IMAGE ENHANCEMENT

Sahil Biswas
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INTRODUCTION

- Image enhancement is basically improving the interpretability or perception of information in images for human viewers and providing `better' input for other automated image processing techniques.

- The principal objective of image enhancement is to modify attributes of an image to make it more suitable for a given task and a specific observer.

- During this process, one or more attributes of the image are modified.

IMAGE ENHANCEMENT

- There exist many techniques that can enhance a digital image without spoiling it.
- The enhancement methods can broadly be divided in to the following two categories:

- Spatial Domain Methods
- Frequency Domain Methods

SPATIAL DOMAIN ENHANCEMENT

Spatial Domain Methods

- In spatial domain techniques , we directly deal with the image pixels.
- The pixel values are manipulated to achieve desired enhancement.
- The value of a pixel with coordinates (x; y) in the enhanced image 'F' is the result of performing some operation on the pixels in the neighborhood of (x; y) in the input image 'f'.

BACKGROUND

- Spatial domain processes are denoted by the expression

$$g(x,y) = T[f(x,y)]$$

where, f(x,y) is input image and g(x,y) is processed image,

T is an operator on f, defined over some neighborhood of (x,y)

- Square or Rectangular subimage area centered at (x,y) is used as neighborhood about a point (x,y).
- *Here*,

T is a gray level transformation function of the form : $s = T(r)$

where, r and s – denote the gray levels of f(x,y) and g(x,y) at any point (x,y).

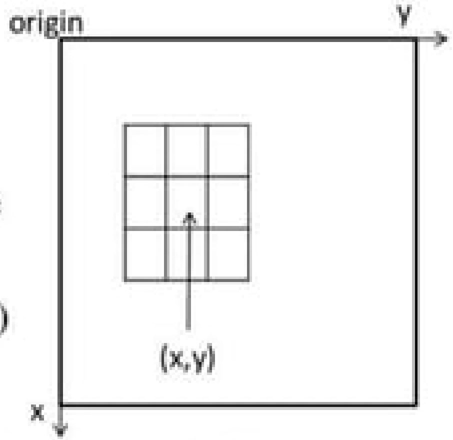
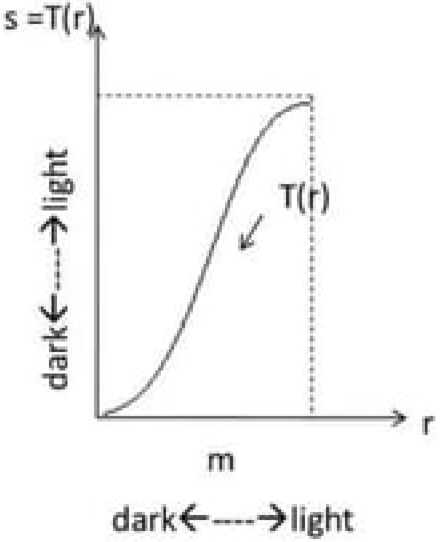
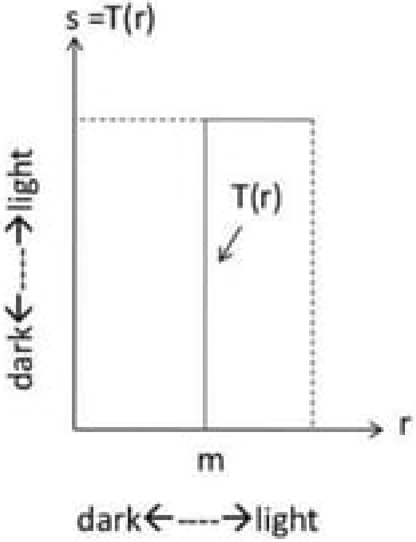


Fig: 3 x 3 neighborhood about a point (x,y) in an image



Contrast stretching



Thresholding function

- A pixel value of ‘r’ is mapped into a pixel value ‘s’ based on type of transformation ‘T’

