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Analytical Study of Wavelet Based Color Image Compression Method

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ABSTRACT

An image is digitized to convert it to a form which can be stored in a computer's memory or on some form of storage media such as a Hard Disk or CD-ROM. Images require much storage space, large transmission bandwidth and long transmission time. The only way currently to improve on these resource requirements is to compress images, such that they can be transmitted quicker and then decompressed by the receiver. Image compression algorithms aim to remove redundancy in data in a way which makes image reconstruction possible. Redundancy reduction is aimed at removing duplication in the image. There are two different types of redundancy relevant to images: Spatial Redundancy and Spectral Redundancy. There are two parts to the compression: Find image data properties; grey-level histogram, image entropy, correlation functions etc.. and Find an appropriate compression technique for an image of those properties.

Keywords : Digitized Transmission, Redundancy, Spatial Redundancy, Spectral Redundancy, Histogram, Entropy

I. INTRODUCTION

In electrical engineering and computer science, image processing is any form of signal processing for which the input is an image, such as photographs or frames of video; the output of image processing can be either an image or a set of characteristics or parameters related to the image.

Image processing operations can be roughly divided into three major categories: Image Compression, Image Enhancement and Restoration, and Measurement Extraction. Image compression is familiar to most people. It involves reducing the amount of memory needed to store a digital image. If the image is in good condition, the Measurement Extraction operations can be used to obtain useful information from the image.

II. IMAGE COMPRESSION

In image processing there are 256 intensity levels (scales) of grey. This means that each pixel in the image is stored as a number between 0 to 255, where 0 represents a black pixel, 255 represents a white pixel and values in-between represent shades of grey. Each level is represented by an 8-bit binary number so black is 00000000 and white is 11111111. An image can therefore be thought of as grid of pixels, where each pixel can be represented by the 8-bit binary value for

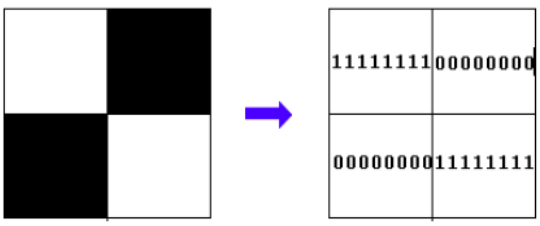


Fig. 1 Grid of Pixels

Image compression algorithms try to exploit redundancies in the data; they calculate which data needs to be kept in order to reconstruct the original image and therefore which data can be 'thrown away'. By removing the redundant data, the image can be represented in a smaller number of bits, and hence can be compressed.

Redundancy reduction is aimed at removing duplication in the image. There are two different types of redundancy relevant to images:

(1) Spatial Redundancy:- Correlation between neighboring pixels.
(2) Spectral Redundancy:- Correlation between different color planes and spectral bands.

Where there is high correlation, there is also high redundancy, so it may not be necessary to record the data for every pixel. There are two parts to the compression:

(1) Find image data properties; grey-level histogram, image entropy, correlation functions etc..
(2) Find an appropriate compression technique for an image of those properties.

A. Image Data Properties

To make meaningful comparisons of different image compression techniques, it is necessary to know the properties of the image. One property is the image entropy; a highly correlated picture will have low entropy. For example a very low frequency, highly correlated image will be compressed well by many different techniques; it is more the image property and not the compression algorithm that gives the good compression rates. Also a compression algorithm that is good for some images will not necessarily be good for all images. One way of calculating entropy is suggested by

If an image has G grey-levels and the probability of grey-level k is P(k) the entropy He is:

$$H_e = -\sum_{k=0}^{G-1} P(k)\log_2[P(k)] \qquad [6]$$

Information redundancy, r, is r = b - He

Where b is the smallest number of bits for which the image quantization levels can be represented. Information redundancy can only be evaluated if a good estimate of image entropy is available. An estimate of He can be obtained from a grey-level histogram.

If h(k) is the frequency of grey-level k in an image f, and image size is M x N then an estimate of P(k) can be made:

$$\widetilde{P}(k) = \frac{h(k)}{MN} \quad [6]$$

Therefore,

$$\widetilde{H}_e = -\sum_{k=0}^{G-1} \widetilde{P}(k) \log_2[\widetilde{P}(k)] \text{ and } \widetilde{r} = b - \widetilde{H}_e \quad [6]$$

The Compression ratio K = b / He

B. Compression Techniques

This paper is concentrate on transform coding and Wavelet Transforms. Image data can be represented by coefficients of discrete image transforms. Usually the image is split into blocks or sub images of 8x8 or 16x16 pixels, and then each block is transformed separately.

This does not take into account any correlation between blocks, and creates "blocking artifacts", which are not good if a smooth image is required. If wavelets transform is applied to entire images, rather than sub images, so it produces no blocking artifacts. This is a major advantage of wavelet compression over other transform compression methods.

C. Threshold in Wavelet Compression

For some signals, many of the wavelet coefficients are close to or equal to zero. Threshold can be modifying the coefficients to produce more zeros. Any coefficient below a threshold λ is set to zero. This produce many consecutive zero's which can be stored in much less space, and transmitted more quickly by using entropy coding compression.

