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A BRIEF STUDY OF VARIOUS WAVELET FAMILIES AND COMPRESSION TECHNIQUES

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Abstract: Medical image compression is essential for huge database storage in various hospitals and data transfer for diagnosis. Wavelets give one such approach for compression purpose. A wavelet is a wave-like oscillation with an amplitude starts from zero, increases, and then decreases again to zero. Compression techniques are divided into lossless and lossy techniques. Lossless technique involves exact reconstruction of image but poor compression ratio. Lossy technique gives higher compression ratio. This paper outlines wavelets, wavelets families, types of compression techniques.

Keywords**:** Coiflets, DWT, haar, Image compression, wavelets.

INTRODUCTION

Digital image processing is a computer algorithms used to achieve image processing on digital images. An image can be defined as a 2-D signal processed by the visual system. The signals that represent images are normally in analog form. Although for storage, processing and transmission by computer applications, images are changed from analog to digital form. A digital image is more often than not a 2-Dimensional array of pixels. Images outline the significant part of data, mainly in, biomedical, remote sensing video conferencing applications. Various different medical images like magnetic resonance imaging (MRI), X-ray angiograms (XA) etc. are extensively used in medical diagnosis. Compression is the process of reducing storage and transmission bandwidth required to store and transfer data. Compression techniques are divided into lossy and lossless. Lossy provide high compression ratio then lossless. Wavelets are suitable method for compression of biomedical images [1,2]. Now-a-days wavelet based compression techniques have become more popular because they provide exceptional image quality at high compression rate. [3].One intent of the paper to give brief overview about wavelets and compression techniques.

KEY STAGES OF DIGITAL IMAGE PROCESSING

Various stages of digital image processing are following in figure 1.

Image Acquisition:

Image acquisition can be as simple as given an image that is already in digital form the image acquisition includes preprocessing like scaling etc.

Image enhancement:

It is a collection of procedures that seek to get better the visual appearance of an image or to convert the image to a shape better suited for examination by a human or a machine.

Image Restoration*:*

To get better the quality of images obtained by optical, electrical and electro-optical means is one of the vital tasks in digital image processing.

Color Image processing:

Color image processing is an area which has been gaining importance because of the use of digital images have been significantly increasing over the internet. This also include color processing and modeling in a digital domain etc. This also include color processing and modeling in a digital domain etc.

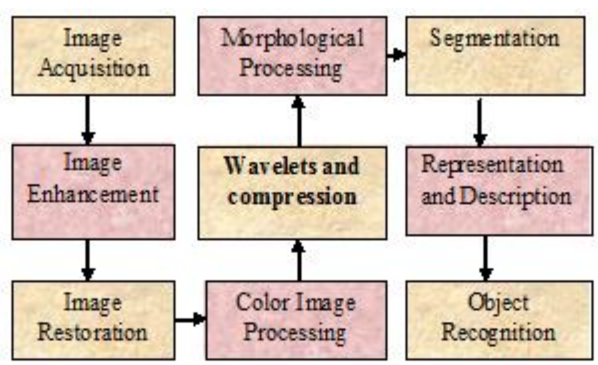


Figure. 1 Key stages of digital image processing

Wavelets and compression:

A wavelet is defined as wave-like oscillation with an amplitude starts at zero, increases, and decreases back to zero. Wavelets are appropriate method for compression of images. Compression is a way to reduce the size of data stored. Image compression is the process of converting images into smaller files for efficiency of storage and transmission. Uncompressed digital images require huge storage capacity and band-width. Therefore efficient image compression techniques are becoming more necessary with the growth of intensive web applications.

Morphological processing:

Morphological processsing deals with tools and techniques for extracting image parts which are useful in the representation and description of shape.

