Digital Watermark Technique: A Review

Zainab F. makhriv1* and Abdulamir A. karim 2
1Computer Science Department, university of Technology, Baghdad, Iraq, 
cs.19.13@grad.uotechnology.edu.iq
2Computer Science Department, university of Technology, Baghdad, Iraq, 
110004@uotechnology.edu.iq
E-mail: cs.19.13@grad.uotechnology.edu.iq

Abstract. Multimedia security is extremely significant concern for the internet technology because of the ease of the duplication, distribution and manipulation of the multimedia data. The digital watermarking is a field of information hiding which hide the crucial information in the original data for protection the illegal duplication and distribution of multimedia data. This paper presents a survey on the existing digital image watermarking techniques. In the digital watermarking the secret information are implanted into the original data for protecting the ownership rights of the multimedia data. The image watermarking techniques may divide on the basis of domain like spatial domain or transform domain. The while spatial domain techniques directly work on the pixels and the frequency domain works on the transform coefficients of the image. This survey elaborates the most important methods of spatial domain and transform domain and focuses on the merits and demerits of these techniques.

1. Introduction

Digital Watermarking is a technology of embedding watermark with intellectual property rights into images, videos, audios and other multimedia data by a certain algorithm. This kind of watermark contains the author, which could be the owner’s logo, serial number or control information. In fact, it’s making use of the ubiquitous redundancy and randomness in data, and adding to the data information which is difficult to be detected but can be distinguished to protect product copyright and data integrity. It may also be text only [1-3]. At present, it is very common to access and use digital multimedia data available over internet. Digital advancement of technological facilities makes it very easy for everyone to use digital information to fulfill their different needs. Number of digital images is transmitted over the internet the digital communication technology, like internet technology confronts various troubles related to the privacy and security of the data. Security techniques are required because of illegal access of data without permission. Therefore, it is necessary to protect data in the internet. For providing the security of digital data various techniques are used like encryption, decryption, and cryptography [4, 5]. Digital image watermarking technology has got high attention by the international academia and the business community, and become one of the fastest growing hot technologies in information security field

The earliest method used for copyright protection of multimedia content is the password authentication technology [6]. In the decade, digital, media have emerged and there is a vital need for protecting the digital content against counterfeiting, piracy and malicious visible or invisible watermarks are embedded inside an image to show authenticity or proof of ownership. The hidden watermark should be inseparable from the host image, robust enough to resist any manipulations while preserving the image quality [7, 8]. Copyrighted material can be easily exchanged over peer-to-peer networks, and this has caused major concerns to those content providers who produce these digital contents [9, 10].

2. Related Work

Some related works are addressed by the literature review to present a brief about the Digital watermark:

- In 2010 C. Lai and C. Tsai suggested a hybrid image-watermarking scheme based on discrete wavelet transform (DWT) and singular value decomposition (SVD). The watermark is not embedded directly on the wavelet coefficients but rather on the elements of singular values of the cover image's DWT sub bands. Experimental results are provided to illustrate that the proposed approach is able to withstand a variety of image-processing which attacks technique used in many safety-critical systems. Complexity in hardware and software reduces the reliability of the system. To reduce the probability of failure on demand, need to optimize the complexity of hardware and software. The technique fully exploits the respective feature of these two transform domain methods: spatial-frequency localization of DWT and SVD transactions on instrumentation and measurement efficiently represents intrinsic algebraic properties of an image. Experimental results of the proposed technique have shown both the significant improvement in imperceptibility and the robustness under attacks [11].

- In 2012 Surya Pratap Singh and et.al suggested that approach a robust watermarking using DCT-DWT this presents a robust watermarking technique for color and gray scale image. In the proposed technique the watermark is embedded in 3rd level of DWT (Discrete Wavelet Transform) and before embedding the watermark image is passed through chaotic encryption process for its security, other important thing is that in the proposed method watermark is embedded in the form of DCT (Discrete Cosine Transform) with special coefficient shifting algorithm to minimize the impact on main image. The performance of the proposed watermarking is robust to a variety of image processing techniques, such as JPEG compression, Enhancement, resizing, and geometric operations. The results show that the proposed method gives very good results and the watermark is resilient to many types of attack. The overall analysis also shows that the works better for color images than gray images, the other important thing is that by the proposed technique we can embed full color watermark image which is not possible with many previously proposed techniques. [12].

