evaluation metric wormed are Peak Signal to Noise Ratio (PSNR) and Normalized Correlation (NC). The quality is evaluated by the use of PSNR criterion in between the original images with the watermarked images and the extracting fidelity is compared using the NC value with original watermark and the extracted watermark. The high NC and PSNR obtained for the technique with an average NC of 0.9948 and PSNR of 49.6594. This suggested procedure has performed well by having higher PSNR and NC values in comparison to other approaches. The processing time elapsed for the run of the proposed algorithm with respect to the considered image datasets is 81 sec.

MWT-OPSO Model: The primary objective of this proposed research in this thesis is to develop an efficient reversible image watermarking scheme based on Multi Wavelet Transform (MWT) and Oppositional Particle Swarm Optimization (OPSO). The overall process of the proposed system is illustrated in Fig. 3.

The system consists of mainly two processes such as embedding and extraction. In the embedding process at first, the source image is decomposed into different bands based on Haar wavelet transform. In which low frequency band is selected and then the bi-orthogonal wavelet transform is applied to decompose the image. Out of all bands, the approximation band is neglected and entropy of other bands is computed. The band with maximum entropy is selected as the band and from it, the best position is found out using OPSO algorithm.

The proposed approach to population initialization used the opposition based approach in which the population and its opposite population are considered as input. The fitness of both populations is evaluated and the ideal one is selected. Each particle (potential solution) updates its position by moving in the solutions hyperspace in search of optimal solutions. All the particles in a swarm move stochastically for optimal positions and update their locations. The algorithm discontinues its execution only if the maximum number of iterations is achieved and the particles which are holding the best fitness value is

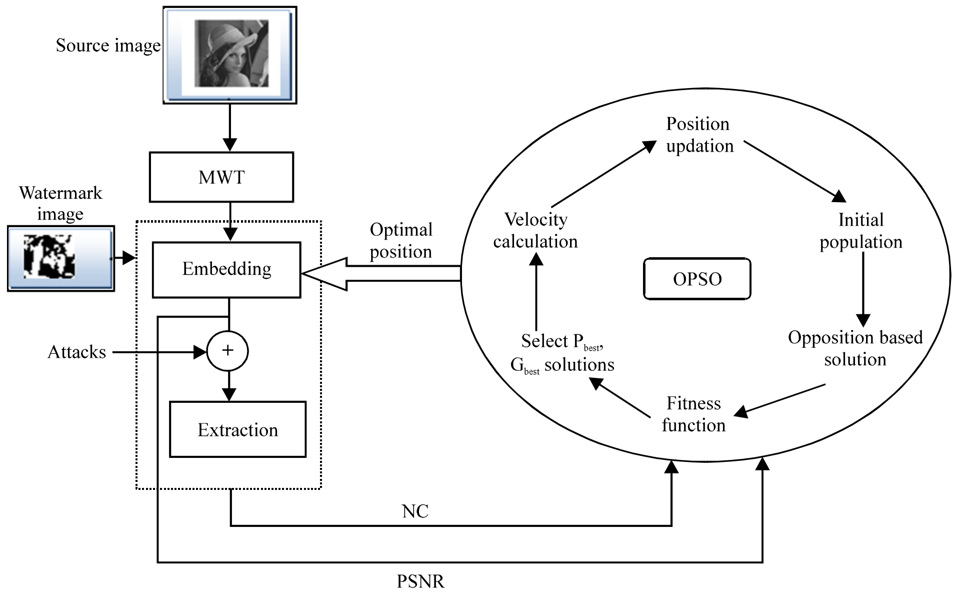

Fig. 3: Proposed hybrid MWT-OPSO based watermarking system

selected and it is given as the best position for imposing the watermark. Then, the secret image is imposed into the source image in order to secure the information from un-authorized person.

The performance of the proposed research is investigated with many grey-level images inclusive of medical images. The investigation cadets used are peak signal to noise ratio and normalized correlation. PSNR is used to measure the imperceptibility of the embedded watermark in carrier image. NC is used to measure the similarity between the reproduced watermark and the watermark embedded. From the investigation results, it is found that the maximum PSNR of 59.84, NC of 1 and average embedding capacity of 1024 bits is obtained in the proposed watermarking scheme which shows clearly that the quality of the image is not compromised. The processing time elapsed for the run of the proposed algorithm with respect to the considered image datasets is 72 sec.

