The Intelligent Texture Anti-counterfeiting Algorithm Based on DCT

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Abstract—This paper put forward an algorithm based on DCT and human visual characteristics for the identification of texture anti-counterfeiting tags. Firstly, the method extracted the visual feature vectors of texture image through DCT, and then created a database of texture images’ feature vectors. Compare the Normalized Cross-correlation (NC) between the feature vectors in database of the NC using DCT, and compare the feature vector of texture-tag with the NC coefficient matrix obtained. Random selected seven low-frequency coefficients (coefficients having a value of zero), and “1” indicates a positive coefficient. We can get the symbol sequence “1001010” as the image feature vectors.

Keywords—texture anti-counterfeiting tag; feature vector; DCT; strong robustness

I. INTRODUCTION

In recent years, counterfeit caused serious harm to the world economy and consumers[1]. Texture anti-counterfeiting is one kind of new anti-counterfeiting technology developed in recent years. It’s a collection of information queries, database storage, digital printing and other technologies in one. In addition, there are many advantages of texture anti-counterfeiting. Such as random selection, difficult to counterfeit, easy to identify, widely applicable, long-term and effective[2]. Texture anti-counterfeiting technology that uses packaging material itself inherent speckle mark as anti-fake identifying mark[3]. Therefore, texture anti-counterfeiting research and development become a new anti-counterfeiting technology in recent years.

Although technical advantages are obvious, but it still have some shortcomings. For example, identification is difficult to educate consumers to verify and distinguish, and it need to enter the serial number query[4]. Although the two-dimensional code scanning don’t need to enter the serial number[5], but in the case of poor light, the identification is more difficult and it takes a long time.

Currently, identification of security and intelligence about the texture does very little. Inspired by Kutter and Kaewkammerd extracted the visual feature by wavelet transform[6,7]. We propose an algorithm based on DCT. Acquire the visual feature vectors of the texture image by using DCT, and compare the feature vector of texture-tag with the feature vectors in database of the NC[7-12]. The experiment results showed that the algorithm has good robustness against common and geometrical attacks.

II. THE FUNDAMENTAL THEORY

A. The discrete Cosine transform (DCT)

Two-dimensional discrete cosine transformation formula is as follows:

\[ F(u,v) = c(u)c(v) \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y) \cos \left( \frac{2\pi x u M}{2M} \right) \cos \left( \frac{2\pi y v N}{2N} \right) \]

where \( u, v = 0, 1, \ldots, M - 1, N - 1 \). In this formula:

\[ c(u) = \begin{cases} \frac{1}{\sqrt{M}} & u = 0 \\ \frac{1}{\sqrt{M}} & u = 1, 2, \ldots, M - 1 \end{cases} \]

\[ c(v) = \begin{cases} \frac{1}{\sqrt{N}} & v = 0 \\ \frac{1}{\sqrt{N}} & v = 1, 2, \ldots, N - 1 \end{cases} \]

Two-dimensional discrete cosine transform (IDCT) using the following formula:

\[ f(x,y) = \sum_{u=0}^{M-1} \sum_{v=0}^{N-1} c(u)c(v) F(u,v) \cos \left( \frac{2\pi x u M}{2M} \right) \cos \left( \frac{2\pi y v N}{2N} \right) \]

Where \( x, y = 0, 1, \ldots, M - 1, N - 1 \).

B. Texture feature vector selection

First, DCT transform the original texture image globally, DCT coefficient matrix obtained. Random selected seven low-frequency coefficients in DCT coefficient matrix. "1" indicates a positive DCT coefficients (coefficients having a value of zero), and "0" indicates a negative coefficient. We can get the symbol sequence "1001010" as the image feature vectors. Observe in Table I we can find that the symbol sequence can be maintained similar to the original texture image whether the image through common attacks, geometric attacks or local nonlinear geometric attacks. As the same as the original texture image normalized correlation coefficient is 1.0.

The work is supported by the National Natural Science Foundation of China (No.61263033) and the Hainan Province Special projects in colleges and universities scientific research (Hnykxs2014-02).
It can be seen in Table II, the sequence of different texture images symbol are different. The correlation is small and less than 0.5. This shows that the symbols of DCT coefficient sequence can be used as a texture feature vector V (j) by DCT coefficients symbolic computation.