- In 2013 Anumol Joseph and et.al they worked on image robust watermarking algorithm that is DWT SVD technique. DWT (Discrete Wavelet Transform) and SVD (Singular Value Decomposition) have been used to embed two watermarks in the HL and LH bands of the host image. The host image and the watermark images are decomposed by DWT using Haar wavelet. The watermark images are embedded on the HL and LH bands of the host image by modifying the singular values of the host image .a new image watermarking algorithm that is robust against various attacks is presented. The proposed techniques withstand various attacks As a quantitative measure of the degradation effect caused by the attacks PSNR is used. The protection of ownership and the prevention of unauthorized manipulation of digital audio, image, and video materials has become an important concern due to the ease of editing and perfect reproduction. Watermarking is identified as a major means to achieve copyright
protection. The performance was evaluated using RMSE, PSNR and correlation coefficient. Simulation results show that this method is robust against various types of attacks [13].

- In 2018 Poonam and et.al suggested A DWT-SVD based Robust Digital Watermarking for Digital Images, where a digital watermark can be embedded in host data in spatial domain as well as in frequency domain. In this work a hybridized technique incorporating Discrete Wavelet Transform (DWT) and Singular Value Decomposition (SVD) has been presented. The watermark has been inserted over the singular values of the cover image’s sub bands. Simulation results have shown that this technique is able to attain good imperceptibility, as the perceptual quality has not been degraded. Experiment results presented illustrates that there are noteworthy improvements in terms of imperceptibility. The attained values of MSE, PSNR and SSIM demonstrates that DWT-SVD provide significant robustness when subjected to different image signal processing attacks [14].

- In 2019 Hung-Jui Ko and et.al This study presents a robust and transparent watermarking method that exploits block-based discrete cosine transform (DCT) coefficient modification. The difference in the DCT coefficients of two blocks is calculated and modified based on the watermark bit to adjust this difference to a predefined range. The first coefficient in the upper left corner of the array basis function is known as the direct current (DC) Coefficient, whereas the remainder includes the alternating current (AC) coefficients. The extent of the DCT coefficient modifications depends on the DC coefficient and median of the AC coefficients ordered by a zigzags sequence. And experimental results demonstrate that the proposed method possesses great robustness against various single and combined attacks. The proposed method considers coefficient correlation and we apply minor changes in each 8 × 8 DCT block. The proposed watermarking method outperforms the previous methods. We demonstrated good robustness against single and combined attacks, such as cropping, rotation, and median filtering. In comparison with the previous methods, the proposed method is more effective for the copyright protection of digital images [15].

- In 2020 Tuba and et al. suggested that, where combined both LSB and DWT technique which has been implemented to form a secure and robust digital image watermarking has reviewed and implemented the discrete wavelet transform and singular value decomposition with LSB-based techniques to protect the digital rights. The schemes are to develop authentic intellectual properties and prevent them from exhibiting to unknown user. The cover image (the image in which watermark is inserted) is to be fractioned into (HH, LH, LL, and HL) by using commonly used method of transforming frequency domain. This transform can be directly applied to each and every subordinate bands of the original image. The extraction mechanisms work in accordance with the previous work done by the embedding algorithm. The output and the frequency of image will determine strength, apparently maintaining the better quality and robustness to many attacks to compromise the security of intellectual property such as JPEG compression, Gaussian noise, and there are many more. Experimental results of the proposed technique have shown both the significant improvement in imperceptibility and the robustness under attacks. If you are the watermarked image attacked by trimming, compression, brightness adjusting, filtering, and noises which can be modified to get the private intellectual property, the process will become more visible and robust. These outcomes conceal that the proposed method is more suitable [16].

