JOURNAL OF SOUTHERN COMMUNICATION ENGINEERING
ISLAMIC AZAD UNIVERSITY BUSHEHR BRANCH

E-ISSN: 2980-9231
https://jce.bushehr.iau.ir

https://doi.org/10.30495/jce.2023.1998526.1230

Vol. 13/ No. 51/Spring 2024

Research Article

A New Automatic Watermarking Algorithm based on Fuzzy Logic and Harris Hawks Optimization

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Received: 11 October 2023
Revised: 1 November 2023
Accepted: 21 November 2023

Abstract

This paper presents a new watermarking method to improve the robustness and transparency of extracted and host images. The embedding process is based on decomposing of pyramidal directional filter bank and triangular matrix, while the watermark extraction process is based on Mamdani fuzzy logic. In this design, in order to obtain efficient robustness and transparency, the Harris hawks optimization algorithm is used to find the best value of embedding factor. For this purpose, in the embedding algorithm, pyramid directional filter bank decomposition is utilized and accordingly the approximation sub-bands are divided into 8*8 non-overlapping blocks. Moreover, by decomposing the triangular matrix, which embeds the watermark bits in the matrix element, the use of Mamdani implication and the product inference engine have led to an efficient watermark extraction. The simulation results show that the quality of the watermarked image is equal to 60.6dB. Furthermore, applying the proposed algorithm is strong against attacks.

Keywords: Watermarking, Pyramidal Directional Filter Bank Decomposition, Fuzzy inference, HHO.

Highlights

- Application of fuzzy logic in watermark image extraction.
- Application of the Harris Hawks optimization in the embedding algorithm.
- Applying a new algorithm for embedding a watermark image in the host image.
- Achieving strong robustness of the proposed algorithm to attacks.
- Achieving a watermarked image quality of 60dB.

Citation: M. Falah Kazemi, A. Ahmadpour, and N. Pourmahdi, "A New Automatic Watermarking Algorithm based on Fuzzy Logic and Harris Hawks Optimization" *Journal of Southern Communication Engineering*, vol. 13, no. 51, pp. 65–78, 2024, doi: 10.30495/jce.2023.1998526.1230, [in Persian].

1. Introduction

Advances in integrated circuit manufacturing technology led to the creation of portable digital hardware. On the other hand, the development of the internet portable equipment makes it easy to transfer and distribute images and documents. Therefore, the presence of an invisible watermark to identify the source of the image is important in some applications. For this reason, image broadcasters try to destroy the invisible watermark so that the original source of the image cannot be recognized. As a result, a branch of science is based on proposing algorithms that embed the watermark image in the original image (host) in such a way that it is invisible at first. Secondly, the quality of the original image should not undergo many changes as much as possible.
Implementation of watermarking may be done in the domain of spatial or the domain of transform. Many researchers have presented articles in these two domains. Some of the used transforms are: Discrete Fourier transform (DFT), Discrete Fraction Fourier transform (DFrFT), Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT) and Contourlet Transform (CT) [1-11].

2. Innovation and contributions

In this article, a new watermarking method based on PDFBD and triangular matrix and Harris Hawks optimization along with fuzzy logic feature extraction is presented. In this field, until now, fuzzy logic has not been used in the watermark extraction stage, Harris Hawks optimizer in the optimization stage, and two combinations of PDFB and triangular matrix in the insertion stage, and therefore these methods have been used for the first time in this article, which leads to improve the results.

3. Materials and Methods

The proposed algorithm is divided into four sections. We will investigate preprocessing, watermark embedding, watermark extraction, and optimization, respectively. Moreover, the pseudocode of the algorithm is also introduced in each section.

3.1. Pre-processing Process

In this section, the watermark image is received and scrambled with three different keys using the Arnold transform. Therefore, three scrambled watermark images will be created, which we call MAR, MAG and MAB. The reason for using the Arnold transform and three different keys is increased security and resist against cropping attacks, respectively. On the other hand, the host color image is received in the RGB space and it is separated into three component images of red, green and blue colors. The reason is that the watermark image in the embedding algorithm will be inserted independently in all three-color components of the host image. To prepare the host image for the embedding section, Pyramidal Directional Filter Bank Decomposition (PDFBDec) is applied to each color component of the host image. Reference [12] describes the pyramid directional filter bank decomposition.

3.2. The watermark embedding process

The process of creating a watermarked image is that the approximation pdfbdec (AP) subband of each color component is divided into 8*8 non-overlapping blocks. The AP subband of the 512*512 image is a 256*256 matrix, and as a result, we will have 1024 blocks. Schure decomposition matrix transform is applied to each block. Therefore, two matrices Q and S are obtained. S is an upper triangular matrix and Q is a unitary matrix. The watermark information is inserted in the first row and the eighth column of the S matrix. To form a watermarked image, the process must be done in inverse, that is 8*8 blocks must be formed from the decomposition matrix S and 8*8 blocks are merged and new AP subbands are obtained. An inverse transform (pdfbrec) is applied to the new AP subband and other subbands of pdfb, and therefore the watermarked image will be obtained in the spatial domain.

3.3. Watermark extraction process

In the watermark extraction process, the watermarked image will be received, which may or may not be subject to various attacks. The pdfbdec is applied to all three components of the watermarked image and AP coefficient from pdfbdec is partitioned into 8*8 non-overlapping blocks. Each block is separately decomposed into an upper triangular matrix. Then, the first row and the eighth column of S matrix are selected. This value is selected as the input of the fuzzy set.
It should be mentioned that, adaptive membership is considered based on ALFA. In the third rule, the probability of the original watermark being 1 or -1 is used to assign the set to y, which is calculated in the pre-processing part for each original watermark. Each bit of the watermark is embedded in each color component and the subband of the triangular approximation-matrix.

