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Review Article

A Review On Segmentation Based Image Compression Techniques

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Abstract

Abstract -The storage and transmission of imagery become more challenging task in the current scenario of multimedia applications. Hence, an efficient compression scheme is highly essential for imagery, which reduces the requirement of storage medium and transmission bandwidth. Not only improvement in performance and also the compression techniques must converge quickly in order to apply them for real time applications. There are various algorithms have been done in image compression, but everyone has its own pros and cons. Here, an extensive analysis between existing methods is performed. Also, the use of existing works is highlighted, for developing the novel techniques which face the challenging task of image storage and transmission in multimedia applications.

Keywords: Compression, multimedia applications, transmission bandwidth

1. Introduction

With the continuing growth of multimedia technology, demand for image transmission and storage is increasing rapidly. General- purpose compression algorithms, like the JPEG, JPEG2000, or MPEG standards, usually do not provide satisfactory results for all kinds of applications, because they are not tailored to their geometrical behavior[1]. Hence, segmentation based image compression method is selected for compressing image.

There are two major steps in segmentation based compression namely, segmentation and compression of segmented region. In image segmentation algorithm, the image is segmented, based on any one of the two basic properties of intensity values, namely discontinuity and Similarity. This segmentation step is used to improve reconstructed image quality by preserving edge information. In compression step, the segmentation output are encoded in effective manner to get efficient compression performance. Many research papers with different approaches for segmentation based compression are discussed in the following sections. After discussed about different methods, the novel technique for image compression is proposed in conclusion.

2. Survey on image compression

There are two broad categories of image compression techniques. The first category consists of methods, which completely preserve the original data. When the compressed image is converted back into its uncompressed form, it is identical with the original image. This kind of technique is called “lossless” compression. For this kind of compression to be effective, there must be some redundancy in the original data. The second category of compression technique consists of methods that only approximate the original data. This category of compression is called “lossy” compression. In general, the less accuracy needed of the resulting image, the greater the compression rate and vice versa.

The image compression methods are broadly classified as

1. Fractal Image Compression
2. Quadtree based image compression
3. Transform based coding

A Fractal Based compression

The fractal image compression is based on the partitioned iterated function systems(PIFS) which utilizes the self-similarity property in the image to achieve the purpose of compression [2]. Since high computational complexity is the main drawback of full search Fractal Image Compression(FIC), many speedup schemes were proposed to reduce the searching space [3] &[4]. Another drawback of the fractal image compression algorithm is the poor retrieved image qualities when compressing corrupted images. Hence robust fractal image compression i.e Huber Fractal Image Compression is introduced (HFIC). To encode an image according to self- similarity property, each block to be encoded must search in a large pool to find the best match. For the standard full search method, the encoding process is time

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consuming because a large amount of computations of similarity measure are required. For HFIC, Particle Swarm Optimization is used to speed up the search of a near best match block for a given block to be encoded. Simulation results have shown that HFIC has good robustness against the outliers caused by salt and pepper noise, but does not show significant improvement in image quality for bell-shaped noise such as Gaussian and Laplace noises.

B.Quadtree Based Compression

Quadtree algorithms are the simple compression techniques. Qualitative Image Compression Algorithm Relying on Quadtree was introduced [6]. The quadtree algorithms are based on simple averages and comparisons. A quadtree is a tree-like data structure where each node either terminates on a leaf containing useful information, or branches into four sub-level quadtrees [7]. Here, a qualitative algorithm is designed based on the quadtree to divide the image. This algorithm divides the image into blocks and save them in a way that can restore the blocks again easily. Two stacks are used during the process of dividing the original image into blocks depending on a threshold value. These stacks are used as an alternative of tree, and the divided blocks are numbered effectively to determine these blocks correctly. This is designed to restore compressed images again in easy way quickly. The compression ratio of this algorithm is ranged between 0.12 and 0.68. The compression ratios are dependent on the threshold values, which can be affected the quality of compression [8].

