Introduction to Digital Image Processing

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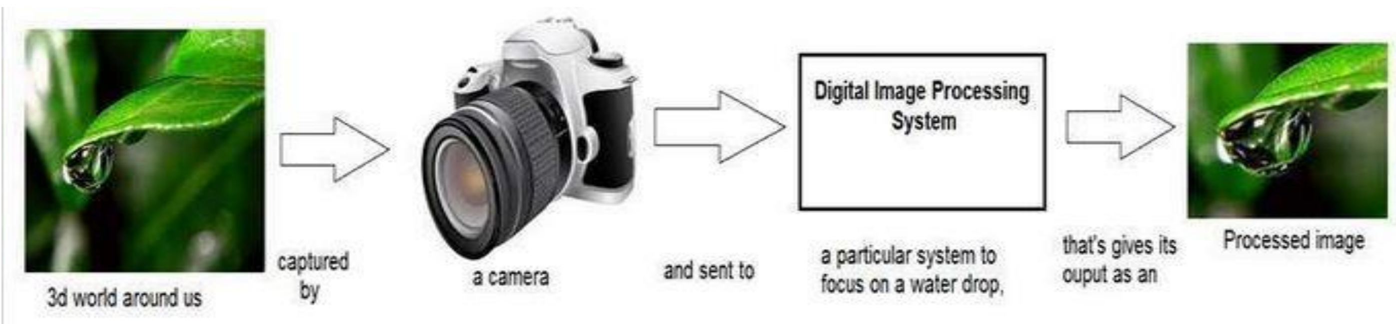
A. Introduction:

1. Digital image processing deals with manipulation of digital images through a digital computer. It is a subfield of signals and systems but focus particularly on images.
2. DIP focuses on developing a computer system that is able to perform processing on an image.
3. The input of that system is a digital image and the system process that image using efficient algorithms, and gives an image as an output. The most common example is Adobe Photoshop.
4. It is one of the widely used application for processing digital images.
5. Signal processing is a discipline that deals with analysis and processing of analog and digital signals, and deals with storing, filtering, and other operations on signals. These signals include transmission signals, sound or voice signals, image signals, and other signals etc.
6. Out of all these signals, the field that deals with the type of signals for which the **input is an image and the output is also an image is done in image processing**. As it name suggests, it deals with the processing on images.

How it works:



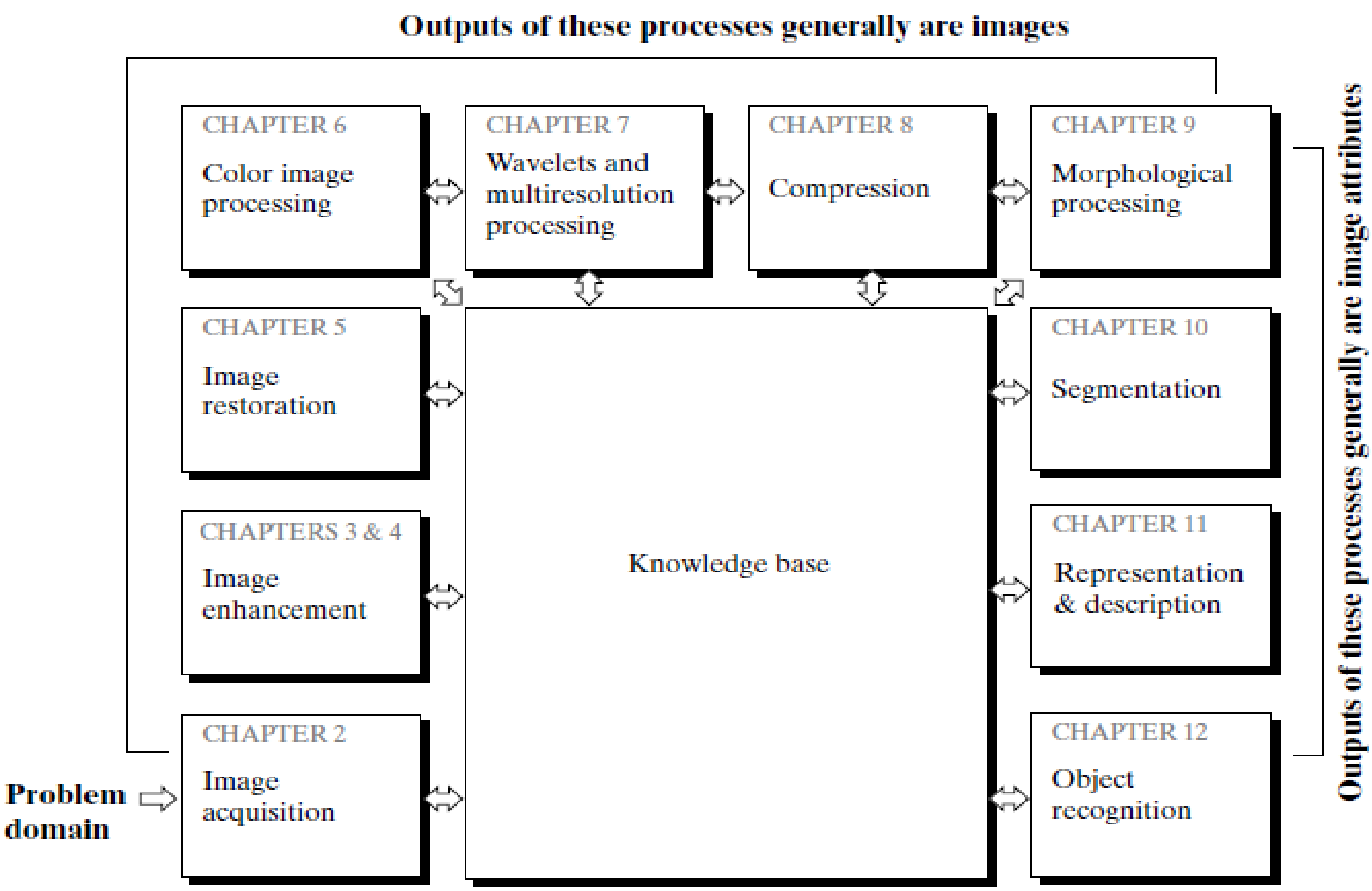
In the above figure, an image has been captured by a camera and has been sent to a digital system to remove all the other details, and just focus on the water drop by zooming it in such a way that the quality of the image remains the same.

- **Defined as**

  "An image may be defined as a two-dimensional function, f(x, y), where x and y are *spatial* (plane) coordinates, and the amplitude of at any pair of coordinates (x, y) is called the ***intensity*** or *gray level* of the image at that point. When x, y, and the amplitude values of f are all finite, discrete quantities, we call the image a *digital image*."

- **DIP** refers to processing digital images by means of a digital computer. Note that a digital image is composed of a finite number of elements, each of which has a particular location and value.
- These elements are referred to as ***picture elements, image elements, pels, and pixels.***

Fundamental Steps in Digital Image Processing:



(Explain- HW)

Different Level of Image Processing:

1.Low-Level Processing

Low-level processes involve primitive operations such as image preprocessing to reduce noise, contrast enhancement, and image sharpening.

