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A Review on Compression Methods for JPEG Image Collections

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Abstract: Owing to the massive developments in the field of photography, photos are something very common these days. With the fast development and prevailing use of handheld cameras, cost as well as required photography skills is much lower than before. This has created a significant problem of storage for personal devices and cloud platforms. Image compression involves reducing the number of bits needed for representing an image, and lossless compression in particular is employed when we need to get the original image reconstructed perfectly from the compressed image. In this paper, a study of different methods used for compressing JPEG image sets is carried out.

Keywords: Image compression, lossy, lossless, JPEG, recompression, image set, image collection, image coding.

I. INTRODUCTION

The increasing number of digital photos on both personal devices and the Internet are creating issues with their storage. As the required photography skills are much lower than it was before, the users today have gotten used to taking and posting photos with mobile phones,digital cameras, and other portable devices to record daily life, share experiences, and promote businesses.A recent survey states that Instagram users have been posting an average of 55 million photos every day [1]. Facebook users are uploading 350 million photos each day [2].Storingand maintainingthis enormous amount of photos in an efficient wayhas become a problem which needs to be addressed as soon as possible.

One of the possible and popular way to reduce the size of photos is via JPEG compression [3].The size of the photos which are taken in realistic scenes with smooth variations of tone and colour are effectively reduced.The compression of unordered collections of multimedia data potentially uploaded by differentusers proves to be a new and challenging task in the signalprocessing world [4]. Also we see that most of these images are similar ones, compressing each of them individually is time consuming and not practical in most of the cases.

Though several superior formats such as JPEG 2000 [5] and JPEG XR [6] have been developed subsequently,the JPEG baseline is exclusively used as a commonand default format in almost all imaging devices like digitalcameras and smart phones.Also consequently most of the images get saved in JPEG format these days. However JPEG baseline leaves huge scope of further compression. Intra redundancies are not taken into account in agreat deal. In fact the most important aspect in compression of photo collections is taking into account both inter and intra redundancies as image collections will obviously have similar images as well as different ones.

Different methods have evolved over the years for compressing image collections.

The paper is organised as follows. Section II gives an account of different image compression schemes. Section III gives an idea about different methods for JPEG image set compression. A table comparing the performance of different methods is also provided in the section. Section IV concludes the paper.

II. LOSSY AND LOSSLESS COMPRESSION

These are the two compression schemes that are commonly used for image compression. Lossy compression does not have the provision of recreating the original image from thecompressed image whereas the original image can be obtained by recompressing the compressed image in the case of lossless compression [7].

A. Lossy Compression

Here, the original data is not exactly reconstructed from the compressed image.The main application of the scheme is in image data compression and decompression.The compression ratio obtained will be comparatively high for this than the lossless scheme. Lossy compression algorithms are transform coding,Karhunen-Loeve Transform (KLT) and wavelet based coding[6].

The three steps are transform coding, quantization and entropy coding.

The first step of a transform code is eliminatingthe inter-pixel redundancy so that information can be packed efficiently. It is a common method for lossy image compression. It decorrelates the original image into a set of constants in transform domain. The constant subsequently gets quantized and is successively coded in transform domain.

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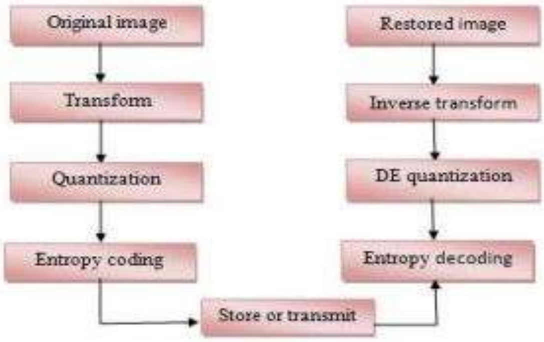

Fig. 1.Lossycompression scheme

The basic Principle of transformation is translating the data into some form where compression is easier. This process will transform the pixels that are connected into a demonstration where they are decorrelated[8].
The aim of quantization is to lower the precision and achieve better compression ratio. Following this, a quantization is applied which inturnremoves psycho-visual redundancy so as to represent the packed information with as few bits as possible. A set of values are replaced withonly one representative value by means of quantisation. Scalar and vector quantisation are basically carried out for the purpose. The former performs many one to one mapping on all value whereas the latter replaces each block of input pixels through the indicator of a vector through in the codebook.This procedure effectively reduces the number of bits required to store numerical value by means of reducing the accuracy of the integer[8].
Then it is entropy coded finally to obtain the compressed image.