TABLE II. DIFFERENT TEXTURE IMAGE FEATURE VECTOR CORRELATION (VECTOR LENGTH 32BIT)

| Image Operation | Sa | Sb | Sc | Se | Sf | Sg | Sh |
|-----------------|----|----|----|----|----|----|----|
| Original image  | 1.00 | -0.08 | 0.10 | -0.06 | 0.06 | -0.09 | 0.13 | -0.01 |
| JPEG compression (5%) | 0.10 | -0.01 | 1.00 | 0.08 | 0.08 | -0.02 | -0.05 | 0.09 |
| Gaussian noise (3%) | -0.06 | 0.01 | 0.08 | 1.00 | -0.01 | 0.00 | -0.01 | 0.08 |
| Median filter (3x3) | 0.06 | 0.03 | 0.08 | -0.01 | 1.00 | 0.13 | -0.09 | 0.05 |
| Translation(5pix) | -0.09 | 0.00 | -0.02 | 0.00 | 0.13 | 1.00 | 0.04 | 0.11 |
| Rotation(clockwise5°) | 0.13 | 0.08 | -0.05 | -0.01 | -0.09 | 0.04 | 1.00 | 0.06 |
| Rotation(anticlockwise5°) | -0.01 | 0.02 | 0.09 | 0.08 | 0.05 | 0.11 | 0.06 | 1.00 |

B. Establish database of the texture feature vector

1) Get the feature vector of the original security image using DCT

All original security pictures DCT transform and obtain DCT coefficient matrix FD (i, j). Random select 7x7 transform coefficients FD7 (i, j) and then obtain the visual feature vector V (j) by DCT coefficients symbolic computation.

\[ FD(i,j) = DCT2(F(i,j)) \]
\[ V(j) = \text{Sign}(FD(i,j)) \]

2) Store the original texture image’s feature vector

3) Intelligent identification texture anti-counterfeiting

Step1: Get the feature vector of the tested texture image using DCT

Suppose the texture image to be F'(i, j), then we use DCT to the tested texture images and obtain DCT coefficient matrix F'(i, j). Establish the database according to the method described above and obtain visual texture feature vector V'(j) of the tested image.

\[ FD'(i,j) = DCT2(F'(i,j)) \]
\[ V'(j) = \text{Sign}(FD'(i,j)) \]

Step2: Obtain the PSNR of the image in order to assess the quality of texture images after attacked.

Assuming the pixel value at each point of the image is I(i, j), and the average value of pixels of the image is \( I' \). M is the length of the texture image, N is the width of the texture image. PSNR is defined as:

\[ \text{PSNR} = 10 \log \left( \frac{MN \max_{i,j} \{I(i,j) \}^2}{\sum_{i,j} \{I(i,j) - I'(i,j) \}^2} \right) \]

Step3: Compare NC of the original texture image with the tested texture image’s NC. Defined as:

\[ NC = \frac{\sum_{j} V(j)V'(j)}{\sum_{j} V^2(j)} \]

The larger the value of NC is, the more approximation between the tested texture image F'(i, j) and the original texture image F(i, j). Determine whether it’s original texture image or not by calculating NC.

Step4: Return the maximum value of NC to the user’s phone.

IV. EXPERIENCE

In our experiments, we randomly select 1000 group of independent binary sequence (value of 1 or -1). Every sequence consists of 32 bits. We randomly select one group in the 1000 data set as the feature vector embedded (we chose the 500th group here). Here the size of the original texture image (a) is 128 x 128. The corresponding DCT coefficient matrix is FD(i,j). We choose the low-frequency coefficients Y(j)(1≤j≤L). The first value Y(1) on behalf of the DC component of the

