Steps for filtering in Frequency domain

$f(x,y) \longrightarrow$ Preprocessing $\longrightarrow$ FT

$\downarrow$

Filter function $H(u,v)$

$\downarrow$

$g(x,y) \longleftarrow$ Post processing $\longleftarrow$ Inverse FT

Enhanced Image

Steps

1 Image $f(x,y)$ of size $M \times N$

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

3 $F(u,v) \rightarrow$ FT of $f(x,y)$

4 $H(u,v) \rightarrow$ Filter in freq domain

5 $g(x,y) = IFT[G(u,v)]\,(-1)^{x+y}$

Sharpening Spatial Filter

- It highlights the details of the image
- High spatial freq components have detailed information in the form of edges and boundaries
- Image sharpning algorithm is used to seperate object outlines. There fore Image sharpening algorithms are ~~used to~~ called edge enhancement / crispening algorithm

Blurring Vs Sharpening

Blurring → It is done in spatial domain by pixel averaging in a neighbours, it is a process of Integration

Sharpening → It is an inverse process to find the difference by the neighborhood done by spatial differentiation

Derivative Operator:

It calculates the gradient of the image intensity at each point, giving direction of the largest possible increase from ~~&~~ light to dark and the rate of change in that direction

Image differentiation

- enhances edge and other discontinuities (noise)
- deemphasizes area with slowly varying gray level values

1D Image

1st order derivatives

$$\frac{\partial f}{\partial x} = f(x+1) - f(x)$$

2nd order derivatives

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

1st and 2nd derivatives of a 2D Images

Gradient operator (linear operator) $\nabla f = \frac{\partial f(x,y)}{\partial x \partial y} = \frac{\partial f(x,y)}{\partial x} + \frac{\partial f(x,y)}{\partial y}$

Laplacian operator (non-linear) $\nabla^2 f = \frac{\partial^2 f(x,y)}{\partial x^2} + \frac{\partial^2 f(x,y)}{\partial y^2}$

Gradient Filter

Edges can be extracted by taking gradient of the images. If neighbouring pixels have same intensity, difference is zero. and hence there is no edge. Edges exit when there is a significant local Intensity variation.

For function $f(x,y)$,

$$\nabla f \equiv grad(f) = \begin{bmatrix} g_x \\ g_y \end{bmatrix} = \begin{bmatrix} \partial f / \partial x \\ \partial f / \partial y \end{bmatrix}$$

The magnitude of vector ∇f, denoted by $M(x,y)$, is given by

$$M(x,y) = mag(\nabla f) = \sqrt{g_x^2 + g_y^2}$$

- Gradient Magnitude provides information about edges & strength

- Gradient direction ~~provides~~ is perpendicular to the direction of the edge. It is useful detecting sudden change in image intensity

Laplacian Filter

It is a derivative operator which highlights grey-level discontinuities in an image

It de emphasizes region with slowly varying gray level It deemphasizes regions with slowly varying gray level.

It tends to produce image that have

- grayish edge lines and other discontinuities all superimposed on a dark

- featureless background

The 2nd order isotropic derivatives operator is the Laplacian for $f(x,y)$

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

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

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

$$\nabla^2 f = f(x+1, y) + f(x-1, y) + f(x, y+1) + f(x, y-1) - 4f(x,y)$$

High Boost Filter

- It is used to prevent the loss of low frequency components and restore the visual detail in an image. This is done by adding an offset to the filtered image by retaining some low frequency components.

- A high pass filtered image can be computed as the difference bet^n the original and a low pass filtered version of image.

$$\text{High boost} = \overset{\nearrow \text{ amplification factor}}{A} \cdot \text{Original} - \text{Lowpass}$$

$$= (A-1)\,\text{Original} + \text{Original} - \text{lowpass}$$

$$= (A-1)\,\text{original} + \text{Highpass}$$

$$f_s(x,y) = \begin{cases} f(x,y) - \nabla^2 f(x,y) \\ f(x,y) + \nabla^2 f(x,y) \end{cases}$$

$$h_{hb}(x,y) = \begin{cases} Af(x,y) - \nabla^2 f(x,y) \\ Af(x,y) + \nabla^2 f(x,y) \end{cases}$$

High boost Mask

$A \geq 1$

If $A=1$ it becomes standard laplacian sharpening

Any $N \times N$ high boost mask can be created using the value of $A = (N \times N) - 1$

Unsharp Masking

- It is hybrid filter technique
- It is useful for removing both impulse and Gaussian noise present in an image
- It is simple sharpening operator which enhances edge

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

Procedure

Read the image

Blur the original Image

Subtract the original Image

~~Su~~ Add the mask to the original Image

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

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

$$k \geq 0$$

When $k > 1$, the process is called

high boost filtering