B. Lossless Image Compression

Lossless compression aims at compressing the file by reducing the information in such a way that there is no loss when the compressed file is decrypted back to the initial file. It mainly finds application in instances where it is very particular that the original image be exactly reconstructed from the compressed one. Thus it mainlygets used in images, computer data bases, copy forms, computer applications etc. The compression ratio will be lower when compared to lossy compression. The compression algorithms include Huffman, run length, LZW etc.

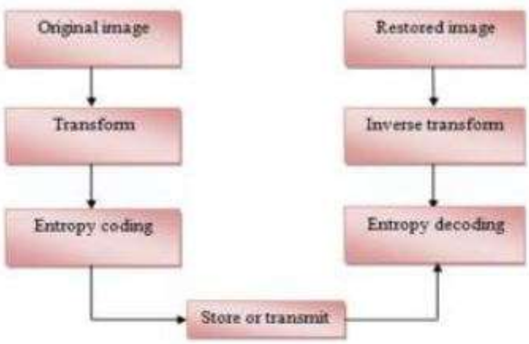

Fig. 2.Lossless compression scheme

Lossless compression is mainly based on two step algorithms; first step being somewhat similar to lossy compression where the original image gets transformed to some other format in which interpixel redundancy is concentrated and consequently removing the coding redundancy using an entropy coder. The decompressorworks exactly opposite to the compressor in order to obtain the original image.

The first block in the process is transform coding just like in lossy scheme.Here knowledge of the application is used to choose information that is to be discarded. The rest is compressed using entropy coding.
The primary objective of entropy coding is accomplishing less average length for image. Here code words are assigned to equivalent signals according to the possibility of the signals. The minimum size of data set required to express a particular amount of information is represented by 'Entropy'. The process is generally categorised as modelling and coding. The common schemes used include Huffman coding, LZ (Lempel-Ziv) and arithmetic coding. Huffman coding utilises variable length code where short code words are assigned to more common value and longer codes for lesser frequently occurring values.Modified Huffman coding and dynamic Huffman coding are the two variants of Huffman

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technique. LZ scheme replaces repeated substrings in the input data by means of references of the previous instances of strings. LZ7742 and LZ7843 are the two different approaches in this compression scheme [8].
Hence, entropy coding further compresses the quantized value in lossless manner although the compression ratio will be less than that of lossy scheme [8].

III.DIFFERENT COMPRESSION METHODS FOR PHOTO COLLECTIONS

The image collections eat up a lot of space when they are stored. With development in the field of photography, taking photos has become an easy and common thing and people are eager to capture every precious moments which helps them to cherish those memories for a long time. So storage and backing up are becoming alarming issues. So compression mechanisms are applied to these image sets so that they can be restored without much difference in quality and reducing their size at the same time.

A.Lossless Compression of Individual JPEG Images

This one of the most straight forward way to reduce the storage size of a JPEG coded image losslessly. Here the arithmetic coder replaces an existing Huffman coder in the basic JPEG baseline compression scheme [9]. JPEG extension in fact already supported an adaptive binary arithmetic coder which reduces the file size by 8-10% [10]. Better performance is achievable if intra-block correlation in the intra prediction is effectively exploited. Designing of a dedicated entropy coder also adds to this. A study is proposed with help of which quantised DCT coefficients can be effectively separated into bit planes and context models can be designed with regard to the correlation of coefficients that are within a block, between neighbouring blocks and among different colour layers. It is then possible to re order or group the quantised DCT coefficients based on their similar statistical properties either using sorting transform where the order of DCT coefficients get predicted from the previous coded blocks or by using three scan patterns for middle low and high bands respectively for arithmetic coding. Another approach is proposed which is based on derivation of one dimensional DCT coefficients of boundary columns or rows from those of adjacent blocks succeeded by an adaptive predictive entropy coding method. Another approach proposed is based on employing a H.264 alike intra prediction method which exploits the inter-block correlations of quantised DCT coefficients before the adaptive arithmetic coder [11].
This image works efficiently when it comes to compressing single images. This is mainly due to the fact that all the techniques listed under this mainly relies on exploiting redundancies within each image, not across images. Photo collections are bound to have correlated images as a result of which inter-image redundancies will be produced. This inter image redundancy across the images remain unaddressed in this method. Thus this method is not that efficient when it comes to compression of an image set rather than a single image.

