Optimized Image Compression using Geometric Wavelets and Genetic Algorithm

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ABSTRACT

Image compression enables us to reduce the size of the image in order to be able us to store or transmit data in an efficient form. Compressing an image is significantly different than compressing raw binary data. Of course, general purpose compression programs can be used to compress images, but the result is less than optimal. We propose an improved image compression algorithm using binary space partitioning scheme and geometric wavelets. The presented method produces the PSNR values that are competitive with the state-of-art coders in literature. The advantage of this method is the improvement in the PSNR values at high and medium bit rates. In the proposed algorithm slope intercept form of the straight line is used and it has increased the domain of the bisecting lines and hence at each step of the BSP there is better possibility of optimal rate distortion with minimum cost functional. In order to obtain better results in distortion rate and computational complexity we replace the pruning method with genetic algorithm which out performs the existing optimization process.

Index Terms

Binary space partition scheme, Geometric Wavelets, Piecewise polynomial approximation, Sparse geometric representation.

1. INTRODUCTION

Multimedia files are large and consume lots of hard disk space. Compression shrinks files, making them smaller and more practical to store and share. It works by removing repetitious or redundant information, effectively summarizing the contents of a file in a way that preserves as much of the original meaning as possible. The use of and dependence on information and computers continue to grow, and the need for efficient ways of storing and transmitting large amounts of data also grows.

Compression is the process of representing information in a compact form so as to reduce the bit rate for transmission or storage while maintaining data quality.

There are two ways we can classify the type of Image Compression namely

❖ Lossy/Lossless Compression

It refers to data compression techniques that allow the exact original data to be reconstructed from the compressed data. Lossless compression is used when it is important that the original and the decompressed data be identical. It refers to data compression techniques in which some amount of data is lost. Lossy compression technologies attempt to eliminate redundant or unnecessary information. Lossy compression is most commonly used to compress multimedia data (audio, video, still images).

The wavelet transform has emerged as a cutting edge technology, within the field of image analysis. Wavelet transform exploits both the spatial and frequency correlation of data by dilations (or contractions) and translations of mother wavelet on the input data. It supports the multi resolution analysis of data which allows progressive transmission and zooming of the image without the need of extra storage. The implementation of wavelet compression scheme is very similar to that of subband coding scheme: the signal is decomposed using filter banks. The output of the filter banks is down-sampled, quantized, and encoded. The decoder decodes the coded representation, up-samples and recomposes the signal. Wavelet-based coding [6] provides substantial improvements in picture quality at higher compression ratios.

The advantages of wavelet compression are wavelet coding schemes at higher compression avoid blocking artifacts. Compression with wavelets is scalable hence very high compression ratios can be achieved. Wavelet based compression allow parametric gain control for image softening and sharpening. Wavelet compression is very efficient at low bit rates. Wavelets provide an efficient decomposition of signals prior to compression.

In this paper, section II deals with literature survey, section III introduces the Problem Definition, section IV. The proposed method for rate distortion optimization is given in section IV , In section V, we report our experimental results and makes several concluding remarks in section VI .

2. LITERATURE SURVEY

The wavelet compression schemes are very similar to subband coding scheme which are being using in several applications. Over past few years variety of wavelet based image coding schemes have been developed .These includes DWT, EZW, SPHIT, Pruning Tree, Geometric Wavelets. Here the various wavelet based image compression methods analyzed and their characters are mentioned.

2.1 Discrete Wavelet Transform

Wavelets are functions generated from one single function by dilations and translations. The wavelet coefficients are coded considering a noise shaping bit allocation procedure. The basic idea of the wavelet transform is to represent any arbitrary function f as a super position of wavelets. Any such super position decomposes f in to different scale levels, where each level is then further decomposed with a resolution adapted to the level .This technique exploits the psycho-visual as well as statistical redundancies in the image data, enabling bit rate reduction.

2.2 Embedded Zero tree Wavelet (EZW)

Embedded Zero tree Wavelet (EZW) Coding introduced by J.M. Shapiro [9] is a very effective and computationally simple technique for image compression. The embedded zerotree wavelet algorithm (EZW) is a simple, yet remarkably effective, image compression algorithm, having the property that the bits in the bit stream are generated in order of importance, yielding a fully embedded code. The embedded code represents a sequence of binary decisions that distinguish an image from the "null" image. Using an embedded coding algorithm, an encoder can terminate the encoding at any point thereby allowing a target rate or target distortion metric to be met exactly. Also, given a bit stream, the decoder can cease decoding at any point in the bit stream and still produce exactly the same image that would have been encoded at the bit rate corresponding to the truncated bit stream. The algorithm runs sequentially and stops whenever a target bit rate or a target distortion is met. A target bit rate can be met exactly, and an operational rates-distortion function (RDF) [9] can be computed point by- point.

