International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-4, November 2019

Watermarking Schemes for High Security with Applications and Attacks: Research Challenges and Open Issues

Rahul Ajithkumar, K. Satyanarayan Reddy, G.Glan Devadhas

Abstract: ***Recently, the growth of the internet is increased day by day also the digital data such as videos, images and audio availability to the public get increased rapidly. The society required intellectual property protection. To protect the media from other attack intruders and avoid business loss is the requirement of digital media produced. Introducing watermarks can be useful to safeguard copyright. In this review an effort is made to explore various aspects of watermarking, algorithms used, and to carry out a comparative study of these techniques based on their classifications.***

Keywords: Watermarking, Capacity, Robust, DCT, DWT, PCA, Spread Spectrum

I. INTRODUCTION

With the usage of any digital media, the useful information is hidden by watermarking process [40]. The user checks a digital media authentication by water marking process. The Steganography is interlinked with video, text, audio and image of digital media. Since, the digital signal consists of both hide messages of Steganography and water marking respectively [40]. The basic difference between the two is: The actual content of the digital signal messages are converted by watermarking. Nevertheless, there is no other message contact by Steganography. There are two images are needed for the watermarking process, from this, the initial one is original and another one is watermark image. The Unauthorized author hides the valuable information of watermark image. The watermark image is useful for the sender level as well as for the receiving level. So it should be protected from the unauthorized access at the sending level as well as at the receiving level. Watermark is extractable or detectable to live helpful.

Manuscript published on November 30, 2019.
* Correspondence Author
Rahul Ajithkumar*, Research Scholar, VTU, Belagavi, Karnataka, India
K. Satyanarayan Reddy, Professor & Head, Department of Information Science & Engineering,
Cambridge Institute of Technology, Bangalore, Karnataka State, India
G.Glan Devadhas, Professor, Department of Electronics & Instrumentation, Vimal Jyothi Engineering College, Kerala

Therefore, the moving and non-moving fraction of the frames are the classification of Non-blind color video frame watermarking algorithm [4], [11]. The round causing errors are corrected with the help of Cat Swarm Optimization (CSO) [47] [48] [49]. The image transformation process of frequency domain to spatial domain image with the real number conversion into integer is to cause the errors [29]. When
compared to the DCT-based method, the performances of DWT-based watermarking method are optimal and produce better results
[36]. The barcodes is considered as a watermark for obtaining well secure and robust watermarking process [37].

The watermarking algorithms are inserted based on the nature of each algorithm and the approaches are distinct in nature [24]. Fig 1 represents the watermarking algorithm. The encryption of solution visual impacts and computational overheads are minimized as well as high efficiency video coding (HEVC) standards and Advanced Video coding (H.264/ AVC) watermarking compliant are designed correctly [41]. The Un-compressed Video Watermarking optimization depends upon DWT and SVD has proposed to improve the robustness [38]. Different Watermarking scheme based on spread spectrum, Blind extraction process, Non blind process, Path work, PCA extraction, MAP detector, DCT, DWT-SVD, DCT-DWT-SVD, SVD has been proposed to provide the security for data has been discussed below.

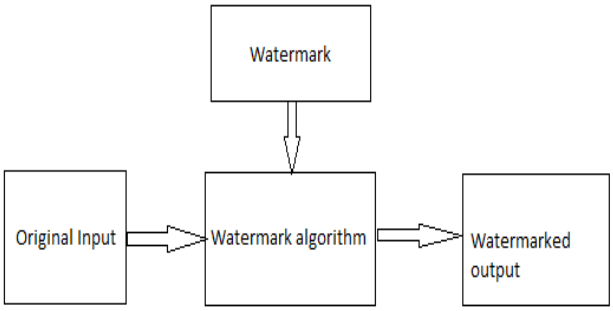

Fig 1.Process of Watermarking Algorithm

II. DIGITAL WATERMARKING ASPECTS

Based on the technology usage and types with more number of digital watermarking applications are established. Based on the number of properties such as robustness, imperceptibility, security, verifiability, fidelity, transparency, capacity, false-positive rate, quality with the watermarking systems is categorized. These different aspects are discussed below.

A. Robustness

The resultant of common signal processing operation with its watermark ability detection is called as robustness. The watermarking characteristics are highly robust against the attacks such as geometrical and non-geometrical [42].

B. Imperceptibility

The watermark never is observed through simply observation or simply certainly not get observed with the simply individual scalp, and found as a result of a specific command or perhaps faithful circuits. The imperceptibility found by a state corporation only. Like watermarks can be utilized by material or perhaps author accreditation and for stinking unauthorized copier [40].

C. Security

If the embedding algorithm is implemented means then the watermarking system should be protected.

