

Image Color Watermarking within Past Seven Years

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Abstract— In these day and age by fast growing the knowledge and internet, producing, distributing and manipulating of digital date become an easy task to do. Based on the other researcher result, illegal reproduction of digital information reported as the main concerned and a real problem [1, 2]. There are many problems, which arise such as copyright protection, tamper detection, ownership rights and so on [3-6]. This has raised questions and concerns about [4]. Thus, many researchers try to find the solution to addressing these problems. Digital watermarking provides a solution which purpose to solve these problems [5].

Keywords— Image watermark, Robustness, Watermark method, RGB, Human Visual System

I. INTRODUCTION

In these day and age by fast growing the knowledge and internet, producing, distributing and manipulating of digital date become an easy task to do. Based on the other researcher result, illegal reproduction of digital information reported as the main concerned and a real problem [1, 2]. There are many problems, which arise such as copyright protection, tamper detection, ownership rights and so on [3-6]. This has raised questions and concerns about [4]. Thus, many researchers try to find the solution to addressing these problems. Digital watermarking provides a solution which purpose to solve these problems [5].

In short, Digital Watermarking refers to embedding a secret imperceptible data (called watermark) in the original digital data [6]. The watermark should be embedded into digital data in such a way that the attacker could not remove it.

There are many researchers has been worked to purpose new solution. Thus, it is necessary to gathering information for existing and new researchers to find some solutions in one shut. In this paper, we provide the review of twenty-five research work papers which focusing on colour image watermarking. Because of colour image is more common these days (instead of gray scale image), this paper focus on colouring image only. The purpose of this paper is to gathering abstract of recently five years' researcher's methods, attacked that they show result, compare their methods and result of these papers on color image watermarking. The paper structured to define basic knowledge of watermarking, category of methods that used for watermarking, define some attacks, and compare their results.

II. BACKGROUND

Shows the digital watermarks, features, their techniques and application are classified and segmented into various categories.

A. Characteristics / robustness

1) *The Robust* refers to the signing of copyrights on a digital media. The watermark has the ability to withstand from general editing, image processing or compression of the image by cutting out parts. The watermark will still remain in place despite these attacks and be recognisable enough [7]. 2) *Fragile* helps to determine whether the data has been tampered or not. It is highly sensitive to changes for integrity protection [7]. 3) *Semi fragile* has the ability to sustain some attack or a change to an image, such as compression or the inclusion of quantization noise [7].

B. Attached media / host signal

1) *Image watermarking* can be used to conceal unique information into the image, which can also be retrieved at any time [8]. 2) *Video watermarking* can be controlled by adding a watermark to the stream. Video watermarking makes use of updated time extraction and robustness for compression [9]. 3) *Audio watermarking* can be easily downloaded for free via the internet and therefore audio watermarking remains as one of the most popular issues of today [10]. 4) *Text watermarking* is the most common type of watermark is text watermarking. It is used to protect confidential text files such as PDF file [11]. 5) *Graphic watermarking* is the watermarks are embedded into 2D or 3D graphics in order to indicate its copyrights [12].

C. Perceptivity

1) *Visible watermarking* is the widely watermarks printed or stamped in large font over text files or the logo [13, 14]. 2) *Invisible watermarking* is hidden inside the media and can only be recovered with especial suitable software. It can help prove the authentic author's ownership [13, 14].

D. Watermarking Purpose

1) *Copyrighting Protection watermarking* can be visible over the image if the owner wishes so. The watermark will exist even if it is attacked [15]. 2) *Tamper Tip watermarking* is maintained with this method as it avoids tampering such as

copying [16]. 3) *Anti-counterfeiting watermarking* can usually be detected after processes such as scanning or printing and embedded within the paper notes [17]. 4) *Anonymous mark watermarking* is Confidential data can be protected. Watermarking conceals the important notes related to the confidential text [11].

E. Watermarking Type

1) *Noise type* includes pseudo noise, Gaussian random and chaotic sequences [11]. 2) *Image type* is the binary, logo, stamps and labels [11].

F. Watermarking Domain

1) *Spatial domain* is mainly working on changing or modifying some pixels in certain regions by directly loading the information into the picture. Some of the algorithms used are LSB and SSM [18]. 2) *Frequency domain* is also known as the transform domain. Some Frequencies can be changed from their original mode. The most common modes are DCT, DWT, and DFT [19]. To compare these two domains, you can follow Table 1.