A low-level process is characterized by the fact that both its inputs and outputs are images .

2. Mid-level processing

Mid-level processing on images involves tasks such as segmentation (partitioning an image into regions or objects), description of those objects to reduce them to a form suitable for computer processing, and classification (recognition) of individual objects.

A mid-level process is characterized by the fact that its inputs generally are images, but its outputs are attributes extracted from those images (e.g. edges, contours, and the identity of individual objects)

3. Higher-level processing

Involves "making sense" of an ensemble of recognized objects, as in image analysis, and, at the far end of the continuum, performing the cognitive functions normally associated with vision.

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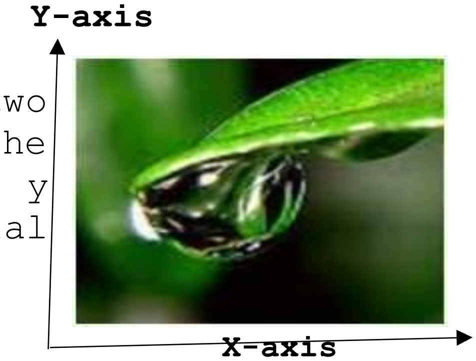
Analog image processing and digital image processing:

Analog image processing	**Digital image processing**
Analog image processing is done on analog signals. It includes processing on two dimensional analog signals. In this type of processing, the images are manipulated by electrical means by varying the electrical signal. The common example include is the television image. Digital image has dominated over analog image processing with the passage of time due its wider range of applications.	The digital image processing deals with developing a digital system that performs operations on an digital image.

What is an Image:



An image is nothing more than a two dimensional signal. It is defined by the mathematical function f(x,y) where x and y are the two co-ordinates (spatial coordinates) horizontally and vertically.

The value of f(x,y) at any point is gives the pixel value at that point of an image is intensity or grey level.

The above figure is an example of digital image that you are now viewing on your computer screen. But actually, this image is nothing but a two dimensional array of numbers ranging between 0 and 255.

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Image acquisition process

How a digital image is formed?

Since capturing an image from a camera is a physical process. The sunlight is used as a source of energy.

A sensor array is used for the acquisition of the image. So when the sunlight falls upon the object, then the amount of light reflected by that object is sensed by the sensors, and a continuous voltage signal is generated by the amount of sensed data. In order to create a digital image, we need to convert this data into a digital form.

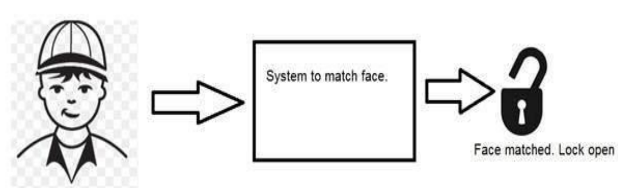
This involves **sampling and quantization.** The result of sampling and quantization results in an two dimensional array or matrix of numbers which are nothing but a digital image.

Overlapping fields (Deep knowledge/ Uses):

1. Machine/Computer vision:

Machine vision or computer vision deals with developing a system in which the input is an image and the output is some information.

For example: Developing a system that scans human face and opens any kind of

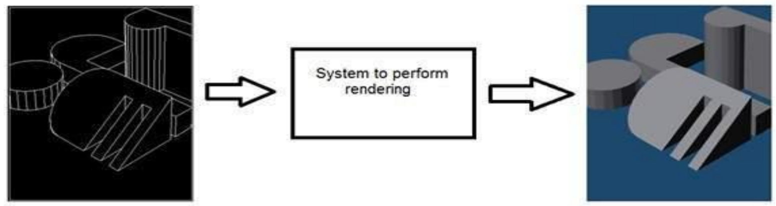


lock. This system would look something like this.

2. Computer graphics:

Computer graphics deals with the formation of images from object models, rather than the image is captured by some device.

For example: Object rendering. Generating an image from an object model.



Such a system would look something like this.

3. Artificial intelligence:

Artificial intelligence is more or less the study of putting human intelligence into machines and has many applications in image processing. For example: developing computer aided diagnosis systems that help doctors in interpreting images of X-ray , MRI e.t.c and then highlighting conspicuous section to be examined by the doctor.

4. Signal processing

Signal processing is an umbrella and *image processing lies under it*. The amount of light reflected by an object in the physical world (3d world) is pass through the lens of the camera and it becomes a 2d signal and hence result in image formation.

This image is then digitized using methods of signal processing and then this digital image is manipulated in digital image processing.

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B. Signals and Systems Introduction

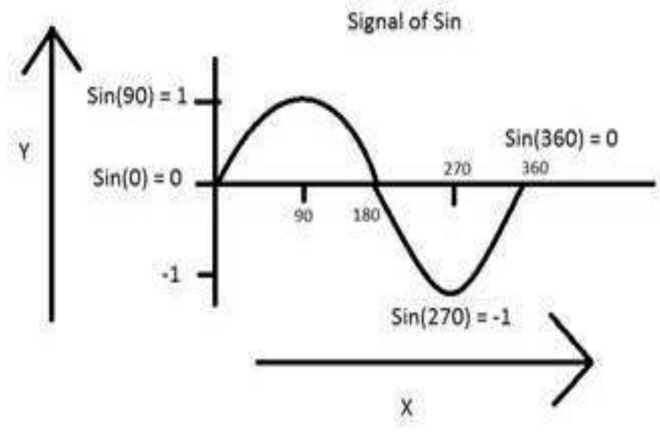
Signals

1.The fundamental quantity of representing some information is called a signal. It does not matter what the information is i-e: Analog or digital information.

2.In mathematics, a signal is a function that conveys some information. In fact, any quantity measurable through time over space or any higher dimension can be taken as a signal. A signal could be of any dimension and could be of any form.

Types of Signal: Analog Signal and Digital Signal

Analog signals



1.A signal could be an analog quantity that means it is defined with respect to the time.

2.It is a continuous signal. These signals are defined over continuous independent variables.

3. They are difficult to analyze, as they carry a huge number of values.

4.They are very much accurate due to a large sample of values. In order to store these signals, you require an **infinite memory** because it can achieve infinite values on a real line. Analog signals are denoted by sin waves.

For example: *Human voice*

Human voice is an example of analog signals. When you speak, the voice that is produced travel through air in the form of pressure waves and thus belongs to a mathematical function, having independent variables of space and time and a value corresponding to air pressure.

Another example is of sin wave which is shown in the figure below.

Y = sin(x) where x is independent

Digital signals

1.As compared to analog signals, digital signals are very easy to analyze. They are discontinuous signals. They are the appropriation of analog signals.

2.The word digital stands for **discrete values** and hence it means that they use specific values to represent any information.

3. In digital signal, only two values are used to represent something i-e: **1 and 0 (binary values**. Digital signals are denoted by square waves.

For example: *Computer keyboard*

Whenever a key is pressed from the keyboard, the appropriate electrical signal is sent to keyboard controller containing the ASCII value that particular key. For example the electrical signal that is generated when keyboard key a is pressed, carry information of digit 97 in the form of 0 and 1, which is the ASCII value of character.

