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An Overview of Robust Video Watermarking Techniques

Yasmin Alaa Hassan*[1], Abdul Monem S. Rahmah[2]

[1] *Department of Computer Science, College of Science, University of Baghdad, Baghdad, Iraq*

[2] *Department of Computer Science, Al-Maarif University College, Alanbar, Iraq*

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Abstract

Copyright hacking and piracy have increased as the Internet has grown in popularity and access to multimedia material has increased. Security, property protection, and authentication have all been achieved via watermarking techniques. This paper presents a summary of some recent efforts on video watermarking techniques, with an emphasis on studies from 2018 to 2022, as well as the various approaches, achievements, and attacks utilized as testing measures against these watermarking systems. According to the findings of this study, frequency-domain watermarking techniques are more popular and reliable than spatial domain watermarking approaches. Hybrid DCT and DWT are the two most used techniques and achieve good results in the field of video watermarking, and the system is more robust against attacks. PSNR was taken into consideration as a comparison metric in various recent articles in terms of robustness in the video watermarking field.

Keywords: Robust Watermark, Hybrid watermark, Imperceptibility, Capacity, Robustness.

نظرة عامة على تقنيات العلامات المائية القوية للفديو

ياسمين علاء حسن[1*] ، عبد المنعم صالح رحمة [2]

[1] قسم علوم الحاسوب، كلية العلوم، جامعة بغداد، بغداد، العراق

[2] قسم علوم الحاسوب، كلية المعارف الجامعة، الانبار ، العراق

الخلاصة

لقد ازدادت عمليات القرصنة المتعلقة بحقوق النشر مع تزايد الانترنت شيوعاً و زيادة امكانية الوصول للبيانات المتعددة الوسائط لذلك تم استعمال تقنيات العلامة المائية لتحقيق الامن وحماية الممتلكات والمصادقة على الشخص المخول. تقدم هذه الورقة ملخصاً لبعض الجهود الحديثة المتعلقة بتقنيات العلامة المائية للفديو والتركيز على الدراسات من سنة 2018 الى 2022 والتي تتضمن الاساليب المختلفة والانجازات والاعتداءات المستعملة كإجراءات اختبار ضد انظمة العلامات المائية هذه. ومن خلال هذه الدراسة تم التوصل الى ان تقنيات العلامة المائية في مجال التردد تكون اكثر شيوعاً وموثوقية من اساليب العلامة المائية للمجال المكاني. ان تقنيات التحويل (dct و dwt) الهجينة هي الاكثر استخداماً وتحقق نتائج جيدة ويكون النظام اكثر قوة عند التعرض للهجمات. تم اخذ (PSNR) في الاعتبار كمقياس للمقارنة بين المقالات الحديثة المختلفة من حيث المتانة في مجال العلامة المائية للفديو.

*Email: yasmin.a@sc.uobaghdad.edu.iq

1. Introduction

Because of advances in image and video processing software and internet technologies, digital media authentication and copyright protection have become difficult subjects. Data security solutions rely heavily on digital watermarking techniques. In the last two decades, the world of watermarking has seen the rise of new trends. [1]

Multimedia data, such as movies, may now be readily delivered at fast speeds across 4G/5G networks. These movies are extensively utilized in a variety of applications, including entertainment, advertising, pattern and activity identification, social networking sites, and so on. High-end multimedia tools can be used to unlawfully copy, modify, and share these videos. This leads to video infringement, which has an impact on the owner's financial benefits as well as his or her intellectual property rights. For the past few decades, digital watermarking has been used to secure the owner's intellectual property rights as well as the integrity of video material. To protect intellectual property rights and the content of video data, a watermark is inserted into the video in digital watermarking to safeguard intellectual property rights and the integrity of video content [2].

Due to the fast expansion of the internet and technology, which has led to a rise in data transmission and consumption of digital media over the last decade, authentication and copyright protection have become a crucial focus in protecting video material. Watermarking digital video is a contemporary and frequently used method of securing digital assets by adding extra data alongside the video stream. [3]

Due to the availability of video content and modern video editing tools on the Internet, however, accessing and manipulating video content has become a simple operation, compromising the process of authentication and copyright protection. As a result, it is more important than ever to develop solutions that can protect copyrights while also identifying and locating video modification [4].