B.Image Set Compression

This can be applied when we are dealing with a group of correlated images. The compression schemes coming under this scheme can be broadly divided into two classes.
The first class approach generates a representative signal (RS)which is an average image from all correlated images used to extract the common redundancy among them. After that, both RS and difference image between each correlated image and the RS are compressed. Approaches in this class puts effort into average image generation mainly by Karhuen-Leove transform(KLT) [12], Centroid method [13] and max min predictive method [14].However these approaches are bound to work efficiently only when the images in a set or collections are similar enough but have the same limitation of the previous method when dealing with general image sets. It is mainly because they are not robust enough with respect to rotation, scale and illumination changes which are same for an image set. Also they are not sufficiently capable of exploiting pair wise image correlation between images as different pairs of image have different correlations [11].
The second class of approach focuses on pair-wise correlations between images. In this, one group finds optimal coding order for an image set. The image set can be clustered by minimum spanning forest (MSF) and each cluster can be described by a minimum spanning tree coded with inter image prediction.Though it is better compared to RS based method, this method also loses efficiency when dealing with sets having large variations in rotation, scaling and illumination [11].
This method compresses the pixels in images in a lossy way. But when obtaining the initial image from the compressed one is an objective, the method is subsequentlyextended for lossless compression. But it becomes worse in that case in terms of its performance as they do not take in consideration the JPEG coding effects at all. This is one necessary step when we deal with JPEG images and skipping this leads to poor compression.

C. Compression Based on Low Frequency Template

This method is applicable for similar image sets. The compression is done in a lossless way. The theory of the method is that the frequency components of images are very much similar to other images as the images under consideration

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are similar in this case. The method involves computing a low frequency template extracted from the image sets. This template is used as prediction for each image in computing its residue [15].

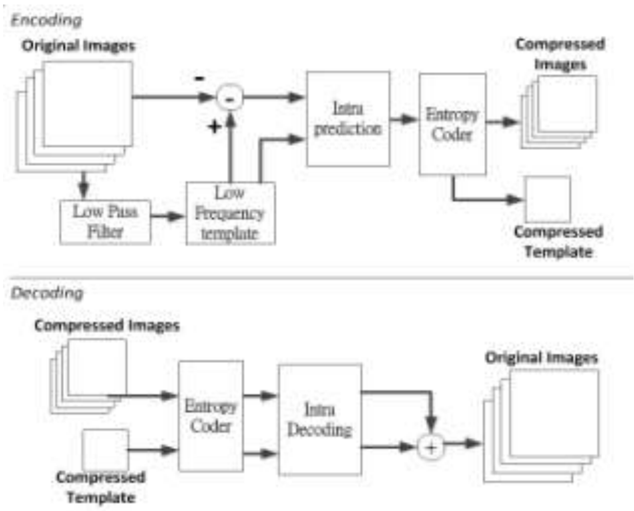

Fig.3.Low frequency template based compression block diagram

The theoretical model aims at reducing the entropy and hence lowers the bit rate. The experiments conducted relating this proves there is almost 30% gain over the existing set redundancy methods. The method can be also be applied practically as it is very flexible in its updates and the model is actually a lot simple.The similar images are considered as low frequency while details of the images as high frequency. Compared to the motion compensation technique used in video compression, this method is superior as it has more tolerance to the alignment of the image. A draw back of the method is related to the alignment of the images in a set as they are often out of phase. The block diagram of the method is shown by fig 3, which shows the simplicity of the model, especially at the decoder side [15].
This method has over 25% gain when compared with other method existing methods back then namely centroid and MMPM.The method ismore tolerable to alignment of the images and as the gain is more significantly seen in smaller image sets, this method works well when we categorise the large image sets into smaller image sub sets. The method compresses JPEG images in a lossy way whereas approach is lossless in case of grey scale images with transformation and quantisation being the last two steps respectively.The method works excellent for grey scale images but gives only satisfactory performance when it comes to JPEG colour images.

