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A New Image Watermarking Algorithm by Using Contourlet Transform Accompanied by PSO Algorithm

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Abstract

One of the ways to enhance the security and concealment of data used today is image watermarking. In image watermarking operation, we try to hide image inside another image without letting others know about the hidden image. In this paper, Contourlet Transform and SVD Transform are used to embedded watermark in the host image. The PSO Optimization Algorithm is also used in the watermark extraction step to find the best scale factor. The results of the proposed algorithm in this article show an improvement over the comparative methods.

Keywords: Watermarking, Contourlet Transform, PSO Algorithm

1. Introduction

Advances in technology and the popularization of digital devices such as computers, digital cameras, printers, scanners and a variety of software have led to the widespread use of digital data in data storage. The simplicity of editing and replication of information without losing its quality and transmitting it widely across the networks have increased the popularity of digital data. Creating copies without recognizing the original data, editing data with various available software and accessing

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data through networks such as the Internet provide ways of exploiting and forging data for profiteers. Watermarking was proposed to prevent these abuses or forgery of information. Watermarking by embedding data related to its use in the main data, provides purposes such as copyright protection, data authentication, copy control, data tracking, etc. various methods have been suggested to meet these goals. Methods of watermarking in frequency domain are one of the best image watermarking methods that are used [1, 2]. For example, it can be included the watermarking methods by using Discrete Cosine Transform (DCT) [[3] - [5]], and Discrete Wavelet Transform (DWT) [[6] -[9]].

2. Contourlet Transform

In image processing, how to present an image in a way that its important and desireable features such as the surrounding border can be extracted is very important. Contourlet Transform is one of the relatively new transforms that has been developed to enhance the presentation of images with wavelet transform [10]. Unlike discrete wavelet transform which uses only three vertical, horizontal and diagonal filters to extract the components of the relevant images, in the Contourlet Transform, it is possible to apply a bank of filters with multiple angles and at different resolutions [11]. Figure 1 shows the frequency-domain analysis of the image by Contourlet Transform:

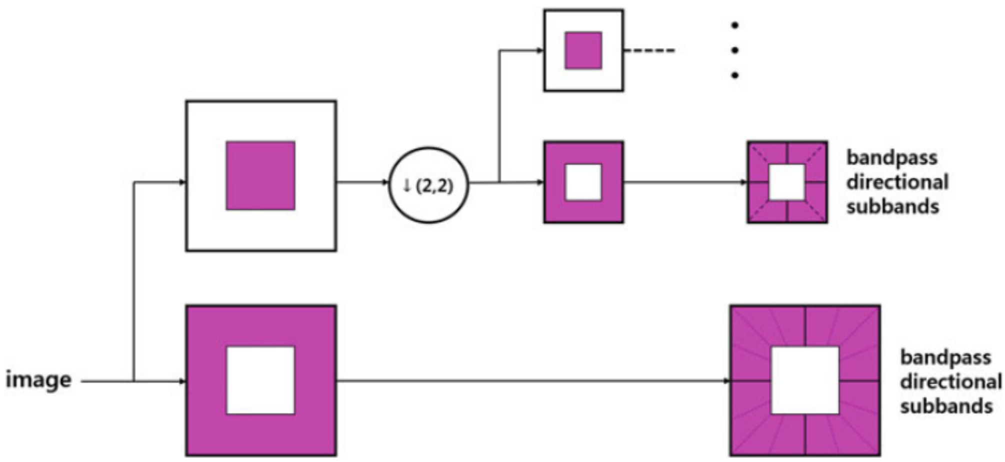

Figure 1: Display of Contourlet Transform in frequency domain.

3. SVD Transform

Singular value decomposition is a method that decomposes one matrix into three other matrixes [12]. For example, matrix A can be written by using Equation (3.1):

$$A = USV^T \tag{3.1}$$

A is an $m \times n$ matrix, U is an $m \times n$ orthogonal matrix, S is a $m \times n$ diagonal matrix, V is a $m \times n$ orthogonal matrix.
Using SVD Transform in digital image processing has some advantages, some of which are listed below [13]:

- The maximum energy of image is obtained by the largest coefficients of individual image values.