- In 2020 Hilkiya Joseph and et.al they proposed method is Combination of DWT and DCT is capable to produce best quality digital watermark. Using combination of appropriate transforms with the DWT will result in the beneficial effect on working of the watermarking system. Digital Watermarking can be performed by embedding the secret image on the DWT sub bands of the image in which the secret image is inserted, and then DCT was performed in the chosen DWT sub bands. The proposed method improved the quality of watermarking and achieves imperceptibility & robustness when compared to the prevailing watermarking approach. The results obtained were analyzed on the basis of PSNR and MSE value. The
calculated PSNR and MSE value proven that the watermarking does not affect quality of image severely when compared to other prevailing methods [17].

3. Digital Watermarking
Digital image watermarking is a technique of embedding a watermark image inside the cover image or data. Watermarking is a technique that shows the proof of ownership of the data or a multimedia object. Digital image watermarking provides copyright protection and authentication of data. Many authors are using various techniques for embedding watermark images inside the cover image. The embedding method is used to determine the location in which the watermark is embedded inside the cover image. The embedding method also determines whether a watermarking which is robust against various attacks like cropping, Gaussian noise, and other image processing attacks [18].

Digital watermarking increases the security of the data and protects the information from unauthorized access. Watermark information can be patent information, authentication information to determine the copyright owner of the digital works, it also certifies the reliability and probity of the multimedia works. It is used for the identification of the ownership of the copyright of an image. Digital watermarking is a code that is embedded in the image. It is very similar to steganography as in both the information is embedded inside the cover message with less or no degradation of the cover–object [19-23].

4. Digital Image Watermarking stages
Digital Watermarking is a technique that is used in digital signal processing by embedding hidden information into multimedia data. This information is not usually visible, only a dedicated detector or extractor can see and extracts that information. Digital Image Watermarking uses the digital image for embedding the hidden information, after embedding the watermarked image is generated and the watermarked image must be robust against attacks. Figure 2 shows the stages of digital watermarking. The working of digital image watermarking can be divided into three stage [24-27].

4.1. Embedding Stage
The embedding stage is the first stage in which the watermark is embedded in the original image by using the embedding algorithm and the secret key. Then the watermarked image is generated. The watermarked image is transmitted over the network.

4.2. Distortion/Attack Stage
In this stage, when the data is transmitted over the network. Either some noise is added with the watermarked image or some attacks are performed on the watermarked image. So, our watermarked data is either modified or destroyed.

4.3. Detection/Retrieval Stage
In the detection stage, the watermark is detected or extracted by the dedicated detector from the watermarked image by applying some detection algorithm and by using the secret key. In addition to this, noise is also detected [28][29].

![Figure 2 Stages in Digital Image Watermarking.](image-url)
5. Digital Image Watermarking Techniques

In the field of digital watermarking, digital image watermarking has attracted a lot of awareness in the research community for two reasons: one is its easy availability and the other is it conveys enough redundant information that could be used to embed watermarks. Digital watermarking contains various techniques for protecting digital content [32, 33].

Digital Watermarking Technique is classified into two major approaches these are:
- Spatial Domain
- Frequency Domain

The algorithm used for a spatial domain is less robust for various attacks as the changes are made at the Least Significant bit (LSB) of original data. While in the transform domain the watermark is embedded by changing the magnitude of coefficients in a transform domain with the help of discrete cosine transform (DCT), discrete Fourier transform (DFT), discrete wavelet transform (DWT)[34-36].

5.1. Spatial Domain Watermarking

The spatial domain represents the image in the form of pixels. The spatial domain watermarking embeds the watermark by modifying the intensity and the color value of some selected pixels [37, 38]. The strength of the spatial domain watermarking is
- Simplicity.
- Very low computational complexity.
- Less time-consuming.

The spatial domain watermarking is easier and its computing speed is high than the transform domain but it is less robust against attacks. The spatial domain techniques can be easily applied to any image. The most important method of the spatial domain is LSB [38-39].