3.4. Optimization of embedding factor

In this work, we use harris hawks optimization (HHO) [13] to optimize the embedding factor. The aim of optimization is to obtain the best embedding factor to find the best SSIM and BER for the watermarked image and watermark extracted image, respectively. It is clear that the BER is different for various attacks, so we use the scenario of several attacks in the optimization. Attacks include a 3*3 average filter (BA3), a 5*5 average filter (BA5), a 3*3 median filter (BM3), a 5*5 median filter (BM5), a compression 90 (BC9), a compression 70 (BC7), a gaussian noise 0.001 (BG1), a gaussian noise 0.01 (BG2), a salt & pepper noise 0.001 (BP1), a salt & pepper noise 0.01 (BP2), spark noise 0.001 (BS1), spark noise 0.01 (BS2) and histogram equalization (BH). It is also important here to consider the extraction of non-attacking (BN) in the fitness equation. In the fitness equation, different weights are considered for SSIM and BER of different attacks. These weights are selected based on the importance of SSIM and BER. If the weights are not chosen right, one measurement parameter will improve more than other one which can degrade another parameter

4. Results and Discussion

In this section, the results of the presented work will be reviewed. For this purpose, six famous Lena, Sailboat, Baboon, Avin, flower and Peppers have been used in watermarking research. The results are expressed based on the optimized ALPA value for each image. The used measurement parameters are SSIM and PSNR, in which SSIM shows the degree of structural similarity between the two hosts and the watermarked image [14]. Table 1 shows the SSIM and PSNR of the watermarked images for the proposed algorithm. The optimized embedding factor which was calculated from HHO has been utilized in the watermarked images. The extracted watermark for combined attacks is also shown in Figure 1.

4.1. Comparing the results of the proposed scheme with similar works

The results of three papers have been used for comparison, the articles are: In [9], the author proposed a watermarking based on FRFT and SVD. In [10], they used RDWT and SVD to implement watermarking and in reference [8], watermarking is done in DCuT-RDWT domain. The comparison of transparency is done based on PSNR, the watermarking scheme introduced with similar work is calculated for Lena’s image and shown as a chart. In the present work, the transparency obtained is 60.6dB, which is a significant improvement compared to the articles under comparison.NC measurement quantity is used to compare the extracted watermark for different attacks. As it is known, the proposed scheme has excellent transparency despite good robustness to attacks. To compare the robustness of the proposed scheme with similar schemes, the watermarking image of Lena is subjected to average filtering, median filtering, Gaussian noise, spark noise, histogram equalization, salt and pepper noise, cropping, resizing, and JPEG compression attacks and then the degree of similarity extracted and the original watermark obtain by NC calculation. In order to get an estimate of the improvement in robustness to attacks, here we add all the NCs together and consider them as scores. It is clear that a higher score means better robustness to attacks. In the proposed work, the score is equal to 9.88 and for articles [9], [10] and [8] it is equal to 8.86, 6.45 and 8.02 respectively. Therefore, the proposed algorithm has efficient robustness against attacks in comparison with other works.

5. Conclusion

In this paper, a watermarking scheme based on pyramid directional filter bank decomposition and triangular decomposition was proposed. A fuzzy logic approach was also utilized at the watermark extraction level. As a result, high transparency of the watermarked image along with an improvement in the extraction watermark was achieved. Due to the fact that the embedding factor does not change linearly with SSIM and robustness, an optimization algorithm was used to obtain the optimal embedding factor. Simulation results indicated that the proposed scheme has high robustness and transparency. A 60.6dB PSNR was obtained for the image of Lena. Furthermore, the NC measurement was suitable for most of the attacks and the extracted watermark detection was recognizable as well.

6. Acknowledgement

The authors are grateful to the Islamic Azad University (IAU), Lahijan Brach in supporting the present research.

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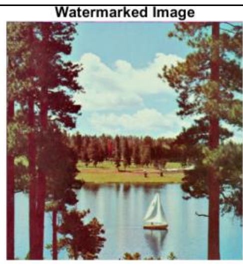
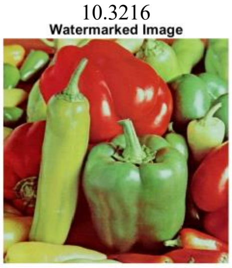
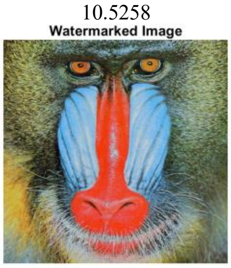
Appendix

Table 1. SSIM and PSNR for various images

Watermarked Image			
PSNR/SSIM ALFA	60.6147/0.9969 10.3216	60.32/0.9964 10.5258	55.04/0.9960 14.8737
Watermarked Image			
PSNR/SSIM ALFA	62.66/0.9980 9.0691	53.4765/0.9983 16.2352	54.7649/0.9966 15.1762

No Attack	Median & Average Filtering 3*3	Gaussian noise 0.001 & Average Filtering 3*3
		
NC=1.0000/0.0000	NC=0.9805/0.0098	NC=0.9961/0.0020
Gaussian noise 0.01 & Average Filtering 3*3	Gaussian noise 0.001 & JPG QF=80 &	Gaussian noise & Salt Peppers & Speckle (0.001)
		
NC=0.8516/0.0742	NC=0.9258/0.0371	NC=0.8613/0.0693

Figure 1. The extracted watermark image for combined attacks

Declaration of Competing Interest: Authors do not have conflict of interest. The content of the paper is approved by the authors.

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Author Contributions: All authors reviewed the manuscript.

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