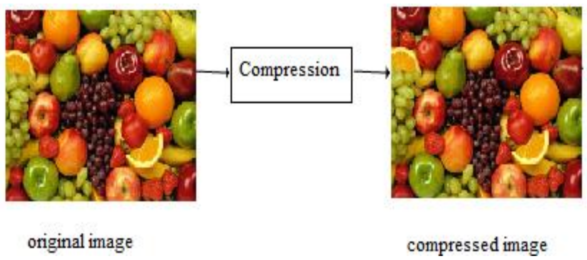


Figure. 2 Compression of an image

Image segmentation:

It is the process of subdividing an image into a number of uniformly homogeneous regions. Segmentation is defined by a set of regions that are linked and non overlapping, so that every pixel in a segment in the image get a exclusive region label which indicates the region it belongs to. Segmentation is one of the most crucial elements in automated image analysis

Representation and description:

It always use the output of a segmentation stage, which is raw pixel data, form either the boundary of a region or all the points in the region itself. Choosing a representation is the only part of the solution for transforming raw data into a figure suitable for subsequent computer processing. Description deals with extracting features that result in some quantitative information.

Image recognition:

Image Recognition is the process which assigns a label, like, "vehicle" to an object based on its descriptors [4,5].

TYPES OF DIGITAL IMAGES

Various types of digital image exists with various properties are given below.

Binary image

Each pixel is just black (0) or white (1). We need one bit per pixel as there are only two possible values for each pixel. These images can therefore be very efficient in terms of storage. Images for which a binary representation may be suitable include fingerprints, text, or architectural plans. Figure 3 shows binary image with its matrix.

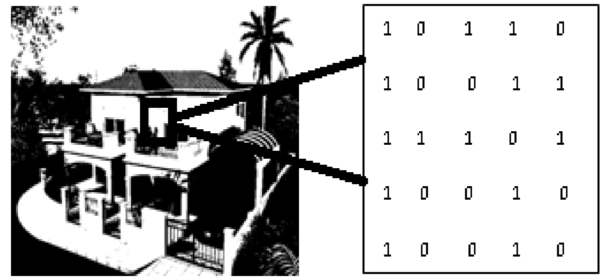


Figure. 3 binary image with 5*5 matrix

Grayscale image:

Each pixel is a shade of grey, from 0 (black) to 255 (white) as shown in figure 4. This range defines that every pixel will be represented by one byte or eight bits. This is a very natural range for image file handling.

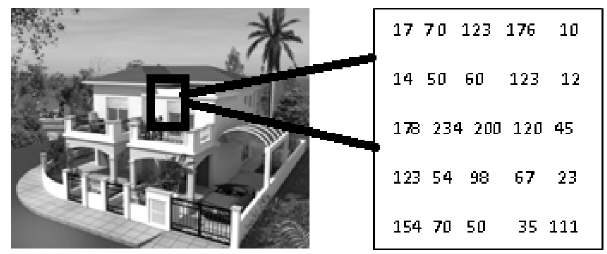


Figure. 4 Grayscale image with 5*5 matrix

RGB images:

Each pixel has a particular color which is being described by red, green and blue amount in it as shown in figure 5.Since the total number of bits required for each pixel is 24, such images are also called 24-bit color images [6].

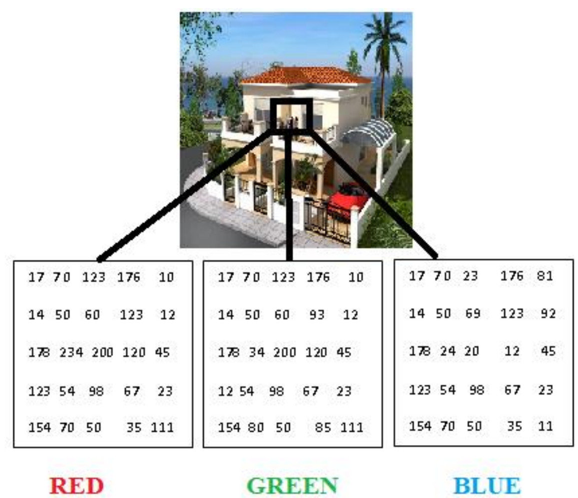


Figure. 5 showing red, green, blue color amount in the RGB image

WAVELET TRANSFORMS

The wavelet transform is defined as a mathematical technique in which a particular signal is analyzed (or synthesized) in the time domain by using different versions of a dilated (or contracted) and translated (or shifted) basis function called the wavelet prototype or the mother wavelet. A wavelet function ψ(t) is a small wave, which is oscillatory in some way to discriminate between different frequencies. The wavelet contains both the analyzing shape and the window.

