International Journal of Electrical and Electronics Engineers
Vol. No. 9, Issue No. 02, July - December 2017
ISSN (O) 2321-2055
ISSN (P) 2321-2045

LOSSLESS IMAGE COMPRESSION AND WATERMARKING

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Abstract

In present day technology the need for compression of data, to be transmitted from one place to another, in information processing fields is becoming necessary to achieve the fast and efficient transmission of data. Unfortunately, images and videos commonly contain lots of redundant information and they require significantly large amount of the memory. The encoded images and video contain more number of bits and hence the transmission time increases with number of bits. This is the reason why various compression techniques have been developed. The process of removing the redundancy results in two types of compression techniques, namely lossy and lossless image compression. If the process of redundancy removing is reversible, i.e., the removed data can be fully reconstructed from the compressed data it is called as lossless image compression. Whereas, in the lossy image compression the removed data cannot be fully reconstructed from the compressed data.

A digital watermark is information that is imperceptibly and robustly embedded in the host data such that it cannot be removed. An information hiding method embeds the secret data into a cover image so that the data is invisible to an observer. Only someone with the embedding key can extract the secret data from the embedded cover image. There are different methods for information hiding. One of them is based on the removal of the Least Significant Bit of each pixel and replaces it with a bit of the embedded message.

In this work, SCAN based image compression is used for compressing the images. It is compared with already existing Raster SCAN compression method and concluded that the SCAN compression reduces the prediction of errors when compared to the Raster SCAN compression. Image compression and compressed image water marking are performed using Least Significant Bit substitution method. The advantage of this method is huge amount of data can be embedded into the host image.

I. INTRODUCTION

Data compression is the process of eliminating or reducing the redundancy in data representation in order to achieve savings in storage and communication costs. Data to be compressed can be divided into symbolic or diffuse data. Symbolic data is data that can be discerned by the human eye. These are combinations of symbols, characters or marks. Examples of this type of data are text and numeric data [1, 2, 3]. Unlike the symbolic data, diffuse data cannot be discerned by the human eye. The meaning of the data is stored in its structure and cannot be easily extracted. Examples of this type of data are speech, image, and video data. The approaches taken to compress diffuse and symbolic data are different but not exclusive. In symbolic data the approach most taken is reduction of redundancy. For diffuse data the approach to compression is the removal of unnecessary information. Images commonly contain lots of redundant information, and thus they are usually compressed to remove redundancy and minimize the storage space or transport bandwidth. If the process of redundancy removing is reversible, i.e., the exact reconstruction of the original image can be achieved, it is called lossless image compression otherwise, it is called as lossy image compression. While lossy compression is widely used due to its high compression ratio, some special areas require lossless image compression. Business and patent documents, because of legal reason, lossy compression is prohibited. Satellite images, because of its expensive collecting cost, lossless compression is recommended. Medical images, lossless image compression is required to avoid diagnostic inaccuracy. In the approaches that uses lossless compression techniques, meaning that the compression process is reversible with 100 percent accuracy.

The advent of the Internet has resulted in many new opportunities for creating and delivering content in digital form. Applications include electronic advertising, real time video and audio delivery, digital repositories and libraries, and Web publishing. An important issue that arises in these applications is protection of the rights of content owners. It has been recognized for quite some time that current copyright laws are inadequate for dealing with digital data. This has led to an interest in developing new copy deterrence and protective mechanisms. One approach that has been attracting increasing interest is based on digital watermarking techniques. Digital watermarking is the process of embedding information into digital multimedia content such that the information (which is known as the watermark) can later be extracted or detected for a variety of purposes, including copy prevention and control. Digital watermarking has become an active and important area of research, and development and commercialization of watermarking techniques is deemed essential to help address some of the challenges faced by the rapid proliferation of digital content. A digital watermark can be visible or invisible. A visible watermark is intended to be seen with the content of the images and at the same time it is embedded into the material in such a way that its unauthorized removal will cause damage to the image. In case of the invisible watermark, it is hidden from view during normal use and only becomes visible as a result of special visualization process. The existence of an invisible watermark can be determined only by using an appropriate watermark extraction or detection algorithm. An important point of watermarking technique is that the embedded mark must carry information about the host in which it is hidden. Digital watermarks are potentially useful in many applications, including the following.

