ISSN:0975-9646

Kitty Arora et al, / (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 5 (2) , 2014, 1169-1172

A Comprehensive Review of Image Compression Techniques

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Abstract: Digital image compression has been the focus of a large amount of research in recent years. As a result, Image compression methods grow as new algorithms or variations of the already existing ones are introduced. In order to utilize digital images effectively, specific techniques are needed to reduce the number of bits required for their presentation. It has led to an instant growth in Area of Digital Image Processing. In image compression, we do not only concentrate on reducing size but also concentrate on doing it without losing quality and information of image. The survey summarizes the major image compression techniques that maybe lossy and lossless, advantages, disadvantages and research possibilities. This analysis of various compression techniques provides knowledge in the identifying the advantageous features and help in choosing correct method for compression. In this paper survey of different image compression techniques have been discussed from which researchers can get an idea for efficient techniques to be used.

Key words- Image compression, compression techniques, Lossless image compression techniques, Lossy image compression techniques.

1. INTRODUCTION

An image is essentially a 2-D signal processed by the human visual system. The signals representing images are usually in analog form. However, for processing, storage and transmission by computer applications, they are converted from analog to digital form. A digital image is basically a 2-Dimensional array of pixels. Image compression is a method through which we can reduce the storage space of images, videos which will helpful to increase storage and transmission process's performance.Image compression may be lossy or lossless. Lossless compression involves with compressing data which, when decompressed, will be an exact replica of the original data. But in lossy compression techniques, some of the finer details in the image can be sacrificed for the sake of saving a little more bandwidth or storage space.

2. IMAGE COMPRESSION

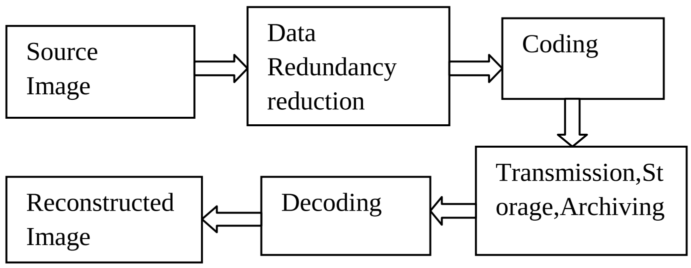
The objective of image compression is to reduce irrelevance and redundancy of the image data in order to be able to store or transmit data in an efficient form.Compression is achieved by the removal of one or more of three basic data redundancies

(1)Coding redundancy, which is present when less than optimal (i.e. the smallest length) code words are used.

(2) Interpixel redundancy, which results from correlations between the pixels of an image

(3) Psycho visual redundancy, which is due to data that is ignored by the human visual system (i.e. visually non essential information).

Image data Compression exploits redundancy for more efficient coding:



2.1 HOW MOST IMAGE COMPRESSION TECHNIQUES WORK

The usual steps involved in compressing an image are

1. Specifying the Rate (bits available) and Distortion (tolerable error) parameters for the target image.
2. Dividing the image data into various classes, based on their importance.
3. Dividing the available bit budget among these classes, such that the distortion is a minimum.
4. Quantize each class separately using the bit allocation information derived in step3.
5. Encode each class separately using an entropy coder and write to the file. Reconstructing the image from the compressed data is usually a faster process than compression. The steps involved are
6. Read in the quantized data from the file, using an entropy decoder. (Reverse of step 5).
7. Dequantize the data. (Reverse of step 4).
8. Rebuild the image. (Reverse of step 2).

2.2 Why do we need compression?

- Sufficient amount of storage space increased.
- To reduce the time taken for transmission of an image to be sent over the internet or download from the web pages.
- Image Archiving :Satellite Data
- Image Transmission: Web Data
- Multimedia Applications: Desktop Editing

3. BROAD SPECTRUM OF IMAGE COMPRESSION TECHNIQUES

Digital image compression can be divided mainly in two categories: lossless and lossy compression. When lossless data is decompressed, the resulting image is identical to the original. Lossy compression algorithms result in loss of data and the decompressed image is not exactly the same as the original.

A) Lossless Image Compression Techniques
Lossless compression is preferred for archival purposes and often for medical imaging, technical drawings, clip art etc.
Methods for lossless image compression are:

- Run-length encoding – used as default method in PCX and as one of possible in BMP, TGA, TIFF.
- DPCM and Predictive Coding
- Entropy encoding
- Adaptive dictionary algorithms such as LZW – used in GIF and TIFF
- Deflation – used in PNG, MNG, and TIFF
- Chain codes
- Huffman Encoding

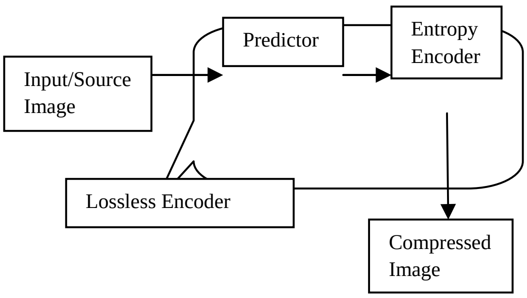


Fig. Lossless Compression

B) Lossy Image Compression Techniques
Lossy methods are especially suitable for natural images such as photographs in applications where minor (sometimes imperceptible) loss of fidelity is acceptable to achieve a substantial reduction in bit rate.

