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Image Information Hiding Algorithm Research of Network Sensor Based on Visual Characteristic

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Abstract: This paper optimizes the AQIM image hiding algorithm ,proposes the information hiding method combined of ICA feature extraction and iteration AQIM algorithm ,at the same processes blind detection to hiding information with statistical method from the impact perspective of visual characteristics to information hiding algorithm based on Watson visual network sensor models. The result shows: the image features obtained by extraction ICA have good statistical characteristics, and have a better robustness than other algorithms. *Copyright © 2013 IFSA.*

Keywords: Network sensor, Image information, Hiding algorithm, AQIM algorithm.

1. Introduction

With the spread of digital media on the internet, how to protect the copyright of digital products has become an issue to be addressed. Researchers proposed all kinds of embedded algorithm, while the invisibility and robustness of digital watermark algorithm is the key to solve copyright protection.

Now the frequently-used image information hiding algorithm [1] mainly includes spread spectrum watermarking algorithm and QIM algorithm. Watson [1] proposed a DCT quantization matrix with 8×8 pieces based on the frequency sensitivity, luminance masking and contrast masking of HVS.

Christone [2] and so on proposed self-adaption watermarking algorithm of DCT domain and wavelet domain according to Watson visual models. Kundur and so on adapted the conspicuousness with wavelet coefficients as the watermark embedding strength based on the visual models proposed by Levine. Because QIM algorithm with the characteristics of large amount of embedded, good robustness and bind detection allowance ,which has been widely used in information hiding algorithm, but the quantifying step size of traditional QIM algorithm is changeless, which results in the poor invisibility of image local areas in hiding information, and be sensitive [3] to the change of numerical measurement. Saravanan [4] and so on proposed a functional QIM algorithm with the luminance as the quantifying step size, uses

[1] Andrew B. Watson, DCT Quantization Matriees Visually Optimized for Individual Images, *Proc. SPIE on Human Vision,Visual Proeessing, and Digital DisPlay,* IV, 1993, pp. 202-216.

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luminance masking features adapt different quantifying step size in the different partitioning of images, but the quantifying step size can not self-adaption adjust with the change of re-quantitative values. Cox [5] and so on proposed a self-adaption QIM (AQIM) algorithm, which uses the self-adapt adjustment quantifying step size of contrast masking features, the relative traditional QIM algorithm has a better invisibility and robustness, but the disadvantages [6] of this algorithm is can not solve the problem of different quantifying step size before embedding, which causes the watermarks can not be extracted completely even in the situation without interference. This aims at the above problems, through the causes generated of the defects of this algorithm to make theoretical analysis, and propose an iterative algorithm with feasible theories. With the spread of digital media on the internet, how to protect the copyright of digital products has become an issue to be addressed. Researchers proposed all kinds of embedded algorithm, while the invisibility and robustness of digital watermark algorithm is the key to solve copyright protection.

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2. AQIM Algorithm Based on Watson Visual Models

In information hiding algorithm researches, the visual features of human eyes mainly consider the factors of three aspects, which are: frequency sensitive feature, luminance masking features and contrast masking features. Waston establishes a kind of visual model based on 8×8 DCT pieces, this model consists of sensitivity function, and the masking parts based on luminance and contrast.

Contrast masking feature describes the detectability of one signal on the condition of the existing of other signal, especially when these two signals with the same spatial frequency, orientation and position, the elusive is the strongest. In Watson models, the calculation expression of contrast hiding threshold $t_s(i,j,k)(i,j=1,2,...,8)$ is:

$$t_s(i,j,k)= = \max\left\{t_L(i,j,k), \left|C(i,j,k)\right|^{\beta(i,j)} t_L(i,j,k)^{1-\beta(i,j)}\right\} \quad (1)$$

In algorithm, $\beta(i,j)$ is a constant between 0-1, which varies from frequency coefficient to frequency coefficient, in Watson model, $\beta(i,j)$ usually be assumed as constant 0.7.