System

1.A system is a defined by the type of input and output it deals with.

2.Since we are dealing with signals, so in our case, our system would be a mathematical model, a piece of code/software, or a physical device, or a black box whose input is a signal and it performs some processing on that signal, and the output is a signal.

3.The input is known as **excitation** and the output is known as **response.**

4.In the above figure a system has been shown whose input and output both are signals but the input is an analog signal. And the output is an digital signal. It means our system is actually a conversion system that converts analog signals to digital signals.

Lets have a look at the inside of this black box system

Conversion of analog to digital signals:

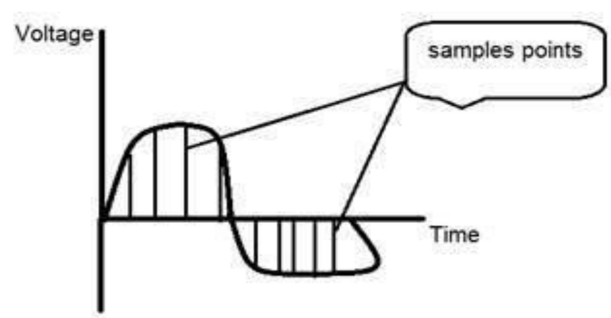
Since there are lot of concepts related to this analog to digital conversion and vice-versa.

We will only discuss those which are related to digital image processing. There are two main concepts that are involved in the conversion.

- **Sampling**
- **Quantization**
- **Encoding**

Sampling

1.Sampling as its name suggests can be defined as take samples.



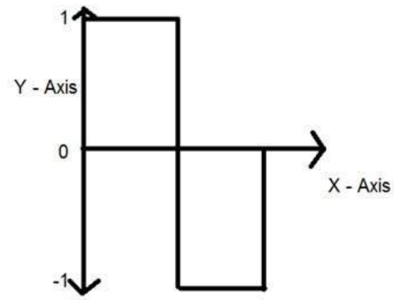
2.Take samples of a digital signal over x axis. Sampling is done on an independent variable. In case of this mathematical equation:

3.Sampling is done on the x variable. We can also say that the conversion of x axis (infinite values) to digital is done under sampling.

4.Sampling is further divide into **up sampling and down sampling.** If the range of values on x-axis are less, then we will increase the sample of values. This is known as up sampling and its vice versa is known as down sampling.

Quantization

1.Quantization as its name suggest can be defined as dividing into quanta (partitions). Quantization is done on dependent variable. It is opposite to sampling.



In case of this mathematical equation **y = sin(x)**

2.Quantization is done on the Y variable. It is done on the y axis. The conversion of y axis infinite values to 1, 0, -1 (or any other level) is known as Quantization.

3.These are the two basics steps that are involved while converting an analog signal to a digital signal.

Example of Digital Image

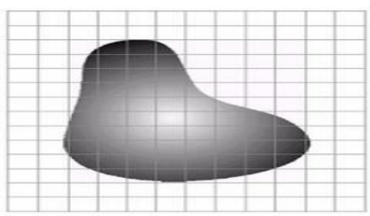


Fig A

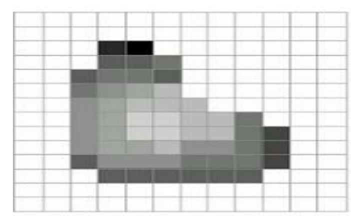


Fig B

A. Continuous image Projected into a sensor array
B. Result of image after sampling and quantization

Encoding

The encoding operation reduces the result of the conversion to a binary code acceptable to the digital equipment's that use the data.

There is a variety of coding systems in use. You have already been introduced to one of the most common ones, **natural binary code.** This binary code expresses quantities are weighted in sum. Each bit position represents a specified value when set. The sum of the values of the set bits defines the value of the quantity.

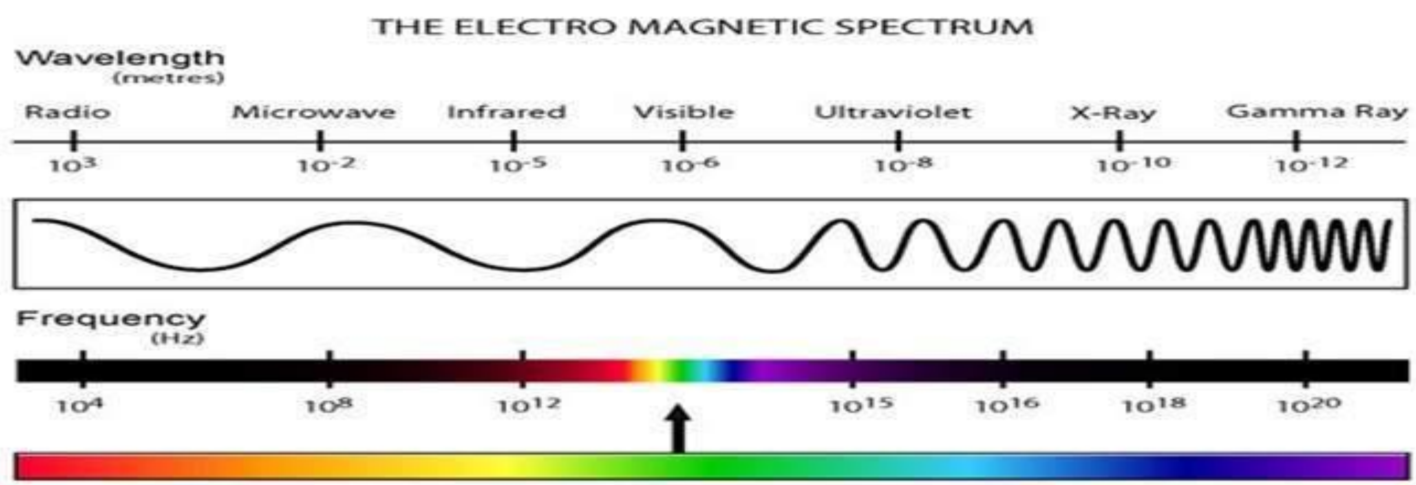
Que: Why do we need to convert an analog signal to digital signal?

1.The first and obvious reason is that digital image processing deals with digital images, that are digital signals. So whenever the image is captured, it is converted into digital format and then it is processed.

2.The second and important reason is, that in order to perform operations on an analog signal with a digital computer, you have to store that analog signal in the computer. And in order to store an analog signal, infinite memory is required to store it. And since that's not possible, so that's why we convert that signal into digital.

Electromagnetic waves:

Electromagnetic waves can be thought of as stream of particles, where each particle is moving with the speed of light. Each particle contains a bundle of energy. This bundle of energy is called a photon.



The electromagnetic spectrum according to the energy of photon is shown below.

1.In this electromagnetic spectrum, we are only able to see the visible spectrum. Visible spectrum mainly includes seven different colors that are commonly term as **(VIBGOYR)**. VIBGOYR stands for ***violet, indigo, blue , green , orange , yellow and Red.***

2.Our human eye can only see the visible portion; in which we saw all the objects. But a camera can see the other things that a naked eye is unable to see.