D. Compression Based on Block-Adaptive Intra Prediction
This is also a lossless compression scheme where the images are compressed without much loss of quality. Here H.264 like block-adaptive is employed for compression. It successfully exploits the inter-block correlations of quantised DCT coefficients stored in the JPEG file.

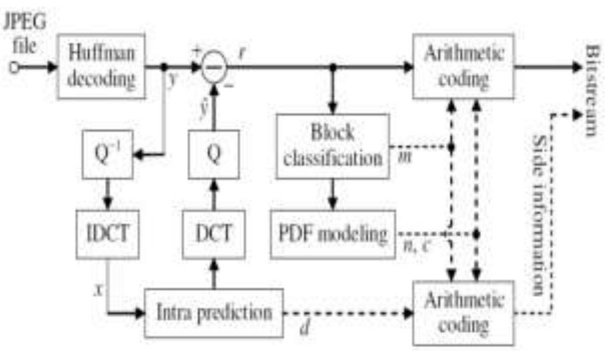

Fig.4. Block-adaptive intra prediction method block diagram

The prediction is performed in the spatial domain of each block composed of 8x8 pixels but the corresponding residues are calculated in the DCT domain. This ensures that reconstruction of coefficients is done in a lossless way. Also block based classification is carried out to allow the accurate modelling of probability density functions (PDF) of the

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prediction residuals.Amultisymbol arithmetic coder along with the PDF model is used for arithmetic coding of the prediction residual for each DCT coefficient [18].
Fig 4 depicts the basic block diagram for the process. Results of the method indicate that it has coding efficiency comparable with Stuffit scheme [16] [17] which gave the best compression during the period when this method was proposed. Further improvements areguaranteed for there is improvement in the intra predictive structure. Also additional reduction of 18-20 % coding rates is obtained for monochrome JPEG images [18].

E. Compression Based on Geometrical Information

The method provides a novel scheme for joint compression of photo sets framing same object or scenes. The approach begins by locating corresponding features in the various images and subsequently exploiting a structure from motion algorithm to estimate the geometric relationships between the various images and their view points. Then the 3D information and warping is used to predict images one from the other. In addition, graph algorithms are used to compute minimum weight topologies and identify the ordering of input images that maximises efficiency of prediction. The obtained data is fed to an HVEC coder to perform compression [20].
This is a good scheme when it comes to compression of unordered images. The 3D information provided by match key points [19] helps in finding corresponding visual information. Also graph based optimisation scheme involves the problem of finding correct image ordering.The experimental results show that compression is good for images taken with different camera and in different lighting conditions. The method but relies solely on geometric properties of the image which is a drawback.

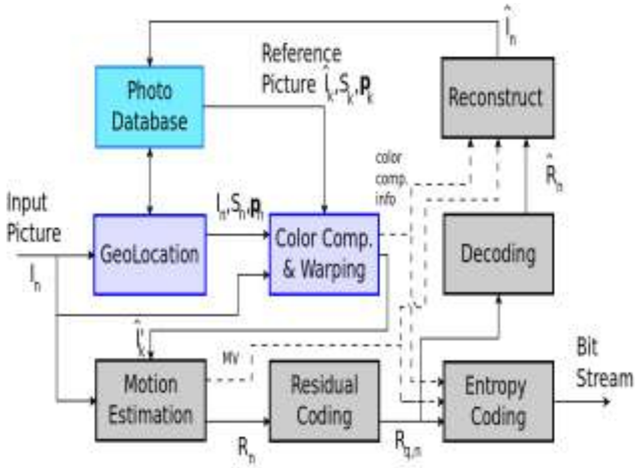

Fig.5.Geometric information based compression block diagram

F. An Innovative Compression Scheme for JPEG Photo Collections

This is by far the best lossless method among the all previous methods for compression of JPEG image sets. Here unlike other methods image collections are compressed by making use of both inter correlation among images and intra correlation within each image thereby enabling us to reduce the inter/intra redundancy in these domains respectively. For this purpose, images are converted into pseudo video by minimising the global prediction cost in the feature domain. This is followed by exploiting both the global and local correlations among the images in the spatial domain using a hybrid disparity compensation method. Subsequentlyredundancy between each compensated image and target image is is adaptively reduced in frequency domain.