Traditional QIM algorithm based on fixed quantifying step size, thus will lead to a poor invisibility in local area, Cox and so on adapted contrast hiding threshold $t_s(i,j,k)$ as the quantifying step size of $\left|C(i,j,k)\right|$ in Watson visual models proposed by self- adaption QIM algorithm to realize the adjustment quantifying step size of self-adaption , the relative traditional QIM algorithm has a better robustness in the same reliability condition.

The quantifying step size of AQIM is:

$$step = t_s(i,j,k) = = \max\left\{t_L(i,j,k), \left|C(i,j,k)\right|^{\beta(i,j)} t_L(i,j,k)^{1-\beta(i,j)}\right\}, \quad (2)$$

When

$$t_L(i,j,k) \ge \left|C(i,j,k)\right|^{\beta(i,j)} t_L(i,j,k)^{1-\beta(i,j)},$$

namely

$$t_L(i,j,k) \ge \left|C(i,j,k)\right|,$$

$$step = t_L(i,j,k), \quad (3)$$

When

$$t_L\left(i,j,k\right)<\left|C\left(i,j,k\right)\right|^{\beta(i,j)}t_L\left(i,j,k\right)^{1-\beta(i,j)},$$

namely

$$t_L\left(i,j,k\right)<\left|C\left(i,j,k\right)\right|,$$

$$step=\left|C\left(i,j,k\right)\right|^{\beta(i,j)}t_L\left(i,j,k\right)^{1-\beta(i,j)}, \quad (4)$$

From the above algorithms we can know, on the first situation, the quantifying step size has nothing to do with $\left|C\left(i,j,k\right)\right|$, the quantifying step size is constant and will not cause information detecting mistakes, while on the second situation, the quantifying step size if $\left|C\left(i,j,k\right)\right|$ function, after quantizing obtained $C_e\left(i,j,k\right)$, although $C_e\left(i,j,k\right)\approx C\left(i,j,k\right)$, but both are not equal. In the information extraction progress, because $C\left(i,j,k\right)$ is unknown in detecting elements , only through $C_e\left(i,j,k\right)$ to estimate $t_s\left(i,j,k\right)$, which causes the inconformity of quantifying step size in using and extracting is different when embedded, and causes AQIM algorithm cannot extract hiding information perfectly even on the condition without disturbance.

Defect analysis of AQIM algorithm

Even on the condition without disturbance, the quantifying step size of AQIM algorithm while in detecting and embedding is inconformity, which causes the watermark can not be extracted perfectly and reliably. Next analysis this issue.

Omitting symbol $\left(i,j,k\right)$ in derivation progress, suppose hiding information of binary system is W, the quantifying step size while information hiding is step:

$step, q=\left|C\right|/step, m=round\left(q\right), \delta=q-m,$

where $\left|\delta\right|\le 1/2$. And according to algorithm (4) we can obtain:

$$\left|C\right|=t_L\bullet q^{\frac{1}{1-\beta}}=t_L\cdot\left(m+\delta\right)^{\frac{1}{1-\beta}}, \quad (5)$$

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3.1. Information Hiding Progress

If $\mathrm{mod}\left(m,2\right)=w$, then

$$\left|C_e\right|=m\cdot step=m\cdot\left|C\right|^{\beta}t_L^{1-\beta}=m\cdot\left(m+\delta\right)^{\frac{\beta}{1-\beta}}\cdot t_L, \quad (6)$$

If $\mathrm{mod}\left(m,2\right)\neq w$, then (1) $0\le\delta\le\frac{1}{2}$

$$\begin{aligned}\left|C_e\right|&=\left(m+1\right)\cdot step=\left(m+1\right)\cdot\left|C\right|^{\beta}t_L^{1-\beta}=\\&=\left(m+1\right)\cdot\left(m+\delta\right)^{\frac{\beta}{1-\beta}}\cdot t_L\end{aligned}, \quad (7)$$

(2) $-\frac{1}{2}\le\delta<0$

$$\begin{aligned}\left|C_e\right|&=\left(m-1\right)\cdot step=\left(m-1\right)\cdot\left|C\right|^{\beta}t_L^{1-\beta}=\\&=\left(m-1\right)\cdot\left(m+\delta\right)^{\frac{\beta}{1-\beta}}\cdot t_L\end{aligned}, \quad (8)$$

3.2. Information Extraction Progress

Suppose $q_d=\left|C_e\right|/step_d, m_d=round\left(q_d\right)$.