- Image transparency remains almost constant even after embedding the watermark in individual image

4. Particle Swarm Optimization (PSO)

Particle Swarm Optimization algorithm is one of the most important intelligent optimization algorithms which is located in the field of swarm intelligence that was designed by Dr. Eberhart and Dr. Ebrahart Kennedy in 1995 [14]. In the PSO algorithm, the members of the population of the answers are directly related to each other and solve the problem by exchanging information with each other and recalling good memories. In this paper, we use the PSO algorithm to find the best value of the scale factor in the watermark extraction step. The PSO Algorithm is initialized with a group of random particles and then searches for optima by updating generations. In every iteration, each particle is updated by following two "best" values. The first one is the best solution the particle has achieved so far. This value is called pBest. Another "best" value that is tracked by the particle swarm optimizer is the best value obtained so far by any particle in the population. This best value is a global best and called gBest. When a particle takes a part of the population as its topological neighbors, the best value is a best local and is called lbest. After finding the two best values, the particle updates its velocity and positions with following equation (4.1) and (4.2):

$$\begin{aligned} [] = v[] + c1 \times rand() \times (pbest[] - present[]) + \\ c2 \times rand() \times (gbest[] - present[]) \end{aligned} \tag{4.1}$$

$$present[] = persent[] + v[] \tag{4.2}$$

$v[]$ is the particle velocity, $persent[]$ is the current particle (solution). $pest[]$ and $gbest[]$ are defined as stated before. $rand()$ is a random number between $(0, 1)$. $c1$, $c2$ are learning factors. usually $c1 = c2 = 2$.
The pseudo-code of the PSO Algorithm is as follows:

```
for each particle do
    Initialize particle
end for
Do
for each particle do
    Calculate fitness value
    If the fitness value is beter than the best fitness value
    (pBest) in history set current value as the new pBest.
end for

choose the particle with the best fitness value of all particles as the gBest
for each particle do
    Calculate particle velocity accrording equation (a)
    Update particle position accrording equation (b)
end for
```

5. Proposed Algorithm

In order to embedded and extract the watermark, we act as shown in Fig.2 and 3, respectively.

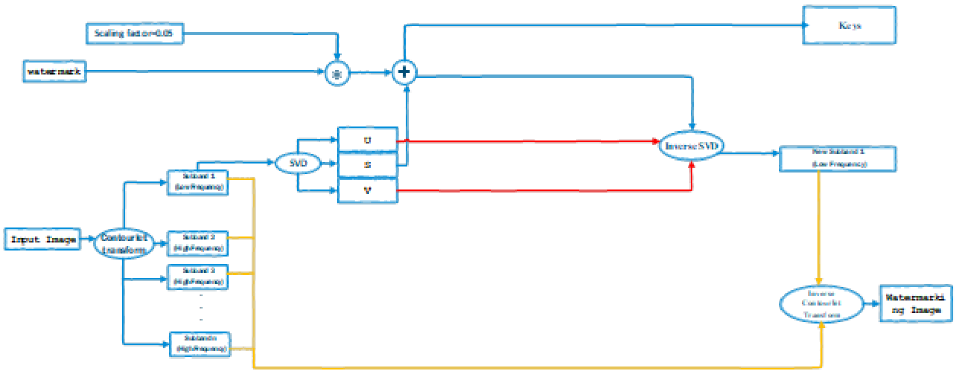

Figure 2: Embedded watermark algorithm.

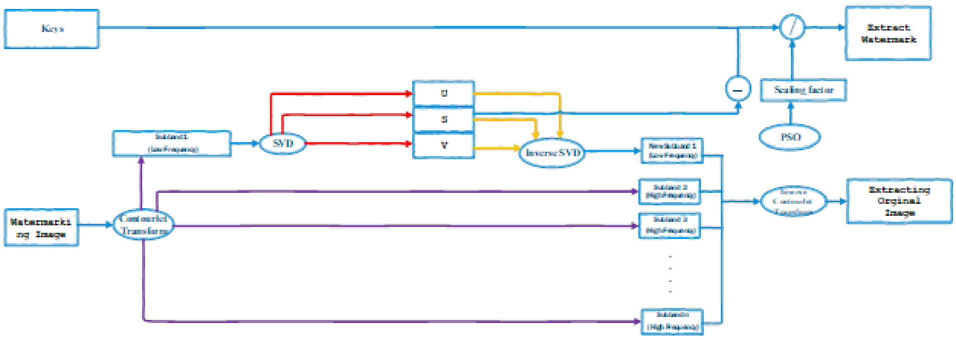

Figure 3: Extended watermark algorithm.

6. Results

In order to implementation of the experiments, we used two host images of the Airplane and Lena as well as a Peugeot watermark image is shown in Figures 4 and 5, respectively. The size of the host image is 128×128 pixels and the size of the watermarked image is 32×32 pixels.

Figure 4: Host image.

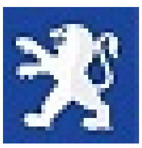

Figure 5: Watermarked image.