TABLE I. CHANGE OF DCT LOW-FREQUENCY COEFFICIENTS WITH RESPECT TO DIFFERENT ATTACKS

| Image Operation         | PSNR(dB) | F(1,1) | F(1,2) | F(1,3) | F(1,4) | F(1,5) | F(1,6) | F(1,7) | Coefficient symbol |
|-------------------------|----------|--------|--------|--------|--------|--------|--------|--------|------------------|
| Original image          | 42.14    | 73.69  | -0.52  | -25.34 | 0.26   | -19.79 | 0.48   | -11.69 | 1001010          |
| JPEG compression (5%)   | 23.00    | 75.05  | -0.65  | -25.29 | 0.38   | -19.96 | 0.60   | -11.65 | 1001010          |
| Gaussian noise (3%)     | 18.02    | 73.03  | -0.53  | -22.59 | 0.11   | -17.65 | 0.46   | -10.46 | 1001010          |
| Median filter (3x3)     | 23.43    | 74.73  | -0.33  | -25.88 | 0.25   | -20.08 | 0.24   | -11.90 | 1001010          |
| Translation (5pix)      | 11.55    | 66.56  | -0.77  | -24.09 | 0.45   | -18.97 | 0.61   | -11.21 | 1001010          |
| Rotation(clockwise5°)   | 13.32    | 73.53  | -0.57  | -25.76 | 0.26   | -19.47 | 0.35   | -10.78 | 1001010          |
| Cropping (4% from y)    | 13.74    | 63.89  | -0.82  | -23.11 | 0.49   | -18.23 | 0.62   | -10.74 | 1001010          |
| Scaling (0.5)           | 36.84    | -0.26  | -12.67 | 0.13   | -9.90  | 0.24   | 5.85   | 1001010          |
| Pinch distortion (30%)   | 15.59    | 68.21  | -0.51  | -24.80 | 0.49   | -20.19 | 0.45   | -10.50 | 1001010          |
| Ripple distortion (100%)| 17.91    | 70.68  | -0.61  | -24.86 | 0.29   | -19.33 | 0.72   | -11.23 | 1001010          |
| Spherical distortion (20%)| 14.16   | 75.02  | -0.85  | -24.17 | 0.23   | -18.46 | 0.61   | -11.95 | 1001010          |
| Twirl distortion (30°)   | 19.07    | 70.66  | -0.71  | -24.83 | 0.50   | -19.43 | 0.38   | -11.36 | 1001010          |
| Wave distortion (2%)    | 21.41    | 70.65  | -0.47  | -24.79 | 0.57   | -19.50 | 0.49   | -11.27 | 1001010          |
| Random wave distortion (Triangle) | 12.04 | 70.80  | -0.59  | -24.36 | 0.31   | -18.13 | 0.54   | -10.04 | 1001010          |
image, and then arranged from low to high frequency order. We chose the low-frequency coefficients do 4x8 = 32 to be feature vector V, le L=32. Select the DCT coefficient matrix as FD (i, j), 1≤i≤4,1≤j≤8. Extraction algorithm to extract the V' and determine whether it’s original texture image or not by calculating NC of V and V'.

Currently, the original texture image store in the database and each original texture image size is 10K, namely 10240 bytes. Therefore, the database can be reduced share of 2560 times, greatly saves storage space, but also improve the transmission rate that improves the identification rate.

In the simulation, PSNR is used to access the quality of the tested image. The larger PSNR values represent higher image quality. NC is used to access the results of similarity detection. It represents the original texture image if the value of NC is greater than 0.5.

A. Common attacks

1) Adding Gaussian noise

The texture image under Gaussian attacks (3%) is shown in Fig.2 (a). The similarity can be detected as shown in Fig.2(b), NC=1.0. It proved that our proposed algorithm has strong robustness against noise attacks.

B. Geometrical attacks

1) Rotation attacks

Fig.4 (a) is the texture of the image rotation is 5°, PSNR =13.32dB. Fig.4 (b) is the similarity detection, the detection can be clearly judged as the original texture images, NC = 0.83.
Table V is the texture image anti-rotation attack experimental data. NC = 0.75 when the texture image is rotated 10° and it still can be judged as the original texture image. 

2) Scaling attacks

Fig.5(b) is a scaling factor of 0.5 for the texture image, then the center of the image is smaller than the original image; Fig.5(b) is a similarity detection, NC = 1.00, it can be determined to be the original texture image.

Table VI shows it can still be judged as the original texture image, indicating that the invention has strong anti-scaling capability.

3) Pinch distortion attacks

Fig.6 (a) shows the texture image under the pinch distortion (30%) attacks, PSNR = 15.59dB. Fig.6 (b) is a similarity detection, it can be judged as the original texture image, NC = 0.94.

Table VII is the texture image anti-rotation attack experimental data. NC = 0.94 when the texture image is rotated 10° and it still can be judged as the original texture image. The data show that the scheme is robust against pinch distortion attacks.

V. CONCLUSION

We propose an algorithm based on DCT in order to identify intelligently. It combines the visual feature vector and database technology, and doesn’t require the original texture image in the identification process. The experimental results show that the algorithm can resist certain degree of common attacks and geometric attacks. Moreover, we just need to store the feature vectors of the texture images with our proposed algorithm, which can save a lot of storage space. Therefore, this method has good utility in the actual application process.

Acknowledgment

The work is supported by the National Natural Science Foundation of China (No.61263033) and the Hainan Province Special projects in colleges and universities scientific research (Hkyyzx2014-02).

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