TABLE 1. COMPARISON BETWEEN SPATIAL AND FREQUENCY DOMAIN [18, 19]

Factors	Spatial Domain	Frequency Domain
Computation Cost	Low	High
Robustness	Fragile	More Robust
Perceptual Quality	High Control	Low Control
Computational Complexity	Low	High
Computational Time	Less	More
Capacity	High	Low
Example	Mainly Authentication	Copyrights

G. Detection process

1) *Visual watermarking*: The robustness of this watermarking is high and needs the original data [7]. 2) *Semi blind watermarking*: It is not require an original media work in order to detect [7]. 3) *Blind watermarking*: It is not required any original media for detection. It means, it needs a much higher level of watermarking [7].

H. Use of keys

1) *Asymmetric watermarking*: It used different keys in embedding and different keys in detection [7]. 2) *Symmetric watermarking*: It used the same key to both embed and detect the watermark [7].

I. Digital Watermarking Features

The features of digital watermarking are shown in Fig. 1.

J. Region of Interest (ROI)

1) The Region of interest is one of the most important factors in watermarking. Finding the ROI almost is the consideration of researchers [42]. In the previous researchers, focusing the method to implement a mathematical way to find ROI, but recently one researcher, working on the way to find ROI before do implementations [42].

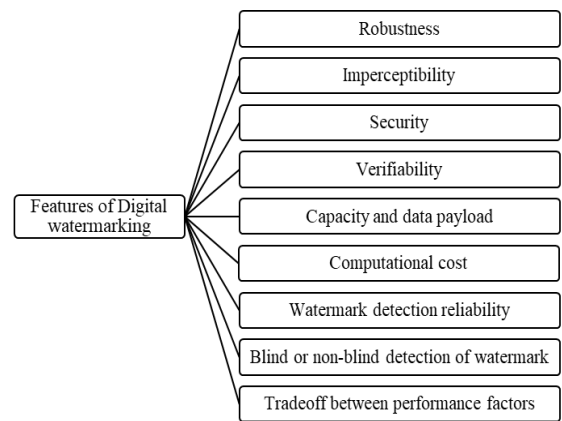


FIGURE 1. DIGITAL WATERMARKING FEATURES

K. Digital Watermarking Requirements

2) *Robustness* of a watermark is its ability to withstand modifications. The more fragile the watermark is, the more easily can be image manipulation. Two issues that can occur in guaranteeing robustness are that either the watermark must still be available despite its modifications or the software must be able to detect the watermark [7]. 2) *Security* a truly secure watermark means that cannot be detected even with knowledge of the algorithms and only works with the original key. A well secured watermark cannot be distorted without altering the main signal. Watermarking security aims to protect secrecy, integrity and information while having the ability to hold out against attacks [20]. 3) *Capacity* of a watermark determines the number of bits that can be concealed. The requirement for capacity must always be seen in relation to imperceptibility and robustness. If you need a higher capacity, then you need to sacrifice on the strength of robustness and/or imperceptibility [11]. 4) *Imperceptibility* means that the watermark should not be visible to the human eye and should not damage the original content. Therefore, it is imperative to make use of unnoticeable watermarks in different areas of the image to counter any problems faced by signals [21]. 5) *Modification and Multiple Watermarks* of modifying a watermark can be either removing the first one and replacing it with another, or simply adding a second watermark. The first method however makes the fact that the watermark is not tamper-resistant evident as it can be easily removed and therefore it is preferred to use the second option. However, there are security issues regarding the coexistence of multiple watermarks [11]. 6) *Invertibility* talks about the ability to create the original data while attempting to retrieve the watermark. For example, if someone wants to conceal a large amount of data, they cannot require a high level of robustness at the same time. Therefore, an acceptable level of balance is required. A message than can be concealed well should not be too lengthy as robustness is an issue [11].

III. RELATED WORK

Since 2001, there are number of works related to digital color image watermarking. This section describes the most recently 20 papers related to novel methodologies for colour image watermarking between years 2013 till 2019.

1) *A blind dual color images watermarking based on singular value decomposition:* A blind watermarking scheme based on Singular Value Decomposition (SVD) is presented. According to the feature of SVD which efficiently represents intrinsic algebraic properties of an image, the color watermark image is embedded into a color host image by modifying the relation between the second ($u_{2,1}$) and the third ($u_{3,1}$) elements of U matrix in each block after SVD. Without the original host image or original watermark, the embedded watermark can be extracted from different attacked images successfully. The experimental results show that It is scheme succeeds in making the watermark perceptually invisible and also robust against various signal processing operations and geometric attacks [22].

