Research on the Algorithm of Micro-Character Anti-Counterfeiting Image Generation Based on Feature Matching

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Abstract. In the field of printing anti-counterfeiting, the miniature character is an important method, which realizes printing anti-counterfeiting and information hiding through tiny text symbols, at the same time, this method also can achieve the effect of artistic expression. In this paper, through feature matching of carrier image and template images, then using the maximum likelihood estimation to select the best matching template in order to use tiny text symbols to represent the carrier image and the symbols’ print size is 0.1-0.3 mm, to realize anti-counterfeiting and information hiding, and to achieve a good artistic performance effect.

1. Introduction
At present, many companies use anti-counterfeiting labels to realize counterfeiting and many anti-counterfeiting technologies are also competing to appear, more common anti-counterfeiting technology include the following: laser anti-counterfeiting, stealth pattern anti-counterfeiting technology, ultraviolet fluorescent anti-counterfeiting technology, thermal anti-counterfeiting technology, reactive color anti-counterfeiting technology, visual encryption technology, dripping vanishing technology, LCD anti-counterfeiting technology, photochromic anti-counterfeiting, holographic anti-counterfeiting technology, miniature anti-counterfeiting technology[1-5].

Miniature character anti-counterfeiting technology is the most advanced digital image replication technology, it can copy the digital image, and it has a unique anti-counterfeit marking technology, just click on the product label to form a micro-point, can record the information that enterprise wants. In general, its micro-point is not can be seen, we must use a specific magnifying glass in the correct way, and find the location of the miniature anti-counterfeiting in the label, we can clearly see the microcontent. So the anti-counterfeiting effect of this method is pretty good.

Miniature character anti-counterfeiting technology has the following three advantages: it is difficult to print; improve the authenticity of the product; decorative product appearance.

In this paper, we study the algorithm of miniature character anti-counterfeiting image generation based on feature matching, which combines image gray matching and morphological matching to select the appropriate characters in character library, and then uses maximum likelihood estimation to select the best matching template. The anti-counterfeit information in the anti-counterfeite image generated by this method is concealed, the anti-counterfeit effect can be achieved, and it is easy to detect.

2. Selection of Optimal Matching Template Based on Maximum Likelihood Estimation Method
The maximum likelihood estimation is to use the known result of a sample to deduce the most likely (maximum probability) parameter value that results in such a result (the model is known and the parameter is unknown) [6]. This paper uses this method to select the template image that best matches the carrier image.
2.1. Maximum Likelihood Estimation

The basic idea of the maximum likelihood estimation is [7]: When the sample observation values of N group are randomly sampled from the model, the most reasonable parameter estimation should make the probability of extracting the N group samples from the model is the greatest, rather than the least squares estimation is aimed at making the model can get the best fitting parameter estimation of sample data.

The data in this paper is discrete, so we only discuss the situation when the total X is discrete.

Suppose X is a discrete random variable, its form of the probability distribution is \( P(X = x) = p(x; \theta_1, \theta_2, \Lambda, \theta_k) \), so the probability distribution of sample \( X_1, X_2, \Lambda, X_n \) is \( P(X_i = x_i, \Lambda, X_n = x_n) = \prod_{i=1}^{n} p(x_i; \theta_1, \theta_2, \Lambda, \theta_k) \). When \( \theta_1, \theta_2, \Lambda, \theta_k \) is fixed, the probability that the upper formula represents the value of \( X_1, X_2, \Lambda, X_n \) as \( x_1, x_2, \Lambda, x_n \); when \( x_1, x_2, \Lambda, x_n \) is fixed, it's a function of \( \theta_1, \theta_2, \Lambda, \theta_k \), we write it as \( L(\theta_1, \theta_2, \Lambda, \theta_k) \), and call \( L(\theta_1, \Lambda, \theta_k) = \prod_{i=1}^{n} p(x_i; \theta_1, \Lambda, \theta_k) \) as likelihood function. The size of the value of the likelihood function \( L(\theta_1, \theta_2, \Lambda, \theta_k) \) means the size of the probability that the sample value appears. Since the sample value \( x_1, x_2, \Lambda, x_n \) has been obtained, the likelihood that it will appear is large, that is, the value of the likelihood function should be large. So we choose the \( \theta \) that makes \( L(\theta_1, \theta_2, \Lambda, \theta_k) \) reach the maximum as an estimate of true \( \theta \).