C. Transform based compression

Several ad-hoc image compression algorithms have been proposed in last few years. Most of them rely on transform based compression, because of its simplification and better performance. Existing Transform based coding techniques improve their performance by modifying or replacing the transform which is used to decor relate the input image.

a. Image Compression Methods - Modifications or Replacement of transform

The standards for compression of still (e.g., JPEG) and moving images (e.g., MPEG-1,MPEG-2) use DCT, which represents an image as a superposition of cosine functions with different discrete frequencies[39]. The image is divided into blocks of NXN samples and each block is transformed independently to give NXN coefficients. DCT coefficients measure the contribution of the cosine function at different discrete frequencies. DCT provides excellent energy compaction, and a number of fast algorithms exist for calculating the DCT. Most existing compression systems use square DCT blocks of regular size. The use of uniformly sized blocks simplified the compression system, but it does not take into account the irregular shapes within real images. The block based segmentation of source image is a fundamental limitation of the DCT-based compression system[9]. The degradation is known as the "blocking effect" and depends on block size. A larger block leads to more efficient coding, but requires more computational power. Image distortion is less annoying for small than for large DCT blocks, but coding efficiency tends to suffer.

DWT is a standard tool in image compression applications because of their data reduction capability. In a wavelet compression system, the entire image is transformed and compressed as a single data object rather than block by block as in a DCT -based compression system. It allows uniform distribution of compression errors across the entire image. DWT offers adaptive spatial-frequency resolution(better spatial resolution at high frequencies and better frequency resolution at low frequencies) that is well suited to the properties of an Human Visual System(HVS). It can provide better image quality than DCT, especially on a higher compression ratio[10]. However, the implementation of the DCT is less expensive than that of the DWT. The most efficient algorithm for 2-D 8X8 DCT requires only 54 multiplications[11], while the complexity of calculating the DWT depends on the length of wavelet filters.

Sonja Grgic et al, examined different wavelet functions for image compression [12]. The fundamental difficulty in testing an image compression system is how to decide which test images to use for the evaluations. Hence the analyzed spectral activity of test images is evaluated using DCT applied to the whole image. DCT coefficients shows the frequency content of the image. Four types of test images with different frequency content: Peppers, Lena, Baboon and Zebra used. Images with high spectral activity are more difficult for a compression system to handle [12]. These images usually contain large number of small details and low spatial redundancy. The choice of wavelet function should be adjusted to image content [13]. The compression performance for images with high spectral activity (Baboon image) is fairly insensitive to choice of compression method. The compression performance for images with moderate spectral activity(Lena image) is more sensitive to choice of compression method. The best way for choosing wavelet function is to select optimal basis for images with moderate spectral activity. This wavelet will give satisfying results for other types of images. The DWT compression results show that bior2.2 give the best results for all image types.

Gabor transform is used to compress the Synthetic Aperture Radar (SAR) imagery[14]. The image compression is the one of the most important applications of the wavelet transform [15],[16],[17] &[18]. But at low bit rates the wavelet transform basis functions can sometimes produce annoying artifacts in reconstructed image. The Gabor transform is a combined spatial - spectral transform that provides local spatial - frequency analyses in overlapping neighborhoods of the image. In SAR imagery, the compression system based on Gabor transform tends to reconstruct the background textures batter than those based on wavelet transform. Because Gabor transform basis functions exhibit more orientational selectivity than other transforms, such as the separable wavelet transform and sample spatial frequencies differently than the separable wavelet transform. The simulation results have shown that the Gabor/TCQ Trellis coded quantization compression system outperforms JPEG on SAR images. Also, at a bit rate of 0.5bpp, the reconstructed images from this system were rated as just noticeably different from the original.

Direction-Adaptive discrete Wavelet Transform was introduced for image compression [19]. The 2-D discrete wavelet transform (DWT) is the most important new image compression technique in the last decade [20],[21] & [22]. An early work of an adaptive wavelet transform that adapts the transform directions to image content is presented in [23]. The image is partitioned into blocks. Each image block is then sheared through a reversible resampling filter such that the edges in the sheared block are oriented either vertically or horizontally. The conventional 2-D DWT is applied to the sheared block and, thus, provides vanishing moments along the edges. The more recent work of the *directionlets* achieves this ability by adapting both the wavelet filtering direction and the subsampling grid to the image feature orientation without resampling [24]. The two approaches share the same limitations. First, independent processing of image blocks fails to exploit the correlation across block boundaries and can produce blocking artifacts in the reconstruction. Second, support for spatial scalability is limited since the subsampled low-pass image no longer resides on a regular orthogonal grid.