If $\mathrm{mod}\left(m_d,2\right)=w$, if guarantees the information extraction is right, then should meet $m-\frac{1}{2}<q_d<m+\frac{1}{2}$, then

$$t_L\cdot\left(m-\frac{1}{2}\right)^{\frac{1}{1-\beta}}<\left|C_e\right|<t_L\cdot\left(m+\frac{1}{2}\right)^{\frac{1}{1-\beta}}, \quad (9)$$

namely

$$t_L\cdot\left(m-\frac{1}{2}\right)^{\frac{1}{1-\beta}}<m\cdot\left(m+\delta\right)^{\frac{\beta}{1-\beta}}\cdot t_L<t_L\cdot\left(m+\frac{1}{2}\right)^{\frac{1}{1-\beta}}, \quad (10)$$

From which we can see that because $\left|\delta\right|\le\frac{1}{2}$, algorithm (10) constantly come into existence, thus will not cause information extraction errors

If $\mathrm{mod}\left(m_d,2\right)\neq w$

(1) $0\le\delta\le\frac{1}{2}$, if guarantees the information extraction is right, then should meet $m+\frac{1}{2}<q_d<m+\frac{3}{2}$, then

$$t_L \cdot \left(m+\frac{1}{2}\right)^{\frac{1}{1-\beta}} < |C_e| < t_L \cdot \left(m+\frac{3}{2}\right)^{\frac{1}{1-\beta}}, \quad (11)$$

Namely

$$t_L \cdot \left(m+\frac{1}{2}\right)^{\frac{1}{1-\beta}} < (m+1)\cdot(m+\delta)^{\frac{\beta}{1-\beta}} \cdot t_L < t_L \cdot \left(m+\frac{3}{2}\right)^{\frac{1}{1-\beta}}, \quad (12)$$

When $\delta = 0$

$$(m+1)\cdot m^{\frac{\beta}{1-\beta}} < \left(m+\frac{1}{2}\right)^{\frac{1}{1-\beta}}, \quad (13)$$

Because of $\beta = 0.7$, the effectiveness of algorithm (13) can through the monotony of function $\frac{(x+1)\cdot x^{\frac{\beta}{1-\beta}}}{\left(x+\frac{1}{2}\right)^{\frac{1}{1-\beta}}}$ to prove.

When $\delta = \frac{1}{2}$,

$$\begin{aligned}&(m+1)\cdot(m+\delta)^{\frac{\beta}{1-\beta}} = \\ &= (m+1)\cdot\left(m+\frac{1}{2}\right)^{\frac{\beta}{1-\beta}} > \left(m+\frac{1}{2}\right)^{\frac{1}{1-\beta}}\end{aligned}, \quad (14)$$

$(m+1)\cdot(m+\delta)^{\frac{\beta}{1-\beta}}$ is a continuous function of q, so there exists $\lambda\left(0<\lambda<\frac{1}{2}\right)$, which makes

$$(m+1)\cdot(m+\delta)^{\frac{\beta}{1-\beta}} = \left(m+\frac{1}{2}\right)^{\frac{1}{1-\beta}}, \quad (15)$$

Therefore, when $0 \le \delta < \lambda$, information extraction is error.