2.2. The Solution of Maximum Likelihood Estimation

Suppose now has observed a group of sample \( x_1, x_2, \Lambda, x_n \) to estimate the unknown parameter \( \theta_1, \theta_2, \Lambda, \theta_k \). An intuitive idea is which group of numbers can make the current sample \( x_1, x_2, \Lambda, x_n \) the most likely to appear, this group of parameters may be the real parameters, we need to use it as an estimate of the parameters. Suppose we have a group of sample \( x_1, x_2, \Lambda, x_n \). If we have two different groups of values for the parameter \( \theta_1, \Lambda, \theta_k \) and \( \theta_1^*, \Lambda, \theta_k^* \), the likelihood function has the following relationship:

\[
L(x_1, \Lambda, x_n; \theta_1^*, \Lambda, \theta_k^*) > L(x_1, \Lambda, x_n; \theta_1^*, \Lambda, \theta_k^*)
\]

Then, from the point of view that \( L(x_1, \Lambda, x_n; \theta_1, \Lambda, \theta_k) \) is the probability density function, the meaning of the above form is the possibility of parameter \( \theta_1^*, \Lambda, \theta_k^* \) to make \( X_1, X_2, \Lambda, X_n \) appear is bigger than parameter \( \theta_1^*, \Lambda, \theta_k^* \) to make \( X_1, X_2, \Lambda, X_n \) appear, of course, parameter \( \theta_1^*, \Lambda, \theta_k^* \) compared with parameter \( \theta_1^*, \Lambda, \theta_k^* \) is more like a real parameter. This analysis leads to a method of parameter estimation, that is, the point \( (\theta_1^*, \Lambda, \theta_k^*) \) with the maximum value of the likelihood function is used as an estimate of unknown parameters, which is the so-called maximum likelihood estimation. Now we discuss the specific method of finding the maximum likelihood estimate. For simplicity, the following written \( L(\theta) = L(x_1, \Lambda, x_n; \theta_1, \Lambda, \theta_k) \), the maximum likelihood of the estimate of \( \theta \) is summed up to find the largest value of \( L(\theta) \) point. Because the logarithmic function is a monotone increment function, so
\[ \log L(\theta) = \sum_{i=1}^{n} \log f(x_i; \theta_1, \Lambda, \theta_k) \] (1)

and \( L(\theta) \) have the same maximum point. In many cases, find the maximum value of \( \log L(\theta) \) is simpler, so we will find the maximum value of \( L(\theta) \) to find the maximum point of \( \log L(\theta) \) rather than to find the maximum value of \( L(\theta) \). \( \log L(\theta) \) about \( \theta_1, \Lambda, \theta_k \) derivation number, and let it equal to zero, get the equation group

\[ \frac{\partial \log L(\theta)}{\partial \theta_i} = 0, i = 1, \Lambda, k \] (2)

called the likelihood equations group. Solution this equation group, and can verify that it is a maximum point, then it must be \( \log L(\theta) \), that is, the largest point of \( L(\theta) \), which the maximum likelihood estimate.

In this paper, using this method to filter out the data that can make the best match between carrier image and template image within the data concentration, which generated after feature matching of the carrier image and the template image, to realize the hidden of security information.

3. Processing Flow of Feature Matching

In this paper, a character library is created to store the template images. The template image needs to meet the following two conditions:

- The size of all templates should be the same, and the size in this article is 8*8 (the length of the template is 8 pixels and the width is 8 pixels).
- The equivalent gray value of all templates in the character library is roughly evenly distributed in the range of 0~64. So that there is more choices when matching the grayscale with the carrier image block, and can also ensure that each carrier image block has a corresponding template image, to ensure the effect of the match.

The process is shown as follows:

- First we divide the carrier image into blocks, and the carrier image of m*n (the length of the carrier image is m pixels and the width is n pixels) is partitioned with 8*8 as the unit, each small block is recorded as \( M_{i}(i) \) (i=12,..., N):
  - To compare the comparison of gray scale and comparison of morphology between the unit image \( M_{i0} \) and the template in the character library respectively, select the template that its equivalent gray value is the same as the equivalent gray value of \( M_{i0} \) and the template that its shape is roughly the same as that of \( M_{i0} \);
  - Double matching of gray and shape, and further screen out the template that the equivalent gray value and shape can match the template approximately;
  - Using the maximum likelihood method to select the best matching template in the template selected by the above steps, filling the carrier image with the template;
  - Repeat above steps until all \( M_{i0} \) is traversed.

The main program flow chart is shown in figure 1.
3.1. Gray Scale Comparison
The purpose of gray scale comparisons is to divide the templates in the character library that its equivalent gray value is the same as the equivalent gray value of $M_{O_n}$ into a class, on this basis, when double matching of gray and shape we can directly use all the templates that belong to the same equivalent gray value and to match with $M_{O_n}$ don’t need to match the template in the character library. The operation of grayscale comparison can shorten the time required for matching, improve the efficiency of the program, and improve the quality of matching.

