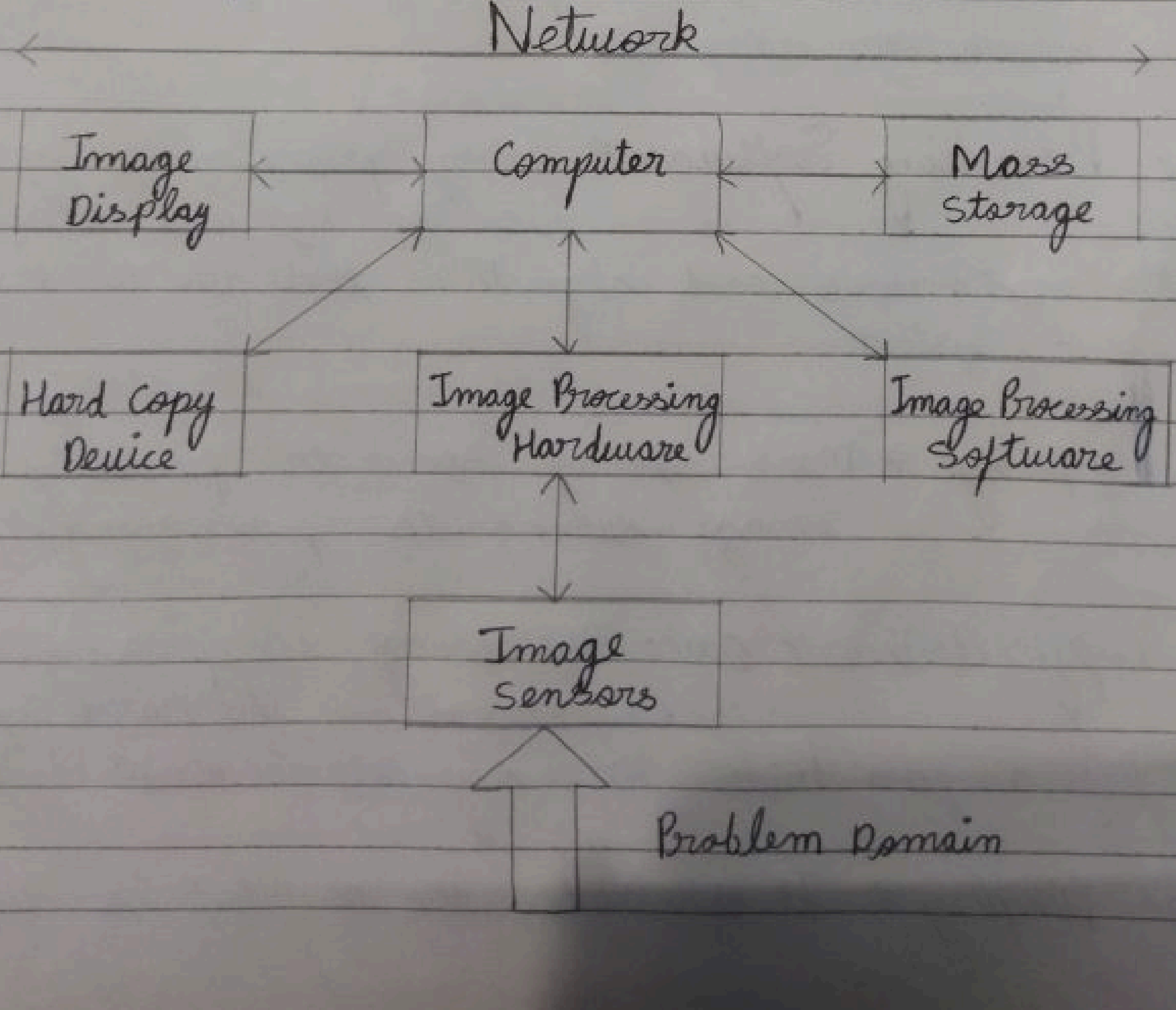
ASSIGNMENT

Que-1 ⇒ Explain component of image processing system and its application.

