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Chapter 5 (2Q)
Data Compression

1) What do you understand by the term data compression?

Ans: Data compression is the process of reducing the amount of data required to represent a given quantity of information.

-> It is a technique which is used to reduce the size of large files.

-> It optimizes disk space when saving data.

-> It reduces the time in data transmission.
i.e it maximize the use of bandwidth across a network.

-> There are two types of data compression techniques.
1. Lossless data compression
2. Lossy data compression.

-> The data compression involves two main components :-

1) Encoding algorithm

-> It takes a message/file and generates a compressed representation of that message.

2) Decoding algorithm -> reconstructs the original message

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{3 marks}

1111 2) Why do we need to compress the data?

or

Necessity of data compression.

or

Advantages of data compression in terms of multimedia computing.

Ans: We need to compress the data to reduce the amount of data required to represent an information.

→ Mainly, there are two necessity for data compression. They are:-

i) Storage requirement

→ Uncompressed graphics, audio, and video data require considerable storage capacity.

→ In order to reduce the storage requirement of the multimedia data it should be compressed.

→ The compression should be such that there should not be a loss of quality of the data and hence compression should not reduce the information content of the data.

Eg: 90% of the raw audio can be deleted without affecting the quality of the audio.

ii) Bandwidth requirement

→ Uncompressed data transfer requires greater bandwidth.

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→ If the data is compressed then ~~it~~ there will be reduction in the bandwidth requirement for the transmission of the data.

→ It will help ~~to~~ to reduce the time taken in data transmission.

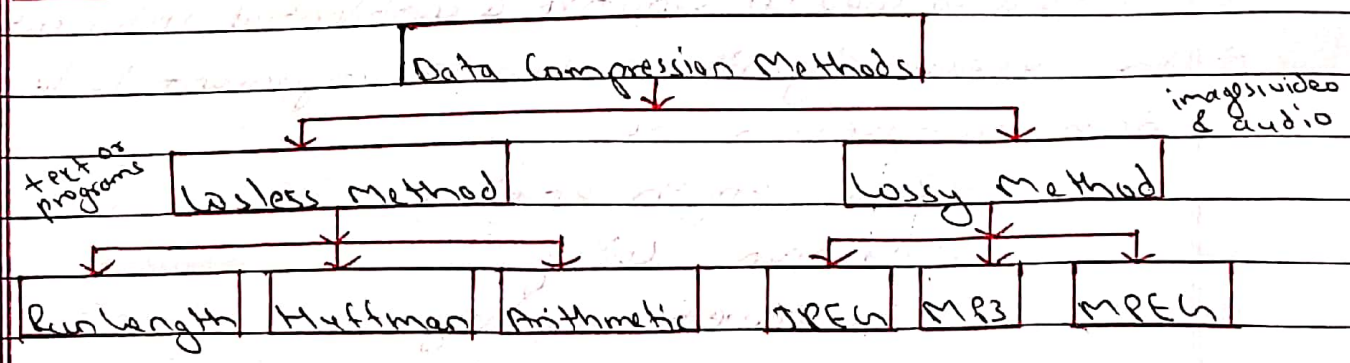
Example [Optional]

One 90 minutes color movie, each second plays 24 frames. When we digitize it, each frame has 512 x 512 pixels, each pixel has 3 components RGB each one occupies 8 bits respectively, the total byte number is:

$$90 \times 60 \times 24 \times 3 \times 512 \times 512 = 97{,}200 \text{ MB}$$

→ A CD may save 600 megabytes data, the movie needs 160 CDs to save.

→ This is not practical. Hence, data compression is required.



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III 3) Differentiate between lossless and lossy compression technique.

Ans: There are two types of data compression techniques.

→ They are:-

i) Lossless data compression

ii) Lossy data compression.

i) Lossless data compression

→ Lossless data compression is used to compress the files without losing an original file's quality and data.

→ In this type of compression, no information is lost during the compression and the decompression process.

→ In this technique, file size is reduced but the quality of data remains same.

→ Here, the reconstructed data is mathematically and visually identical to the original one.

→ It is used to compress files such as executable code, text files and numeric data.

→ It is also used in sensitive & confidential information.

→ The various algorithms used to implement lossless data compression are

1. Run length encoding

2. Huffman coding

3. Arithmetic coding

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ii) Lossy data compression

→ Lossy data compression is used to compress larger files into smaller files where some specific amount of data and quality are removed from the original file.