Fig : Gray level transformation functions for contrast enhancement

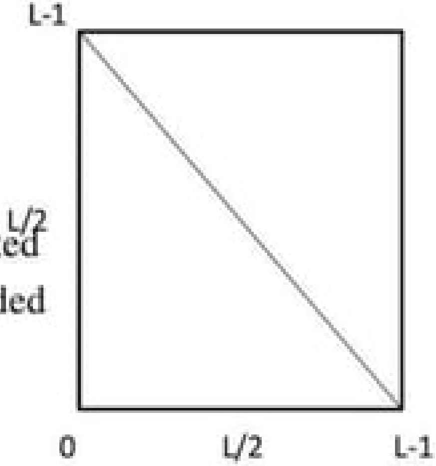
BASIC GRAY LEVEL TRANSFORMATIONS

1. IMAGE NEGATIVES

- The negative of an image with gray levels in the range[0,L-1] is obtained using negative transformations as in fig. and the expression is :

$$s = L\text{-}1 - r$$

- This type of processing is particularly suited for enhancing white or gray detail embedded in dark regions of an image, especially when the black area is dominant in size.



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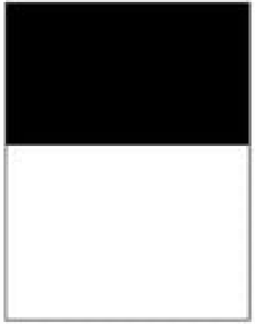


Fig1: original image

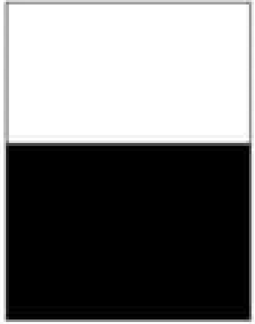


Fig2: image negative

Fig1 is the original image and fig2 is the result of the image negative where the dark region of the image gets converted into the light region .i.e. binary 1 becomes binary 0 and vice versa.

2. LOG TRANSFORMATIONS

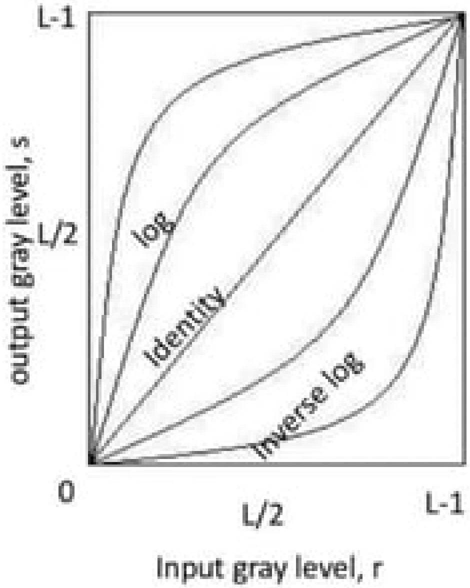
- The general form of the log transformation is shown in fig and the expression is :

  $$s = c \log(1+r)$$

  where, c is a constant and

  assume $r \geq 0$

- The shape of the log curve indicates that the transformation maps a narrow range of low gray-level values in the input image into a wider range of output levels and vice versa.
- It is used for spreading/compressing of gray levels in an image.



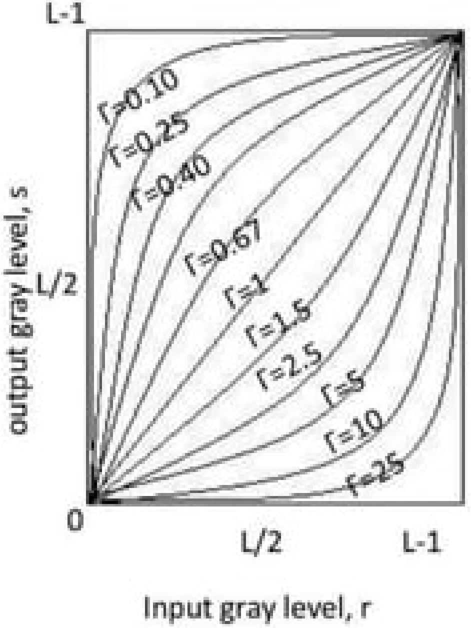
3. <u>POWER-LAW TRANSFORMATION</u>

power-law transformation has the basic form:

$$s = cr^{\gamma}$$

where, c and r are positive constants.

