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Underwater image copyright protection using robust watermarking technique

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ABSTRACT

It became possible to send and reformat underwater images for copyright theft due to the rapid advancement of computer networks and image forgery tools. Acquiring underwater images is dangerous and requires much efforts, expensive imaging equipment, and professional photographers. Therefore, there is an urgent need to develop copyright protection methods to ensure that property rights are not lost. This paper presents a robust watermarking technique that ensures proof of ownership for underwater images, preventing unauthorized individuals from claiming ownership. The suggested watermarking technique's main contribution depends on using the Hough transform in order to find appropriate regions to hide the watermark information within the underwater images. The Hough transform is useful for identifying areas of difficult texture that can be used as a host for watermark information with minimal distortion. Also, the Twofish algorithm has been used to encrypt the watermark information before being hidden in the underwater image. The performance of the suggested watermarking technique is tested by two metrics: quality and robustness. The results show that the suggested method works because of the quality of the images that were made after the watermark was added and because it could withstand the attacks on it.

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1. INTRODUCTION

At present, underwater images play an important role in scientific research that deals with the study of bodies living under the surface of the water in the seas and oceans, in addition to the study of the marine environment. Despite the preceding argument, there is a great difficulty facing photographers in taking pictures underwater due to the danger of predatory creatures, the instability of the aquatic environment, and the lack of light, which makes the photographic process require high resolution, advanced and high-cost devices, in addition to the means of protection for workers in this field. As a result, there is a serious need to maintain the property rights of underwater images to ensure that copyrights can be protected and eventually unauthorized persons can be prevented from infringing [1]. The digital watermarking technique provides one of the best solutions for copyright protection of underwater images [2]. There are many definitions of digital watermarking, which can be defined as the process of hiding information in multimedia content without realizing its presence. After that, the watermark is extracted from the locations that were used during the hiding process [3]. The watermark can be used in many applications: proof of ownership rights (copyright protection), prevention of illegal copying, content authentication, secret communication, and tracking control [4]. The watermark can be classified based on several factors. It can be visible or invisible, fragile, or robust, spatial or frequency, private or public [5]. The watermarking techniques need specified requirements depending on the application domain. The common requirements are i) Imperceptibility, ii) Robustness, and iii) payload. These requirements cannot all be met at the same level, so a compromise must be made between them [6]-[8].

The research problem can be stated as preserving the copyright of underwater images and preventing their illegal use by unauthorized persons. So the main aim is to propose a robust watermarking technique for copyright protection. In the literature review, many watermarking methods have been proposed to prove ownership rights to digital images. Shahadi *et al.* [9] proposed a novel and robust approach to protect the copyright of digital images and restrict unauthorized persons from using this property. The discreet wavelet transform (DWT) transforms the digital image into multi-level wavelet levels. In the hiding process, the watermark is hidden in the coefficients of the lowest frequency level. It aims to reduce the total error resulting from the hiding process and protects hidden bits against many attacks such as JPEG-compression, noise adding, rotation, translation and cropping. Yuan *et al.* [10] proposed a new digital watermarking method to find a satisfactory solution to the problem of copyright protection. The idea is based on mixing the frequency domain with the spatial domain. The discrete cosine transform (DCT) plays a major role in choosing the locations that hide the watermark in contrast to the spatial domain. The processes of hiding and extracting watermark information are accomplished in the spatial domain without a real DCT domain. This method achieved a large capacity with better transparency and high robustness level. Daoui *et al.* [11] presented a novel zero-watermarking technique against complex image attacks on grayscale images. The proposed technique exploits the histogram descriptor to produce a private series of binary bits to select the region of interest (ROI). The sine cosine algorithm (SCA) is utilized to determine the ROI in the host image. Afterward, the resulting histogram of detected ROI is binarized and combined with a secret method. The experimental results prove the effectiveness and robustness of the proposed technique to resist geometric attacks.

