ISemantic Thebichef

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Tchebichef Image Watermarking based on PN-Sequence

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***Abstract*— In the modern era, sharing and distribution of digital data over the internet have increased significantly. This makes it easier to duplicate data, even though not all data may be duplicated without permission because it has copyright. Image watermarking is the most popular solution for protecting copyright in digital images. The way to embed copyright is generally by transforming the image into the frequency domain, which in this way proves that copyright embedding is more resistant to various attacks. Discrete Tchebichef transform (DTT) is a domain transformation that has advantages in computational speed, is low in complexity and can reduce memory usage and has properties similar to discrete cosine (DCT) transformations. DCT is the most popular transformation to be developed, wherein one of the studies using the PN Sequence combined with DCT at the time of the embedding process, it was proven to improve imperceptibility quality. However, the increase in imperceptibility generally makes watermark resistance less. Based on this hypothesis the research aims to implement a watermark embedding scheme with PN Sequence on DTT to obtain a watermarking scheme that produces better imperceptibility and keeps the quality of watermark resilience against various manipulations. Based on the results of testing and measurement using PSNR, it is evident that the imperceptibility quality rises around 3dB. Watermark resistance testing for attacks also proves that using the proposed scheme but can maintain watermark resistance.**

Keywords*— *Tchebichef, Copyright Protection, Spread Spectrum, Imperceptibility, Image Watermarking

I. INTRODUCTION

The traffic of transmission, distribution, and sharing of multimedia data in the cyber world is increasingly dense in today's modern era. This is due to a revolution in the way manual data is stored using hard files into digital file storage. So that the security of digital files in cyberspace becomes the main requirement. Various methods have been carried out by several security techniques such as cryptography, steganography, watermarking to become a popular technique used, and even combined to improve security[1]–[6]. Multimedia files such as images, audio, and videos are some files whose numbers continue to increase and not a few of these files are copyrighted. Of the three methods, watermarking is the most important role to maintain copyright security[1].

Research on digital watermarking has been done a lot, especially in image media. Several discrete domain transformation methods have been proposed, such as Fourier (DFT), Cosinus (DCT), Wavelet (DWT), Tchebichef (DTT), and Singular Value Decomposition (SVD) [2], [7]–[11]. Of the four transformations, Fourier is the oldest transformation, while Cosinus and Wavelet are the most popular transformations applied in various watermarking researches. Unlike the three, Tchebichef's transformation is not as popular and has not been widely developed in image watermarking research. DTT is also actually not a new transformation model, in some studies, it has even proven to have several advantages in computational speed, low complexity and can reduce memory usage, so this transformation has a greater chance to be examined again and applied to image watermarking. Some studies such as [1], [2], [7], [8], [12]–[15] have applied Tchebichief's transformation to image watermarking, its advantages have also been proven and even proven that DTT has properties similar to DCT, even with some modifications and combinations methods can solve imperceptibility and robustness trade-off problems.

Imperceptibility and robustness are the two most important aspects in image watermarking, in addition, there are also several other aspects such as security and capacity. But imperceptibility and robustness are the two most studied things. Generally, imperceptibility and robustness are two contradictory things, where if imperceptibility increases, robustness will decrease, and vice versa. This is the biggest challenge in image watermarking research. Some image watermarking research uses Tchebichef transformation as in [1], [2], [8] has successfully solved this problem by combining it with other methods such as color space conversion and edge detection, Psychovisual Threshold, and combining with singular value decomposition (SVD). Other techniques such as PN-Sequence can also be used so that copyright embedding spreads, so it can also solve this [4]. So in this research the PN-Sequence technique was implemented and analyzed the results of the tradeoff in these two aspects.

II. RELATED WORK

Tchebichef's transformation has been applied in several image watermarking studies, as in the research of Ernawan et al.[8]. In this research Tchebichef transformation was applied based on small blocks with dimensions of 8 * 8 pixels. From the results of the transformation of each block the coefficient (1.1), (2.0), and (0.2) are selected. From the three coefficients, one of the coefficients is chosen to insert a watermark based on random numbers generated from the PN generator. The strength of the watermark insertion can be adjusted using the threshold values of 0.25, 0.5, 0.75 and 1. Using this scheme the PSNR value is around 45dB up to 57dB, depending on the threshold value. This scheme is also resistant to various attacks.

