Journal of Information Hiding and Multimedia Signal Processing ©2015 ISSN 2073-4212
Ubiquitous International Volume **6**, Number **3**, May **2015**

A New Watermarking Frame Based on the Genetic Algorithms and Wavelet Packet Decomposition

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Received November, 2014; revised January, 2015

Abstract. *Digital watermarking techniques are still hot today for the great contribution for the information security problems which have been paid a lot attention for several security events in recent years. A new watermarking frame based on the genetic algorithms is proposed in this paper. Good performance in the experiments shows its efficiency. The traditional genetic algorithm is introduced here to complete the whole embedding and extracting process.*

Keywords: Digital watermarking, Information security, Genetic algorithm, Wavelet packet

1. **Introduction.** The digitization of data provides great convenience for the storage of multimedia information, and also improves the efficiency and accuracy of the expression of information. With popularization of the Internet, the communication in multimedia information format has reached the depth and scope beyond compare, and the distribution form is also more and more diversified. Nowadays people can publish their own works or important information over the Internet and trade over the Internet, but at the same time the works can be easily pirated and tampered with. Therefore, people has attached great importance to the problem how to utilize the convenience, a burgeoning interdiscripline—information hiding formally comes into being. Nowadays, as a mains to covert communication and intellectual property protection, information hiding has been widely investigated and applied.

Actually, traditional information hiding includes the Steganography and Watermarking. The difference between them is the different emphases in the techniques: the Steganography emphases on the secret information itself and the Watermarking emphases on the carrier.

Roughly speaking digital watermarking systems contain two main parts, embeders and detectors. The embeder has at least two inputs, the original information, which means the signals standing by embedding after proper transforms as watermrks, and the carrier object, which will be embedded with watermarks. Its output results are carrier objects with watermarks, which are usually used for transmissions and transcriptions. Then the work or another work, which has not past the embeder, can be input values of the detector. Most detectors try their best to estimate whether there are watermarks in the work or not. If the answer is yes, outputs are the embedded watermarking signals. The following figure 1 gives the basic framework of digital watermarking systems. The following description shows the basic idea of such a process:

1. O is the original information.
2. W is the set of all possible watermarking signals w.
3. K is the set of watermarking secret keys k.
4. W is the watermarked information.
5. W is the after extracting information.
6. Em is the embedding algorithm, which embeds the watermark w into the digital product x, i.e.
$$Em : O \times W \to W' \tag{1}$$
To enhance the security, sometimes secret keys are included in the embedding algorithms.
7. D is the detection algorithm, i.e.
$$D : W' \times K \to 0, 1, D(W', K) = \begin{cases} 1 & if \quad w' \subset W \\ 0 & if \quad w' \not\subset W \end{cases} \tag{2}$$
8. Ex is the extraction algorithm, i.e.
$$Ex : W' \times K \to W'', w'' = Ex(w', k) \tag{3}$$

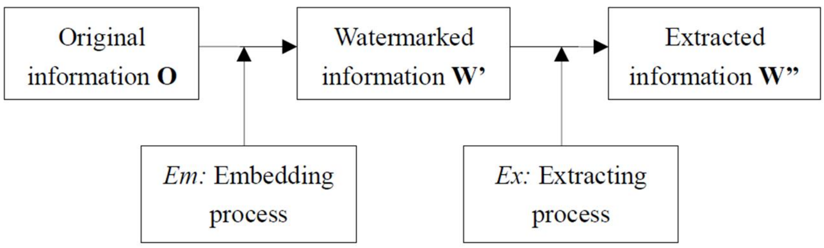

FIGURE 1. The basic framework of digital watermarking systems

Basically, the watermarking techniques can be classified into three categories based on different domains: the spatial domain watermarking techniques [1, 2, 3, 4, 5], the transform domain techniques [6, 7, 8] and the compression domain techniques [9, 10]. All these techniques have been greatly improved during the past twenty to thirty years. As for the robust watermarking techniques, lots of work has been done on the wavelet domain which can be easily combined with all kinds of compression coding standards [11].