- The curve generated with the value of $\gamma>1$ has exactly the opposite effect as those generated with $\gamma<1$.
- By convention, the exponent in the power law equation is referred to as ***gamma***. The process used to correct this power law response is called ***gamma correction.***
- Images that are not corrected properly can look either bleached out or too dark.



4. PIECEWISE-LINEAR TRANSFORMATION

1.CONTRAST STRETCHING

Low contrast images can result from poor illumination, lack of dynamic range in image sensor or even wrong setting of a lens aperture during image acquisition.

- If r1=s1 & r2=s2, the transformation is a *linear function* that produces no change in gray levels.
- If r1=r2,s1=0&s2=L-1,the transformation is a *thresholding function* that creates binary image.
- Intermediate values of (r1,s1) & (r2,s2) produces various degrees of spread in gray levels of output image thus affecting its contrast.

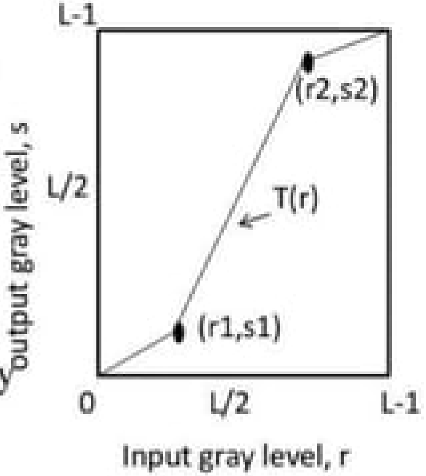


Fig: transformation used for contrast stretching

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Fig1: low contrast image

Fig2: high contrast image

ENHANCEMENT USING ARITHMETIC/LOGIC OPERATIONS

- It involves operations performed on a pixel by pixel basis between two or more images (excluding NOT, which is performed on single image)
- Any logical operators can be implemented by using only 3 basic functions(*AND, OR & NOT).*
- The *AND* and *OR* operations are used for *masking*; i.e. for selecting subimages in an image. light represents binary1 and dark represents binary 0.

IMAGE SUBTRACTION

The difference between two images f(x,y) and h(x,y) expressed as

$$g(x,y) = f(x,y) - h(x,y)$$

The key usefulness of subtraction *is the enhancement of differences between images*. Difference is taken between corresponding pixels of 'f' and 'h'.

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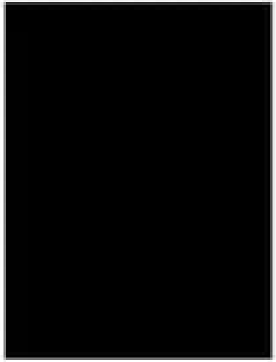


Fig1: image1

Fig2: image1

Fig3: result of subtraction

The above figure 1 &2 indicates the image taken for subtraction and the figure3 indicates the result of subtraction of image1 with itself.

IMAGE AVERAGING

The purpose of image averaging is *noise removal.*

Consider a noisy image g(x,y) formed by the addition of noise n(x,y) to an original image f(x,y); i.e.

$$g(x,y) = f(x,y) + n(x,y)$$

If the noise satisfies the constraint (*uncorrelated at every coordinate (x,y)*), then averaged image is given by

