Digital Image Processing

- Digital Image Processing denotes the process of digital images with the use of digital computer.

- Digital images are contains various types of noises which are reduces the quality of images. Noises can be removed by various enhancement techniques.

- Noise is anything in the image that are unwanted or undesired information

  Examples:
  - Light fluctuations
  - Sensor noise
  - Transmission

Smoothing

- Smoothing is often used to reduce noise within an image.
- Image smoothing is a key technology of image enhancement, which can remove noise in images. So, it is a necessary functional module in various image-processing software.
- Image smoothing is a method of improving the quality of images.
- Smoothing is performed by spatial and frequency filters

Spatial filtering

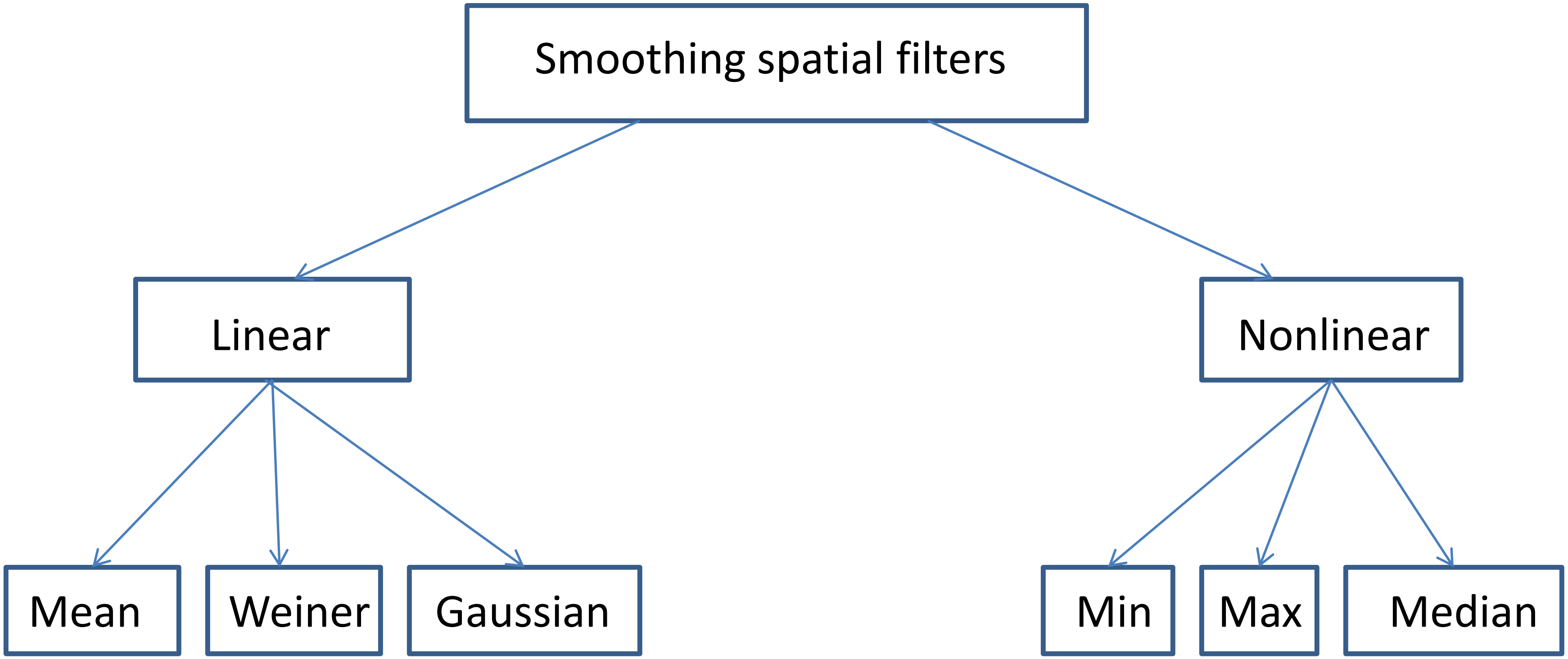
- Spatial filtering term is the filtering operations that are performed directly on the pixels of an image. The process consists simply of moving the filter mask from point to point in an image.