The utilized cryptographic techniques are to produce security [5].

D. Verifiability

Watermark ought to control to supply complete and trustworthy information for the possessing copyright protected information and facts products.

E. Transparency

The version of original and the watermarked cover work with its equivalent perceptual is called transparency. If the image is watermarked means the original image quality is never affected by digital watermark [42]

F. Capacity

In extraction, the successful detection with how much data can be embedded by watermark ability is called capacity [42].

G. False Positive Rate

Here, the recognition of watermark image into a cover image doesn't contain actually. In decoding process with watermarked cover images are quickly identified using minimum false positive rate.

H. Quality

The minimization of embedding distortion is created with choosing intra predicted blocks in support of watermark embedded bits. Thus, the watermarked video degradation quality is improved by the minimization of distortion.

III. RESEARCH BACKGROUND

Recently, the digital image security is the major challenging topic in the network. Nevertheless, the researchers introduced many watermarking methods for the enhancement of image securities and a few of the existing research ideas are explained in this section.

A Singular Value Decomposition (SVD) [17] and Tabu Search based digital image watermarking concept was introduced. In this approach, the singular value of the original data has been modified using multiple scaling factors for embedding the watermark image. These multiple scaling factors are generated using a meta-heuristic approach known as Tabu search. In [23], the author introduced a digital image watermarking method. The permanent watermark is a major part of this technique. The permanent embedding of the cover image is accessible towards everyone. The watermarked images are affected by several attacks and it's decoded with lower accuracy [43].

The simplified detector is used to accommodate the signal amplitude quickly. The codeword is extracted from the pirated copy after that the distortions are examined [7].

DWT-PCA based non-blind digital color image watermarking scheme was used to copyright protection and authentication of the color image data [19]. The self-recognized Image Protection Technique was used to achieve better visualization of different types of host image [46].

A. Method based on Spread Spectrum

Authors in [3] have designed a method of Double Random Phase Encoding Spread-Space Spread-Spectrum Watermarking (DRPE SS-SS). The digital barcode images are the representation of watermark and the optical DRPE process is to simulate the numerical encryption. The complex images are randomly produced by the DRPE process with fewer quantization levels and real-valued random images are obtained. The host image adds theses signals. Applying the inverse DRPE procedure to the low pass filter and watermarked image, as a result of barcodes are extracted. When compared to Cox's method, the DRPE algorithm produces optimal spatial and spatial frequency.

Authors in [5] have presented a method of Generalized Spread Spectrum Watermarking (GSSW). Thus, the binary watermarks with its theoretical capabilities are described. The applications of engineering demand and approximate expressions are illustrated. The channel capabilities of optimal parametric values are collected. When compared to the traditional spread spectrum scheme, the enlarger capacity of GSSW is obtained. The embedded process is the part of host signal information.

Authors in [6] have designed a concept of SS-based audio watermarking for the obtaining of embedding capacity is high. Thus, the resultant of robustness and larger imperceptibility ranges are ensured.

Authors in [9] have proposed a Watermarking algorithm depends on Spread Spectrum. The local instruction statistics is to possess good concealment and robustness.

Authors in [13] have designed an Algorithmic Digital Audio Watermarking in Perceptual Domain by means of Psycho Acoustic Auditory Model of Direct Sequence Spread Spectrum. The audio signal masking threshold calculations are estimated. For imperceptibility, the watermark shaping is used to threshold the masking. The process of embedding and extraction is extremely fair. This method does not provide more robustness.

Authors in [8] have proposed a distortion optimization technique of spread-spectrum watermarking for security demand. Thus, the Natural Watermarking (NW) is to create strong security properties such as subspace-security and key-security. The watermarked signals never changes as well as the host distributions are particularly embedded. The global distortions are reduced with the usage of elements of transportation theory.

B. Method based on Blind Extraction Process

Authors in [1] have designed a watermarking framework with a blind extraction process for encoded video such as HEVC. The video compression of Spatio-temporal behavior is discovered as well as the watermarking securities are ensured.

Therefore, the selection of the embedded region is performed using the random key. This method is highly robust against compressions and filtering. The noises are removed and optimal image qualities are obtained.

Authors in [10] have designed a blind extraction procedure using the video watermarking method. The embedded watermarks are retrieved without the usage of original watermark or video data. In video streams compression of H.264/AVC with imperceptible watermark, bits are embedded into P-frames. The increasing amount of video bit rates are minimized by embedding algorithm and correct block selection process. The set of the existing selected block is to produce a pseudo-random key. Then the pseudo-random keys are used to select the candidate blocks respectively. The attack insertion and frame drop withstand is to create a robust watermark also the optimal performance results are obtained.