Actually, one of the most important steps in watermarking is to decide the parameters which include the embedding strength, the embedded location, the embedding quantity and so on. How to choose a better parameter is a hot problem for researchers. As we all know, optimal algorithms are good tool for finding a proper answer of an optimal problem. Thus it is also an efficient method to solve our problem in the watermarking parameter decision. In fact, lot of researchers have used such an efficient tool in this area [12, 13, 14, 15, 16].

2. Related work.

2.1. Related work. The so called GA, Genetic Algorithm was firstly proposed by professor J. Holland in 1975. It is a computing model which is based on the Darwin's theory of natural selection and genetic selection evolution. It introduces the survival of the fittest evolutionary theory into the string structure, and apply the organized and random information exchange onto the different strings. Through this genetic manipulation, makes good quality being reserved, combination, so as to continuously generate better individuals. Progeny contains amount of parent information, and generally better than the parent generation. All these allow groups to evolve forward and to near the optimal solution.

Science the genetic algorithm is the combination of natural genetic theory and the computer science, there are many natural evolution basic terms are introduced in this area which can be shown as follows.

1. enumerate
   Genetic algorithms dealing with chromosomes, or genotype, usually use the one-dimensional chain structure to the performance. A number of individuals construct population or the so called group.
2. Population size
   The number of the individuals is called the population size.
3. Fitness function
   The appropriateness of each individual is called the fitness. For the optimal problems, the fitness function is the aim function. And the fitness functions should be the comparing non-negative functions required by the genetic algorithm.
4. Coding, decoding
   Mapping the solution in the answer space into the individual in the genes space is called coding and the inverse process is named decoding.
5. Selection The selection rule is to decide whether to choose the individual as a father individual to generate more son individuals or not by considering its chosen property which can be shown in the following formula (4).
   $$p_{si} = \frac{f_i}{\sum_{j=1}^{n} p_j} \tag{4}$$
   Here, n is the number of the population, f_i is the fitness function of the individual i and then p_{si} can be seen as the chosen probability.
6. Crossover
   Let A and B are two individuals, the crossover process can be shown as below.
   A: 10011|011—10011|100 new individual A'
   B: 01101|100—01101|011 new individual B'
7. Mutation
   The commonly used mutation process is to change 1 to 0 or change 0 to 1 in some special mutation locations as shown in the following example.
   10001100—10111100
   Here the mutation locations are in the third and fourth bits.

Generally speaking, the basic process of the genetic algorithm can be described as below.

- *Initialization*: To set the number counter for evolution: $t \leftarrow 0$; let the max evolution number is T and then generate M individuals as an initialization group $P(0)$.
- *Evaluation*: Calculate the fitness for each individual in group $P(t)$.
- *Selection*: Apply the selecting operator onto the group.
- *Crosser*: Apply the crossing operator onto the group.

- *Mutation*: Apply the mutating operator onto the group. And we can get the next generation group $P(t+1)$.
- *Termination judgment*: If $t < T$, then $t \leftarrow t+1$ and turn to the evaluation step; and if $t > T$, then choose the max fitness individual as the optimal output and stop the program.

2.2. **Wavelet Packet Decomposition.** The traditional wavelet transform is to get a pyramid structure by decomposing the low frequency part step by step. Different from this operation, the wavelet packet transform is to get a full decomposition results from both the low and the high frequency part. The two decomposition methods can be shown as in the following figure 2.

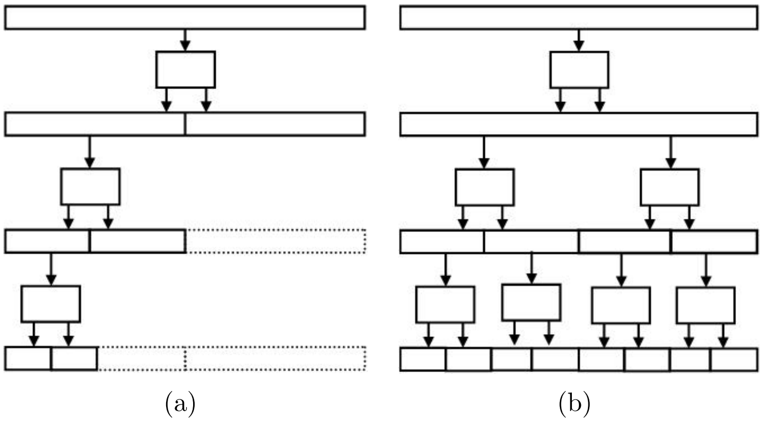

FIGURE 2. Wavelet (a) and wavelet packet (b) decomposition of one dimension signal