- Transform Coding
- Discrete Cosine Transform(DCT)
- Discrete Wavelet Transform(DWT)
- Fractal Compression

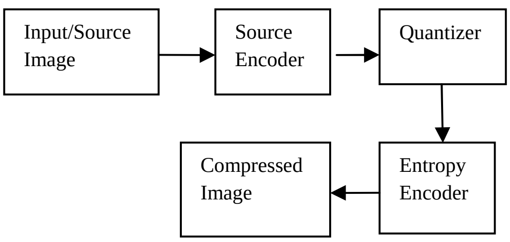


Fig2.Lossy Compression

3.1 VARIOUS IMAGE COMPRESSION TECHNIQUES

1) Run Length Encoding
RLE is a lossless data compression technique which replaces data by a(length, value)pair, where value is the repeated value and length is the number of repetitions.RLE is a simple form of data compression in which data is in the form of runs. Runs is sequences in which the same data value occurs in many consecutive data elements are stored as a single data value and count, rather than as the original run. For example, consider a screen containing plain black text on a solid white background. There will be many long runs of white pixels in the blank space, and many short runs of black pixels within the text.
Consider a single scan line, with B representing a black pixel and W white pixel :

WWWWWWWWWWWWBWWWWWWWWWWW
WWWBBBWWWWWWWWWWWWWWWWWW
WWWWWWWBWWWWWWWWWWWWWW

If we apply the run-length encoding (RLE) data compression algorithm to the above hypothetical scan line, we get the following:

12W1B12W3B24W1B14W

This is to be interpreted as twelve Ws, one B, twelve Ws, three Bs, etc.

The run-length code represents the original 67 characters in only 18. **.** But, the actual format used for the storage of images is generally binary rather than ASCII characters like this, but the principle remains the same.

2) Predictive Coding
Lossless predictive coding predicts the value of each pixel by using the value of its neighboring pixels. Therefore, every pixel encoded with a prediction error rather than its original value. These errors are much smaller compared with original value so that fewer bits are required to store them. Such as DPCM (Differential Pulse Code Modulation) is a lossless coding method, which means that the decoded image and the original image have the same value for every corresponding element. A variation of the lossless predictive coding is adaptive prediction that splits the image into blocks and computes the prediction coefficients independently for each block to high prediction performance.

3) Arithmetic Encoding
AC is the compression technique for lossless encoding that represents a message as some finite intervals between 0 and 1 on the real number line.Basically,it divides the intervals between 0 and 1 into a number of smaller intervals corresponding to probabilities of the message's symbols.Then,the first symbol selects an interval ,which is further divided into smaller intervals. The next input symbol selects one of these intervals, the procedure is repeated. As a result, the selected interval narrows with every symbol, and in the end, any number in the final interval can be used to represent a message. Each bit in the output code refines the precision of the value of input code in the interval. AC is the most efficient method to code symbols according to the

probability of their occurrence. A variation of arithmetic coding is the Q-Coder, developed by IBM in the late 1980's.

4) Entropy Coding

Entropy represents the minimum size of dataset necessary to convey a particular amount of information. Huffman coding, LZ (Lempel-Ziv) coding and arithmetic coding commonly used entropy coding method. In Entropy Coding a characteristic called redundancy is used to decrease the size of file. There are usually many repeating characters in a file, these repeated symbols noted down and instead of repeating them at every pixel, positions of these pixels are recorded and they are all noted to have the same symbol.Thus,there is no loss of information so called non-lossy coding

5) LZW Coding

LZ Coding replaces repeated substrings in input data with references to earlier instances of strings. It refers to two different approaches to dictionary- based compression:-LZ77 and LZ78.LZ77 utilizes a sliding window to search for substrings encountered before and then substitutes them by the (position, length) pair to point back to existing substring.LZ78 dynamically constructs a dictionary from the input file and then replaces substrings by index in the dictionary.LZW is one of the method based on these ideas.

6) Huffman coding

Huffman Coding is an entropy encoding algorithm used for lossless data compression.Huffman Coding utilizes a variable length code in which short code words are assigned to more common values or symbols in the data, and longer code words are assigned to less frequently occurring values. The Huffman's algorithm is generating minimum redundancy codes as compared to other algorithms. The Huffman coding has effectively used in text, image, video compression, and conferencing system such as, JPEG, MPEG-2, MPEG-4, and H.263 etc..

7) Multiresolution Coding

HINT (hierarchical interpolation) is a multiresolution coding scheme based on sub-samplings. It starts with a low-resolution version of the original image, and Interpolates the pixel values to successively generate higher resolutions. The errors between the interpolation values and the real values are stored, along with the initial low-resolution image. Compression is achieved since both the low-resolution image and the error values can be stored with fewer bits than the original image.