2) *A blind color image watermarking based on DC component in the spatial domain:* This paper proposed a color image blind watermarking algorithm. Firstly, the Y luminance of host image is divided into 8×8 sub-blocks and the DC coefficients of each block are directly calculated in the spatial domain without DCT transform. Secondly, according to the watermark information and the quantization step, the DC coefficients are calculated, and their increments are further utilized to modify directly the values of all pixels in the spatial domain instead of the DCT domain to embed watermark. The experimental results have been shown that the proposed algorithm has a higher watermark invisibility and robustness. The eminent features of this algorithm are: (1) the watermark is embedded into the DC components in the spatial domain, rather than in the DCT domain; (2) the proposed algorithm is simpler and high efficient [23].

3) *A novel blind digital watermarking algorithm for embedding color image into color image:* A robust and blind watermarking technique for dual color images proposed in this paper. According to the energy-concentrating feature of DCT, the two-level DCT is introduced and used to embed color watermark image into color host image, which is completely different with the traditional DCT. The color watermark image is embedded into a color host image by modifying the AC coefficients of two-level DCT. Without the original data, the embedded watermark can be successfully extracted from the watermarked image. The experimental results show that the proposed scheme outperforms other works, more robustness and invisibility of watermark [24].

4) *A robust blind color image watermarking in quaternion Fourier transform domain:* This paper talks based on quaternion Fourier transform and least squares support vector machine (LS-SVM), it is a robust blind color image watermarking in quaternion Fourier transform domain, which has good visual quality. The proposed methods do not have (i) sensitive to color attacks because of ignoring the correlation between different color channels, and (ii) not robust to geometric distortions for neglecting the watermark resynchronization disadvantages. The experimental results show that the proposed method is not only robust against common image processing operations such as filtering, JPEG

compression, histogram equalization, and image blurring, but also robust against the geometrical distortions [25].

5) *A blind double color image watermarking algorithm based on QR decomposition:* In this paper, proposed a double color image-watermarking scheme. The strong correlation, between the second row first column coefficient and the third row first column coefficient in the unitary matrix Q of QR decomposition, has been utilized to embed and extract watermark. Watermark invisibility has been achieved by compensatory method in R matrix. Watermark robustness has been ensured by coefficients Second and third row of first column in the unitary matrix Q. The security by using the Arnold transform and the MD5 algorithm with different private keys enhanced. The experimental results have shown that it not only attains higher invisibility of watermarking and the method is robust against most common attacks including JPEG compression, JPEG 2000 compression, low-pass filtering, cropping, adding noise, blurring, rotation, scaling and sharpening [26].

6) *Adaptive color image watermarking by the use of quaternion image moments:* The proposed method exploits rotation invariance, high reconstruction capability and computation accuracy of the quaternion radial moments' (QRMs), subject to the tradeoff between robustness and imperceptibility. The method manages to experimentally justify and further eliminate the attack-free phenomenon that state-of-the-art methods suffer. The simulation results justified that the proposed to highly secure its carrying information under common signal processing and geometric attacking conditions. Three quaternion radial discrete orthogonal moment families (QRTMs, QRKMs and QRdHMs) have been examined as information carriers. There are no restrictions/limitations applying it in different domains such as DCT, DWT and QFT [27].

7) *Color image blind watermarking scheme based on QR decomposition:* This paper proposed a blind image watermarking scheme to embed color watermark image in to color host image, which is different from the binary or gray-level image as watermark based on QR decomposition work. Firstly, the color host image is divided to 4×4 non-overlapping pixel blocks. Then, each selected pixel block is decomposed by QR decomposition and the first row fourth column element in the matrix R is quantified for embedding the watermark information. In the extraction procedure, the watermark can be extracted from the watermarked. The experimental results, compared with the related existing methods, show that the proposed color image scheme has stronger robustness against most common attacks such as image compression, filtering, cropping, noise adding, blurring, scaling, sharpening and etc [28].

8) *Robust hybrid color image watermarking method based on DFT domain and 2D histogram modification:* This paper, proposed robust hybrid watermarking method applied to color images for authentication. First, the luminance component (Y) information is used to embed the watermark

bit sequence into the magnitude of the middle frequencies of the Discrete Fourier Transform (DFT). Second, a selected region of 2D histogram composed by blue-difference and red-difference (Cb–Cr) chrominance components is modified according to the watermark bit sequence. Also, the method is robust against several common signal processing distortions such as JPEG compression, median and Gaussian filtering, impulsive and Gaussian noise perturbation, brightness, contrast and sharpen and histogram equalization [29].

