UNIT II - IMAGE ENHANCEMENT

Spatial Domain: Gray level transformations – Histogram processing – Basics of Spatial Filtering– Smoothing and Sharpening Spatial Filtering

Frequency Domain: Introduction to Fourier Transform – Smoothing and Sharpening frequency domain filters – Ideal, Butterworth and Gaussian filters.

PART - A

1. Whether two different images can have same histogram? Justify your answer. [Nov/Dec 2017]

Yes, there is a possibility that two different images can have the same histogram. For example, consider an image and its flipped version. Since the values of the pixels are not affected by a flipping operation the histogram of the original image is the same as the histogram of the flipped image.

2. For an eight bit image, write the expression for obtaining the negative of the input image. [Nov/Dec 2017]

The digital negative of an image can be given as, s = (L-1)-r, where s is output pixel value, r is input pixel value and L-1 is maximum pixel value. For 8 bits image maximum pixel value is 255.so **s=255-r**

3. Differentiate between image enhancement and restoration. [Apr/May 2017, Nov/Dec 2015]

S.No.	Image Enhancement	Image Restoration
1.	Image enhancement is a subjective process i.e., it is a heuristic procedure designed to manipulate an image in order to please the viewer.	Restoration techniques are oriented towards modeling the degradation and applying the inverse process in order to recover the original image.
2.	Modeling of degradation process is not required.	Modeling of degradation is a must.
3.	Apriori knowledge of the degradation is not required. Ex: Contrast stretching	Apriori knowledge of the degradation function is required to model the degradation function. Ex: Removal of motion blur

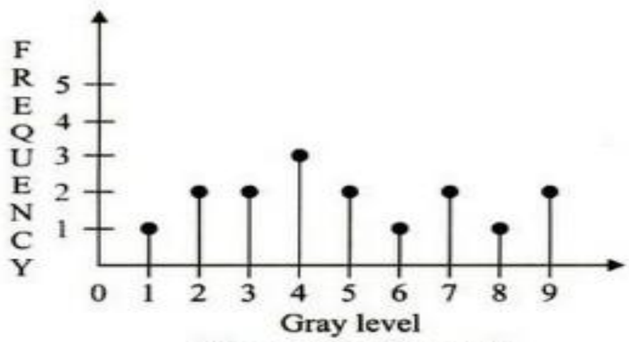
4. If all the pixels in an image are shuffled will there be any change in the histogram? Justify your answer. [Apr/May 2017]

If all the pixels in an image are shuffled there will not be any change in the histogram of the image. For example consider image 2 obtained from image 1 by shuffling the row 1.

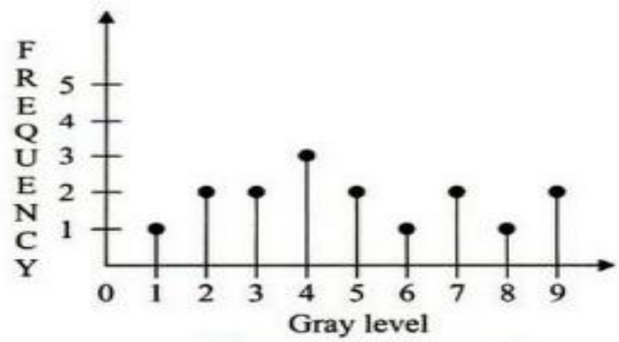
$$\begin{bmatrix} 1 & 2 & 4 & 8 \\ 3 & 5 & 7 & 9 \\ 4 & 2 & 4 & 6 \\ 9 & 7 & 3 & 5 \end{bmatrix} \qquad \begin{bmatrix} 9 & 7 & 3 & 5 \\ 3 & 5 & 7 & 9 \\ 1 & 2 & 4 & 8 \\ 4 & 2 & 4 & 6 \end{bmatrix}$$

Image 1 **Image 2**

The corresponding histogram are



Histogram of Image 1



Histogram of Image 1

It is clear from above histogram that there will not be any change in the histogram even if the pixels are shuffled, as histogram gives only the frequency of occurrence of the gray level.

5. What is meant by bit plane slicing? [Nov/Dec 2016]

Highlighting the contribution made to total image appearance by specific bits might be desired. Suppose that each pixel in an image is represented by 8 bits. Imagine that the image is composed of eight 1-bit planes, ranging from bit plane 0 for LSB to bit plane-7 for MSB. Highlighting the higher order bit planes to achieve enhancement is called bit plane slicing.