The main contribution of the suggested watermarking technique depends on using the Hough transform to find appropriate regions to hide the watermark information within the underwater images to preserve the image's quality and copyright protection. This paper is prepared in the following style. Section 2 presents the Hough transform. The robust watermarking technique for underwater images is proposed in section 3. The experimental results and explanation are offered in section 4. The conclusions of this paper are stated in section 5.

2. HOUGH TRANSFORM

Through a review of the literature survey it can be seen that Hough transforms as an edge detector to identify the edge features in the digital image. Hough transform can be a mapping function that transforms a pixel in the image surface into a line segment or an arc in the Hough surface. The Hough transform can be used in many applications, such as image analysis, pattern recognition, and object clustering [12]. Hough transform introduces an important way to the issues related to line identification in an image. It was first used to detect straight lines and was later developed to detect irregular lines such as curves, ellipses or circles and was then generalized to any shape. The Hough transform applies to the image with a low noise level. Therefore, noise removal is required before applying this transform [13].

3. PROPOSED ROBUST WATERMARKING METHOD

In general, the underwater image can be attacked by many types of tools, such as image processing techniques and fabrication attacks. Therefore, we propose a new robust watermarking technique based on Hough transform for ownership proof of underwater images. The proposed technique consists of two parts, watermarking hiding and watermarking extraction. In this part, a full description of the steps of the proposed robust watermarking technique will be presented. The major target of the proposed technique in this paper is to achieve copyright protection for the underwater image. One of the most important strengths that distinguish the proposed technique is its ability to resist potential attacks and the absence of the need for the original image during proof of ownership. The proposed technique includes two main processes, one at the sender part for hiding and another at the receiver side for extraction. All steps of the proposed technique are shown in Figure 1.

3.1. Original underwater image

The underwater colour images are input to the proposed technique taken from the enhancing underwater visual perception (EUVP) dataset. The EUVP dataset includes many underwater images with low and high perceptual quality, which are used for scientific research purposes. In the EUVP dataset, each image is in RGB space with a size of 256×256 pixels. In this work, the underwater image is used as a host to insert the watermark information. The sample of the input underwater image is shown in Figure 2.

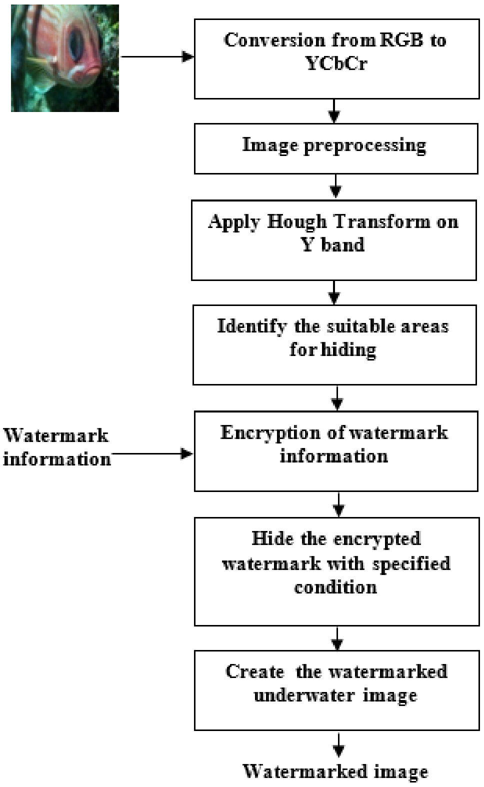

Figure 1. Block diagram of the hiding watermarking process

Figure 2. Sample of an underwater image from EUVP dataset [14]

3.2. Conversion from RGB to YCbCr

The main aim of the proposed robust image watermarking technique is to get very high degree as possible of robustness and transparency. So, it is needed to convert the host underwater image to the YCbCr color system. The YCbCr system contains three color levels. the first component is Y and also called luminance; it contained important information about the host image which should not be lost when doing compression operations. Therefore, the Y component is used as the host to hide the watermark information. On the contrary, other components Cb and Cr contain less important information and are not suitable to hide the watermark.