The rest of this paper is organized as follows: Section 2 explains video watermarking and common types according to domains. In Section 3, the literature review has been described. Section 4 presents the classification of the watermark based on domains and the most important transform used today. Section 5 summarizes the types of watermarks on video. Several properties have been found in video watermarking and are presented in Section 6. Lastly, Section 7 presents the conclusions of this work.

2. Video Watermarking

Watermarking is a technique used to protect important media from forgery, tampering, and copyright protection. There are several types of watermarking approaches based on domains, types of cover media, and human perceptibility, as mentioned in Figure 1.

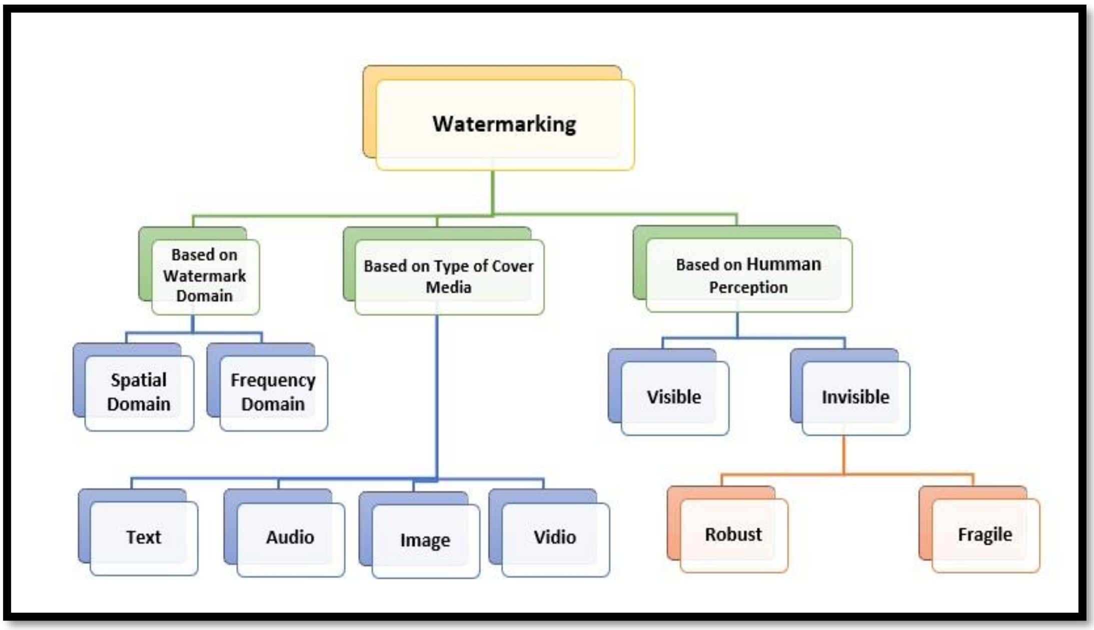

Figure 1: General block diagram of watermarking

Frames, the most important component of video, make up a whole digital video and are loaded at a specified rate called the "frame rate." By reading the frames from the video file one by one, all video watermarking approaches are treated the same as image watermarking techniques, and each frame is treated as a colored image [5]. The two main processes in watermarking are embedding and extraction, which are applied in the spatial or frequency domains [6].

The watermark is embedded in the spatial domain by directly changing the pixel values of the host image/video. To obtain the frequency component, a transformation must be applied by converting the original signal to the frequency domain, and this process is done prior to embedding the watermark and then returning to the spatial domain. As a consequence, spatial domain watermarking is less complicated than frequency domain watermarking [5].

Since frequency coefficients better capture the characteristics of the human visual system (HVS) than spatial coefficients, they provide better imperceptibility and more robustness against attacks like noise addition, pixel removal, rescaling, rotation, and shearing, which are the most popular and important characteristics of frequency-domain watermarking techniques. Many evaluation metrics are used to determine the robustness of the video watermarking techniques and compare them with others like peak-to-noise ratio (PSNR), normalized correlation (NC), normalized cross-correlation (NCC), correlated coefficient (CC), structure similarity index measure (SSIM), mean square error (MSE), bit error rate (BER), mean opinion source (MOS), root mean square error (RMSE), signal-to-noise ratio (SNR), pixel-based visual information fidelity (VIFP), and video multimethod assessment fusion (VMAF). Because of the huge size of digital video, compression must be performed, and due to the real-time needs of video transmission, the watermark in these approaches is included immediately in the compressed video [7].