6. What is unsharp masking? [Nov/Dec 2016]

Unsharp masking is the process of subtracting a blurred version of an image from the original image itself to sharpen it. Unsharp masking is defined as,

$$f_s(x,y) = f(x,y) - \bar{f}(x,y)$$

Where f(x,y) refers to the original image, $\bar{f}(x,y)$ refers to the blurred version of f(x,y) and $f_s(x, y)$ refers to the sharpened image obtained. Unsharp masking is used in the publishing industry to sharpen images.

7. What is image filtering? [Apr/May 2016]

Image filtering is the process of modifying the pixels in an image based on some function of a local neighborhood of the pixels.

8. Specify the need for image enhancement. [Apr/May 2016]

Image enhancement technique process an image so that the resulting image is more suitable than the original image for a particular application.

9. What is histogram equalization? [Nov/Dec 2015]

Histogram equalization is an image enhancement process that attempts to spread out the gray levels in an image so that they are evenly distributed across their range. Histogram equalization produces an output image that has a uniform histogram. The transform is given by,

$$s_k = T(r_k) = \sum_{j=0}^{k} p_r(r_j)$$
$$= \sum_{j=0}^{k} \frac{n_j}{n} \qquad k = 0, 1, 2, \dots, L-1$$

Thus a processed (output) image is obtained by mapping each pixel with level r_k in the input image to a corresponding pixel with level s_k in the output image.

10. Define directional smoothing filter. [Nov/Dec 2015]

A directional averaging filter is used to protect edges from blurring while smoothing.

11. Explain spatial filtering /Averaging? [May-Jun 2014]

Spatial filtering is the process of moving the filter mask from point to point in an image. For linear spatial filter, the response is given by a sum of products of the filter coefficients, and the corresponding image pixels in the area spanned by the filter mask.

12. What are the advantages of histogram equalization? [Nov-Dec 2013]

- Histogram Equalization produces image with gray level values that cover the entire gray scale.
- Histogram Equalization is fully automatic i.e. histogram equalization is only based on information that can be directly extracted from the given image.
- Very simple computation.

13. What is contrast stretching/Adjustment? [Nov-Dec 2013]

Contrast stretching is an enhancement technique used to increase the dynamic range of the gray levels in an image.

14. Explain the two categories of image enhancement.

Image Enhancement methods are broadly classified into two types:

i) Spatial domain method refers to image plane itself & approaches in this category are based on direct manipulation of pixels in an image.

ii) Frequency domain methods are based on enhancing the image by modifying its Fourier transform.

15. What are the types of spatial domain processing?

Spatial domain processing methods are classified into three types:

i. Point Processing
ii. Mask Processing
iii. Global Operation

Point Processing is an image enhancement technique in which enhancement at any point in an image depends only on the gray level at that point. In mask processing each pixel is modified according to the values in a predefined neighborhood. In global operation, all pixel values in the image are taken into consideration for the enhancement process.

16. What is meant by gray level transformation? What are its types?

Gray level transformation is the simplest of all image enhancement techniques. It is a point processing method. In this method each pixel value in the original image is mapped on to a new pixel value to obtain the enhanced image. In its general form, a gray level transformation is represented as, $s = T(r)$

Where 'r' denotes the pixel value before processing, 's' denotes the pixel value after processing and T represents the transformation that maps a pixel value 'r' to a pixel value 's'.

Types of Gray Level Transformation

1. Image Negative
2. Log Transformations
3. Power Law Transformations
4. Piece wise linear Transformations

17. What is image negatives?

The negative of an image with gray levels in the range [0, L-1] is obtained by using the negative transformation, which is given by the expression. s = (L-1)-r
Where s is output pixel, r is input pixel and L-1 is the maximum pixel value.

18. What is thresholding?

Thresholding is an image enhancement technique that create a binary image. All gray level values above a threshold 'T' is mapped to (L-1) and gray level values below the threshold is mapped to 0.

$$s = \begin{cases} 0, r < T \\ L-1, \ otherwise \end{cases}$$

19. What is gray level slicing?

Highlighting a specific range of gray levels in an image often is desired. It displays a high value for all gray levels in the range of interest. Applications include enhancing features such as masses of water in satellite imagery and enhancing flaws in x-ray images.

20. Define image subtraction

The difference between 2 images f(x,y) and h(x,y) expressed as, g(x,y)=f(x,y)-h(x,y)
The difference image g(x,y) is obtained by computing the difference between all pairs of corresponding pixels from f and h.