The direction-adaptive DWT (DA-DWT) locally adapts the filtering directions to image content based on directional lifting. With the adaptive transform, energy compaction is improved for sharp image features. A mathematical analysis based on an anisotropic statistical image model is presented to quantify the theoretical gain achieved by adapting the filtering directions. The analysis of this DA-DWT is more effective than other lifting-based approaches. Subjectively, the reconstruction from the DA-DWT better represents the structure in the image and is visually more pleasing.

Discrete Shearlet Transform is used to represent the geometrical features of an image in an efficient manner[25]. The main task in image compression is finding an efficient image representation that characterizes the significant image features in a compact form. One of the most useful features of wavelets is their ability to efficiently approximate signals containing point wise singularities. However, wavelets fail to capture the geometric regularity along the singularities of surfaces because of their isotropic support. Several image representation have been proposed to capture the geometric regularity of a given image[26],[27],[28],[29],[30] & [31]. They include curvelets, contourlets, bandlets. The discrete shearlet transform (DST) is developed, which provides efficient multiscale directional representation and show that the implementation of the transform is built in the discrete framework based on a multiresolution analysis (MRA). The performance of the DST in image approximation outperforms the discrete wavelet transform (DWT) while the computational cost of this scheme is comparable to the DWT.

D. Summary on image compression techniques

Thus different algorithms and methods have been proposed for image compression. The quadtree based image compression is easy to implement but the compression ratios are dependent on the threshold values, which can be affected either quality or compression ratio. The Fractal based image compression is also efficient method. The high computational complexity is the main drawback of full search FIC. Another drawback of the fractal image compression algorithm is the poor retrieved image qualities when compressing corrupted images

Efficient and reliable compression techniques for remote sensing imagery become more and more necessary as the number and size of images to be archived and transmitted over general purpose networks grow constantly. Various methods have been proposed for image compression. In DCT based lossy image compression, the use of uniformly sized blocks simplified the compression system, but it does not take into account the irregular shapes within real images. The block based segmentation of source image is a fundamental limitation of the DCT-based compression system. The degradation is known as the "blocking effect" and depends on block size. A larger block leads to more efficient coding, but requires more computational power. Image distortion is less annoying for small than for large DCT blocks, but coding efficiency tends to suffer. Vector quantization (VQ) is another lossy compression technique which is used to achieve high compression ratio. But the implementation of VQ is more complex while increasing code vector size. The subband coding algorithm based on discrete wavelet transform has been proven to be a feasible alternative to the aforementioned techniques. In DWT, the complexity of calculating the DWT depends on the length of wavelet filters and also it fails to represent geometrical features of an image in all directions. In DWT based compression, to achieve high compression ratio, the high frequency components considered important for the reconstruction of image details are discarded. The reconstructed image is blurred and exhibits adverse ringing artifacts.

Then multi directional transform is introduced for efficient representation of the geometrical features of the image in all directions [33],[34],[35],[36],[37],[38] & [39]. First multi directional wavelet transform is contourlet, in which bases are constructed with elongated basis functions using the combination of a multiscale and a directional filter bank. However, contourlets have less clear directional features than curvelets, which leads to artifacts in compression. Bandelets [34] are representation elements adapted to the function that is represented. Asymptotically, the resulting bandelets are regular functions with compact support, which is not the case of contourlets[37]. However, in order to find basis optimally adapted to an image of size , the bandelet transform searches for the optimal geometry. For an image of pixels, the complexity of this best bandelet basis algorithm requires extensive computation [38].

To improve the image compression performance rather than current standards and existing methods, it is necessary to find, an efficient transform which represents geometrical features of an image in all directions with less computations unlike wavelet transform. Hence for this proposed method, the shearlet transform and the tetrolet transform are selected for representing geometrical features of an image in efficient manner.

3. Literature Survey on Segmentation based Image Compression

An efficient(high CR & PSNR) and reliable(adaptive) compression techniques for remote sensing imagery become more and more necessary as the number and size of the images to be archived and transmitted over general purpose networks grow constantly. Moreover all the remote sensing imagery are having huge amount of high frequency components. So it is important to achieve high compression ratio while maintaining moderate computational complexity of implementation and high visual quality of the reconstructed image, and is possible by only Segmentation based image compression.There are number of segmentation based image compression methods have been proposed for general and remote sensing images.