Ans-1 ⇒ Image processing system is the combination of the different elements involved in the digital image processing. Digital image processing is the processing of an image by means of a digital computer. Digital image processing uses different computer algorithms to perform image processing on the digital images.

It consists of following Components :-



- Image Sensors ⇒ Image Sensors senses the intensity amplitude, co-ordinates and other features of the images and passes the result to the image processing hardware. It includes the problem domain.

- Image Processing Hardware ⇒ Image processing Hardware is the dedicated hardware that is used to process the instructions obtained from the image sensors. It passes the result to general purpose computer.

- Computer ⇒ Computer used in the image processing system is the general purpose computer that is used by us in our daily life.

- Image Processing Software ⇒ Image processing software is the software that includes all the mechanisms and algorithms that are used in image processing system.

- Mass Storage ⇒ Mass storage stores the pixels of the image during the processing.

- Hard Copy device ⇒ Once the image is processed then it is stored in the hard copy device. It can be a pen drive or any external ROM device.

- Image Display ⇒ It includes the monitor or display screen that displays the processed images.

- Network ⇒ Network is the connection of all the above elements of the image processing System.

★ APPLICATIONS ⇒

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

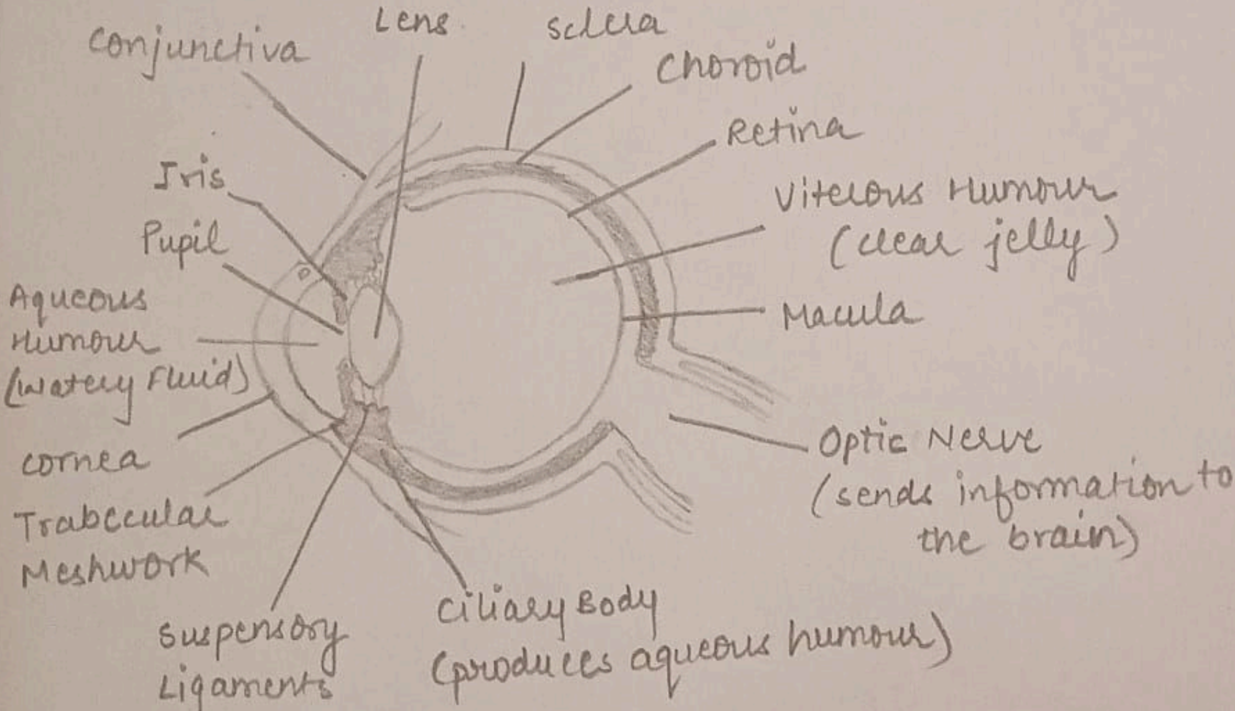
- Image sharpening and restoration
- Medical field
- Remote Sensing
- Transmission and encoding
- machine / Robot Vision
- Color processing
- Pattern recognition
- Video processing
- Microscopic imaging

Q.2 → Explain element of visual perception & also explain sampling and Quantization.