→ i.e data may be lost

→ In this technique, the ~~imag~~ data is separated into important and unimportant data. The system then discards the unimportant data.

→ It provides higher compression ratio than the lossless algorithms.

→ This technique is generally useful for us when the quality of data is not our first priority.

→ The main advantage is that the loss cannot be visible eye i.e human eye doesnot measure the loss of data.

→ It is most widely used in JPEG images, MPEG video and MP3 audio formats.

Lossless data compression	Lossy data compression
1. No loss of data & quality.	1. Loss of data and quality.
2. File is stored in its original form.	2. File is not stored in it's original form.
3. Used to compress text, images, etc.	3. Used to compress audio, video & images.
4. File quality is high.	4. File quality is low.
5. It supports RAW, ~~BM~~ PNG, WAV file formats.	5. It supports JPEG, MP3, MPEG file formats.

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coding → encoding
(almost same)

4) Explain Entropy, Source and hybrid encoding.

i) Entropy encoding
→ It is a type of lossless coding where decompression process regenerates the data completely.
→ This method is used to compress digital data by representing frequently occurring patterns with few bits and rarely occurring patterns with many bits.
→ Run-length encoding, Huffman encoding and Arithmetic encoding are a type of entropy encoding.

ii) Source encoding
→ It is a lossy encoding where the encoded data are not identical with original data.
→ Here, degree of compression depends on the content of the data.
→ Semantics of data are taken into account.
(Semantic of data → meaning of data)
→ DCT (Discrete Cosine Transformation) is a type of source encoding.

iii) Hybrid encoding
→ It is the combination of both entropy and source encoding.
→ It is used by most multimedia systems.
→ Examples: JPEG, MPEG, DVI etc.

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runs of data → sequence of same value.

MIII 5) What is run-length coding? (3 marks)

Ans: It is a simplest data compression technique.

-> It is a form of lossless data compression in which runs of data are stored as a single data value and count rather than original run.

OR

-> This method replaces the consecutive occurrences of a given symbol with only one copy of the symbol along with a count of how many times that symbol occurs.

-> Redundant data is stored as a single data value and how many times it appears.

Example: If the string is :-

AAAAABBBBTMMMMMMMMM

it is encoded as

A!5 B!4 TM!8

-> This method of compression must be used carefully. If there is not a lot of repetition in the data then it is possible the run length encoding scheme would actually increase the size of a file.

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(Sure Que) (Either Example or Numerical)

IIIII 6) Briefly explain the Huffman coding with example.

→ It is a lossless data compression algorithm.
→ It is a type of entropy encoding.
→ Huffman coding technique encodes any message sequence into shorter encoded messages.
→ This method ~~ref~~ represents frequently occurring patterns with fewer bits and rarely occurring patterns with many bits.

Steps to build Huffman Tree {Tree method}

* Input is array of characters ~~with~~ along with frequency of occurances.
1) Select two least frequent characters and form a tree with root sum of frequencies.
2) List the new root as part of input
3) Repeat step 1 & 2 until no input is left.

Example: {
Construct Huffman code for following grey level and calculate the average length

Gray level	0	1	2	3	4	5	6	7
No. of pixels	4500	1500	900	750	1200	1300	550	100

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Note: If equal value then recently calculated value is placed on top.

Total no. of pixels = 10,800

Probability of 0 = $\frac{4500}{10,800}$ = 0.4167
Probability of 1 = 0.1389
Probability of 2 = 0.0833
Probability of 3 = 0.0694
Probability of 4 = 0.1111
Probability of 5 = 0.1204
Probability of 6 = 0.0509
Probability of 7 = 0.0093

Arranging in ascending order, the order will be
7, 6, 3, 2, 4, 5, 1, 0

Descending order

Original Source — Source reduction

Symbol	Prob						
0	0.4167	0.4167	0.4167	0.4167	0.4167	0.4167	0.5833 (0)
1	0.1389	0.1389	0.1389	0.1944	0.25	0.3333 (00)	0.4167 (1)
5	0.1204	0.1204	0.1296	0.1389	0.1944 (000)	0.25 (01)	
4	0.1111	0.1111	0.1204	0.1296 (010)	0.1389 (001)		
2	0.0833	0.0833	0.1111 (0000)	0.1204 (011)			
3	0.0694	0.0694 (0100)	0.0833 (0001)				
6	0.0509	0.0602 (01010) (0101)					
7	0.0093	(01011)					