Optimal position selection: Once the best band is selected, the next task is to find the optimal position where the embedding can take place. For this, OPSO algorithm is used. The Particle Swarm Optimization (PSO) algorithm is a simple evolutionary algorithm which differs from other evolutionary algorithms in which it motivates the simulation of social behaviour. PSO has shown high-quality performance in finding fine solutions to optimization problems. PSO is a population-based search algorithm and starts with an initial population of randomly generated solutions called particles[15]. Each particle in PSO has a position and a velocity. PSO remembers both the best position found by all particles and the best positions found by each particle in the search process. One problem found in the standard PSO is that it could easily fall into local optima in many optimization problems[16, 17]. To overcome this problem in this study, the Opposition based PSO (OPSO) algorithm explains how to avoid the premature convergences and allows OPSO to continue the search for global optima by applying opposition-based learning[18, 19]. The basic concept of Opposition Based Learning (OBL) is the consideration of an estimate and its corresponding opposite estimate simultaneously to approximate the current candidate solution. The proposed approach for population initialization used the opposition based method in which the population and its opposite population are taken as input. The fitness of both populations is evaluated and the best one is selected. Finally, the watermark image is imposed into the source image to obtain the watermarked image.

RESULTS AND DISCUSSION

Performance comparison: The basic idea of this research is reversible image watermarking based on the proposed Multi Wavelet Transforms and Oppositional Particle Swarm Optimization algorithm (MWT and OPSO). The main motivation of using this approach is to employ the capability of MWT in yielding high embedding capacity, more security and better quality of watermarked image. Here, the effectiveness of the proposed approach is proved by comparing the developed hybrid MWT and OPSO technique with that of the

Table 1: Comparison results of PSNR values employing proposed MWT-OPSO approach and other methods from literature

	PSNR values						
Image type	Coordinate prediction approach[20]	Weighted median prediction approach[21, 22]	Optimal selection channel approach[23]	Shearlet domain approach[16]	Proposed BWT and importance measure in Chapter 3	Proposed dyn-amic prediction approach in Chapter 4	Proposed MWT and OPSO approach
Brick	28.7658	29.2234	30.1876	30.9675	31.0200	38.9291	57.8657
Cameraman	29.8071	30.2656	30.8941	31.9276	32.3750	41.4327	58.5632
Lena	30.0248	36.1505	38.9908	39.0421	40.2169	49.8573	58.1942
Baboon	34.3219	34.8876	39.4621	39.9902	42.0060	51.2626	57.6514
Peppers	33.2765	35.2109	38.7631	38.9190	40.0890	48.5672	58.6792
Lake Boat	31.2640	33.7765	39.0871	39.7310	41.1260	50.6216	59.0023
Girl	30.2876	34.9981	37.6209	38.9176	42.1890	49.4876	58.7726
House	32.4564	33.2670	36.4481	38.0231	41.4300	50.2654	58.9901
Barbara	29.7584	35.6278	37.5533	38.9997	38.7081	49.2935	58.3261
Soldier	30.1204	35.7529	38.2629	38.2980	38.5477	52.8050	58.9972
Balls	31.2488	33.2121	37.1341	38.4642	41.2760	50.4347	59.6702
Boy ice	32.3308	34.0005	37.4288	39.2281	40.9510	49.8703	58.3208
Chest	30.4016	35.7076	38.1870	38.9703	43.4050	54.0593	58.9483
Brain MRI	31.6565	37.1192	36.5408	37.6542	41.8530	53.1919	59.8466
Lung MRI 1	31.2415	36.5422	37.0091	39.2621	41.6970	52.4645	58.2217
Lung MRI 2	32.6657	34.2187	36.5442	38.4452	40.8810	52.0072	57.9963

Table 2: Comparison results of NC values employing proposed MWT and OPSO approach and other methods from literature