(2) $0 \le \delta \le \frac{1}{2}$, if guarantees the information extraction is right, then should meet $m-\frac{3}{2} < q_d < m-\frac{1}{2}$ then

$$t_L \cdot \left(m-\frac{3}{2}\right)^{\frac{1}{1-\beta}} < |C_e| < t_L \cdot \left(m-\frac{1}{2}\right)^{\frac{1}{1-\beta}}, \quad (16)$$

Namely

$$t_L \cdot \left(m-\frac{3}{2}\right)^{\frac{1}{1-\beta}} < (m-1)\cdot(m+\delta)^{\frac{\beta}{1-\beta}} \cdot t_L < t_L \cdot \left(m-\frac{1}{2}\right)^{\frac{1}{1-\beta}} \quad (17)$$

when $\delta = 0$

$$(m-1)\cdot m^{\frac{\beta}{1-\beta}} > \left(m-\frac{1}{2}\right)^{\frac{1}{1-\beta}}, \quad (18)$$

Similarly, the effectiveness of algorithm (18) can through the monotony of function $\frac{(x-1)\cdot x^{\frac{\beta}{1-\beta}}}{\left(x-\frac{1}{2}\right)^{\frac{1}{1-\beta}}}$ to prove.

When $\delta = -\frac{1}{2}$,

$$\begin{aligned}&(m-1)\cdot(m+\delta)^{\frac{\beta}{1-\beta}} = \\ &= (m-1)\cdot\left(m-\frac{1}{2}\right)^{\frac{\beta}{1-\beta}} < \left(m-\frac{1}{2}\right)^{\frac{1}{1-\beta}}\end{aligned}, \quad (19)$$

$(m-1)\cdot(m+\delta)^{\frac{\beta}{1-\beta}}$ is the continuous function of δ, therefore exists $\lambda'\left(0<\lambda'<\frac{1}{2}\right)$, which makes

$$(m-1)\cdot(m+\delta)^{\frac{\beta}{1-\beta}} = \left(m-\frac{1}{2}\right)^{\frac{1}{1-\beta}}, \quad (20)$$

From the above analysis, when $\mathrm{mod}(m_d, 2) \ne w$ and $\lambda' < \delta < \lambda$, the information extraction is error.

4. Improvement of AQIM Algorithm-Iteration AQIM Algorithm

Through theoretical analysis we can see that the reason AQIM algorithm cannot extract hiding information correctly lies in :during information hiding progress, C_e has not exceeded to specific threshold, original information embedded can not insure the extraction correctly of information. Aiming at this issue, this paper proposes iteration AQIM algorithm, namely processes information extract detection while during information embedded, when extract information is inconformity with hiding information, then makes re-embedding on the basis of coefficient C_e of embedded information, until detects hiding information correctly. The specific algorithm is showed as follows:

$$\mathrm{mod}(m_d, 2) \ne w$$

(1) If $0 \le \delta < \lambda$

$$|C_n| = (m+1)\cdot step = (m+1)\left|C_{(n-1)}\right|^{\beta} t_L^{1-\beta}, \quad (21)$$

$C_{(n-1)}$ shows the coefficient after embedding hiding information on the $n-1$ times, which can see $\{|C_n|\}$ is ascending series, the limit is $t_L \cdot (m+1)^{\frac{1}{1-\beta}}$. Thus through finite iteration,

$|C|$ must meet $|C| > t_L \cdot \left(m+\frac{1}{2}\right)^{\frac{1}{1-\beta}}$.

(2) If $\lambda' \leq \delta < 0$

$$|C_n| = (m-1)\cdot step = (m-1)\left|C_{(n-1)}\right|^{\beta} t_L^{1-\beta}, \quad (22)$$

$\{|C_n|\}$ is descending series, the limit is $t_L \cdot (m-1)^{\frac{1}{1-\beta}}$, thus through finite iteration. $|C|$ must meet $|C| < t_L \cdot \left(m-\frac{1}{2}\right)^{\frac{1}{1-\beta}}$.

This iteration embedded algorithm only iterative embedding the error DCT coefficient during detecting while not influence other embedded, the data needs iteration is about 40 %, and the iterations are not more than 50 times.

