A High Capacity Information Hiding Algorithm Based on Invariance Properties of JPEG Compression

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***Abstract*—Imperceptibility, robustness and hiding capacity are main indexes to measure information hiding algorithm. However, they always restrict each other. Invariance of JPEG compression has been analyzed at first. Then, according to invariance of JPEG compression, information hiding algorithm which can embed information in DCT median and high frequency coefficients has been proposed. Information embedding capacity adaptively determined by smooth state of subblocks, hence hiding capacity can be increased under the condition of satisfy imperceptibility. The algorithm has strong robustness against lossy compression with quality factor not exceed default, besides, experiences show that it has a certain degree of antinoise ability.**

***Index Terms*—information hiding; hiding capacity; DCT transformation; invariance of JPEG compression**

I. Introduction

Discrete cosine transformation (DCT) is one of most frequently used linear transformation in digital signal processing technology. DCT has good energy compression ability. It converge energy of image into numbered low frequency coefficients. Besides, it has relatively good perception model in DCT domain. Therefore it often is used in information processing and image processing, lossy data compression of information and image for instance [1] (including static and motive image). Compression standard like JPEG, MPEG and H261/263 all use DCT. Information hiding algorithm based on DCT domain is a commonly used transform algorithm. This kind of information hiding algorithm can separate embedded information into many pixel points and can combine with JPEG compression process. As it has robustness to JPEG compression, it is widely valued. Therefore since Cox proposed that spread spectrum information hiding method based on DCT domain[2], using DCT coefficients as host signal comes to be one of main choice of image information hiding technology. As a result of that human vision system is much more sensitive to signal in low frequency than in high frequency, hiding information in low frequency of DCT has better robustness while hiding in median and high frequency has better imperceptibility. In standard quantization matrix commended by JPEG, high frequency has bigger quantization value, utilize additive or additive or multiplicative algorithm, information embedded in high frequency will be easily filtered by JPEG compression. Besides, because rounding error exists in DCT inverse transformation, embedded information may be destroyed even without JPEG compression which has been taken by image carried information. In addition, experiments show that noise data may easily break information embedded in high frequency. Therefore many documents tend to choose median frequency coefficients[3 , 4] and low frequency coefficients[1] even dc component[5] as host sequence. However, owing to that human vision system is more sensitive to variance of median and low frequency coefficients, capacity and intensity of information embedded in median and low frequency coefficients can't be too large, this has became the biggest deficiency of algorithm based in DCT transformation domain[6]. What's more, many information hiding information algorithms based on DCT domain need original carrier image in testing while capacity of algorithms which don't need carrier image is much lower than capacity of algorithm based on spatial domain just like LSB. Hence application of DCT transformation algorithm has been confined in some territory like copy protection (watermarking for instance) but hard to be used in other territory like secret storage and secret communication.

There are many scholars pay attention to increase hiding capacity of information hiding algorithm based on DCT transformation in order to spread its application to wider territory. For example, Chen et al. [7] proposed a hiding algorithm on DCT domain which based on adjustment of quantization table，this algorithm modify

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part of coefficients of quantification table（generally choose value much smaller than standard quantification table） to resist bit drop-out made by quantification. Yu Pengfei, et al. [8] proposed a hiding algorithm on DCT domain ,this algorithm adjust plus-minus value of DCT coefficients which have smaller absolute value to represent 1 and 0, because value of most DCT coefficients are small, there are lots of DCT coefficients to hide information. Liu Guangjie et al. [9] proposed a improved quantization embedding algorithm using steepest decent method to choose control parameter in embedded algorithm. Those algorithms have much higher capacity compare with classical DCT domain algorithm [2, 10]. Nevertheless those algorithms have an apparent deficiency that they can't extract all the embedded information exactly after lossy JPEG compression while in practical application apply lossy compression to image, vision quality won't be declined, is regular process for propose to decline transmission or storage capacity. From principle view, information hiding technology use redundant space of multi-media information as data compression technology try to minish redundant space, those two are incompatible. Therefore how to extract all of hidden information accurately after lossy compression is a problem waiting for solution. Hiding algorithm based on DCT transformation domain which can resist JPEG compression, embedding information in median and high frequency, has been proposed using invariance of JPEG compression of DCT transformation coefficients. [11] The algorithm has good capacity to resist JPEG compression, besides, it has higher embedding capacity, and what's more, the algorithm doesn't need original image and other assistant information in information extraction.