Other research was also conducted by Setiadi et al.[7], in his research the performance of DTT and DCT was tested and analyzed. This is done because many of the references contained in his research say that these two transformations have similarities, then a performance test is performed. Performance tests are carried out by measuring the output quality (imperceptibility) and resistance to various attacks. Based on the results of the test it was found that Tchebichef's performance was quite identical to DCT, a striking difference was the superiority of Tchebichef's transformation in terms of computational speed.

Najih et al. [4] proposed a combination of PN Sequence and DCT for information hiding. In his research, it has been proven that the use of PN Sequence to insert a watermark can make watermarks more spread throughout the image so that the watermarked image looks better. This is evidenced by the PSNR value increasing around 3dB. Another research conducted by Ernawan [2], has developed a scheme found in research [8]. The Tchebichef transformation is applied to 24-bit imagery by converting to the YCoCg-R color space and using edge detection. In this way better results are obtained in terms of quality and resistance to attacks.

From some related research above, in this research, the image watermarking scheme using Tchebichef's transformation in research [7] was developed with a combination of PN Sequence on the insertion scheme to improve the image quality of the watermark, as in the research conducted in [4]. This is done because of the similarity of the Tchebichef transformation with DCT. Based on this hypothesis, the watermark insertion scheme using the PN Sequence-based Tchebichef transformation should improve the quality of the watermarking scheme using the Tchebichef transformation.

III. PROPOSED METHOD

Image watermarking has two main processes, namely embedding and extraction. At the embedding stage, three inputs are needed in the form of container images, watermark images, and PN keys. In more detail, the watermark insertion stages are explained in the flowchart presented in Fig. 1.

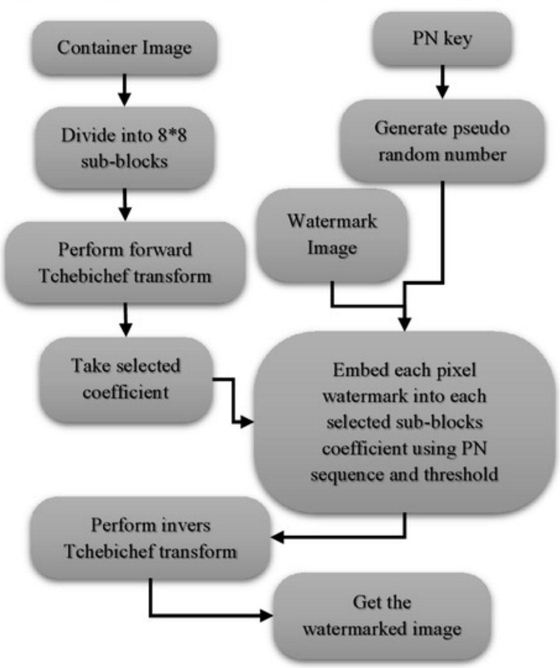

Fig. 1. Embedding proposed scheme

Based on Fig. 1 it appears that the Tchebichef transformation is carried out based on small sub-blocks with dimensions 8 * 8. The 8 * 8 pixels dimension was chosen to be a standard dimension in the image transformation process in various researches [1], [2], [7], [8]. After the transformation in the sub-block, the spatial value of the image changes to the frequency value, the frequency value that is at the coefficient (0,0) is chosen to do the watermark embedding. Each coefficient (0,0) in the sub-block is filled with one-pixel watermark value. Where the embedding process is done based on random numbers generated by PN generators and PN keys. The embedding algorithm is shown in formula (1).

$$\begin{cases} M_{0,0} = T_{0,0} + (\alpha * W_{x,y}), PN = 1 \\ M_{0,0} = T_{0,0} - (\alpha * W_{x,y}), PN = 0 \end{cases} \quad (1)$$

Where T is the selected Tchebichef coefficient value, W is the watermark value, x and y are watermark pixel coordinates, M is the modified coefficient value after the watermark is embedded, α is the watermark embedding threshold value.

After obtaining the modified coefficient value after pinned a watermark. Each frequency sub-block is returned to the spatial value by inverse transformation, then rearranged into the watermarked image. Furthermore, the quality of the watermarked image was measured using MSE and PSNR which can be calculated using formula (2) for MSE and formula (3) for PSNR.