5. Correlation Detection of Image Information Hiding Method and Symbol

5.1. Image Information Hiding Method Combined of ICA Feature Extraction and Iteration AQIM

IAC is a signal process and data analysis generated during researching blind source separation. ICA basic model can be showed as:

$$x = As, \quad (23)$$

$$\hat{s} = Wx, \quad (24)$$

where $x = [x_1, x_2, ..., x_M]^T$ expresses the observing signal vector of m-dimensional, $s = [s_1, s_2, ..., s_N]^T$ shows unknown source signal vector, A expresses unknown mixing matrix, $\hat{s} = [\hat{s}_1, \hat{s}_2, ..., \hat{s}_N]^T$ expresses the estimation vectors of resource signals, W expresses unknown unmixing matrix, ICA is to solute unmixing matrix W, thus estimates the unknown resource s according to observing signal X.

FastICA algorithm is a fast fixed-point independent component analysis algorithm, which first makes per-whitening to observing signals with PCA, transmits observing signal X to $v = Ux$, make makes the component of V with unit variance and not connected, the autocorrelation matrix of V is unit matrix, U is albino array.

FastICA uses the objective function based on kurtosis:

$$kurt(D^T v) = E\left[(D^T v)^4\right] - 3\left\{E\left[(D^T v)^2\right]\right\}^2 = , \\ = E\left[(D^T v)^4\right] - 3\|D\|^4 \quad (25)$$

The training formula of unmixing matrix is :

$$D(k) = E\left[v\left(D(k-1)v\right)^3\right] - 3D(k-1), \quad (26)$$

where K is iteration, the whole unmixing matrix is $W = D^T U$, because FastICA algorithm with the characteristics of orthogonality, iterative stability and rapidity, this paper selects FastICA to make simulation experiment. Because the image autonomous block features obtained by adapting re-extraction method can better reflect the image global properties, therefore this paper adapts re-extraction ICA algorithm to make simulation experiment of image information hiding. Based on the ICA feature extraction and iteration, the hiding and extracting of AQIM combined information is showed as Fig. 1.

During hiding progress, first make re-extraction to original image to obtain four subgraphs, and make ICA to obtain the autonomous block features of original images to four subgraphs, then adapted iteration AQIM algorithm embedded hiding information to independent features, and obtained hiding information images after inverse transformation.

5.2. Symbol Correlation Detection

The following Laplace distribution models [8] based on nost sequence [7] and obtained symbol correlation blind test detection algorithm with low calculation complexity but high performance.

The null hypothesis and alternative hypothesis of lind watermark detection respective is:

$H_0 : z^*_i = z_i, i = 1, 2, ..., l$ (no watermark)

$H_1 : z^*_i = z_i + \alpha\omega_i, i = 1, 2, ..., l$ (with watermark)

From the Laplace distribution hypothesis of host signal $Z = (z_1, z_2, ..., z_l)^T$, obtained the prior probability of z_i is:

$$p(z_i) = \frac{1}{\sqrt{2}\sigma}\exp\left(-\frac{\sqrt{2}}{\sigma}|z_i|\right), \quad (27)$$