Authors in [18] have designed adaptive, DCT based, blind image watermarking algorithms. The adaptability was developed, while exploring the properties of the Human Visual System (VHS), to embed robust watermarks in DCT matrices while making them the least visible in the space domain. This algorithm was computationally simple because it extracts the needed features directly from the DCT coefficients. This computational simplicity of the algorithm makes it very useful in real-time applications.

Authors in [16] initially introduced a watermarking method depends on blind digital video. The higher watermarked video qualities are obtained by chrominance channel of complex dual-tree wavelet transform. The one-level dual-tree complex wavelet transform is obtained by the embedding of the watermark. The embedded usages with similar keys are extracted. Therefore, the complex dual-tree wavelet transform depends on a resolution of the downscaled description. Therefore, the arbitrary resolution is obtained by a downscaled resolution complex. Any stages watermarks are extracted by this wavelet transform method. The frame information is used to extract watermark frames. This method is highly robust alongside the attacks of temporal synchronization.

Author in [44] have designed a method of discrete wavelet transform for the extraction of blind watermarking image. The watermarking requirements are satisfied with the usage of DWT properties. Thus, the method is the proper reconstruction method and the edge properties are detected. The process is entirely blind and no other requirement of host image and watermark. This process is highly recommended for blind extraction as well as applications like copyright protections, copy and fingerprint respectively.

Authors in [45] Lin has designed a copyright protection procedure of blind watermarking of maximum wavelet coefficient quantization algorithm. Here, various kinds and groups of wavelet coefficients are used. The various sub-bands are randomly chosen by blocks. Under a few constraints, the maximum wavelet coefficients are obtained by the addition of different energies as well as maximum wavelet coefficient contains maximal blocks. The different kinds of attacks are effectively minimized and the local maximum coefficients are embedded successfully.

C. Method based on PCA Extraction

PCA extraction-based watermarking scheme was developed [2] to achieve optimal performance.

The practical audio watermarking application of higher potential is obtained. It is not suitable for random cropping and replication of de-synchronization attacks.

Authors in [19] have proposed a watermarking method of DWT-PCA based non-blind digital color image. The extraction and embedding process is developed by the combination of DWT-PCA methods. Initially, the original image decomposed using DWT after that the color watermarks is applied. The terms of principal component analysis are used for original image segmentation there before the watermark embedded. The scheme is used for copyright protection and authentication of the color image data.

Authors in [20] have designed an image watermarking concept, which is the amalgamation of the Support Vector Machine (SVM) and Dynamic Stochastic Resonance (DSR) method. There are three levels of host image frequency sub-bands decompositions that are achieved by Lifting Wavelet Transform (LWT). The watermark embedding is opted by low-pass and high-pass frequency sub-band. The incorporation of DSR based coefficient is to enhance the watermarks effectively.

Authors in [21] have introduced Digital Video Watermarking that based on the DWT-PCA method and it is used for Copyright protection. This method is highly robust against different kinds of attacks and it is invisible in nature. The embedding process robustness is enhanced with the usage of low LL sub-band. The video quality, noise detection and information loss functions are reduced using Haar- filter filters.

D. Method based on Path work watermarking method

Authors in [12] have suggested patchwork methods that are based on the audio watermarking and the jitter, pitch-scaling, time-scaling of de-synchronization attacks are restricted. The term of Discrete Cosine Transform (DCT) is to embed the watermarks are entrenched keen on the host audio signal. The domain of Logarithmic DCT (LDCT) is used to implant the synchronization bit sets into a watermarked signal. Thus, the attack imposing of scaling factor such as LDCT domain of received audio is analyzed in the decoding level. Subsequently, to eliminate the effect of scaling they modify the received signal and the embedded synchronization bits are combined. Thus, the modified signal is to produce the extracted result of watermarks. When compared to the patchwork watermarking concept, this LDCT method is extremely robust alongside with various kinds of attacks. Authors in [15] suggested a digital audio watermarking method of patchwork-based embedding and decoding method. In watermarked audio signal enclosing with a pair of information are never required.

The optimal imperceptibility is ensured by the pair of DCT frame. In the decoding phase, the best possible DCT frame pairs are introduced for the determination of DCT frame pairs. The multiple watermark embedding and selected frequency regions are to produce the optimal robustness result. Based on the decoding process, the secret keys are used for security purposes.

E. Classification based on Nature Inspired methods

Authors in [25] have designed a genetic algorithm for the determination in embedding strength of watermark. One of the population-based techniques is Genetic algorithm (GA) and it is introduced by Charles Darwin that is enthused with the concept of "survival of the fittest". The genetic Algorithm has been to find the optimal value of the scaling factor of the watermark. The parametric usages are an important part of this genetic algorithm. The optimal output of watermarking is obtained with the usage of correct parametric updation.