$$\bar{g}(x,y) = \frac{1}{K}\sum_{i=1}^{K} g_i(x,y)$$

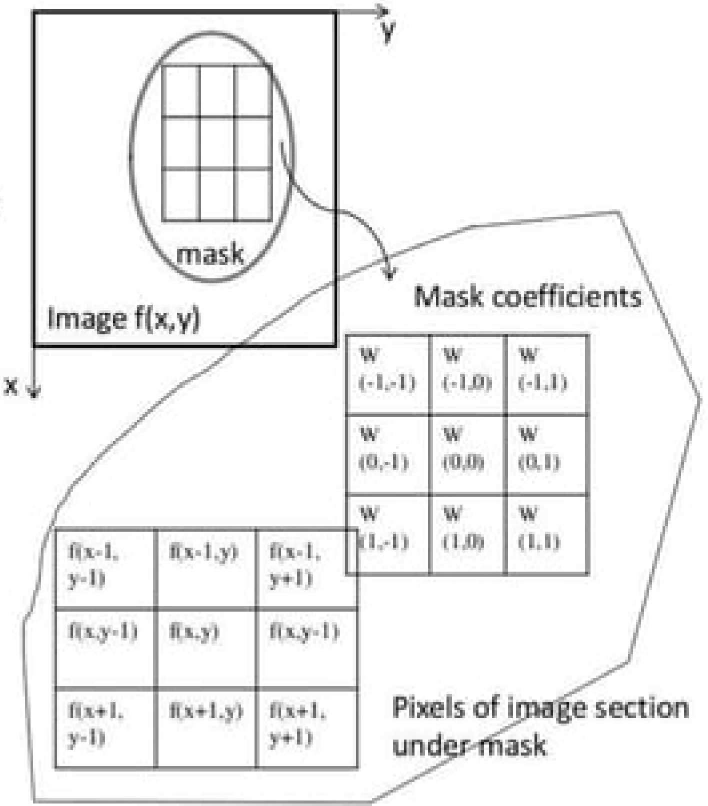
then it follows that,

$$E\{\bar{g}(x,y)\} = f(x,y)$$

i.e. *it is expected the averaged image approaches to the original image as the number of noisy images used in the averaging process increases.*

BASICS OF SPATIAL FILTERING

Fig: mechanics of spatial filtering



Contd..

- The process consists of moving the filter mask from point to point in an image.
- For linear spatial filtering, the response is given by a sum of products of the filter(mask) coefficients and the corresponding pixels directly under the mask as:

$$R = w(-1,-1)\, f(x-1,y-1) + w(-1,0)\, f(x-1,y) + \ldots\ldots +$$
$$w(0,0)f(x,y) + \ldots + \ldots\ldots\ldots + w(1,0)f(x+1,y) + w(1,1)f(x+1,y+1).$$

- In general, linear filtering of an image f of size MxN with a filter mask of size mxn is given by the expression,

$$g(x,y) = \sum_{s=-a}^{a} \sum_{t=-b}^{b} w(s,t) f(x+s, y+t)$$

where, a=(m-1)/2 and b=(n-1)/2

- The process of linear filtering is similar to a frequency domain concept called *convolution.* for this reason, linear spatial filtering often is referred to as "*convolving a mask with an image*". Filter masks are sometimes called *"convolution masks" or "convolution kernel"*.

FREQUENCY DOMAIN ENHANCEMENT

- In frequency domain methods, the image is first transferred into frequency domain.
- It means that, the Fourier Transform of the image is computed first.
- All the enhancement operations are performed on the Fourier transform of the image and then the Inverse Fourier transform is performed to get the resultant image.

FREQUENCY DOMAIN ENHANCEMENT

- These enhancement operations are performed in order to modify the image brightness, contrast or the distribution of the grey levels.
- As a consequence the pixel value (intensities) of the output image will be modified according to the transformation function applied on the input values.
- Image enhancement is applied in every field for example medical image analysis, analysis of images from satellites etc.

