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Audio, Text, Image, and Video Digital Watermarking Techniques for Security of Media Digital

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Abstract— The proliferation of multimedia content as digital media assets, encompassing audio, text, images, and video, has led to increased risks of unauthorized usage and copyright infringement. Online piracy serves as a prominent example of such misuse. To address these challenges, watermarking techniques have been developed to protect the copyright of digital media while maintaining the integrity of the underlying content. Key characteristics evaluated in watermarking methods include capability, privacy, toughness, and invisibility, with robustness playing a crucial role. This paper presents a comparative analysis of digital watermarking methods, highlighting the superior security and effective watermark image recovery offered by singular value decomposition. The research community has shown significant interest in watermarking, resulting in the development of various methods in both the spatial and transform domains. Transform domain approaches such as Discrete Cosine Transform, Discrete Wavelet Transform, and Singular Value Decomposition, along with their interconnections, have been explored to enhance the effectiveness of digital watermarking methods.

Keywords— Digital Watermarking Techniques, Discrete Cosine Transform, Discrete Wavelet Transform, Singular Value Decomposition, Robust Security, Copyright.

I. Introduction

Most communication happens inside of sharing multimedia content, which includes images, audio, and video. The ease of accessing digital data, makes someone who is unauthorized or irresponsible to misuse the copyright of others. One example of this is online piracy. The procedure of embedding any information in a multimedia file is known as digital watermarking. A noticeable watermark commonly amounts to an outstanding message or company logo implying ownership of the media content. Because digital content is perhaps quickly copied or downloaded via the Internet, the issue of copyright infringement arises. Copyright protection, usage management, data description, principle verification, and content credentials are all reasons for doing so [11].

Digital watermarks must have significant characteristics such as invisibility and resistance to incidents [25]. The watermarking method that is employed must be resistant to manipulation techniques; this method is known as robust watermarking [28]. Many watermarking methods there have been introduced may fall into two categories in recent years: spatial domain watermarking and frequencies domain watermarking. A significant number of bits can be inserted in a spatial domain watermark without creating visible artifacts, but frequencies domain watermarks are extremely resistant to the effects of JPEG compression, filtering including noise pollution [16]. For security reasons, new techniques to encrypt the watermark or methods for embedding it into the object's picture there have been created. Every sequence at issue includes desirable characteristics similar noise behaviors and unpredictability along predictable orbits including sensitivity to basic conditions and parameters. In this paper we offer three iterative problem-based techniques [2]:

1.1 Spatial domain watermark: Bit scrambling method with random sequences.

1.2 Domain watermark transformation (with binary watermarks): 2D Discrete Cosine Transformation Method.

1.3 Feature watermark transformation (with grey-level watermarks): Bit scrambling and 2-D Discrete Cosine Transform method.

II. Background

2.1. Related Work

Many techniques developed in the literature to address the problem of digital watermarking for grey and color images [11]. Therefore, from Emir Ganic et al, Wavelet and SVD have been proposed, in which the image is first separated into four frequencies bands using DWT. Each sub-band's SVD is subsequently computed. The SVD value of the image is then adjusted by using the SVD value of the watermark. This technique achieves robustness by inserting the watermark in each frequencies band. The author claims that approach is superior to inserting the watermark using only the SVD scheme [8].

Manjunatha Prasad R et al, in this approach addition to wavelet decomposition, the image itself is sent into the MD5 algorithm to obtain a hash value is also fed into the MD5 method to get a hash value. This hash value is inputted into a random function generator, which produces a random matrix the size of the image. The created mask matrix is used to integrate a binary watermark into the HH sub-band. The marked image is created by mapping this HH sub-band to its original position and then performing the inverse Haar wavelet transform [14].