	NC values						
Image types	Coordinate prediction approach[20]	Weighted median prediction[22, 21]	Optimal channel selection approach[23]	Shearlet domain approach[16]	Proposed BWT importance and measure in chapter 3	Proposed dyna-mic prediction approach	Proposed MWT-OPSO approach
Brick	0.55640	0.9643	0.9655	0.9746	1.0000	1.0000	1.00000
Cameraman	0.44310	0.9529	0.9571	0.9649	1.0000	1.0000	1.00000
Lena	0.48902	0.9786	0.9800	0.9809	0.9835	0.9856	1.00000
Baboon	0.29261	0.9341	0.9415	0.9731	0.9976	1.0000	1.00000
Peppers	0.43890	0.9376	0.9432	0.9650	0.9981	0.9994	0.99980
Lake boat	0.42990	0.9128	0.9200	0.9498	1.0000	1.0000	1.00000
Girl	0.51670	0.9561	0.9652	0.9701	0.9945	0.9967	0.99830
House	0.51990	0.9399	0.9411	0.9633	0.9900	0.9989	0.99970
Barbara	0.53217	0.9541	0.9743	0.9877	0.9975	0.9943	1.00000
Soldier	0.47273	0.9347	0.9401	0.9502	0.9565	0.9989	1.00000
Balls	0.49551	0.9444	0.9639	0.9746	0.9995	1.0000	1.00000
Boy ice	0.50672	0.9511	0.9674	0.9899	1.0000	1.0000	1.00000
Chest	0.53605	0.9600	0.9616	0.9621	0.9634	0.9943	0.98860
Brain MRI	0.35627	0.9643	0.9742	0.9882	1.0000	0.9870	0.92342
Lung MRI 1	0.51224	0.9600	0.9688	0.9701	0.9768	0.9867	0.98960
Lung MRI 2	0.47690	0.9137	0.9257	0.9439	0.9532	0.9749	0.98420

weighted median approach[21,22,24-26], coordinate prediction approach[20, 27], optimal channel selection approach[23], shearlet domain approach[16] and that of the earlier methods BWT and IMM and DPEIRIW proposed.

Table 1 and 2 shows the comparative analysis of proposed against existing approaches based on PSNR and NC metrics, respectively. Here, the maximum PSNR of 59.8466 dB is computed for the brain Magnetic Resonance Imaging (MRI) image. From the results, it is clearly understandable that this proposed approach is having better attainment than that of existing approaches available in the literature.

CONCLUSION

Reversible watermarking requires high embedding capacity, content distortion which should be as low as possible and robustness against attacks. These conflicting requirements carve the path for this research. Considering these challenges, a reversible watermarking scheme resistant to geometrical attacks was proposed in this investigation. The proposed scheme does not require the original image for extracting the watermark. This investigation aimed at creating a scheme, robust to geometrical distortions, compression and filtering attacks. This research mainly addresses privacy, reversibility, payload and robustness related goals. To achieve these goals BWT and IMM, DPEIRIW and MWT and OPSO methods were proposed.

RECOMMENDATIONS

Based on this investigation, a few areas of further research are identified as follows: further improvement could be possible where in the same approaches could be practiced on the video files of different types. Applying this technique on MPEG, H.264 and 3D video files could be a future guidance for this research.

As the ongoing trend is now towards multi-core computing and the requirements for the real time video communication is very much in demand, the ownership right information also required to be preserved. It could be a great future direction to deploy this design approach under multi-core platforms.

In addition to that, the research can be protracted from strict authentication to soft authentication. Along with authentication verification, small secret data such as session keys can also be imposed in encrypted format and traded between two communication ends. Hence, authentication and confidentiality can also be achieved together.