In fact, for the different purpose of the user, not all the wavelet packet decomposition will be done thoroughly. For example, for different images, if the author wants to get a higher compression rate, the thorough decomposition is not the best choice in common. This is an optimal problem. One can get more detail information from other paper.

Two-dimension wavelet packet decomposition is shown below in figure 3. Generally speaking, wavelet packet transform is different from the DWT by decomposing the high-pass filtered output along with the lowpass filtered output, thereby providing more sub-bands for data hiding. In the wavelet packets, the basic two channel filter bank can be iterated either over the low-pass branch or the high-pass branch, this provides a random tree structure with each tree corresponding to a wavelet packet basis.

Actually, there is another good advantage for us to use the wavelet packet transform instead of the DWT. More decomposed sub-bands provide more resolution in time and thereby increase the robustness and imperceptibility of the watermarking scheme.

3. **Our proposed frame.** As a common digital watermarking algorithm, our proposed frame also has two parts: embedding process and extracting process.

Firstly, we will introduce a new whole watermarking frame in the following figure 4. As we can see, there are two important usages for it in our proposed method. One is to decide the wavelet packet base from a large orthogonal base library; the other is to find proper embedding locations for the watermarks.

As we can see from the above figure 4, the genetic algorithm is used twice in this paper. The first time is for choosing a proper base for the WPT and the second time is for choosing some proper coefficients in the subbands to be used in the watermarking embedding step. For the first time application of genetic algorithm, the different wavelet