Properties of wavelets function:

To describe a particular function a wavelet system, it has to fulfill the following properties:

- ***a.*** ***Wavelets are building blocks for functions:*** Wavelets are used to represent signals and generally functions. A function is represented by mean of infinite series of wavelets in the wavelet space.
- ***b.*** ***Wavelets have space-frequency localization:*** Most of the energy of a wavelet is confined in a finite interval and the transform contains frequencies from a certain frequency band.
- ***c.*** ***Wavelets support fast and good transform algorithms:*** This requirement is needed when implementing the transform. The wavelet transforms need O(n) operations, which means that the number of additions and multiplications follows linearly the length of the signal. This is a direct inference of the compactness property of the transform.
- ***d.*** ***Multiresolution ability:*** states the ability of the transform to represent a function or signal at different level, derived from the original one. .
- ***e.*** ***Ability to generate lower level coefficients from the higher level coefficients:*** This can be achieved by the use of tree-like structured chain of filters called Filter Banks[7].
- ***f.*** ***Symmetry:*** Symmetric filters are preferred be-cause they are most valuable for minimizing the edge effects in the wavelet representation of discrete wavelet transform(DWT) of a function; large coefficients resulting from false edges due to periodization can be avoided.
- ***g.*** ***Size of the filters:*** Long filters results in greater computation time for the wavelet or wavelet packet transform [8].

Types of Wavelet Transforms:

- ***a.*** ***Discrete wavelet transform (DWT):*** The DWT is an implementation of the wavelet transform that uses a discrete set of the wavelet scales and translations following some defined rules. The transform decomposes the signal into mutually orthogonal set of wavelets, which is the difference from CWT, or its implementation for the discrete time series known as discrete-time continuous wavelet transform (DT-CWT).
- ***b.*** ***Continuous Wavelet Transform (CWT):*** CWT is an implementation of the wavelet transform that uses arbitrary scales and nearly arbitrary wavelets. The data obtained by this transform are highly correlated and the wavelets used are not orthogonal. For the discrete time series we use this transform , with a limitation that the smallest wavelet translations should be equal to the data sampling. This is called Discrete Time Continuous Wavelet Transform (DT-CWT) and it is the most appropriate way of computing CWT in real applications [9].

Wavelet families:

- ***a.*** ***Haar wavelet:*** discontinuous and resembles a step function. It represents the similar wavelet as Daubechies db1. Hungarian mathematician Alfred Haar invented the first DWT. The Haar wavelet transform may be considered to pair up input values, store the difference and passing the sum. This process is repeated again and again, pairing up the sums to provide the next scale, finally results in differences and one final sum. The Haar wavelet is a simple form of compression which involves average and difference terms, storing detail coefficients, eliminating data, and reconstruct the matrix so that the resulting matrix is similar to the initial matrix[10].

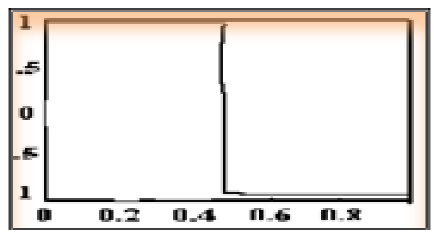


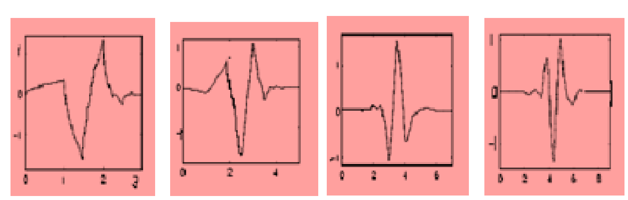
Figure. 6 haar wavelet

Advantages:

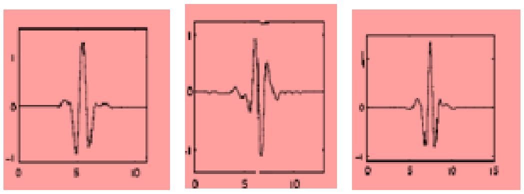
a) Haar wavelet is the only wavelet that is compactly supported, orthogonal and symmetric.
b) The compact support of the haar wavelets enables the haar decomposition to have a good time localization. Specifically, this means that the haar coefficients are effective for locating jump discontinuities and also for the efficient representation of signals with small support.