Yang Qianli et al, have proposed watermarking based on DWT-DCT, where an image is decomposed into wavelet coefficients up to three levels. The DCT of these coefficients is calculated. Watermarking is also converted into DCT coefficients and then incorporated into the DCT coefficients of the image that is converted into wavelets. PSNR is used to test the quality of the watermarked image and normalized Cross Correlation is used to detect the presence of watermarks [33].

Biki Baruna et al, their present an image watermarking algorithm based on DWT, DCT, and SVD in this work. They utilize Arnold transform in the first stage to randomize the order of the watermark, which strengthens the security of the embedded watermark. The host image is then subjected to a discrete wavelet transform. The intermediate frequencies is then subjected to a second discrete wavelet treatment. At low frequencies, the integrated watermark makes the watermark apparent. Watermark information, on the other hand, should not be included to withstand data compression. As a result, the middle-frequencies area is commonly used for embedding watermarks. The middle frequencies area is then subjected to DCT and SVD. Finally, we integrate the watermark into the original image [3].

S Aishwarya et al, their paper is divided into the sections listed below. These sections describe the digital watermarking procedure. They also define the primary picture watermarking requirements. Furthermore, they explore the primary applications of watermarking and provide a full study on how to create a strong watermarking algorithm. This type of study in this subject has resulted in the development of numerous watermarking approaches, including spatial domain and transform domain. Discrete cosine Transform (DCT), discrete wavelet Transform (DWT), singular value decomposition (SVD), and their crosslinks can all be found in the transform domain [25].

Some key fundamental principles of digital watermarking are introduced, including qualities and requirements, foundations, multiple classifications, and a comparison of digital watermarking with steganography. Following that, common watermarking techniques are discussed; techniques in the spatial and frequencies domains are introduced with an examination of the advantages and downsides. The frequencies domain is introduced, along with an appraisal of the pros and cons. Analyze the advantages and disadvantages [31].

2.2. History of Digital Watermarking

Although paper was assumed in China about before a thousand years, watermark paper was early used in Italy in 1282. A tiny wire design in a paper mold is used to create paper watermarks. The wiring pattern will result in a slightly thinner translucent area. Watermarks can be used to create a mystical symbol or simply for decoration. Paper watermarks, on the other hand, are utilized for more practical reasons. Watermarks are used to indicate how and where the paper was manufactured [22].

In the nineteenth century, watermarks in Europe and America had more functional uses. Tirkel and Osborne's was derived from the Japanese "Denshi Sukashi," which means "Electronic Watermark". Nevertheless, digital watermarks can also be a form of steganography, as in the case of invisible digital watermarks in plain sight. The phrase "digital watermark" is acclimated to specific technologies a certain enable invisible differentiation of “identical" a copy of the material. Many watermarking systems add another level, data concealment in such a way that removal attempts would degrade the quality of the content [4].

2.3. Purpose of Digital Watermarking

Digital watermarks, on the other hand, perchance a type of steganography, for example, a digital watermark concealed from plain view. That phrase "digital watermark” descriptive words are technologies that enable invisible differentiation of "identical" copies of content [6]. Many watermarking systems advance a step, concealing data in such a way that removal attempts would degrade the quality of the content. The best watermark for digital media. The best digital watermark should be resilient to most data transformations and changes in media content quality. A Digital watermark is a technology that aims to protect a set of files from illegal distribution even after a legitimate customer has purchased the product. Due to the fact that digital watermarks cannot be deleted, they might secure the product even after the client has purchased it [2].

The watermarking method is based on the human visual system which, due to small variations, is unrecognizable. Cover images are familiar with concealing sensitive information in this technique, and the watermarked image is the cover image with secret data encoded in it [15]. This technique secretly hides confidential information in a general file first, therefore transfers this file over the network; since it appears the same as a common file, it can easily avoid the attention of unauthorized listeners, accordingly confidential information is not easily attacked. The gap between copy protection and copyright protection is that the former will limit copying while the latter will reveal who is the content's rightful owner. Digital has additional features, but the majority of interest in this field is focused on copy protection and copyright [27].