II. DCT AND JPEG COMPRESSION STANDARD

Two dimensional DCT is core idea of lossy digital image compression system---JPEG, which is most frequently used recently. After DCT transformation, energy of original image mainly converged in few low, middle frequency coefficients at upper left corner of DCT coefficient matrix. They constitute importance element of vision perception. High frequencies components distribute at lower right corner are not so important comparatively. Therefore actually DCT transform is a low pass filter on space domain. According to human vision system model, if process or modify high frequency data then re-transform to original form, human eyes Will not distinguish easily although it has some difference with original data. Joint Photographic Effort Group (JPEG) is a static image compression standard appointed by ISO/IEC joint image panel. JPEG compress image data through ignore high frequency components in DCT domain. It contains five steps:

(1)Transform image from RGB space into YCbCr color space (this step will not be processed if the image is gray image)

(2)Separate the image into blocks in 8x8 size (copy right most and under most line and column to make line number or columns number be multiple of 8 if they are not.)

(3)Apply discrete cosine transformation to every 8x8 size sub blocks, to get a DCT coefficient matrix of size 8 ×8.

(4)According to human vision characteristic, take quantification process of weighted optimization to transformed coefficients meanwhile rounding to closest integer

(5)Code quantified cosine transform coefficients by a principle.

In DCT coefficient matrix of size 8×8, the top left coefficient (the coefficient at coordinate (0,0))is DC coefficient. It reflects the average brightness. Other 63 coefficients are AC coefficients. Because they reflect detail situation of image block, AC coefficients also called detail component. In DCT coefficient matrix, level frequency increase from left to right and perpendicular frequency increase from top to bottom. Compare with DC component, AC energy of component is very small. Most coefficients concentrate around point 0. There also exist a few coefficients with big amplitude, but most of them concentrate in low frequency band. Reininger et.al utilize Kolmogorov-Smirnov goodness of fit test proof that DCT coefficient of image block obey Laplace distribution.

Quantification is a method to compress. Under premise of assure certain quality standard, it can drop information which has little influence to vision effect. Cosine function in different frequency has different influence to vision effect. Hence, quantification use vision threshold, got from vision experiment, of different frequency to choose size of element in quantification table. Because human vision is more sensitive to low frequency, quantification step present ascendant tends from low frequency to high frequency. In principle, quantification parameter of coefficients can determine by user. So some scholars proposed some information hiding algorithm based on adjustment of quantification table [12]. But generally use standardized quantification table Q as shown in formula (1). It use characteristic of human vision system to comparative efficiently compress image on the condition that assure quality of image. Besides, only when adopt standardized quantification table recommended by JPEG can image embedded information has ability of anti-compression of standardized JPEG.

$$Q=\begin{bmatrix} 16 & 11 & 10 & 16 & 24 & 40 & 51 & 61 \\ 12 & 12 & 14 & 19 & 26 & 58 & 60 & 55 \\ 14 & 13 & 16 & 24 & 40 & 57 & 69 & 56 \\ 14 & 17 & 22 & 29 & 51 & 87 & 80 & 62 \\ 18 & 22 & 37 & 56 & 68 & 109 & 103 & 77 \\ 24 & 35 & 55 & 64 & 81 & 104 & 113 & 92 \\ 49 & 64 & 78 & 87 & 103 & 121 & 120 & 101 \\ 72 & 92 & 95 & 98 & 112 & 100 & 103 & 99 \end{bmatrix} \quad (1)$$

Different quality factor can be used while use standardized quantification matrix provided by JPEG. Quality factor is a new quantification matrix formed by zoom a set of quantification matrixes by certain proportion (algorithm). For example, JPEG realization provided by Independent JPEG Group (IJG) takes integer between 1 and 100as quality factor. 100 present highest quality, 1 present lowest quality. IJG first transform its quality factor then put it as coefficient multiply chose quantification matrix to form new quantification matrix in purpose of realize different compression effect.

