Project Thesis (2013-14)

Submitted to **NIT Rourkela** in partial fulfillment of requirements for the **Award** of **B-Tech Degree** during Academic Year 2013-2014.

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Efficient Video Compression Schemes using the DCT approach

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CONTENTS

Pages

List of Tables :

List of Figures:

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CERTIFICATE

This is to certify that the thesis titled "**Efficient Video Compression Schemes using the DCT approach**" submitted by Sri **Konapala Prem Shankar** in partial fulfillment of **Bachelor of Technology** in **Electronics and Communication Engineering** at **National Institute of Technology, Rourkela** is an authentic work carried out by him under my supervision and guidance.

Prof Sukadev Meher
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DECLARATION

I, hereby declare that the project work entitled "**Efficient Video Compression Schemes using the DCT approach**" is a record of our original work done under **Prof. Sukadev Meher** in **National Institute of Technology, Rourkela**. Throughout this documentation wherever contributions of others are involved, every endeavor was made to acknowledge this clearly with due reference to literature. This work is being submitted in the partial fulfillment of the requirements for the degree of **Bachelor of Technology in Electronics and Communication Engineering** at National Institute of Technology, Rourkela for the academic session 2010– 2014.

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ACKNOWLEDGEMENT

An endeavor over a long period can be successful only with the advice and support of many well-wishers. I now take this opportunity to express our gratitude and appreciation to all of them.

I would like to express my gratitude towards my **Parents** for their kind co-operation and encouragement which help me in completion of my final year project.

I express my most heartfelt gratitude to my guide **Prof. Sukadev Meher, HOD**, Department of ECE, NIT Rourkela, for his invaluable guidance, technical supervision, valuable feedback and constructive discussions & suggestions for improving the quality of my project at NIT Rourkela. Without his involvement and supervision it would have been impossible to complete final year project.

Last but not the least; I would like to express my special gratitude and thanks to my friends, especially **Vivek Krishna** for giving me such attention and time for my project.

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ABSTRACT

To store an uncompressed colour video, even the DVDs of 5 Gbytes are not capable of handling more than few minutes of video. Hence video compression has become very essential. There are two types of compression: lossy and lossless. Generally the video compression is lossy as it checks for areas of redundancy between the successive frames and saves only the differences between the frames. Although the modern video compression techniques are well advanced, video compression still uses the basic steps in image compression and principles such as motion estimation and compensation are implemented to achieve compression in the video. In this project, the DCT method is applied to achieve the compression as the DCT algorithm is symmetrical, efficient and easy to implement. The main objective is to reduce the size of the video without much loss in the information. Video compression is always a tradeoff between the quality and the compression ratios. To achieve higher compression ratios, loss in the quality has to be acceptable. All the required coding is done using the MATLAB software.

Chapter 1 - THESIS OVERVIEW

1.1 Thesis Motivation and Background:

In today's world, video compression is a very important tool to save the amount of space the video uses for its storage. Video is nothing but the transmission of individual frames/images at a faster rate (usually 25 frames per second for a movie). Instead of sending each frame one after another, the differences in the frames can be stored and transmitted to reduce the size and also to save time. This is the actual idea behind the video compression technique. In recent days, as the video streaming has been the trending topic, compression of the video has become more significant and vital. Compression can be either lossy or lossless. With the lossless compression, after reconstructing the original image using some decompression technique, the final image obtained is numerically equal to the input image. The lossless compression technique can be applied to video also but this is seldom used, as the lossy compression provides better compression ratios without much loss in the quality of the video.

There are many compression techniques for compressing the video or image. One of the most common methods of video compression is the Discrete Cosine Transform method. In spite of several advanced video compression methods being used, the basic steps used for still image compression can also be used along with the inclusion of motion estimation and compensation. In this project, video compression is achieved by applying the Discrete Cosine Transform method.

1.2 Achieving Compression:

In a given video, similarities exist among different frames, generally among the neighbouring frames. This is called redundancy. Exploiting those redundancies is the primary aim for video compression. In a video signal, redundancy can be observed mainly in two forms. One of them is the spatial redundancy which exists in every frame. The other one is the difference between the corresponding frames, known as the temporal redundancy. Spatial redundancy can be eliminated by using basic image

compression techniques but in order to remove temporal redundancy, certain techniques like motion estimation and compensation are to be used definitely.

In some videos, neighbouring frames contain the same data, either still or moving. Inter frame coding can be applied to such videos for achieving compression. Inter frame type of coding uses powerful techniques such as motion estimation and compensation to remove the temporal redundancy due to high correlation between the successive frames. But in some other videos, motion may involve more complexity. In such videos, estimation becomes difficult and large amount of processing may be required to achieve compression.

1.3 Literature Review:

Since it is known that video compression can be achieved by using image compression techniques on each frame of the video and then applying techniques such as motion estimation and compensation, it is always a better idea to have some knowledge about how to apply motion estimation technique to achieve compression. Though the actual project is based on applying DCT to achieve compression, many other algorithms have also been studied and some of them are described in this literature review.