Ans The basic element of visual perceptions are:-

1. Structure of Eye
2. Image formation in the eye
3. Brightness Adaptation and Discrimination

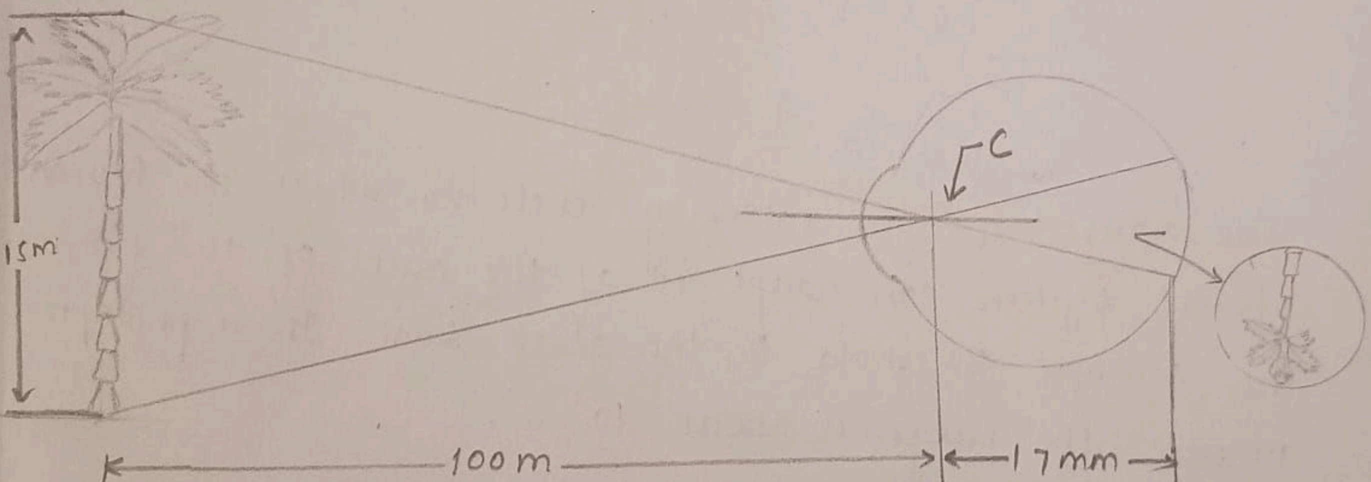
1. Structure of Eye :



The human ~~is~~ eye is just like camera. The external object is seen as the camera take picture of any object. Light enters the eye through a small hole called pupil, a black looking aparture having the quality of contraction of eye when exposed to bright light and is focused on the retina which is like a camera film.