- Ownership Assertion.
- Fingerprinting.
- Copy Prevention or Control.
- Fraud and Tampering Detection.
- ID card Security.

There are several techniques of digital watermarking such as spatial domain encoding, frequency domain embedding, DCT domain watermarking, and wavelet domain embedding. A spatial-domain watermarking method has larger capacity than that of a frequency domain method where more data can be embedded in the spatial domain than in frequency domain. Therefore, there is a tradeoff between the capacity and robustness. Still a large quantity of data must be embedded in the host image if a visually meaningful watermark is adopted. Thus the embedding algorithm must adapt its insertion strategy to accommodate a large quantity of data in the host image.

Using Least Significant Bit manipulation, a huge amount of information can be hidden with very little impact to image quality. This technique is performed in the spatial domain. The embedding of the watermark is performed choosing a subset of pixels and substituting the least significant bit of each of the chosen pixels with watermark bits. Extraction of the watermark is performed by extracting the least significant bit of each of the selected image pixels. If the extracted bits match the inserted bits, then the watermark is detected. The extracted bits do not have to exactly match with the inserted bits. A correlation measure of both bit vectors can be calculated. If the correlation of extracted bits and inserted bits is above a certain threshold, then the extraction algorithm can decide that the watermark is detected.

1.1. Motivation

Data compression is the process of eliminating or reducing the redundancy in data representation in order to achieve savings in storage and communication costs. Image files not only occupy storage but also take up a large portion of bandwidth during transmission hence; the process of compressing images has become a necessity. Digital images commonly contain lots of redundant information, and thus they are usually compressed to remove redundancy and minimize the storage space or transport bandwidth. The redundancy in digital image representation can be classified into two categories: local and global. These two types of redundancy could be attributed to two specific characteristics exhibited by the image data. Local redundancy corresponds to the coherence, smoothness or correlation in the image data that is due to the fact that the gray level values within a neighborhood vary gradually rather than abruptly. Illumination and shadowing effects also contribute to gradual variation of data in images. Global redundancy could be attributed to the repetition of patterns within an image. Image compression algorithms eliminate or reduce local redundancy by representing the neighborhood in a compact form. Lossless compression algorithms include entropy coding. If a sufficiently small amount of information is removed from a video segment, most viewers would not be aware of the change. Therefore, some of this data can be discarded. Lossy data compression techniques include transform coding.

Image compression techniques available in the current literature are categorized into lossy image compression techniques and lossless image compression techniques. Lossless image compression is a class of image compression algorithms that allows the exact original image to be reconstructed from the compressed image. This can be contrasted to lossy compression, which does not allow the exact original image to be reconstructed from the compressed image. Lossy compression is widely used due to its high compression ratio. But some special areas require lossless image compression. Business and patent documents, because of legal reason, lossy compression is prohibited. Satellite images because of its expensive collecting cost, lossless compression is recommended. In lossy image compression, while reconstructing the original image some data is lost. While reconstructing original image from lossless image compression there is no lost of data. So lossless image compression is recommended.

By exploiting different redundancy, there are many lossy compression schemes, such as Joint Photographic Experts Group (JPEG), vector quantization, wavelet image compression, and fractal-based image compression. Lossless image compression can be classified into two categories according to the different redundancy removed from the compressed image. The first category removes coding redundancy, such as Huffman encoding, Arithmetic encoding, and Lempel-Ziv-Welch (LZW). LZW also removes the spatial redundancy. The second category removes spatial redundancy or inter-pixel redundancy, such as run-length encoding. Huffman coder always assigns long code words to less frequent symbols and short code words to frequent symbols. Huffman codes are optimal in the sense that they generate a set of variable length binary code words of minimum average length. In Arithmetic coding, code words are constructed by partitioning the range of numbers between zero and one. As each symbol is encoded, the range is decreased by the amount inversely proportional to the probability occurrence of the symbol. When the range is sufficiently narrow, the partitioning is terminated and the codeword is assigned a binary fraction which lies within the final range. LZW coder, which was originally developed for text compression, has also been applied to signal compression. LZW is actually a dictionary-based technique. When a sequence of symbols matches a sequence stored in the dictionary, an index is sent rather than the symbol sequence itself. If no match is found, the sequence of symbols is sent without being coded and the dictionary is updated.