Disadvantages:

a) However, the fact that they have jump discontinuities in particular in the poorly decaying haar coefficients of, smooth functions and in the blockiness of images reconstructed from subsets of the haar coefficients
b) ***Symlets:*** The family of symlet wavelet is short of "symmetrical wavelets"



sym2 sym3 sym4 sym5



sym6 sym7 sym8

Figure. 7 symlet wavelet

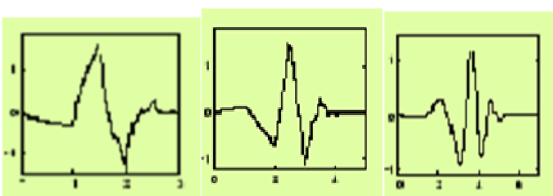
Advantages:

a) symlets are "symmetrical wavelets".
b) They are designed so that they have the least asymmetry and maximum number of vanishing moments for a given compact support.

Disadvantages:

a) These are not perfectly symmetrical.

a. Daubechies Wavelets: Ingrid Daubechies invented what are called compactly supported orthonormal wavelets , one of the brightest stars in the world of wavelet research, thus making discrete wavelet analysis practicable. The Daubechies family wavelets are written as dbN, where N is the order, db is the "family name of the wavelet. [11]



db2 db3 db4

Figure. 8 Daubechies wavelet

Advantages:

a) The Daubechies wavelets are orthogonal in nature which is energy preserving.
b) compactly-supported, orthogonal wavelets.

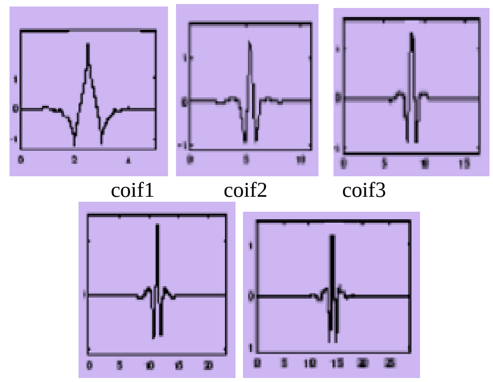
a. Coiflets Wavelets: This wavelet function has 2N moments equal to 0 and its scaling function has 2N-1 moments equal to 0. The two functions have support of length 6N-1.

Advantages:

a) The coiflets wavelets have nearly symmetric graphs
b) Coiflets wavelet are similar to daubechies wavelet they have a maximum number of vanishing moments.

Disadvantages:

a) There is no any formula for coiflets for arbitrary genus, and there is no formal proof of their existence for arbitrary genus at this time.

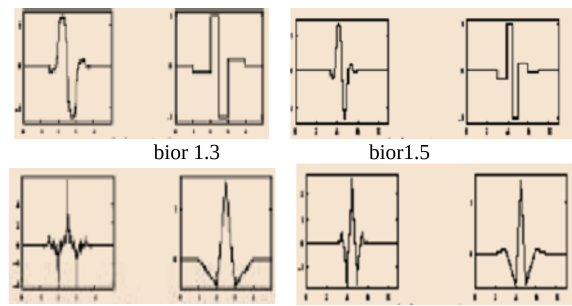


coif1 coif2 coif3

coif4 coif5

Figure. 9 coiflet wavelet

b. Biorthogonal Wavelet: compactly supported wavelets.



bior 1.3 bior1.5

bior2.2 bior2.5

Figure. 10 Bior wavelet

Advantage:

a) Current compression systems use biorthogonal wavelet instead of orthogonal wavelets.

Disadvantage:

b) It is not energy preserving.

Meyer wavelet: The Meyer wavelet is an orthogonal wavelet proposed by Yves Meyer. It is defined in frequency domain and indefinitely differentiable with infinite support.

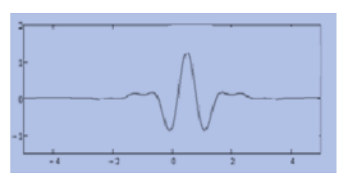


Figure. 11 Meyer wavelet

Advantage:

a) Compact support.

BASIC COMPRESSION MODEL

There are three essential stages in a wavelet transform image compression system transformation, quanti-zation and coding. Firstly the original image is trans-formed using wavelet transform, after that the transformed data is quantized and then entropy coding is done which provide compressed image. Again reverse process is done in decoding. Figure 12(a) depicts block diagram of encoding process and figure 12(b) depicts block diagram of decoding process.