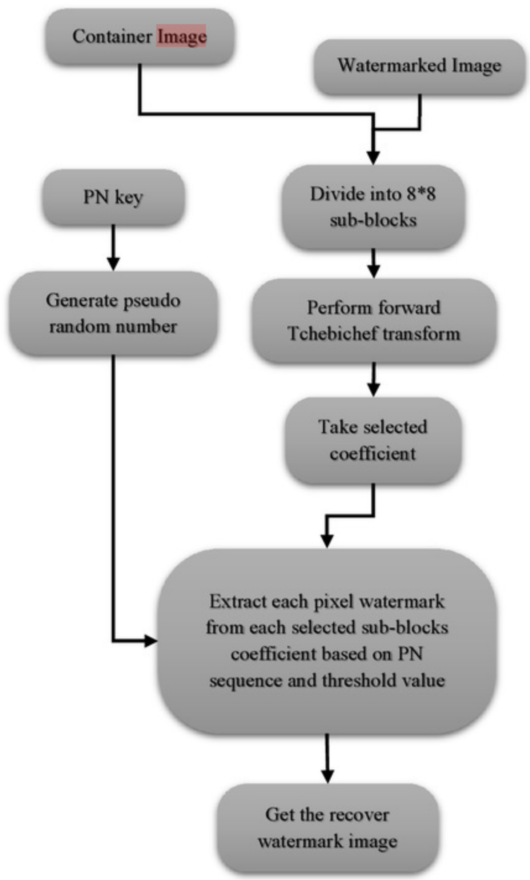

Fig. 2. Extracting proposed scheme

$$MSE = \sum_{w=0}^{W}\sum_{h=0}^{H}\|I(w,h) - I'(w,h)\| \quad (2)$$

$$PSNR = 10\, log_{10}\left(\frac{255^2}{\sqrt{MSE}}\right) \quad (3)$$

Where I is the image of the original container, I 'is the watermarked image, w is the image width and h is the image height.

The MSE value that is getting closer to zero indicates that the error squared value is getting smaller, in other words, the watermarked image has good image quality. Conversely, the better the value of the PSNR must be greater. At least the PSNR value must reach 40dB so that it is included in the excellent quality category[5].

While the proposed watermark extraction stage is presented in Fig. 2. In the extraction phase, three inputs are also needed, namely the original container image, watermarked image, and PN key used during the embedding process. In the original image container, the watermarked image carried the same first three processes, namely dividing the image into sub-blocks of dimension 8 * 8. Next, transform each sub-block with DTT. Then take the coefficient (0,0) in each sub-block. On the other hand the PN key is used to generate random sequence numbers for the extraction process. To retrieve the pixel value of a watermark image taken from the extraction process, formula (4) is used. Then each pixel is rearranged into a retrieved watermark.

$$\begin{cases} R_{x,y} = (W'_{0,0} - C_{0,0})/\alpha, PN = 1 \\ R_{x,y} = (C_{0,0} - W'_{0,0})/\alpha, PN = 0 \end{cases} \quad (4)$$

Where R is retrieved watermark image, W' is the watermarked image, and C is the original container image.

IV. Implementation and Results

At this stage, the first container image dataset is selected as shown in Fig. 3. The selected container images are standard test images that are widely used. This image has dimensions of 512 pixels wide and 512 pixels high with 8-bit depths.

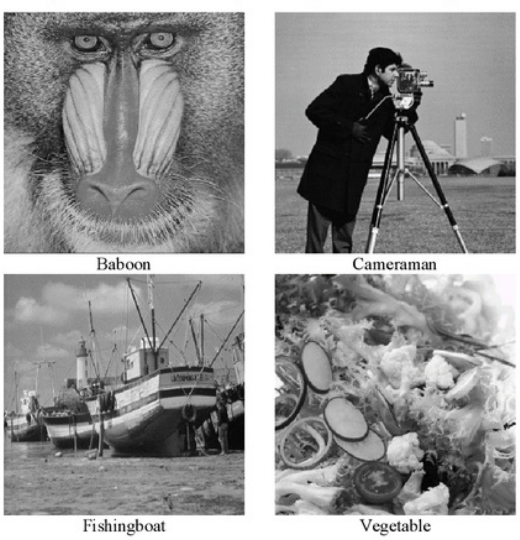

Fig. 3. Container image used

Fig. 4. Binary watermark image

Whereas for the watermark image used is presented in Fig. 4. Then for the embedding stage, first the container image is divided into N * N sub-blocks as described in the previous section. Each sub-block is transformed using two dimensions (2D) - forward DTT with the formula (5).