5.1.1. Least Significant Bit

Least Significant Bit (LSB): Least Significant Bit (LSB) method is the simplest technique of this domain. The watermarks are embedded in the last (i.e., least significant) bit, of selected pixels of the image. This method is easy to implement and does not generate serious distortion to the image; however, it is not very robust against attacks. For instance, an attacker could simply randomize all LSBs, which effectively destroys the hidden information. Figure 3 shows the least significant bit (LSB) scheme [40].

5.2. Transform Domain Watermarking

The transform domain watermarking is achieving very much success as compared to the spatial domain watermarking. In the transform domain watermarking, the image is represented in the form of frequency. In the transform domain watermarking techniques, firstly the original image is converted
by a predefined transformation. Then the watermark is embedded in the transformed image or the transformation coefficients. Finally, the inverse transform is performed to obtain the watermarked image. The most commonly used transform domain methods are Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), and Discrete Fourier Transform (DFT) [41-43].

5.2.1. Discrete Cosine Transform
Discrete Cosine Transform (DCT) is used for signal processing. It transforms a signal from the spatial domain to the frequency domain. DCT is applied in many fields like data compression, pattern recognition, and every field of image processing. DCT watermarking is more robust as compared to the spatial domain watermarking techniques. The main steps which used in DCT [44]:

1. Segment the image into non-overlapping blocks of 8x8.
2. Apply forward DCT to each of these blocks.
3. Apply some block selection criteria (e.g. HVS).
4. Apply coefficient selection criteria (e.g. highest).
5. Embedded watermark by modifying the selected Co-efficient.
6. Apply inverse DCT transform on each block.

In DCT, for embedding the watermark information, we divide the image into a different frequency. FL denotes the lowest frequency component of the block, while FH denotes the higher frequency component and FM denotes the middle-frequency component which is chosen as the embedding region. The Discrete cosine transform achieves good robustness against various signal processing attacks because of the selection of perceptually significant frequency-domain coefficients [45]. Merits of DCT:

• DCT is better than any of the spatial domain techniques because it is robust against various kinds of attacks like cropping, noising, filtering, and sharpening.
• DCT is a real transform with better computational efficiency.
• The DCT gives a better performance in the bit-rate reduction.
• DCT also implements fast algorithms.

5.2.2. Discrete Wavelet Transform
Discrete wavelet transform (DWT) of the image produces a multi-resolution representation of an image. The multi-resolution representation provides a simple framework for interpreting the image information. The DWT analyses the signal at multiple resolutions. DWT divides the image into high-frequency quadrants and low-frequency quadrants. The low-frequency quadrant is again split into two more parts of high and low frequencies and this process is repeated until the signal has been entirely decomposed. The single DWT transformed two-dimensional images into four parts. One part is the low frequency of the original image, the top right contains horizontal details of the image, the bottom left contains vertical details of the original image, the bottom right contains the high frequency of the original image. The low-frequency coefficients are more robust to embed watermark because it contains more information of the original image. The reconstruct of the original image from the decomposed image is performed by IDWT [46-48]. The digital wavelet transform is scalable. DWT is more frequently used in digital image watermarking because of its excellent spatial localization and multi-resolution techniques. The excellent spatial localization property is very convenient to recognize the area in the cover image in which the watermark is embedded efficiently [49]. Merits of DWT over DCT:

• DWT gives better visual image quality as compared to the DCT.
• In DWT, dividing the input coding into the non-overlapping 2-D block is not necessary; its higher compression ratios avoid blocking artefacts.
• DWT allows better localization as compared to the DCT.
• The watermarking method is robust to wavelet transform-based image compression as well as to other common image distortions like rescaling half toning, additive noise, etc. This is also an advantage over DCT [50].
• The DWT understands the working of HVS more clearly than the DCT.
• DWT defines the multi-resolution description of the image. So, the image can be shown in different levels of resolution and proceed from low resolution to high resolution.