9) *Color image watermarking based on quaternion Fourier transform and improved uniform log-polar mapping:* This paper, proposed a blind color image watermarking scheme based on quaternion discrete Fourier transform (QDFT) and on an improved uniform log-polar mapping (IULPM). The proposed watermarking scheme embeds dual watermarks: one is a meaningful binary image watermark and the other is a bipolar watermark. The former is embedded in the real part of mid-frequency QDFT coefficients using quantization index modulation. The experimental results show that precision gained from IULPM remarkably enhances the watermark excellent robustness to histogram equalization, light adjustment, contrast adjustment, average filtering, JPEG compression, and cropping operation [30].

10) *A Robust Color Image Watermarking Scheme Using Entropy and QR Decomposition:* This Paper, proposed imperceptible non-blind color image watermarking algorithm which benefit from the fact that watermark can be hidden in different color channel. The method uses some algorithms such as entropy, discrete wavelet transforms, Chirp z-transform, orthogonal-triangular decomposition and Singular value decomposition in order to embed the watermark in a color image. First it divides cover image into three RGB color channels and then divides each channel into blocks with low entropy value are found and are used for watermark embedding. Each low entropy block is decomposed into frequency channels and further decomposed using CZT. Afterwards orthogonal-triangular decomposition is used to obtain upper-triangular matrix and unitary matrix. After that diagonal matrix is found and singular values are calculated. Watermark image singular values are added with decomposed singular values from original image and watermark is embedded. The experimental results are presented is robust, imperceptible and it outperforms other state-of-the art watermarking methods [31].

11) *A perception-based color image adaptive watermarking scheme in YCbCr space:* This paper, an image adaptive optimized DWT-SVD based color image watermarking scheme in YCbCr color space using HVS model has been proposed. The YCbCr color space is found as the optimum color space for watermark embedding with respect to RGB, YIQ and YUV color spaces and Barni et. al's HVS model is found equally applicable for that color space. The 'Cb' component of YCbCr color space is used for watermark embedding, as HVS is least sensitive in changes of blue color. Multiresolution property of DWT and stability of SVD makes the scheme robust [32].

12) *Robust and Invisible Image Watermarking in RGB Color space using SVD:* In this paper, two separate methods for robust and invisible image watermarking proposed in RGB color space. First, gray scale of watermark is embedded on the blue color channel elements and in second, the blue color channel elements of watermark are embedded on the blue color channel elements of host image. Then, Singular Value Decomposition (SVD) is employed on the blue channel of the host image to retrieve the singular values and the watermark is embedded in these singular values. The performances of the methods are assessed using Normalized Correlation (NC) and Peak-Signal-to-Noise-Ratio (PSNR) measures. The results are proving that the two proposed methods are provides good robustness [33].

13) *Discrete wavelet transform based color image watermarking using uncorrelated color space and artificial bee colony:* This paper, discrete wavelet transform (DWT) based color image watermarking method has been proposed which embeds the color watermark into host image using uncorrelated color space (UCS) and artificial bee colony (ABC) method. The results validate that the proposed method is better than other methods for all the considered parameters except slight decay in JPEG compression and rotation attacks as compared to Su et al. 23. It can be further investigated for other multimedia contents such as video signals. Also a comparative study of GA, PSO and ABC can also be taken up for future research in terms of computational time, complexity, etc [34].

14) *A novel blind color image watermarking based on Contourlet transform and Hessenberg decomposition:* This paper proposed, blind color image watermarking based on Contourlet transform and Hessenberg decomposition to protect digital copyright of color image. Firstly, each color channel of the host image is transformed by Contourlet transform and its low frequency sub-band is divided into 4×4 non-overlap coefficient blocks. Secondly, the coefficient block selected by MD5-based Hash pseudo-random algorithm is decomposed by Hessenberg decomposition. Thirdly, the watermark information permuted by Arnold transform is embedded into the biggest energy element of the upper Hessenberg matrix by quantization technique. The results show that the proposed scheme has higher imperceptibility and robustness against most common image attacks. The advantages are (1) The low frequency subband of Contourlet domain is selected to improve the robustness; (2) The biggest energy element of upper Hessenberg matrix is adopted to embed watermark to improves the imperceptibility; (3) The embedded watermark information can be blindly extracted from the attacked images [35].