REFERENCES

01. Vanco, B.M. and J.L. Christensen, 2016. Ego depletion increases regulatory success in educational digital media environments. Comput. Hum. Behav., 62: 602-612.
02. Sohrabi, B. and H. Iraj, 2016. Implementing flipped classroom using digital media: A comparison of two demographically different groups perceptions. Comput. Hum. Behav., 60: 514-524.
03. Orzech, K.M., M.A. Grandner, B.M. Roane and M.A. Carskadon, 2016. Digital media use in the 2 h before bedtime is associated with sleep variables in university students. Comput. Hum. Behav., 55: 43-50.
04. Qi, X. and X. Xin, 2015. A singular-value-based semi-fragile watermarking scheme for image content authentication with tamper localization. J. Visual Commun. Image Represent., 30: 312-327.
05. Cox, I.J., M.L. Miller and J.A. Bloom, 2002. Digital Watermarking. Morgan Kaufmann Publishers, Burlington, Massachusetts, ISBN:9781558607149, Pages: 542.
06. Cox, I., M. Miller, J. Bloom, J. Fridrich and T. Kalker, 2007. Digital Watermarking and Steganography. 2nd Edn., Morgan Kaufmann Publishers, Burlington, Massachusetts, ISBN:978-0-12-372585-1, Pages: 594.
07. Shih, F.Y., 2007. Digital Watermarking and Steganography: Fundamentals and Techniques. CRC Press, Boca Raton, Florida, ISBN-13: 978-1-4200-4758-5, Pages: 177.
08. Khan, A., A. Siddiqa, S. Munib and S.A. Malik, 2014. A recent survey of reversible watermarking techniques. Inf. Sci., 279: 251-272.
09. Feng, G., Z. Qian and N. Dai, 2012. Reversible watermarking via extreme learning machine prediction. Neurocomput., 82: 62-68.
10. Chen, C.C. and Y.H. Tsai, 2011. Adaptive reversible image watermarking scheme. J. Syst. Software, 84: 428-434.
11. Chen, T.P.C. and T. Chen, 2000. Progressive image watermarking. Proceedings of the 2000 IEEE International Conference on Multimedia and Expo (ICME'2000) Vol. 2, July 30-August 2, 2000, IEEE, New York, USA., pp: 1025-1028.
12. Cox, I.J. and M.L. Miller, 1997. Review of watermarking and the importance of perceptual modeling. Proceedings of the Conference on Human Vision and Electronic Imaging, June 3, 1997, SPIE, San Jose, California, pp: 92-99.
13. Chen, M., Z. Chen, X. Zeng and Z. Xiong, 2010. Model order selection in reversible image watermarking. IEEE. J. Sel. Top. Signal Process., 4: 592-604.
14. Khan, A., S.A. Malik, A. Ali, R. Chamlawi and M. Hussain *et al*., 2012. Intelligent reversible watermarking and authentication: Hiding depth map information for 3D cameras. Inf. Sci., 216: 155-175.
15. Hu, X., Y. Shi and R. Eberhart, 2004. Recent advances in particle swarm. Proceedings of the 2004 Congress on Evolutionary Computation (CEC'04) Vol. 1, June 19-23, 2004, IEEE, Portland, Oregon, ISBN:0-7803-8515-2, pp: 90-97.
16. Wang, C.P., X.Y. Wang, Z.Q. Xia, C. Zhang and X.J. Chen, 2016. Geometrically resilient color image zero-watermarking algorithm based on quaternion Exponent moments. J. Visual Commun. Image Represent., 41: 247-259
17. Hu, H.T., L.Y. Hsu and H.H. Chou, 2014. Variable-dimensional vector modulation for perceptual-based DWT blind audio watermarking with adjustable payload capacity. Digital Signal Process., 31: 115-123.
18. Hu, H.T. and L.Y. Hsu, 2016. A mixed modulation scheme for blind image watermarking. AEU. Intl. J. Electron. Commun., 70: 172-178.
19. Hu, H.T., J.R. Chang and L.Y. Hsu, 2016. Robust blind image watermarking by modulating the mean of partly sign-altered DCT coefficients guided by human visual perception. AEU. Intl. J. Electron. Commun., 70: 1374-1381.
20. Naskar, R. and R.S. Chakraborty, 2011. Reversible image watermarking through coordinate logic operation based prediction. In: Information Systems Security. Chandan, S. and C. Mazumdar (Eds.). Springer Berlin Heidelberg, Berlin, Germany, pp: 190-203.
21. Naskar, R. and R.S. Chakraborty, 2012a. Performance of reversible digital image watermarking under error-prone data communication: A simulation-based study. IET. Image Process., 6: 728-737.

22. Naskar, R. and R.S. Chakraborty, 2012b. Reversible watermarking utilising weighted median-based prediction. Image Process. IET., 6: 507-520.
23. Huynh-The, T., O. Banos, S. Lee, Y. Yoon and T. Le-Tien, 2016. Improving digital image watermarking by means of optimal channel selection. Expert Syst. Appl., 62: 177-189.
24. Sujatha, T. and K. Geetha, 2014. Reversible image watermarking using bi-orthogonal wavelet transform and importance measure model. J. Theor. Appl. Inf. Technol., 60: 531-542.
25. Sujatha, T. and K. Geetha, 2016a. Multi wavelet transforms and oppositional particle swarm optimization for an efficient reversible image watermarking. Intl. J. Adv. Eng. Technol., 7: 978-978.
26. Sujatha, T. and K. Geetha, 2016b. Dynamic prediction error integrated reversible image watermarking. Asian J. Inf. Technol., 15: 3311-3319.
27. Hu, Y. and B. Jeon, 2006. Reversible visible watermarking and lossless recovery of original images. Circuits Syst. Video Technol. IEEE. Trans., 16: 1423-1429.