Several algorithms have been developed for motion estimation by different researchers. Usually, two types are mostly discussed in the search types of motion estimation. They are:

1) Pixel based motion estimation
2) Block based motion estimation

In the pixel base motion estimation, motion vector for every pixel in the image is determined. This is based on the fundamental principle that the intensity of a pixel remains constant even it is displaced, hence this is also called optimal flow method. But in the direction normal to the intensity gradient, there is no unique match for the pixel in the reference frame. Hence an additional constraint is introduced in the neighborhood in terms of smoothness displacement vector. Because of this

smoothness constraint, the algorithm requires large time for executing and practically this is not suitable for real time applications.

That is why, the block based motion estimation has become more popular for its faster approach. Also, the computational complexity of this model is much lower compared to the pixel based motion estimation. This model takes an assumption that the image is made up of significant objects in translational model. This technique estimates the exact zooming motion in spite of the fact that the assumption is a major drawback in the presence of zoom. So, the block based motion estimation technique is used more widely and practically produces better results. This is extensively used in video compression for its simplicity and hardware implementation.

Block Matching algorithms differ in the following parameters :

1) The matching criteria
2) The search strategy
3) The determination of block size

In literature survey, many algorithms used for video compression are studied and it is observed that the practically used techniques for video compression are lossy compression techniques and the technique used in this project is the DCT method.

1.4 Scope of the project:

The main theme of this project is to work on different video compression techniques and implement the better and efficient techniques for compression. But the compressed video should not lose much information and even much loss of quality is also not expected. The size of the video should only be reduced but the compressed video should retain the quality of the original video. The DCT approach has produced the results but there are several other video compression techniques that give better compression ratios without much loss in the quality. In this project, the DCT approach is used for the video compression as it is one of the most fundamental and basic compression techniques.

1.5 Thesis Outline:

Chapter 2 discusses the fundamentals of video compression and different video compression formats and standards

Chapter 3 explains the exact objective of the project and how the DCT algorithm is applied to compress the given video

Chapter 4 shows the results obtained after applying compression techniques and the snapshots of the videos are also given

Chapter 5 concludes the thesis and references are represented at the end.

Chapter 2 - FUNDAMENTALS OF VIDEO COMPRESSION

2.1 Introduction:

The high requirement of bandwidth has been the major problem in a video. A typical system needs to send several frames per unit second so that the illusion of a moving picture can be generated. For instance, a colour video clip recorded with a resolution of 1920x1080 assuming 30 frames per second requires memory of 1.5 Gb for 1 second. This means even a DVD of capacity 5 Gb cannot handle a video of 4 minutes duration. It is exactly for this reason video compression has become very significant. To eliminate the redundancy, each individual frame is coded. Also with motion compensation, a great amount of redundancy can be eliminated between two successive frames. In spite of the continuous development in the storage space and transmission bandwidth now-a-days, as the amount of data obtained by digitalizing the video signal is huge, compression is very important in most of the digital video applications.

2.2 Video Formats:

A variety of video standards are there which define the resolution and colours for display. For a PC, both the monitor and the video adapter determine the support for a graphics standard. The monitor must be capable of displaying the resolution and the colours defined by the standard whereas the video adapter needs to transmit the appropriate signals to the monitor. Some of the popular video standards along with their respective parameters are listed here in tabular forms.

Table 1 displays the uncompressed bit rates of some video formats. It can be clearly observed that even QCIF at 15 fps (i.e., relatively low quality video suitable for video telephony) requires 4.6 Mbps for storage or transmission. Table 2 shows typical capacities of popular storage media and transmission networks.

Video format	Colour Resolution	Intensity Resolution	Bits per second (uncompressed)	Frames per second
QCIF	88 x 72	176 x 144	4.6 Mbps	15
CIF	176 x 144	352 x 288	36.5 Mbps	30
ITU-R 601	429 x 525	858 x 525	216 Mbps	30

Table 2.2.1: Uncompressed bit rates

Media/Network	Capacity
ADSL	Typical 1-2 Mbps (downstream)
Ethernet LAN (10 Mbps)	Maximum 10 Mbps / Typical 1-2 Mbps
V.90 MODEM	56 kbps downstream / 33 kbps upstream
ISDN-2	128 kbps
CD-ROM	640 Mbytes
DVD-5	4.7 Gbytes

Table 2.2.2: Typical storage capacities

2.3 Video Standards:

Basically there are two families of standards:

1) ISO/IEC (International Standards Organization and International Electro-Technical Commission)
2) ITU (International Telecommunications Union)

ISO/ IEC produced the MPEG standards which are the standard formats for video compression.

ITU-T developed several recommendations for video coding such as H.261, H.263 starting from 1984 till it was approved in 1990.

2.4 Fundamentals of Lossy Compression:

Lossy compression is applied usually to the video to obtain good results for compression. The name itself implies that the compressed video loses some information from the original one but also its size is reduced to a great extent. Though the quality of the compressed video is lower than that of the original video, the size of the compressed video is much lesser than the size of the original video. Lossless compression is the compression type in which the compressed file is used and the original file can be reconstructed exactly as before.

2.5 Representation of colours:

For displaying a perfect colour picture, three primary colours (red, green, blue) are basically needed. Because of this, every pixel contains minimum three different information channels. RGB and YUV are the generally used representation methods for colours. RGB includes the three primary colours along with the information about brightness. Generally the displays are monitored using this RGB representation. The colour space is divided into chrominance (colour) and luminance (brightness) in the YUV representation. Human beings are less sensitive to colour than to brightness. Hence the chrominance information can be suppressed than the brightness information such that most of the quality is not lost. YUV data also helps in deriving the 3 basic colours (red, green, blue). In video compression, as the YUV representation produces better compression results, this representation is extensively used than the RGB representation.