2.4. Classification of Digital Watermarking

a) Video Watermarking

A superset of normal image watermarking is regarded to be video watermarking. Video images can be created using any approach that is applicable to static images [26]. However, since the video has a high frame rate, live transmissions require almost real-time embedding. This restriction is absent if the content is created offline. The use of a visible watermark is a relatively common method of online video watermarking [10].

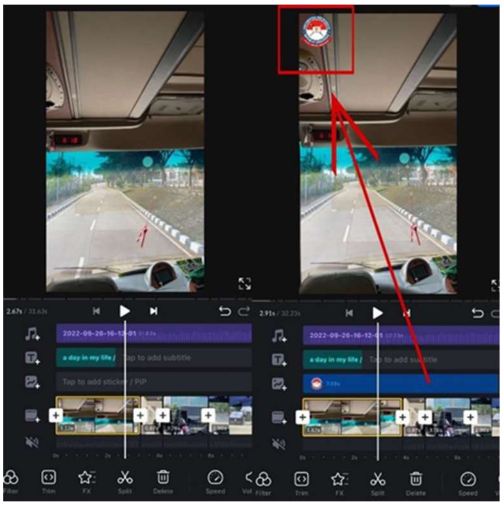

Fig. 1. Example Video Watermarking Techniques

b) Audio Watermarking

Audio watermarking is currently at the forefront of technological innovation in an effort to prevent unauthorized duplication and dissemination. One implementation that has sparked much interest is MP3 audio compression and watermarking technology. Audio watermarking can be used successfully at frequencies above the human hearing range [9].

Fig. 2. Example Audio Watermarking Techniques

c) Text Watermarking

There are two types of text: formatted text and raw unformatted ASCII text. To incorporate watermark information into a produced document, the inter-line and inter-word spacing can be slightly altered. Consider the typeset text to be one large image, and embed a watermark using the typical procedures for images. The watermarking technique has significant issues with raw text. One such method is to include white space after each sentence [32].

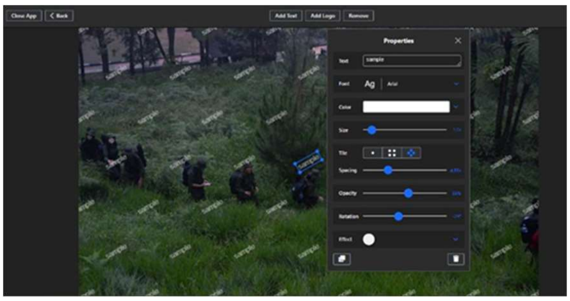

Fig. 3. Example Text Watermarking Techniques

2.5. Characteristics and Requirements of Digital Watermarking

In digital image watermarking there are some characteristics and requirements needed in the process, including [27]:

a) Undetectable or Invisible

In the watermarking system it is useless if the main image is distorted, actually the watermarked image should look the same as the original image and it is impossible to distinguish it from the original image [5].

b) Robust or Strong

Watermarks must be robust enough to withstand distortions that may occur during attacks, either intentional or unintentional attacks that aim to remove the existing watermarked image. Unintentional attacks usually involve changes to the image during resizing, cropping, editing, enhancing and so on [12].

c) Unambiguous

In unambiguous watermarking retrieval means it should clearly identify the owner and the accuracy of the owner identification should degrade gracefully in the face of any attack [19].

d) Capacity

The amount of watermark information that can be inserted into a host signal refers to the watermarking capacity itself. In sacrificing both strength and robustness as well as invisibility it requires higher capacity [7].

e) Protection

In terms of watermark security, this means that the watermark should be challenging to alter or delete without compromising the host signal [7].