Suppose quality factor is q ($1<q<100$), IJG first apply transformation

$$k=\begin{cases}\dfrac{5000}{q}, & q<50\\ 200-2q, & 50\le q\le 100\end{cases} \quad (2)$$

So $0<k<5000$. Use $k/100$ to multiply every digit in quantification matrix Q, then rounding the result (rounding to 1 if the result is smaller than 1). Therefore new quantification matrix is formed. q=100 present all of quantification coefficients are 1 without quantification error.

That is:

$$Q_m(i,j)=\max(1,\lfloor Q(i,j)*k/100+0.5\rfloor) \quad (3)$$

Where $\lfloor\bullet\rfloor$ present rounded down.

In JPEG decoding process, all the DCT coefficient inverse quantify (multiply quantification value while coding) then use IDCT transformation to reconstruct data. Restored image is very close to original image with a little distortion. If set quantification value appropriately, human eyes will not notice difference easily.

III. Invariance attribute of JPEG compression

Suppose $F(u,v)$ is a DCT coefficient matrix of some non-overlaped 8×8 subblock of a image X, Q_m is JPEG lossy compression quantization table corresponding with a predetermined quality factor. To random u, v=∈{0,1,…,7}. Define :

$$\hat{F}(u,v)=round\left(\frac{F(u,v)}{Q_m(u,v)}\right)\bullet Q_m(u,v)$$ and

$$\tilde{F}(u,v)=round\left(\frac{\hat{F}(u,v)}{Q_n(u,v)}\right)\bullet Q_n(u,v)$$, if

$Q_n(u,v)\le Q_m(u,v)$, then formula (4) is always holds.

$$round\left(\frac{\tilde{F}(u,v)}{Q_m(u,v)}\right)\bullet Q_m(u,v)=\hat{F}(u,v) \quad (4)$$

Certification if formula (4) is as below:

From $\tilde{F}(u,v)=round\left(\frac{\hat{F}(u,v)}{Q_n(u,v)}\right)\bullet Q_n(u,v)$, we can get

$$\tilde{F}(u,v)-\frac{1}{2}Q_n(u,v)\le\hat{F}(u,v)\le\tilde{F}(u,v)+\frac{1}{2}Q_n(u,v) \quad (5)$$

Namely

$$\hat{F}(u,v)-\frac{1}{2}Q_n(u,v)\le\tilde{F}(u,v)\le\hat{F}(u,v)+\frac{1}{2}Q_n(u,v) \quad (6)$$

When $Q_n(u,v)\le Q_m(u,v)$, we can get

$$\hat{F}(u,v)-\frac{1}{2}Q_m(u,v)<\tilde{F}(u,v)\le\hat{F}(u,v)+\frac{1}{2}Q_m(u,v) \quad (7)$$

Formula (7) satisfies formula (4), hence formula (4) is established.

Formula (4) indicates that: if use some predetermined quantization step Q_m to quantize a DCT coefficients $F(u,v)$ and get coefficients matrix $\hat{F}(u,v)$. After that, if use quantization matrix Q_n, whose quantization step is smaller than Q_m ,to quantize , then $\hat{F}(u,v)$ can still be reconstruct accurately. Method of reconstruction is to use the same quantization step Q_m to divide compressed coefficients, and then implement quantization and rounding. Because the higher the quality factor is, the smaller the quantization step, namely if some image has taken JPEG lossy compression by some predetermined quality factor, the image can remain unchanged to every follow JPEG lossy compression which has bigger quality factor, and if quality factor of follow JPEG compression is smaller than the predetermined one, DCT coefficients of original quantization image can't be reconstructed. This is the invariance properties of JPEG compression. On the basis of invariance properties of JPEG compression, we can get *I'* through use quality factor *q*1 to quantify image *I* then inverse quantify it. If use quality factor *q*2 to quantify and inverse quantify *I'* we can get *I**. When *q*2<=*q*1, *I** can certainly resume to *I'*.

