UNIT IV
WAVELETS AND IMAGE COMPRESSION

Wavelets – Subband coding - Multiresolution expansions

Compression: Fundamentals – Image Compression models – Error Free Compression – Variable Length Coding – Bit-Plane Coding – Lossless Predictive Coding – Lossy Compression – Lossy Predictive Coding – Compression Standards.

PART – A

1. Mention the conditions for function to be called as wavelets. [Nov/Dec 2017]

A function ψ (x) can be called a wavelet if it posses the following properties.

a) The function integrates to zero or its Fourier transform is zero at the origin.

$$\int_{-\infty}^{\infty} \psi(x)dx = 0$$

b) It is square integrable or has finite energy

$$\int_{-\infty}^{\infty} |\psi(x)|^2 dx < \infty$$

c) The Fourier transform must satisfy the admissibility condition given by,

$$C_\psi = \int_{-\infty}^{\infty} \frac{|\psi(\omega)|^2}{|\omega|} d\omega < \infty$$

2. When a code is said to be "prefix code"? Mention one advantage of prefix code. [Nov/Dec 2017]

A code is said to be prefix code if no codeword is a prefix of any other codeword. The advantages of prefix code are

- It is uniquely decodable
- It is not necessary to provide delimiter that indicates where one code word ends and next begins. Eliminating delimiters saves additional space in the encoded file.

3. What is run length coding? [Apr/May 2017, Nov/Dec 2015]

Run-length Encoding, or RLE is a technique used to reduce the size of a repeating string of characters. This repeating string is called a ***run***; typically RLE encodes a run of symbols into two bytes, a symbol and count. RLE can compress any type of data regardless of its information content, but the content of data to be compressed affects the compression ratio.

4. What are the operations performed by error free compression? [Apr/May 2017]

Error free compression or Lossless compression is achieved by

- Reducing interpixel redundancy
- Reducing coding redundancy

5. What is an image pyramid? [Nov/Dec 2016]

Image pyramid is a powerful structure for representing images at more than one resolution. In an image pyramid, a collection of decreasing resolution images are arranged in the shape of a pyramid. The base of the pyramid contains a high resolution approximation and the apex contains a low resolution approximation.

6. State whether the given Huffman code 0, 10, 01, 011 for the symbols a1, a2, a3, a4 is uniquely decodable or not? [Nov/Dec 2016]

Yes, the given Huffman code is uniquely decodable.

7. Determine whether the code (0, 01, 11) is uniquely decodable or not. [May/June 2016]

Yes, the code is uniquely decodable

8. Differentiate scalar and vector quantization. [May/June 2016]

S.No.	Scalar quantization	Vector quantization
1.	Each input symbol is treated separately in producing the output	The input symbols are combined together in groups called vectors, and processed to give the output
2.	Computational complexity is less	Computational complexity is more

9. Define coding redundancy. [Nov/Dec 2015]

The information is represented in the form of codes. If the codes fails to minimize the average number of bits required to represent each pixel, it leads to coding redundancy.

10. State the need for data compression and compare lossy and lossless compression techniques. [Apr/May 2015, May/June 2013/14]

Compression is the process of reducing the size of data. Compression is needed to reduce storage space and hence bandwidth requirements and cost.

S.No.	Lossy compression	Lossless compression
1.	Lossy compression will result loss of data in exchange for a substantial increase in compression	Lossless compression can recover the exact original data after compression
2.	It is irreversible	It is reversible
3.	Higher compression rate can be achieved	Compression rate achieved is low
4.	It is used to compress images, video and audio.	It is used mainly for compressing database records, spreadsheets or word processing files, where exact replication of the original is essential

11. List the advantages of transform coding. [Apr/May 2015]

- Energy is highly compacted
- Robust relative to channel errors

12. What is the need for Wavelet Transform?

Fourier Transform provides only frequency information, when the time localization of the spectral components are needed, a transform giving the time frequency representation of the signal is needed. Thus a wavelet transform which provides the time-frequency representation is needed. Wavelet transform is based on small waves called wavelets, of varying frequency and limited duration.

13. What do you understand by the term Multi Resolution theory?

Multi Resolution theory is concerned with the representation and analysis of images at more than one resolution. Features that may go undetected at one resolution may be easy to detect at another resolution.

14. What is Multi Resolution Analysis (MRA)?

MRA, as implied by its name, analyzes the signal at different frequencies with different resolutions. In MRA, a scaling function is used to create a series of approximations of an image, each differing by a factor of 2 in resolution from its nearest neighboring approximations. Wavelets are used to encode the difference in information between adjacent approximations.

