Abstract—With the fast development of communication and multimedia technology, the rights of the owners of multimedia products is vulnerable to the unauthorized copies and watermarking is one of the best known methods for proving the ownership of a product. In this paper we prosper the previous watermarking method which was based on Tabu search by Chaos, the modification applied in the permutation step of watermarking and the initial population generation of the Tabu search. We analyze our method on some well known images and experimental results shows the improvement in the quality and speed of the proposed watermarking method.

Index Terms—Chaos, Watermarking, DCT, Tabu search

I. INTRODUCTION

The fast advancement in information and communication technology which cause easier access to multimedia contents, new challenges has appears. Digital multimedia suffer from copyright violation, unlimited duplication, modification and easily transfer over the Internet. Thus privacy, confidentiality and un-modification of data are serious issues. Hence some copyright schemes used to conquer these issues. In this paper we focus on image watermarking for copyright protection [15].

Digital watermarking of images is a method to embed secret information or watermark into the image which uses to protect the ownership of the image [2]. Watermarking methods generally categorized as visible and invisible methods. The visible watermarks are the methods that the watermark could be seen in the original image for instance company logos on the corner of pictures or TV programs. Although these watermarks could easily be seen, they are not robust against cropping and could be removed from original image [4]. The invisible watermarking is in contrast with visible watermarking. Invisible watermarking could not be seen easily and it is more robust against attacks. The embedded location is secret and only authorized person who has sufficient knowledge about method and secret key could extract the watermark [13].

From another aspect, digital watermarking could be categorized to Robust watermarking and Fragile watermarking. Fragile watermarking methods designed to become invalid even after delicate modification of an image. These methods do not resist against intentional or unintentional image operations or attacks and mainly used for authentication purposes. In contrast Robust methods are designed to tolerate attacks. The watermark needs to be extractable even after some attacks. For this goal the watermarks need to be highly correlated with the host image [13].

There are two general methods for embedding the watermark into the original image [5]. Spatial-domain watermarking and transform-domain techniques. Spatial-domain techniques mainly include embedding bits of watermark image in the lowest value bits of host image and thus they could implement easily and their execution time is small but they are fragile against noise, filters and image compression methods. Transform-domain techniques are based on discrete wavelet transform (DWT) [11], discrete cosine transform [5-7] and discrete Fourier transform (DFT). One of the biggest challenges in the scope of DCT watermarking is how to choose the pre-determined set. Embedding watermark in higher frequency bands, although the original image quality is assured it causes vulnerability against the low pass filtering attack and embedding in the lower frequency bands will degrade the image quality significantly [9]. The reason is that most natural images are focusing on lower bands which has the more sensitivity in human eyes thus obtaining optimal frequency bands is so important. Even though the watermarks are embedded in the middle band of the original image, finding the optimal frequency band is still an open problem [19]. To solve this problem so many approaches have been proposed [15]. Recently artificial intelligence techniques have been applied to solve this issue. These techniques try to solve this problem as an optimization problem [18]. One of the most popular approaches is GA [3] to find the optimal band to embed DCT-based watermark in the original image which improves robustness, security and image quality or watermarked image.

The rest of this paper organized as follow. in section two the background of this field will be described briefly. The proposed method will be explained in the section four. The experimental results are shown in section five and finally section six is the conclusion of this paper.
II. BACKGROUND

A. Discrete Cosine Transform (DCT)

DCT is a method which converts signal into elementary frequency components. The DCT could be applied to an image I, that have M*N pixels to transform image based on equation 1 [6].

\[ y(u,v) = \sqrt{\frac{2}{M}} \sqrt{\frac{2}{N}} \alpha_u \alpha_v \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} I(m,n) \cos \left( \frac{(2m+1)u\pi}{2M} \right) \cos \left( \frac{(2n+1)v\pi}{2N} \right) \]

Which \( y(u,v) \) is the coefficient of the DCT in the row \( u \) and column \( v \) of the image matrix. \( I(m,n) \) is the intensity of the pixel and if \( u \) and \( v \) are zero, \( \alpha_u = \alpha_v = \frac{1}{\sqrt{2}} \) else 1. The image could be reconstructed by using IDCT based on equation 2.

\[ I(m,n) = \sqrt{\frac{2}{M}} \sqrt{\frac{2}{N}} \sum_{u=0}^{M-1} \sum_{v=0}^{N-1} \alpha_u \alpha_v y(u,v) \cos \left( \frac{(2m+1)u\Pi}{2M} \right) \cos \left( \frac{(2n+1)v\Pi}{2N} \right) \]

Watermarking methods that use DCT are based on two concepts. The lowest frequency sub-band contains the highest signal energy that contains the most important visual parts of the image and the highest frequency sub-band has the lowest visual parts of the image and usually removed through filtering, noise and compression attacks. Thus watermarking methods based on DCT use middle frequency bands to embed the watermark to preserve the host image quality and tolerate the mentioned attacks. Extracting optimal bands is the most important issue in here and we are going to solve this problem in the proposed method [17].