3. Literature Review

Video watermarking approaches have been employed by many researchers. This work combines major past studies that are concerned with robust watermarking that is embedded in digital video, and it starts in 2018. However, the topic began before, and it is summarized as follows:

- Wang C. et al. [8] propose a method that successfully reduces the impact of the watermark on the carrier's subjective quality. The recovered watermark still has high picture quality, according to experimental findings, even when the quantization value is more than 40. The algorithm also performs well in terms of noise resistance.
- Vidya K. and Sujithra T. [9], the proposed watermarking approach stands up to image compression, noise addition, and geometric distortion significantly better by using SVD, DWT, and depth image-based rendering (DIBR) techniques to satisfy good robustness.
- In this paper, Xiaoyan Y. et al. [10] present some basic facts and the quantitative estimation of many performances, which are studied and compared to enable researchers to rapidly comprehend several existing robust watermarking techniques.
- Kaur G. et al. [2] use symmetric transforms to embed a watermark into selected luma transform blocks. The results of this scheme are imperceptibility and robustness against different attacks like re-compression, noise, and temporal attacks.
- Joshi A. et al. [11] perform real-time watermarking to insert the watermark at the time of capturing the video itself using the DCT coefficients correlation concept. The system shows normalized correlation values of more than 98% in the case of various temporal attacks, and this is considered good robustness.
- Mareen H. et al. [12] propose a watermarking scheme for videos that uses implicit distortions generated by a video encoder to help combat piracy by identifying malicious users that illegally distribute the video, even when they significantly lower the video quality.
- Sathya S. and Ramakrishnan S. [13] propose a new approach that is more resistant to a variety of image and video processing assaults. It also improves the stability and quality of both the host video and the watermark.
- Shanmugam M. and Chokkalingam A. [14] develop an efficient scheme for video watermarking, involving 2-level discrete wavelet transform (DWT) and proficient decomposition technique of singular value decomposition (SVD).
- In LIU Y. et al. [15], the solution is presented to avoid intra-frame distortion drift, and the Bose–Chaudhuri–Hocquenghem (BCH) code technique is used to improve the robustness of data hiding based on the H.265 standard.
- In Yu X. et al. [16], a robust video zero-watermarking algorithm based on the discrete wavelet transform, the all-phase biorthogonal transform, and singular value decomposition is proposed. The suggested technique was resistant to various video attacks using different quantization parameters like geometrical attacks, compression, and frame-based attacks.
- Latha S. et al. [17], a novel method of video watermarking using the Cuckoo search algorithm in the DWT-SVD transform domain is proposed. The proposed method uses the "secret share" method to increase the security of the watermark.
- Kadian P. et al. [18] presented two blind watermarking techniques, DWT-SVD and RDWT-SVD, in this paper. Redundant discrete wavelet transform-singular value decomposition (RDWTSVD) has shown more resistance to geometrical and nongeometrical attacks except for rotation and cropping.
- Elrowayati A. et al. [4] introduce a systematic literature review (SLR) to identify HEVC challenges and potential research directions for interested researchers and developers. The main purpose of this paper is to collect the related resources and references according to a clear process and specific rules in order to identify the challenges and open problems in high-efficiency video coding (HEVC) video watermarking.
- Showkat H. et al. [19] compare the simulation results of SVD, DWT-SVD, LWT-SVD, and

RWDT-SVD for video watermarking to give an insight into various evaluation parameters.

- Asikuzzaman M. et al. [43] present a new video watermarking scheme that is blind and robust to camcorder attacks. This approach uses the mixing of the dual-tree complex wavelet transform (DTCWT) and singular value decomposition (SVD) to achieve robustness against geometric attacks.
- Shital G. and Megha K. [46] present extreme learning machine (ELM)-based machine learning as the basis for a reliable digital video watermarking technique. Hybrid transformations were used (DCT and DWT). The proposed algorithm presents good robustness against different watermarking attacks and good accuracy in the creation of watermarked frames.