Demerits of DWT over DCT:
The main disadvantage of DWT is that the DWT is more complex than the DCT. When DCT is used it takes 54 multiplications to compute for a block of 8x8, distinct wavelet calculation depends upon the length of the filter used, whom at least one multiplication per coefficient. The other drawback is that computation cost is higher and its computation time is longer.

5.2.3. Discrete Fourier Transform
Discrete Fourier Transform (DFT) offers robustness against geometric attacks like rotation, scaling, cropping, translation, etc. DFT decomposes an image in sine and cosine forms. The DFT-based watermark embedding techniques are divided into two types: one is direct embedding and the other one is template-based embedding.

According to the direct embedding technique, the watermark is embedded by modifying DFT magnitude and phase coefficients. The template-based embedding technique introduces the concept of templates. A template is a structure that is embedded in the DFT domain to estimate the transformation factor. Once the image transforms this template is searched to resynchronize the image, and then the detector is used to extract the embedded spread spectrum watermark [51].

Some characteristics of DFT:
• In the DFT, the real image is normally complex-valued, which results in the phase and magnitude representation of an image.
• The main & strongest component of the DFT is the central component which contains low frequency.
• DFT is also resistant to cropping because the effect of cropping leads to the blurring of the spectrum. If the watermarks are embedded in the magnitude, which is normalized coordinates, there is no need for any synchronization.
• Scaling of the image results in amplification of the extracted signal and can be detected by correlation coefficient.

Advantages of DFT over DWT and DCT:
The DFT is Rotation Scaling Translation (RST) invariant. So, DFT can be used to recover from geometric distortion, whereas the spatial domain, DCT, and DWT are not RST invariant. Hence, it is difficult to overcome geometric distortions [52].

The disadvantage of DFT over DWT and DCT:
The main disadvantage of the DFT is that the output of the DFT is always in complex value and it requires more frequency rate. Its computational efficiency is very poor. So, the DFT is not used because of these disadvantages.

Table 1 Comparisons between watermarking techniques.

| Method | Speed | Payload | Attacks |
|--------|-------|---------|---------|
| LSB    | This method has the advantage that comprehension, quick implementation | It provides high perceptual transparency with a negligible impact on the host image | Can be affected by undesirable noise, cropping, lossy compression, the embedded watermark easily without any difficulty |
| DCT    | Implement fast algorithms. | Watermarks in high frequency band tend to have less influence on the quality of original image | Proving the better robustness, security, and imperceptibility against various attacks, such as compression, noise, filtering |
| DWT    | The computation cost is higher and its computation time is | More robust to embed watermark because it contains more information of the | Algorithm achieves higher security and robustness against JPEG compression as well as |
6. Conclusions

Digital watermarking is a very useful method for providing security to the digital media on the internet technology. In this paper, a survey of different techniques based on spatial domain (LSB) and the transform domain (DCT, DWT, and DFT). This survey analyses the limitations and strengths of the watermarking methods. Digital watermarking is still a challenging research field with many interesting problems like it does not always prevent copying or distribution and also cannot survive in every possible attack. One future research pointer is the development of the truly robust, transparent, and secure watermarking technique for different digital media including images, video, and audio.