21.What is image averaging? Give its application.

It is a process of adding a set of noisy images and then averaging. Image averaging is done to reduce the noise content in the image. An important application of image averaging is in the field of astronomy, where imaging with very low light levels is routine, causing sensor noise frequently to render single images virtually useless for analysis.

22. What is meant by mask?

Mask is the small 2-D array in which the values of mask co-efficient determines the nature of process. The enhancement technique based on this type of approach is referred to as mask processing.

23.Define Histogram.

The histogram of a digital image with gray-levels in the range [0, L-1] is a discrete function, $h(r_k) = n_k$, where r_k is the k^{th} gray level and n_k is the number of pixels in the image having gray level r_k . Histogram is a plot of r_k vs n_k.

24. What is meant by Histogram Matching (or) Histogram Specification?

The method used to generate a processed image that has a specified histogram is called histogram matching or histogram specification. It allows the user to specify the shape of the histogram that the processed image is supposed to have.

25. What is a smoothing filter and what are its types?

Smoothing filters are used for noise reduction and blurring. Smoothing filters remove the high frequency components hence it is also called as low pass filters. Smoothing filters are broadly classified into two types: i) Linear smoothing spatial filters ii) Non-linear smoothing spatial filters

26. Give some examples of linear smoothing spatial filters.

i) Mean filters

a) Box filter b)Weighted Average filter

ii) Geometric filters

iii) Harmonic filter

iv) Contra harmonic filter

27. What is a non-linear smoothing spatial filters or order statistics filter? What are its types?

These are spatial filters whose response is based on ordering the pixels contained in the image area encompassed by the filter. Types of order statistics filters

- Median filter
- Max and Min filter
- Midpoint filter
- Alpha trimmed mean filter

28. What are the applications of smoothing filters?

Smoothing filters are used for

i) Removal of random noise

ii) Smoothing of false contours

iii) Reduction of irrelevant details in an image.

29. What is a sharpening filter?

Sharpening filters are used to highlight fine details in an image or to enhance details that has been blurred. Sharpening filters are called as high pass filters. Derivative filters are used for image sharpening. First order derivative filter produces thicker edges in an image. Second order derivative filter produces thin edges in an image.

30. Name the different types of derivative filters.

Derivative filters are of two types: First Order Derivative Filters and Second Order Derivative Filters.

First Order Derivative Filters (Gradient Operators)

- Roberts cross gradient operators
- Prewitt operators
- Sobel operator

Second Order Derivative Filters

- Laplacian Filters

31. Define first order derivative filter or Gradient filter.

For a function f(x, y), the gradient of f at coordinates (x, y) is defined as the two-dimensional column vector

$$\nabla \mathbf{f} = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix}$$

The magnitude of this vector is given by

$$\begin{aligned}\nabla f &= \text{mag}(\nabla \mathbf{f}) \\ &= \left[G_x^2 + G_y^2\right]^{1/2} \\ &= \left[\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2\right]^{1/2}\end{aligned}$$

32. Define the second order derivative filter or Laplacian operators.

Second order derivative filters are commonly referred to as Laplacian operators. Laplacian is a linear isotropic filters. A simple Laplacian operator for a function (image) f(x,y) is defined as,

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$$

Where,

$$\frac{\partial^2 f}{\partial^2 x^2} = f(x+1, y) + f(x-1, y) - 2f(x, y)$$

$$\frac{\partial^2 f}{\partial^2 y^2} = f(x, y+1) + f(x, y-1) - 2f(x, y)$$

The digital implementation of the two-dimensional Laplacian is obtained by summing these two components

$$\nabla^2 f = \left[f(x+1, y) + f(x-1, y) + f(x, y+1) + f(x, y-1)\right] - 4f(x, y).$$

Simple Laplacian masks are given by,

0	1	0
1	−4	1
0	1	0

1	1	1
1	−8	1
1	1	1

0	−1	0
−1	4	−1
0	−1	0

−1	−1	−1
−1	8	−1
−1	−1	−1

33.Define Robert's cross, Prewitt's and Sobel's Operators.