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Symbol	Probability	Codeword	Length
0	0.4167	1	1
1	0.1389	001	3
2	0.0833	0001	4
3	0.0694	0100	4
4	0.1111	0000	4
5	0.1204	011	3
6	0.0509	01010	5
7	0.0093	01011	5

Average length = Sum of (Probability × length)

$= 0.4167 \times 1 + 0.1389 \times 3 + 0.0833 \times 4 + 0.0694 \times 4 + 0.1111 \times 4 + 0.1204 \times 3 + 0.0509 \times 5 + 0.0093 \times 5$

$= 2.5508$ bits/symbol

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v. Imp

7) Explain the JPEG Compression Technique with block diagram.

or

Is JPEG lossy or lossless? Explain ~~with~~ how compression can be achieved using it.

Ans: JPEG stands for Joint Photographic Experts Group.

→ It is a lossy compression technique used to compress images.

→ It is most popular method for image compression because it provides higher compression ratio and the loss is not visible to the human eyes.

Following requirements are to be fulfilled by JPEG

i) The JPEG implementation should be independent of image size.

ii) It should be applicable to any image and pixel aspect ratio.

iii) Image format may be of any complexity.

iv) JPEG should achieve very good compression ratio and good quality image.

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YUV = Y, Cb, Cr

Steps of JPEG compression Process

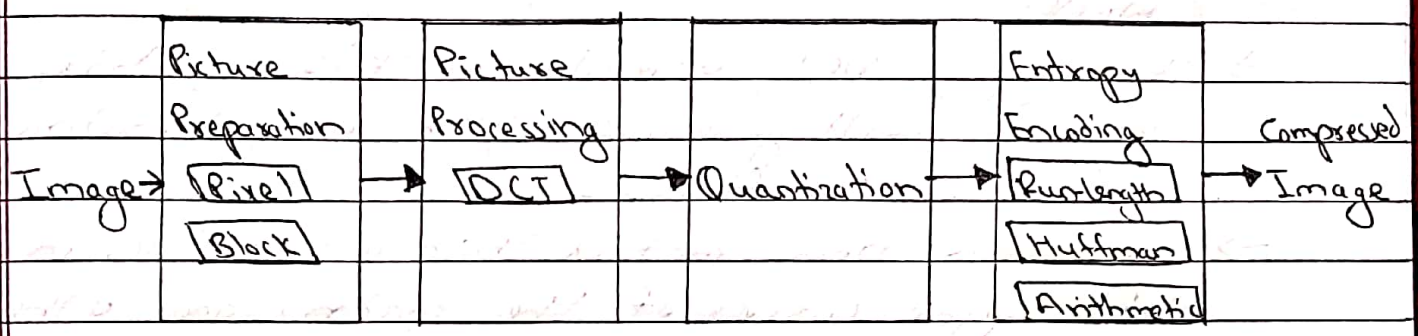

fig:- Steps of JPEG Compression

a) Picture Preparation

→ Splitting: Split the image into 8×8 non-overlapping blocks. Here, each ~~block~~ ~~is~~ unit is called pixel. Pixel is smallest unit of any image.

→ Color Space Transform: Color images are transformed from RGB to Y, Cb, Cr model. This step is not required for gray scale images.
→ Here, Y is for brightness, Cb is for color blueness & Cr is for color redness

b) Picture Processing
→ DCT is performed in this step. DCT stands for Discrete Cosine Transformation.
→ DCT uses a cosine function and doesnot use complex numbers.
→ ~~It~~ ~~converts~~ Each of the 8×8 pixel groups can be exactly replicated by 64 cosine waves.

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→ Now, creating a pixel matrix of a choosen block.

→ We apply DCT formula in this matrix, and we will generate 8×8 output matrix of DCT coefficients.

→ In this new matrix, there are values in left upper corner of the matrix and other places are almost nearly zero.

c) Quantization (lossy)

→ Quantization is the process ~~of~~ to determine what information can be safely discarded with significant loss in visual accuracy.

→ Humans are unable to see aspects of an image that are at really high frequencies. So these high frequencies can be removed.