3.3. Image preprocessing

In this step, the underwater images are initialized for the purpose of making them suitable for applying the Hough transform, which requires the images to be noise-free. This step involves performing two sub-processes on Y component: de-noising and converting to binary representation. For the purpose of de-noising, a non-linear filter called the median is used. The reason for choosing this filter is that it preserves the edges and does not destroy its original structure. The adaptive thresholding process is used to represent the image in binary mode. One of the most important features of the adaptive thresholding process is it deals with the image according to regions, not the entire image, which takes into account each region according to its nature and texture. The result obtained will be passed to the next step.

3.4. Apply Hough transform

It is also known that areas with many edges and textures are more suitable for hiding watermark information, achieving high robustness and transparency. Therefore, the Hough transform was used to identify the real edge areas (it is useful during the hiring process) and to exclude the smooth areas that are not useful for the hiding process due to poor security. The edges areas such as lines, circles, and ellipses within objects in underwater images are used in the next stage as an indication to choose the appropriate pixels to hide the watermark information at the sender part for a proof of ownership.

3.5. Identify the suitable areas for hiding

After the implementation of the Hough transform is completed, the challenge is the selection of appropriate places for the watermark hiding. In this step, the underwater image is separated into two classes: edges area and smooth area. Initially, the smooth area is excluded, while edge areas are taken into account by selecting a part of them based on 8-neighbour pixels in and random manner. This step's output is a location map used during the hiring process.

3.6. Encryption of watermark information

In this step, the Twofish encryption algorithm was applied to encrypt the watermark before it is hidden into the underwater images. Figure 3 illustrates the structure of Twofish algorithm. Watermark information security is one of the most important requirements that must be taken into account when designing watermark systems. Therefore, the watermark information is encrypted to increase its security level. The Twofish algorithm is fast, secure and depends on a same key for both encryption and decryption.

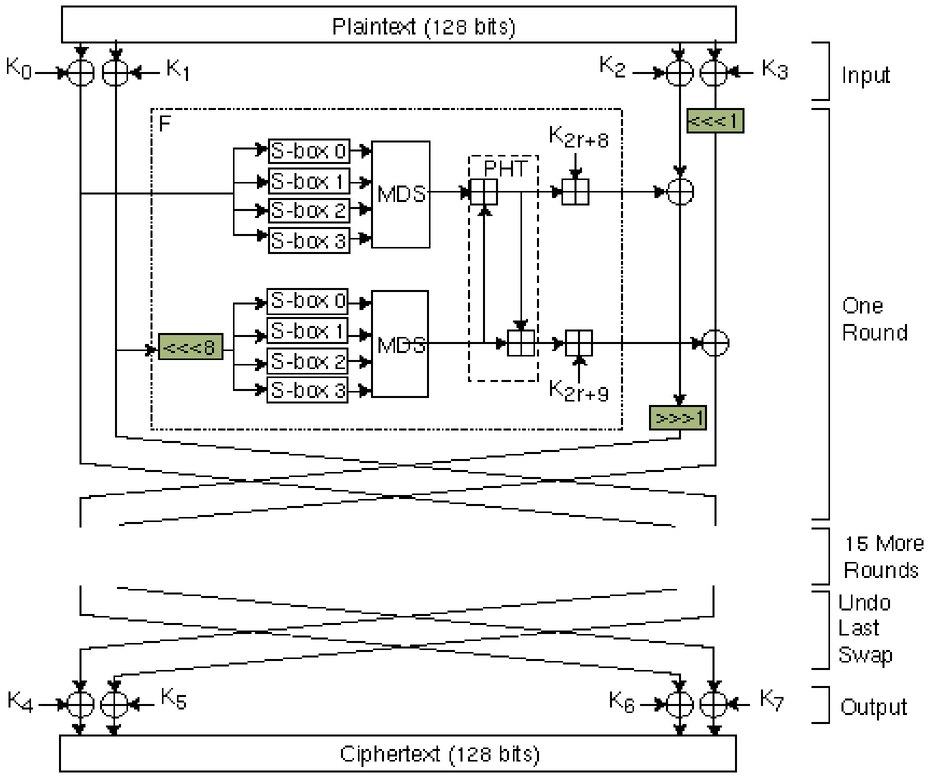

Figure 3. The structure of the Twofish algorithm [15]-[17]