Robert's Cross operator:

Robert's cross gradient operators is defined using a 2 x2 masks as,

$$\Delta f \simeq |G_x| + |G_y| = (Z_9 - Z_5) + (Z_8 - Z_6)$$

Roberts cross Gradient operators

-1	0
0	1

0	-1
1	0

Prewitt's Operator

Prewitt's operator is defined using a 3 x 3 mask and the digital approximation of the Prewitt's operator is defined as,

$$\nabla f \approx |(z_7 + z_8 + z_9) - (z_1 + z_2 + z_3)| + |(z_3 + z_6 + z_9) - (z_1 + z_4 + z_7)|$$

Prewitt's operators

-1	-1	-1
0	0	0
1	1	1

-1	0	1
-1	0	1
-1	0	1

Sobel's Operator

The Sobel's operators is defined as,

$$\nabla f \approx |(z_7 + 2z_8 + z_9) - (z_1 + 2z_2 + z_3)| + |(z_3 + 2z_6 + z_9) - (z_1 + 2z_4 + z_7)|$$

Sobel operators

-1	-2	-1
0	0	0
1	2	1

-1	0	1
-2	0	2
-1	0	1

34. Write the application of sharpening filters.

Important applications of sharpening filters are in the fields of

- Electronic printing
- Medical imaging
- Industrial application
- Autonomous target detection in smart weapons.

35. What is an isotropic filter?

Isotropic filters are rotation invariant filters i.e., rotating the image and then applying the filter gives the same result as applying the filter to the image first and then rotating the result. Example: Laplacian filter

36. List the applications of spatial enhancement filters (or) Sharpening Filters.

- Printing industry
- Image based product inspection
- Forensics
- Microscopy
- Surveillance

37. What is high boost filtering?

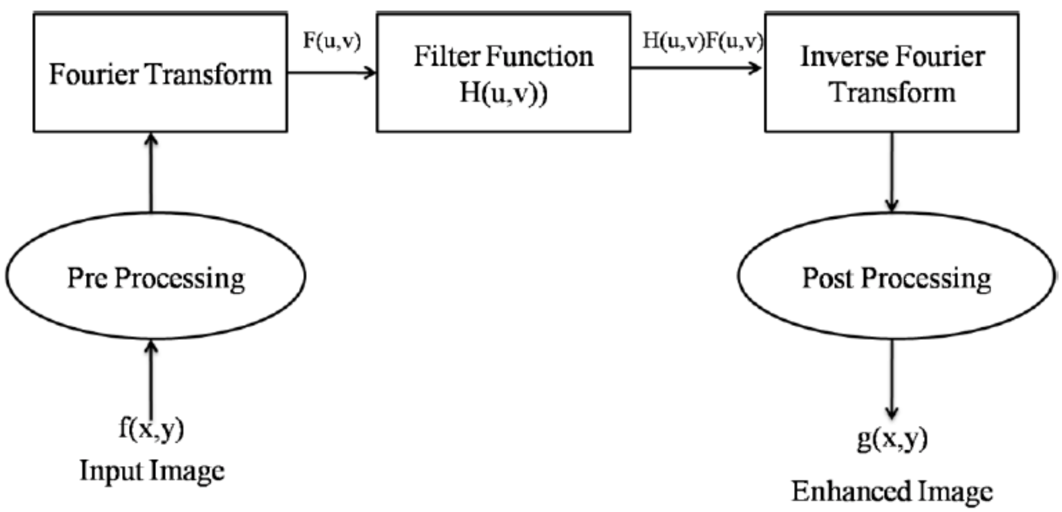
High boost filtering is a slight modification of unsharp masking. A high boost filtered image f_{hb} is defined as,

$$f_{hb}(x,y) = Af(x,y) - \bar{f}(x,y)$$

Where $A \geq 1$, f(x,y) refers to the original image, $\bar{f}(x,y)$ refers to the blurred version of f(x,y) and $f_{hb}(x,y)$ refers to the sharpened image obtained.

38. Write the steps involved in frequency domain filtering.

1. Multiply the input image by $(-1)^{+y}$ to center the transform.
2. Compute F(u,v), the DFT of the image from (1).
3. Multiply F(u,v) by a filter function H(u,v).
4. Compute the inverse DFT of the result in (3).
5. Obtain the real part of the result in (4).
6. Multiply the result in (5) by $(-1)^{+y}$



39. What are the types of frequency domain filters?

Frequency domain filters are classified into two types: i) Low Pass Filters ii) High Pass Filters

Types of Low Pass Filters (Smoothing Filters)

- Ideal Low Pass Filters
- Butterworth Low Pass Filters

- Gaussian Low Pass Filters

Types of High Pass Filters (Sharpening Filters)