Laplacian Pyramid is another multiresolution image compression method developed by Burt and Adelson. It successively constructs lower resolution versions of the original image by down sampling so that the number of pixels decreases by a factor of two at each scale. The differences between successive resolution versions together with the lowest resolution image are stored and utilized to perfectly reconstruct the original image. But it cannot achieve a high compression ratio because the number of data values is increased by 4/3 of the original image size.

8) Discrete Cosine Transform (DCT)

DCT is a lossy Compression technique which is widely used in area of image and audio compression. Example: JPEG Images.DCTs are used to convert data into the summation of series of cosine waves oscillating at different frequencies. These are very similar to Fourier Transforms, but DCT involes use of Cosine functions and real coefficients, Fourier Transforms use both sine and cosine functions and complex numbers. For compression, Cosine functions are much more efficient as fewer functions are needed to approximate a signal. Both Fourier and DCT convert data from a spatial domain into a frequency domain and their respective functions converting thing back.

9) Discrete Wavelet Transform (DWT)

The DWT represents an image as a sum of wavelet functions, known as wavelets, with different location and scale. The discrete wavelet transform usually is implemented by using a hierarchical filter structure. It is applied to image blocks generated by the pre-processor. Two-dimension DWT leads to a decomposition of approximation coefficients at level j in four components: the approximation at level j+1, and the details in three orientations (horizontal, vertical, and diagonal).

10) Fractal Compression

The fractal compression technique relies on the fact that in certain images, parts of the image resemble other parts of the same image. Fractal algorithms convert these parts, or more precisely, geometric shapes into mathematical data called "fractal codes" which are used to recreate the encoded image. Once an image has been converted into fractal code its relationship to a specific resolution has been lost; it becomes resolution independent. The image can be recreated to fill any screen size without the introduction of image artifacts or loss of sharpness that occurs in pixel-based compression

11) Vector Quantization

Vector Quantization is a lossy compression method. It is a fixed-to-fixed length algorithm called LBG-VQ algorithm. Its principal is based on dividing a large set of data points(vectors) into groups having approximately the same number of points closest to them. Thus VQ is also called "Block Quantization" or "Pattern matching Quantization". It works by encoding values from a multidimensional vector space into a finite set of values from a discrete subspace of lower dimension. A lower space vector requires less storage space, so data is compressed. Due to density matching property of vector quantization, the compressed data has errors that are inversely proportional to density. The transformation is usually done by a Codebook. Vector Quantization is used in many applications such as voice and image compression, Voice recognition.

12) Quarter-tree decomposition

The Quarter-tree decomposition of image compression method characters with relative simplicity and fast calculation, however compression ratio is not very high. Fractal coding and Quarter-tree decomposition are both based on image decomposition and fractal coding always could get a good compression ratio and reconstruction quality, but it is difficult to extract the interactive function which is the key point for quality of reconstruction and it's also need massive calculation. The calculation of Quarter-tree decomposition image compression method is relatively simple and calculates fast. What's more, it deals with image based on image's data

13) Rectangle Segmentation and SparseMatrix Storage (RSSMS) compression algorithm.

In order to overcome this flaw, one new segmentation method named the Rectangle Segmentation is proposed, in which adjacent pixel points satisfying consistency condition are viewed as the same image block. Also, without the restriction of square which abides to 2n, the image block can be rectangle which reduces the amount of block, and improves the compression ratio. Image compression ratio can be further augmented by combining the storage method of sparse matrix. Correlation itself, so approachable for image which has been processed by other compression method. However, it also has its limitation on compression ratio, especially for complex images.

4. PERFORMANCE EVALUATION METRICS

Two of the error metrics used to compare the various image compression techniques are the Mean Square Error (MSE) and the Peak Signal to Noise Ratio (PSNR). The MSE is the cumulative squared error between the compressed and the original image, whereas PSNR is a measure of the peak error. The mathematical formulae for the two are

$$MSE = \frac{1}{MN} \sum_{y=1}^{M} \sum_{x=1}^{N} [I(x,y) - I'(x,y)]^2$$

PSNR = 20 * log10 (255 / sqrt (MSE)).

The compression ratio is defined as follows:

CR=n1/n2.

Where *n1* is the data rate of original image and *n2* is that of the encoded bit-stream.

Where I(x,y) is the original image, I'(x,y) is the approximated version (which is actually the decompressed image) and M,N are the dimensions of the images.. Logically, a higher value of PSNR is good because it means that the ratio of Signal to Noise is higher. Here, the 'signal' is the original image, and the 'noise' is the error in reconstruction.

5. CONCLUSIONS

Although the image compression is a trade of between compression ratio and peak signal to noise ratio, better and efficient compression-decompression algorithm is yet a demanding in the field. Though extensive research have been taking place in this area, keeping in view the ever increasing need for low bit rate compression methods, scope exists for new methods as well as evolving more efficient algorithms in the existing methods. The review makes clear that, the field will continue to interest researchers in the days to come.

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