15) *A Hybrid LWT-DWT Digital Image Watermarking Scheme using LSVR and QR-factorization:* The proposed hybrid model comprises several attractions towards imperceptibility and robustness on watermarking process. This integrated approach provides liberty on maximum watermarking capacity and less distortion rate enough authenticity to avoid illegal copying and protection against

copyrights. The correlation property of LWT is used to decompose grayed QR-bar code into non-overlapping blocks. The adopted LSVR scheme is to train the input samples in order to find the relationship between non-linear elements. The authenticity is deployed. The result shows increase the decoding rate and detection rate. The proposed model is compared with traditional wavelet transform and classical SVR schemes, and produces more efficacy in terms of faster processing and computational cost [36].

16) *An improved color image watermarking scheme based on Schur decomposition*: This paper, an improved color image blind watermarking scheme based on Schur decomposition is proposed, which is different from using the binary or gray-level image as watermark. The novelty of this paper includes: 1) Using the results features obtained by Schur decomposition to embed or extract watermark with blind manner; 2) The embedded watermark is color image which has more watermark information than random sequence, binary image or gray-level image. Experimental results show It has better performance, such as in the aspects of the invisibility, robustness, computational complexity, security, capacity etc [37].

17) *Robust Color Image Watermarking Technique Using DWT and Homomorphic based SVD*: This paper proposes an image watermarking hybrid technique using the DWT-homomorphic based SVD technique. It embeds the watermark during applying the SVD on the reflectance components of the sub-band LL by utilizing the DWT to divide the image into non-overlapping bands. The reflectance components of the sub-band LL is extracted using the homomorphic transform for each color (red, green and blue). The novelty of this paper includes: 1) Using the features of the results obtained by Schur decomposition to embed or extract watermark with blind manner; 2) The embedded watermark is color. The experimental results have shown that it not only guarantees the but also has strong robustness in the operations of common image processing and geometric attacks [38].

18) *A new algorithm of blind color image watermarking based on LU decomposition*: This paper proposed blind color image watermarking based on LU decomposition. Arnold transform is applied to improve the watermark security and the MD5 is used to improve the watermark robustness. In extraction process, the watermark embedding strength and private key are needed to extract watermark information from the attacked host image with blind manner. The experiment results reveal that the proposed method outperforms other related methods in the aspects of the invisibility, robustness, embedding payload and computational complexity [39].

19) *A novel blind color image watermarking using upper Hessenberg matrix*: This paper, analyze the feature of the upper Hessenberg matrix, and propose a blind color image-watermarking scheme using upper Hessenberg matrix of Hessenberg transform. Arnold transform is used to improve the security, and the MD5-based Hash pseudo-random algorithm is also used to improve the robustness [40].

20) *An Improved DWT-SVD Based Robust Digital Image Watermarking for Color Image*: In this paper, a DWT-SVD based digital watermarking was proposed using Alpha Blending and Arnold Transformation in YCbCr Color space. The proposed method is the Non-Blind Digital Watermarking where there is a need of the cover image for the watermark extraction. It is invisible robust digital watermarking is proposed using Discrete Wavelet Transform and Singular Value Decomposition in YCbCr Color space. The proposed algorithm seems to behave more robustness against different geometric attacks in comparison to referenced algorithms [41].

According to these 20 papers, two types of techniques has been used to improved robustness. First, watermarking methodology to find best embedding place in host, and second, transform methods to embed watermark in the host. Table 2 is shown all of the watermark and Table 3 transform methods, which has been used.

TABLE 2. WATERMARK METHODS, WHICH USED IN THESE PAPERS

Mark	Watermark Method	Mark	Watermark Method
M1	DWT	M7	QDFT
M2	DCT	M8	IULPM
M3	DFT	M9	USC-ABC
M4	FFT	M10	LWT
M5	LSB	M11	QDFT
M6	LS-SVM	M12	QPP

TABLE 3. TRANSFORM METHODS WHICH USED IN THESE PAPERS

Mark	Transform Method	Mark	Transform Method
T1	Arnold transformation	T10	Schur Decomposition
T2	QRTMs & QRKMs & QRdHMs	T11	YIQ color transformation
T3	AC Coefficient	T12	CZT
T4	DC Coefficient	T13	SVD
T5	PK (Private Key)	T14	QEMs decomposition
T6	MD5	T15	2D Cb-Cr Color histogram modification
T7	QR decomposition	T16	Contourlet transform
T8	Hessenberg decomposition	T17	LSVR
T9	LU Decomposition		

In the reviewed papers, the researchers combined two or more methods based on Table 2 and Table 3 to achieve more robust algorithm. Some of them tried to manipulate the main methods such as DWT to find novel method. According to their results experiments, the most of the examined their proposed method with several attacks (Minimum five and maximum fifteen watermark attack methods).