III. DIGITAL WATERMARKING METHOD

The method in addition to watermarks in multimedia objects is known as watermarking. Watermarks are included in digital content for various arguments, including copyright refuge, content authentication, tamper detection, and so on [25]. Watermarks on digital images can be visible or invisible. Visible watermarks are usually a sentence or company emblem that recognizes the multimedia content owner. A visible watermarking is commonly a sentence or company emblem that indicates the owner of the photo. The watermark in this scenario can be a logo or image that identifies the rightful owner [13]. There are currently two digital technologies that are particularly well-liked, namely the methods in the time domain and the methods in the transformation domain. While the second approach is more widespread and has a stronger anti-attack function, the earlier approach is simpler to install but has inferior robustness. Singular Value Decomposition of Singular Values (SVD), Discrete Cosine Transform (DCT), Discrete Fourier Transform (DFT), Discrete Wavelet Transform (DWT), and Contour Transform (CT) are just a few of the techniques that can be used in the transform domain [30].

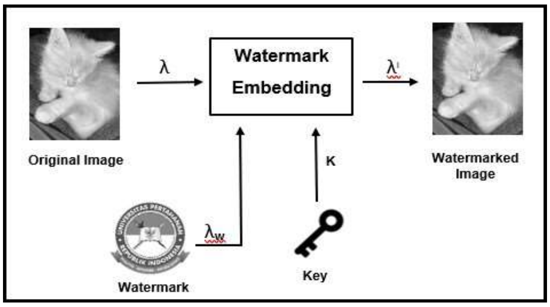

Fig. 4. Image Watermark Embedding

A digital image watermark system consists of two functions: embedded and extraction or detecting. The original image is delivered to the internet after the embedding function adds a watermark—a type of hidden message—on it. In this case, the image may be exposed to standard processing procedures in turn assaulted by an attacker in an attempt to remove or eliminate the watermark. The watermark can be removed for verification or its presence can be confirmed for monitoring purposes using extraction or detection capabilities [25].

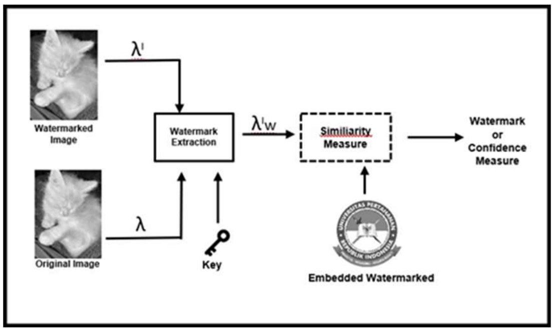

Fig. 5 Image Watermark Extraction and Detection

Researchers are interested by watermarking because of the importance it has. As a result of this kind of field research, several watermarking approaches, including spatial domain and transform domain, have been created. That is transform domain, singular value decomposition (SVD), discrete wavelet Transform (DWT), and discrete cosine transform (DCT) are used.

3.1. Discrete Cosine Transform (DCT)

Similar to a Fourier Transform, the DCT turns data into frequencies space rather than amplitude space. This is advantageous because it allows for the rejection and non-detection of light that cannot be seen because it is more similar to how humans perceive light. In comparison to spatial domain methods, DCT-based watermarking approaches are more dependable. In common image processing procedures such as brightness correction, color contrast correction, blurring, low pass filtering and so on. Although these methods are usually more difficult to implement and require more expensive computation. The DCT domain itself has two types of watermarks namely Global DCT Watermark and block-based DCT Watermark. Image data decoration is a goal of the discrete cosine transform (DCT). The following below is the formula of equation (1) to calculate DCT and the formula of equation (2) for inverse DCT [18].