For example: **x rays, gamma rays,** etc. Hence the analysis of all that stuff too is done in digital image processing.

This discussion leads to another question which is **why do we need to analyze all that other stuff in EM spectrum too?** The answer to this question lies in the fact, because that other stuff such as X-rays has been widely used in the field of medical. The analysis of Gamma ray is necessary because it is used widely in nuclear medicine and astronomical observation. Same goes with the rest of the things in EM spectrum.

C. Applications of Digital Image Processing

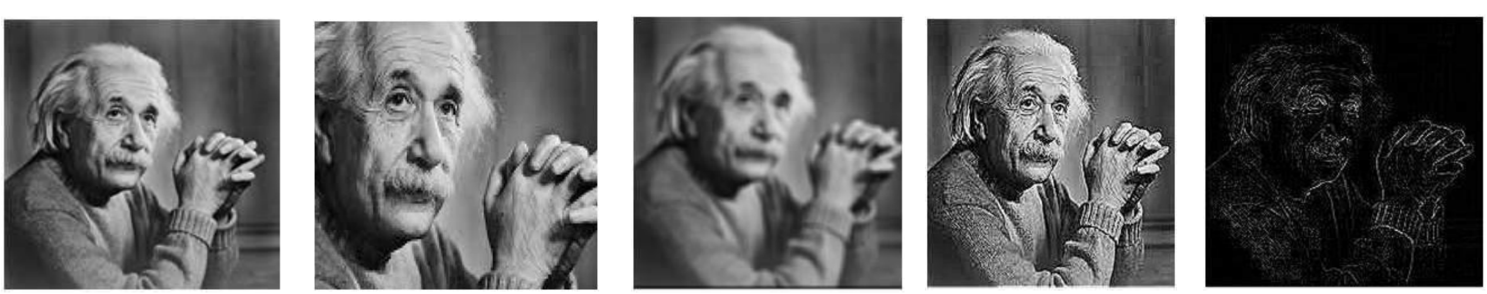
Some of the major fields in which digital image processing is widely used are mentioned below

- Image sharpening and restoration
- Medical field
- Remote sensing
- Transmission and encoding
- Machine/Robot vision
- Color processing
- Pattern recognition
- Video processing
- Microscopic Imaging
- Others

1. Image sharpening and restoration

Image sharpening and restoration refers here to process images that have been captured from the modern camera to make them a better image or to manipulate those images in way to achieve desired result. It refers to do what Photoshop usually does.

This includes Zooming, blurring , sharpening , gray scale to color conversion, detecting edges and vice versa , Image retrieval and Image recognition. The common examples are:



1. Original image 2. Zoomed image 3. Blur image 4. Sharp image 5. Edges

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2.Medical field

The common applications of DIP in the field of medical is

Gamma ray imaging	PET scan	X Ray Imaging
Medical CT	UV imaging	

3.UV imaging

In the field of remote sensing, the area of the earth is scanned by a satellite or from a very high ground and then it is analyzed to obtain information about it.

One particular application of digital image processing in the field of remote sensing is to detect infrastructure damages caused by an earthquake.

As it takes longer time to grasp damage, even if serious damages are focused on. Since the area effected by the earthquake is sometimes so wide, that it not possible to examine it with human eye in order to estimate damages.

Even if it is, then it is very hectic and time consuming procedure. So a solution to this is found in digital image processing. An image of the affected area is captured from the above ground and then it is analyzed to detect the various types of damage done by the earthquake.

The key steps include in the analysis are

- ***The extraction of edges***
- ***Analysis and enhancement of various types of edges***

4.Transmission and encoding

The very first image that has been transmitted over the wire was from London to New York via a submarine cable. The picture that was sent is shown below.

The picture that was sent took three hours to reach from one place to another.

Now just imagine, that today we are able to see live video feed, or live cctv footage from one continent to another with just a delay of seconds. It means that a lot of work has been done in this field too.

This field does not only focus on transmission, but also on encoding. Many different formats have been developed for high or low bandwidth to encode photos and then stream it over the internet or etc.

5.Machine/Robot vision

Apart from the many challenges that a robot faces today, one of the biggest challenge still is to increase the vision of the robot. Make robot able to see things, identify them, identify the hurdles etc.

Much work has been contributed by this field and a complete other field of computer vision has been introduced to work on it.

6.Hurdle detection

Hurdle detection is one of the common task that has been done through image processing, by identifying different type of objects in the image and then calculating the distance between robot and hurdles.

7.Color processing

Color processing includes processing of colored images and different color spaces that are used.

For example, ***RGB color model, HSV***. It also involves studying transmission, storage, and encoding of these color images.

8.Pattern recognition

Pattern recognition involves study from image processing and from various other fields that includes machine learning (a branch of artificial intelligence). In pattern recognition, image processing is used for identifying the objects in an images and then machine learning is used to train the system for the change in pattern.

Pattern recognition is used in computer aided diagnosis, recognition of handwriting, recognition of images etc.

9.Video processing

A video is nothing but just the very fast movement of pictures. The quality of the video depends on the number of frames/pictures per minute and the quality of each frame being used.

Video processing involves noise reduction, detail enhancement, motion detection , frame rate conversion , aspect ratio conversion , color space conversion e.t.c.

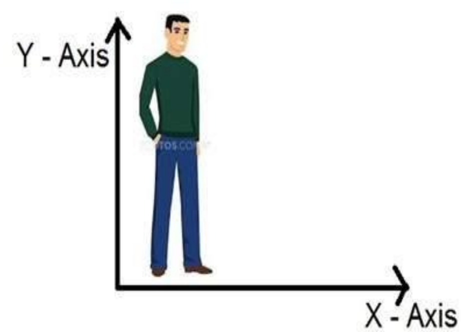
Dimension

Dimensions define the minimum number of points required to point a position of any particular object within a space.

Consists of three pair of co-ordinates. The first one is called longitude, the second one is called latitude, and the third one is called altitude.

Since we are studying this concept in reference to the digital image processing, so we are now going to relate this concept of dimension with an image.

Dimensions of image



So if we live in the 3d world, means a 3 dimensional world, then what are the dimensions of an image that we capture.

An image is a two dimensional, that's why we also define an image as a 2 dimensional signal. An image has only height and width. An image does not have depth. Just have a look at this image below.

If you would look at the above figure, it shows that it has only two axis which are the height and width axis. You cannot perceive depth from this image. Thats why we say that an image is two dimensional signal. But our eye is able to perceive three dimensional objects.

Scenario / Example 1: How television works?

If we look the image above, we will see that it is a two dimensional image. In order to convert it into three dimension, we need one other dimension. Let's take time as the third dimension, in that case we will move this two dimensional image over the third dimension **time**. The same concept that happens in television, that helps us perceive the depth of different objects on a screen. Does that mean that what comes on the T.V or what we see in the television screen is 3D? Well we can yes.

The reason is that, in case of T.V we if we are playing a video. *Then a video is nothing else but two dimensional pictures move over time dimension*. As two dimensional objects are moving over the third dimension which is a time so we can say it is 3 dimensional.