IV. Median and high coefficients information hiding algorithm based on invariance of JPEG compression

The most typical formation hiding algorithm in transformation domain is spread spectrum information hiding algorithm and quantification information hiding algorithm. Embedding method can separate into additive method, additive or multiplicative method. In additive or multiplicative method, original image is needed in information extraction, that is to say, blind extraction can not realize. In order to realize blind extraction, embedding method based on quantification index modulation (QIM), main idea of which is utilize embedded information bit to modulate quantification interval. Simply, there are two group quantification points in carrier signal space. Signal carrying secret information choosing which group is decided by embedded information. Comparing to embedding method based on spread spectrum, QIM is totally blind information hiding algorithm and have relatively large information hiding capacity. Therefore it is first choice of large capacity algorithm of embedding method. Suppose *S* is transformation domain coefficient of original carrier. W presents encode information waiting embedding, range of which is [0, 1]. X presents transformation domain coefficient of secret carrier. Δ is minimum quantification interval. Common quantification method to embed information in transformation domain coefficient is:

If $w_i = 0$ and $round(s_i / \Delta)$ is odd number, or if $w_i = 1$ and $round(s_i / \Delta)$ is even number, then

$$x_i = round(s_i / \Delta) \times \Delta + \Delta \quad (8)$$

In other situation:

$$x_i = round(s_i / \Delta) \times \Delta \quad (9)$$

Most nature images are low frequency signal. DCT transformation has good energy compression ability that it converge image energy into numbered low frequency coefficients. That is to say number of DCT transformation coefficients which have comparatively big extent is relatively small. Meanwhile those coefficients centralize in low or middle and low frequency coefficient area while DCT coefficients in high or medium-high frequency area are very small. When use formula (7) or formula (8) to embed, $round(s_i / \Delta) = 0$. So embedding algorithm in high or medium-high frequency coefficients of DCT transformation domain can simplified into:

$$x_i = \Delta \times w_j \quad (10)$$

Utilizing invariance properties of JPEG compression and quantification embedding method, if embed secret information after quantification with a predetermined quantification step, secret information can support JPEG compression with step not exceed the quantification step. The information hiding algorithm first use quality factor $q1$ to quantify image I and get DCT coefficient matrix S of image. Then modify any DCT coefficient in the matrix to get new DCT coefficient matrix $S1$. Then process applies quantification to $S1$ and get image $I1$. If modified number is integral multiple of corresponding quantification coefficient, because $round\left(\frac{F(u,v)}{Q_m(u,v)}\right) \bullet Q_m(u,v)$ and $round\left(\frac{F(u,v)+kQ_m(u,v)}{Q_m(u,v)}\right) \bullet Q_m(u,v)$, have same rounding error, it can be proved that, proof process is similar with proof of formula (4), if only $q2 <= q1$, image $I1$ can certainly recovered form $I2$. Image $I2$ is got from applying quantification and inverse quantification to image $I1$ with quality factor $q2$. After normally recovered into $I1$, extraction algorithm utilizing quantification algorithm can extract embedded information exactly. Therefore using invariance properties of JPEG compression, while embedding information with quantification method, whatever coefficient be embedded in, extract embedded information after JPEG compression with quality factor not lower than appointed one can solve the problem that robustness of embedded information in high frequency is not strong. Meanwhile as imperceptibility of information embedded in high and medium-high frequency coefficient is better than in low and middle and low frequency coefficient. Therefore using invariance properties of JPEG compression to embed information in high or medium- high frequency coefficient can realize information embedding with relatively large capacity under premise of ensuring certain robustness and imperceptibility.

According to invariance of JPEG compression, if embed secret information on the basis of quantization with some predetermined quantization step, the secret information can resist JPEG compression with smaller step comparing with the quantization step. Namely that whatever coefficient does information embedded in, the information can be extracted after JPEG compression. Hence median and high frequency can be used to embed information, thus we can embed more information on the basis of ensuring a certain degree of robustness. Suppose carrier image is $I=\{f(x, y), x, y=0,1,\ldots,N-1\}$, information waiting for hiding is $W=\{w, j=0,1,\ldots,L-1\}$, algorithm description is as below:

(1) Chose a quality factor q. Generally set it as the lowest quality factor human eye could accept. That's to say every image with quality factor lower than that one is unacceptable. Acceptable quality factor commended by JPEG standard is from 50 to 75, in this algorithm can be decided by compression quality factor which algorithm needs to sustain, but it should higher than 50, otherwise when embed too much information will cause perceptive distortion.