2. Image Formation in the eye

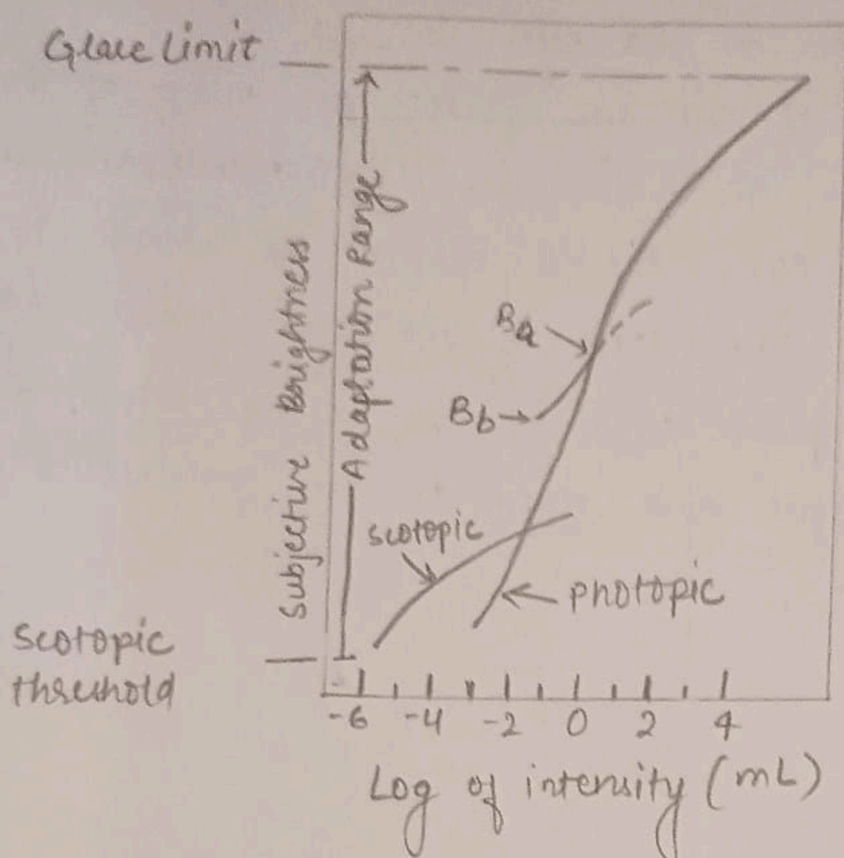
When the lens of the eye focus an image of the outside world onto a light-sensitive membrane in the back of the eye, called retina the image is image is formed. The lens of the eye focuses light on the photoreceptive cells of the retina which detects the photons of light and responds by producing neural impulses.



The distance b/w the lens and the retina is about 17mm and the focal length is approximately 14mm to 17mm.

3. Brightness Adaptation and Discrimination.

Digital images are displayed as a discrete set of intensities. The eyes ability to discriminate black and white at different intensity levels is an important consideration is presenting image processing result.



The range of light intensity levels to which the human visual system can adapt is of the order of 10^{10} from the scotopic threshold to the glare limit. In a photopic vision, the range is about 10^6.

Image Sampling and Quantization

Sampling + Quantization → Analog-to-Digital conversion.

Sampling

The process of measuring the continuous values of an analog signal in a discrete form. Usually sampling is performed using a sampler.

Quantization

The process of representing each level of the discrete values obtained from sampling using a fixed discrete finite set of values.

To create a digital image, we need to convert the continuous sensed data into digital form.

Sampling :- Digitizing the co-ordinate value is called sampling.

Quantization :- Digitizing the amplitude value is called Quantization.

To convert a continuous image $f(x,y)$ into digital form, we have to sample the function in both co-ordinates and amplitude.

Que 3. Explain image enhancement in spatial domain

Ans- It refers to techniques that manipulate individual pixels based on their neighboring pixels, enhancing the quality of the image. This approach operates directly on the pixel values, without transforming the image into the frequency domain.

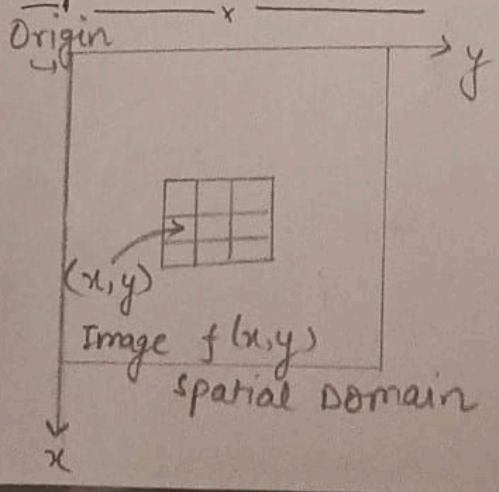
Key techiques -

⇒ Process → Improves the quality of an image.