We also used the PSNR criterion to evaluate the test results. This criterion calculates the similarity between two input images and the final image in the watermarking operation. We calculate the PSNR value by using Equations (6.1) and (6.2) [15]:

$$MSE(I, I_w) = \frac{1}{MN} \sum_{i=0}^{N-1} \sum_{j=0}^{M-1} (I(i,j) - I_w(i,j))^2 \tag{6.1}$$

$$PSNR(I, I_w) = 10 \times \log 10 \frac{MAX_I^2}{MSE} \tag{6.2}$$

M, N are the dimensions of image. I, I_w are the input image and the final image. Also, MAX is a variable equal to 255 in 8-bit images.
The proposed algorithm in this paper is compared with the similar algorithm by Discrete Wevelet Transform (DWT) presented in the article [16]. The results of experiments that was performed on watermarked images can be seen in Table1.

Table 1: Comparing the transparency of the proposed method with the traditional method.

	Evaluate Parameter	DWT_SVD [16]	**Proposed Method**		DWT_SVD [16]	**Proposed Method**	
Type of Attack		Airplane image	Airplane image	alpha	Lena image	Lena image	alpha
No Attack	PSNR	21.9887	27.68	0.049541	22.1424	27.68	0.049541
Average Filter 3*3	PSNR	5.0495	24.4189	0.04986	6.1167	25.9561	0.049684
Average Filter 5*5	PSNR	-0.188	20.7285	0.050598	0.7797	23.4325	0.049987
Gaussian Low-Pass Filter 3*3	PSNR	14.7156	27.2839	0.04958	15.9669	27.4938	0.049559
Gaussian Low-Pass Filter 5*5	PSNR	14.6593	27.2797	0.049581	15.9094	27.5076	0.049559
Median Filter 3*3	PSNR	11.3875	27.3412	0.049548	12.1789	27.5638	0.049542
Median Filter 5*5	PSNR	5.5602	26.7261	0.049575	5.8633	27.3119	0.049548
Crop [150,150]	PSNR	-0.2934	21.034	0.050357	4.28	17.1371	0.052089
Rotation 5	PSNR	2.6289	15.9094	0.053323	8.1568	24.2562	0.049873
Rotation 30	PSNR	-4.9592	14.0285	0.055611	-0.9957	18.8979	0.051182
Rotation 45	PSNR	-4.1504	16.3118	0.052801	0.1081	16.3986	0.052707
Rotation 70	PSNR	-5.4453	13.7112	0.056165	-1.1157	16.9544	0.052331
Rotation 110	PSNR	-5.1083	11.6419	0.061389	-0.0082	20.8645	0.05051

Transition (5,10)	PSNR	-0.3362	8.1631	0.087169	3.1051	10.4037	0.066634
Transition (10,10)	PSNR	-2.7841	6.948	0.11534	0.2918	8.5871	0.081249
Transition (10,15)	PSNR	-4.8295	6.3342	0.14425	-1.6355	7.6904	0.095245
Horizontal Flip	PSNR	21.9887	27.68	0.049541	22.1424	27.68	0.049541
Vertical Flip	PSNR	21.9887	27.68	0.049541	22.1424	27.6795	0.049541
Blurring 0.3	PSNR	22.6795	27.684	0.049541	22.7695	27.6821	0.049541
Blurring 0.5	PSNR	14.6593	27.2797	0.049581	15.9094	27.5086	0.049559
Blurring 1	PSNR	3.7335	24.0507	0.049909	4.795	25.7613	0.049702
Motion Blur(15,20)	PSNR	-3.1544	15.044	0.05427	-3.0288	18.8801	0.05126
Motion Blur(15,45)	PSNR	-2.8112	14.3542	0.055205	-0.3996	18.4205	0.051479
Sharpening 0.3	PSNR	21.548	27.6795	0.049541	21.8401	27.679	0.049541
Sharpening 0.5	PSNR	12.9629	27.6692	0.049541	13.9077	27.6214	0.049541
Sharpening 1	PSNR	5.302	27.6523	0.049541	6.2613	27.2741	0.049552
JPEG Compression Q=5	PSNR	7.6878	24.2985	0.049845	6.3203	23.9306	0.049879
JPEG Compression Q=10	PSNR	9.3801	24.1435	0.049858	10.7079	26.7397	0.049581
JPEG Compression Q=20	PSNR	12.0118	27.1813	0.049568	13.4874	27.3066	0.049571
JPEG Compression Q=80	PSNR	16.0991	27.6719	0.049544	18.2342	27.6824	0.049545
JPEG Compression Q=90	PSNR	17.9799	27.6912	0.049543	19.7938	27.6825	0.049543