2.6 Video Compression Techniques:

There are several video compression techniques developed in the last two decades. However the DCT compression and the wavelet compression are used much extensively. In video compression, the video is converted into individual frames and then compression techniques are applied on the images to compress the given file. The compressed images are decompressed and again a video could be created from those so that the compressed video is obtained.

In the DCT method, the image is divided into small blocks and then the DCT is applied on each block. Applying DCT converts every pixel value into the frequency domain. DCT converts the pixel values into the frequency domain in such a way that the low frequencies are on the top-left and higher frequencies are on the bottom right. Then quantization is done so that the DCT coefficients become integers as they have been scaled by a scaling factor. By applying inverse discrete cosine transform (IDCT), original images can be reconstructed but not 100% similar to the actual ones.

In wavelet compression, the compression techniques are applied on the image as a whole (i.e., image need not be divided into smaller blocks). The aim of this compression technique is to store the image data in as little space as possible.

The standard formats for video compression such as the MPEG methods and the recommended methods such as H.261, H.263 are also used widely. MPEG standards are again developed periodically to meet the required demands with the progress of time such as MPEG-1, MPEG-2, MPEG-4, MPEG-7, etc.

2.6.1 JPEG:

JPEG is an acronym for Joint Photographic Experts Group. It is one of the compression techniques used for still image compression. It typically achieves a compression ratio of 10 upto acceptable loss of quality and as known already, there will be a tradeoff between the compression ratio and the quality. Generally most of the digital cameras save images in this format. For paintings on realities and for photography, JPEG is the best technique. JPEG is a type of lossy compression and it uses DCT approach to achieve the compression.

Figure 2.6.1: Left-original image and right-JPEG compressed image

2.6.2 Motion JPEG:

This is nothing but a series of still JPEG pictures. But the disadvantage is that it uses image compression techniques on the moving JPEG frames but no video compression technique has been used here. But it is also an advantage that if a single frame is lost during transmission, still the video will not be affected.

2.6.3 JPEG 2000:

This was developed after JPEG. Instead of the DCT approach used in the JPEG for compression, wavelet transformation is used in the JPEG 2000 and this technique achieves better compression ratios.

The main advantage of this technique over the JPEG is that the blockiness observed in the JPEG is removed and replaced by an overall fuzzy image, as shown in the following figure.

Figure 2.6.2: Left-original image and right-JPEG 2000 compressed image

2.6.4 Motion JPEG 2000:

This is also used to compress a video file. It has the similar advantages compared to the JPEG but with the tradeoff between complexity and the compression ratios, a better compression ratio can be achieved in this technique. This technique has the same drawback as that of the motion JPEG that it is just an image compression technique for individual frames but it does not perform any video compression techniques. This may result in the lower compression ratios compared to the real video compression schemes. As a video compression technique, motion JPEG 2000 has never been a success.

2.6.5 H.261/ H.263:

These are not the international standards but the recommendations by the ITU. They can be considered as the simplified versions of the MPEG techniques. Since they were actually developed for low bandwidth i.e., for applications like video conferencing; they cannot provide the efficient usage of the bandwidth as some of the most advanced MPEG techniques are not included in these techniques. Hence it can be conclude that H.261 and H.263 are generally not used for video compression.

2.6.6 MPEG-1:

This was the basic compression standard developed by the ISO/IEC family in the year 1993. The idea is to store the video files in a format suited to CDROMs. Using this standard, video is encoded at a data rate of less than 1.4 Mbps. This standard introduced the mp3 audio format which is the most popular today.