→ So we call process of removing high frequency data quantization.

→ We can zero out elements of matrix, thereby freeing the memory that had been representing these values. (values of high frequency)

→ This step will now convert the values near to 0 to the 0 and other elements will be shrink towards zero.

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→ For encoding, we take our quantized output and then serialize into our file in a zig-zag fashion.

→ Zigzag scanning is used to group low frequency coefficients to the left top corner of the matrix and high-frequency coefficients to the bottom. (i.e most of the coefficients towards the right corner are zero)

→ The zigzag ordering rearranges the coefficients in one dimensional order, in result most of the zeros will be placed at the end of the stream.

→ We can exploit redundancy now.

d) Entropy Encoding (lossless)

→ This is the final step and this method uses either runlength encoding or Huffman encoding.

→ What this encoding method does is it gets the frequency of different pixels and store that pixels and the frequency instead of storing each pixel.

→ It reduces the large amount of data without loosing any detail of the image.

→ Most of the time it saves upto 70% of the memory.

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1 8) H.261

or

Explain H.261 (px64) method of compression in detail

Ans. H.261 is a video coding standard.

→ It is most widely used digital video compression technique.

→ It describes the video encoding/decoding method.

→ It is targeted for ISDN telephone ~~networks~~ networks. (Integrated Service Digital Network)

→ It is intended for use in video conferencing & video calling.

→ H.261 compression is a combination of

i) Inter-picture prediction
↳ to remove temporal redundancy.

ii) Transform coding -
↳ to remove spatial redundancy.

iii) Motion vectors
↳ for motion compensation.

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→ The three design elements are :-

1) Prediction
→ blocks are intra or inter coded
→ intra coded is similar to JPEG still image compression.
→ inter coded is employed with or without motion compensation.

2) Block transformation
→ Each block is composed into 8 X 8 blocks & processed by DCT function.
⇒

3) Quantization & Entropy Encoding
→ Achieves further compression by representing DCT coefficients with only the necessary precision.
→ Entropy encoding using Huffman encoding.

Advantages
i) Optimized for low data rates.
ii) Works best for movie which have little changes between frames

Disadvantages
i) Doesnot provide good quality

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11 g) MPEG

Ans: MPEG stands for Motion Pictures Expert Group and is used for encoding videos.

→ It is a lossy video compression technique.

→ It also involves the compression of audio.

→ MPEG has video extension with mp4 and Audio extension with mp3.

→ It provides high compression ratio.

→ There are several MPEG standards:-
MPEG-1, MPEG-2, MPEG-4, MPEG-7, etc.

→ MPEG standard explicitly considers functionalities of other standards:-

i) JPEG: Since a video can be regarded as a sequence of still images.
→ MPEG makes use of JPEG.

ii) H.261: It is most widely used video compression technique which was developed before MPEG.
→ MPEG makes use of H.261 too.

→ Steps of MPEG Video Compression

1) Reduction of Resolution

→ RGB to YUV {Y, Cb, Cr}

2) Motion Estimation

→ Calculate motion vector to find the matching blocks.

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Temporal redundancy → pixels in two video frames that have the same values in the same location. (same object repeated in each frame)
→ It is removed by motion compensation.

→ Matching blocks are found by comparing future frame with current frame.
i.e it detects temporal redundancy

3) Motion Compensation and Image substraction
→ ~~Motion vector is used for motion compensation.~~
~~and same matching blocks are~~
→ Temporal redundancy is removed by motion compensation.

4) DCT (Discrete Cosine Transformation)
→ Same as JPEG
→ Each of 8x8 pixel groups can be exactly replicated by 64 cosine waves.
→ Apply DCT formula to matrix & generate 8x8 output matrix of DCT coefficients.

5) Quantization (Same as JPEG)
→ Removing high frequency data for freeing the memory.

6) Entropy Encoding
→ It uses either Run-length or Huffman encoding
→ This process reduces the large amount of data without loosing any detail of the image.

Advantages of MPEG
→ produce high quality result
→ this format is compatible with most web browser.

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Date
Page

11 b) Explain the different image frames in MPEG

or

Explain the purpose of different types of frames used by MPEG compression techniques.

Ans: MPEG has 4 different types of image frames.

→ They are required for efficient coding and to achieve a high compression ratio.