⇒ To highlight the important details

⇒ To remove noise → Image → more appealing.

Spatial Domain :→ Image Plane itself.



→ Direct manipulation of pixels.

(a) Intensity Transformation

(b) spatial filtering.

T → Operator

$$\boxed{g(x,y) = T\{f(x,y)\}}$$

How it works →

1. The image is divided into small regions, typically 3 x 3 or 5 x 5 pixels, called pixels or neighborhoods.
2. For each neighborhood, the algorithm calculates a new pixel value based on the values of the neighboring pixels.
3. The new pixel value is determined by a set of weights or coefficients, which define the spatial filter or kernel.
4. The filter is applied to each neighborhood, and the resulting pixel values are used to create the enhanced image.

ASSIGNMENT

ues1- Short notes -

Aspect	Grey level function	Piecewise Linear Transfo. func.
Definition	A general transformation that modifies pixel intensity values in an image.	A specific type of transformation where the transformation is defined in linear segments for diff. ranges of input intensity.
• Type of Transformation	can be linear or non-linear (log, exponential, power-law, etc)	Always linear, but applied piecewise to diff intensity intervals
• Function Form	can take various forms: logarithmic, exponential, negative etc.	Linear functions defined over diff intensity ranges (e.g. contrast stretching, thresholding).
• Complexity	Can be more complex depending on the type (eg, log transformation is non-linear)	Typically simpler, involving straight lines between defined points.
• Use cases	use to enhance or correct the overall intensity or dynamic range of an image (eg, histogram equalization).	used when specific control over different intensity ranges is needed. (eg, contrast stretching, piecewise thresholding)
• Flexibility	Flexible, as it covers a wide variety of transformations.	Less flexible but useful for more specific adjustments.
• Example	Logarithmic transformation, Negative Transformation.	Contrast stretching, Thresholding.

(11)

Feature	Histogram Specification	Histogram Equalization
• Objective	Matches the histogram of an image to a specified histogram	Enhances contrast by spreading out the intensity values uniformly across the available range.
• Target	A predefined target histogram.	uniform distribution across all intensity levels.
• Contral over output	Provides contral over the shape of the output histogram	Less contral, output histogram is approx. uniform.
• Desired Intensity distribution	can match to any custom histogram shape (eg, Gaussian, bimodal)	Aims for a flat (unifor intensity distribution.
• Applications	used when a specific visual appearance or contrast distribution is needed.	used for improving overall contrast in low-contrast images.
• Complexity	More complex, requires additional steps to calculate transformation functions	Simpler, involves a straightforwar transformation
• Suitability for images	useful for images requiring specific tonal adjustments	Suitable for images w poor contrast or unev lighting.
• Output variability	Output varies based on the target histogram.	Output is typically predictable, as it se uniformity.

) Feature	Local Enhancement	Enhancement using arithmetic operations
Objective	Improves image quality by enhancing specific regions (local areas)	enhances the image by applying mathematical operations to pixel values globally or locally.
Scope of operation	Focuses on small, localized areas in the image.	can be applied globally or locally to the entire image depending on the operation
Common Methods	Filtering, adaptive histogram equalization, local contrast enhancement.	Addition, subtraction, multiplication, division, or blending operations on pixel values.
Adaptiveness	Adaptive to local image characteristics like texture and edges.	Non-adaptive; enhancement is based on predefined arithmetic operations.
Control over contrast	enhances contrast & details in specific regions	alters overall intensity or combines multiple images using arithmetic formulas.
Complexity	more complex, requires careful selection of parameters for local regions.	simpler, depends on basic arithmetic functio[ns] and operations.
Computational cost	Typically higher, due to the need for local processing.	Lower, unless complex operations (like blendi[ng]) are used.
Examples	Local histogram equalization, unsharp masking, local edge enhancement	Image blending, brightn[ess] adjustment (additio[n]), contrast scaling (multiplication)

Ques 2 - Explain Fourier Transformation and Frequency Domain.