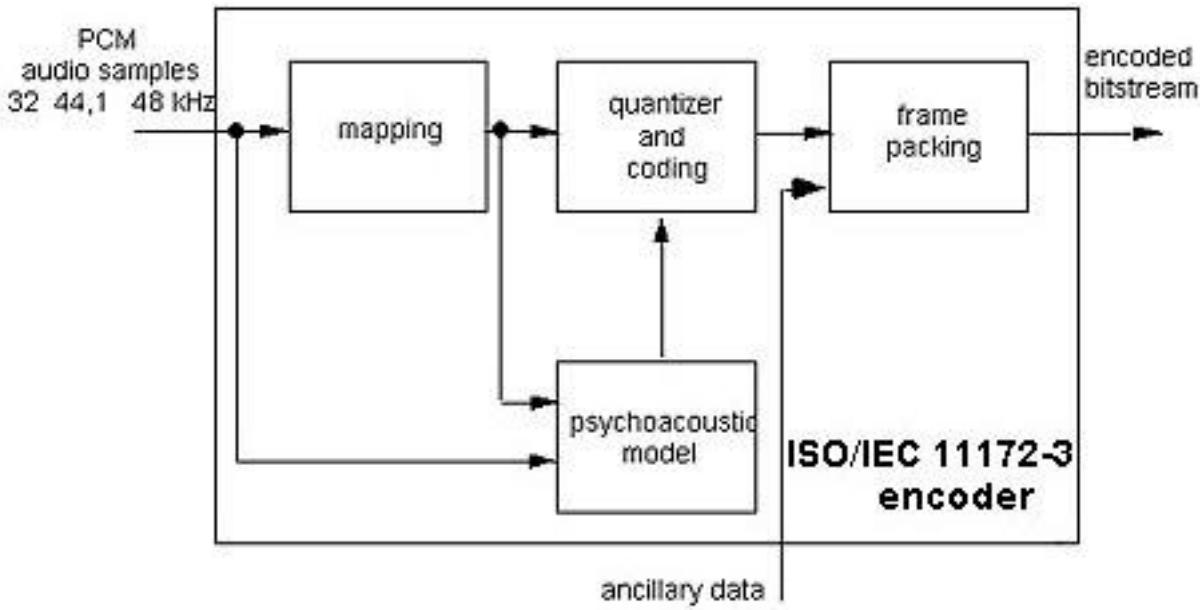

Figure 2.6.3: Basic structure of the MPEG-1 audio encoder

2.6.7 MPEG-2:

This is an extended version of MPEG-1 which uses higher bandwidth to achieve higher quality and to cover bigger images. These compression techniques are used for the television and telecommunication standards. These techniques are also used in compressing the DVD movies. Higher resolution and a higher transmission rate of 10 Mbps can be observed in this compression technique.

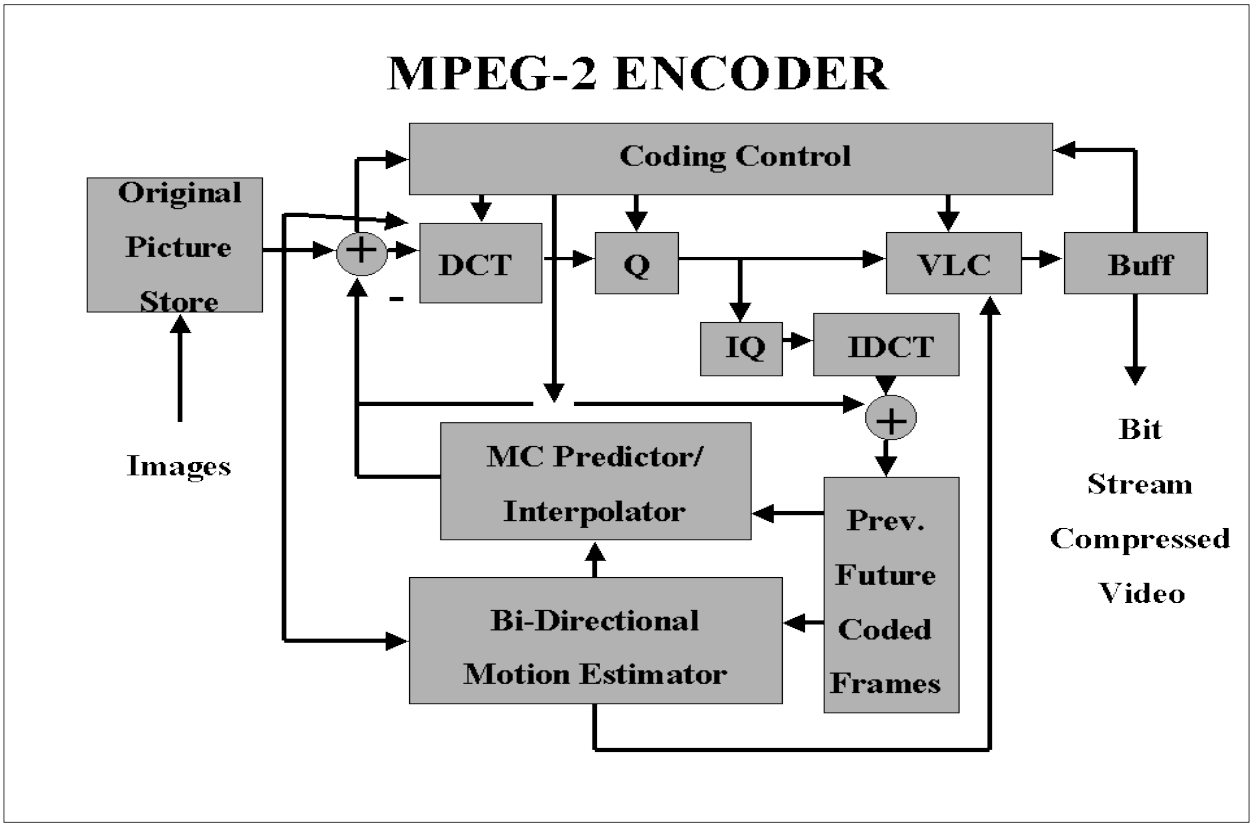

Figure 2.6.4: MPEG-2 encoder

2.6.8 MPEG-3:

This was developed as an extension to MPEG-2 but later it was found that by making small adjustments to the MPEG-2, it performs the operations to be done by MPEG-3 i.e., to handle HDTV. Hence the research on MPEG-3 has not been done widely and now it has been stopped.

2.6.9 MPEG-4:

This technique was developed intending to interactive multimedia, video telephony. The transmission of full-motion video at a low bit-rate of only 9-40 kbps is done with this technique. “The classic MPEG-4 video streaming standard is called the MPEG-4 Visual”.