→ They are explained below:-

i) I-frames (Intra coded Images)
ii) P-frames (Predictive-coded frames)
iii) B-frames (Bi-directionally predictive coded frames)
iv) D-frames (DC coded frames)

i) I-frames (Intra coded Images)

→ I-frames are coded independently.
i.e they are coded without any reference to other image.

→ They are treated as a still image.

→ They are compressed as if they are JPEG images.

→ First, an image is converted from RGB color model to YUV color model.

→ Then Applying DCT.
↳ DCT is performed on small blocks of 8*8

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pixels to produce blocks of DCT coefficients.

-> Apply Quantization
↳ removing high frequency data for freeing the memory.

-> Finally, perform entropy encoding and achieving ~~compressed~~ compression.

ii) P-frames (Predictive-coded frame)

-> It requires information of the previous I-frame or P-frames for encoding and decoding.

-> In most of the video sequences there is a little change in the contents of image from one frame to the next.
i.e same objects are repeated again and again in every frame.

-> So, this video compression schemes take advantage of this redundancy by using the previous frame.

-> It removes the temporal redundancy.

-> Hence, by removing temporal redundancy, P-frames offers increased compression compared to I-frames.

iii) B-frames (Bi-directionally predictive coded frame)

-> It require information of the previous and following I-frames and P-frames for encoding and decoding. {frames are also predicted from future frame}

-> B-frame is defined as the difference of a prediction of the past ~~image~~ and the following I frame & P-frame.

-> The highest level of compression ratio is attained by using this frame.

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iv) D-frames (DC-coded frame)

→ They can be used for fast forward or fast rewind modes.

→ They only consist the lowest frequencies of an image.

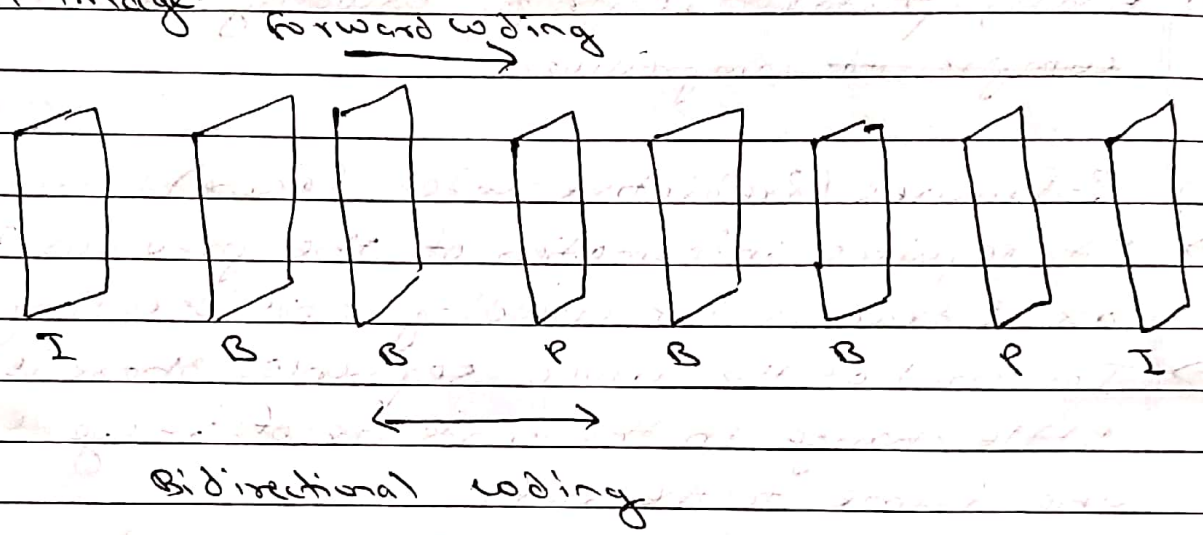

fig: Types of Images in MPEG

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1 ii) MPEG audio encoding

or

Explain the ~~audio~~ MPEG audio encoding techniques with a suitable diagram.

Ans: MPEG audio encoding is a ~~lossless~~ lossy data compression technique.

→ Here, it only removes inaudible part of the sound and maintains the quality of the audio file.

