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Image Compression Technique based on Discrete 2-D wavelet transforms with Arithmetic Coding

Deepika Sunoriya[1], Uday Pratap Singh[2], Vineet Ricchariya[3]
M.Tech Scholar[1], Assistant Professor[2], Professor and Head[3]
Department of Computer Science and Engineering, LNCT Bhopal[1, 2, 3]

Abstract

Digital Images play a very important role for describing the detailed information about man, money, machine almost in every field. The various processes of digitizing the images to obtain it in the best quality for the more clear and accurate information leads to the requirement of more storage space and better storage and accessing mechanism in the form of hardware or software. In this paper we apply a technique for image compression. Our proposed approach is the combination of several approaches to make the compression better than the previous used approach. In this technique we first apply walsh transformation. Split all DC values form each transformed block 8x8.After that we apply arithmetic coding for compress an image. In this paper we also present a brief survey on several Image Compression Techniques.

Keywords

Walsh Transformation, Digital Images, Image Compression, Spilt DC Values

I. Introduction

In computer science and information theory, image compression is the process of encoding information using fewer bits than the original representation would use. According to Yu Shen [1] Compression is useful because it helps reduce the consumption of expensive resources, such as hard disk space or transmission bandwidth. Image compression may be lossless or lossey. Lossless image compression is a class of image compression algorithms that allows the exact original data to be reconstructed from the compressed data. The term lossless is in contrast to lossy image compression, which only allows an approximation of the original data to be reconstructed, in exchange for better compression rates. Lossless compression is preferred for archival purposes and often for medical imaging, satellite imaging, or technical drawings. In order to make the volumes of data smaller and more capable for transmission of communication system, we always apply image data compression schemes on different image data. There are many image compression schemes, such as JPEG, JPEG2000 [2] and JPEG-LS [3, 4], designed for lossless or lossy high quality image compression.

In 2005, the Consultative Committee for Space Data Systems (CCSDS) presents the recommendation for satellite image compression (CCSDS 122.0-B-1) based on previously adopted lossless compression technique [5]. The design goals of the recommendation [6] are a) reduction of transmission channel bandwidth; b) reduction of the buffering and storage requirement; and c) reduction of data-transmission time at a given rate. In general, low complexity image compression techniques should been adopted to take care of the volumes and quality trade-off problem of satellite imaging system. In this paper, we present a near lossless image compression algorithm to utilize the CCSDS recommendation and specific residue image bit-plane compensation. The algorithm can further increase the compression ratio at high image quality level.

Data compression methods can be reversible (error-free) or irreversible (lossy) [7][8][9]. A reversible scheme can only achieve a maximum compression ratio of about 2.5, but will allow exact recovery of the original image from the compressed version. This compression ratio is limited by the noise in the image which degrades the correlation between pixels [10].An irreversible scheme will not allow exact recovery after compression but can achieve much more compression ratio. More compression is obtained at the expense of image quality. The compression ratio for an irreversible technique can be as high as 25 for projection chest radiographs without noticeable loss of image quality [9]. Halpern et al. [11] used a quad tree-based data compression algorithm to provide different levels of compression within and outside of regions of interest (ROIs). They concluded that at any given compression ratio, diagnostic sensitivity was greater with ROI compression than with uniform quadtree compression. Today, lossy compression methods are not being used by radiologists in primary diagnoses because radiologists are concerned with the legal consequences of incorrect diagnosis based on a lossy compressed image. However, large-scale clinical tests are under way by several research laboratories to develop reasonable policies and acceptable standards for the use of lossy processing on medical images [12].

We provide here an overview of Image Compression Technique. The rest of this paper is arranged as follows: Section 2 introduces Image Compression Techniques; Section 3 describes about Recent Scenario; Section 4 shows the proposed approach; Section 5 describes Conclusion and outlook.