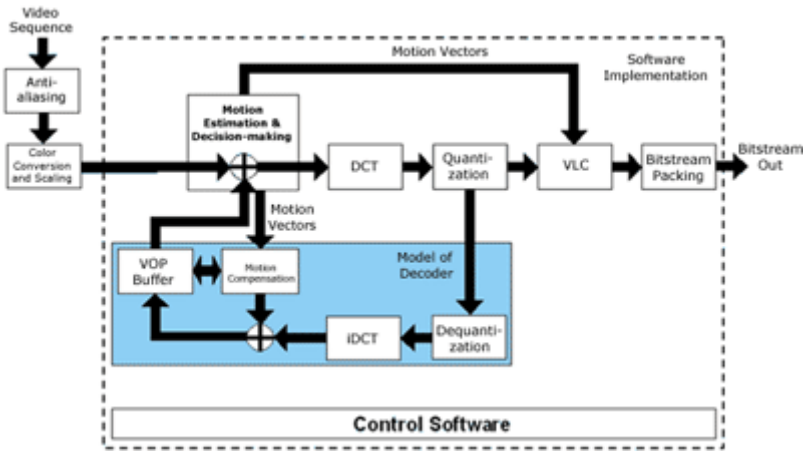

Figure 2.6.5: MPEG-4 encoder

MPEG-4 has been developed for the transfer of video over the internet and hence it has lower data rate of 64 kbps only.

2.6.10 H.264:

The latest standard developed for the video compression is the H.264 standard. It should provide a better video quality at the same bit rate. In this technique as the more applications are possible, all of these have to be implemented without much increase in the complexity of the system. This technique also provides the flexibility to perform a vast range of operations. Some of the important applications to be done using H.264 are:

a) Cable TV, broadcasting, satellite etc.

b) Streaming services

c) Telecom services

Also, the H.264 encodes the HD-DVD and Blu-ray support movies.

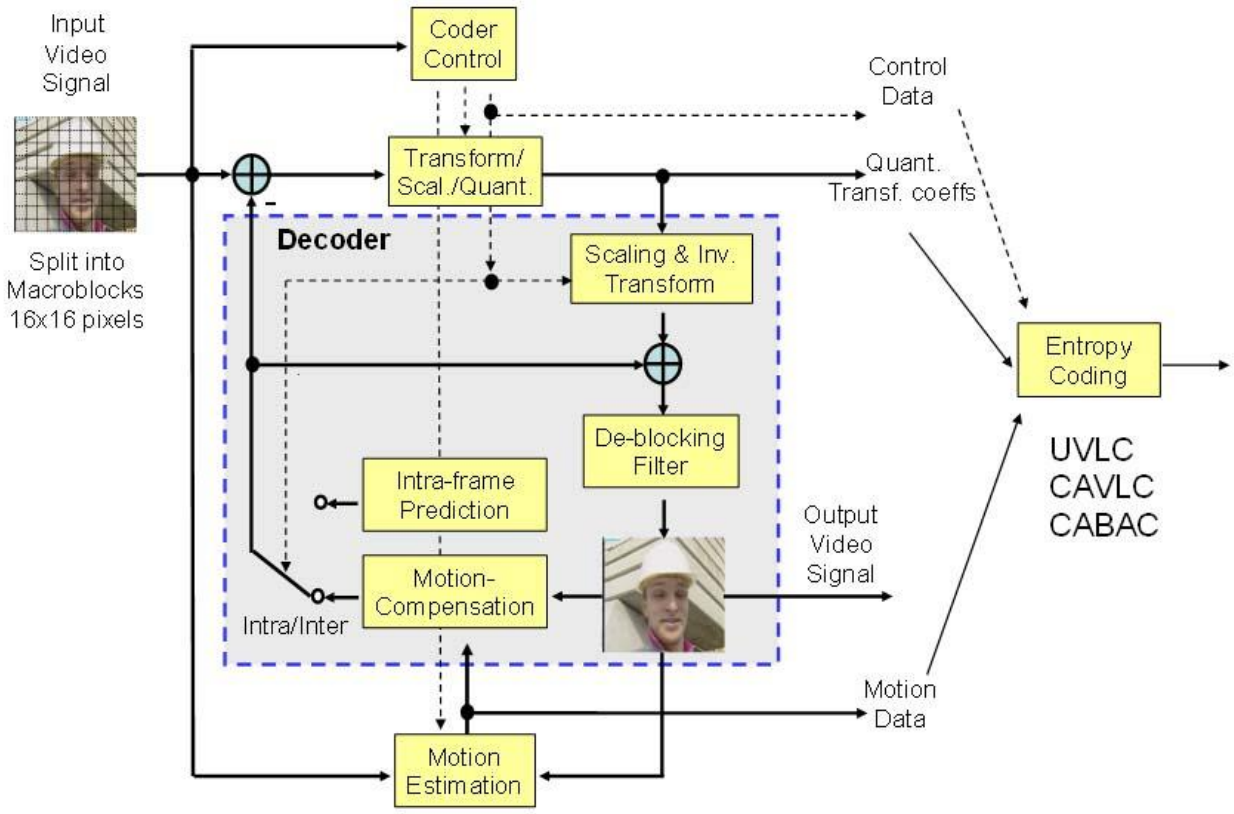

Figure 2.6.6: H.264/AVC video encoder

2.6.11 MPEG-7:

This technique does not involve in the compression of any moving image or audio. This is often used in the video surveillance. Multimedia content description interface is done here. A meta-data for audio-video streams is generated by the MPEG-7. Though this model does not depend on the actual multimedia compression techniques, the MPEG-4 representation can also be suited to the MPEG-7 technique. Some of the applications of MPEG-7 are used in video analytics.