3.7. Hiding of watermark information

In this step, the encrypted watermark is inserted into the selected areas (edges areas) using pixel value difference (PVD) technique. The PVD can be considered as one of the effective significant techniques used within information hiding because it fulfills the three most important requirements, which are the large amount of data that will be hidden, resistance to attacks, and high quality. In other words, it can insert a large amount of data within the underwater image without a perceptible deterioration in the fidelity, which makes it hard for people to observe. The edges areas split into small areas with no overlapping in a zigzag manner. Figure 4 shows the zigzag process. In this process, the watermark information hides in selected pixels based on the differences between the two successive pixels, $p_{i,}$ and p_{i+1}. In the last step, the watermarked underwater image is produced by reassembling all components in the underwater image.

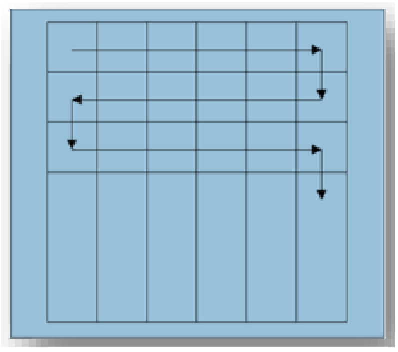

Figure 4. The zigzag process

3.8. Watermark extraction

On the receiving side, the watermark information is extracted from watermarked underwater image based on the sequence of the same steps used during the hiding process. The Hough transform is applied to determine areas that store the watermark information in the Y band at the underwater image. This watermark is used as a reference to prove the copyright of the image vendor.

4. RESULTS AND DISCUSSION

This part provides the experimental results obtained from applying and testing the proposed watermarking technique. In this testing, the many hosts' underwater images taken from the EUVP dataset have been used to evaluate and test the proposed technique's performance activities. Figure 5 presents the three original underwater images, and Figure 6 provides the resulting images after applying the Hough transform for each image.

Figure 7 provides the watermarked underwater images afterhiding the encrypted watermark information in each image. As it can be seen in Figure 7, the watermarked images are very similar to the original images without significant distortions as a result for inserting the watermark information. This is due to the use of the Hough transform in selecting hiding areas.