(2) Get scaling parameter k of quantization table according to chosen quality factor q and formula (1).

(3) Multiply scaling parameter k with each term of Q, and then get a predetermined quantization table Q_m.

(4）partitioning the image I into 8×8 subblocks.

(5) Apply information embedding process to every subblocks. Procedure is as below:

Step 1: Perform DCT transformation to subblock, and obtain DCT coefficients matrix $S=\{s(u, v), u, v=0,1,\ldots,7\}$.

Step 2: Arrange DCT coefficients according to zig-zag order in inverse sequence. Choose t coefficients to be used in information embedding. The bigger is t, the more information can be hidden, whereas imperceptibility will decline. In order to ensure good imperceptibility, value of t should be decided by smooth degree of subblock: t of smoother subblock should be smaller while t of rougher subblock can be bigger. That is, for more embedded information and better imperceptibility, value of t should adapt to smooth degree of subblock. Because after DCT transformation, most coefficients of smooth area are smaller while coefficients of rough area are bigger, smooth situation can be decided through distribution state of coefficient after subblock has been DCT transformed, and value of t can be decided by distribution state of DCT coefficient. Experiments show that it's suitable to assign t as the number of coefficients. The number is nonzero coefficients account of subblock's DCT coefficients which have been quantized using quantification matrix presented by formula (1).

Step 3: Directly modify those high frequency coefficients, which have been chosen to embed information, to embed information w_j (embed 1 bit information in one coefficient), modify way is as below:

$$s(u,v) = Q_m(u,v) \times w_j \tag{11}$$

What should be pay attention to is that those DCT coefficients haven't been chose to embed information should not be quantized. This can decrease image degradation caused by quantization.

Step 4: Take inverse DCT transformation to DCT coefficient matrix of modified subblock, and then get subblock containing secret information.

(6) Reset subblocks which have embedded information, and get image containing secret information.

Extract steps is basically the same as embedding step. According to quality factor q, which is chosen in information embedding and formula (1) to get a predetermined quantification table Q_m. Then separate image I into blocks of size 8×8. After that, extract embedded information from every subblock. In this process, determine which DCT coefficient has information embedded in by situation of middle frequency and low frequency coefficients. That is only consider middle frequency and low frequency coefficients while calculating how many high frequency coefficients embedded information. Extract algorithm of embedded information is described as blow:

(1) Get a predetermined quantification table Q_m on basis of quality factor q and formula (2) and (3). q is chosen in information embedding.

(2) Separate image I into blocks of size 8×8

(3) Extract embedded information from every subblock, steps are:

Step 1: Apply DCT Transformation to subblock to get DCT coefficient matrix $S=\{s(u, v), u, v=0,1,\ldots,7\}$;

Step 2: Divide DCT coefficients matrix with matrix Q presented by formula (1) and round. Then get quantified and rounded matrix $S'=\{s'(u, v), u, v=0,1,\ldots,7\}$. That is $s'(u,v) = round(s(u,v)/Q(u,v))$;

Step 3: Calculate number x on the basis of zig-zag order. x is the not-zero number of first 32 coefficients in matrix S'. According to embedding principle, x is the embedding bit number of the subblock. That is x is also the extraction bit number of the subblock;

Step 4: Put DCT coefficient S in anti-order of zig-zag order. Then choose x high frequency coefficients. Then we can extract information directly.