2.6.12 MPEG-21:

In the modern days, digital data can be distributed illegally. Hence in order to prevent these kinds of events, this technique has been developed. This defines the ways for sharing the permissions, digital rights, licenses of the digitalized data. In video surveillance applications, MPEG-21 cannot be used.

2.7 MPEG Frame Types:

A video frame is compressed using different compression algorithms. For video frames, these different algorithms are called picture types or frame types. Basically there are three different frame types used in the different video compression algorithms. They are:

I-frames (don’t require other frames and is least compressible**)**

P-frames (uses data from previous frame to decompress**)**

B-frames (uses data both from the previous frame and future frame to decompress**)**

- “**I-frame** means Intra frame in which every block is coded using raw pixel values, so it can always be decoded without additional information”.
- **“P-frame** is the name to define the forward Predicted pictures. The prediction is made from an earlier picture, mainly an I-frame, so that require less coding data (≈50% when compared to I-frame size)”.
- **“B-frame** is the term for bi-directionally predicted pictures. This kind of prediction method occupies less coding data than P-frames (≈25% when compared to I-frame size) because they can be predicted or interpolated from an earlier and/or later frame”.

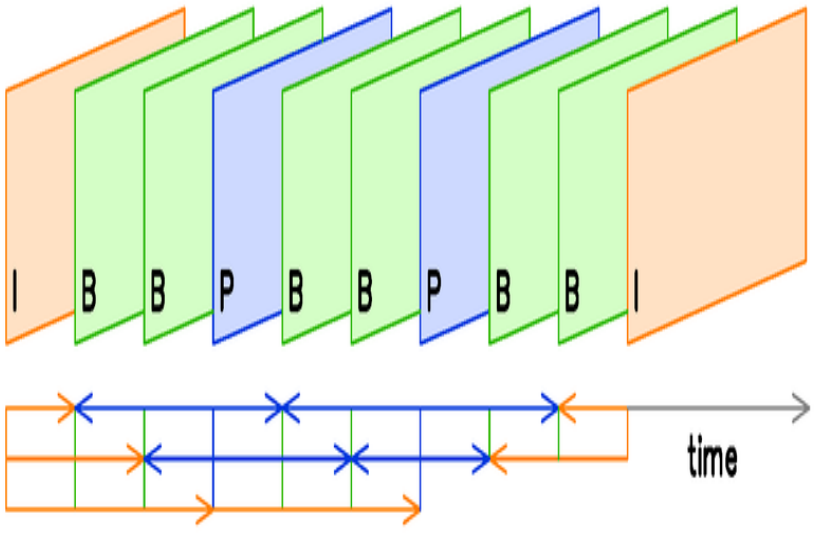

Figure 2.7.1: IPB frames inter-sequence

2.8 Group of Pictures (GOP):

A GOP specifies the order in which the frames are arranged. The group of successive pictures within a coded video stream is the GOP. Each encoded video stream contains successive GOPs. The visible frames are generated from the pictures contained within it.

2.9 Other Compression Techniques:

2.9.1 Intra frame coding and Inter frame coding:

Inter frame coding refers to the compression done by comparing the data with the successive frames and just storing the differences between frames; whereas intra frame coding applies compression technique on every individual frame without any reference. This implies that the intra frame compression is effectively the image compression only.Some of the popular intra frame codecs are:

- MJPEG- JPEGs bunched together
- Prores – Apple's favorite
- DNxHD – Avid's baby
- ALL-I – Found in the newer DSLRs
- Cinema DNG – Adobe's baby for RAW image sequences

Some of the popular inter frame codecs are:

- H.264
- MPEG-2
- MPEG-4
- XD-CAM
- XAVC
- AVCHD

2.9.2 Run-length coding:

In earlier days, this coding was used in fax machines to transmit the information. In this type of encoding all the pixel values are arranged in the form of an array and then checks for repetition of the same pixel values.

Suppose if the data is XXXXXXXYYYYYYYYYXXXXXXXYYYXX and run-length coding is applied on this data, that results in 7X9Y7X3Y2X i.e., the data is represented as 7X9Y7X3Y2X etc.

Hence using the run-length coding, the given data of 28 characters has been reduced to 10 characters and thus the compression is achieved.

To improve the compression ratios considerably, the original data should contain the less frequent runs and this will in turn cause the betterment in the compression ratios.

This compression comes under lossless compression and some other important lossless techniques are Huffman coding, Variable length-coding etc.

2.9.3 Variable Length Coding:

This is one of the efficient lossless compression techniques. This coding technique encodes the data in such a way that more frequently occurring bits are encoded using short codes and the less frequently occurring bits are coded using more number of bits. In this way, the number of bits used to transmit the data can be reduced after encoding the given data as explained above.

Huffman coding is an example of variable length-coding.

Winzip (one of the famous compression file) uses Huffman coding only.

Dynamic Pattern Substitution:

This refers to the situation where no prior information of the frequently occurring symbols is available.

A look up table should be built while coding this type of bit stream.