Among the various compression methods, predictive techniques have the advantage of relatively simple implementation. Predictive schemes exploit the fact that adjacent pixel values from a raster image are highly correlated. With a predictive codec, the encoder (decoder) predicts the value of the current pixel based on the value of pixels which have already been encoded (decoded) and compresses the error signal. If a good predictor is used, the distribution of the prediction error is concentrated near zero, meaning that the error signal has significantly encoded by a lossless coding scheme like the Huffman coding.

Digital watermarking is the process of embedding information into digital multimedia content such that the information (which we call the watermark) can later be extracted or detected for a variety of purposes, including copy prevention and control. Digital watermarking has become an active and important area of research, and development and commercialization of watermarking techniques is deemed essential to help address some of the challenges faced by the rapid proliferation of digital content.

SCAN is a special purpose context-free language that describes and generates a wide range of array accessing algorithms from a set of simple ones. These algorithms represent scan techniques for image processing, but at the same time they stand as generic data accessing strategies. SCAN language is actually a bit-plane based two dimensional spatial accessing methodology, which focuses on the spatial redundancy that exists between neighboring pixels. It can represent and generate a large number of wide variety of scanning paths or space filling curves easily. The SCAN-based lossless compression method compresses a given binary image, by specifying a scanning path of the image using a SCAN pattern, and by specifying the bit sequence along the scanning path. For a given binary image, the compression algorithm determines a near optimal or a good scanning path which minimizes the total number of bits needed to encode the SCAN pattern and the bit sequence. After the binary image is compressed, the bits of the compressed image are arranged using a set of SCAN patterns which forms the encryption key, to obtain the compressed and decompressed image. SCAN based image compression technique is used for its advantage for attaining compression along with information hiding capability.

II. RASTER SCANNING

The word raster comes from the Latin word for a rake, as the pattern left by a rake resembles the parallel lines of a scanning raster. A Raster scan, or raster scanning, is the pattern of image detection and reconstruction, and is the pattern of image storage and transmission used in most computer bitmap image systems. In a raster scan, an image is cut up into a sequence of strips known as “scan lines”. This ordering of pixels by rows is known as raster order, or raster scan order. The raster scan consists of processing the image top to bottom, going row by row and from left to right within each row. Figure 2.1depicts the four non-empties and context supports that arise in the raster scan; for instance, the first context corresponds to the pixels in the top row sans the top-left corner pixel in the image. It is straightforward to compute the frequency with which each such context supports is encountered. This invention provides a simple, low precision, and low cost method of reducing the effect of errors in the positioning of scan lines on an area. For a raster scan device having multiple simultaneous scan lines, a method in accordance with this invention includes the steps of separating scan lines to be placed adjacent to each other into different scan groups, so that no two scan lines to be placed adjacent to each other are in the same scan group; and scanning a set of scan lines from a different one of the scan groups on each scan across the area. An error reducing raster scan apparatus has a means to separate scan lines into different scan groups, and a means for scanning a set of scan lines from a different one of the scan groups on each scan of the multiple simultaneous scan lines across the area. In this way, the border between sets of scan lines has been distributed into the interlace of many scan lines, reducing the effect of errors in spacing between the sets of scan lines.

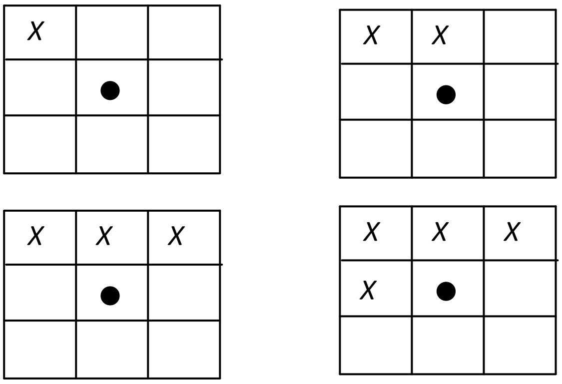

Figure 2.1 Raster scan: Non-empty context supports.