Table 1: Comparison of different watermarking techniques

Reference and Year	Technique	Evaluation Metrics	Achievements	Limitations	Results (PSNR)
[8] 2018	All phase biorthogonal transform (APBT), SVD	PSNR, Normalized correlation	Capacity and noise resistance	with the increase of quantization parameters (QP), the PSNR of the reconstructed image after compression is getting smaller	*42.45 **28.42
[9] 2018	DWT, SVD, Depth-Image-Based-Rendering (DIBR)	PSNR, MSE, RMSE and SNR	Resistance against image compression, noise addition and geometric distortion.	NM	* 47. 266 ** 34. 884
[10] 2018	Spatial domain and frequency domain	PSNR, MSE, SSIM, BIR	Capacity, Robustness, and imperceptibility	Challenge to tradeoff between watermark capacity, invisibility, and robustness	*50.89 **36.33
[2] 2018	DST, DCT	PSNR, Bit increase rate, correlation coefficient	imperceptibility , robustness against re-compression, bit increase rate, noise, and temporal attacks.	Rotation attacks not testing	*47.51 **44.05
[11] 2018	DCT	NC, PSNR, and BER.	robustness against temporal attack.	Not good frame quality	*41.39 **40.91
[12] 2018	implicit distortion	correlation coefficient	Imperceptibility and robustness	Not resistant to artificial distortions	NM
[13] 2018	DWT–SVD	PSNR, NCC, BER	Increase efficiency of the robustness and quality of both host video and watermark.	The watermarked video quality is dramatically decreased and less data is lost after applying various attacks.	* 62.7 **57.5
[14] 2018	DWT- SVD	PSNR, NC	Capacity, Robustness and Invisibility.	Blind watermark detection consumes more time period.	* 52.04 **46.85
[15] 2018	BCH syndrome and DCT	PSNR	greater robustness, better visual quality, and higher	NM	*39.7 **3458

			embedding capacity		
[16] 2019	DWT, APBT, and SVD	PSNR, SSIM, MSE, NCC, BER	Robustness and security	Not robust against high-intensity rotation attacks	*49.93 **47.35
[17] 2019	The cuckoo search algorithm in DWT-SVD transform domain	PSNR, SSIM, BER	Imperceptibility , robustness, security and more resistance to attacks	Lower robustness against salt and pepper attack.	* 53.98 **45.67
[18] 2019	DWT-SVD and RDWT-SVD	MSE, PSNR, and SSIM	robustness and imperceptibility	Not resistant to cropping and rotation attacks	*56.58 **28.01
[44] 2020	Barcodes using Code-128, Arnold transform	PSNR, and BER	imperceptibility , robustness, capacity, algorithm complexity, and real-time implementation	NM	*37.58 **36.1
[45] 2021	Depth-image-based rendering (DIBR), DCT	PSNR, MOS, and BER	good robustness and imperceptibility .	NM	*46.76 **41.51
	SVD, DWT-SVD, LWT-SVD, and RWDT-SVD for video watermarking	PSNR, CC	reliability and robustness	Lowe performance when using SVD only	*76.04 **27.19
	ELM, DWT, DCT	NC, MSE, PSNR.	robust in high-efficiency video coding attacks, fast frame processing	NM	*61 **58
	DCT	NC, BER, PSNR	Robustness, imperceptibility , video attacks resistance, localize the position of attack.	No trade-off between BER and NC	*41.33 **36.33
[43] 2022	DTCWT and SVD	PSNR, SSIM, VIFP and VMAF.	Robustness, imperceptibility and limited capacity	Lower resolution of video frame when using low-frequency transform coefficients	*59.64 **48.47
[47] 2022	AES, RSA	MSE, PSNR, correlation coefficient	Robustness, imperceptibility and resistant against watermarking attacks	NM	*54.99 **53.42
[49] 2022	Integer Wavelet Transform (IWT)	PSNR, SSIM, NC and BER.	Robustness, localize temper and classify it legitimate or not legitimate.	Time consumption and imperceptibility affected when increase or decrease the group size	*54 **51

*=highest result **=lowest result NM=not mentioned

4. Classification of Watermarking based on Domain

There are a few video watermarking techniques available. These approaches are categorized based on their intended use.