2.9.4 Lempel-Ziv encoding:

UNIX compress utility uses this type of coding technique and the objective is never to copy a sequence of bytes to the output stream which are previously seen by the encoder.

2.9.5 Progressive Scanning versus Interlaced Scanning:

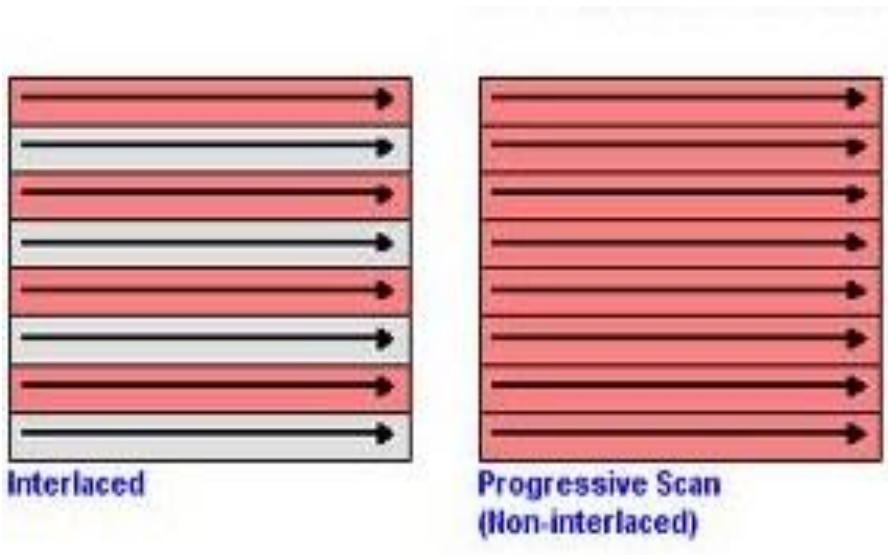

Figure 2.9.1: Interlaced Scanning and Progressive Scanning

Progressive scanning is the technique in which all the fields in a frame are scanned one after the other. In interlaced scanning, all the fields are divided into odd

and even fields and the scanning of all the odd fields (even fields) is done and then the scanning of the even fields (odd fields) occurs. The above figure clearly demonstrates the idea behind these two scanning techniques.

The progressive scanning has some drawbacks regarding the flickering and utilization of the bandwidth. Progressive scanning is also called the non-interlaced scanning. Progressive scanning is normally done in the televisions used in households.

2.10 Compression Constraints:

Quality:

While performing compression operations, the quality of the compressed video should be taken into account and the compressed video should not lose its quality beyond a certain acceptable level.

Complexity:

While executing the different algorithms to obtain compression, the complexity of the algorithm is an important factor. It should not be too complex.

Delay:

The execution time should be optimum while running a compression algorithm on a given video. While applying complex algorithms, it usually takes time to implement but the delay should not be very large.

Compression ratio:

The ratio of the original file size to the compressed file size is called compression ratio. To obtain better compression ratios, the quality of the video has to be forfeited.

The above constraints for the compression are all very essential and according to the need of the user, there will be a tradeoff between these constraints. For example, both the better quality and high compression ratios cannot be achieved together. To achieve one of these, the other can be neglected.

Chapter -3 DCT APPROACH FOR THE VIDEO COMPRESSION

3.1 Introduction to the project:

To compress a video, it has to be converted into individual frames and then compression techniques are applied on the frames. DCT method is an intra-frame compression type as it applies DCT to each frame and compresses the picture. After all the frames are compressed, the compressed video can be obtained whose size is relatively smaller when compared to the original video.

Basically while applying the compression techniques for a digital video, especially the DCT method, the compression occurs in a three step process.

First, the image is converted into small blocks and then DCT is applied on the image which converts the entire pixel values into frequency domain such that the larger frequencies occupy the bottom-right and the lesser frequencies occupy the top-left positions in the matrix. As the human eye is sensible only to lower frequencies, higher frequencies are discarded.

Secondly, the quantization is applied on the matrix obtained such that the coefficients discard their values after the decimal point. The scaling factor is selected wisely so that even after the values after the decimal point are discarded, the value remains almost the same.

Then, finally the coding technique is applied for compression and after applying the Inverse DCT, the original file can be reconstructed but not exactly similar to the original one.

The DCT algorithm is simple and symmetrical, so it is easy to be implemented compared to the other compression techniques that involve much complexity.

The algorithm used here takes any number of jpeg video frames and a video of any size can be compressed.

3.2 Flow Chart of the algorithm:

The steps followed while applying the desired compression technique on the given video file are explained clearly in the flowchart shown below.

The video file should be converted to avi file if it is in some other format and then the compression techniques can be applied. Otherwise MATLAB cannot read the video file and further process cannot be done.