B. Tabu search

Tabu search is a meta heuristic search algorithm that can solve combinational optimization problems. TS has two big advantages, it is less likely to trap in local optimum and its execution time is better than GA because it does not revisit already explored solutions. The old visited solutions are considered as taboo in this method. The Tabu search starts with an initial population and tries to find the optimum solutions. But it also considers the past solutions to avoid them. The overall procedure of the Tabu search is as below [8] [12].

Algorithm 1 Tabu Search Pseudo Code

\begin{algorithm}
\caption{Tabu Search Pseudo Code}
\begin{algorithmic}
\State Iteration $\leftarrow 1$
\State Generate Initial Population
\While {The stopping criterion is not met}
\State $\text{Determine N}(s)$, \( \text{(Neighborhood set)} \)
\State $\text{Determine T}(s, \text{Iteration})$, \( \text{(Tabu set)} \)
\State $\text{Determine A}(s, \text{Iteration})$, \( \text{(Aspirant set)} \)
\State Choose the best $s'$ and $s''$
\State $\text{Aspirant set} = N(s) - T(s, \text{Iteration}) + A(s, \text{Iteration})$
\If {$S'$ improve the solutions, memorize it $S \leftarrow S'$}
\State Iteration $\leftarrow$ Iteration + 1
\EndIf
\EndWhile
\end{algorithmic}
\end{algorithm}

III. PROPOSED METHOD

In this section we are going to describe the proposed method which is based on chaotic permutation and also chaotic Tabu search [12] to achieve better permutation and thus robustness. The proposed watermarking method has two main parts, embedding and extraction [11].

A. Watermark embedding

If we have a M*N input image, our goal is to input a robust watermarking such that the image quality do not affected [10]. Before starting the embedding procedure, we transform the spatial domain pixels into DCT Frequency bands domain. At the beginning we choose 8*8 blocks of the picture and compute DCT coefficient in the frequency bands, \( Y \). If the blocks have no overlapping, the 64 DCT bands of the \( Y \) could be represented by equation 3.

\[ Y(m,n) = \bigcup_{k=0}^{63} Y(m,n)(k), \]

\[ 1 \leq m \leq \frac{M}{8}, 1 \leq n \leq \frac{N}{8} \]

Which is the zigzag ordered DCT coefficients. The previous methods used a pseudo-random number traversing method to disperse the spatial relationship by permuting the watermark. Using \( Key_1, Key_2 \) and a random number generating system, the \( W_p \) could be extracted by equation 4.

\[ W_p = \text{Permute}(W, \text{Key}_l) \]

It has been studied that pseudo-random functions could not generate completely ideal random sequences, so we use a deformed chaotic sequence to achieve this goal [16].

We used the Gauss map which is a real value chaotic map and could supply a chaotic sequence. The chaotic Gauss map is represented by equation 4. So we could execute permutation with this chaotic map to achieve completely permuted list, the permutation Pseudo-code is depicted in algorithm 2.

Then embedding process need to be executed. The simplest solution is to randomly embed the watermark, but this causes the image quality degradation and also the robustness of
Algorithm 2 Chaotic Permutation with Gauss map

1. \( IM \leftarrow \text{input array} \)
2. \( PA : \text{Permuted array} \)
3. \( p, n \leftarrow \text{Number of Blocks} \)
4. \( k \leftarrow \text{Key} \)
5. for \( i=1 \) to \( N \) do
   6.     if \( k=0 \) then
       7.         \( k \leftarrow 0 \)
   8.     else
       9.         \( k \leftarrow k \mod 1 \)
   10. end if
    11. \( PA \leftarrow IM \lfloor \text{int}(k \ast p) \rfloor \)
    12. Remove element \( IM \lfloor \text{int}(k \ast p) \rfloor \) from array
    13. \( p \leftarrow p - 1 \)
   14. end for

the watermark. So choosing an optimum frequency band for embedding watermark is important. For this goal we modify the Tabu search algorithm. the improvement in Tabu search has been done on its initial population by using logistic map. logistic map is a chaotic map which is a polynomial map. it is represented in equation 6 [14].

\[
X_{n+1} = \alpha X_n (1 - X_n) \quad (5)
\]

The behavior of this map is highly related to the parameter \( \alpha \). For our usage we could use \( \alpha = 4 \) to have the complete chaotic behavior and generate the fully distributed initial population. Note that in both represented chaotic maps, the \( X \) must have values between 0 and 1. if we need bigger range we need to multiply \( X \) to the desire factor.