Authors in [26] have designed a Particle Swarm Optimization (PSO). The distortions of image quality are recognized by Image Quality Index Metrics (IQIM). The contrast distortion, luminance distortion and correlation loss are the important factors of distortion. The watermarked image imperceptibility and its robustness are entirely operated by PSO training. Thus, the technique is highly robust against various attacks detection.

Authors in [27] have designed a method of Differential Evolution (DE) for optimal watermarking. The domains of Discrete Wavelet Transform-Singular Value Decomposition (DWT–SVD) transform are used to insert and extract watermarks. The third stage of DWT helps to divide the host image into various frequencies during the embedding process. The Low Pass (LL) and High Pass (HH) sub-bands at third level of SVD. In a lossless manner, the host image with a binary watermark is fixed and the false positive issues are overcome.

Authors in [28] have planned Lifting Wavelet Transform (LWT) and Singular Value Decomposition (SVD) for an optimal watermarking process by means of Multiple Scaling Factors (MSF) that are optimized by Multi-Objective Ant Colony Optimization (MOACO). There is no other loss of watermark transparency with better robustness are achieved by the combination of Single Scaling Factor (SSF) or MSFs. The watermarking algorithms of SVD are caused by false positive detection issue and it is solved using the measurement of watermark encryption and one-way hash function respectively.

Authors in [30] have proposed a method for embedding audio watermarks that are depends upon the optimal position.

Initially, the shots are the arrangements of input video sequences and that are embedded by audio watermarks. Therefore, the discrete cosine transform is used for the segmentation process. Thereafter, the CS algorithm helps to choose the best frames also each frame calculations are estimated with the usage of PSNR value. The digital video sequences are embedded and the audio data are considered as a watermark. The encryption process is performed also the audio data is turned into 9-bit sequence.

Authors in [22] have reviewed different Nature Inspired algorithm. When compared to a few attacks, as a result of specific robustness is obtained at each solution.

Authors in [31] have designed a watermarking method based on SVD and it minimizes the load. There is no other usage of extra information with the watermarks are directly extracted from the original image. The security is enhanced because of deciding embedded position using a secure pseudo-random number generator.

DCT-DWT [32] was proposed to protect digital media copyright efficiently. This method can highly robust in noise, cutting, JPEG compressing and low pass filtering.

Authors in [39] have made a comparative performance analysis of DCT, DWT-SVD, DCT-DWT-SVD; digital water marking algorithms they concluded that that DCT approach is not resistant to various attacks as it has less PSNR. DWT-SVD scheme is though robust under normal condition, its robustness decreases as the change in frequency. The scheme based on DCT-DWT-SVD has proved to be robust under normal and also under various attacks. The PSNR value is highest among all other approaches states that this approach is best suited for the digital image watermarking.

F. Comparison of Existing Algorithms with features and limitations

- *Spread spectrum concept*

The images are applied to the input of DRPE SS-SS and it can be highly robust in scaling, and JPEG compression distortion with very lower false-positive errors. There is a restriction in Low detection performance [3]. Ying et al. [5] debated about Generalized spread spectrum watermarking (GSSW) with Audio Signals are fed as the input. The high WNR with traditional channel capacity is collected by means of optimal parameters. It does not provide robustness. The audio input of SS-based audio [6] watermarking technique Provide optimal capacity of embedding although the acceptable imperceptibility and robustness are ensured with its accuracy is much less. Benjamin et al. [8] suggested Transportation natural watermarking (NW) concept with image input. Minimize the Global distortion and maximized the robustness. The concept of Local Instruction Statistic [9] with the merits of low influences on the program and can resist a series of attacks are received. Naresh et al. [13] introduced a Direct Sequence Spread Spectrum concept by means of bit error reduction and less accuracy.

- *Blind extraction procedure*

Tanim et al. [1] projected video input of HEVC method and robust against image processing attacks that resistant against re-encoding attacks. It doesn't provide robustness against all class of attacks. Muhamed Hamid et al. [18] introduced image input of the DCT method with high visual quality and highly robust against JPEG compression. Lag in compression ratio while comparing with other works. Tanima Dutta et al. [m planned video image of Embedding Algorithm with the entire performance are well but watermarking attacks are achieved. Asikuzzaman et al. [16] proposed Chrominance Embedding with video or image input are used. Provide optimal results in terms of geometric attacks. The original quality of the watermarked video is maintained and no other security is possible.