If extracting strictly according to inverse embedding process, in high frequency coefficient embedded information, coefficient value is 0 if embedding 0, otherwise is 1. In order to eliminate rounding error may exist in DCT coefficient inverse transformation. Then use the formula below to confirm information embedded in corresponding DCT coefficient.

$$w_j = \begin{cases} 0 & s(u,v)/Q_m(u,v) < 0.5 \\ 1 & s(u,v)/Q_m(u,v) \geq 0.5 \end{cases} \tag{12}$$

V. SIMULATION EXPERIMENTS AND DISCUSSION

According to JPEG compression process, if choose larger quantification factor, image quality reduce less, effect to information embedded in middle, high frequency coefficients is smaller, robustness of information hiding and imperceptibility is better. On the basis of parameter provided by JPEG, when image take lossy compression, if quality factor is bigger than 75, degradation of the image is imperceptible to human eye, if quality factor is from 50 to 75, its still acceptable, if quality factor is smaller than 50, then it's unacceptable. In information hiding application, requiring that compare with original image, the image hidden information have no apparent reduce of quality. Hence quality factor smaller than 50 won't be used in image compression, hence we choose quality factor q 50 to perform experiments. First utilize algorithm in this paper to execute fully embedding experiments separately to Lena and mandrill standard test image of 512×512 in three kinds: smoothness is smooth, normal and coarse as shown in Fig.1(a) , Fig.2(a) and Fig.3(a). Capacity of embedded information is 28572, 40362 and 68058 bit. Ratio of embedded bits to pixels is 10.93%, 15.40% and 25.96%. Average capacity of information can be embedded in each subblock is 6.9952bit, 9.8540bit and 16.6143bit. The embedding capacity is much high than algorithm's which is proposed by document [3-6, 11], and is approximate with document [10], however document [10] can't resist compression. From those data, it can be seem that capacities of images which have different smooth degree are distinctly different. This situation reflects the characteristic human vision system has, that the system is sensitive to noise in smooth area but do not sensitive to noise in rough area. Choose random noise to execute fully embedding to Fig.1(a) , Fig.2(a) and Fig.3(a) then get results as shown in Fig.1(b) , Fig.2(b) and Fig.3(b). PSNR of original image and image in which information has embedded separately is 33.6274, 32.1065and 30.6817. Both of them are bigger than the 30, which is recognized to be the lowest value to satisfy imperceptibility request. Actually, naked eye can't distinguish original image and image in which information has embedded in Fig.1, Fig.2 and Fig.3.

If use measuring method, mentioned in document [8], which utilizes distortion structural similarity to weigh distortion degree after information hiding, thus distortion of image embedded information compared with original one of Fig.1 and Fig.2 are totally the same. That's to say that imperceptibility of PSNR information hiding algorithm has deficiency. When choose higher quality factor to repeat experiment above, PSNR between original and image embedded information ascent along with raise of quality factor.

(a) Original image (b) Image carried secret

Figure 1. Comparison 1 of original image and image carried secret

(a) Original image (b) Image carried secret

Figure 2. Comparison 1 of original image and image carried secret

(a) Original image (b) Image carried secret

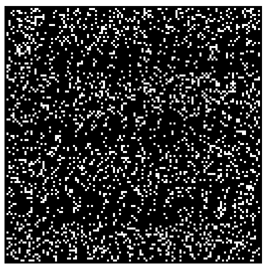
Figure 3. Comparison 3 of original image and image carried secret

After Fig.1(b), Fig.2(b) and Fig.3(b) take compression with quality factor 70, 60, 51, apply extraction of hidden information separately to them . Hidden information can be 100% accurately extracted, this is coherent with theory analyze. Whereas after those two images take compression with quality factor 40, 20, almost all the information are missed, this is accordant with theory analyze as well, namely that the algorithm is robust to compression with quality factor higher than predetermined value.

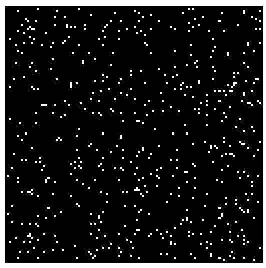
Use 128×128 binary image as shown in Fig.4(a) as secret information and embed it into Fig.3(a) to execute anti-compression and anti-jamming experiments (choose quality factor be 75). PSNR of image embedded information and original image is 36.6231. Perform extraction after compression with quality factor higher than the predetermined one and result is as shown in Fig.4(b), it's completely coherent with Fig.4(a), the ratio of accurately extraction is 100%. Then, perform extraction after compression with quality factor lower than the predetermined one. While quality factor separately descend 0.3% and 0.6%, extraction results are shown in Fig.4(c) and Fig.4 (d). Afterwards separately add 0.05% salt and pepper noise and Gaussians noise into image in which secret information embedded, and then apply extraction. Extraction results are as shown in Fig.4 (e) and Fig.4 (f). Use quality factor not lower than predetermined one to compress image which added noise, then extract and results are shown in Fig.4 (g) and Fig.4 (h). It can be seen that compress after add 0.05% pepper and salt noise do not influence information extraction. But compare with image only add noise, image applied compression extraction after add 0.05% gauss noise have apparently quality descent. Still, extracted image information can be distinguished apparently. That is to say that the algorithm has a degree of robustness to noise interference.