The goal of Tabu search is that it tries to find the frequency band that do not degrade the image quality and simultaneously robust against attacks. To achieve this goal we define the fitness function as equation 7.

\[
F = \text{PSNR} + \sum_{n=1}^{N} (NC \ast \lambda_n) \quad (6)
\]

That \( F \) is the fitness function of the Tabu search, PSNR is the signal to noise ratio, NC is the normalized cross correlation values and \( \lambda \) is the importance of each attack. Thus PSNR tries to preserves the image quality and NC tries to keep robustness. In this implementation we use \( \lambda = 1 \) for all attacks.

After finishing this procedure, the host image contains the watermark signal that could be extracted by knowing the key1. The key1 could be sent to any other parties with a secure channel or using cryptography.

B. Watermark Extraction

The proposed method does not need the original image for watermark extracting, but it is probable that the image has been changed by intentional or unintentional attacks such as image compression, noise, filtering and etc. If the DCT of this is image showed by \( I' \) and by knowing the secret key1 and the used chaotic map for permutation, we could reproduce the \( R' \) which is the estimated reference table of attacked \( I' \). the extraction procedure is as equation 8.

\[
W'_p = \bigcup_{m=0}^{N} \bigcup_{n=0}^{N} W'_{p,(m,n)}(i) \quad (7)
\]

And finally with having key1 and proposed Gauss chaotic map of equation 5 and algorithm 2 we could extract the watermark by equation 10.

\[
W' = \text{inv - permutation}(W'_p, \text{key}1) \quad (8)
\]

By this method the watermark image will be extracted.

IV. EXPERIMENTAL RESULTS

In this section we are going to evaluate the proposed method on some well known images such as Lena, camera man and ape. All images are 512*512 and the watermark is a 70*20 copyright image. Experiments done on a laptop computer with a Intel Core i5 2.5 GHz processor, 4GB of Ram, MATLAB R2010 and Windows 7. the original images are depicted in figure 1-3. the host image will be broken to 8*8 non-overlapping blocks and the bits of the watermark will be embedded in them based on the proposed method in the DCT domain.the initial population of the Tabu search algorithm is 20. Then three well known types of attack will apply on different copies of the image. these attacks are LPF, MF, Jpeg compression with quality factors of 50%. Then the the watermark extraction method will be executed and PSNR of the image and NC and BCR of the extracted watermark will be calculated.

The Results of execution of the basic method and proposed method is depicted in the following images.

As it is obvious the proposed method improves the image quality and robustness of the basic method simultaneously. Also as depicted in Table III using the chaos to generate the initial population of the Tabu search in the proposed method the execution time of the algorithm decreases with out reducing the effectiveness of the method. From another aspect by using the well distributed initial population the speed and quality of the Tabu search algorithm has been prospered. Table I,II shows the execution results of the proposed method.
V. Conclusion

In this paper we propose a method based on chaos for improving the watermarking quality and robustness. The proposed method used chaos maps for applying permutation and also generating the initial population.
We test the proposed method on image benchmarks and the results show the improvement in the robustness and quality of the image simultaneously. Also, we decrease the execution time by using chaos map for generating initial population of the Tabu search which make a well distributed population.

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**TABLE I: The result of Median Filter attack**

| Factor | Basic For Lena | Proposed For Lena | Basic For Camera man | Proposed For Camera man |
|--------|---------------|-------------------|----------------------|------------------------|
| PSNR   | 35.1374       | 35.1889           | 36.4201              | 36.1418                |
| NC     | 0.94857       | 0.97464           | 0.94022              | 0.95652                |
| BCR    | 0.95071       | 0.97286           | 0.94571              | 0.95857                |

**TABLE II: Averaging Filter attack**

| Factor | Basic For Lena | Proposed For Lena | Basic For Camera man | Proposed For Camera man |
|--------|---------------|-------------------|----------------------|------------------------|
| PSNR   | 31.8242       | 31.8266           | 32.3204              | 32.3158                |
| NC     | 0.9221        | 0.90014           | 0.88356              | 0.90036                |
| BCR    | 0.92329       | 0.96236           | 0.900711             | 0.91143                |

**TABLE III: Execution Time**

| Image   | Basic Method | Proposed Method |
|---------|--------------|-----------------|
| Lena    | 323 (s)      | 259 (s)         |
| Camera man | 305 (s)   | 267 (s)         |
| Ape     | 314 (s)      | 263 (s)         |