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Near Reversible Data Hiding Scheme for images using DCT

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Abstract
Certain level of modifications to the original content can be acceptable. These schemes are called near-reversible. It has emerging application in remote sensing. In remote sensing application the image is captured while monitoring the damaged regions in the natural disasters such as tsunami, volcanic eruption, etc. Instead of more alterations to the pixels or coefficients here we go for less alterations , low hiding capacity and complexity that exhibit while reversible data hiding. There exist a few near reversible hiding schemes which address the limitations to the triangular trade-off that exists between capacity, robustness and visual quality characteristics. However, for achieving better vision of image, there is a need for near reversible data hiding schemes. Therefore, the traditional metric
PSNR are not sufficient to assess the distorted image when the data is embedded in image for assessing the better visual quality of the image with hidden data we present a HVS based metrics like PSNR-HVS, MSSIM. Using DCT evaluates the overall image quality
Keywords: DCT (Discrete Cosine Transform), , PSNR-HVS (peak signal to noise ratio-Human visual System), MSSIM Mean Structural Similarity Index.

I. Introduction

The proliferation of high capacity digital recording devices and the rapid growth in using the Internet technology, though it is an indication of technological growth, is becomes a threat to the multimedia content owners. Since, this advancement made the illicit users to share and distribute the multimedia contents like image, audio, video, etc. easily and illegally. The Digital Watermarking and Steganography have become a backbone for the multimedia content owners for providing the security to their contents. In both the contests, the multimedia content is altered for providing the security. They refer the process of altering the multimedia content for providing the security as the data embedding to capture both the Watermarking and Steganography contests. A data embedding scheme alters the cover contents such as image, audio, video, etc. for embedding the data. The data to be embedded can be secret information, identity of the content owner, information about the cover content, etc. depending up on the application for which the embedding scheme is designed.

The multimedia content is altered when the embedding process alters the cover content. Some schemes do not concentrate on restoring the image rather the concentration is on other requirements such as visual quality, robustness, capacity of embedding and such scheme is known as Irreversible data embedding schemes. But some schemes require the restoration of original content after extraction process such scheme is known as Reversible data embedding schemes [1, 2, 3, 4]. With more modifications to the original content, the reversibility and embedding capacity becomes the limited characteristic. For some schemes accurate reversibility is not in concentration instead the extent of moderation in contents is user defined. These schemes are called near-reversible or near-lossless or semi-reversible schemes. Recently, the interest in this category of data embedding schemes is increasing. Probably due to the limitations involved in reversible schemes such as more modifications, low embedding capacity. Moreover, the urgent need of near reversible schemes is due to the applications, viz. copyright protection of remote sensing images [6].

A fundamental task in many image rocessing tools is the visual evaluation of digital data. The Image Quality Assessment metric used for evaluation, is of two types: subjective and objective. The Subjective evaluation is done with help of viewers. The objective evaluation is done with help of assessment models. The subjective assessment uses more number of human viewers, time consuming, expensive and difficult to perform on large number of human viewers. Therefore, we move to objective model such as Peak Signal-to-Noise Ratio (PSNR) which generally does not correlate well with viewer's opinion. After extensive Research in this area many metrics based on Human Visual System (HVS) are developed.

The metric used based on HVS are PSNR_HVS, MSSIM where PSNR_HVS is a metric which calculate Peak signal to noise ratio (PSNR) while considering into account Human Visual System (HVS). MSSIM is a metric which calculates the between- coefficients contrast masking of DCT basis function based on HVS and the contrast sensitivity function (CSF). Structural SIMilarity (SSIM) Index metric checks the similarity between two images where one image should be of perfect quality.

The unfolded research area has been evolving to address the limitations such as more alterations to the pixels or coefficients, low hiding capacity and complexity that exhibit while reversible data hiding. Limiting the triangular trade-off that exists between capacity, robustness and visual quality is challenging. However, for achieving better visual quality, there is a need for HVS based near reversible data hiding schemes.

II. Introduction to DCT transform

DCT is an orthogonal transformation that is very widely used in image compression and is widely accepted in the multimedia standards. Like other transforms, the Discrete Cosine Transform (DCT) attempts to de-correlate the image data. After de-correlation each transform coefficient can be encoded independently without losing compression efficiency. The 1-D DCT the most common DCT definition of a 1-D sequence of length N is

$$C(u,v) = \propto(u) \sum_{x=0}^{N-1} f(x) \cos\left[\frac{\pi(2x+1)u}{2N}\right] \quad (2.1)$$

Where $f(x)$ a original signal to be transformed and u = 0, 1, 2, ….., N −1.

Similarly, the inverse transformation is defined as

$$f(x) = \sum_{u=0}^{N-1} \propto(u) C(u) \cos\left[\frac{\pi(2x+1)u}{2N}\right] \quad (2.2)$$

Where $C(u)$ is transformed coefficient, $u = 0,1,2,\ldots,N-1$ and $\propto = (u)\ is$ defined below.

$$\propto(u) = \begin{cases} \sqrt{\frac{1}{N}} \ for\ u = 0 \\ \sqrt{\frac{2}{N}} \ for\ u \neq 0. \end{cases}$$

Foru=0,1DDCT $, when\ u = 0, C(u) = \sqrt{\frac{1}{N}} \sum_{x=0}^{N-1} f(x)$. Thus, the first transform coefficient is the average value of the sample sequence. In literature, this value is referred to as the DC Coefficient. All other transform coefficients are called the AC Coefficients.