Fig 6 depicts the architecture of the encoder block of the lossless encoder. For all the JPEG image collections,they are decoded before further compression, resulting in YUV image sets. Based on the similarity between each pairs in the feature domain, a prediction structure is determined which is essentially a minimum spanning tree(MST) from which children can be predicted from parent node.Intra and inter redundancies are exploited subsequently in the spatial domain. Differences between images are reduced using local and global compensation techniques, larger deformations being dealt by the former and smaller disparities by the latter. All the parameters of MST, transformations and modes are entropy coded and stored for the sake of use in decoding. Difference from other methods here are that, it is the predictive difference between each pair of compensated reference block that is taken into consideration. Also unlike decoded pixel values of input JPEG images, here the entropy decoded coefficients are taken as target information. Each compensated reference block is transformed to DCT domain followed by scalar quantisation. The resulting DCT coefficients are subtracted from target ones. The generated residues then get coded by context adaptive arithmetic coding. The last step involves mixing up coded residues and parameters to obtain the coded binary file [11].

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Fig 7 shows the decoding process of the same. The first step involves decoding intra coded root image in the MST. Quantised decoded coefficients are subsequently recovered by means of adding decoded residues to the DCT transformed and quantised intra-compensated predictions. They then get inversely quantised and DCT transformed providing recovered pixels of the block which are buffered as reference for subsequent coding. Quantised DCT coefficients are recovered for each inter-coded image by adding decoded residues to the compensated signal in the frequency domain where the compensated signal gets generated by local and global compensations. Pixels of original image are hence obtained by inverse quantisation and DCT. JPEG binary image on the other hand is recovered by recompressing quantised DCT coefficients by entropy coding in JPEG [11].
Bit savings of almost 48% is obtained here and it can be further improved by using parallel techniques to improve the encoding and decoding process and also by reducing the complexity of local compensation by reducing the overall complexity. Feature based distance approximation should also be improved by means of an advanced distance matrix which takes into account both matched figures as well as overlapped area of images in the image set.