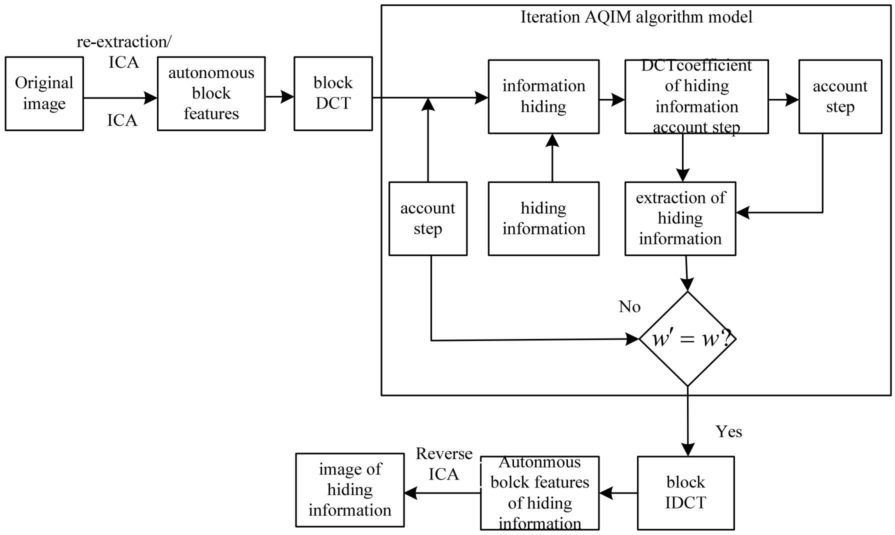

Fig. 1. Information hiding block diagram based on ICA feature extraction and iteration AQIM.

Considering additivity information hiding, then the distribution condition of test signal $Z^* = \left(z^*_1, z^*_2, ..., z^*_l\right)^T, i = 1, 2, ..., l$ is :

$$p\left(z^*_i / H_0\right) = \frac{1}{\sqrt{2}\sigma} \exp\left(-\frac{\sqrt{2}}{\sigma}\left|z^*_i\right|\right), \tag{28}$$

$$p\left(z^*_i / H_1\right) = \frac{1}{\sqrt{2}\sigma} \exp\left(-\frac{\sqrt{2}}{\sigma}\left|z^*_i - \alpha\omega_i\right|\right), \tag{29}$$

Its log-likelihood ratio is

$$\ln \Lambda\left(Z^*\right) = -\frac{\sqrt{2}}{\sigma}\left(\sum_{i=1}^{l}\left|z^*_i - \alpha\omega_i\right| - \sum_{i=1}^{l}\left|z^*_i\right|\right), \tag{30}$$

Considering watermark signal is weak signal relative to host signals, when insert depth α is very low, then

$$\left|z^*_i - \alpha\omega_i\right| - \left|z^*_i\right| = \\ = \left(z^*_i - \alpha\omega_i\right)\operatorname{sgn}\left(z^*_i\right) - z^*_i \operatorname{sgn}\left(z^*_i\right) \approx -\alpha\omega_i \operatorname{sgn}\left(z^*_i\right), \tag{31}$$

where sgn(·) symbol function, that is:

$$\operatorname{sgn}(x) = \begin{cases} 1, & x > 0 \\ 0, & x = 0 \\ -1, & x < 0 \end{cases}, \tag{32}$$

Then the log-likelihood ratio briefly is :

$$\ln \Lambda\left(Z^*\right) = \frac{\sqrt{2}\alpha}{\sigma} \sum_{i=1}^{l} \omega_i \operatorname{sgn}\left(z^*_i\right), \tag{33}$$

From these structures the symbol correlation detector of blind watermark is:

$$T_{SCD} = \frac{1}{l} \sum_{i=1}^{l} \omega_i \operatorname{sgn}\left(z^*_i\right), \tag{34}$$

When T larger than detection threshold, then considered watermark exists.

6. Simulation Experiment and Symbol Correlation Detection Result.

In order to test the superiority of basing on re-extraction ICA and iteration AQIM information hiding algorithm, we proposed information hiding method combined of two other ICA and iteration AQIM: method one, adapt block ICA to extract carrier image features, using iteration AQIM algorithm to embed hiding information into the features of information embedded extraction: method two, re-extraction the carrier images, using iteration AQIM algorithm to embed hiding information into one of the subgraph directly. In the experiment, select the Lena standard pictures with 512×512 as the carrier image, and the two-value image of 32×32 as the hiding information, NC value as the indicator of hiding information detection performance, the invisibility is consistency, the PSNR value is 35.