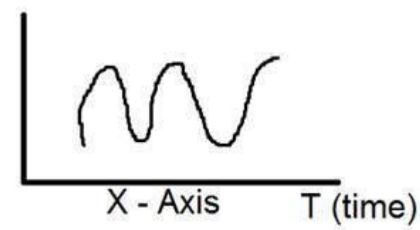
Different dimensions of signals

1-dimension signal

The common example of a 1 dimension signal is a waveform. It can be mathematically represented as

F(x) = waveform

Where x is an independent variable. Since it is a one dimension signal , so thats why there is only one variable x is used. Eg Voice

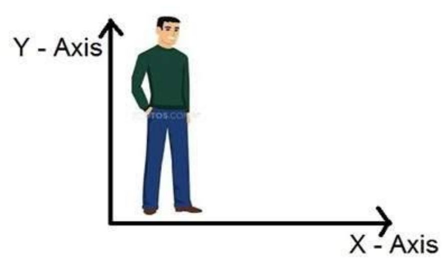


2 dimensions' signal

The common example of a two dimensional signal is an image, which has already been discussed above. As we have already seen that an image is two dimensional signal, i-e: it has two dimensions. It can be mathematically represented as:

F (x , y) = Image

Where x and y are two variables. Eg Image



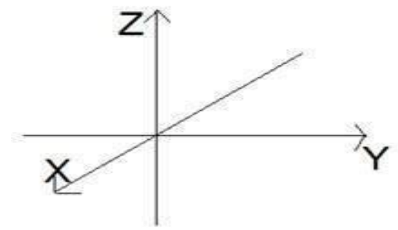
3-dimension signal

Three dimensional signal as it names refers to those signals which has three dimensions. The most common example is of our world that we see. We live in a three dimensional world.

Another example of a three dimensional signal is a cube or a volumetric data or the most common example would be animated or 3d cartoon character.

The mathematical representation of three dimensional signal is:

F(x,y,z) = animated character.



Another axis or dimension Z is involved in a three dimension, that gives the illusion of depth. In a Cartesian co-ordinate system, it can be viewed as:

4-dimension signal

In a four dimensional signal, four dimensions are involved. The first three are the same as of three dimensional signal which are: (X, Y, Z), and the fourth one which is added to them is T(time). Time is often referred to as temporal dimension which is a way to measure change.

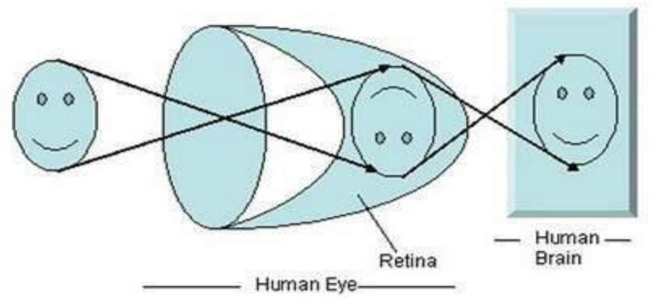
F(x,y,z,t) = animated movie

The common example of a 4 dimensional signal can be an animated 3d movie. As each character is a 3d character and then they are moved with respect to the time, due to which we saw an illusion of a three dimensional movie more like a real world.

E. Elements of Visual perception

How human eye works?

1.The basic principle that is followed by the cameras has been taken from the way, the human eye works. So we have to first manipulate or discuss the image formation on human eye.



2.When light falls upon the particular object, it is reflected back after striking through the object. The rays of light when passed through the lens of eye, form a particular angle, and the image is formed on the retina which is the back side of the wall (Photoreceptors convert light into electrical impulses that are decoded by brain).

3.The image that is formed is inverted. This image is then interpreted by the brain and that makes us able to understand things. Due to angle formation, we are able to perceive the height and depth of the object we are seeing. This mechanism of image formation is known as **perspective transformation**.

4.As you can see in the above figure, that when sun light falls on the object (in this case the object is a face), it is reflected back and different rays form different angle when they are passed through the lens and an invert image of the object has been formed on the back wall.

5.The last portion of the figure denotes that the object has been interpreted by the brain and re-inverted.

6. **Photoreceptors**

Rods & Cones: Convert light into nerve signal that is transmitted to the brain via the optic nerve.

- **Rods** – Dim light vision Dim light vision

  – SCOTOPIC vision

- **Cones** – Bright light vision Bright light vision

  – PHOTOPIC vision

Now let's take our discussion back to the image formation on analog and digital cameras.

Image formation on analog cameras > chemical reaction (silver halide) > 35mm film cartridge > photon particles(light)> result image (known as negative)

Photons (light particles) + silver halide = image negative

Image formation on digital cameras > no chemical reaction > > image sensor (intensity of photon) > CCD array (charge-coupled device) > CCD array image store

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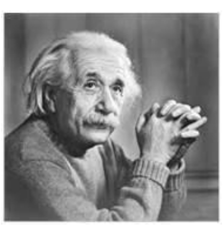
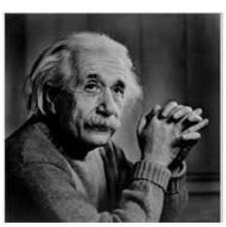
Aperture

Aperture is a small opening which allows the light to travel inside into camera. Here is the picture of aperture (octagonal shape).

Its hole from which the light would have to pass would be bigger. The bigger the hole, the more light is allowed to enter.

Effect





The effect of the aperture directly corresponds to brightness and darkness of an image. If the aperture opening is wide, it would allow more light to pass into the camera. More light would result in more photons, which ultimately result in a brighter image.

Consider these two photos: (right side looks brighter (aperture wide open left side), left side very dark (aperture was not wide open)

Shutter

The light when allowed to pass from the aperture, falls directly on to the shutter. Shutter is actually a cover, a closed window, or can be thought of as a curtain.

As soon as the shutter is open, light falls on the image sensor, and the image is formed on the array.

Effect

If the shutter allows light to pass a bit longer, the image would be brighter.

Similarly, a darker picture is produced, when a shutter is allowed to move very quickly and hence, the light that is allowed to pass has very less photons.

Shutter has further two main concepts: 1. Shutter Speed 2. Shutter time

Shutter speed

The shutter speed can be referred to as the number of times the shutter get open or close. Remember we are not talking about for how long the shutter get open or close.

Shutter time

When the shutter is open, then the amount of wait time it take till it is closed is called shutter time.

Example /Scenario Fast moving objects:

If you were to capture the image of a fast moving object, could be a car or anything. The adjustment of shutter speed and its time would effect a lot.

So, in order to capture an image like this, we will make two amendments:

- *Increase shutter speed*
- *Decrease shutter time*

What happens is, that when we increase shutter speed, the more number of times, the shutter would open or close. It means different samples of light would allow to pass in. And when we decrease shutter time, it means we will immediately capture the scene, and close the shutter gate.

If you will do this, you get a crisp image of a fast moving object.

