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Robust Digital Watermarking for Colour Images Using GBT & SVD

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Abstract: Copyright infringement poses a significant challenge in the creative industry, particularly with the exponential growth of digital content. Digital watermarking is a promising technique to mitigate this problem. Its primary objective is to embed an imperceptible digital watermark into digital content, such as images or videos, to protect against unauthorized use or reproduction. This paper presents a novel hybrid approach for digital watermarking that addresses the limitations of existing methods, namely the Discrete-Haar Wavelet Transform (DHWT) and Least Significant Bit (LSB) steganography. The proposed approach integrates Graph Based Transform (GBT) and Singular Value Decomposition (SVD) for data watermarking, while incorporating a scrambling operation to enhance the security of the watermark. Compared to DHWT, the proposed approach has lower computational cost and reduced distortion near image or video edges. In contrast to LSB, it utilizes transform domain techniques resulting in a more robust aftermath. The experimental results demonstrate the effectiveness of the proposed approach, indicating its potential as a viable solution for digital watermarking.

Keywords: DHWT, digital watermarking, LSB, SVD, GBT, scrambling

I. INTRODUCTION

The rise of digital content creation has led to an increase in copyright infringement cases, with several countries being listed as priority or watch lists by the United States Trade Representative [1]. To combat this issue, Digital Right Management (DRM) technology has been developed, with digital watermarking being one of its techniques [2].

Digital watermarking is a technique used to hide messages within digital content to regulate access and limit the use of digital creations. Several studies have been conducted on digital watermarking using different techniques. For instance, discrete wavelet transform (DWT) has been used to implement digital watermarking for colour images [4]. Least significant bit (LSB) has also been used for digital watermarking [5]. Another technique used for digital watermarking is discrete cosine transform (DCT) [6].

This paper proposes the use of Discrete-Haar Wavelet Transform (DHWT) as the method for digital watermarking due to its low computing requirements, making it highly suitable for two-dimensional signal processing applications. DHWT is a method of decomposing a signal into sub-signals, which are then processed separately. The proposed approach combines DHWT with LSB to add more security to the digital contents. The digital watermark is inserted into colour images, and the LSB technique is used for steganography.

By combining these two methods, the colour image is protected by a digital watermark that is hidden from the human eye, providing a robust solution for protecting against copyright infringement. The DHWT-LSB approach offers a number of benefits, such as low computational complexity, high robustness, and the ability to withstand common image processing operations such as compression and cropping.

Overall, the proposed approach presents a promising solution to the issue of copyright infringement in digital content. It provides a secure and reliable method of protecting digital content, while also ensuring that the content can be accessed and used by authorized parties. As digital content continues to grow in popularity, the need for effective copyright protection will only increase, and DHWT-LSB digital watermarking can be an effective solution to protect digital content.

II. RELATED WORK

2.1 DIGITAL WATERMARKING

Digital watermarking is a technique used to insert or hide secret information within a host without altering the host in a noticeable manner. This technique can be used to insert a variety of media types, including text, images, audio, or random bits with no discernible meaning. The watermark is embedded within the digital data without causing any damage to the data itself, and cannot be easily removed once inserted.

There are two primary types of watermarking techniques: embedding the watermark within the host and extracting the watermark from the host.

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Several key criteria must be met in order for a watermarking process to be considered effective [7]. Firstly, the fidelity of the host should not be significantly impacted by the watermarking process. The watermark itself must also be imperceptible to the human eye. Additionally, a unique key should be required to extract the watermark, and the watermark should not be easily reversible without access to the original data. The watermark must be retrievable from the host, and must also be robust against potential attacks that may be directed towards the host. Finally, the watermarking process should be tamper-resistant and able to withstand attempts to alter or remove the watermark from the host. These criteria ensure that the watermarking process is effective and that the embedded information is securely protected within the host.

2.2 Graph Based Transform (GBT)

Graph-Based Transform (GBT) is a novel mathematical framework for signal processing that has recently gained significant attention in the research community [8]. GBT is a transformation technique that represents signals in the form of graphs and applies graph theoretical concepts to analyses and process them [9]. This approach is particularly useful for analyzing non-Euclidean and irregularly structured data such as social networks, brain connectivity graphs, and other complex systems.

GBT is a generalization of traditional transform techniques such as Fourier Transform, Wavelet Transform, and Singular Value Decomposition (SVD) to graphs. GBT is based on the concept of graph shift operators, which are linear operators that describe the transformations between the vertices of a graph. These operators can be used to represent signals as vectors in a high-dimensional space, where each dimension corresponds to a different vertex of the graph.