A lossless Image Compression Algorithm Using Variable Block Size Segmentation was proposed [39]. The redundancy in digital image representation can be classified into two categories: local and global. In this work , a lossless image compression scheme that exploits redundancy both at local and global levels in order to obtain maximum compression efficiency. This algorithm segments the image into variable size blocks and encodes them depending on the characteristics exhibited by the pixels within the block. This performance of this algorithm is superior than other lossless compression schemes such as the Huffman, the arithmetic, the Lempel-Ziv and the JPEG. But estimating the distribution of image characteristics and the resulting compression efficiency is a very difficult task due to the huge amount of computations involved.

The block-based MAP segmentation for image compression was proposed [40]. Here, the segmentation algorithm using the maximum a posteriori (MAP) criterion was used. The conditional probability in the MAP criterion, which is formulated by the Bayesian framework, is in charge of classifying image blocks into edge, monotone, and textured blocks. On the other hand, the *a priori* probability is responsible for edge connectivity and homogeneous region continuity. After a few iterations to achieve a deterministic MAP optimization, a block-based segmented image in terms of edge, monotone, or textured blocks are obtained. Then, using a connected block labeling algorithm, then assigned a number to all connected homogeneous blocks to define an interior of a region. Finally, uncertainty blocks, which are not given any region number yet, are assigned to one of neighboring homogeneous regions by a block-based region-growing method. During this process, also need to check the balance between the accuracy and the cost of the contour coding by adjusting the size of the uncertainty blocks. This algorithm yields larger homogeneous regions which are suitable for the object based image compression.

An edge-preserving image compression model based on subband coding is presented[41]. The extracted edge information from the source image used as a *priori* knowledge for the subsequent reconstruction. The edge information can be lossily conveyed. Subband coding is used to compress the source image. Vector quantization, a block-based lossy compression technique, is employed to compromise the bit rate incurred by the additional edge information and the target bit rate. Simulation results have shown that the approach could significantly improve both the objective and subjective quality of the reconstructed image by preserving more edge details. Specifically, the model incorporated with SPIHT (set partitioning in hierarchical trees) outperformed the original SPIHT with the 'Baboon' continuous-tone test image. In general, the model may be applied to any lossy image compression systems.

Hannes investigated highly image-adaptive partitions in order to improve the rate-distortion performance of fractal coding[42]. This fractal coder can be seen as a combination of segmentation-based image coding and fractal compression. The partitions are derived in a bottom-up approach using region merging. The image is first uniformly partitioned, and then neighboring range pairs are successively merged reducing the total number of partitioned blocks (ranges) one by one. Because of the large number of choices during the merging process, a heuristic strategy has to be applied which performs well. Moreover, an efficient coding scheme for the resulting partitions. The region merging strategy and the efficient partition coding have led to a much improved rate-distortion performance compared to the results reported in [43], e.g., a gain of about 5 dB PSNR is obtained for the Lenna image at a compression ratio of 40. But compared to hierarchical tree-structured partitions a higher rate is required for encoding the irregular partitions. However, this investment pays off in terms of an improved rate-distortion performance.

An efficient image compression algorithm based on energy clustering and zero quadtree representation (ECZQR) in the wavelet transform domain is proposed [44]. In embedded coding, zeros within each subband are encoded in the framework of quadtree representation instead of zerotree representation. To use large rectangular blocks to represent zeros, it first uses morphological dilation to extract the arbitrarily shaped clusters of significant coefficients within each subband. This encoding method results in less distortion in the decoded image than the line-by-line encoding method. Experimental results show that this algorithm achieved high coding efficiency and fast encoding/decoding.

The multiscale segmentation for image compression is presented [45]. Multiscale segmentation is obtained using a transform [46] which provides a tree-structured segmentation of the image into regions characterized by grayscale homogeneity. In this algorithm, pruned the tree to control the size and number of regions thus obtaining a rate-optimal balance between the overhead inherent in coding the segmented data and the coding gain that derived from it. An image model is used for comprising separate descriptions of pixels lying near the edges of a region and those lying in the interior. The results shown that, the performance is comparable to the JPEG lossless compression standard for a wide range of images.