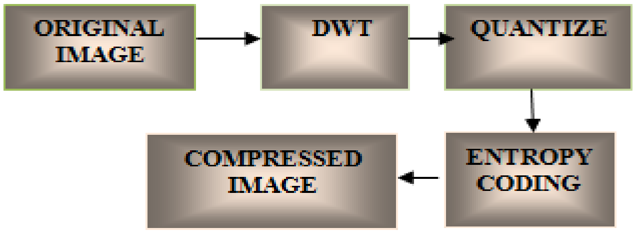


Figure. 12(a) Block diagram for encoding process

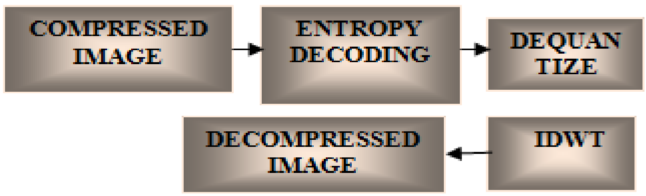
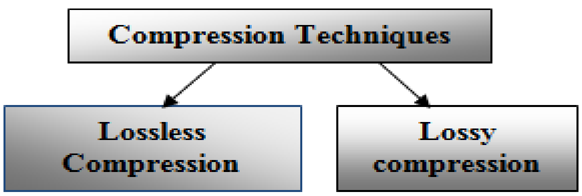


Figure. 12(b) Block diagram for decoding process

VARIOUS IMAGE COMPRESSION TECHNIQUES

Image compression techniques are broadly divided into two categories depending on upto what extent accurate information is required.



Lossless compression:

If image is compressed using this technique, original and compressed images both are exactly same.

Advantage:

b) Original image is reconstructed

Disadvantage:

c) The compression ratio is very poor.

Application:

Most of the time lossless techniques are used for medi-cal imaging.

Types of lossless techniques:

a) *Runlength encoding:* RLE is a simple form of compression in which data is in the form of runs. Runs are sequences in that the same data value occurs in various consecutive data elements are saved as a single data value and count, rather than as the original run. It is also be used to refer to an early graphics file format.

Advantages:

RLE schemes are simple and fast,

Disadvantage:

It does not work well at all on continuous-tone images such as photographs, even though JPEG uses it on the coefficients quite effectively that remain after transforming and quantizing image blocks.

a) ***Entropy encoding:*** This is a coding scheme which involve assign codes to symbols so that length of the code match with the symbol's probability. These encoders are used to compress data by replacing symbols represented by equal-length codes with symbols represented by codes proportional to the negative logarithm of the probability. So the common symbols use the shortest codes.

b) ***Huffman coding:*** The huffman‟ s algorithm is generating minimum redundancy codes compared to other algorithms. The Huffman coding are used in text, video compression image, conferencing system such as, JPEG, MPEG-2, MPEG-4 etc. It collects unique symbols from the source image and its probability value is calculated for each symbol.

c) ***Arithmetic Encoding:*** It provides code words with an ideal length. It is required to know the probability for the appearance of the individual symbols like for every other entropy coder. AC is the most efficient method to code symbols according to the probability of their occurrence. The average code length is very close to the possible minimum given by information theory. The AC assigns an interval to each symbol whose size reflects the probability for the appearance of this symbol. The code word of a symbol is an arbitrary rational number belonging to the corresponding interval.

Advantage: It provides more flexibility and better efficiency than the huffman coding does.

d) ***LZW Coding:*** This algorithm's working is based on the occurrence multiplicity of character sequences in the string to be encoded. The principle consists of pattern substituting process with an index code, by increasingly building a dictionary. Then that dictionary is initialized with the 256 ASCII values. The file that we want to compress is split into strings of bytes.

Lossy Compression:

If image is compressed with this technique, there is some loss of data and original image is not reconstructed exactly.

Advantage: Lossy schemes provide much higher compression ratios than lossless schemes.

Disadvantage: Some loss of data is there

Application: Lossy schemes are mostly used since the quality of the reconstructed images are adequate for most applications as the decompressed image is not identical to the original image, but resembles it.