The specific process of gray scale comparison is as follows:
- Calculate the equivalent gray value of each template in the library.
  Traversing every pixel in every template, if the pixel value equals 255, it is recorded as 1. If the pixel value equals 0, it is recorded as 0. To count the number of pixels in each template image equal to 1 and 0, which is represented by sumw1 and sumb1 respectively, then sumb1 is the equivalent gray value of the template. The gray value of each template is calculated by this method, and the template with the same gray value is divided into one class. In this paper, the template in the character library are all two-valued image of 8*8 size, so the range of the equivalent gray value of these templates is 0–64.
- Traversing each carrier image block $M_{O_n}$, calculate the equivalent gray value of each carrier image block according to the above method.
• For each carrier image block $M_{(i)}$, in the template that divides the class according to the equivalent gray value, select the same type of template as the equivalent gray value of $M_{(i)}$.

• Repeat above steps until all the carrier image blocks are traversed. At this point, the operation of the gray scale comparison is completed. By this step, each carrier image block has the corresponding equivalent gray value of a class of templates.

3.2. Morphological Comparisons
The purpose of the morphological comparison is to find a template that is roughly the same shape as the carrier image block in the template of the character library. On this basis, we can directly call all the templates similar to the template block to match the $M_{(i)}$ when the gray and morphological double match is matched.

The methods of morphological comparison are as follows:
The similarity between all the carrier image blocks and the template in the character library is compared one by one. The comparison method of similarity degree is as follows:
Taking a carrier image block and a template image as an example, a point by point comparison is used when comparing. Using $\text{sumb2}$, $\text{sumw2}$ respectively represent the image block and the template at the same point, black and white pieces of the same number, using $\text{sumbw}$ to represent the image blocks and templates at the same point the number of white and black pieces completely different. That is, if at a point, the gray value of the carrier image block and the template is equal to 0, then the number of $\text{sumb2}$ plus 1; if at a point, the gray value of the carrier image block and the template is equal to 255, then the number of $\text{sumw2}$ plus 1; if at a point, the gray value of the carrier image block is equal to 255, the gray value of the template is equal to 0 or the gray value of the carrier image block is equal to 0, the gray value of the template is equal to 255, then the number of $\text{sumbw}$ plus 1. After sorting the data, we can get the situation $\text{sum1}$ ($\text{sum1} = \text{sumb2} + \text{sumw2}$) that the carrier image block and template are identical and the situation $\text{sum2}$ ($\text{sum2} = \text{sumbw}$) that the carrier image block and template are completely different.

This step of morphological comparison allows each carrier image block to have a template similar to its shape and corresponding to it.

After the gray comparison, morphological comparison, the image blocks and templates are double matched by gray scale and morphological, using the data obtained from the above operation to select all the templates that are consistent with the gray values of the carrier block and similar in shape, finally select the best matching template by the maximum likelihood estimation in these templates and fill the carrier image with the template.

4. Experimental Results
In figure 2, there are carrier images, anti-counterfeit images generated by this algorithm, and local enlarged plot of anti-counterfeit images. Direct observe with naked eye, we can see the anti-counterfeit image retains the carrier image’s details and the differences between anti-counterfeit image and carrier image are not obvious; intercept a part of the security image, after being amplified and observed, the character images hidden in it can be clearly seen.
Figure 2. carrier image, anti-counterfeit image and local enlarged image

By matching the carrier image with the template, using the maximum likelihood estimation to select the best matching template, there are no obvious differences between the carrier image and the anti-counterfeiting image generated by this method. Only using a high magnification magnifying glass can we see the differences between the two, so that the authenticity of the image can be judged. This method is relatively simple, the anti-counterfeiting effect is better and the detection is convenient. It can achieve the expected anti-counterfeiting effect and increase the aesthetic, and has a certain practicality.

5. Conclusion
In this paper, the anti-counterfeiting image is generated based on the feature matching of the miniature characters, the anti-counterfeiting effect is realized by using the character that miniature character is not easy to be found when directly observed with the naked eye. In the process of realization, on the basis of gray scale matching of the carrier image and the template image in the existing character library, the morphological matching is carried out, and using maximum likelihood estimation to select the best matching template images in the selected template images, and hide the template images with characters in the carrier image. The experimental results show that this kind of anti-counterfeiting image is easy to generate, has good anti-counterfeiting effect, convenient detection and low cost, and has a broad development prospect.

In the next work, I will study how to effectively hide the Chinese characters in the form of micro-character in the image, and combine the printing technology to realize information hiding and information anti-counterfeiting.

6. Acknowledgment
Thanks to National Natural Science Foundation of China (61370140) and Beijing special science and technology project (Z161100005016007).

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