1.shutter speed to 1 second

2.shutter speed to a faster speed

3. shutter speed to even more faster

1

2

3

You can see in the last picture-3, that we have increase our shutter speed to very fast, that means that a shutter get opened or closed in 200th of 1 second and so we got a **crisp image**.

ISO

ISO factor is measured in numbers. It denotes the sensitivity of light to camera. If ISO number is lowered, it means our camera is less sensitive to light and if the ISO number is high, it means it is more sensitive.

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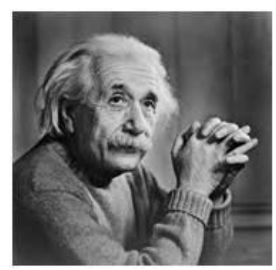
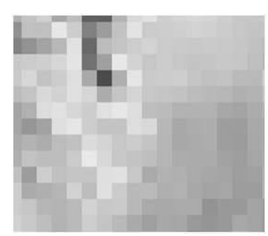
Pixel (PEL)



Pixel is the smallest element of an image.

Each pixel corresponds to any one value.

In an ***8-bit gray scale image, the value of the pixel between 0 and 255***.



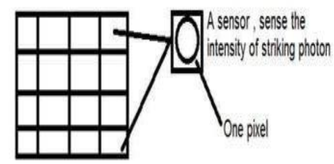
The value of a pixel at any point correspond to the intensity of the light photons striking at that point. Each pixel stores a value proportional to the light intensity at that particular location.

A pixel is also known as **PEL**. You can have more understanding of the pixel from the pictures given below.

In the above picture, there may be thousands of pixels, that together make up this image. We will zoom that image to the extent that we are able to see some pixel's division. It is shown in the image below.

Calculation of total number of pixels

We have defined an image as a two dimensional signal or matrix. Then in that case the number of PEL would be equal to the number of rows multiply with number of columns.



Total number of pixels = number of rows (X) number of columns

Or we can say that the number of (x,y) coordinate pairs make up the total number of pixels.

Pixel value (0)

Each pixel can have only one value and each value denotes the intensity of light at that point of the image.

0	0	0
0	0	0
0	0	0

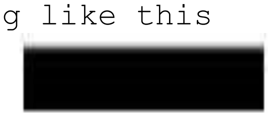
We will now look at a very unique value 0. The value 0 means absence of light. It means that 0 denotes dark, and it further means that whenever a pixel has a value of 0, it means at that point, black color would be formed.

Now this image matrix has all filled up with 0. All the pixels have a value of 0. If we were to calculate the total number of pixels form this matrix, this is how we are going to do it.

Total no of pixels = total no. of rows X total no. of columns= 3 X 3 = 9

It means that an image would be formed with 9 pixels, and that image would have a dimension of 3 rows and 3 columns and most importantly that image would be black.

The resulting image that would be made would be something like this



Now why is this image all black. Because all the pixels in the image had a value of 0.

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Bits in mathematics:

1.Bpp or bits per pixel denotes the number of bits per pixel. It’s a binary bits.

2.How many numbers can be represented by one bit. (0 1)

3. How many two bits combinations can be made.00 01 10 11)

3. formula for the calculation of total number of combinations that can be made from bit, it would be like this.

$$(2)^{bpp}$$

Where ***bpp denotes bits per pixel***.

Bits per pixel	Number of colors
1 bpp	2 colors
2 bpp	4 colors
3 bpp	8 colors
4 bpp	16 colors
5 bpp	32 colors
6 bpp	64 colors
7 bpp	128 colors
8 bpp	256 colors
10 bpp	1024 colors
16 bpp	65536 colors
24 bpp	16777216 colors (16.7 million colors)
32 bpp	4294967296 colors (4294 million colors)

4.Put 1 in the formula you get 2, put 2 in the formula, you get 4. It grows exponentially.

$$\text{Shades} = \text{number of colors} = (2)^{bpp}$$

Color images are usually of the **24 bpp format, or 16 bpp**.

We will see more about other color formats and image types in the tutorial of image types.

Black color:

Remember, ***0-pixel value always denotes black color***. But there is no fixed value that denotes white color.

White color:

The value that denotes white color can be calculated as :

$$\text{White color} = (2)^{bpp} - 1$$

In case of **1 bpp**, 0 denotes black, and 1 denotes white.

In case **8 bpp**, 0 denotes black, and 255 denotes white.

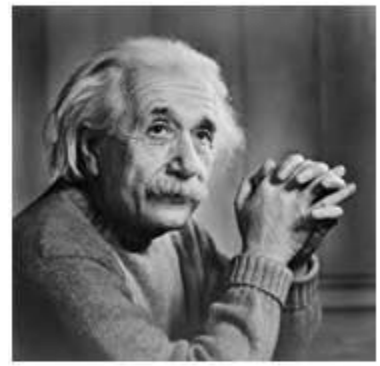
Gray color:

When you calculate the black and white color value, then you can calculate the pixel value of gray color.

Gray color is actually the midpoint of black and white.

In case of 8bpp, the pixel value that denotes g**ray color is 127 or 128bpp** (if you count from 1, not from 0).

Image storage requirements



After the discussion of bits per pixel, now we have everything that we need to calculate a size of an image.

Image size

The size of an image depends upon three things.

- Number of rows
- Number of columns
- Number of bits per pixel

Size of an image = rows * cols * bpp

Assuming it has **1024 rows and it has 1024 columns.** And since it is a gray scale image, it has 256 different shades of gray or it has bits per pixel.

Then putting these values in the formula, we get

Size of an image = rows * cols * bpp

= 1024 * 1024 * 8

= 8388608 bits = 8388608 / 8

= 1048576 bytes =1048576 / 1024

= 1024 kb = 1024 / 1024 = **1 Mb.**

Case Analysis:

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Basic types of Digital image

Binary images /Two-valued images

Grayscale image/Intensity images

RGB image

1.Binary images /Two-valued images

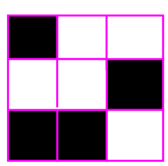
A binary image is a digital image that has only two possible values for each pixel.

Typically, the two colors used for a binary image are **black and white** though any two colors can be used.

Binary images are also **called *bi-level* or *two-level*.** It means that each pixel is stored as a single bit (0 or 1).

Binary images often arise in digital image processing as mask or as the result of certain operations such as **segmentation, thresholding, and dithering.**

Value of pixels:0 or 1



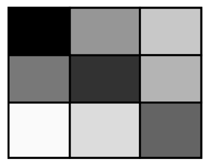
$$I = \begin{bmatrix} 0 & 1 & 1 \\ 1 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

2.Grayscale image

A grayscale or greyscale digital image is an image in which the value of each pixel is a ***single sample***, that is, it carries only ***intensity information***.

Images of this sort, also known as black-and-while, are composed exclusively of ***shades of gray***, varying from black at the weakest intensity to white at the strongest.

Value of pixels: 0 ~ 255



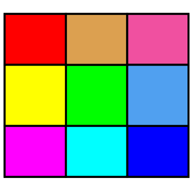
$$I = \begin{bmatrix} 0 & 150 & 200 \\ 120 & 50 & 180 \\ 250 & 220 & 100 \end{bmatrix}$$

3.RGB image/ Color Image

The **R G B** color model is an additive color model in which red, green, and blue light are added together in various ways to reproduce a broad array of colors.