The main advantage of EZW algorithm is that the Zero tree coding reduces the cost of encoding the significance map using self-similarity, employs progressive transmission, uses predefined scanning order and produces good results without using codebooks or pre stored tables. The disadvantage of using EZW is the transmission of coefficient position is missing.

2.3 Set Partitioning in Hierarchical Trees

The SPIHT coder is a highly refined version of the EZW algorithm [8] and is a powerful image compression algorithm that produces an embedded bit stream from which the best reconstructed images in the mean square error sense can be extracted at various bit rates.

One of the main features of the SPIHT algorithm is that the ordering data is not explicitly transmitted. Instead, it is based on the fact that the execution path of any algorithm is defined by the results of the comparisons of its branching points. One important fact in the design of the sorting algorithm is that there is no need to sort all coefficients.

A tree structure, called spatial orientation tree, naturally defines the spatial relationship on the hierarchical pyramid. With this algorithm the rate can be precisely controlled because the transmitted information is formed of single bits.

The advantage of SPHIT method is that it employs progressive transmission ,has high PSNR value, produces perceptual image quality. The disadvantage is that the algorithm only implicitly locates position of significant coefficients and the perceptual image quality is not optimal.

2.4 Pruning Tree

The prune binary tree algorithm [5] is similar in spirit to the algorithm proposed in for searching the best wavelet packet bases. In this algorithm, each node of the tree is coded independently and, as anticipated before, each node approximates its signal segment with a polynomial. Finally the prune tree algorithm utilizes rate-distortion framework with an MSE distortion metric. One can observe that the prune tree scheme could not merge the neighboring nodes representing the same information. Since this coding scheme fails to exploit the dependency among neighbors in the pruned tree, it is bound to be suboptimal.

The major drawback of pruning tree method [5] is high computational complexity.

2.5 Geometric Wavelets

Geometric Wavelets [7]is a new multi-scale data representation technique which is useful for a variety of applications such as data compression, interpretation and anomaly detection.

To form a compact representation for the data at this finer scale, as in wavelet decomposition, we only encode the differences between the original coarse projections of the data and the points projected onto the planes at the finer scale. In order to do this an efficient scheme is derived based on the construction of a minimal space spanning this set of differences. The axes of this difference space are called "geometric wavelets", and the projections of the finer-scale corrections [14] to the data points onto the plane spanned by these axes are called the "wavelet coefficients". The process is continued, forming a binary tree of parents and children at finer and finer scales until no further details are needed to approximate the data up to a pre-specified precision. The drawback of this method is high time complexity.

2.6 Geometric Wavelet With BSP

Segmentation techniques partition the digital image into a set of different geometric regions which are approximated by simple functions (low order polynomials). This technique subdivides an initial convex domain into two sub domains by intersecting it with a hyper plane. In image processing applications, the convex domain is the plane on which a straight line acts as a hyper plane. The subdivision process is performed to minimize the given cost functional. The BSP[1][2] approach partitions the desired image recursively by straight lines in a hierarchical manner.

The major drawback of this method is low distortion rate and high computational complexity.

2.7 Comparative Study

METHOD	FEATURES	DRAWBACKS
EZW	• Employs progressive and embedded transmission. • Uses zero tree concept. • Uses predefined scanning order. • Good results without codebooks.	• Transmission of coefficient position is missing. • No real compression
SPIHT	• Employs spatial oriented tree structure. • Quad tree are set partitioned. • Keep tract of states of sets of indices by means of 3 lists: LSP, LIS, LIP. • Employs progressive and embedded transmission.	• Only implicitly locates position of significant coefficient. • More memory required due to 3 lists. • Transmitted information in terms of single bits.
Geometric Wavelets	• Sparse representation of image. • Used for low bit rate compression • Encode sparse wavelet representation of image.	• High time complexity • Low distortion rate • High computational complexity. • Low coding

		efficiency
GW + BSP	• Binary Space Partition tree is constructed. • Partition proceeds repeatedly on sub domains until exit condition is met. • Suited for low bit rate compressions. • Uses Pruning method for rate distortion	• High computational cost • Low distortion rate.

3. PROBLEM DEFINITION

The existing system the algorithm is used to improve the GW image coding method. The slope intercept form of the straight line is used in the binary space partition scheme (BSP) which result in low Rate distortion with high computational cost.

4. PROPOSED METHOD

The proposed method consists of six steps as given below:

1.Preprocessing

2.Construction of BSP forest

3.Geometric Wavelet

4.Encoding

5.Rate distortion optimization

6.Decoding

4.1 Preprocessing:

Read the image from database and if its color images its convert to gray scale image and rescaling the image to fixed size like 512x512. To reduce the computational cost image Tile size is generally taken as 128x128.

