DIGITAL IMAGE PROCESSING-1

Unit 3: Lecture 37

Dr. Shikha Tripathi

Department of Electronics &
Communication Engineering

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Unit 3: Image Enhancement

Dr. Shikha Tripathi
Department of Electronics & Communication Engineering

Last Session

- Image Enhancement: Frequency domain methods
  - 2D DFT and its properties
  - Gaussian Filters
  - Smoothing using frequency domain filters
  - Correspondence between filtering in spatial and frequency domains

This Session

- Image Enhancement: Frequency domain methods
  - Sharpening using frequency domain filters
  - Homomorphic Filtering

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- Image Enhancement: Frequency domain methods
  - Sharpening using frequency domain filters
  - Homomorphic Filtering

Types of Enhancement Techniques

Image Enhancement

- **Point Operations**
  - Contrast Stretching
  - Histogram Modeling
  - Noise Clipping
  - Window Slicing
- **Spatial Operations**
  - Noise Smoothing
  - Median Filtering
  - Unsharp Masking
- **Transform Operations**
  - Linear filtering
  - Homomorphic Filtering
- **Pseudocoloring**
  - False Coloring
  - Pseudocoloring

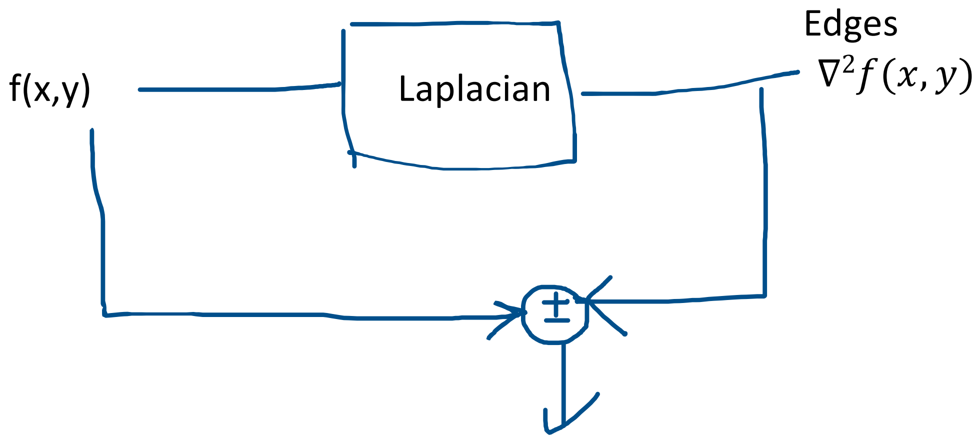
Spatial Domain

Image Sharpening in Frequency Domain

- Using Laplacian
- Unsharp Masking
- Highboost Filtering
  - To improve the visual quality while retaining the edge information extracted by HP filter

Image Sharpening using Laplacian

- Laplacian operator is a derivative operation which highlights intensity discontinuities of an image and reduces slowly varying intensity values



Sharpened Image g(x,y)

$f_s(x,y)=g(x,y)=f(x,y) \pm \nabla^2 f(x, y)$

Subtract if center of mask is negative

Add if center of mask is positive

0	1	0
1	−4	1
0	1	0

0	−1	0
−1	4	−1
0	−1	0

With negative centre: $f_s(x,y)=f(x,y) - [-4f(x,y) + f(x+1,y) + f(x-1,y) + fx, y\text{-}1) + f(x,y+1)$

$f_s(x,y)=f(x,y) + 4f(x,y) - f(x+1,y) - f(x-1,y) - fx, y\text{-}1) - f(x,y+1)$

$=5f(x,y) - f(x+1,y) - f(x-1,y) - fx, y\text{-}1) - f(x,y+1)$

Image Sharpening using Laplacian

- Hence the sharpening mask in spatial domain is:

$$\begin{matrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{matrix}$$

g(x,y)=f(x,y) $\pm \nabla^2 f(x, y)$

- In frequency domain:

G(u,v) = F(u,v) –H(u,v)F(u,v)

Or G(u,v) = F(u,v)(1- H(u,v))

Now for a Laplacian H(u,v) = $-4\pi^2$ ($u^2 + v^2$)

Or G(u,v) = F(u,v)(1+ $4\pi^2 D^2(u,v)$)

For sharpening H(u,v)= 1+ $4\pi^2 D^2(u,v)$

Transfer function to sharpen images

Image Sharpening using Laplacian

a b

FIGURE 4.56
(a) Original, blurry image. (b) Image enhanced using the Laplacian in the frequency domain. Compare with Fig. 3.46(d). (Original image courtesy of NASA.)