The name of the model comes from the initials of the three additive primary **colors, red, green, and blue.**

RGB Three matrix



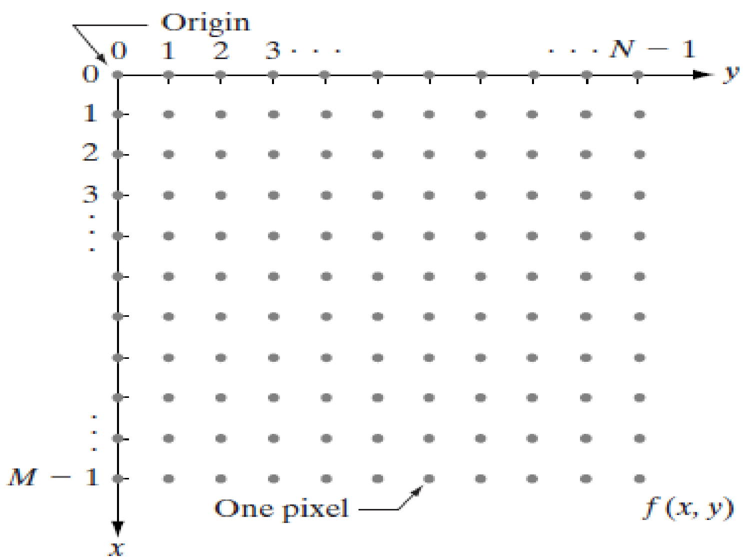
$$R = \begin{bmatrix} 255 & 240 & 240 \\ 255 & 0 & 80 \\ 255 & 0 & 0 \end{bmatrix} \quad G = \begin{bmatrix} 0 & 160 & 80 \\ 255 & 255 & 160 \\ 0 & 255 & 0 \end{bmatrix} \quad B = \begin{bmatrix} 0 & 80 & 160 \\ 0 & 0 & 240 \\ 255 & 255 & 255 \end{bmatrix}$$

Relationships Between Pixels

An image **f(x, y)** is sampled so that the resulting digital image has **M rows and N columns.**

The values of the coordinates (x, y) now become ***discrete* quantities.**

For notational clarity and convenience, we shall use integer values for these discrete coordinates.



Thus, the values of the coordinates at the origin are ***(x, y)=(0, 0)***.The next coordinate value s along the first row of the image are represented as (x, y)=(0, 1).

$$f(x, y) = \begin{bmatrix} f(0,0) & f(0,1) & \cdots & f(0, N-1) \\ f(1,0) & f(1,1) & \cdots & f(1, N-1) \\ \vdots & \vdots & & \vdots \\ f(M-1,0) & f(M-1,1) & \cdots & f(M-1, N-1) \end{bmatrix}.$$

Each element of this matrix array ***is called an image element, picture element, pixel, or pel***

Neighbors of a Pixel

A pixel p at coordinates (x, y) has four ***horizontal* and *vertical* neighbors** whose coordinates are given by

(x+1, y), (x-1, y), (x, y+1), (x, y-1)

called the 4-neighbors of p, is denoted by N_4(p)

The four diagonal neighbors of p have coordinates

(x+1, y+1), (x+1, y-1), (x-1, y+1), (x-1, y-1)

and are denoted by N_D(p).

Adjacency, Connectivity, Regions, and Boundaries

Connectivity:

In a binary image with values 0 and 1, two pixels may be 4-neighbors, but they are said to be connected only if they have the same value.

Adjacency:

Let *V* be the set of gray-level values used to define adjacency. In a binary image, V= {1} if we are referring to adjacency of pixels with value 1.

Three types of adjacency:

(a) 4-*adjacency*. Two pixels' p and q with values from *V* are 4-adjacent if q is in the set N_4(p).

(b) 8-*adjacency*. Two pixels' p and q with values from *V* are 8-adjacent if q is in the set N_8(p).

(c) *m-adjacency* (mixed adjacency). Two pixels' p and q with values from *V* are m-adjacent if

(i) q is in *N*4(p), *or*

ii) q is in N_D(p) *and* the set has no pixels whose values are from *V*.

Let *S* represent a subset of pixels in an image. Two pixels' p and q are said to be *connected* in *S* if there exists a path between them consisting entirely of pixels in *S*.

For any pixel p in *S*, the *set* of pixels that are connected to it in *S* is called a *connected component* of *S*. If it only has one connected component, then set *S* is called a ***connected set***.

Region:

Let *R* be a subset of pixels in an image. We call ***R* a *region*** of the image if *R* is a connected set.

Boundary:

The *boundary* (also called ***border or contour***) of a region *R* is the set of pixels in the region that have one or more neighbors that are not in *R*.

If *R* happens to be an entire image (which we recall is a rectangular set of pixels), then its boundary is defined as the set of pixels in the first and last rows and columns of the image.

Distance Measures

For pixels p, q, and z,

with coordinates (x, y), (s, t), and (v, w),

respectively,

D is a *distance function* or *metric* if

$$\text{(a)}\ D(p,q) \geq 0 \quad \big(D(p,q) = 0 \ \text{ iff } \ p = q\big),$$

$$\text{(b)}\ D(p,q) = D(q,p), \text{ and}$$

$$\text{(c)}\ D(p,z) \leq D(p,q) + D(q,z).$$

and the

The *Euclidean distance* between p and q is defined

$$D_e(p,q) = \left[(x-s)^2 + (y-t)^2\right]^{\frac{1}{2}}.$$

Question Papers

POKHARA UNIVERSITY

Level: Bachelor
Programme: BCIS
Course: Computer Graphics and Image Processing

Semester – Spring

Year : 2017
Full Marks: 100
Pass Marks: 45
Time : 3hrs.

Candidates are required to give their answers in their own words as far as practicable.
The figures in the margin indicate full marks.

Section "A"
Very Short Answer Questions

Attempt all the questions. 10×2

1. Define digital image and digital image processing.
2. Briefly explain Gray Level Slicing Operation?
3. Give two properties of Fourier Transform.
4. Write down steps for Image Enhancement in frequency domain.
5. Explain steps for Image Enhancement in frequency domain.
6. What are different noise models?
7. Differentiate First order derivate based filter with Second order derivative based filter.
8. What are different types of redundancy in an Image?
9. What are use of Opening and Closing operation?
10. How do you detect a point in an Image?

Section "B"
Descriptive Answer Questions

Attempt any **six** questions 6×10

11. Define Colour Image? Why color image is important? Explain different models for colour image representation.
12. What do you mean by coding redundancy? Calculate Huffman Code for intensity values in following normalized histogram.

Gray Level (r_k)	0	1	2	3	4	5	6
$P(r_k)$	0.2	0.04	0.06	0.4	0.15	0.05	0.1

13. What do you mean by Morphological Operations? Explain Dilation and Erosion Operation with expression and example, what is the relationship between Dilation and Erosion?
14. Why segmentation is important? What are different similarities based image segmentation techniques? Explain Basic Global Thresholding

1

based segmentation with algorithm.