Adapting re-extraction method to get the four subgraph of original image, and view these subgraphs as the four observation signals of original images to make ICA, low frequency parts of carrier images. Fig. 2 (b) is similar with itself, which can reflect the overview features of carrier original images, thus select Fig. 2 (b) as the information hiding regions. While in block ICA algorithm, the features with maximum variance yields are used to embed information ,then uses iteration AQIM to embed images which need to be hided into DCT regions respectively, one of each 8×8 embedded hiding images. Fig. 3 is the secret information detection NC value through the JPEG compressing of symbol correlation detectors.

Fig. 2 (a). Original carrier image.

Fig. 2 (b). The independent element obtained from re-extraction ICA.

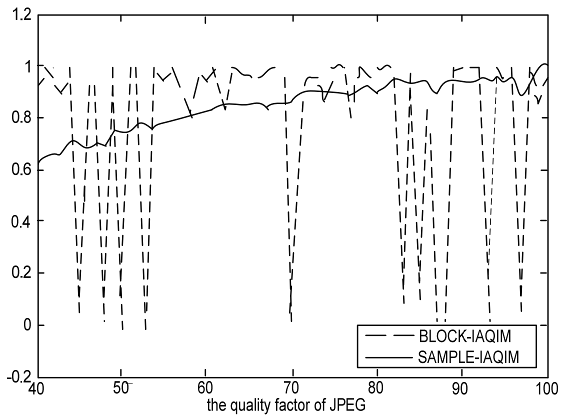

Fig. 3. The NC value of JPEG adapting method one after compression and this paper adapting the method.

From the above image we can see that the performance of block ICA algorithm is not stable than re-extraction algorithm, this is because the features obtained by adapting ICA algorithm is the statistical characteristic of image, even is the same image, the results of ICA algorithm each time is not just the same. Therefore, in block ICA algorithm, the feature block of maximum variances selected during information hiding process are not always the same feature block obtained from information extraction process, which causes the information extraction error, the extraction error rate of block ICA is about 20 %. But re-extraction ICA algorithm does not exist this problem, it can guarantee the feature blocks with maximum variance obtained each algorithm is the same feature block, which guarantees the stability of algorithm.

This paper makes simulation experiment to resist Gaussian noise of different intensity, spiced salt noise, median filter of 8×8, GLPF and average filtering, zoom, shear of geometric attack and brightness variation process, the results are showed as table 1, it is easy to see that the information hiding method based on the combination of re-extraction ICA algorithm and iteration AQIM algorithm has the optimal robustness. From another perspective, the method proposed in the same embedded has a better robustness that is providing security of embedded on keeping the same robustness. The robustness comparison of several common attack and picture processing is adduced in Table 1.

Table 1. Robustness comparison of several common attack and picture processing.

Attack		Method 1	Method 2	Method of this paper
Glitch attacks	Gaussian noise (0,0.003)	0.81384	0.56027	0.84657
	Spices salt noise (0.003)	0.71789	0.84463	0.76645
Filtering attacks	Median filter (3×3)	0.76632	0.11328	0.84352
	Gaussian filtering (3×3)	0.83984	0.48514	0.96266
	Average filtering (3×3)	0.70898	0.10642	0.74415
Image resizing	2	0.84112	1	0.93432
Removal attacks	1/4	0.52151	0.75639	0.61413
Brightness processing	[0-1.2]	0.58241	0.63251	1

6. Conclusion

The AQIM algorithm proposed by Cox and so on even on the free-attack condition also cannot extract hiding information perfectly, this paper aims at the disadvantage of this algorithm proposed a kind of improved iteration AQIM algorithm, and be able to extract hiding information perfectly without disturbed condition. And combined the visual features to information hiding embedded selection and embedded algorithm impact proposed the information hiding method based on the combination of re-extraction ICA feature extraction and iteration AQIM algorithm, meanwhile using symbol correlation detector to make detection, the experimental result showed the image features obtained from re-extraction ICA has a better statistical features and stronger robustness than other algorithms.

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