4.2 Binary Space Partitioning

The process of constructing a BSP[3] tree is fairly straitforward:

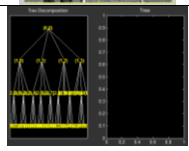
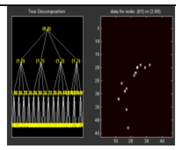
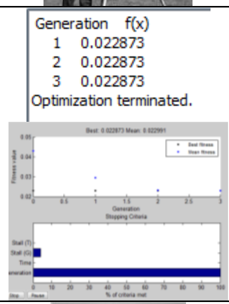
1. First, select a partition hyperplane. For this dicussion, we will use a 2 dimensional world and our root node will be a line.
2. Partition all polygons in the world with the initial partition hyperplane, storing them in either the front or back polygon list.
3. Recurse or iterate through the front and back polygon list, creating a new tree node and attaching it the the left or right leaf of the parent node.

As pointed out in by Fuchs in [3], the choice of a root node will directly influence the size of the tree. If a root node cuts across many different polygons, it will probably result in a large tree. Since calculating a BSP tree is usually done before rendering, the easiest method for finding an optimal root node is test a small number of candidates. The node that results in the smallest number of nodes in the BSP tree should be chosen.

There are four cases to deal with when a polygon or line is partitioned by the hyperplane[1]: polygon is infront, behind, coincident ,spans the hyperplane. For the first two cases, polygon is added to the appropriate node of the tree. If the polygon is coincident, it can be handled by storing multiple polygons in the node of the BSP tree. If the polygon spans the hyperplane, the polygon splitting algorithm must find the intersection point of the polygon and plane. This can be done with ray plane intersection approach for convex polygons.

Finally, the BSP tree algorithm [1] [3] can perform either recursively or iteratively. The recursive BSP tree is very simple to understand because it simply performs a partition based on the current hyper plane and then recurses the front and back leaf nodes.

Fig 1: Steps in Image compression

STEPS	RESULTING IMAGE
Input Image	
Preprocessing	
Construction of BSP	
Geometric Wavelet	
Encoding	
Rate Distortion Optimization	
Decoding	

3. Geometric Wavelet

Take a function f(x) over any (convex) region S[11]. The function is approximated by some polynomial (of fixed degree), call it p(x). Split the region exactly in two by a straight line, so that the two remaining regions S1 and S2 are still convex. Over each sub regions, by regression, solve for the polynomials (of fixed degree) p1(x) and p2(x) approximating f(x). Optimize the splitting so that the approximation error made by p1 and p2 is minimal. Then your two new wavelets are the polynomials p(x)-p1(x) and p(x)-p2(x) limited to S1 and S2 respectively. These wavelets are not continuous, but if f(x) is itself a polynomial (up to a fixed degree), then the wavelets vanish. Repeat this splitting for as long as needed.

4. Encoding

There are two types of information to be encoded, the geometry of the support of the wavelets participating in the sparse representation and the polynomial coefficients of the wavelet. Before encoding the extracted BSP forest[1], a small header is written to the compressed file. Header consists of the minimum and maximum values of the Coefficients of the participating wavelet and the image graylevels. Out of header size of 26 bytes, 24 are used in the storage of the minimum and the maximum values of the coefficients while 2 bytes are utilized to store the extremal values of the image. Root geometric wavelets[12] have maximum contribution in the approximation so each root wavelet is encoded.

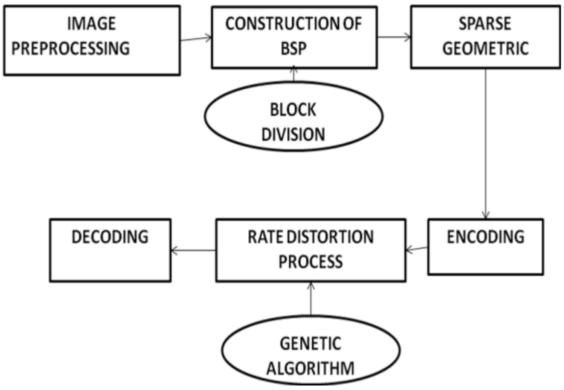


Fig 2: Block Diagram

5. Rate Distortion Optimization

After the encoding step a rate distortion optimization process is performed in order to attain the desired bit rate by using Genetic Algorithm[14] shown in figure 3.

6. Decoding

In this step compressed bit stream is read to find whether the participating node is the leaf node, has 1 child or 2 children. An ortho normal basis was used during the encoding of the coefficients of geometric wavelet. Thus, before using the decoded geometric wavelets in n-term sum, its representation in the standard basis is found. This process is repeated until entire bit stream is read.