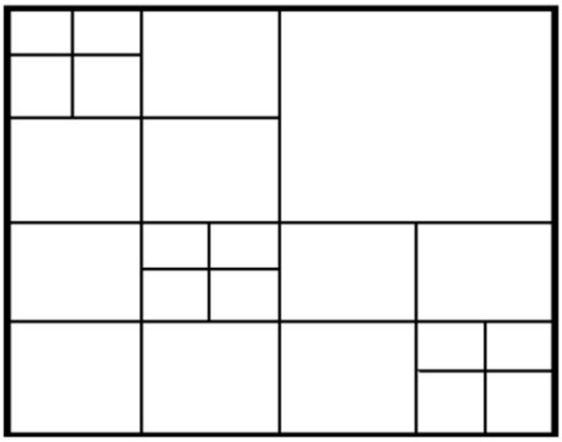

FIGURE 3. One wavelet packet decomposition structure

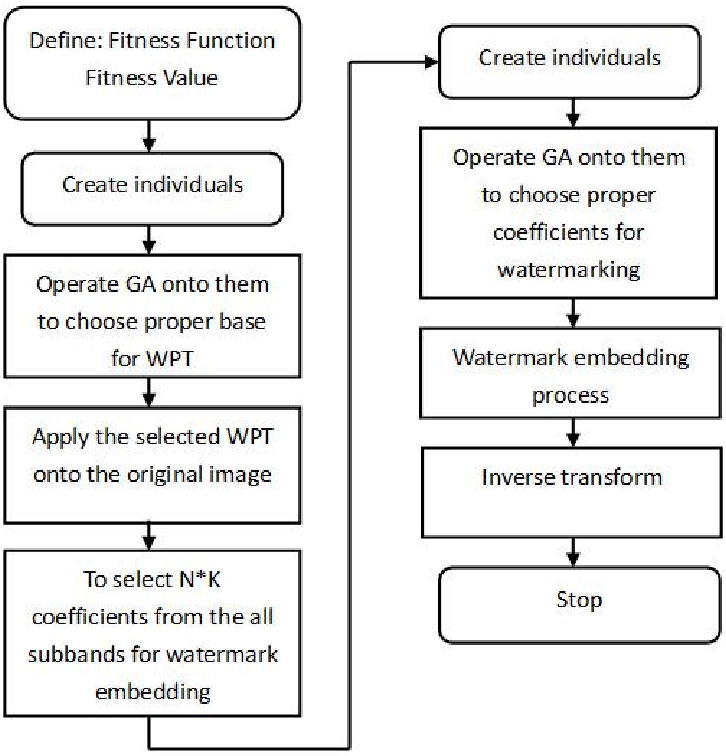

FIGURE 4. Our proposed algorithm frame

packet base can be used to form the different chromosomes and to realize the selection of the translation base. For the second time application, we focus on searching for the robust watermarking embedding method. The experimental results and the detailed process are given in the following section 4.

4. **Experimental results.** A 512×512 Lena image is used here and a randomly generated watermark 1000-bit length is used throughout the experiments.

Firstly, the PSNR value is used as the fitness value for the base selection process. Three-level wavelet packet transform is applied onto the original image. And the possible decomposition structure is used as the chromosome and to form the binary string individual as shown in the following figure 5. It is similar to work in reference [17], the difference is in the decomposition level and the corresponding chromosome length.

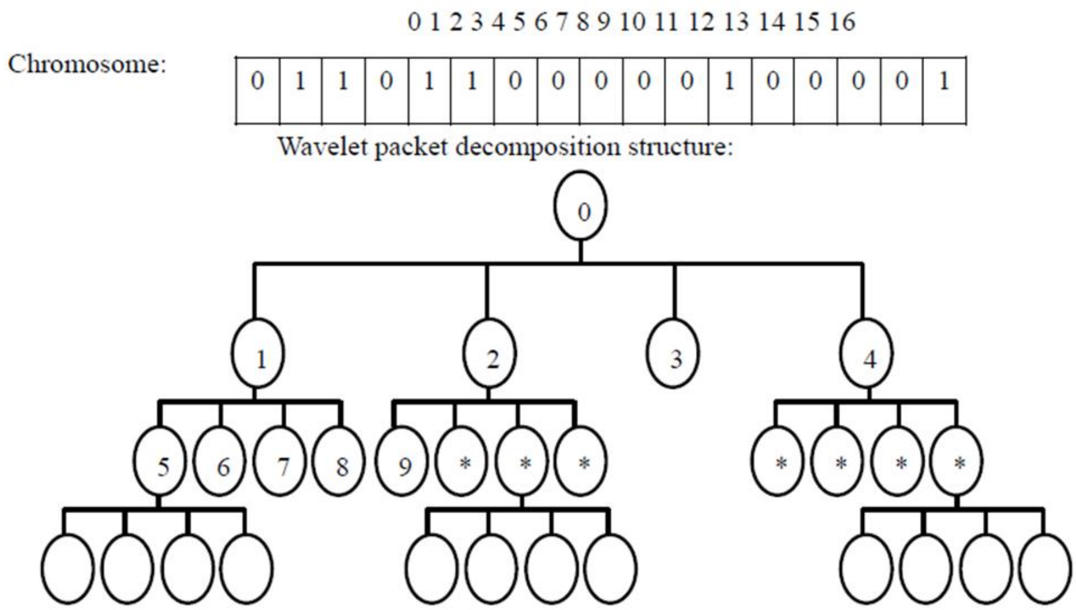

FIGURE 5. Chromosome and wavelet packet decomposition structure

The number of chromosome is 120, the selection and mutation rates are set to be 0.5 and 0.02. The training iteration is 280. It is worth to say that the above figure 5 shows the corresponding structure of the decomposition figure 3.

Then the coefficients from the middle frequency are organized to form the chromosome. In our experiments the three-level orientation tree is used in the second application of the GA method to find the proper embedding coefficients for the randomly generated watermark. A three-level tree structure can be shown in the following figure 6.