The 2-D DCT is defined as

$$C(u,v) = \propto(u) \propto(v) \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} f(x,y) \cos\left[\frac{\pi(2x+1)u}{2N}\right] \cos\left[\frac{\pi(2x+1)v}{2N}\right]$$

Where $f(x,y)$ is a 2-D signal (image) and $C(u,v)$ is a 2-D DCT transform signal and $u,v = 0,1,2,\ldots,N-1$ and $= \propto(u)$ and $\propto(v)$ are defined below.

$$\propto(u) = \begin{cases} \sqrt{\frac{1}{N}} \ for\ u = 0 \\ \sqrt{\frac{2}{N}} \ for\ u \neq 0. \end{cases}$$

The inverse transform is defined as

$$f(x,y) = \textstyle\sum_{u=0}^{N-1} \sum_{v=0}^{N-1} \propto(u) \propto$$
*(v)Cu,v*cos*π2x+1u2N*cos*π2x+1v2N*

(2.4)

Where $f(x,y)$ is the restored signal and $x,y = 0,1,2,\ldots,N-1$. The 2-D basis functions can be generated by multiplying the horizontally oriented 1-D basis functions with vertically oriented set of the same functions.

A. Existing Method

In existing system, reference image taken as input is portioned into 8×8 blocks of intensity values and 2- dimensional DCT is applied on each block. Then each block is divided by quantization table of 8×8 block. In embedding process, the data is embedded in all non-zero DCT coefficients i.e. the block whose number of non-zero DCT coefficients is greater than zero then the data is embedded in that block is embedded. The log function is used for embedding data. After this process the difference obtained between the original Non-zero AC coefficient and data embedded coefficient is much greater as a result the watermarked image obtained has blocking artifacts.

B. Proposed Method

The objective of the proposed solution is to improve the visual quality of the images i.e. avoiding the blocking artifacts. In existing system, reference image taken as input is portioned into 8×8 blocks of intensity values and 2- dimensional DCT is applied on each block. Then each block is divided by quantization table of 8×8 block. In embedding process, the data is embedded in all non-zero DCT coefficients i.e. the block whose number of non-zero DCT coefficients is greater than zero then the data is embedded in that block is embedded as shown in figure 4.1. The mathematical function is used for embedding data. After this process the difference obtained between the original Non-zero AC coefficient and data embedded coefficient is much greater as a result the watermarked image obtained has blocking artifacts.

The extraction process extracts the image with well suitable equation and the HVS metrics used such as PSNR, PSNR_HVS, PSNR_HVS_M, MSSIM and reversibility schemes give good values with good visual quality.

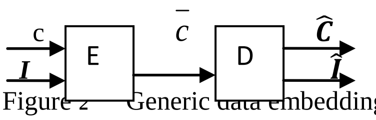


Figure 2 Generic data embedding and extraction procedure

The data embedding procedure is given by $E(C, I) = \bar{C}$ and the data extraction procedure is given by $D(C) = (\hat{C}, \hat{I})$. Here $\hat{I}$ is the extracted data and $\hat{C}$ is the cover object after extracting the data. When $C = \hat{C}$ and $I = \hat{I}$, we define the data extraction procedure as reversible, otherwise it is irreversible.

A. Watermark Embedding Process

The data is embedded in all non-zero AC Coefficients pixels in each block except the blocks where all AC Coefficients are equal to zero. For better visual quality, the design is proposed to reduce the modifications to the original coefficients i.e. the watermarked coefficients are retained to nearer value of original coefficients.

Algorithm:

1. Take an input image I and
2. Partition I using DCT I→ $\{B_1, B_2, \dots B_l\}$
   For each $B_j \in I$, where $1 \le j \le 8$

(a) Quantize the DCT coefficients in B_j as below.

for $i_1 \leftarrow 1$ to 8 do
  for $i_2 \leftarrow 1$ to 8 do
    $C_j(i_1, i_2) = B_j(i_1, i_2) / Q(i_1, i_2)$;
  end
end

(b) Compute T as shown in equation (3.1) after converting the matrix to row or column vectorization, If $T > 0$, then modify all the non-zero AC coefficients and embed the data using equation (3.2). Let the resultant block be C_j.

3. Combine all the C_j blocks into I= $\{C_1, C_2, \dots C_l\}$.
4. For all the blocks repeat step 1 to step 3.

$$T = \sum_{j=2}^{64} c_j \qquad (3.1)$$

$$e = \begin{cases} \frac{c}{|c|} \left| \sqrt[0.94]{c} * 0.9 \right| & \text{if } S = 0, \\ \frac{c}{|c|} \left| \left(\sqrt[1.2]{c} * 1.5 \right) - 1 \right| & \text{if } S = 1. \end{cases} \qquad (3.2)$$

Where c is the non-zero AC Coefficient, S is the secret bit and e be the modified version of c. Here |c| is round of c.