5. DISCUSSION

The proposed algorithm is implemented in MATLAB and tested on still images of Lena, Cameraman, House,

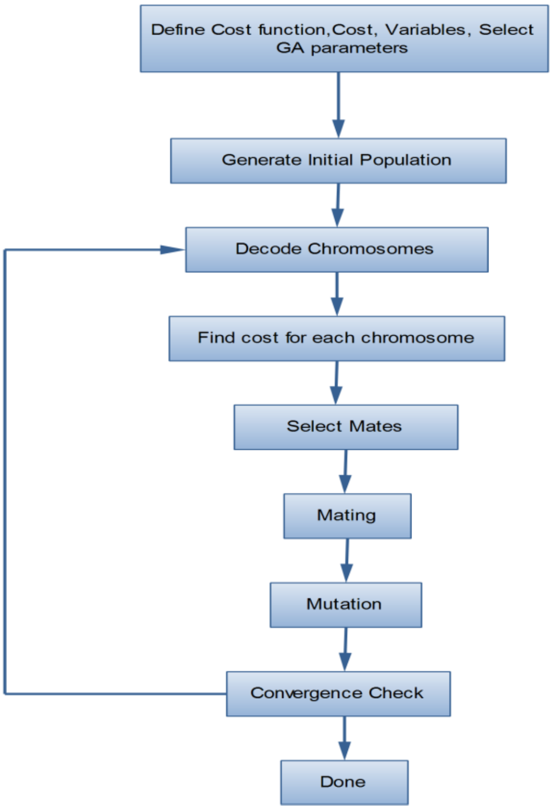


Fig 3: Steps In Genetic Algorithm

Barbara, Boat of size 512X 512. The PSNR value for Lena test image is given as follows. The histogram for compression ratio, bit rate and PSNR rate for above 5 images are given below. The performance is compared with four methods.

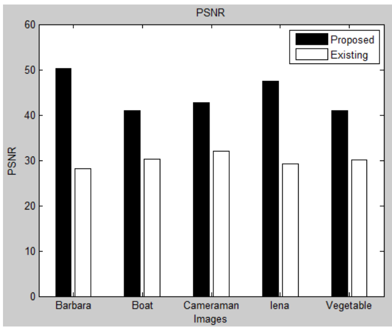


Fig 4: Histogram of PSNR value

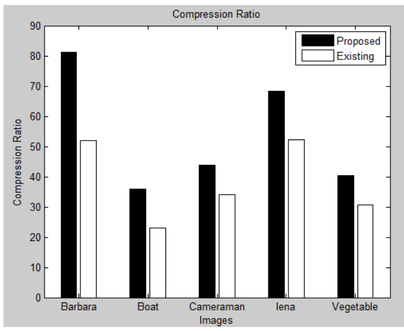


Fig 5: Histogram of Compression ratio

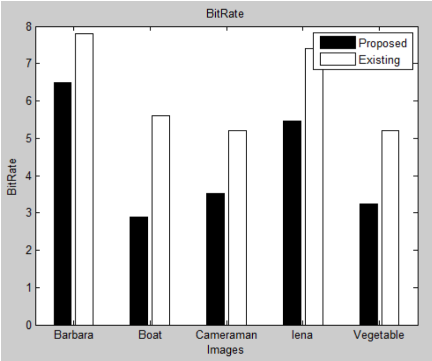


Fig 6: Histogram of bit rate for various images

Table 1. Compression Ratio For Lena Tested Image

Method	**Compression Ratio**
	64:1
EZW	**30.23**
SPHIT	**31.10**
GW	**30.73**
GW + BSP	**30.82**
Proposed method	**37.16**

Table 2. Compression Ratio For Cameraman Tested Image

Method	**Compression Ratio**
	64:1
SPHIT	**25**
GW	**25.07**
GW + BSP	**25.29**
Proposed method	**41.83**

Fig 7

Fig 8

Fig 9

Fig 7: Original Image 8: Compressed Image Using Existing Method,9: Compression method using Proposed method for Cameraman tested image.

Table 3. Bit Rate

Input images	**Bit rate**	
	Existing	**Proposed**
BARBARA	1857.27	110.18
BOAT	1777.62	109.53
LENA	1511.99	95.75
VEGETABLE	85.38	39.11

Table 4. PSNR Value

Input images	**PSNR Value**	
	Existing (GW+BSP)	**Proposed**
BARBARA	28.1200	36.7834
BOAT	30.3000	37.7352
CAMERAMAN	32.1000	41.8368
LENA	29.2000	37.1607
VEGETABLE	30.1000	42.0351

The tables 3 & 4 explains the bit rate and PSNR value comparison for the different input images.

6. CONCLUSION

Thus the presented method produces the PSNR values that are competitive with the state-of-art coders in literature. The advantage of this method is the improvement in the PSNR values at high and medium bit rates. In the proposed algorithm the existing pruning method is replaced by the genetic algorithm which reports a gain of 16.54 dB over the existing method for cameraman image (Fig c) which improves the distortion rate and minimizing the cost functional.

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