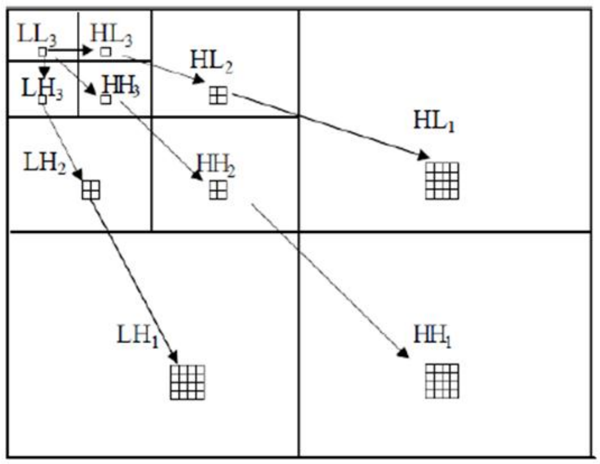

FIGURE 6. Three-level wavelet orientation tree

The orientation tree points are organized to form the chromosome. Science our purpose to design this frame is to improve the robustness of the watermarking, the fitness function is defined as follows:

$$Fitness = \frac{1}{p}\sum_{k=1}^{p}(NCC_{k,l} \times \alpha_k) \tag{5}$$

Here, l is GA generation number, p is the total number of attacks used in the optimization process, $NCC_{k,l}$ is the NCC value with attack k and α_k is the weighting factor for NCC.

The watermark embedding method is a simple process as the traditional non-adaptive embedding method in reference [18]. And the basic embedding process can be shown as the follows.

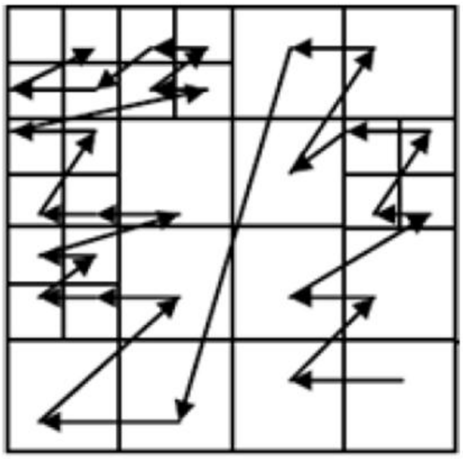

FIGURE 7. Wavelet packet decomposition and embedding method

The original image and the watermarked image can be shown in the following figure 8. As we can see from it, after we use the GA method for the whole embedding process the PSNR or the quality of the watermarked image is fairly well.

(a) (b)

FIGURE 8. watermarking effect: (a) original image (b) watermarked image with PSNR=45.21

To show the robustness of the proposed frame, we choose some classical attacks to test our method shown in the following figure 9.

In fact, we introduce such attacks aim to compare with some classical algorithm proposed in the reference [18]. And the following results show the efficiency of our method in the table 1. As we can see from it, the results of our method after some special attacks

Figure 9. Different attacks for the watermarked image: (a) JPEG compression with quality ratio 10%; (b) low-pass filter (9 × 9); (c) wiener filter (9 × 9); (d) shearing 50% of its surrounding

are much better than the two of the classical methods and is nearly as good as the so called GadugadDMT1 method.

Table 1. Comparison results for robustness

Attacks / Results	JPEG	Low-pass	Wiener filter	Shearing
Our frame	37.56	38.97	38.79	38.99
Dugad's	35.50	37.22	36.59	36.64
DugadDMT1	35.11	37.01	36.13	36.41
GadugadDMT1	37.66	38.87	38.85	38.90

5. **Conclusions.** A digital watermarking frame based on the GA and WPT is proposed in this paper. The use of the GA gives a great help for improving the performance of embedding and extracting process. And also it improves the robustness of the whole digital watermarking system. It can be checked in the comparison experiments and the good performance has shown our proposed methods efficiency. The only shortcoming is to find a faster way to realize all these process and it is our future work.

Acknowledgment. The authors would like to thank for the support from the project NSFC (National Natural Science Foundation of China) with the Grant number 61202456, the Harbin Institute of Technology Innovation Fund project. References:

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