The GBT is capable to capture the local and global structures of a signal simultaneously. Traditional transform techniques, such as Fourier Transform, are global in nature and do not capture the local properties of the signal. GBT, on the other hand, can capture both local and global properties of a signal, making it suitable for a wide range of applications.

GBT has been applied in various fields such as image processing, speech analysis, and computer vision [10]. One of the popular applications of GBT is in image demolishing, where it has shown superior performance compared to traditional methods. GBT has also been used for graph clustering, community detection, and anomaly detection in various applications.

2.3 Singular Value Decomposition (SVD)

Singular Value Decomposition (SVD) is a widely used linear algebra technique that decomposes a matrix into three separate matrices, providing useful insights into the properties of the original matrix [11]. It has many applications in various fields, including signal processing, data analysis, and image compression.

The SVD factorizes a matrix into three matrices: U, Σ, and V, where U and V are orthogonal matrices and Σ is a diagonal matrix. The diagonal entries of Σ, known as singular values, represent the amount of variation present in the original matrix. SVD can be used to reduce the dimensionality of data by selecting only the most important singular values, thus simplifying the original matrix while retaining most of its essential features. This property has made SVD a popular tool for data compression and noise reduction.

SVD has several important properties, including the fact that it is unique for any given matrix, and that it can be used to compute the rank of a matrix. It can also be used for computing the pseudo-inverse of a matrix, which is useful in solving linear systems of equations. Furthermore, SVD is widely used in data analysis and machine learning, where it is used for tasks such as principal component analysis (PCA) and collaborative filtering.

2.4 Scrambling

Image scrambling is a technique used in image processing to modify the pixel values of an image in a non-reversible way, making the resulting image difficult to interpret. The main goal of image scrambling is to protect the confidentiality of an image by hiding its content from unauthorized access. The process of image scrambling involves the manipulation of the pixel values of an image using various mathematical algorithms or techniques such as permutation and substitution.

Image scrambling can be used in a variety of applications, including digital watermarking, image encryption, and data hiding. It is an effective technique for protecting sensitive information in images, such as personal information or confidential documents, from being accessed by unauthorized individuals.

One of the major advantages of image scrambling is that it does not require additional storage space to protect the original image. Instead, it modifies the pixel values of the original image in a way that is not visually perceptible, ensuring that the original content remains secure while maintaining the same size and resolution.

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III. PROPOSED WORK

In the digital era, copyright infringement has become a significant challenge for the creative industry. To address this issue, digital watermarking has emerged as a potential solution for protecting digital content, especially images, from unauthorized use. However, traditional methods such as Discrete-Haar Wavelet Transform (DHWT) and Least Significant Bit (LSB) steganography have certain limitations. For instance, DHWT may require high computing costs and produce blurring and ringing noise near the edges of images or video frames when larger basis functions or wavelet filters are used, leading to longer compression times. Meanwhile, LSB is a spatial domain technique that is vulnerable to various attacks.

To overcome these limitations, a hybrid approach combining Graph Based Transform (GBT) and Singular Value Decomposition (SVD) is proposed for data watermarking. This approach offers improved security compared to spatial domain techniques as it operates in the transform domain, which provides a more robust aftermath. Additionally, to enhance the security of the watermark, a scrambling operation is performed on the watermark data. This proposed method aims to embed digital watermarks covertly into digital content, ensuring the fidelity, imperceptibility, key uniqueness, non-invertibiltiy, recovery, robustness, and tamper resistance of the watermarking process.

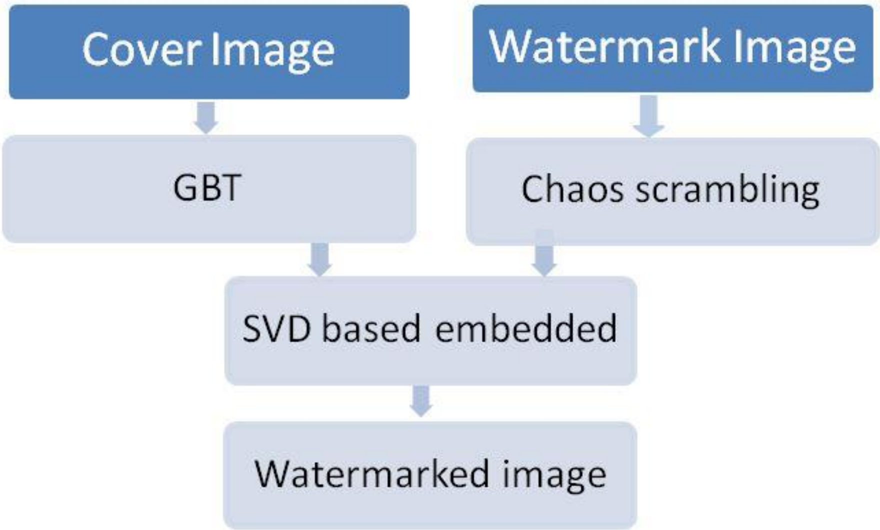

Fig. 1 Flow diagram of the proposed scheme

3.1 Methodology

There are some steps are mentioned below which included in the proposed methodology:

1. Select a cover image: The first step is to select a cover image in which we want to store the data. The cover image can be any digital image that we want to use for this purpose.
2. Select a watermark or secret image: The next step is to select a watermark or secret image that we want to store in the cover image. The watermark or secret image can be any digital image that we want to keep secure.
3. Apply chaos scrambling on the secret image: To make the secret image more secure, we apply chaos scrambling. Chaos scrambling is a technique that uses chaotic systems to shuffle the pixels of the image. This process makes it difficult for anyone to decode the secret image.
4. Get the output scrambled image: After applying chaos scrambling, at the output scrambled image will be produced. This image will be used for embedding the data into the cover image.
5. Apply graph-based transform (GBT) on the cover image: The next step is to apply GBT on the cover image to transforms an image into a graph structure. This process makes it easy to manipulate the image data.
6. Embed the chaos scrambled image using SVD: Further embed the chaos scrambled image into the cover image using SVD (singular value decomposition). SVD is a mathematical technique that decomposes a matrix into three parts. This process makes it easy to embed the secret image into the cover image.
7. Apply inverse GBT on the new image: After embedding the chaos scrambled image, apply the inverse GBT on the new image. This process converts the image back to its original form.
8. Calculate parameters like PSNR: The next step is to calculate the parameters like PSNR (Peak Signal to Noise Ratio) to measure the quality of the encrypted image. The higher the PSNR value, the better the quality of the encrypted image.

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9. Recover the watermark image: To recover the watermark or secret image, apply SVD techniques on the encrypted image. This process extracts the embedded data from the encrypted image. After this step, original watermark or secret image will be reproduced.

The combination of mathematical techniques used in this image encryption method provides a reliable means of storing and transmitting digital images securely. By utilizing chaos scrambling, SVD, GBT, and PSNR, this approach makes it challenging for unauthorized parties to gain access to the hidden data in the image.

4. RESULTS AND DISCUSSION

In order to evaluate the performance of the proposed digital watermarking method, this proposed method conducted simulations using MATLAB software and compared it with an existing method. The peak signal to noise ratio (PSNR) is used as a performance metric. The proposed method is a combination of Graph Based Transform (GBT) and Singular Value Decomposition (SVD), and its efficacy was tested on three different cover images and one watermark image at varying resolutions. The results indicate that the proposed method outperforms the existing method, which was found to have limitations when dealing with extreme pixel values during the watermarking process.

The proposed method showed significant improvement over the existing method in terms of preserving the watermark values and avoiding extreme pixel values during the watermarking process. The use of GBT and SVD helped in achieving better robustness against various image processing attacks, such as compression and noise addition, while maintaining high image quality.

In addition, the proposed method was tested on various image sizes and resolutions, ranging from 512x512 pixels to 2048x2048 pixels for the host image and from 16x16 pixels to 64x64 pixels for the watermark image. The dataset used in this study includes three host images named “line.png”, “baboon.png”, “pepper.png”, sourced from reference [12}. These images were chosen as they represent a diverse range of visual content and are commonly used in image processing research. To create the watermark images, Adobe Photoshop was used. The results showed that the proposed method is scalable and can be applied to images of different sizes and resolutions without compromising the quality of the watermark or the host image. Results of proposed method are shown below as:

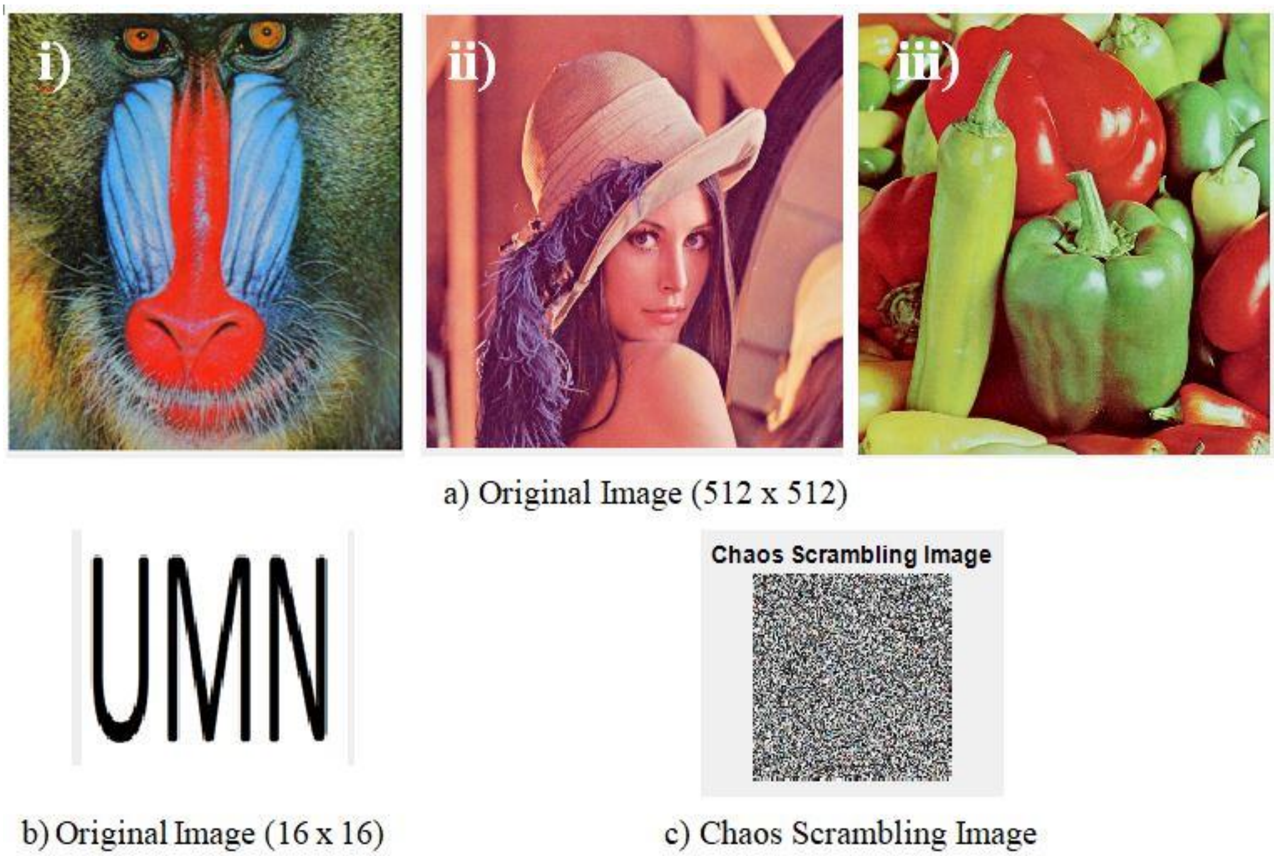

Fig 2. Original Image (512x512, 16x16, Chaos Scrambling)

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a) Watermarked Image (512 x 512)

b) Watermarked Image (16 x 16)

Fig 3. Watermarked Image (512x512, 16x16)

According to the average resolution and watermark technique, the image quality is shown in the below mentioned table: as shown in Table 1.

TABLE I COMPARISON TABLE FOR THE PROPOSED SCHEME ON VARIOUS FACTORS

Sl No	Cover and Watermark Image Resolution	DWHT	GBT-SVD
1	512 x 512 and 16 x 16	76.91	78.78
2	1024 x 1024 and 32 x 32	85.06	88.22
3	2048 x 2048 and 64 x 64	85.15	89.25

IV. CONCLUSION

Based on the results obtained from the proposed method, it can be concluded that the application of Graph Based Transform (GBT) and Singular Value Decomposition (SVD) in digital watermarking provides better results compared to the existing method. The average PSNR values obtained for the host image with 512 x 512 pixels and 16 x 16 pixels' watermark image, 1024 x 1024 pixels host image with 32 x 32 pixels' watermark image, and 2048 x 2048 pixels host image with 64 x 64 pixels' watermark image are 78.78 dB, 88.22 dB, and 89.25 dB, respectively. These results show an improvement in the PSNR value compared to the existing method. Therefore, it can be concluded that the proposed method is more effective in embedding and extracting the watermark while maintaining the quality of the host image. Further studies could investigate the potential of the proposed method in enhancing the security features of other applications such as face recognition [13] and plagiarism detection [14].

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BIOGRAPHY

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