Naja et al. [44] denoted a method of an image input in discrete wavelet transform (DWT) with Robustness against various geometrical and non-geometrical attacks and accuracy performance is much low. The input images of wavelet coefficient quantization with PSNR parameters are used. Finally, the DWT method is more robust against geometry and Non-geometry attacks. There is no maximization of the robustness.

- *PCA extraction procedure*

Rangkun Li et al. [2] wished-for PCA extraction-based watermarking with audio signals is used as an input and WSR is considering as a parameter. There is an optimal performance and the watermarking applications of great potential for practical audio are shown. It never performs well under de-synchronization attacks. Anand kumar et al. [19] created DWT and PCA methods by means of an image. The PSNR and NC are denoted as the parameters. It is robustness against various attacks yet it never provides robustness against all classes of attacks. The amalgamation of DSR and SVM with image input and NC BER CR factors are used. This method is robust against geometrical and signal processing attacks but doesn't provide robustness against all class of attacks. Habiba et al. [21] established Advance Digital Video Watermarking with PSNR and NC factors are utilized. Robustness against various attacks but false-positive errors is obtained.

- *Path work watermarking*

Yong Xiang et al. [1] notified audio signal inputs of patchwork-based watermarking method with DR parameters are utilized. It is robustness against a variety of common attacks such as de-synchronization attacks. It doesn't provide robustness against all classes of attacks. Michael Arnold et al. [14] Introduced Baseline audio watermarking system which is high-fidelity but Embedded watermarks still suffer a slight degradation during signal reconstruction. Iynkaran Natgunanathan et al. [15] established Patchwork-Based Embedding and Decoding of the audio signal by BER factors. It is a highly robust and secure yet small amount of information that can hide.

- *Natural inspired classification*

Anshul Kanchan Khanna et al. [25] suggested a genetic algorithm among the parameters of PSNR and NC is applicable. It is invisibility, fewer computations, and resistance to various attacks. But never provide robustness against all class of attacks. Kuppusamy et al. [26] noted PSO algorithm and high Secure and provide robustness against various common attacks JPEG compression. Musrrat et al. [27] debated Differential evolution (DE) method. The IQIM, Imperceptibility, Robustness are the parameters with Improve the quality of watermarked image and robustness of the watermark. But the time complexity is larger. Khaled Loukhaoukha et al. [28] noted MOACO method which is more robustness and high probability of false positive detection. There is a limitation of very small amount of information can hide. G.Yamuna et al. [30] debated the input image method of CWT and CS with the parameters of PSNR and MSE are used. Highly robust against the attacks such as salt and Pepper, widespread geometrical, Cropping and Rotation attacks. Not high robustness is the limitation. Chih-Chin Laiget al. [31] introduced SVD method which is able to withstand a variety of image processing attacks. This will not able to hide high volume of data. Yang Qianli et al. [32] proposed DWT and DCT method. Robust to the common signal JPEG compressing, noise, low pass filtering and cutting. It doesn't provide robustness against all class of attack. Vijay R Ayangar et al. [33] discussed the amalgamation of DWT with SVD method. Wide range of robust attacks and the evolutionary technique has not been considered. Shojanazeri et al. [34] noted DCT-DWT is the input image by means of robustness against various attacks. Keta et al. [35] proposed video input of the DCT concept. It is robust to a wide range of attacks and never provides extra security.

IV. PERFORMANCE ANALYSIS

Experimentally, the robustness of the proposed technique and its performance analysis are carried out in this section. The signal processing attacks and geometric distortion resistance is the major goal of this research. The performance of the different watermarking technique is calculated based on the following

Execution Time

Based on time with the working and performance of watermarking algorithms parameters are computed. The watermarks are extracted as well as the number of time requirements is measured successfully [2].

Peak Signal to Noise Ratio

Here, the watermarked image imperceptibility such as the equality among the watermarked and original image are measured via peak signal to ratio of noise. The extracted and original watermarks are compared and discussed.

Table 1. Comparison of PSNR values

Host Image	PSNR(db)		
	Blind Watermarking	Self-recognized protection method	DCT based, blind image watermarking algorithm
Lena	40.58	41.29	43.10
Boat	39.75	40.54	41.57
Baboon	38.41	39.79	42.30
Peppers	40.37	41.91	43.84

Table 1 delivers the comparison of the PSNR value of the water marked image. The PSNR values of the DCT based, blind image watermarking algorithm was higher than the other two methods.