Unsharp masking in Frequency Domain

It is applied by subtracting an unsharp or smoothed or low-pass filtered version of an image from the original image.

$$f_{hp}(x,y)=f(x,y) - f_{lp}(x,y)$$

- Taking its Fourier Transform

$$F_{hp}(u,v)=F(u,v) - F_{lp}(u,v)$$

$$H_{hp}(u,v)F(u,v) = F(u,v) - H_{lp}(u,v)F(u,v)= (F(u,v)(1 - H_{lp}(u,v)$$

Hence, $H_{hp}(u,v)=1 - H_{lp}(u,v)$

Highboost Filtering in Frequency Domain

- To improve the visual quality while retaining the edge information extracted by HPF, we use highboost filters

$$g_{\text{mask}}(x,y) = f(x,y) - f_{\text{LP}}(x,y)$$

$$g(x,y) = f(x,y) + k\,g_{\text{mask}}(x,y)$$

Hence, H_{hp} (u,v)=1 + k(1-H_{lp}(u,v))

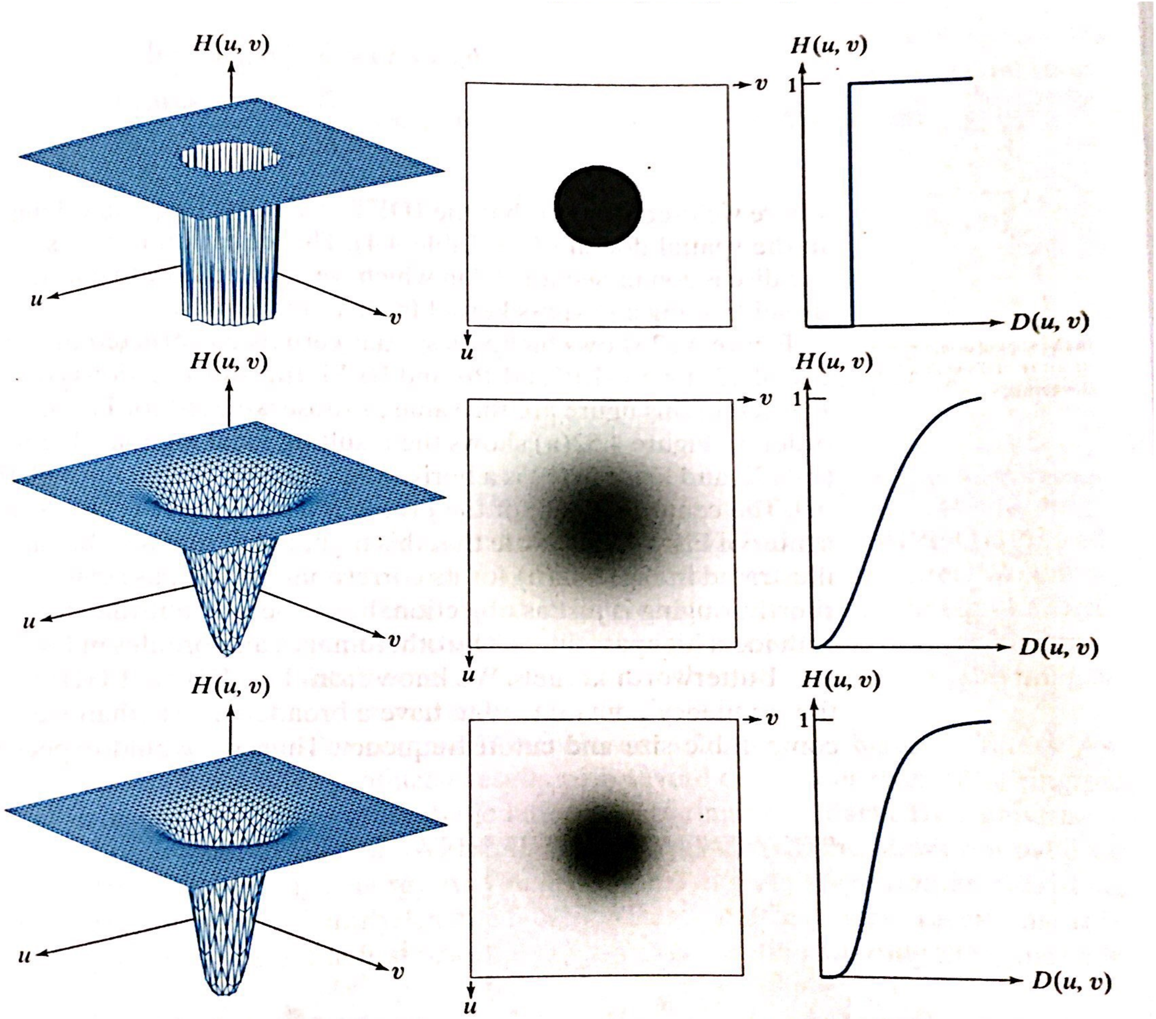
$$g(x,y) = \Im^{-1}\left\{\left[1 + kH_{\text{HP}}(u,v)\right]F(u,v)\right\}$$