II. Image Compression Techniques

The performance of a compression algorithm is measured in two ways: compression ratio and distortion incurred during compression. Compression ratio, Cr, is the relation of the number of bits input to the source coder, to the number of output bits of the source coder as shown in equation:

C_r = Source Input Size / Source Output Size

The distortion measure or fidelity criterion for comparison of the original image to the reconstructed image are the mean squared error (MSE) and the peak signal to noise ratio (PSNR), as indicated below:

$$\text{MSE}=\frac{1}{N\sum_{i=1}^{i=N}\left(x_i-y_i\right)^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$\text{PSNR}= 10 \log_{10} 255^2/\text{MSE} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

In these equations, x_i is the original pixel from the original image and y_i is the corresponding reconstructed pixel. Accompanying these error measurements, a subjective qualitative comparison is also used to assess performance.

Some Compression Techniques are explained below:

1) Lossless Compression Techniques

Run Length Encoding Algorithm

According to S.R. Kodituwakkur et al. in [13] Run Length Encoding or simply RLE is the simplest of the data compression algorithms. The consecutive sequences of symbols are identified as runs and the others are identified as non runs in this algorithm. This algorithm deals with some sort of redundancy [14]. It checks whether there are any repeating symbols or not, and is based on those redundancies and their lengths.

Huffman Encoding

According to S.R. Kodituwakkur et al. in [13] Huffman Encoding Algorithms use the probability distribution of the alphabet of the source to develop the code words for symbols. The frequency distribution of all the characters of the source is calculated in order to calculate the probability distribution. According to the probabilities, the code words are assigned. Shorter code words for higher probabilities and longer code words for smaller probabilities are assigned. For this task a binary tree is created using the symbols as leaves according to their probabilities and paths of those are taken as the code words.

The Shannon Fano Algorithm

According to S.R. Kodituwakkur et al. [13] this is another variant of Static Huffman Coding algorithm. The only difference is in the creation of the code word. All the other processes are equivalent to the above mentioned Huffman Encoding Algorithm.

Arithmetic Encoding

In this method, a code word is not used to represent a symbol of the text. Instead it uses a fraction to represent the entire source message [13]. The occurrence probabilities and the cumulative probabilities of a set of symbols in the source message are taken into account. The cumulative probability range is used in both compression and decompression processes. In the encoding process, the cumulative probabilities are calculated and the range is created in the beginning. While reading the source character by character, the corresponding range of the character within the cumulative probability range is selected. Then the selected range is divided into sub parts according to the probabilities of the alphabet.

2) Lossy Compression Techniques

The compressed data is not the same as the original data, but a close approximation of it. Yields a much higher compression ratio than that of loss-less compression.

Distortion Measures

The three most commonly used distortion measures in image compression are:

MSE=

$$\frac{1}{N\sum_{i=1}^{i=N}(x_i - y_i)^2}$$

SNR= 10 log $_{10}$ Average Square Value / Original data Sequence

PSNR= 10 log $_{10}$ 255^2/MSE

The Rate-Distortion Theory

Provides a framework for the study of trade o s between Rate and Distortion. The maximum average distortion D and the rate distortion function R(D) is the lower bound for the transmission.

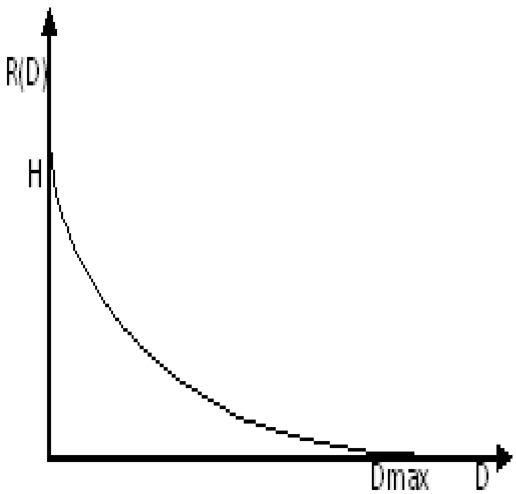

Figure 1: Typical Rate Distortion Function

Quantization

It reduces the number of distinct output values to a much smaller set. Three different forms of quantization are:

Uniform: In uniform quantization each axis of the color space is treated independently. Each axis is then divided into equal sized segments. The planes perpendicular to the axis' that pass through the division points then define regions in the color space. The number of these regions is dependent on the scheme used for dividing the color space. One possible scheme is to divide the red and green axis into 8 segments each and the blue axis into 4 resulting in 256 regions. Another possibility is dividing the red and blue into 6 and the green into 7 segments resulting in 252 regions. Each one of these regions will produce a color for the color map. Once the color space has been divided each of the original colors is then mapped to the region which it falls in. The representative colors for each region is then the average of all the colors mapped to that region. Because each of the regions represents an entry in the color map, the same process for mapping the original colors to a region can be repeated for mapping the original colors to colors in the color map. While this algorithm is quick and easy to implement it does not yield very good results. Often region in the color space will not have any colors mapped to them resulting in color map entries to be wasted.

Non uniform: If the probability density function (pdf) of the input variable is not uniform. This is expected, since we should perform finer quantization (that is, the decision levels more closely packed and consequently more number of reconstruction levels) wherever the pdf is large and coarser quantization (that is, decision levels widely spaced apart and hence, less number of reconstruction levels), wherever pdf is low.

Vector Quantization: A vector quantize maps k-dimensional vectors in the vector space R^k into a finite set of vectors Y = {y_i: i = 1, 2, ..., N}. Each vector y_i is called a code vector or a codeword , and the set of all the code words is called a codebook. Associated with each codeword, y_i, is a nearest neighbor region called Voronoi region, and it is defined by:

$$V_i = \{x \in R^k : \|x - y_i\| \le \|x - y_j\|, for\,all\; j \ne i\}$$

The set of Voronoi regions partition the entire space R^k such that:

$$\bigcup_{i=1}^{N} V_i = R^k$$

$$\bigcap_{i=1}^{N} V_i = \phi \qquad \text{for all } i \neq j$$

A uniform scalar quantizer partitions the domain of input values into equally spaced intervals, except possibly at the two outer intervals. The output or reconstruction value corresponding to each interval is taken to be the midpoint of the interval. The length of each interval is referred to as the step size denoted by the symbol Δ.

P(x, y) = trunk (I(x, y) + 0.5)

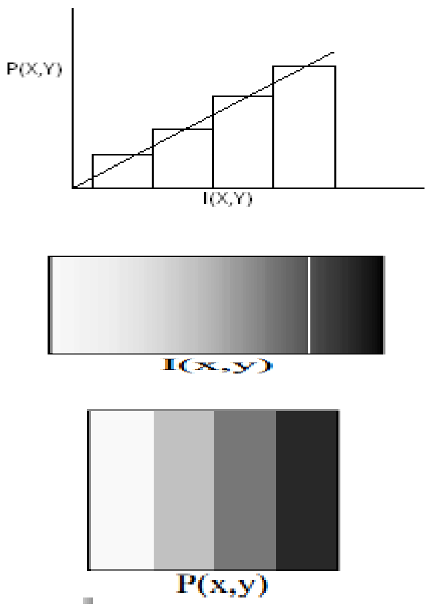

Figure 2: Quantization

Images with decreasing bits per pixel:

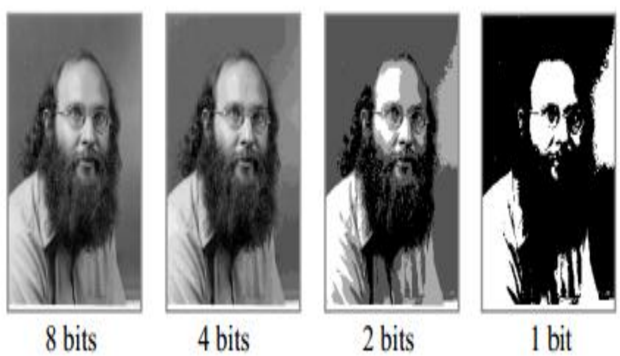

Figure 3: Notice contouring

For the special case where $\Delta = 1$, we can simply compute the output values for these quantizers as:
Qmidrise(x) = [x] − 0:5 (8:4)
Qmidtread(x) = [x + 0:5]