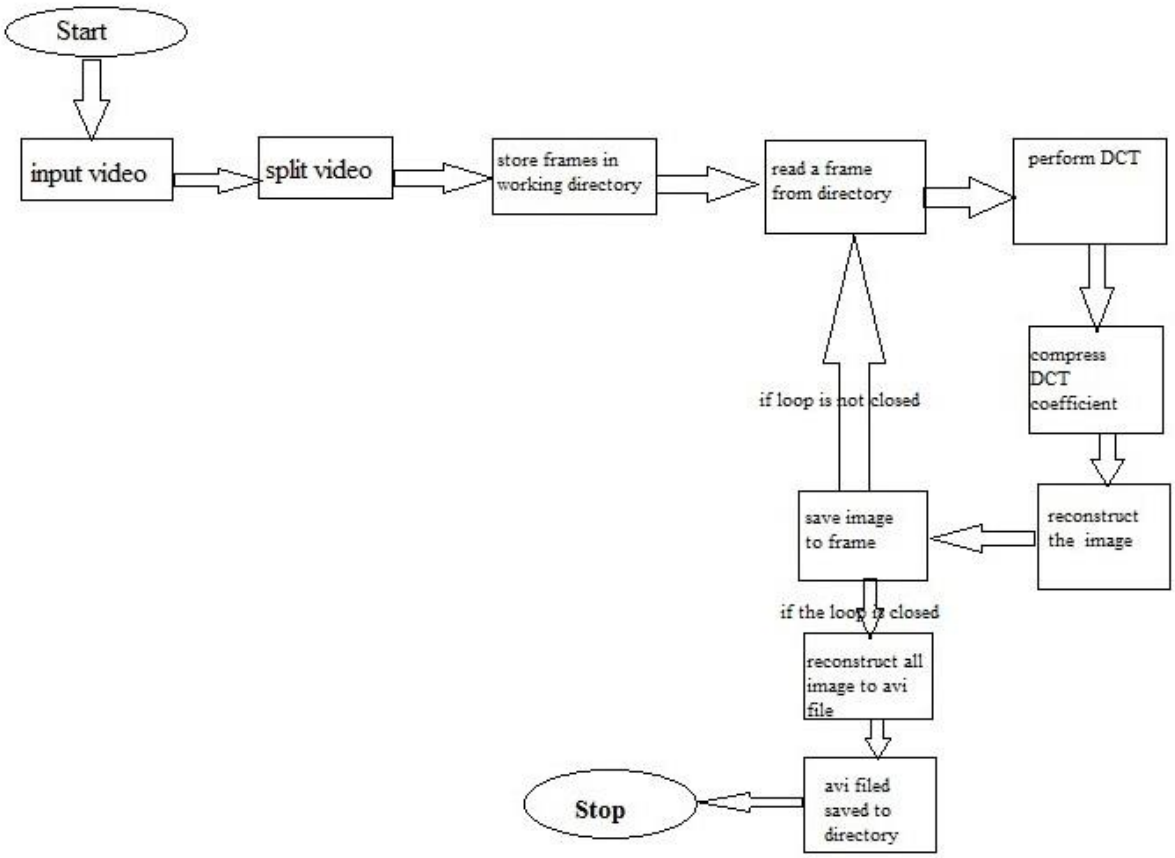

Figure 3.2.1: Flow chart of the algorithm

3.3 Benefits due to the application of DCT:

- This has been proved to be good transformation for high number of images
- The DCT coefficients are quantized easily to obtain good compression ratios
- DCT is symmetric
- DCT algorithm is very easy to be executed and also efficient
- DCT algorithm follows orthogonality: that is, the image is converted from the spatial domain to the frequency domain and thus the data points are decreased

.

Chapter – 4

RESULTS AND DISCUSSION

First an input video is taken. If the video is in other format other than the .avi format, convert it into the .avi format. I have taken a video (.avi) of size 7.75MB and duration 79 seconds. I have executed the MATLAB code written for converting the given video into a number of individual frames and the input video has been converted into number of frames. All these frames/images are selected and copied in a separate folder. Now another code is written (the DCT approach) such that the redundancy is removed and thus the compressed video is obtained finally. This is done by executing that code and then selecting the folder in which all the individual frames were saved. The final video obtained is the desired compressed video with its size approximately 4.35 MB and its duration is same as that of the original video.

Though the DCT method does not provide better compression ratios compared to the other compression techniques, this technique can be implemented for a video containing any number of frames and the implementation of this algorithm is also easy without much complexity in its nature.

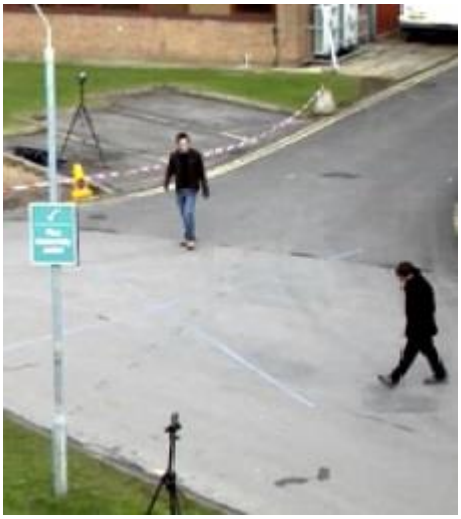

Figure 4.1: Snapshot from the original video

Figure 4.2: Snapshot from the compressed video

Chapter – 5
CONCLUSION

Video compression technique is very important as the size of a video file needs to be compressed according to the convenience of the user. For example, in a HDTV of resolution 1920x1080, it occupies 1.99 GB/s. If the duration of the video is 1 hour, one could imagine how much memory is required for that. Hence compression of the video is necessary and hence the compression algorithm is applied on the video and the results obtained are quite satisfactory. The compressed video obtained is of the same duration as that of the original video but its size is reduced drastically.

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