4.1 Spatial domain

The technique of embedding the watermark in the spatial field involves adding or altering the pixel value of the embedding path of the video frame. [20]. Because the frame does not need to be modified, the embedding and extraction processes take less time [21]. Watermarking in the spatial domain has the advantages of being easy, taking less time to compute, and having low computational complexity [22]. It isn't resistant to common image processing processes [23]. The least significant bit (LSB) approach is the most commonly employed as a spatial domain [24].

4.1.1 Least Significant Bit (LSB)

The most basic method entails embedding the watermark into the original video's least significant bit; in this approach, the least amount of important information is altered with the watermark bits, rendering them undetectable. The watermark can be set anywhere on or in a particular area of the video frame. The watermark, on the other hand, is readily erased due to the vulnerability of the LSB to a number of attacks [25].

In [26], the most dominant and least dominant channels to add a watermark were given as a novel approach to determining the best location to put a watermark. The author creates a high-quality watermarked image while also adding a high level of difficulty, ensuring protection against an unwanted attacker.

While in [27], the watermark in LSB is implanted in two stages: a comparison operation, then a shift and rotation of the key. This results in a high level of security because the embedding isn’t done immediately.

4.2 Transforms Domain

The primary advantage of transform domain approaches in solving spatial domain problems [28]A transformation method is used to convert the original video frame in the transform domain to obtain frequency values. After that, the watermark is applied to the coefficient of transformed frames. The inverse transform of the embedding process is employed to create the watermarked video [29]. Due to the availability of extra data, video watermarking differs from image watermarking in that it permits information to be embedded more redundantly and reliably [30].

Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), Singular Value Decomposition (SVD), and Discrete Sine Transform (DST) are some of the most commonly utilized techniques in the transform domain [31].
In [32] using contourlets and the DCT transform, and in [35] using the DWT and GSO, both of them achieve robustness, imperceptibility, and security, using metrics to evaluate their results like PSNR, MSE, NCC, and BER.

4.2.1 Video Watermarking Based on DCT and DWT

Based on our research analysis, inserting the watermark in the frequency domain was shown to be more secure against possible violation.

Most researchers combine DCT and DWT because the hybrid method produces good results, reduces the limitations of the watermarking process, and allows them to profit from both DCT and DWT's benefits [21], [33].

The discrete cosine transform (DCT) [34] expresses data in frequency space rather than time. When compared to spatial domain approaches, DCT-based watermarking techniques are more reliable. Low frequencies, medium frequencies, and high frequencies are divided into three bands by the DCT. Low frequencies are associated with lighting conditions. High frequencies are noise, whereas medium frequencies include important information and the image's underlying structure. The middle frequencies were chosen to insert the watermark since they do not spread the information.

Another approach [35] to DWT is to process the picture in each dimension using 2-D filters. The filters divide the input image into four non-overlapping multi-resolution sub-bands called LL1, LH1, HL1, and HH1. The sub-band LL1 is further split to get coarser wavelet coefficients, and the watermark is incorporated in the final low-frequency region. The suggested approach is resistant to a wide variety of picture distortions [36].

Table 2: Comparison of video watermarking based on DCT and DWT

Ref. and Year	Achievement	Imperceptibility	Robustness	Capacity	Security
[37] 2011	The suggested algorithm is safer, more reliable, and more efficient.	NM	Yes*	Yes*	Yes
[38] 2015	The watermarked video is resistant to rotation, translation, corner detection, and edge detection, as well as other geometric attacks.	NO	Yes	NO	NM
[39] 2017	The suggested approach has a higher embedding capacity and is extremely resistant to all types of attacks.	NM	Yes*	Yes*	Yes
[40] 2020	Because it generates random frames, the suggested approach is simple to implement. It is resistant to a variety of watermarking assaults, including the Gaussian filter and sharpens attacks.	NM	Yes	Yes*	Yes

Yes*=extreme NM= not mentioned

5. Types of Attacks on Watermarks

In watermarking language, the attacker seeks to eliminate all evidence of the watermark to defeat authentication purposes. Knowing the different sorts of assaults and how to analyze them might help you choose the best tool for a certain application in a competitive setting. Removal, geometrical, cryptographic, Oracle, protocol, and security assaults are the most common types of attacks.