References

[1] Zhang Y 2009 Digital watermarking technology: A review 2009 Int. Conf. Futur. Comput. Commun. FCC 2009 250–2
[2] Mohanty S P and Florida S 1999 Digital Watermarking: A Tutorial Review Channels
[3] Bhjet Abdul Wahab H, Jaber Abdul Mohssen and Ahmed Kadhom S 2017 Variant length, Self-extracted audio watermark for verification using LWT and random selections Diyala J. Pure Sci. 13 132–46
[4] Sinhal R, Ansari I A and Ahn C W 2020 Blind Image Watermarking for Localization and Restoration of Color Images IEEE Access 8 200157–69
[5] Saini L K and Shrivastava V 2014 A Survey of Digital Watermarking Techniques and its Applications 2 70–3
[6] Ma Y, Wang S, Song J, Yu Y, Sun W and Bian J 2020 Comparison of the Schemes in Digital Image Watermarking Techniques J. Phys. Conf. Ser. 1617
[7] Sharma P and Swami S 2013 Digital Image Watermarking Using 3 level Discrete Wavelet Transform Conf. Adv. Commun. Control Syst. 2013 129–33
[8] Hiraguchi H 2019 Study on new creep equation using discrete cosine transform for high temperature materials Heliyon 5 e02619
[9] Amudha J, Pradeepa N and Sudhakar R 2012 A survey on digital image restoration Procedia Eng. 38 2378–82
[10] Ali Y H and Mahdi B S 2011 Watermarking for Relational Database by using Threshold Generator Eng. Tech. J. 29 33–44
[11] Lai C and Tsai C 2010 Digital Image Watermarking Using Discrete Wavelet Transform and Singular Value Decomposition 59 3060–3
[12] Singh S P, Ruwat P, Agrawal S and Ransform D I C O T 2012 A Robust Watermarking Approach using DCT-DWT 2 300–5
[13] Joseph A and Anusudha K 2013 Robust watermarking based on DWT SVD 1
[14] Poonam and Arora S M 2018 A DWT-SVD based Robust Digital Watermarking for Digital Images International Conference on Computational Intelligence and Data Science (ICCID 2018) vol 132 (Elsevier B.V.) pp 1441–8
[15] Ko H J, Huang C T, Horng G and WANG S J 2020 Robust and blind image watermarking in DCT domain using inter-block coefficient correlation Inf. Sci. (Ny). 517 128–47
[16] Kumar A 2020 A Review on Implementation of Digital Image Watermarking Techniques Using LSB and DWT vol 933 (Springer Singapore)
[17] Joseph H and Rajan B K 2020 Watermarking Technique 940–5
[18] Panchal U H and Srivastava R 2015 A comprehensive survey on digital image watermarking techniques Proc. - 2015 5th Int. Conf. Commun. Syst. Netw. Technol. CSNT 2015 591–5
[19] Pal M M 2016 A Survey on Digital Watermarking and its Application Int. J. Adv. Comput. Sci. Appl. 7 153–6
[20] Kaur M, Jindal S and Behal S 2012 A Study of Digital Image Watermarking Ijreas 2 126–36
[21] Bhatnagar G and Raman B 2009 A new robust reference watermarking scheme based on DWT-SVD Comput. Stand. Interfaces 31 1002–13
[22] Bellaaj M and Ouni K 2020 Audio watermarking technique in frequency domain: comparative study MDCT Vs DCT Multimed. Tools Appl. 79 27161–84
[23] Khare P and Srivastava V K 2020 A Secured and Robust Medical Image Watermarking Approach for Protecting Integrity of Medical Images Trans. Emerg. Telecommun. Technol. 1–17
[24] Rahma A M S and Meftin N K 2010 Watermarks Technique in MPEG-1Video by B-spline Eng. Tech. J. 28 2162–77
[25] Alrawi S S, Abdulshaheed R and Alhadithy A A 2011 Watermarking in WAV Files Bases on Phase Coding Eng. Tech. J. 29 2011
[26] Saini L K and Shrivastava V 2014 A Survey of Digital Watermarking Techniques and its Applications
[27] Salman H M 2007 A Content-Based Authentication Using Digital Speech Data Eng. Tech. J. 25 1162–70
[28] Singh S, Singh H V and Mohan A 2015 Secure and Robust Watermarking Using Wavelet Transform and Student t-distribution Procedia Comput. Sci. 70 442–7