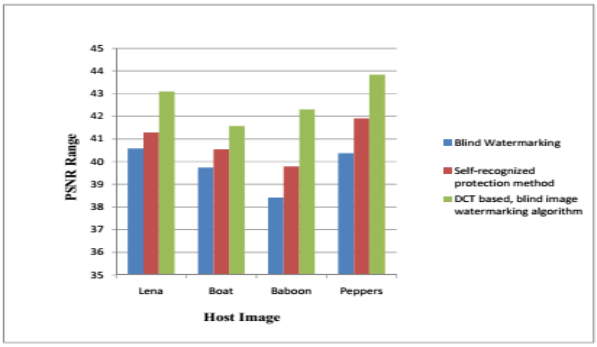

Fig 2.Graph of PSNR values for different methods

Table 2. Compression of CR values after JPEG compression

Q	Correctness rate (%)			
	Wavelet Filter Bank Method	Self-recognized protection method	Edge detection based method	DCT based blind image watermarking method
100	100	100	100	100
90	0	0	99	99.61
80	97.35	97.41	95	98.93
70	0	0	72	98.14
60	95.48	95.94	72	98.05
50	95.01	97.71	70	96.88
40	0	0	30	96.09
30	0	0	45	93.36

Table 2 shows a compression of the CR value after JPEG compression with different quality factors. Fig 2 shows the graph of PSNR values for different methods. DCT based blind image watermarking method achieves higher PSNR value while compared with other methods.

Bit Correct Ratio

From the total number of embedded bits with correct bits are extracted with the help of Bit Correct Ratio (BCR).

Normalized Cross Correlation

The original watermark and recovered watermark also cover image and the watermarked image similarities are measured using normalized cross-correlation.

Correctness Rate (CR)

Correctness Rate was used to evaluate the imperceptibility and robustness against JPEG compression

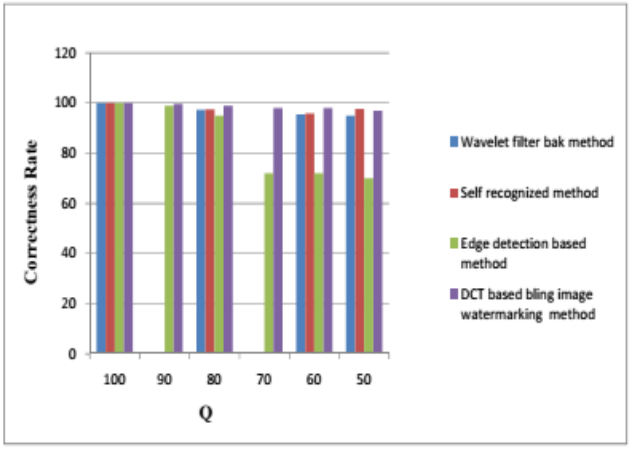

Fig 3. Graph for Compression of CR values after JPEG compression

Fig 3 shows the Graph for Compression of CR values after JPEG compression. DCT based blind image watermarking method achieves higher correctness rate while compared with other methods.

Payload

One of the important performance parameter is called as payload or capacity. This method contains a direct crash on the image robustness. There is no other deteriorating of original image quality are hidden by original watermark. The value of pixel or bits is known as the representation of size or amount of data. The robustness is checked using different kinds of parameters such as MAE (Mean Average Error), NAE (Normalized Absolute Error), SC (Structural Content), SNR (Signal to Noise Ratio), MAE (Mutual Information), UIQI (Universal Image Quality Index) and BER (Bit Error Ratio).

V. CONCLUSION

We have focused on digital watermarking method, Features, and performance analyses of watermarking technique, and also comparison between different watermarking have been presented. Dissimilar methods are utilized to overcome the disadvantages of water marking; unfortunately, there is no method that can provide a fully comprehensive solution. Every solution contains appropriate robustness towards few kinds of attacks. Nevertheless, it is less elastic in the direction of other variety of attacks.