B. Watermark Extraction Process

Data Extraction is an inverse process of Data Embedding.

Algorithm:

1. Take an watermarked input image ($\hat{I}$)
2. Extract C_j from I← $\{C_1, C_2, \dots C_l\}$.
3. For each $C_j \in I$
   (a) when $T > 0$
      i. Extract the data bits using (3.3).
      ii. Restore the modified coefficients using (3.4).
   Let the resultant block be E_j.
4. Dequantize the elements of E_j as follows:
   for $i_1 \leftarrow 1$ to 8 do
     for $i_2 \leftarrow 1$ to 8 do
       $R_j(i_1, i_2) = E_j(i_1, i_2) \times Q(i_1, i_2)$;
     end
   end
5. Combine all the blocks R_j to get I i.e. $I = \{R_1, R_2, \dots, R_l\}$
6. For all embedded $R_j \in I$, repeat step 1 to step 5.

$$I_j = \begin{cases} 0 & \text{if } e\%2 = 0, \\ 1 & \text{otherwise.} \end{cases} \qquad (3.3)$$

$$\bar{c} = \begin{cases} \frac{e}{|e|} \left| (e/0.9)^{0.94} \right| \\ \frac{e}{|e|} \left| (e/1.5)^{1.2} - 1 \right| \end{cases} \qquad (3.4)$$

Where $\bar{c}$ is the restored version of original c. Here |e| refer to round of e.
Note that the data extraction and embedding is the near-reversible.

III. Experimental Results

We have implemented our proposed scheme using MATLAB. We used 512×512 GIF formatted grayscale images in the implementation.
Where Function 1 is y=AC coefficients of original image,
Function 2 is $y = \left| \sqrt[0.94]{c} * 0.9 \right|$,
Function 3 is $y = \left| \left(\sqrt[1.2]{c} * 1.5 \right) - 1 \right|$,

Where c be the non-zero AC coefficient and y be the modified version of c., we can observe that other than these changes drastically with respect to their

original coefficients which cause the distortion or blocking artifacts. From function 2 and function 3 graphs it is observed that the pixel values are nearer to function 1. Function 4 $y = \left| \sqrt[0.94]{c} * 0.9 \right|$,
Function 5 $y = \left| \left(\sqrt[1.2]{c} * 1.5 \right) - 1 \right|$,
Where c be the non-zero AC coefficient and y be the modified version of c. we can observe two functions nearer to function 1 Hence the above two equations are considered in code because they retain maximum values to original values. Here we have chosen function 4 and 5 for hiding the data.

		aerial	**airplane**	**baboon**	**barb**
capaciy	**existing**	56562	12608	74002	39346
	proposed	56563	12608	74002	39346

Figure 4.1: Comparison of Capacity

We can observe from the table 4.1 that existing

PSNR_HVS_M	**existing**	27.7434	35.7368	30.5262	30.9697
	proposed	32.0989	38.5642	37.2993	36.2757

scheme and proposed scheme address same. And for some images there are more number of non-zero AC coefficients, we achieve higher capacity and whenever there is less number of non-zero AC coefficients, we achieve less capacity.

MSSIM	**existing**	0.977	0.995	0.9809	0.983
	proposed	0.9952	0.9985	0.9976	0.9969

Figure 4.2: Comparison of MSSIM

We can observe from table 4.2 that the proposed scheme achieves better results for MSSIM i.e. results are nearer to one (structures in embedded image are more similar to Original image). Therefore, proposed scheme achieves better result for MSSIM than the existing scheme.

Figure 4.3: Comparison of PSNR_HVS_M

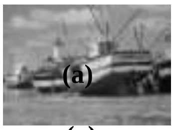
We can observe from figure 4.3 that the proposed scheme achieves better results for PSNR_HVS_M for all the images than the existing scheme. Therefore, proposed scheme performs better than the existing scheme.

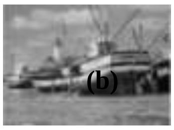
We present different images of GIF format of size 512×512 in the following and their corresponding distorted images can also be observed from all the observations, we can find that the existing scheme distorts the images more where as the proposed scheme achieves better visual quality.

a) Existing watermark images:
b) Proposed watermark images:

(a) **(b)**

Figure 4.4: Embedded Barb image of existing and proposed scheme





(a) **(b)**

Figure 4.5 Embedded Boat image of existing and proposed scheme

IV. Conclusion

With the invention of the new category near-reversible data embedding, there is a need for more sophisticated scheme. There are many applications in remote sensing which can be addressed by near reversible schemes. The existing scheme degrades the visual quality and creates many blocking artifacts due to use of log function which transforms the coefficients with larger difference. The proposed scheme achieves higher visual quality as it minimizes the difference between original non-zero AC coefficients to the embedded coefficients. However there is a little drawback when concerned bit error rate.

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