Ans - • Fourier Transforation (FT) :-

Fourier Transformation is a mathematical technique used to transforms a signal or an image from the spatial domain (original domain) to the frequency domain. In simpler terms, it decomposes a signal (or image) into its constituent frequencies.

(i) Spatial Domain → This is where we Typically work with signals or images, where the data points represent values at specific locations (like pixel intensity at specific coordinates in an image).

(ii) Frequency Domain → This is a different way of representing the signal or image, where instead of showing values at specific locations, we show the contributions of different frequency components that make up the original signal.

Key concepts in the Frequency Domain -

• Low Frequencies : Represent slow changes in the signal (eg, large, smooth regions in an image)

• High Frequencies : Represent rapid changes (eg, edges, fine details, noise in an image).

Types of Fourier Transformation :

(i) Continuous Fourier Transform (CFT) : used for continuous signals and mathematically defined as:

$$F(u) = \int_{-\infty}^{\infty} f(x)\, e^{-2\pi i u x}\, dx$$

where $f(x)$ is the original signal, and $F(u)$ is the transformed signal in the frequency domain.

Discrete Fourier Transform (DFT): used for discrete signals, often with digital processing and mathematically defined as

$$X(\omega) = \sum_{n=-\infty}^{\infty} x[n]\, e^{-j\omega n}$$

where $x[n]$ is discrete-time signal, $X(\omega)$ is frequency domain representation, and ω is Angular frequency (in radians per sample).

- Fast Fourier Transform (FFT): An algorithm to compute the DFT efficiently, widely used in practical applications.

Q- Basic of filtering in frequency Domain.

Ans- Filtering in the frequency Domain is a powerful technique used to modify a signal by altering or removing specific frequency components. This process is often simpler and more efficient than filtering in time-domain, particularly when dealing with complex signals, such as images or audio, because certain operations (like removing noise) are easier to perform when the signal is expressed in terms of its frequencies.

Steps for Frequency-Domain Filtering-

(1) Apply Fourier Transform: Convert the original signal (in the time or spatial domain) to the frequency domain using Fourier Transform (FFT).

(2) Design & Apply a Filter: Create a filter in the frequency domain (low-pass, high-pass, band-pass, etc) which is usually represented as a mask or a func that will modify the frequency components of the signal.

(3) Apply the filter: Multiply the fourier-transformed signal by the filter. This operation keeps the desired frequencies and attenuates or remove the undesired ones.

Assignment

①

Q1 ⇒ Explain Image Subtraction, image Averaging and Basics of Spatial filtering.

Ans ⇒ **Image Subtraction**

is a process of subtraction where pixel values of one image are subtracted from another.

☆ It is commonly used to highlight difference between two images.

Formula

$$D(x,y) = |I_1(x,y) - I_2(x,y)|$$

where,

$I_1(x,y)$ & $I_2(x,y)$ are pixel intensities at location (x,y)

$D(x,y)$ is resulting difference image.

Image Averaging

is the process of averaging multiple images to the reduce noise or enhance the quality of the image

☆ It smooth out random variations.

Formula

$$A(x,y) = \frac{1}{n} \sum_{K=1}^{n} I_K(x,y)$$

where,

$I_K(x,y)$ represent pixel intensity of the K^{th} image at location (x,y)

n is number of images

$A(x,y)$ averaged image.

Basics of Spatial Filtering

involves modifying the pixel values of an image based on the values of neighbouring values.

A spatial filter is applied using kernel that is convolved with image.

There are two types of filter

(a) Low-pass filters (smoothing)
filters reduce high-frequency noise & make image smoother.

(b) High-pass filters (sharpening)
filters highlight high-frequency

components to make image sharper.