Table 4 has been provided based on Table 2, Table 3, and their experimental methods. This Table explains paper reference number, combination of watermarking, transform methods, attacks, and proposed method PSNR result of their method. Just paper number 25, 27, 29, 36, 38 has not test PSNR for testing result. Star in Table 4 means the result based on PASNR is not available.

TABLE 4. PAPERS METHOD, AND WATERMARK ATTACKS (NC)

Ref No.	Watermarking Methods	Watermarking Attacks										
		Filter		Noise		JPEG Compression	Scaling	Rotation	Cropping	Blurring	Sharpening	
		Median	Low pass	Salt & Pepper	Gaussian							
22	T1,T13	0.80	0.89	0.98	0.88	0.87	0.97			0.87	0.63	0.81
23	T1,T4	0.95		0.93	0.96	0.98	0.90	0.79	0.93			
24	M2,T3,T4, T11	0.91	0.99	0.98		0.99		0.83	0.97			0.99
25	T1,M4,M6	*		*	*	*	*	*	*	*		*
26	T1,T5,T6,T7	0.35	0.86	0.96	0.69	0.89	0.89		0.77	0.88		1.00
27	T1,T2,T5	*		*	*		*	*	*			
28	T1,T5,T6,T7	0.99	0.92	0.83	0.92	0.95	0.99		0.75	0.83		0.99
29	M3,M12,T5,T15	*			*	*	*	*	*			*
30	M7,M8,T1, T5	0.87		0.94	0.85	0.80	0.95	0.73	0.98			
31	M1,T7,T12,T13			0.96	0.93	0.87	0.94	0.95	0.93	0.98		0.99
32	M1,T13	0.94		0.99	1.00	0.96		0.94	0.94			
33	T1,T13	0.98		0.95	0.99	0.95				0.98		
34	M1,M9	0.67		0.89	0.80	0.80	0.96		0.75			
35	T6,T8,T16	0.85		0.86		0.85	0.97	0.96		0.87		
36	M1,M10, T7, T17	*		*	*	*		*		*	*	*
37	T1,T5,T10	0.73	0.93	0.89	0.85	0.93	0.94		0.66	0.94		1.00
38	M1,T13				*	*	*	*		*		
39	T1,T5,T6,T9	0.92	0.96	0.98	0.89	0.96	0.99		0.85	1.00		0.99
40	T1,T5,T6,T8	0.96	0.97	0.97	0.96	0.95	0.99		0.63	0.99	1.00	0.99
41	M1,T1, T13	0.99		0.99	0.99	0.99		0.99	0.99	0.99	0.99	0.99

IV. CONCLUSIONS

A conclusion may review the main points of the paper. Please do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions. Finally, based on these papers, which reviewed in this paper, Fig. 2 show number of usages of the methods and extended methods.

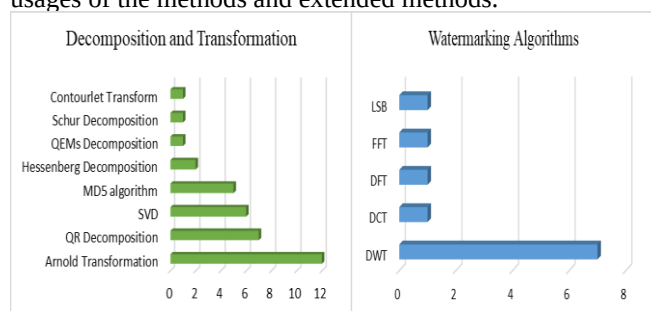


FIGURE 2. WATERMARKING ALGORITHM AND DECOMPOSITION, TRANSFORMATION METHODS HAS BEEN USED IN REVIEWED PAPERS.

For future research has been focussing on the new methods which find the ROI first combining the previous robust methods such as DCT, SVG or DWT. To find ROI, using mathematical algorithm.

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