A hybrid coding system that uses a combination of set partition in hierarchical trees(SPIHT) and vector quantization (VQ) for image compression is presented[47]. Here, the wavelet coefficients of the input image are rearranged to form the wavelet trees that are composed of the corresponding wavelet coefficients from all the subbands of the same orientation. A simple tree classifier has been proposed to group wavelet trees into two classes based on the amplitude distribution. Each class of wavelet trees is encoded using an appropriate procedure, specifically either SPIHT or VQ. Experimental results show that advantages obtained by combining the superior coding performance of VQ and efficient cross-subband prediction of SPIHT are appreciable for the compression task, especially for natural images with large portions of textures. This hybrid coding outperforms SPIHT algorithm.

Distributed source coding theorem based region of interest image compression method is presented[48]. Region-of-interest (ROI) image compression is a new feature in JPEG2000, which allows the ROI to be encoded with better quality than the rest of an image, i.e. background (BG). Two kinds of ROI coding methods are

i. The scaling based method and
ii. The maximum shift (maxshift) method.

There are two major drawbacks to these methods. First, they would significantly reduce the compression efficiency by increasing the dynamic range (or number of bit-planes) of wavelet coefficients. Secondly, they do not have the especial protection for the ROI against the bit errors in image communication applications.

An efficient image segmentation algorithm developed by using the Discrete Wavelet Frame Transform (DWFT) and Multiresolution Markov Random Field (MMRF)[49]. This algorithm avoids the over-segmentation that is common in other segmentation algorithms. The experiments show that the proposed algorithm is very robust and it can be successfully used under noisy conditions.But the over segmentation problem can be avoided only by deliberately choose the level of DWFT for MMRF.

Hierarchical Segmentation-Based Image Coding Using Hybrid Quad-Binary Trees is presented [50]. A hybrid quad-binary (QB) tree structure is utilized to efficiently model and code geometrical information within images. The QB-tree is a compromise between the rigidity of discrete space structures of quadtrees, which allows spatial partitioning for local analysis, and the generality of Binary Space Partitioning tree, which facilitates the creation of more adaptive and accurate representations of image discontinuities. Here a novel image approximation technique using the QB-tree, which is a hybrid structure of the binary and quad-trees. The QB-tree image decomposition is able to:

i. avoid excessive fine partitioning over complex linear features, e.g., junctions, corners, bars and ridges and, hence, thereby obtaining a more efficient single-scale representations of these features;

ii. improve visual representations by producing a more meaningful geometric description of images at coarser scales.

The simulation results of this method shown that this method consistently outperforms other image approximation methods in subjective observations especially for images that contains significant geometrical structures and in low bit rates.

A new approach of edge preserving and edge based segmentation for compression of images using Modified Fast Haar wavelet transform (MFHW) and Bit Plane Encoder to elevate the compression ratio with high picture quality is presented [51]. The edges of an image are preserved to increase the PSNR, and then the detected edges are used to segment the foreground and background images. The Foreground of the image is given more importance than the background images. A wavelet transform is used to extract the redundant information at low frequency and a matching Bit Plane encoder is used to code the segments of the image at different quality levels. This method highly preserves quality of the foreground image. Normal compression algorithms will not preserve the high frequency details such as edges, corners etc., in this method edges are preserved and used for segmenting the layers of the original image. The two level Fast haar Wavelet transform is used to decompose the image at different frequency levels, which has high multi-resolution characteristics. This method increases both the compression ratio and PSNR. But this method only considered edge information in the image and lost remaining geometrical features of the image.

Multiscale methods based on wavelets, have been successfully applied to the analysis and detection of edges. Despite their success, wavelets are however known to have a limited capability in dealing with directional information. Every aforementioned segmentation based compression methods have their own advantages and disadvantages. In the whole, the price for improving reconstructed image quality at high compression ratio is computationally expensive due to segmentation map. Hence in the proposed method, multidirectional transform is used for image compression. In multidirectional transform the transform itself is used to preserve the geometrical features of an image.

4. Conclusion

In this survey, the merits and demerits of various segmentation based image compression techniques are analyzed in detail. The transform based image compression is preferred in real time because it's easy implementation. Hence various transform coding is discussed in detail. When there is need to preserve edge information for reducing visual artifacts then should preferred either segmentation based image compression or multidirectional transform, which improves compression ratio as well as PSNR. The penalty for this improved performance is computational complexity. Hence hybrid transform or techniques may used to solve the computational complexity.

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