Highpass Filters

Ideal Highpass filter

Guassian HP filter

Butterworth HP filter



$$H(u,v) = 1 - e^{-D^2(u,v)/2D_0^2} \quad (4\text{-}120)$$

Homomorphic Filtering

- The illumination-reflectance model can be used to develop a frequency domain procedure for improving the appearance of an image
- Homomorphic filtering is a frequency domain approach to improve the appearance of an image by
  - Gray level range compression
  - Contrast enhancement
- An image captured by camera is formed by the multiplication of illumination and reflectance
  $f(x,y) = i(x,y).r(x,y)$
- In some cases scene is not illuminated properly and some part of image appears very dark

Homomorphic Filtering

- In order to improve these type of images reflectance and illumination has to be treated independently

$$F\left[f(x,y)\right] \neq F[i(x,y)] \times F[r(x,y)]$$

- Hence we take log on either side

$$\begin{aligned} z(x,y) &= \ln f(x,y) \\ &= \ln i(x,y) + \ln r(x,y) \end{aligned}$$

$$\begin{aligned} \Im[z(x,y)] &= \Im[\ln f(x,y)] \\ &= \Im[\ln i(x,y)] + \Im[\ln r(x,y)] \end{aligned}$$

$$Z(u,v) = F_i(u,v) + F_r(u,v)$$

Homomorphic Filtering

- We can filter Z(u,v) using a filter transfer function H(u,v) so that

$$\begin{aligned} S(u,v) &= H(u,v)Z(u,v) \\ &= H(u,v)F_i(u,v) + H(u,v)F_r(u,v) \end{aligned}$$

- The filtered image in the spatial domain is then

$$\begin{aligned} s(x,y) &= \Im^{-1}\left[S(u,v)\right] \\ &= \Im^{-1}\left[H(u,v)F_i(u,v)\right] + \Im^{-1}\left[H(u,v)F_r(u,v)\right] \end{aligned}$$

$$s(x,y) = i'(x,y) + r'(x,y)$$

Homomorphic Filtering

- Finally, because $z(x, y)$ was formed by taking the natural logarithm of the input image, we reverse the process by taking the exponential of the filtered result to form the output image:

$$\begin{aligned} g(x,y) &= e^{s(x,y)} \\ &= e^{i'(x,y)} e^{r'(x,y)} \\ &= i_0(x,y) r_0(x,y) \end{aligned}$$

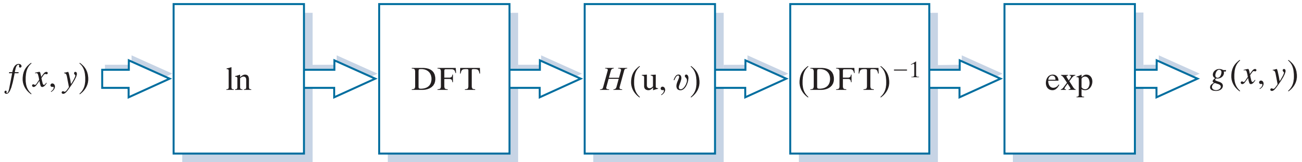
where $i_0(x,y) = e^{i'(x,y)}$

and $r_0(x,y) = e^{r'(x,y)}$

are the illumination and reflectance components of the output (processed) image

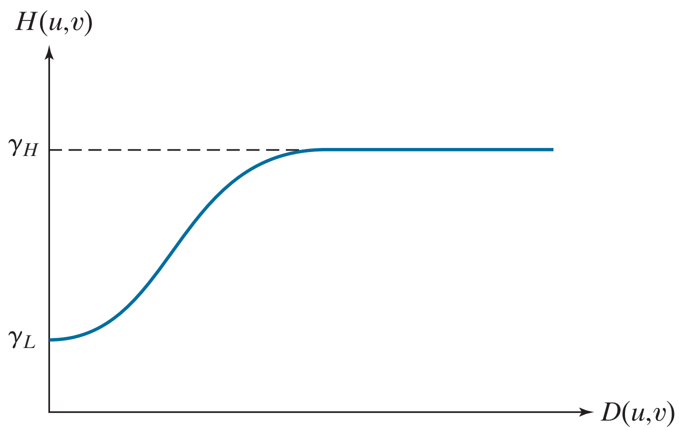
Steps Involved in Homomorphic Filtering

- Take natural log of input
- Take DFT on both sides
- Multiply with filter H(u,v)
- Take inverse DFT on both sides
- Take inverse log transformation to get enhanced image



Steps Involved in Homomorphic Filtering

- In this particular application, the key to the approach is the separation of the illumination and reflectance components
- The *homomorphic filter transfer function*, *H*(u,v), then can operate on these components separately



Next Session

- Image Restoration

THANK YOU

Dr. Shikha Tripathi
Department of Electronics &
Communication Engineering

shikha@pes.edu
+91 9482219115