Formula

$$g(x,y) = \sum_{s=-K}^{K} \sum_{t=-K}^{K} h(s,t) \cdot f(x-s, y-t)$$

where :

$f(x,y)$ = original image

$h(s,t)$ = kernal

$g(x,y)$ = filtered o/p

Q2: Explain low-pass, High-pass filters and also explain frequency Domain.

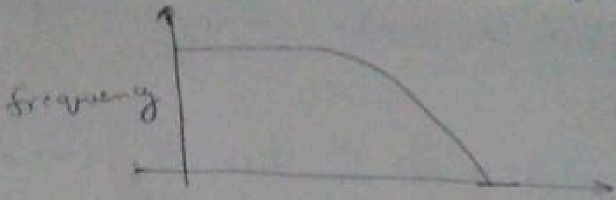
Low-Pass Filters

allow low-frequency components of the image to pass through while attenuating high-frequency components.

low-pass filters smooth out an image by removing fine details

Frequency Domain

terms of

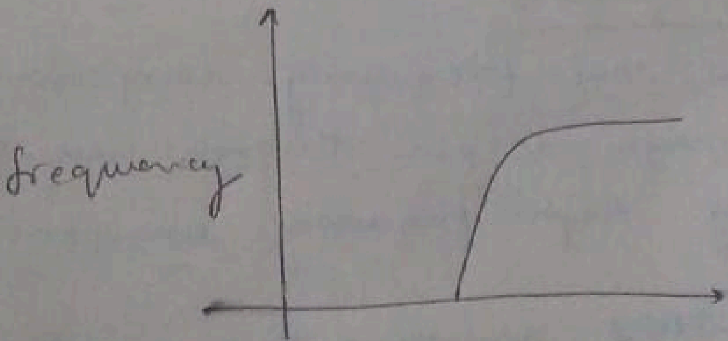


low-pass

High-pass Filters

allows high-frequency components to pass through while blocking low-frequency components.

* High-~~po~~ pass filters are used to sharpening the image and enhance the details.



* used for edge detection, sharpening + enhancing fine details.

Frequency Domain

represents the image in terms of its frequency components, rather than pixel intensity.

An image is converted to the frequency domain using Fourier Transform, which decomposes the image into its sinusoidal components.

Works on

☆ low frequency ⇒ represent slow intensity changes.

☆ High Frequency ⇒ represent fast intensity changes.

Transformations

☆ Fourier Transform ⇒ converts spatial representation of image into frequency component.

Inverse Fourier Transform ⇒ converts the frequency representation back to spatial domain.

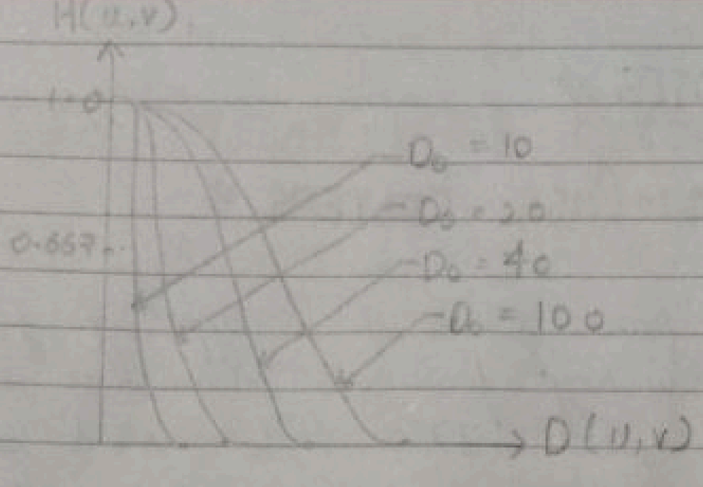
Que. 8 ⇒ SHORT NOTES ⇒

1- GAUSSIAN LOW-PASS FILTERS ⇒

A Gaussian low-pass filter is a type of filter that removes high frequency features from an image, resulting in a blurring effect. It's often used as a post-processing step to make images appear more realistic by concealing discontinuities at the borders of tampered objects.