ACKNOWLEDGMENT

The authors thank the authorities of Cambridge institute of technology, Bangalore affiliated to VTU Belgaum and the authorities of MAR BASELIOS CHRISTIAN college of Engineering and Technology, Kerala affiliated to KTU, who offered a chances and resources for carrying out this research and for the liberal grants extended to the research activities.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. Gu, Zhai Wang, Lin, Min and Ma, “Unified blind quality assessment of compressed natural, graphic, and screen content images,” IEEE Transactions on Image Processing, vol.26, no.11, pp. 5462-5474, 2011.
2. Li, Rangkun, Shuzheng and Huazhong, “Spread spectrum audio watermarking based on perceptual characteristic aware extraction,” Signal Processing, no. 3, vol.10, pp.266-273, 2016.
3. Liu, Hennelly, Sheridan and Guo, “Robustness of double random phase encoding spread-space spread-spectrum watermarking method,” Signal Processing, vol.109, pp.345-361, 2015.
4. Sundararaj, V, “Optimised denoising scheme via opposition-based self-adaptive learning PSO algorithm for wavelet-based ECG signal noise reduction,” International Journal of Biomedical Engineering and Technology, 31(4), pp.325-345, 2019.
5. Ying, Zhengguang, Zhang and Benxiong, “Channel capacity analysis of the generalized spread spectrum watermarking signals,” IEEE: Signal Processing Letters, vol.22, no. 5, pp.519-523, 2014.
6. Xiang, Yong, Iynkaran, Song Guo, Yue Rong and Natgunanathan, “Spread spectrum-based high embedding capacity watermarking method for audio signals,” Transactions of Language Processing, vol.23, no. 12, pp.2228-2237, 2015.
7. Yu Lee and Ho, “Collusion attack resilient 3D mesh watermarking based on anti-collusion fingerprint code,” Applied Sciences, vol.8, no. 7, pp. 1040, 2018.
8. Mathon, Bas, Cayre and Mac, “Optimal transport for secure spread-spectrum watermarking of still images,” Image Processing, vol.23, no.4, pp.1694-1705, 2014.