- Ideal High Pass Filters
- Butterworth High Pass Filters
- Gaussian High Pass Filters

40. Give the filter function of ideal low pass filter and high pass filter.

The filter function of ideal low pass filter is given as,

$$H(U,V) = \begin{cases} 1 & if\ D(U,V) \le D_0 \\ 0 & if\ D(U,V) > D_0 \end{cases}$$

The filter function of ideal high pass filter is given as,

$$H(u,v) = \begin{cases} 0 & if\ D(U,V) \le D_0 \\ 1 & if\ D(U,V) > D_0 \end{cases}$$

Where D_0 is the cutoff distance, D(u,v) is the distance from the point (U,V) in the image to the origin of the frequency rectangle.

41. Give the filter function of Butterworth low pass filter and high pass filter.

A Butterworth Low Pass filter of order n is defined as,

$$H(U,V) = \frac{1}{1 + \left[\frac{D(U,V)}{D_0}\right]^{2n}}$$

A Butterworth High Pass filter of order n is defined as,

$$H(U,V) = \frac{1}{1 + \left[\frac{D_0}{D(U,V)}\right]^{2n}}$$

Where D_0 is the cutoff distance, D(u,v) is the distance from the point (U,V) in the image to the origin of the frequency rectangle.

42. Give the filter function of Gaussian low pass filter and high pass filter.

The filter function of Gaussian low pass filter is given by,

$$H(U,V) = e^{-D^2(U,V)/2\sigma^2} = e^{-D^2(U,V)/2D_0^2}$$

The filter function of Gaussian high pass filter is given by,

$$H(U,V) = 1 - e^{-D^2(U,V)/2\sigma^2} = 1 - e^{-D^2(U,V)/2D_0^2}$$

Where $D0$ is the cutoff distance, D(u,v) is the distance from the point (U,V) in the image to the origin of the frequency rectangle.

43. What is homomorphic filtering?

It is a frequency domain procedure for improving the appearance of an image by simultaneous gray level range compression and contrast enhancement using illumination-reflectance model.

PART – B

Gray level transformation

1. Explain the following gray level transformation techniques in detail. **[Nov/Dec 2017]**
   i) Image negative ii) Thresholding iii) Gray level slicing iv) Logarithmic transformation.

Histogram equalization

1. a) Briefly explain about histogram equalization technique. **[Nov/Dec 2016, Apr/May 2016, Nov/Dec 2015]**
   b) Perform histogram equalization of the image. **[Nov/Dec 2016]**

$$\begin{bmatrix} 4 & 4 & 4 & 4 & 4 \\ 3 & 4 & 5 & 4 & 3 \\ 3 & 5 & 5 & 5 & 3 \\ 3 & 4 & 5 & 4 & 3 \\ 4 & 4 & 4 & 4 & 4 \end{bmatrix}$$

Solution The maximum value is found to be 5. We need a minimum of 3 bits to represent the number. There are eight possible gray levels from 0 to 7. The histogram of the input image is given below:

Gray level	0	1	2	3	4	5	6	7
Number of pixels	0	0	0	6	14	5	0	0

Step 1 Compute the running sum of histogram values.

The running sum of histogram values is otherwise known as cumulative frequency distribution.

Gray level	0	1	2	3	4	5	6	7
Number of pixels	0	0	0	6	14	5	0	0
Running sum	0	0	0	6	20	25	25	25

Step 2 Divide the running sum obtained in Step 1 by the total number of pixels. In this case, the total number of pixels is 25.

Gray level	0	1	2	3	4	5	6	7
Number of pixels	0	0	0	6	14	5	0	0
Running sum	0	0	0	6	20	25	25	25
Running Sum / Total number of pixels	0/25	0/25	0/25	6/25	20/25	25/25	25/25	25/25

Step 3 Multiply the result obtained in Step 2 by the maximum gray-level value, which is 7 in this case.