FREQUENCY DOMAIN ENHANCEMENT

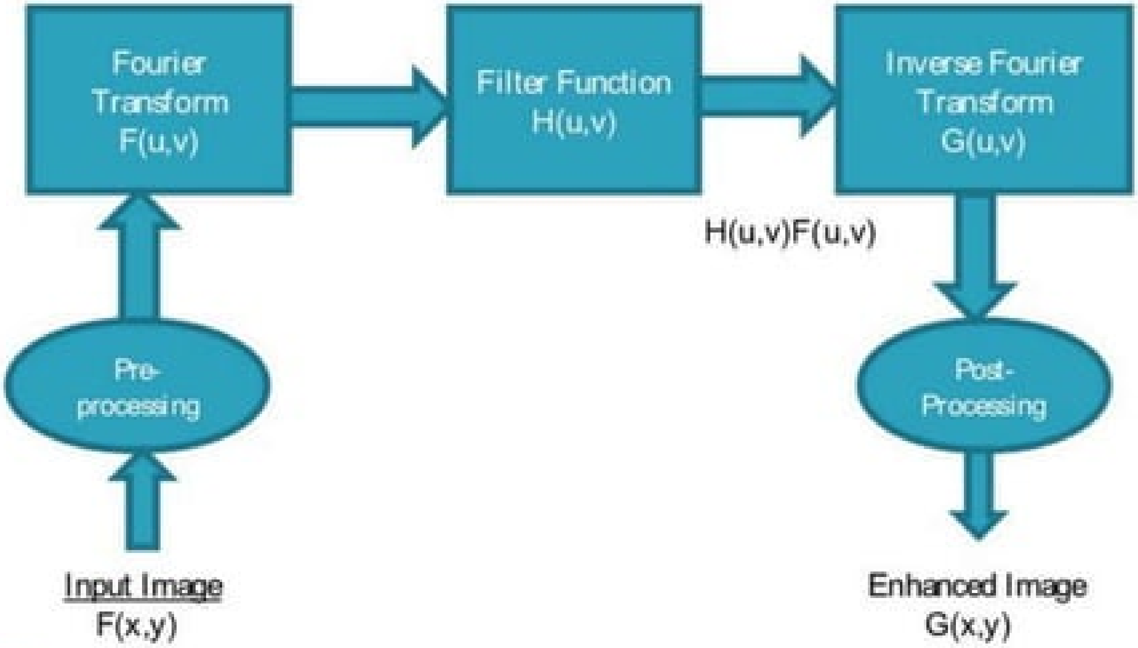
- Image enhancement simply means, transforming an image F into image G using T. (Where T is the transformation function.

- The values of pixels in images F and G are denoted by r and s, respectively. As said, the pixel values r and s are related by the expression

$$s = T(r)$$

- Where T is a transformation that maps a pixel value r into a pixel value s.

FREQUENCY DOMAIN ENHANCEMENT



Frequency domain filtering operations

FREQUENCY DOMAIN ENHANCEMENT

- We can therefore directly design a transfer function and implement the enhancement in the frequency domain as follows.

Transfer function

$$\boxed{G(u,v) = H(u,v)F(u,v)}$$

Enhanced Image

Given Image

FILTERING

- The concept of filtering is easier to visualize in the frequency domain.

- Therefore, enhancement of image can be done in the frequency domain, based on its DFT.

FILTERING

- Filtering can be divided in two categories namely
- Low pass filtering
- High Pass filtering

FILTERING

- Edges and sharp transitions in gray values in an image contribute significantly to high-frequency content of its Fourier transform.

- Regions of relatively uniform gray values in an image contribute to low-frequency content of its Fourier transform.