(a) Image waiting embedding

(b) Extraction after high quality compression

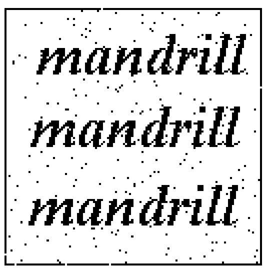


(c) Extract after compression with descending 0.3% quality factor



(d) Extract after compression with descending 0.6% quality factor

(e) Extraction after add salt and pepper noise



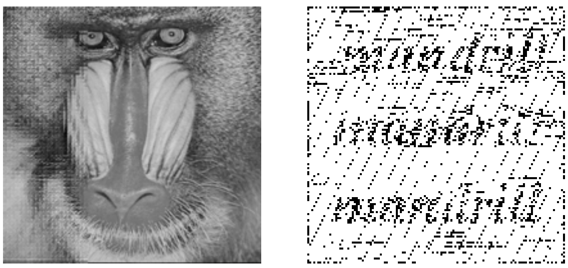
(f) Extract after add Gaussians noise

(g) Extract after compression with pepper and salt noise added

(h) Extract after compression with gauss noise added

Figure 4. Results of anti-compression and anti-jamming.

In order to distinct the algorithm and algorithm based on median and low frequency coefficients. Modify low frequency coefficients according to formula (6), the embedding strength is the same as frequency coefficients have in Fig.3(a). After embed Fig.4(a), image carrying information is shown in Fig.5(a). PSNR of it and Fig.3(a) is 24.9564 that imperceptibility request is not satisfied and even naked eye can perceive blocking effect of the image. Extracted information is shown in Fig.5(b), although still can sense most of content, it's apparently distinctive with Fig.4(a), namely that even without any interference, embedded information can't be extracted correctly. Because there is rounding error and interactions among low frequency coefficients assist in DCT inverse transformation. To majority of algorithm based on low frequency coefficients in DCT domain, this is a widespread problem when hiding large quantity of information.



(a) Image with hidden information

(b) Extracted information

Figure 5. Hiding effect based on low frequency

VI. Conclusions

Currently information hiding algorithm based on DCT domain is the most widely algorithm in transformation domain. For better robustness, information hiding algorithm based on DCT domain generally choose DCT median frequency coefficients, low frequency coefficients even dc components to serve as host sequence. Because human vision is more sensitive to change of median and low frequency, capacity and strength of information embedding in median and low frequency coefficients can't be too large, hence it's hard to be used in some territory like secret storage and secret communication. Utilize invariance of JPEG compression of DCT transformation coefficients, this paper proposed a hiding algorithm which embed information into median and high frequency coefficients and can realize blind-extraction based on DCT domain. As it embed information into median and high frequency coefficients, the embedded information has better imperceptibility, and it have high capacity of hidden information under condition that keep good imperceptibility. As a result of using invariance of JPEG compression, all the embedded information can be extracted accurately after taken lossy compression with quality factor higher than predetermined one. Therefore the incompatible problem has been solved that information hiding technology wants to use redundant space of multi-media information, but data compression technology try to decrease the redundant space. Besides, the algorithm has some degree of robustness. The deficiency of this algorithm is that after JPEG compression, the image embedded information will have more non-zero coefficients in high frequency than nature images have. Although it won't arouse variance of human vision perception, security problem when using some steganography analyze tool might be generated. Solution is to appropriately decrease the number of coefficients in high frequency and increase the number of coefficients in median and high frequency or median frequency. Nevertheless under the same constraint of imperceptibility index, embedding capacity will decrease, but ability of invariance of JPEG compression can be preserved.

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