$$T_{bc} = \sum_{d=0}^{N-1}\sum_{e=0}^{N-1} r_b(d) r_c(e) B(d,e) \quad (5)$$

Where B is are original sub-block with d, e dimensions, T is transformed sub-block with a, c dimensions, $a, c, d, e = 0,1, \ldots N-1$, $r_b(d)$ and $r_c(e)$ is Tchebichef polynomial recursion calculation which is further elaborated in the formula (6) until (11).

$$r_0(d) = \frac{1}{\sqrt{N}} \quad (6)$$

$$r_1(d) = (2d + 1 - N)\sqrt{\frac{3}{N(N^2-1)}} \quad (7)$$

$$r_b(d) = (\Delta_1 d + \Delta_2) r_{x-1}(d) + \Delta_3 r_{x-2}(d), \quad x = 2,3, \ldots N-1 \quad (8)$$

where:

$$\Delta_1 = \frac{2}{a}\sqrt{\frac{4a^2-1}{N^2-a^2}} \quad (9)$$

$$\Delta_2 = \frac{1-N}{a}\sqrt{\frac{4a^2-1}{N^2-a^2}} \quad (10)$$

$$\Delta_3 = \frac{a-1}{a}\sqrt{\frac{2a-1}{2a-3}}\sqrt{\frac{N^2-(a-1)^2}{N^2-a^2}} \quad (11)$$

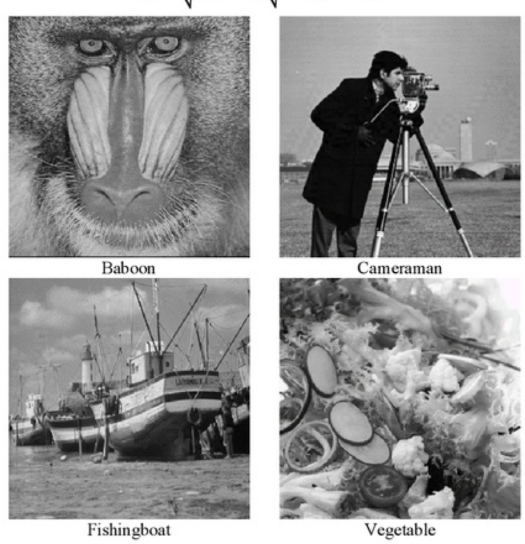

Fig. 5. Watermarked image results

After each sub-block is transformed and a watermark has been inserted using formula (1). Then inverse DTT is performed on each sub-block using formula (12). Furthermore, the results of inverse DTT restructured into the watermarked image is presented in Fig. 5. While the results of PSNR and MSE measurements in each watermarked image are presented in Table 1.

$$B_{(d,e)} = \sum_{a=0}^{N-1}\sum_{c=0}^{N-1} T_{ac} r_a(d)\, s_c(e) \tag{12}$$

TABLE I. PSNR AND MSE MEASUREMENT RESULT

Image	PSNR (dB)	MSE
Baboon	45.4646	1.8477
Cameraman	45.4659	1.8471
Fishingboat	45.4647	1.8476
Vegetable	45.4697	1.8455
Average	45.4662	1.8470

Based on observations on the watermarked image shown in Fig.5 and the measurement values of PSNR and MSE presented in Table 1, it can be concluded that the results fall into very good criteria. The extraction process is then carried out which aims to test and measure the resistance of the results of the retrieved watermark image. Resistance is measured using the corr2 function in Matlab which can be calculated by the formula (13). While the extraction results are shown in Table 2.

$$corr2 = \frac{\sum_m \sum_n (w_{mn} - \overline{w})(r_{mn} - \overline{r})}{\sqrt{\left(\sum_m \sum_n ((w_{mn} - \overline{w}))^2\right)\left(\sum_m \sum_n (r_{mn} - \overline{r})^2\right)}} \tag{13}$$

Where m, n is the dimension of watermark image, $\overline{w}$ is mean of w_{mn} and $\overline{r}$ is mean of r_{mn}.