LOW PASS FILTERING

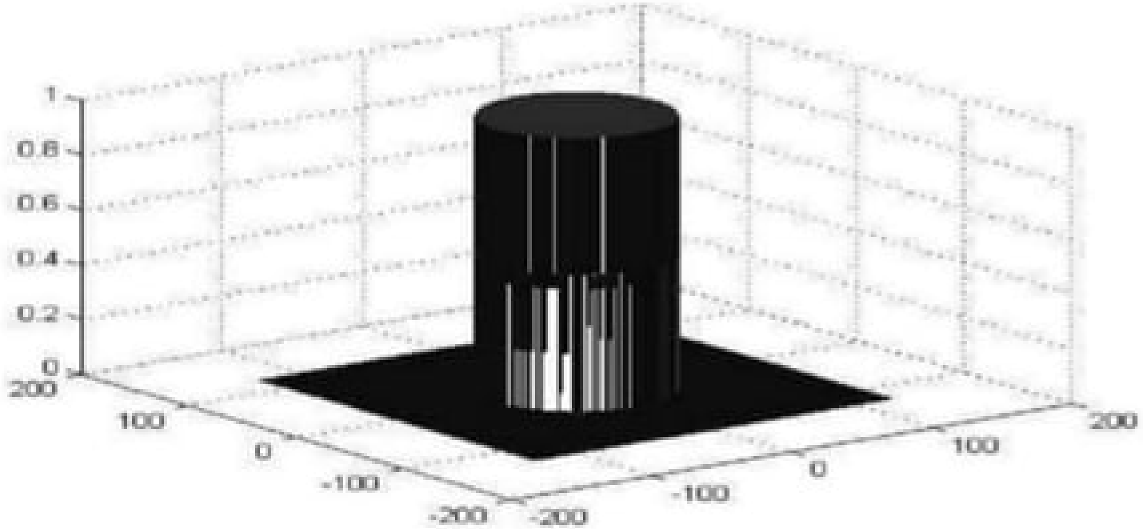
- Hence, an image can be smoothed in the Frequency domain by attenuating the high-frequency content of its Fourier transform.
- This would be a low pass filter.
- For simplicity, we will consider only those filters that are real and symmetric.

LOW PASS FILTERING

- An ideal low pass filter with cutoff frequency 'r_0' is given by following relation.

$$H(u,v) = \begin{cases} 1, & \text{if } \sqrt{u^2+v^2} \le r_0 \\ 0, & \text{if } \sqrt{u^2+v^2} > r_0 \end{cases}$$

LOW PASS FILTERING



Ideal LPF with $r_0 = 57$

LOW PASS FILTER EXAMPLE

Original Image

LPF image, $r_0 = 57$

LOW PASS FILTER EXAMPLE

LPF image, $r_0 = 36$

LPF image, $r_0 = 26$

LOW PASS FILTERING

- The cutoff frequency of the ideal LPF determines the amount of frequency components passed by the filter.

- Smaller the value of r_0 , more the number of image components eliminated by the filter.

- In general, the value of r_0 is chosen such that most components of interest are passed through, while most components not of interest are eliminated.

GAUSSIAN LOW PASS FILTERING

- The form of a Gaussian low pass filter in two-dimensions is given by

$$H(u,v) = e^{-D^2(u,v)/2\sigma^2} \qquad D(u,v) = \sqrt{u^2 + v^2}$$

- Where D is the distance from origin in frequency plane

- The parameter σ measures the dispersion of the Gaussian curve. Larger the value of σ, larger the cutoff frequency and milder the filtering.

HIGH PASS FILTERING

- Hence, an image can be smoothed in the Frequency domain by attenuating the low-frequency content of its Fourier transform.

- This would be a high pass filter.

- For simplicity, we will consider only those filters that are real and symmetric