Gray level	0	1	2	3	4	5	6	7
Number of pixels	0	0	0	6	14	5	0	0
Running Sum	0	0	0	6	20	25	25	25
Runningsum / Total number of pixels	0/25	0/25	0/25	6/25	20/25	25/25	25/25	25/25
Multiply the above result by maximum gray level	$\frac{0}{25}*7$	$\frac{0}{25}*7$	$\frac{0}{25}*7$	$\frac{6}{25}*7$	$\frac{20}{25}*7$	$\frac{25}{25}*7$	$\frac{25}{25}*7$	$\frac{25}{25}*7$

The result is then rounded to the closest integer to get the following table:

Gray level	0	1	2	3	4	5	6	7
Number of pixels	0	0	0	6	14	5	0	0
Running Sum	0	0	0	6	20	25	25	25
Running Sum/Total number of pixels	0/25	0/25	0/25	6/25	20/25	25/25	25/25	25/25
Multiply the above result by maximum gray level	0	0	0	2	6	7	7	7

Step 4 Mapping of gray level by a one-to-one correspondence:

Original gray level	Histogram equalised values
0	0
1	0
2	0
3	2
4	6
5	7
6	7
7	7

The original image and the histogram equalised image are shown side by side.

$$\begin{bmatrix} 4 & 4 & 4 & 4 & 4 \\ 3 & 4 & 5 & 4 & 3 \\ 3 & 5 & 5 & 5 & 3 \\ 3 & 4 & 5 & 4 & 3 \\ 4 & 4 & 4 & 4 & 4 \end{bmatrix} \xrightarrow[\text{Equalisation}]{\text{Histogram}} \begin{bmatrix} 6 & 6 & 6 & 6 & 6 \\ 2 & 6 & 7 & 6 & 2 \\ 2 & 7 & 7 & 7 & 2 \\ 2 & 6 & 7 & 6 & 2 \\ 6 & 6 & 6 & 6 & 6 \end{bmatrix}$$

Original image **Histogram equalised image**

2. Why histogram equalization is considered as an "idempotent operation"? Perform histogram equalization of the image. **[Nov/Dec 2017]**

$$\begin{bmatrix} 3 & 2 & 4 & 5 & 4 \\ 3 & 4 & 5 & 4 & 3 \\ 3 & 5 & 5 & 5 & 3 \\ 3 & 4 & 5 & 4 & 3 \\ 4 & 5 & 2 & 4 & 4 \end{bmatrix}$$

3. Describe histogram equalization. Obtain histogram equalization for the following 8 bit image segment of size 5 x 5. Write the inference on image segment before and after equalization. **[Apr/May 2015]**

200	200	200	180	240
180	180	180	180	190
190	190	190	190	180
190	200	220	220	240
230	180	190	210	230

Spatial domain

1. Explain the various enhancement techniques performed in spatial domain. **[Apr/May 2017, Nov/Dec 2015]**
2. If a low pass filter is formed that averages the 4 neighbors of a point (x,y) but excludes point (x,y) itself. Find the equivalent filter function H(u,v) in the frequency domain. Show that it is a low pass filter. **[Apr/May 2017]**

Solution

a) The spatial average is given by:

$$g(x,y) = \frac{1}{4}\left[f(x,y+1) + f(x+1,y) + f(x-1,y) + f(x,y-1)\right]$$

Then, using the following property:

$$f(x-x_0, y-y_0) \Leftrightarrow F(u,v)e^{-j2\pi(ux_0/M+vy_0/N)}$$

$$\begin{aligned} G(u,v) &= \frac{1}{4}\left[e^{j2\pi v/N} + e^{j2\pi u/M} + e^{-j2\pi u/M} + e^{-j2\pi v/N}\right] F(u,v) \\ &= H(u,v)F(u,v), \end{aligned}$$

Where the H(u,v) is the filter function. We get the following transfer function:

$$H(u,v) = \frac{1}{2}\left[\cos(2\pi u/M) + \cos(2\pi v/N)\right]$$

The H(u,v) Filter function can be centered by:

$$H(u,v) = \frac{1}{2}\left[\cos(2\pi[u - M/2)/M) + \cos(2\pi[v - N/2]/N)\right]$$

b) Consider one variable for convenience. As u ranges from 0 to M, the value of cos(2π[u-M/2]/M) starts at -1, peaks at 1 when u = M/2 (the center of the filter) and then decreases to -1 again when u = M. Thus, we see that the amplitude of the filter decreases as a function of distance from the origin of the centered filter, which is the characteristic of a lowpass filter.

3. Explain gradient operators for image enhancement. **[Nov/Dec 2016]**

Frequency domain

1. Explain in detail the method for smoothening the image in frequency domain. **[Nov/Dec 2016]**
2. Describe how homomorphic filtering is used to separate illumination and reflectance component. **[Apr/May 2015, May/Jun 2013/14, Nov/Dec 2014]**