15. What are the four fundamental requirements of MRA?

MRA Requirement 1: The scaling function is orthogonal to its integer translates

MRA Requirement 2: The subspace spanned by the scaling function at low scales are nested within those spanned at higher scales.

MRA Requirement 3: The only function that is common to all Vj is f(x)= 0.

MRA Requirement 4: Any function can be represented with arbitrary precision.

16. What is subband coding?

In subband coding, an image is decomposed into a set of bandlimited components called subbands. These subbands can be reassembled to construct the original image without error. Digital filters are used to perform decomposition and reconstruction.

17. What is image compression?

Image compression refers to the process of reducing the size of an image for easy storage and transmission. It is achieved by removing the redundant data.

18. What are the types of redundancy?

i) Coding Redundancy

ii) Interpixel Redundancy

iii) Psychovisual Redundancy

19. Define interpixel redundancy.

The value of any given pixel can be predicted from the values of its neighbors. Thus the information carried by individual pixel. This is known as interpixel redundancy.

- Interpixel redundancy in images is known as spatial redundancy.
- Interpixel redundancy in video is known as temporal redundancy.

20. Define psychovisual redundancy.

Certain information which has less relative importance than other information in normal visual processing are said to be psychovisually redundant information.

21. Define compression ratio.

Compression Ratio CR= n1/n2

Where, n1 - is the number of information carrying units in the first data set (original image)

n2 - is the number of information carrying units in the second data set (compressed image)

22. Define source encoder.

Source encoder reduces the redundancy in the data to achieve compression. It performs three operations

1) Mapper -It reduces the interpixel redundancy.

2) Quantizer - It reduces the psycho visual redundancy, this step is omitted if the system is error free(Lossless).

3) Symbol encoder- This reduces the coding redundancy .This is the final stage of encoding process.

23. Define channel encoder.

The channel encoder reduces the impact of the channel noise by inserting redundant bits into the source encoded data. Eg: Hamming code

24. What is variable length coding?

Variable Length Coding is the simplest approach to error free compression. It reduces only the coding redundancy. It assigns the shortest possible codeword to the most probable gray levels. Eg: Huffman Code

25. Define Block code.

If each source symbol is mapped into fixed sequence of code symbols or code words the coding technique is called as block code.

26. Define instantaneous code.

If each codeword in a string of symbols can be decoded without the reference of succeeding symbols then the code is called is called instantaneous code.

27. List the properties of Huffman code.

- It is uniquely decodable code
- It is optimal code.

28. List the procedure for Huffman coding.

- List all the source symbols along with its probabilities in descending order.
- Divide the total number of symbols into block of equal size.
- Sum the probabilities of all the source symbols outside the reference block.
- Now apply the procedure for reference block, including the prefix source symbol.
- The code words for the remaining symbols can be constructed by means of one or more prefix code followed by the reference block as in the case of binary shift code.

29. Define arithmetic coding.

In arithmetic coding one to one corresponds between source symbols and codeword doesn't exist. An entire sequence of source symbol is assigned whereas the single arithmetic code word assigned for a sequence of source symbols. A code word defines an interval of number between 0 and 1.

30. What is blocking artifacts?

It is the block like appearance that results when the boundaries between subimages becomes visible after merging the decompressed subimages to get back the entire image.

31. What is bit allocation?

The process of truncating, quantizing and encoding the coefficients of a transformed sub image is commonly called bit allocation.

Two types

i) Zonal coding

ii) Threshold coding

32. What is JPEG?

The acronym is expanded as "Joint Photographic Expert Group". It is an international image compression standard used to compress both monochrome and color images. It is based on lossy transform coding.

33. What are the coding systems in JPEG?

1. A lossy baseline coding system, which is based on the DCT and is adequate for most compression application.
2. An extended coding system for greater compression, higher precision or progressive reconstruction applications.
3. A lossless independent coding system for reversible compression.

34. What are the basic steps in JPEG?

- Block Extractor
- DCT (Discrete Cosine Transformation)
- Quantization
- Zigzag Scan
- DPCM on DC component
- RLE on AC Components
- Entropy Coding

35. What is MPEG?

The acronym is expanded as "Moving Pictures Expert Group". It is an international standard for video compression used for multimedia video compression.