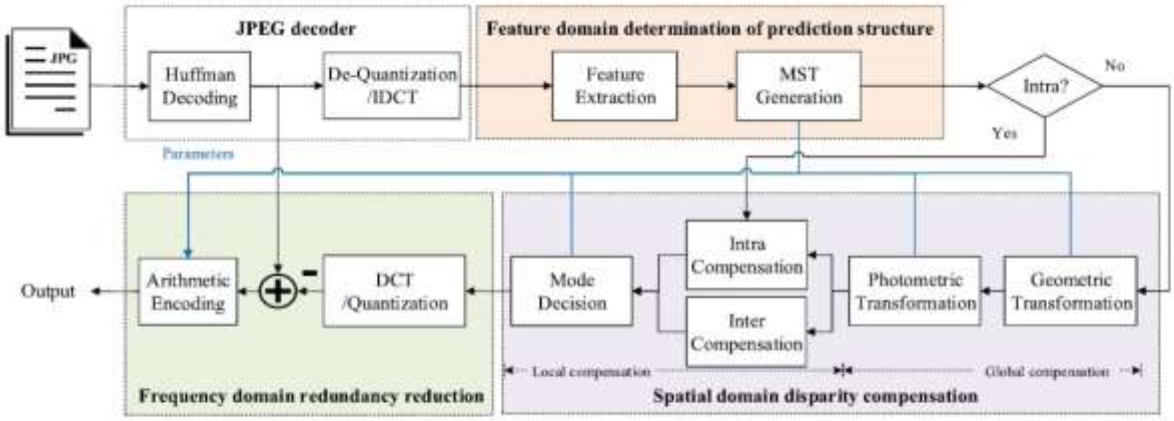

Fig.6.Block diagram of encoder section

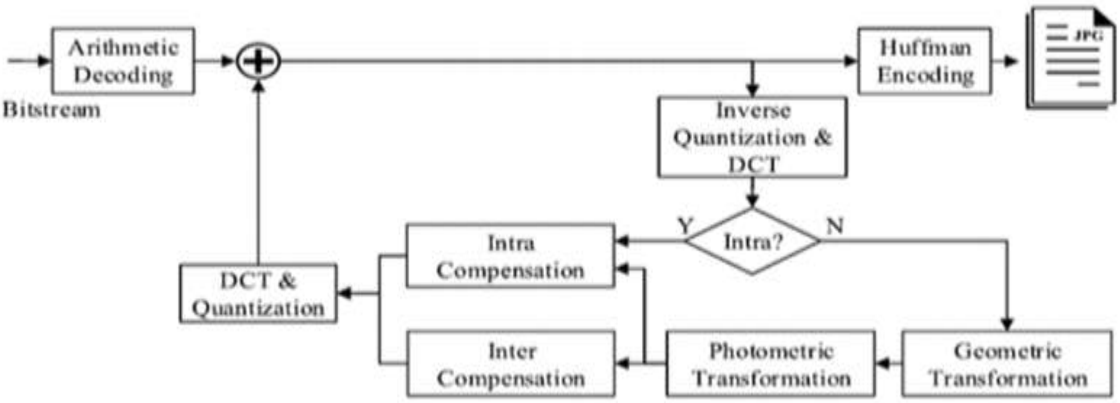

Fig.7.Block diagram of decoder section

TABLE I COMPARISON OF DIFFERENT COMPRESSION METHODS

Methods	Advantages	Disadvantages
Individual JPEG images [11]	Simple implementation Uses an Huffman coder instead of arithmetic coder in basic JPEG compression Works effectively for individual images	Correlation among different images are not taken into consideration Less efficient when applied for a group of images
Image set compression [11]	Correlation among images are taken into consideration	RS approach works well only when the image sets are similarand it fails to exploit the pair wise correlation between different images

		Lossless compression is not as efficient as lossy compression The approach based on pair wise correlation fails when dealing with images having large variations in rotation, scale and illumination
Low frequency template [15]	Works efficiently for similar images compared to the existing methods Over 30% of gain is obtained Has tolerance to the alignment of the images	Alignment of the images under consideration are usually out of phase Fails when dealing with different images in a set
Block-adaptiveintra prediction [18]	Compression without much loss of quality Successfully exploits inter block correlations of quantised DCT coefficients A multi symbol arithmetic coder is used for coding of prediction residual for each DCT Has Coding efficiency comparable with Stuffit scheme [16][17] which was the best existing method then	Monochrome JPEG images have 18-20% coding rate reduction. Intra prediction method has scope of improvement which can reduce coding rate for normal JPEG images
Geometrical information [20]	Uses 3D information and warping to predict images from one another Graph based optimisation schemes used in finding correct image ordering	Method rely solely on the geometric properties of the images Only applicable to photo set which frame same objects
An innovative compression scheme for JPEG photo collections [11]	Bit savings of almost 48% Takes into account both inter and intra correlations; Operations being carried out in feature, spatial and frequency domains Disparity between images is reduced using local as well as global compensation techniques Entropy coded coefficients are taken as target information rather than decoded pixel values of input images	Clustering of images are time consuming when image collections are large The clustering module is complex for large scale image sets. Feature based distance approximation is not always efficient

IV. CONCLUSION

In this paper, different methods for compressing JPEG image collections are reviewed. As the numbers of photos being captured are increasing, storing of them often consumes a lot of space. This has made efficient compression of image collections in order to reduce their size all the more relevant in the current scenario. Different methods including lossy and lossless are considered.

The core idea behind image set compression is that redundancies among the images in a set should also be taken into consideration rather than the redundancieswithin a single image. The former methods were all based on this genre, as they involved extending the methods for a single image to an image set. These methods thus didn't provide the efficiency they were expected to give when applied to similar images. Also some of those which actually worked for image sets were lossy ones, it was difficult to decrepit the original images from the encrypted ones which is a primary concern in some cases. Some other methods do not take into account the alignment of the images. Also compression based on block adaptive prediction is an improved technique comparing other techniques but the intra predictive structure needs to be improvedfor better compression. Compression based on geometric compression is also discussed but it also needs further improvement as it takes into account only geometric features of the images. The best one among the methods is an innovative compression method which operates in spatial, frequency and feature domain. Inter and intra correlations are effectively exploited here and thus best bit savings are obtained in this method.

Various methods of image set compression are reviewed. New methods are developing which gives better compression performance. This review paper intends to give idea about different compression methods for image sets.

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