[29] Salman H M 2008 Content-Based Authentication Using Digital Speech Data Eng. Tech. J. 26 228–38
[30] Dixit A and Dixit R 2017 A Review on Digital Image Watermarking Techniques Int. J. Image, Graph. Signal Process. 9 56–66
[31] mani H and Singh S 2017 A Survey of Digital Watermarking Techniques and Performance Evaluation Metrics Int. J. Eng. Trends Technol. 46 128–32
[32] Pinjari S A and Patil N N 2017 A pixel based fragile watermarking technique using LBP (Local Binary Pattern) Proc. - Int. Conf. Glob. Trends Signal Process. Inf. Comput. Commun. ICGTSPICC 2016 194–6
[33] Nasereddin H H O 2011 Digital watermarking a technology overview 6 89–93
[34] Mnkash S H and Abdulmunem M E 2020 A review of software watermarking Iraqi J. Sci. 61 2740–50
[35] Evsutin O, Melman A and Meshcheryakov R 2020 Digital Steganography and Watermarking for Digital Images: A Review of Current Research Directions IEEE Access 8 166589–611
[36] Hassan N F and Jaber R K 2014 Proposed Algorithm for Digital Image Watermarking Survival against JPEG Compression Eng. Tech. J. 32 114–26
[37] Rahma A M, Abdulmunem M E and Al-janabi R J S 2015 New Spatial Domain Steganography Method Based On Similarity Technique Int. J. Eng. Technol. Vol. 5 45–8
[38] Hassan N F and Jaber R K 2014 Proposed Algorithm for Digital Image Watermarking Survival against JPEG Compression Eng. Tech. J. 32 114–26
[39] Gupta S, Gujral G and Aggarwal N 2012 Enhanced Least Significant Bit algorithm For Image Steganography IJCEM Int. J. Comput. Eng. Manag. ISSN 15 22307893
[40] Telagarapu P, Naveen V J, Prasanthi A L and Santhi G V 2011 Image Compression Using DCT and Wavelet Transformations Int. J. Signal Process. Image Process. Pattern Recognit. 4
[41] Potdar V M, Song H and Elizabeth C 2005 A survey of digital image watermarking techniques 2005 3rd IEEE Int. Conf. Ind. Informatics, INDIK 2005 709–16
[42] Mahdi A F 2015 Hybrid Algorithm to Improve Robustness of Image Watermarking Eng. Tech. J. 33 564–70
[43] Potdar V M, Song H and Elizabeth C 2005 A survey of digital image watermarking techniques 2005 3rd IEEE Int. Conf. Ind. Informatics, INDIN 2005 709–16
[44] Hassan N F and Jaber R K 2015 Propose an Image Watermarking Algorithm Stand against JPEG Compression based on Space Transformation and Image Features Al-Mansour J. 1–16
[45] Awaghate A, Thakare R and Kakde S 2019 A brief review on: Implementation of digital watermarking for color image using DWT method Proc. 2019 IEEE Int. Conf. Commun. Signal Process. ICCSP 2019 161–4
[46] Ali M and Jafer S H 2019 Steganography Secret Message Using Wavelet 2D Image Fusion J. Math. Stat. Sci. 420–32
[47] Mohideen S K, Perumal S A and Sathik M M 2008 Image De-noising using Discrete Wavelet transform Int. J. Comput. Sci. Netw. Secur. 8 8–11
[48] Al-hussaini S M A I H 2007 A Secure Invisible Watermarking Using Rijndael Algorithm and Wavelet Transform Eng. Tech. J. 25 1028–40
[49] Mironov R P and Kushlev S 2019 Simulation Model for Medical Images Watermarking using Wavelet Transform and DCT 27–9
[50] Rashed A A 2011 Information Hiding Based on Discrete Time Wavelet Transform and Huffman Coding Eng. Tech.,Journal 29 295–304
[51] Ahire V K and Kshirsagar V 2011 Robust Watermarking Scheme Based on Discrete Wavelet Transform (DWT) and Discrete Cosine Transform (DCT) for Copyright Protection of Digital Images IJCNSNS Int. J. Comput. Sci. Netw. Secur. 11 208–13
[52] Lone A H and Chauhan R 2017 Comparative Analysis of DCT and DWT based novel methods for Watermarking Int. Res. J. Eng. Technol. 4 230–4