  – Smoothing spatial filters
  – Sharpening spatial filters

Smoothing Spatial Filters

- Smoothing filters are used for noise reduction and blurring operations.
- It takes into account the pixels surrounding it in order to make a determination of a more accurate version of this pixel.
- By taking neighboring pixels into consideration, extreme “noisy” pixels can be filtered out.
- Unfortunately, extreme pixels can also represent original fine details, which can also be lost due to the smoothing process

Cont…


Smoothing spatial filters
Linear
Nonlinear
Mean
Weiner
Gaussian
Min
Max
Median

Smoothing Linear Filters

- Smoothing linear spatial filter is the average of the pixels contained in the neighborhood of the filter mask.

- Averaging filters or low pass filters.
  - Mean filter
  - Gaussian filter

Mean Filter/Box Filter

- Mean filtering is simply to replace each pixel value in an image with the mean (`average') value of its neighbors, including itself.

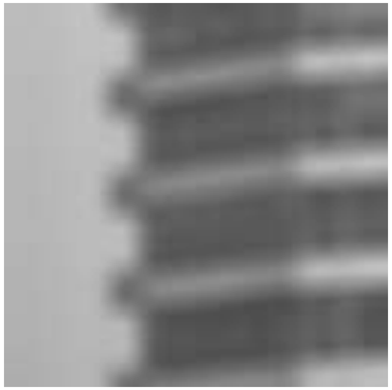
- 3×3 normalized box filter:

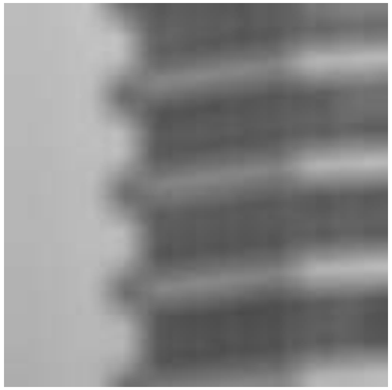
20	40	10
10	20	20
10	20	30

20	40	10
10	**20**	20
10	20	30

Cont…

- Image smoothed with 3×3, 5×5, 9×9 and 11×11 box filters





Cont…

- Often a 3×3 square matrix is used, although larger matrix (*e.g.* 5×5 squares) can be used for more severe smoothing.

- **Drawback:**
  - smoothing reduces fine image detail

Gaussian Filter

- A Gaussian filters smoothens an image by calculating weighted averages in a filter box.
- It is used to `blur' images and remove detail and noise.
- Gives more weight at the central pixels and less weights to the neighbors.
- The farther away the neighbors, the smaller the weight.
- Gaussian Blurs produce a very pure smoothing effect without side effects.

$$\frac{1}{2\pi\sigma^2}\exp\{-\frac{x^2+y^2}{2\sigma^2}\}$$

Gaussian Smoothing Example

Original

Sigma = 3

Smoothing Non Linear Filters

- Nonlinear spatial filters are Order-statistics filters whose response is based on ordering (ranking) the pixels contained in the image area encompassed by the filter, and then replacing the value of the center pixel with the value determined by the ranking result.

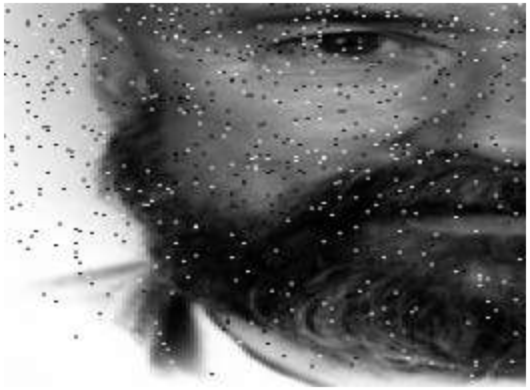
  - Min and Max Filter
  - Median Filter
  - Midpoint Filter

Min and Max Filter

- The minimum filter selects the smallest value within the pixel values and maximum filter selects the largest value within of pixel values.
- Max filter is useful for finding the brightest points in an image i.e. it removes salt noise.
- Min filter is useful for finding the darkest points in an image i.e. it removes pepper noise.
- Both filters require a data sort.