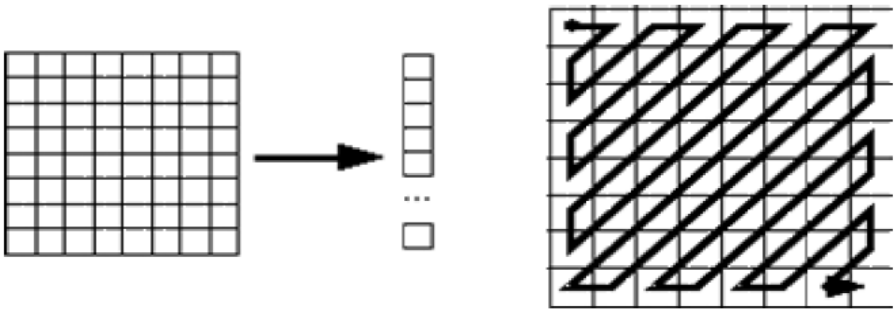
36. What are the types of MPEG standards?

MPEG-1 –used for entertainment quality coding standard, CDROM Storage
MPEG-2 – cable TV distribution, narrow channel satellite broadcasting
MPEG-4 – Internet & Various multimedia applications
MPEG-7 – used for Search Engines

37. What is zig-zag sequence?

The purpose of the zig-zag Scan:

- To group low frequency coefficients in top of vector.
- Maps 8 x 8 to a l x 64 vector



38. Define I-frame, P frame, B frame.

I-frame is Intraframe or Independent frame. The first frame of the video is the I-frame. It is compressed independently.

P-frame is called predictive frame. A P-frame is the compressed difference between the current frame and a prediction of it based on the previous I or P-frame

B-frame is the bidirectional frame. A B-frame is the compressed difference between the current frame and a prediction of it based on the previous I or P-frame or next P-frame. Accordingly the decoder must have access to both past and future reference frames.

39. What is vector quantization?

Vector Quantization is a block coding technique that quantizes blocks of data instead of single sample. The encoder and decoder consist of identical codebook. The code book consists of code vectors (group of image blocks) and corresponding address (index) of it .Thus instead of transmitting the code vector sonly the index of the code vector is transmitted, hence compression is achieved.

40. How compression is achieved with vector quantization?

The encoder and decoder consist of identical codebook. The code book consists of code vectors (group of image blocks) and corresponding address (index) of it.Thus instead of transmitting the code vectors only the index of the code vector is transmitted, hence compression is achieved.

41. What are the types of Vector quantization?

- Tree Search Vector Quantization
- Multistage VQ
- Mean Removed VQ
- Gain Shape VQ
- Classified VQ
- Hierarchical VQ
- Interpolative VQ
- Lapped VQ
- Lattice VQ

PART - B

Wavelets

1. Explain two dimensional Discrete Wavelet Transform (DWT). **[Nov/Dec 2016]**

Huffman coding

1. Construct Huffman code for the word "BABY". Also compute the efficiency of Huffman code. **[Nov/Dec 2017]**
2. With an example explain Huffman coding scheme results with image compression. **[May/June 2016]**
3. Obtain Huffman coding for the source symbols S = {S_0, S_1, S_2, S_3, S_4} and the corresponding probabilities P={0.4,0.2,0.2,0.1,0.1}.**[Nov/Dec 2015]**
4. A source emits letters from an alphabet A=(a1,a2,a3,a4,a5) with probabilities P(a1)=0.3, P(a2)=0.4, P(a3)=0.15,P(a4)=0.05 and P(a5)=0.1 **[Apr/May 2015]**

a) Find Huffman code for this source.

b) Find the average length of the code and its redundancy.

5. Describe run length encoding with examples. **[Apr/May 2015]**

Arithmetic coding

1. Encode the sentence 'I LOVE IMAGE PROCESSING' using arithmetic coding procedure. **[Apr/May 2017, May/June 2014]**
2. Encode the word a_1 a_2 a_3 a_4 using arithmetic code and generate the tag for the given symbol with probabilities. **[Nov/Dec 2016]**

$$a_1 \rightarrow 0.2,\ a_2 \rightarrow 0.2,\ a_3 \rightarrow 0.4,\ a_4 \rightarrow 0.2$$

3. Explain the principle of arithmetic coding with an example. **[Nov/Dec 2015, May/June 2014]**

Transform based coding

1. With a neat block diagram, explain transform based image compression scheme. Also mention different modes in JPEG compression standard. **[Nov/Dec 2017, May/June 2016, Nov/Dec 2015, Apr/May 2015, Nov/Dec 2013]**
2. With a neat block diagram explain transform based image compression scheme. Also give two valid reasons for the choice of "Discrete Cosine Transform" in JPEG image compression standard. **[Apr/May 2017]**
3. What is the need for image compression? Explain image compression standards in detail. **[Nov/Dec 2016]**
4. Describe the stages in MPEG image compression standard. **[May/June 2016]**

Vector quantization

1. Explain vector quantization. **[Nov/Dec 2015, Apr/May 2015, Nov/Dec 2013]**