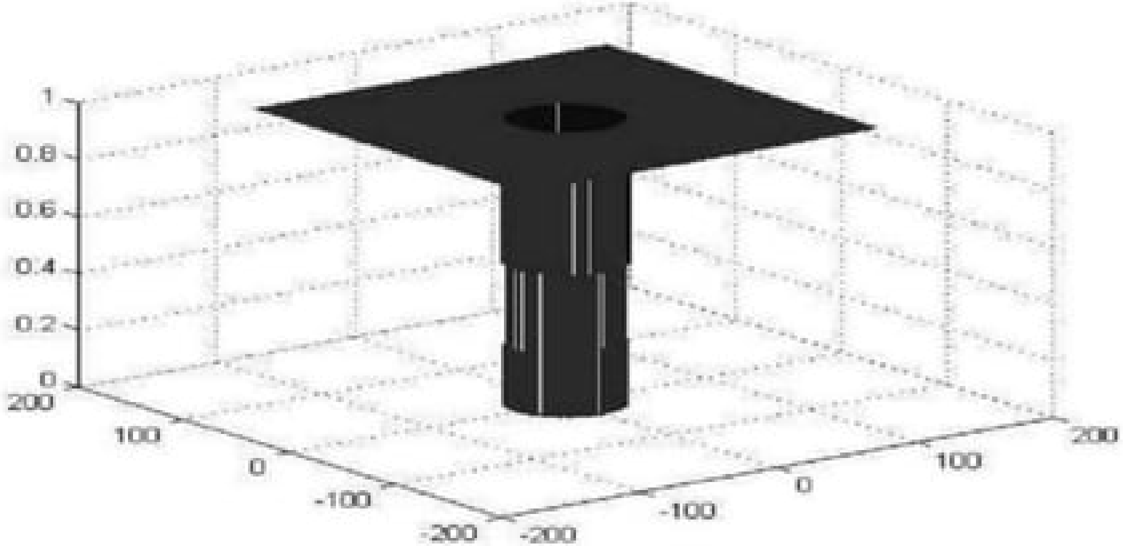
HIGH PASS FILTERING

- An ideal high pass filter with cutoff frequency r_0.

$$H(u,v) = \begin{cases} 0, & \text{if } \sqrt{u^2+v^2} \le r_0 \\ 1, & \text{if } \sqrt{u^2+v^2} > r_0 \end{cases}$$

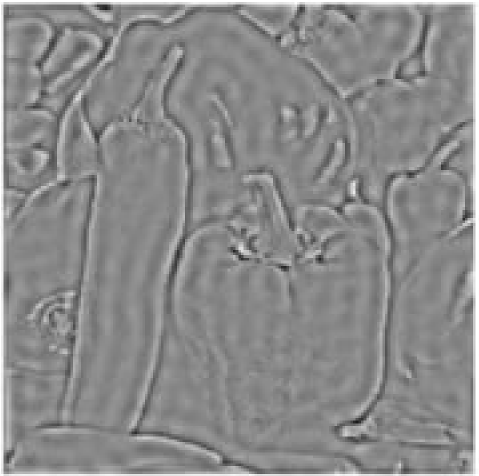
HIGH PASS FILTERING

Ideal HPF with r_0=36



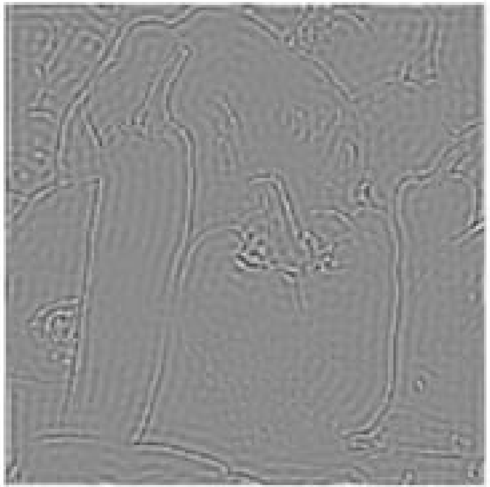
IDEAL HPF EXAMPLES

Original Image

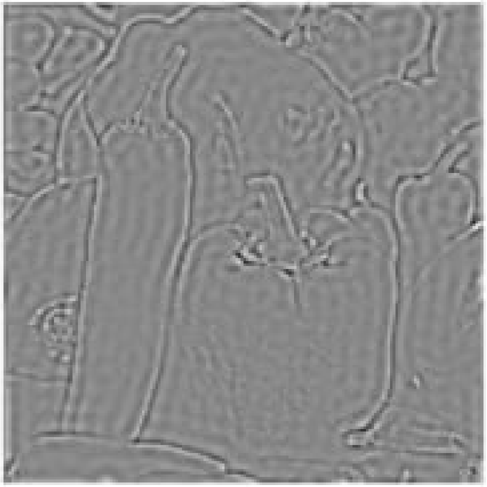


HPF image, $r_0 = 18$

IDEAL HPF EXAMPLES



HPF image, $r_0 = 36$



HPF image, $r_0 = 26$

CONCLUSION

- Image enhancement algorithms offer a wide variety of approaches for modifying images to achieve visually acceptable images.

- The choice of such techniques is a function of the specific task, image content, observer characteristics, and viewing conditions.

THANK YOU