15. Explain Band Reject and Notch filters for removing noise in Frequency Domain.

16. What do you mean by Decision Theoretic Pattern Recognition methods? Explain Minimum Distance Classifier and Template Matching for pattern recognition.

17. Explain a structure of single neuron/node? Explain how neural network can be used for pattern recognition?

Section "C"

Case Analysis

18. a) What are different types of connectivity and Distance Measure used in Image Processing? 5

b) Apply 3x3 Uniform Averaging filter in following image (for bold pixels only). 5

10	70	60	20	20
40	**60**	**20**	30	30
10	**5**	**30**	30	30
20	20	50	25	30
20	20	50	25	20

19. a) Derive equalized histogram for following histogram of an Image. 5

Gray Level	0	1	2	3	4	5	6	7
Frequency	0	0	150	300	400	150	0	0

b) Derive 4 x 4 transform matrix for Haar Transform. 5

4.> Decribe the diff. bet. Mask and edge.

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BE-Question

1 a) Explain the various steps involve in typical image processing system with a neat block diagram. 7

b) What is histogram? Explain the histogram equalization technique. 8

OR

a) Differentiate Digital Image Processing with Computer Graphics. Explain the relationship between pixels with their importance in image processing. 7

b) What is the importance of histogram modeling in image processing? Discuss the algorithm for histogram specification. 8

2 a) Discuss about noise along with its possible types? Explain the suitable working principle of median filter to reduce noise from the image. 8

b) What is zooming? Explain the algorithm of zooming by replication and linear interpolation. 7

OR

a) Discuss the use of averaging filter in brief. 7

b) What is sampling and quantization? Explain its purposes in digital image processing. 8

3 a) What is coding redundancy? Construct Huffman code for each gray level. 8

M	0	1	2	3	4	5	6	7
NM	41	101	300	10	163	75	124	210

Where. M= Gray level

NM= Pixels having M^{th} gray level

b) Explain the components of pattern recognition system in brief. 7

4. a) What is Hough Transform? How it is useful in line detection? 8

b) Explain how feature extraction technique is useful in image analysis field. Also provide some techniques of feature extraction in brief. 7

5. Explain Discrete Cosine Transform with their properties. Also, mention its usage in the digital image processing. 7

a) Define classification and explain the lempiate matching classifler. 8

6. a) What do mean by segmentation? Explain region based segmentation. 7

b) Define Perceptron. Explain the application of neural network in pattern recognition. 8

7. Write short notes on **any two:** 2×5

a) Edge detection using gradient filter

b) Harr transform

c) Hopfield nets

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BCIS 2017PU

[GROUP: A]

Very Short answer questions:
[10x2=20]

1. Draw the neat block diagram of fundamental steps of digital image processing.
2. Explain the histogram equalization technique.
3. Mention the areas where digital image processing is being used.
4. Discuss about noise along with its possible types.
5. What is coding redundancy?
6. Why FFT is faster than DFT? Write the equation for 1D FFT.
7. Describe the difference between mask and edge.
8. Mention the color models that are used in hardware applications and human description with their properties.
9. What do mean by segmentation?
10. Define Hopfield nets.

[GROUP: B]

***Descriptive answer questions (any six)*:**
[6x10=60]

11. Describe the levels of image processing. What is the difference between computer graphics and image processing?
12. What is sampling and quantization? Explain its purposes in digital image processing.
13. Define Fourier series and transform. Write down the recursive relation for Walsh-Hadamard transform for kernel N=4.
14. Discuss about noise along with its possible types? Explain the suitable working principle of median filter to reduce noise from the image.
15. What is image negative? How Tristimulus theory define the color perception for formation image?
16. What is coding redundancy? Construct Huffman code for each gray level.

M	0	1	2	3	4	5	6	7
NM	41	101	300	10	163	75	124	210

Where. M= Gray level NM= Pixels having M^{th} gray level

17. Define Perceptron. Explain the application of neural network in pattern recognition.

[GROUP: C]

Case Analysis

Read the case situation given below and answer the questions: [2x10=20]

Case:

A government agency in Kathmandu plans about datasheet blueprint plan of transportation highway for Mustang in a digital projector that projects the image in the wall of per frame of resolution HD (1920*1080), such that 32 bit operating system(OS) operates on it and give the proper focus of image. Let us assume that we have to send the blueprint image to the construction committee in Mustang via satellite(VSAT) communication from Kathmandu to Upper Mustang, such the image may have contained some noise while transmission and also we have to reduce the size of image for low bandwidth data rate for transmission.

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Program: BCIS Full Marks: 100

Course: Computer Graphics and Image Processing Time: 3:00Hrs.

Candidates are required to give their answers in their own words as far as practicable. The figures in the margin indicate full marks.

Attempt all the questions.

[GROUP: A]

Very Short answer questions:

[10x2=20]

1. What is computer graphics and DIP? Explain the levels of image processing.
2. What is PEL? How do you calculate it?
3. Formulate the steps required for convolution along with filtering in Frequency transformation.
4. What do you mean by data redundancy in an image?
5. Explain Discrete Cosine Transform with their properties. Also, mention its usage in the digital image processing.
6. Explain RGB color model.
7. What is difference between erosion and dilation?
8. Why do we need data compression?
9. Define Hopfield nets.
10. Obtain the transformation for Hadamard transform for N=4.

[GROUP: B]

Descriptive answer questions (any six): [6x10=60]

11. Explain the block diagram of digital image processing. What are application it's been used?
12. What is sampling and quantization? Explain its purposes in digital image processing.
13. Explain the photon theory for formation of visual images.
14. Briefly explain the following enhancement technique in spatial domain as Histogram Stretching, Intensity Level Slicing, Digital Negative
15. Discuss about noise along with its possible types? Explain the suitable working principle of median filter to reduce noise from the image.
16. What is coding redundancy? Construct Huffman code for each gray level.

M	0	1	2	3	4	5	6	7
NM	41	101	300	10	163	75	124	210

Where. M= Gray level NM= Pixels having M^{th} gray level

17. What pattern recognition? Explain the application of neural network in pattern recognition.

[GROUP: C]: Case Analysis

Read the case situation given below and answer the questions: [2x10=20]

Case:

A government agency in Kathmandu plans about datasheet blueprint plan of transportation highway for Mustang in a digital projector that projects the image in the wall of per frame of resolution HD (1920*1080), such that 32 bit operating system(OS) operates on it and give the proper focus of image. Let us assume that we have to send the blueprint image to the construction committee in Mustang via satellite(VSAT) communication from Kathmandu to Upper Mustang, such the image may have contained some noise while transmission and also we have to reduce the size of image for low bandwidth data rate for transmission.

Questions:

18. Calculate the image size per frame on wall of its OS. Check the result on size for per frame on 8bpp, 24bpp, 64 bpp and analyze such that the image may degrade or improve the size and quality?
19. If you able to send the image in Mustang what should you care for restoration of noise?
20. What will be the compression strategy for bandwidth decrement as sending the image?

****