This explains that the wavelet analysis does not actually compress a signal; it simply provides information about the signal which allows the data to be compressed by standard entropy coding techniques, such as Huffman coding. Huffman coding is good to use with a signal processed by wavelet analysis, because it relies on the fact that the data values are small and in particular zero, to compress data. Long strings of zeros can be encoded very efficiently using this scheme. To compare different wavelets, the number of zeros is used. More zeros will allow a higher compression rate, if there are many consecutive zeros, this will give an excellent compression rate.

Indexed images are represented by two matrices: A Color Map Matrix and Image Matrix.

(1) The color map is a matrix of values representing all the colors in the image.
(2) The image matrix contains indexes corresponding to the color map color map.

A color map matrix is of size NX3, where N is the number of different colors in the image. Each row represents the red, green, blue components for a color.

$$\text{e.g. the matrix} \begin{bmatrix} r1 & g1 & b1 \\ r2 & g2 & b2 \end{bmatrix}$$

represents two colors, the first have components r1, g1, b1 and the second having the components r2, g2 and b2.

III. WAVELETS BASED COMPRESSION

Wavelets are useful for compressing signals. They can be used to process and improve signals. They can be used to remove noise in an image, for example if it is of very fine scales, wavelets can be used to cut out this fine scale, effectively removing the noise.

A. The Fingerprint Example

The FBI has been using wavelet techniques in order to store and process fingerprint images more efficiently. The problem that the FBI were faced with was that they had over 200 Million sets of fingerprints, with up to 30,0000 new ones arriving each day, so searching through them was taking too long. The FBI thought that computerizing the fingerprint images would be a better solution; however it was estimated that checking each fingerprint would use 600KB of memory and even worse 2000 TB of storage space would be required to hold all the image data. The FBI then turned to wavelets for help, adapting a technique to compress each image into just 7% of the original space. Even more amazingly, when the images are decompressed they show "little distortion". To compress images used the JPEG format; this breaks an image into blocks eight pixels square. It then uses Fourier transforms to transform the data, then compresses this. However this was unsatisfactory, trying to compress images this way into less than 10% caused "tiling artifacts" to occur, leaving marked boundaries in the image. As the fingerprint matching algorithm relies on accurate data to match images, using JPEG would weaken the success of the process.

However wavelets don't create these "tiles" or "blocks", they work on the image as a whole, collecting detail at certain levels across the entire image. Therefore wavelets offered brilliant compression ratios and little image degradation; overall they outperformed the techniques based on Fourier transforms.

The basic steps used in the fingerprint compression were:
(1) Digitize the source image into a signal S.
(2) Decompose the signal S into wavelet coefficients.
(3) Modify the coefficients from W, using threshold to a sequence W.
(4) Use quantization to convert W to Q.
(5) Apply entropy encoding to compress Q to E.

B. 2D Wavelet Analysis

Images are treated as two dimensional signals, they change horizontally and vertically, thus 2D wavelet analysis must be used for images. In 2D, the images are considered to be matrices with N rows and M columns. At every level of decomposition the horizontal data is filtered, and then the approximation and details produced from this are filtered on columns.

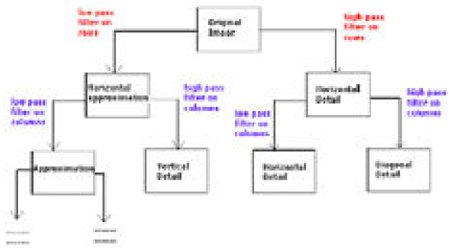
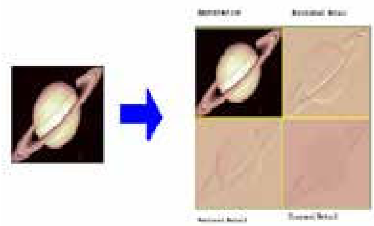


Fig. 2 Level of Decomposition

At every level, four sub-images are obtained; the Approximation, the Vertical Detail, the Horizontal Detail and the Diagonal Detail. Below the Saturn image has been decomposed to one level. The wavelet analysis has found how the image changes Vertically, Horizontally and Diagonally.

To get the next level of decomposition the approximation sub-image is decomposed.



2-D Decomposition of Saturn Image to level 1

C. Wavelet Compression

There are two interfaces which can be used for compressing images, the command line and the GUI. Both interfaces take an image decomposed to a specified level with a specified wavelet and calculate the amount of energy loss and number of zero's.

When compressing with orthogonal wavelets the energy retained is:

$$\frac{100 * (\text{vector - norm}(\text{coeffs of the current decomposition}, 2))^2}{(\text{vector - norm}(\text{original signal}, 2))^2}$$

The number of zeros in percentage is defined by:

$$\frac{100 * (\text{number of zeros of the current decomposition})}{(\text{number of coefficients})}$$

To change the energy retained and number of zeros values, a threshold value is changed. The threshold is the number below which detail coefficients are set to zero. The higher the threshold value, the more zeros can be set, but the more energy is lost. Threshold can be done globally or locally. Global threshold involves threshold every sub band (sub-image) with the same threshold value. Local threshold involves uses a different threshold value for each sub band.

IV. CONCLUSION

It is required to study the various properties of Image. Entropy is the one property of image. If the image is highly correlated pictures the entropy is low. Wavelets are useful for compressing images but they can be used to process and improve images, in fields such as medical imaging where image degradation is not tolerated they are of particular use. They can be used to remove noise in an image, for example if it is of very fine scales, wavelets can be used to cut out this fine scale, effectively removing the noise.

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