Median Filter

- It smooth a few pixels whose values differ significantly from their surroundings without affecting the other pixels.
- Best suited for “salt and pepper” noise
- Salt-and pepper noise can occur due to a random bit error in a communication channel



Comparison Of Median And Box Filter

Noisy image

5x5 median filtered

5x5 box filter

Midpoint Filter

- The Midpoint filter blurs the image by replacing each pixel with the average of the highest pixel and the lowest pixel (with respect to intensity) within the specified window size.

- Midpoint = (darkest + lightest)/2

Frequency filtering

- The basic model for filtering in the frequency domain

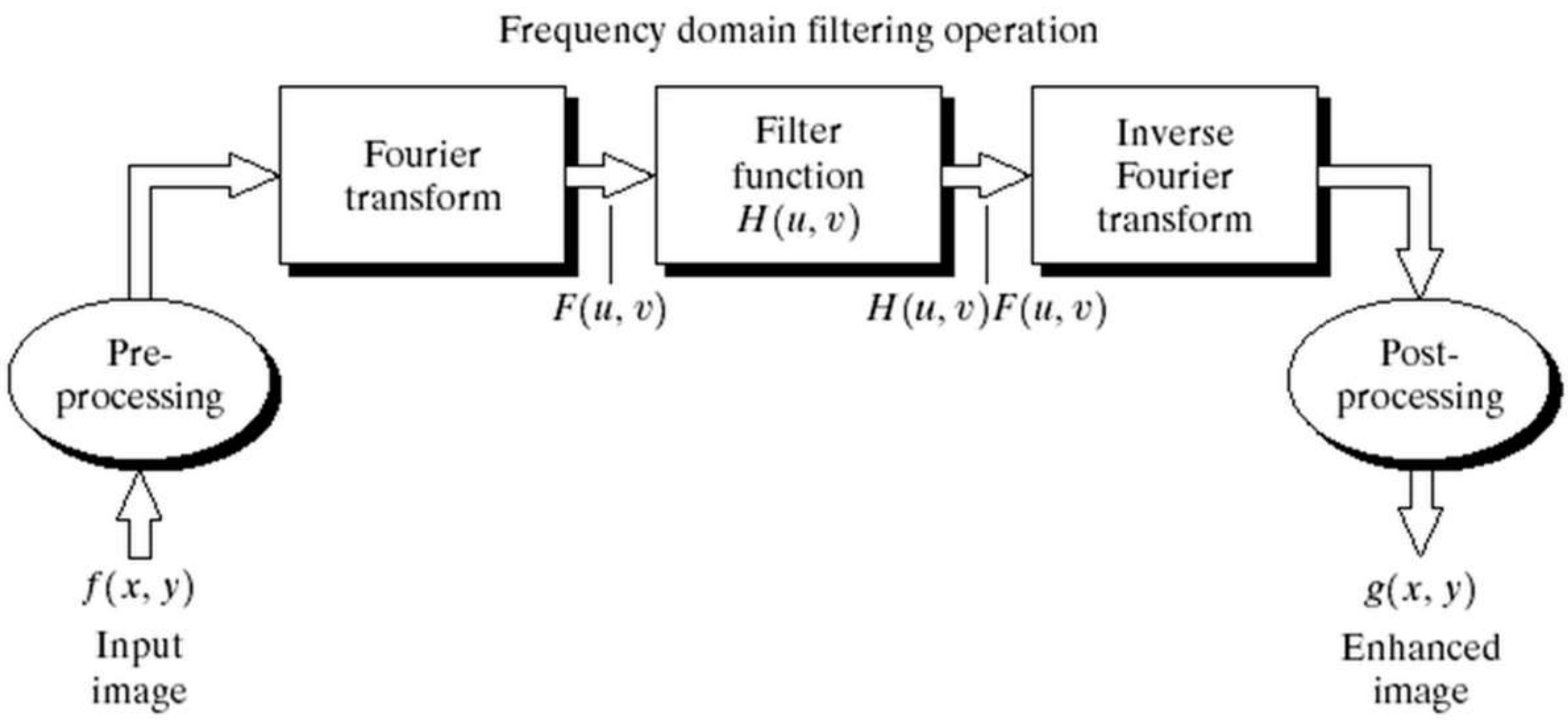
  where $F(u,v)$: the Fourier transform of the image to be smoothed