III. SCAN COMPRESSION

SCAN is a special purpose context-free language that describes and generates a wide range of array accessing algorithms from a set of simple ones. These algorithms represent scan techniques for image processing, but at the same time they stand as generic data accessing strategies. SCAN language is actually a bit-plane based methodology, which focuses on the spatial redundancy that exists between neighboring pixels. Incorporated with DPCM, run-length encoding, and Huffman coding, the system has consistently achieved compressions of 5.3bits/pixel to less than 4.0bits/pixel with the test image Lena. The basic scan paths and their predictors are shown in the table.The scan paths are shown for $4x4$ regions but they extend to all regions of size $2^n x2^n$, $n \geq 2$. Different predictors are placed along different segments such that the predictors use previously scanned neighboring pixels to predict the current pixel. For example, if a region is scanned with $C0$ then predictor UL is used when scanning from left to right and predictor UR is used when scanning from right to left. At the first point or at the corner points of some scan paths where more than one predictor is applicable, the encoder and decoder follow a fixed set of rules as to which predictor is used. The four predictors used are defined in table 3.1.

Predictor	Predictor neighbors	Prediction rule	Context neighbors	Context rule
UR	$\{N,E\}$	$(N+E)/2$	$\{N, NE, E\}$	$(\lvert N-NE\rvert+\lvert NE-E\rvert)/2$
UL	$\{N,W\}$	$(N+W)/2$	$\{N, NW, W\}$	$(\lvert N-NW\rvert+\lvert NW-W\rvert)/2$
BL	$\{S,W\}$	$(S+W)/2$	$\{S, SW, W\}$	$(\lvert S-SW\rvert+\lvert SW-W\rvert)/2$
BR	$\{S,E\}$	$(S+E)/2$	$\{S, SE, E\}$	$(\lvert S-SE\rvert+\lvert SE-E\rvert)/2$

Table 3.1. Four predictors and Context

3.1 Algorithm

The steps for image compression using SCAN compression are as follows:

1. Read the input image A of size MxM .

$$\mathrm{A} = f(x,y) \;\; where \;\; x = 1,2,....M \;\; and \;\; y = 1,2,\ldots, M$$

2. The image is partitioned into blocks of size NxN , where $N = 2^k, k \geq 2$.
3. Scan the block $I_i\,, where\, i = 1\, to\; M/N$, at each pixel $p(x, y)$ using 16 scan paths.
4. While scanning each block, determine the predictor neighbors $\{q, r\}$ using predictors from table 3.1. Where q and r are the predictor neighbors.
5. If the predictor neighbors $\{q, r\}$ are already scanned then calculate the prediction error along each scan path by using $e = p - (q + r)/2$. Otherwise, let s be the pixel which is scanned before the pixel $p(x, y)$ then prediction error along each scan path can be calculated as $e = p - s$.
6. Obtain the absolute value of prediction errors (E) and sequence of prediction errors (L) along each path for each block as given by

$$E_i = E_i + abs(e) \;\; for\; i = 1\, to\;\; M/N$$

$$L_i = Append(L_i, e) \;\; for\; i = 1\, to\;\; M/N$$

7. For each block, the scan path is chosen as the best scan path of the block which minimizes the prediction errors and encoding bits.
8. If $N > 16\; let\; v = 5\; else\; let\; v = 4$, where N is the size of the block and $u = E_{kt}, w = L_{kt}, best\;\, scan\;\, path\;\, kt, where\;\, kt = 1\, to\, 16$
9. Then the image block $I_i \;\; for\; i = 1\, to\;\; M/N$ is partitioned into four sub regions $I_{i1}, I_{i2}, I_{i3}, and\;\, I_{i4}$ of size $\frac{N}{2} x \frac{N}{2}$.

$$\begin{aligned}&(J_k, E_k, B_k, L_k) = bestpath(I_{ik}, N/2)\ \ for\ 1 \le k \le 4\\ &Let\ l = E_1 + E_2 + E_3 + E_4, m = B_1 + B_2 + B_3 + B_4\\ &z = append(L_1, L_2, L_3, L_4)\\ &if\ \ u + v \le l + m\ then\ J = bestpath, E = u, B = v, L = w\\ &else\ J = (J_1, J_2, J_3, J_4), E = x, B = y, L = z\end{aligned}$$