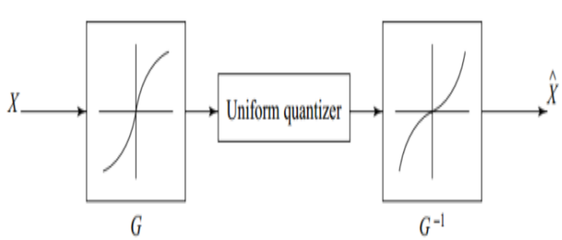

Figure 4: Companded quantization

Companded quantization is nonlinear. As shown in Figure 4, a compander consists of a compressor function G, a uniform quantizer, and an expander function G $^{-1}$. The two commonly used companders are the µ-law and A-law companders. According to Shannon's original work on information theory, any compression system performs better if it operates on vectors or groups of samples rather than individual symbols or samples. Form vectors of input samples by simply concatenating a number of consecutive samples into a single vector. Instead of single reconstruction values as in scalar quantization, in VQ code vectors with n components are used. A collection of these code vectors form the codebook.

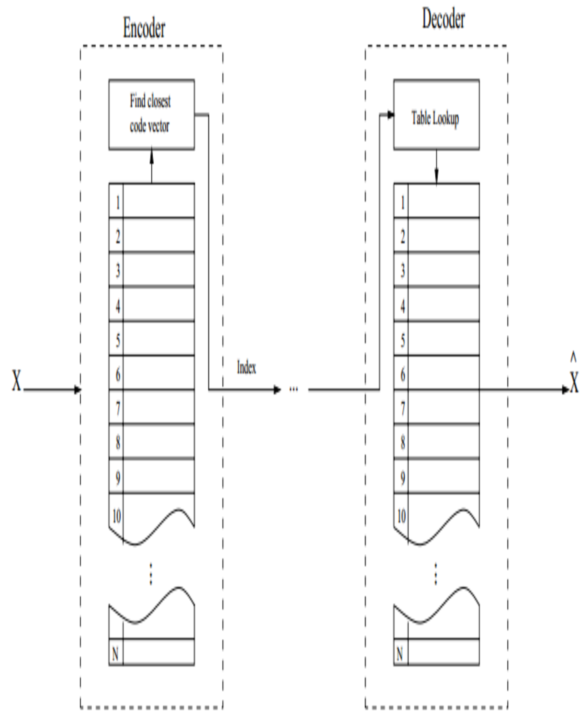

Figure 5: Basic vector quantization procedure

Transform Coding

The rationale behind transform coding: If Y is the result of a linear transform T of the input vector X in such a way that the components of Y are much less correlated, then Y be coded more efficiently than X.

If most information is accurately described by the first few components of a transformed vector, then the remaining components can be coarsely quantized, or even set to zero, with little signal distortion. Discrete Cosine Transform (DCT) will be studied. In addition, we will examine the Karhunen-Loeve

Transform (KLT) which optimally de correlates the components of the input X.

III. Recent Scenario

In 2006, Matthew J. Zukoski et al. [15] as medical/biological imaging facilities move towards complete film-less imaging, compression plays a key role. Although lossy compression techniques yield high compression rates, the medical community has been reluctant to adopt these methods, largely for legal reasons, and has instead relied on lossless compression techniques that yield low compression rates. The true goal is to maximise compression while maintaining clinical relevance and balancing legal risk. They propose a novel model-based compression technique that makes use of clinically relevant regions as defined by radiologists. Lossless compression is used in these clinically relevant regions, and lossy compression is used everywhere else.

In 2007, R.Sukanesh et al. [16] a novel approach of information theory based Minimum Relative Entropy (MRE) and Entropy methods for image compression are discussed. A two stage compression process is performed through homogenous MRE method, and heterogeneous MRE. The compressed images are reconstructed through Region growing techniques. The performance of image compression and restoration is analyzed by the estimation of parametric values such as Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR). Higher the PSNR better the reconstruction process. Six radiographic medical images of various sizes are analyzed and Maximum PSNR of 33 is achieved.