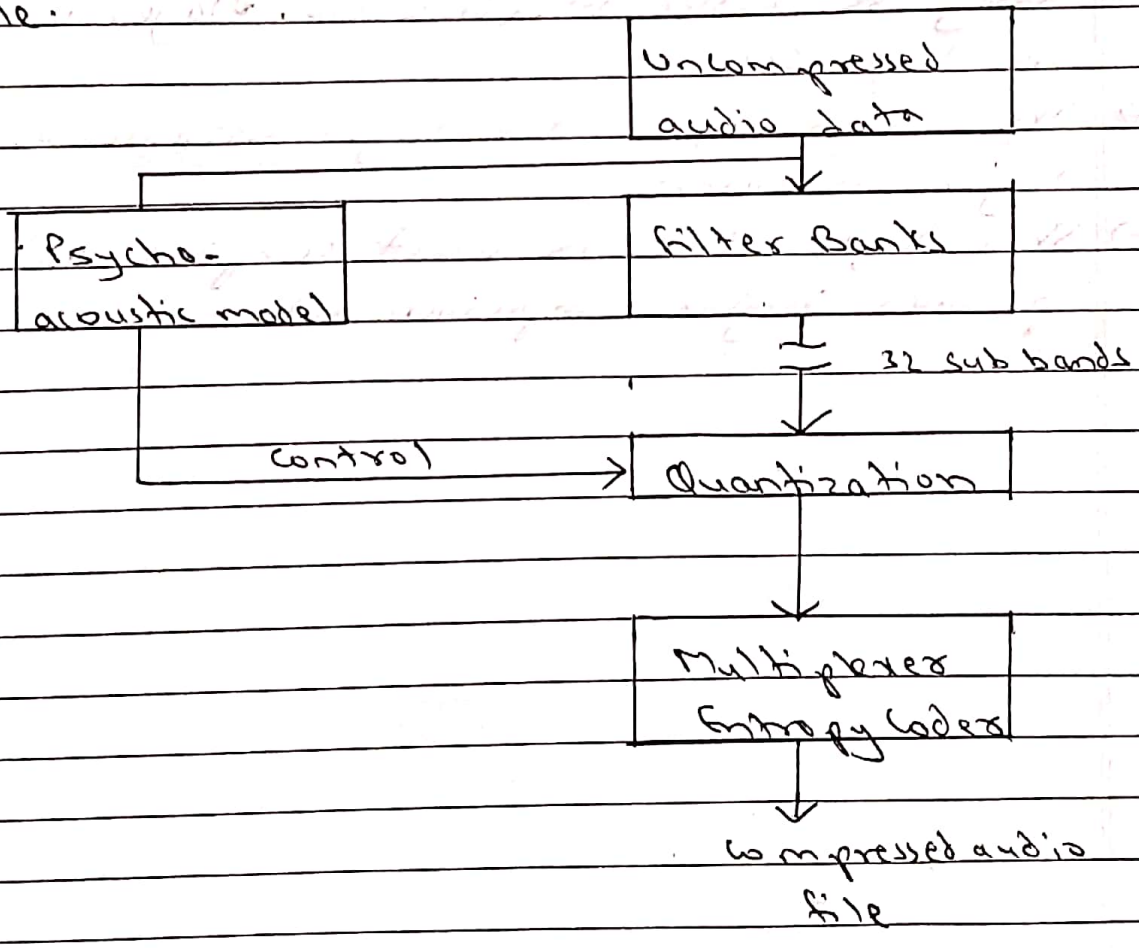

Fig:- MPEG basic steps of audio encoding

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→ Applies a filter banks to the input.
→ In parallel, a psychoacoustic model is applied.
→ Quantization and Entropy coding are performed to release the compressed audio data.

→ MPEG audio is not a single compression algorithm but a family of three audio compression technique.
→ They are called MPEG audio layer-1, layer-2 and layer-3.
→ The complexity of the layer increases as the layer increases.
→ Thus, layer 3 is the most complex and provides higher compression ratio.

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11.2) Digital Video Interactive (DVI)

Ans: DVI stands for Digital Video Interactive.

→ It is the first technology that opened a door to a world of interactive video applications.

→ DVI can process data, text, graphics, still images, ~~video~~ video and audio.

→ It enabled full screen, full motion video, audio, still images, and graphics to be presented on a DOS-based desktop computer.

→ DVI content was usually distributed on CD-ROM discs.

→ Audio and video files for DVI were among the first to use data compression.

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