TABLE II. NC MEASUREMENT AND EXTRACTION RESULTS

Attack	Baboon	Camera man	Fishing boat	Vegeta ble
No Attack	1.0000	1.0000	1.0000	1.0000
JPEG Q = 25	0.9432	0.9496	0.9408	0.9279
Salt and Papper 0.001	0.9531	0.9524	0.9588	0.9584
Gaussian Noise 0.001	0.9263	0.9256	0.9292	0.9078
Low Pass Filter	0.9114	0.8512	0.9408	0.7857
Blur	0.7351	0.8527	0.8256	0.8231

The results of the extraction process shown in Table 2 look very good. Extraction without attack produces a value of 1, this means the image watermark retrieved is extracted perfectly. While the extraction results in values above 0.9, except for the blur attack the average value is around 0.8.

V. COMPARISON AND ANALYSIS

After looking at the results of the proposed method, it can be concluded that the proposed method can work well in the stages of embedding and extraction. But the effect of using PN Sequence still needs to be discussed more deeply by comparing it with a method without PN Sequence. Fig. 6 shows a graph comparing the values of PSNR and MSE with and without PN sequence. The PSNR value of the proposed method appears to be superior around 3dB, while the MSE value is also better, which is around 1.8. Without using the PN Sequence the value of MSE obtained is worse, which is around 3.7.

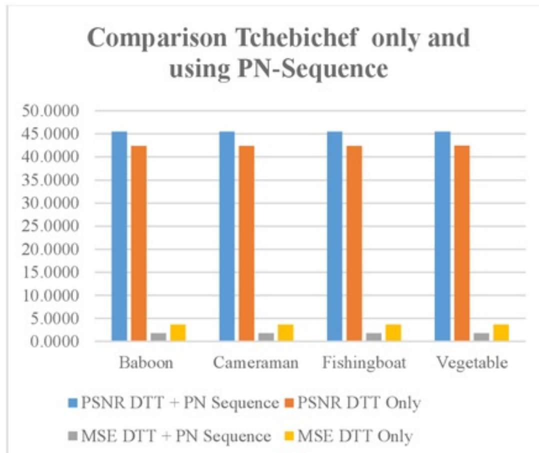

Fig. 6. Comparative chart based on PSNR and MSE results

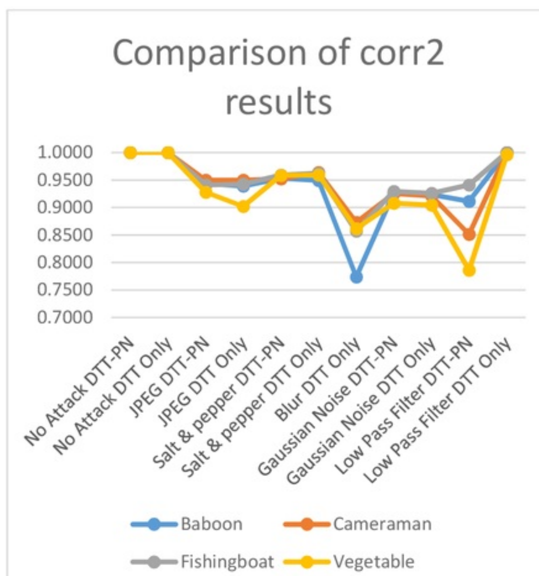

Fig. 7. Comparative chart based on corr2 results

Comparative graph of the watermark resistance value shown in Fig. 7 shows that the resistance of the watermark produced by the proposed method is indeed slightly reduced, but not significant. Even in the JPEG, salt and pepper attacks and the proposed Gaussian noise method produces better corr2 values.

VI. CONCLUSION

This research aims to improve the quality of watermarked images in Tchebichef Image Watermarking. Previous research has proven that the Tchebichef image watermarking works well if it is based on sub-blocks. DTT also has a similar property that is very similar to DCT, where the use of PN Sequence on DCT is proven to improve the quality of watermarked images. From this, the research carried out testing, measuring the results of the combination of DTT and PN sequences in the watermarking scheme. Based on the experimental results and the comparison of the results discussed in the previous section, it is evident that the proposed method is proven to be able to increase imperceptibility. The imperceptibility value increases around 3dB based on PSNR measurements. Whereas in the resistance test there is a decrease and increase in resistance to various variations of attacks where the decrease and increase appear to be insignificant, so it can be concluded that the quality of robustness of the watermark can be maintained.

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