• Watermark Removal Attacks: These attacks try to remove watermarks from watermarked images by executing image processing operations.
• Geometrical Attacks: This seeks to damage rather than remove the watermark. While extracting the watermarks, this causes synchronization issues.

• Copy Attacks: It seeks to predict the presence of a watermark and copy it on other data without revealing the secret keys.

• Legal Attacks: It attempts to cast doubt on technical evidence about watermarks and watermarking techniques when demonstrating ownership in court.

• Cryptographic Attacks: This is an effort to locate the secret keys through a series of thorough searches [41].

Table 3: Types of applied attacks used as testing factors by robust watermark

Reference and Year	Robust Against	Not Robust Against
[8] 2018	Salt and pepper, Gaussian noise	Recompression
[9] 2018	image compression, noise addition and geometric distortion	
[11] 2018	Temporal Attack	
[2] 2018	re-compression, noise and temporal attacks.	
[12] 2018	Implicit distortion (re-encoding)	artificial distortions
[13] 2018	image and video processing attacks	
[16] 2019	high efficiency video coding compression attacks, image processing attacks, geometric attacks (rotation, scaling, cropping, sticking), frame-based attacks, and hybrid attacks	High-intensity rotation attacks
[17] 2019	geometric and image processing attacks	
[18] 2019	geometrical and nongeometrical	cropping and rotation attacks
[44] 2020	intentional and accidental Internet attacks	
[43] 2022	Temporal and geometric attacks, camcording attacks	

In the previous table, some recent research was studied and analyzed to find out the type of attack used when applying the watermark. These attacks are used as a kind of examination to determine the efficiency of the used watermarking technique, and it has been concluded that the most commonly used types of attacks are temporal and geometrical attacks.

6. Robust Video Watermarking Properties

The term "video" refers to a series of uniformly spaced still pictures known as "frames." In general, all image watermarking algorithms may be extended to video watermarking; however, video watermarking addresses certain additional issues. Watermarking systems have a variety of characteristics, such as embedding performance, capacity, and stability. This section goes through some of the most prevalent characteristics of video watermarking.

Perceptual Transparency: Invisibility is the degree to which an embedded watermark in watermarked media goes unnoticed. One of the prerequisites of watermarking is perceptual transparency. Temper resistance and robustness are two other requirements that are connected with this one.

Robustness: The embedded watermark's resistance to removal by typical signal processing operations is characterized as “robustness.” Various signal processing procedures like filtering, compression, rotation, and others are performed on pictures, video, and audio throughout the processing phase. Even after such signal processing processes, a successful watermarking method must be able to retrieve the watermark from watermarked media. Watermarks must be put in perceptually relevant parts of the material to ensure resilience.

Capacity: The quantity of information that can be entered by embedding a watermark is referred to as its “capacity.” The watermark embedding technique must be able to transport ever-increasing amounts of data [42].

7. Conclusions

According to our research in the field of video watermarking, robustness may be achieved by employing transformation for the sake of robustness and a safer way to add watermarks against various violations. Most researchers combine DCT and DWT because the hybrid method produces good results, reduces the limitations of the watermarking process, and allows them to profit from both DCT and DWT's benefits.

The most popular cutting-edge watermarking techniques were studied in this study, and the study concluded that DWT is a high-quality and resilient approach for video watermarking. The fundamental prerequisites for building an efficient watermarking system are robustness, imperceptibility, and capacity. However, meeting all of these needs for a good watermarking system at the same time is very difficult. As a result, a good compromise between these three needs is required. This study compared recent studies in the field of robust video watermarking by examining the techniques, achievements, limitations, results, and attacks that video watermarking is vulnerable to. The most commonly used attacks were temporal and geometrical attacks, which may be considered for future studies in this field.

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