In 2008, K. Veeraswamy,et al. [17] an adaptive image compression algorithm is proposed based on the prediction of AC coefficients in Discrete Cosine Transform (DCT) block during reconstruction of image. In the prediction phase, DC values of the nearest neighbour DCT blocks are utilized to predict the AC coefficients of centre block. Surrounding DC values of a DCT blocks are adaptively weighed for AC coefficients prediction. Linear programming is used to calculate the weights with respect to the image content. Results show that this method is good in terms of good Peak Signal to Noise Ratio (PSNR) and less blocking artifacts. The proposed scheme has been demonstrated through several experiments including Lena. Reconstructed image is of good quality with same compression ratio compared to the existing technique in the literature. In addition, an image watermarking algorithm is proposed using DCT AC coefficients obtained. The performance of the proposed watermarking scheme is measured in terms of PSNR and Normalized Cross Correlation (NCC). Further, this algorithm is robust for various attacks including JPEG compression on watermarked image.

In 2010, Jianfeng Wanget al. [18] proposed an propose an effective and fast shot cut detection algorithm directly in MPEG compressed domain. The proposed shot cut detection test the different between the current frame and next frame through the extracting the feature of each frame. When extract the features of frame, statistical parameters m1-σ from DWT coefficients without its inverse transform was computed, Except this , locating shot cuts is operated by comparison tests. In comparison with the latest research efforts in shot cut detection, our proposed algorithm achieves significant advantages including: (a) use the walsh transform to reduce the computation time for a given resolution or to increase the resolution without drastically increasing the computation time (b) there is no full decompression is needed; (c) adding correlation to judge the different between feature vectors; and (d) detection performance is competitive and fast.

In 2010, Jagadish al. [19] proposed the Lossless method of image compression and decompression using a simple coding technique called Huffman coding. This technique is simple in implementation and utilizes less memory. A software algorithm has been developed and implemented to compress and decompress the given image using Huffman coding techniques in a MATLAB platform.

In 2011, G.M.Padmaja, et al. [20] analyzes various image compression techniques. In addition, specific methods are presented illustrating the application of such techniques to the real-world images. They have presented various steps involved in the general procedure for compressing images. They provided the basics of image coding with a discussion of vector quantization and one of the main technique of wavelet compression under vector quantization. This analysis of various compression techniques provides knowledge in identifying the advantageous features and helps in choosing correct method for compression.

In 2011, S.Parveen Banu et al. [21] a novel hybrid image compression technique for efficient storage and delivery of data is proposed. It is based on decomposing the data using daubechies-4 wavelet in combination with the lifting scheme and entropy encoding. This scheme is concerned with the compression ratio, bits per pixel and peak signal to noise ratio. Experimental results illustrate that the proposed scheme is efficient and feasible in terms of compression ratio, bits per pixel and peak signal to noise ratio.

In 2011, Yu Yanxin et al. [22] presented an image compression method suited to the space-borne application. To solve the problem of large-size RS images taking up large cache, the compression scheme based on overlap blocks was taken. The overlap blocks of the image were multi-levelly decomposed by lifting wavelet. According to human visual characteristics, the lossless encoding method was used for the low-frequency sub-band most sensitive to human vision, and the bit-plane coding method was take for the remaining high-frequency sub-bands. Simulation results show that the algorithm can remove the blocking artifacts and realize the high quality image compression.