10. If $N < 16$ then $J = bestpath, E = u, B = v, L = w$
11. After the determination of best scan path of each block, the scan path is encoded in binary form using the following steps.
12. Let the codes for scan paths as code(C) = 00, code (D) = 01, code (O) = 10, code(S) = 11 and code (0) = 00, code(1) = 01, code(2) = 10, code(3) = 11.
13. For basic scan path kt where, k = C,D,O,S and t = 0,1,2,3 and block size of N the encoded binary form Q is obtained as

$$\begin{aligned}&if\ \ N > 16\\ &Q = append(0, code(k), code(t))\\ &else\\ &Q = append(code(k), code(t))\end{aligned}$$

14. If the scan path KT contains (kt_1, kt_2, kt_3, kt_4) then the encoded path is obtained from step 13.
15. After encoding each block of the image A, the compressed image is formed as given below

Header 1	Scan paths	Header 2	Prediction

Header 1 contains the width and height of the image. Then the binary encoded best scan paths of all blocks are appended sequentially. Header 2 contains the first two pixels which were scanned in the first block of the image, and this header also contains the number of bits in the binary encoding of prediction errors in each of the four contexts. Finally, the binary encoding of prediction errors in all four contexts are appended sequentially.

The main steps for decompression are as follows:

1. The size of the image is decoded from header 1.
2. The blocks of the image (decoder knows block size) and number of encoded scan paths in the compressed image are decoded.
3. Each scan path in the compressed image is decoded and consecutive scan paths are assigned to blocks in C0 order.
4. The first two pixels scanned are decoded from header 2. The number of bits in the binary encoding of errors in each of the four contexts is decoded and the binary encoding of errors in each context is extracted separately.
5. Begin with an empty image. Assign the first two pixels, which are obtained from step 4, to their locations (i.e., scan path of first block as decoded in step 3). Scan the whole image (except first two pixels) by visiting the blocks in C0 order and scanning each block with its scan path. At each pixel of the scan path do:

determine context c of p, determine predicted value q of p, decode next error e from binary encoding of errors in context c , let $p = q + e$ and assign p to current pixel location.

SCAN compression algorithm is justified and its performance in terms of entropy coding is observed in the following section.

3.1.Experimental Results

The performance of the SCAN compression using different images is evaluated in this section. The original Lena image, compressed image and reconstructed images are shown in figure 3.1. The entropy value for Lena image is obtained as 4.4791.

Figure: 3.1original, compressed, and retrieved images

Table 3.1 Entropy of prediction errors

Image	Scan Compression	Raster Scanning
Lena	4.4791	4.6142
Airplane	4.4641	4.5017
Mandrill	6.2114	6.2637
Baboon	4.4641	4.5617

The above table shows predictions of errors are minimized by using SCAN compression.

IV. WATERMARKING

A digital watermark is information that is imperceptibly and robustly embedded in the host data such that it cannot be removed. A watermark typically contains information about the origin, status, or recipient of the host data. A digital watermark can be visible or invisible. A visible watermark is intended to be seen with the content of the images and at the same time it is embedded into the material in such a way that its unauthorized removal will cause damage to the image. In case of the invisible watermark, it is hidden from view during normal use and only becomes visible as a result of special visualization process. The existence of an invisible watermark can be determined only by using an appropriate watermark extraction or detection algorithm. A watermark can be embedded using spatial domain techniques, frequency domain techniques or transform domain techniques. Embedding a watermark in the spatial domain scatters the information to be embedded making it hardly detectable. The most straightforward way to add a watermark to an image in the spatial domain is to add a pseudorandom noise pattern to the luminance values of its pixels. The supplementary information called watermark is embedded into the cover work through its slight modification. These techniques are advantageous in their resistance to cropping and noise, but they are weak to attacks like rotation and compression.

4.1 Techniques Used for Watermarking

There are two methods for performing watermarking, one is spatial domain, and another is frequency domain. Each technique has its own advantages and disadvantages. In the spatial domain, watermark can be inserted into a host image by changing the gray levels of some pixels in the host image. The spatial domain techniques are used LSB substitution. The spatial domain techniques are easily applied to any image. The techniques used for spatial domain are very simple. The spatial domain techniques are used Least Significant Bits to embed the digital data into the original image. By using this technique, huge amount of data can be embedded into the cover image. It has the advantages as well as disadvantages compared with frequency domain techniques. The advantage is large number of bits can be embedded into the host image and it can be easily applied to any image, regardless of subsequent processing. The disadvantage is third party can easily remove the watermarked bits if he knows the watermarked image while transmitting the host image. The watermarked image in spatial domain can go through the various operations.