Gaussian Noise (0.0.001)	PSNR	19.4741	27.6587	0.04954	19.5994	27.6595	0.04954
Gaussian Noise (0.0.01)	PSNR	8.3775	27.4184	0.049564	8.0992	27.3905	0.049566
Gaussian Noise (0.0.1)	PSNR	-4.5191	12.2473	0.059572	-4.0368	16.748	0.052419
Gaussian Noise (0.0.3)	PSNR	-9.2512	7.522	0.099191	-7.9059	10.577	0.065284
Speckle Noise 0.001	PSNR	20.3124	27.654	0.04954	21.335	27.6738	0.049541
Speckle Noise 0.01	PSNR	11.5705	27.6786	0.049544	15.6217	27.5615	0.049552
Speckle Noise 0.1	PSNR	-1.6489	14.1436	0.055561	1.5968	17.9579	0.051682
Speckle Noise 0.3	PSNR	-8.331	7.9245	0.091123	-5.0202	11.4378	0.06189
Pepper And Salt Noise 0.001	PSNR	21.1735	27.6794	0.049543	21.8629	27.6773	0.049541
Pepper And Salt Noise 0.01	PSNR	15.4915	27.3409	0.049576	15.1459	27.4792	0.04955
Pepper And Salt Noise 0.1	PSNR	-0.3985	16.1951	0.053062	1.1564	20.5932	0.050552
Pepper And Salt Noise 0.3	PSNR	-7.5213	8.7046	0.080078	-5.9511	12.1738	0.059379

As we can see from the results of the experiments, the proposed algorithm in this paper by using the PSO optimization algorithm and finding the best scale factor in the watermark extraction step has much better results than the comparable algorithm.

7. Conclusion

In this article, we present a new algorithm for watermarking operations that is better than the compared methods. Using a Contourlet Transform instead of a Wavelet Transform in Watermarking enhances the transparency of the watermark Image. SVD Transform also increases the resistance of the watermarked image against various image processing attacks. We also used the PSO Algorithm to find the optimal scale factor. In the further study, we can use other frequency-domain transformations along with other optimization algorithms to improve the algorithm.

References

[1] S. A. Kasmani and A. R. Naghsh-Nilchi, "Robust digital image watermarking based on joint DWT-DCT," 2009.

[2] H. A. Abdallah, M. M. Hadhoud, A. A. Shaalan, and F. E. A. El-samie, "Blind wavelet-based image watermarking," International Journal of Signal Processing, Image Processing and Pattern Recognition. 4,1, 2011.

[3] A. M. Abdelhakim, H. I. Saleh, and A. M. Nassar, "A quality guaranteed robust image watermarking optimization with Artificial Bee Colony," Expert Systems with Applications, vol. 72, pp. 317-326, 2017.

[4] C. Das, S. Panigrahi, V. K. Sharma, and K. Mahapatra, "A novel blind robust image watermarking in DCT domain using inter-block coefficient correlation," AEU-International Journal of Electronics and Communications, vol. 68, no. 3, pp. 244-253, 2014.

[5] X. Wu and W. Sun, "Robust copyright protection scheme for digital images using overlapping DCT and SVD," Applied Soft Computing, vol. 13, no. 2, pp. 1170-1182, 2013.

[6] M. Ali, C. W. Ahn, and P. Siarry, "Differential evolution algorithm for the selection of optimal scaling factors in image watermarking," Engineering Applications of Artificial Intelligence, 31, 15-26, 2014.

[7] M. Ali and C. W. Ahn, "An optimized watermarking technique based on self-adaptive DE in DWT–SVD transform domain," Signal Processing, 94, 545-556, 2014.

[8] A. Mishra, C. Agarwal, A. Sharma, and P. Bedi, "Optimized gray-scale image watermarking using DWT–SVD and Firefly Algorithm," Expert Systems with Applications, 41, 17, 7858-7867, 2014.

[9] N. M. Makbol, B. E. Khoo, and T. H. Rassem, "Block-based discrete wavelet transform-singular value decomposition image watermarking scheme using human visual system characteristics," IET Image Processing, 10, 1, 34-52, 2016.

[10] M. N. Do and M. Vetterli, "The contourlet transform: an efficient directional multiresolution image representation," IEEE Transactions on image processing, 14, 12, 2091-2106, 2005.

[11] A. Vyas, S. Yu, and J. Paik, Multiscale Transforms with Application to Image Processing. Springer, 2018.

[12] B.-B. Huang and S.-X. Tang, "A contrast-sensitive visible watermarking scheme," IEEE MultiMedia, 13, 2, 60-66, 2006.

[13] P. Vaidya and C. M. PVSSR, "A robust semi-blind watermarking for color images based on multiple decompositions," Multimedia Tools and Applications, 76, 24, 25623-25656, 2017.

[14] J. Kennedy and R. Eberhart, "Particle swarm optimization," in Proceedings of ICNN'95 - International Conference on Neural Networks, 4, 4, 1942-1948, 1995 .

[15] S. M. Mousavi, A. Naghsh, and S. Abu-Bakar, "Watermarking techniques used in medical images: a survey," Journal of digital imaging, 27, 6, 714-729, 2014.

[16] S. M. Arora, "A DWT-SVD based robust digital watermarking for digital images," Procedia computer science, 132, 1441-1448, 2018.