In 2011, Baluram Nagaria et al. [23] discussed the comparative study of different wavelet-based image compression systems. When wavelet transform is applied to image compression, the chosen wavelet base affects the efficiency of signal strength, pixel values and the quality of the reconstructed image, because the property parameters of different wavelet bases are varied, it is very important to research the correlation between the wavelet base properties and image compression. They have discussed various statistical numerical measures and obtained results compared in terms of MSE, PSNR, Normalization and Compression Ratio with lower and higher pixel frames. The main objective of this research measure the quality of image with statistical numerical measures (PSNR, MSE respectively) using different wavelet families with suitable decomposition level. Different test image with 512 X 512 and 1024 X1024 pixel frames are used to evaluate the performance of image compression. The final choice of optimal wavelet in image compression application depends on image quality, minimum error, optimum PSNR and computational complexity. The experiments are performed using different wavelets at various levels of decomposition. This results show that Discrete Mayer wavelet with second and fourth level decomposition yields better quality for Lena (1024 X 124) and quality has been degrade as lower pixel frame with fruits(512 X 512)images. Our results Provide a good reference for application developers to choose a go.

In 2011, Yu Shen et al. [24] addresses Compression are useful because it helps reduce the consumption of expensive resources, such as hard disk space or transmission bandwidth. Image compression may be lossless or lossey. Lossless image compression is a class of image compression algorithms that allows the exact original data to be reconstructed from the compressed data. The term lossless is in contrast to lossy image compression, which only allows an approximation of the original data to be reconstructed, in exchange for better compression rates. Lossless compression is preferred for archival purposes and often for medical imaging, satellite imaging, or technical drawings. For the urgent requirement of efficient lossless compression and high fidelity compression, more and more research of lossless image compression will be concerned. After the introduction of the lifting scheme and the integer to integer multiwavelets, they present the approach to build integer to integer multiwavelets. In addition, experimental results of applying these multiwavelets to lossless image compression are presented.

IV. Comparison Table

Approach	Author	Year	Study	MSE	SNR	PSNR	Compression Ratio
Medical Image Compression	Matthew J. Zukoski [15]	2006	Include a qualitative component to examine the effects of the hybrid compression methodology in a clinical setting.				1.711:1 or 4.676 bpp
Minimum Relative Entropy (MRE)	Dr. (Mrs.) R.Sukanesh [16]	2007	A standard compression ratio of 12 is obtained	Improvement of 0.57 dB		22.15 , 22.96 DB	12
AC-Coefficient Prediction for Image Compression and Blind Watermarking	K. Veeraswamy [17]	2008	reduced PSNR of watermarked image			45.21 DB(Leena), 39.55(Mandrill), 38.96(Peppers)	Compression ranges from 0 to 100, where 0 is best compression and 100 is best quality.
Lossless Method of Image compression	Jagadish [19]	2010	Experimental results show that up to a 0.8456 compression ratio for the above image is obtained.				0.8456
Hybrid Image Compression Scheme	S.Parveen Banu [21]	2011	Higher compression ratio compared to the lossy image compression standards and similar peak signal to noise ratio as that of lossless method.			9519(Mandrill)	
Analysis of Various Image Compression Techniques	G.M.Padmaja [20]	2011	Vector quantization can theoretically attain the maximum achievable coding efficiency.				
Remote Sensing Image Compression Method	Yu Yanxin [22]	2011	A large size RS images use the compression scheme based on overlap blocks.			31.2(p1) 33.5 (P2),34.5(P3)	
Comparative Analysis of an Optimal Image Compression using FDWT Different Pixel Frame	Baluram Nagaria [23]	2011	The final choice of optimal wavelet in image compression application depends on image quality, minimum error, optimum PSNR.	3.3248		42.913	98.534
Integer to Integer multi wavelets for lossless image compression	Yu Shen [24]	2011	Lossless compression is preferred for archival purposes and often for medical imaging, satellite imaging, or technical drawings.	4.62	4.1	3.9	

V. Conclusion and Outlook

In this paper we survey several aspect of image compression technique. Different techniques are presented and compared. In this paper we also discuss our proposed approach which is the combination of walsh, splitting and arithmetic coding. This approach provides a better performance for compression technique. In future we also present a comparative study with our approach.

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I completed my B.E in 2007 from S.G.S.I.T.S Indore college and pursuing M.Tech 2009- 2012 from L.N.C.T Bhopal.