In the frequency domain, watermark can be inserted into the coefficients of a transformed image. But too much data cannot be embedded in the frequency domain because the quality of the host image will be destroyed. An advantage of the spatial domain techniques is that it can be easily applied to any image, regardless of subsequent processing. A possible disadvantage of spatial techniques is they do not allow for the exploitation of this subsequent processing in order to increase the robustness of the watermark. We can also embed the large quantity of data into the cover image. This method satisfies the perceptual transparency property, since only the least significant bit of an 8-bit value is altered. Data can be embedded into the image by choosing the desired values of 0's and 1's for the LSBs. This method was initially designed to work for gray scale images. But it can be easily extended to color images by treating each plane as the single plane in the former.

Frequency domain techniques are complicated to implement when compared with spatial domain techniques. Although it is more robust compared to spatial domain techniques, the embedding capacity is very small. In this domain, the image is portioned into various frequency bands and these bands are used to embed the secret data.

4.2. Algorithm

The steps for image watermarking and retrieving using Least Significant Bit substitution method are as follows:

1. Obtain the pixels from the host image.

$$\mathrm{H} = \{h(i,j), 0 \le i,j < N\}, h(i,j) \in \{0,1,2,....,2^L - 1\}$$

2. Obtain pixels from the watermark.

$$W = \{w(i,j), 0 \le i,j < M\}.$$

3. Substitute the pixels of the watermark into the LSB pixels of the host image.

$$H^* = \{h^*(i,j) = h(i,j)\Theta w(i,j), 0 \le i,j < N\},\ h^* = (i,j) \in \{0,1,2,....,2^L - 1\}.$$

4. Retrieve the pixels of watermark image from the watermarked image.

$$w(i,j) = \{h*(i,j)\Theta h(i,j), 0 \le i,j < N\}.$$

$$h* = (i,j) \in \{0,1,2,....,2^L - 1\}.$$

$$h(i,j) \in \{0,1,2,....,2^L - 1\}.$$

4.3 Experimental Results

In this work, an image Lena of size 512x512 is taken as the host image and the image is scanned by using the scan path. Another secret image Logo of JNTU of size 512x512 is embedded into the host image. The embedding process depends upon the least significant bits of the host image. The pixels which are not used to embed the data are labeled as 0. After scan rearrangement, the bits of the secret image are embedded into the host image. The image is again scan rearranged to obtain the watermarked image. At the receiving side of the image, reverse scan rearrangement is performed and the bits which are embedded in the host image are retrieved. After retrieval of secret data from the watermarked image, correlation factor is calculated between original host image and watermarked image. If the correlation factor is near to 1, then the embedded image is exactly retrieved. In this, the correlation between the host image Lena and the watermarked image is 0.999. So the watermark image is exactly retrieved.

The performance of watermarking algorithm is applied for host image Lena. The secret image is the Logo of JNTU of the size 512x512. It is shown in figure 4.3.1.

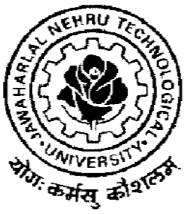

Figure: 4.3. 1 Secret Image of JNTU Logo (512x512)

The watermarked image has the PSNR of 51.09 and the secret image is logo of JNTU is embedded into the Cover image and retrieved with correlation of 0.997. The original, watermarked and the retrieved images are as shown in below figure 4.3.2.

Figure: 4.3.2 Host, Watermarked and Retrieved images.

V. CONCLUSIONS

The use of Raster scanning for image compression results in more entropy value. By applying SCAN based image compression entropy of prediction values for various images are reduced. Hence, we can conclude that the SCAN compression is much better than Raster scanning. SCAN based image compression is also having an advantage of data hiding. The use of Least Significant Bit substitution for watermarking is studied and implemented for image watermarking and compressed image watermarking. By using LSB substitution, large number of bits can be embedded into the host image. The disadvantage of this technique is, it is not secure. To overcome this problem, frequency domain techniques are developed. The disadvantage of frequency domain technique is, it has less embedding capacity.

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