9. Feng, Tianwen, Luo Zhong, Muyao Lu and, Guangli Xiang, "A Spread Spectrum Watermarking Algorithm Based on Local Instruction Statistic," Multimedia Signal Processing, pp. 551-554, 2013.
10. Dutta, Nandi and Sur, "A robust compressed domain video watermarking in P-frames with controlled bit rate increase," pp.1-5, 2013.
11. Ling-Yuan Hsu, Hu and Hwai-Tsu, "Exploring DWT–SVD–DCT feature parameters for robust multiple watermarking against JPEG and JPEG2000 compression," Computers and Electrical Engineering, vol. 41, pp.52-63, 2015.
12. Xiang, Song Guo, Yong, Iynkaran Natgunanathan, Saeid Nahavandi and Wanlei Zhou, "Patchwork-based audio watermarking method robust to de-synchronization," Language Processing, vol.22, no. 9, pp.1413-1423, 2014.
13. Trivedi, Naresh Kumar and Munesh Chandra Trivedi, "An algorithmic digital audio watermarking in perceptual domain using direct sequence spread spectrum," Communication Systems and Network Technologies, pp. 805-809. 2014.
14. Arnold, Michael, Gwenael Doerr and Xiao-Ming Chen, "The phase-based audio watermarking system robust to acoustic path propagation," Information Forensics and Security, vol.9, no. 3, pp. 411-425, 2013.
15. Natgunanathan, Iynkaran, Song Guo and Yong Xian, "Robust patchwork-based embedding and decoding scheme for digital audio watermarking," Language Processing, vol.20, no. 8, pp.2232-2239, 2012.
16. Agoyi, Anbarjafari, Escalera, Rasti and Samiei, "Robust non-blind color video watermarking using QR decomposition and entropy analysis," Image Representation, vol.38, pp.838-847, 2016.
17. Liu, Kong and Niu, "Image watermarking based on singular value decomposition," Intelligent Information Hiding and Multimedia, pp.457-460, 2013.
18. Sarita, Ambadekar, Jayshree Khanapuri and Jayshree Jain, "Digital Image Watermarking Through Encryption and DWT for Copyright Protection," Signal and Image Processing, pp. 187-195, 2019.
19. Kumar, Anand and Mukesh Gupta, "Semi visible watermarking scheme based on PCA and DWT," Conference on Internet of Things, pp. 986-990. 2015.
20. Verma, Vivek Singh, Ajay Kumar Garg, Anuj Bhardwaj, Rajib Kumar Jha and Aparajita Ojha, "Robust image watermarking using combined DSR-SVM with PCA based feature reduction," International Symposium on System Design, pp. 323-327. 2016.
21. Niranjanbabu and Habiba, "Advance Digital Video Watermarking based on DWT-PCA for Copyright protection" vol. 4, no.10, pp. 2248-9622, 2014.
22. Agarwal, Parul and Shikha, "Nature-inspired algorithms and prospects," Journal of Computer Applications, vol.100, pp.14-21, 2014.
23. Navas, Sreevidya and Sasikumar, "A benchmark for medical image watermarking," Signals and Image Processing on Speech and Image Processing, Multimedia Communications and Services, pp. 237-240, 2010.
24. Jung and Cho, "A robust digital watermarking system adopting 2D barcode against digital piracy on P2P network," Computer science and network security, vol.6, no.10, pp.263, 2016.
25. Nihar Ranjan, Bhupendra and Kanchan Roy, "Digital Image Watermarking and its optimization using Genetic Algorithm," Conference on Computing, vol.2, 2017.
26. Kuppusamy, Thamodaran, "Optimized Image Watermarking Scheme Based On PSO," Conference on Modeling Optimization, vol.38, pp.493-503, 2012.
27. Musrrat Ali, Chang WookAhn, Patrick Siarry, "Differential evolution algorithm for the selection of optimal scaling factors in image watermarking," vol.31, pp.15-26, 2014.
28. Loukhaoukha, "Image watermarking algorithm based on Multiobjective ant colony optimization and singular value decomposition in wavelet domain," Journal of Optimization, 2013.
29. Zakaria, Gabi, Ismail, Abraham and Zainal, "Orthogonal Taguchi-based cat algorithm for solving task scheduling problem in cloud computing," Neural Computing and Applications, vol.30, no.6, pp.1845-1863, 2018.
30. Kalaiselvan, Natrajan and Lavanya, "Enhancing the performance of watermarking based on cat swarm optimization method," ICRTIT, pp. 1081-1086, 2011.
31. Hu YS, Lin CC and Chang, "A digital watermarking scheme based on singular value decomposition," In International Symposium on Combinatory, pp. 82-93, 2007.
32. Dhawas, Nitin Patil and Sambhaji, "Invisible Video Watermarking for Data Integrity and Security based on Discrete Wavelet Transform–A Review," Invisible Video Watermarking for Data Integrity and Security based on Discrete Wavelet Transform–A Review, 2019.
33. Mishra, Ashish Tripathi, Saxena and Nitin, "DWT-SVD-based color image watermarking using dynamic-PSO," In Advances in Computer and Computational Sciences, pp. 343-351, 2018.
34. Shojanazeri, Hamid, Wan Adnan Wan Azizun, Mumtadzah Syed Ahma and Sharifah, "Video watermarking techniques for copyright protection and content authentication," Industrial Management Applications and Computer Information Systems, vol.5, no. 1, pp.652-660, 2013.
35. Thanki, Borra, and Dey, "Digital image watermarking: theoretical and computational advances," CRC Press, 2018.
36. Sundararaj V "Optimal task assignment in mobile cloud computing by queue based ant-bee algorithm" Wireless Pers Commun, Vol.104, No.1, pp.173–197, 2019.
37. Kuchenbrod, Harr Caihua Chen and Daniel Brown, "Barcode readers having multiple image sensors and methods associated therewith," vol.10, no.354, pp.110, 2019.
38. Patrikar Joshi, and Mishra, "Design of real-time video watermarking based on Integer DCT for H. 264 encoder," International Journal of Electronics, vol.102, no.1, pp.141-155, 2015.
39. Pradeep Chincholli and Krishnakumar, "A Comparative performance analysis of DCT, DWT-SVD, DCT-DWT-SVD digital water marking algorithms," In Contemporary Computing (IC3), International Journal for Technological Research in Engineering, vol.3, no.8, 2016.
40. Khanapuri, Jain and Ambadekar, "Digital Image Watermarking Through Encryption and DWT for Copyright Protection," In Signal and Image Processing, pp. 187-195, 2019.
41. Mukherjee, "Lightweight IoT security middleware for end-to-end cloud-fog communication, 2017.
42. Indoriya, Aditi and Sharma, "A Chronological Review on Digital Watermarking," Applied Research Engineering, vil.13, no. 21, 15383-15385, 2018.
43. Hana Ouazzane, Hela Mahersia, Kamel Hamrouni, "A Robust Multiple Watermarking Scheme-DWT," Signals and Devices, pp. 18-21, 2013.
44. Najaf, "A robust embedding and blind extraction of image watermarking based on discrete wavelet transform" vol.11, no.4, pp.307–318, 2011.
45. Lin WH, Wang YR, Horng SJ, Kao TW, Pan, "Blind watermarking method using maximum wavelet coefficient quantization," Expert Systems with Applications, vil.36, no.9: pp.11509-16, 2009.
46. Lee, J.S. and Li, B., 2014, "Self-recognized image protection technique that resists large-scale cropping," Multimedia, 2, no.1, pp.60-73.
47. Vinu Sundararaj, "An efficient threshold prediction scheme for wavelet based ECG signal noise reduction using variable step size firefly algorithm," Int J Intell Eng Syst, Vol.9, No.3:pp.117–126,2016.
48. Rejeesh, M.R., "Interest point based face recognition using adaptive neuro fuzzy inference system," Multimedia Tools and Applications, pp.1-20, 2019.
49. Sundararaj Vinu, Selvi Muthukumar, and R. S. Kumar. "An optimal cluster formation based energy efficient dynamic scheduling hybrid MAC protocol for heavy traffic load in wireless sensor networks" Computers & Security, vol. 77, pp. 277-288, 2018.