Equation 1 of calculate DCT 2-D:

$$F(u,v) = \sum_{i=0}^{N-1}\sum_{j=0}^{N-1} C(u)C(v)f(i,j)\cos\left[\frac{\pi(2i+1)u}{2N}\right] * cos\left[\frac{\pi(2j+1)u}{2N}\right] \quad (1)$$

Equation 2 of Inverse DCT 2-D:

$$f(i,j) = \sum_{i=0}^{N-1}\sum_{j=0}^{N-1} C(u)C(v)F(u,v)\cos\left[\frac{\pi(2i+1)u}{2N}\right] * cos\left[\frac{\pi(2j+1)u}{2N}\right] \quad (2)$$

Where,

$$C(u), C(v) = \begin{cases} \sqrt{\frac{1}{N}}, & u,v = 0 \\ \sqrt{\frac{2}{N}}, & u,v = 1 \; to \; N-1 \end{cases} \quad (3)$$

The average value of the sample sequence is equal to the first transformation coefficient. A variant of DCT 1 is 2D DCT. DCT is essential for applications such as image coding and compression. DCT-based watermarking techniques are compatible with current JPEG and MPEG international compression standards. The most widely used image compression transform technology, according to this statement, is DCT [25]. The following steps are involved in the watermark embedding process:

1. First, 256x256 pixels of the original image have been compressed in size.
2. Make the watermark 32x32 pixels in size.
3. The 32x32 watermark can then be fully embedded on the 256x256 image after the original scaled image is block-processed into 8x8 blocks.
4. The 8x8 sub-blocks are then converted from time domain to frequencies domain using the 2D-Discrete Cosine Transform.
5. The watermark image is placed in the center or middle of the frequencies band on the 8x8 block.
6. The frequencies coefficient value should be changed to reflect the watermark data to be embedded.
7. The embedded watermark image is then translated using inverted 2D-DCT from frequencies domain to time domain.

The steps for inverse to extract a watermark are as follows:

1. First, watermarked image is resized to 256x256 pixels if required.
2. Later, block processing is used to create an 8x8 pixel version of the watermarked image.
3. Next, forward 2-D is applied to the block-processed image to achieve frequencies separation.
4. Then perform the extraction process which is done in the same way as the embedding process after that.
5. Based on the comparison between certain pixels where the watermark data is encoded, a decision is made and stored in another empty 32x32 array.
6. This matrix represents the extracted image, which is the original watermark image.

3.2. Discrete Wavelet Transformation (DWT)

The signal processing tool discrete wavelet Transform (DWT) is used for a variety of tasks, including de-noising audio, compressing audio and video, and modeling the deployment of wireless antennas. Since wavelet energy is focused on time. Wavelet transform is well suited for a wide range of applications because most real-world signals vary in time. One of the most challenging components of the watermarking problem is to find a better balance between robustness and perceptibility. Embedding the strength of the watermark can be increased for robustness but this also results in more visual blur [24]. However, the DWT is significantly better as it allows simultaneous spatial localization and frequencies spreading of watermarks within the host image. The primary use of the discrete wavelet transform in digital image processing is to separate the original image into sub-images with distinct independent frequencies and spatial domains. where the district picture data is highly similar to the original image at low frequencies. Level details, upright details, and diagonal details are all reflected in the LH, HL, and HH frequencies districts [1].

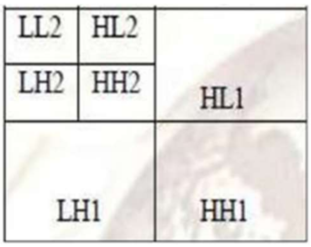

Fig. 6. Decomposition 2 Level DWT

Visually, the human eye can be sensitive to such variations but not so much to the peaks and borders of the image. At high frequencies band coefficients, the DWT image can be harmful as the watermark is easily visible and detectable. Since the human eye cannot detect the presence of a signal, the visual model of brightness as it shows the difference between the embedded signal and the increased brightness in the background. As a result, approximate low-frequencies images can be embedded with higher watermarking capacity than JND. Some attacks that often occur at low frequencies may also cause damage to the host image. Therefore, it is recommended to embed watermarks at low and medium frequencies [17].