Figure 5. Original underwater images

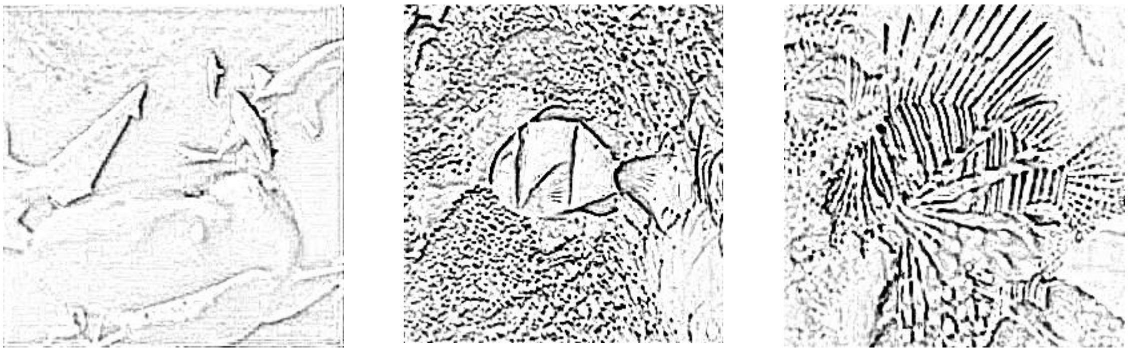

Figure 6. The resulting images after applying the Hough transform

Figure 7. The resulting images after hide the encrypted watermark

4.1. Quality assessment

In this experiment, four objective measures are used to assess the quality level of watermarked underwater images. These measures included: mean squared error (MSE), peaksignal-to-noise ratio (PSNR), structural similarity index (SSIM), and feature similarity (FSIM). Table 1 provides the quality assessment results for the four quality measures of the proposed robust watermarking technique. As shown in Table 1, the quality measurements proved that the degradation of the watermarked underwater images is not perceptible for each sample. This means the watermark information that is embedded in the forked edge regions is difficult to notice and thus gives a high-quality index.

Table 1. Quality assessment results of the proposed technique

Watermarked underwater Images	MSE [18]	PSNR(dB) [18]	SSIM [19]	FSIM [20]
Sample_1	0.873	51.76	0.983	0.957
Sample_2	0.971	50.32	0.978	0.949
Sample_3	0.654	53.29	0.992	0.962

4.2. Robustness evaluation against attacks

Another important indicator that depends on when evaluating the efficiency and effectiveness of the proposed robust watermarking technique is robustness. So, some attacks are applied on watermarked underwater images included: blurring image, additive noise, and image sharpness. Figure 8 shows the attacked watermarked images.

As illustrated in Figure 8, the three common kinds of attacks have been used in order to test the robustness level of the watermarked underwater images. So, we will try to extract the watermark information from attacked images and then compare it with the watermark information before the hiding process. The normalized correlation (NC) measure was used as an indicator for robustness level. The obtained results are stated in Table 2. Through the NC values shown in Table 2, it is clear that the proposed watermarking technique has a high level of robustness.

Figure 8. The attacked watermarked images, the first row represents blurring attack, the second row represents additive noise attack, and the third row represents sharpness attack

Table 2. The NC values of robustness evaluation

Attacks	Attacked watermarked images		
	Sample_1	Sample_2	Sample_3
Blurring attack [21]	0.873	0.991	0.983
Additive noise attack [22]	0.971	0.966	0.978
Sharpness attack [21]	0.654	0.860	0.992

4.3. Comparison with related works

In this section, the obtained results are compared against the results of other works in terms of image quality. Table 3 provides the results of comparison for the quality index with other works. Another important indicator that will be adopted in comparison with other works is the robustness. Table 4 provides the results of NC for proposed technique and other works.

Table 3. The Quality assessment results for proposed technique and other works

Watermarked underwater Images	MSE	PSNR(dB)	SSIM
Ayu *et al.* [23]	2.023	45.07	0.999
Lidyawati *et al.* [24]	0.34	37.24	0.94
Proposed method	0.654	53.29	0.992

Table 4. The results of robustness for proposed technique and other works

Methods	NC
Ernawan [25]	0.823
Ernawan and Ariatmanto [26]	0.879
Proposed technique	0.902

As it was noted in Table 3 and Table 4, the proposed method achieved satisfactory results and an optimal trade-off between quality and robustness factors. Also, the proposed method performed better than some of the works that were compared with it. Therefore, the proposed technique has achieved an effective performance in terms of imperceptibly of watermark in images and its resistance to many attacks.

5. CONCLUSION

Due to the growing interest in exploring and studying the underwater environment, the process of underwater photography is now being managed by specialized experts and requires high budgets. Therefore, protecting the copyright of such content is an important issue. This paper proposed a robust watermarking technique to guarantee copyright protection for underwater images. The Hough transform was used to determine the textures and edge areas suitable for embedding the watermark information imperceptibly and robustly. Also, the robust watermarking technique is simple and does not require complex computations. The experimental results proved the strength of the proposed technique in terms of quality, as it is difficult to notice the effect of hiding the watermark information. In terms of robustness, the proposed technique has outperformed most of the common attacks.

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