Types of lossy techniques

a) ***Transform Coding:*** This algorithm mainly start by partitioning the original image into sub images (blocks) of small size (usually 8 x 8). The transform coefficients are calculated for each block, effectively converting the original array of pixel values into an array of coefficients closer to the top-left corner usually contain most of the information needed to quantize and encode the image with little distortion. The resulting coefficients are quantized and their output of the quantizer is used by a symbol encoding technique for producing the output bit stream which represents the encoded image. The reverse process will take place at the decoder's side, and the dequantization stage will only generate an approximated version of the original coefficient values. Whatever loss is introduced by the quantizer in the encoder stage is not reversible.

b) ***DCT:*** The discrete cosine transform process is usually applied on blocks of 16 * 16 or 8 * 8 pixels, which will convert into series of coefficients, define spectral composition of the block. The Transformer transforms the input into a format to reduce interpixel redundancies in the input image. These techniques use a linear, reversible mathematical transform to map the pixel values onto a set of coefficients, which are quantized and then encoded. The key factor after the success of transform-based coding schemes is that many of the resulting coefficients for most natural images have small magnitudes and be quantized without making significant distortion in the decoded image.

Discrete Wavelet Transform (Dwt): The DWT represents an image as a sum of wavelet functions, with different location and scale called as **wavelets**. DWT represents the image data into a set of low pass (approximate)and high pass (detail) coefficients. Image is first divided into blocks of 32×32. Then each block is passed throughout the two filters: the first level decomposition is performed to decompose the input data into an approximation and detail coefficients. Then after obtaining the transformed matrix, detail and approximate coefficients are identified as LL, HL, LH, and HH coefficients. All the coefficients, except the LL coefficients are discarded that are transformed into the second level. After then these coefficients are passed through a constant scaling factor to achieve the desired compression ratio.

c) ***Fractal Compression*:** This fractal compression technique based on the fact that in most of the images, parts of the image be similar to other parts of the same image. So Fractal compression convert these parts, into mathematical data called "fractal codes" which are used to remake the encoded image. Just the once an image has been converted into fractal code, it becomes resolution independent, its relationship to a specific resolution has been lost[12,13].

Performance Parameters:

For comparing original image and uncompressed image, we calculate following parameters:

a) ***Mean Square Error(MSE):*** The MSE is the cumulative square error between the encoded and the original image defined by:

$$MSE = \frac{1}{mn}\sum_{0}^{m-1}\sum_{0}^{n-1}\|f(i,j) - g(i,j)\|^2$$

Where, f is the original image and g is the uncompressed image. The dimension of the images is m x n. Thus MSE should be as low as possible for effective compression.

b) ***Peak signal to Noise ratio(PSNR):*** is the ratio between the maximum possible power of a signal and the power of distorting noise which affects the quality of its representation defined by:

$$PSNR = 20\log_{10}\left(\frac{MAX_f}{\sqrt{MSE}}\right)$$

Where MAX_f is the maximum signal value that exists in our original "known to be good" image.

c) ***Bit Per Pixel (BPP):*** It is defined as number of bits required to compress each pixel. It should be low to reduce storage requirement.

d) ***Compression Ratio:*** The compression ratio is defined as the size of the original image divided by the size of the compressed image. The ratio provides an clue of how much compression is achieved for a particular image.

e) ***Signal to noise ratio:*** is defined by the power ratio between a signal and the background noise.

$$\mathrm{SNR} = \frac{P_\mathrm{signal}}{P_\mathrm{noise}},$$

Where *P* is average power. Both noise and power must be measured at the same points in a system, and within system with same bandwidth.

CONCLUSION

Compression is necessary task in digital image processsing. Wavelets are best for compression of images. In this paper we describe various wavelet families and compare their properties. Compression techniques are divided into two parts lossy and lossless compression. After studying lossy and lossless both techniques, if image is compressed with lossless technique, original and compressed images both are exactly same but compression ratio is low and if image is compressed with lossy technique, there is some loss of data and original image is not reconstructed exactly but compression ratio is higher. There should be minimum loss of data in medical image processing which do not affects the end results. Wavelet compression gives high data compression ratio and MSE is minimized and PSNR is maximized. So wavelet compression is good for medical image compression.

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