★ SOME CHARACTERISTICS OF GAUSSIAN LOW-PASS FILTERS ⇒

- Effect ⇒ Gaussian low-pass filters remove high frequency features, resulting in a loss of detail and a blurring effect.
- Amplitude Bode plot ⇒ The amplitude Bode plot of a gaussian low-pass filter is a parabola.
- Blurring effect ⇒ Gaussian filters produce a more natural blurring effect than box-like filters.
- Comparison to Butterworth filters ⇒ Butterworth filters are sharper than Gaussian filters.
- The Gaussian low pass filter can be represented as:-



NOTE ⇒ The smooth curve transition, due to which at each point, the value of D_0, can be exactly defined.

2- SHARPENING FREQUENCY DOMAIN FILTERS ⇒

Sharpening frequency domain filters Or (High-pass frequency Domain filters) Sharpening of an image in the frequency domain can be achieved by high pass filtering process which attenuates (Suppress) low frequency components without disturbing high frequency information in the fourier transform of the image.
The high-pass filter H_{hp} is often represented by its relationship to the low-pass filter (H_{lp}) as:

$$H_{hp}(U,V) = 1 - H_{lp}(U,V)$$

Where $H_{lp}(U,V)$ is the corresponding lowpass filter.

3-GAUSSIAN HIGH-PASS FILTERS ⇒

A Gaussian high-pass filter is a type of filter used in image processing to enhance high-frequency components, effectively removing low-frequency elements like gradual changes in intensity. It operates in the frequency domain, defined by a Gaussian function that attenuates low frequencies while preserving high frequencies.

- **Mathematical Formulation ⇒** The filter is based on the Gaussian function, characterized by its standard deviation (σ), which determines the filter's sensitivity.

- **Frequency Domain Representation ⇒** In the frequency domain, it is defined as

$$H(U,V) = 1 - e^{-\frac{(U^2+V^2)}{2\sigma^2}}$$

- **Applications ⇒** Commonly used for edge detection and noise reduction, enhancing image details while minimizing background ~~noise~~ noise.

- **Advantages ⇒** Provides a smooth transition in frequency response, helping to preserve important features in image.

Overall, Gaussian high-pass filters are valuable tools for enhancing image quality and detail.

QUE-9 ⇒ Explain Homomorphic Filtering and Sharpening.

ANS-9 ⇒ HOMOMORPHIC FILTERING ⇒

- Homomorphic filtering is a generalized technique for Signal and image processing, involving a nonlinear mapping to a different domain in which linear filter techniques are applied, followed by mapping back to the original domain.

- It is sometimes used for image enhancement. It simultaneously normalises the brightness across an image and increases contrast.

- It is most commonly used for correcting non-uniform illumination in images.

- It is one such technique for removing multiplicative noise that has certain characteristics.

♦ Here are some steps involved in homomorphic filtering:

1. Convert the image to the log domain.

2. In the log domain, transform the multiplicative components into additive components.

3. Use a high-pass filter to remove the low-frequency

illumination component while preserving the high-frequency reflectance component.

$I(x,y) \rightarrow \boxed{\ln} \rightarrow \boxed{\text{High-Pass Filter}} \rightarrow \boxed{\exp} \rightarrow I'(x,y)$

Homomorphic Filtering.

★ SHARPENING - THE LAPLACIAN

To sharpen an image using a laplacian filter, you can:-

1- Apply the laplacian filter to the original image.
2- Add the original image to the output image from step 1 to get the sharpened image.

The Laplacian filter highlights areas of rapid intensity change, which are typically associated with edges. This emphasizes the high-frequency components of the image, which accentuates the edges. However, the laplacian filter can also amplify noise, So you can combine the filtered image with the original image to preserve detail.

- Here are some things to keep in mind when sharpening an image:-

- Sharpening filters are specific to different types of images and can create undesired edge effects.
- Sharpening cannot correct a severely blurred image.
- You can implement the laplacian sharpening algorithm using the scikit-image filters module's laplace() function.