The following are the steps embedded into the watermark:

1. Expanding the original image to 512x512 pixels which will only result in a 256x256 pixel image on DWT decomposition.
2. Requires the exact size needed to embed 32x32 pixels into 8x8 sub-blocks in the entire 256x256 pixel image since our watermark is 32x32 pixels in size.
3. The image is then divided into four components using a 1-level Discrete Wavelet Transform, as was previously explained.
4. The low-high frequencies components are then added with the watermark.
5. Then, to combine it with the rest of the image, a 1- level IDWT is applied.
6. In the final image, there is already a watermark.

The steps for extracting a watermark are as follows:

1. Converting the watermarked image to 512x512 pixels if required.
2. Deconstructing the watermarked image by using the level-1 DWT transform.
3. Then perform the embedding method by extraction comparison.
4. The watermark image that has been extracted is the image created through comparison.

3.3. Singular Value Decomposition (SVD)

A technique to make a diagonal matrix is SVD. Singular values are a genuine characteristic of matrices and they offer several wonderful characteristics. They are somewhat resistant to matrix alterations that could slightly alter how the elements in the picture matrix are related [29]. Given that a digital image may be represented as a matrix whose entries each correspond to a pixel's intensity value, the SVD of an image M with dimensions m x m is given by:

$$M=USV\text{-}1 \tag{4}$$

Where S, also known as the singular matrix, is a diagonal matrix containing the non-negative singular values of matrix M and U and V are orthogonal matrices. The left and right singular vectors of M, respectively, are the columns of U and V. They essentially outline the original image's geometry in depth. The horizontal details of the original image are represented by the left singular matrix, U, and the vertical details by the right singular matrix, V. The diagonal values of matrix S are organized in decreasing order, which denotes that from the first singular value to the last one, the entries' relevance is decreasing [24]. From the point of view of liniear algebra, an image is a non-negative array of scalar entries that can be thought of as a matrix. If A is a square image without loss of generality, it can be denoted as $A \in Rnxn$ where, the real number domain is represented by R, then the SVD of A defined as $A = USVT$ where, diagonal matrix represented by S along with orthogonal matrix represented by U and V, as

$$S = \begin{bmatrix} s_1 & & \\ & \ddots & \\ & & s_n \end{bmatrix} \tag{5}$$

S is a single value and satisfies the diagonal element $S_1 \geq s_2 \geq \cdots s_r \geq s_{r+1} \geq= \cdots = s_n = 0$. The optimal matrix decomposition technique is the SVD technique which packs the maximum signal energy into as few coefficients as possible in the least squares sense. The result of SVD is represented by a single value recorded in a diagonal matrix. SVD is categorized as a non-blind watermarking technology as it requires the extraction of the original image and the watermarked image. U, S, and V are the three matrices generated when an image is decomposed using SVD. The S matrix contains a single value, which will be used during the insertion process [18].

IV. Conclusion

This study demonstrates the effectiveness of fast discrete cosine transform (DCT)-based digital image watermarking techniques in ensuring the preservation of image quality and enhancing robustness against signal processing. The decoding key consists of four center frequencies coefficients, two random permutation vectors, and a quantization matrix, which collectively normalize the watermark and the original image. By incorporating a secret watermark containing confidential information into the host image, these digital watermarking techniques serve as invaluable tools for verifying the authenticity of audio, text, image, and video digital assets and providing copyright protection.

Throughout the analysis, a comprehensive overview of various digital watermarking systems has been provided, encompassing methodologies in both the spatial and transform domains, such as DCT, discrete wavelet Transform (DWT), and discrete Fourier transform (DFT). The advantages and disadvantages of different approaches have been carefully examined, highlighting their applicability to audio, text, image, and video digital watermarking.

Considering the ongoing advancements in data security, this technology remains an intriguing subject for further investigation. Future research in this field will focus on the exploration and development of novel techniques specifically tailored to enhance the security and robustness of audio, text, image, and video digital watermarking systems. These advancements will contribute to the continued protection of media digital assets, facilitating improved authentication and copyright safeguarding in an ever-evolving digital landscape.

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