  $H(u,v)$: a filter transfer function

- Smoothing is fundamentally a low pass operation in the frequency domain.

- It is computationally faster than spatial domain.

Operation of frequency filter

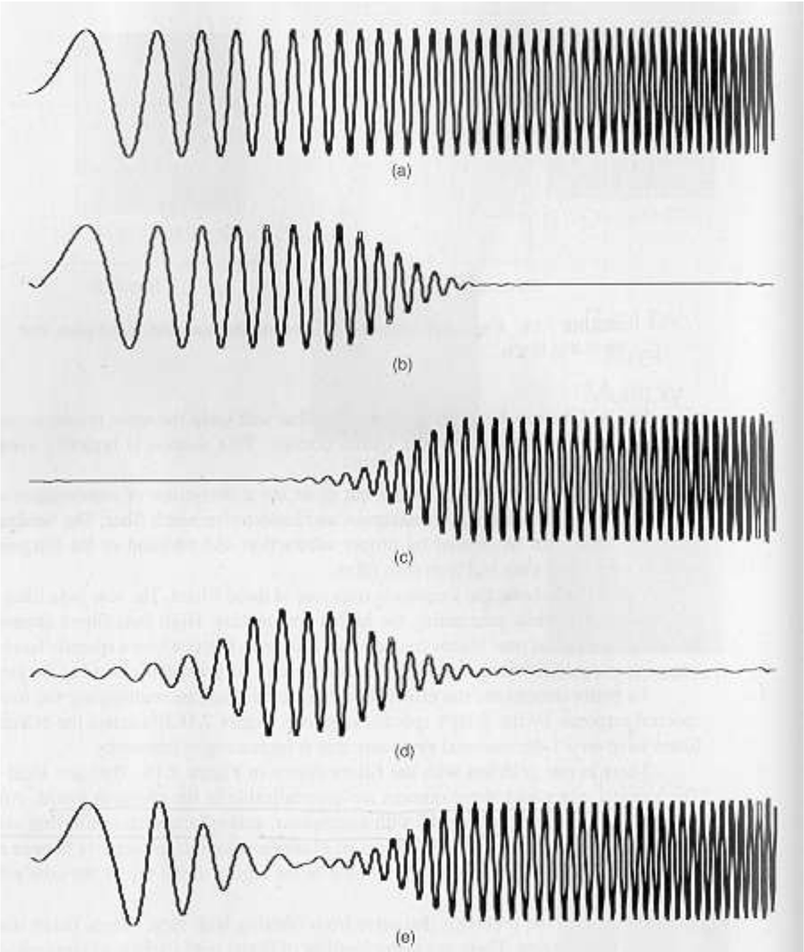


Major filter categories

- Typically, filters are classified by examining their properties in the frequency domain:

    (1) Low-pass for smoothing
    (2) High-pass for sharpening
    (3) Band-pass
    (4) Band-stop

Example



Original signal

Low-pass filtered

High-pass filtered

Band-pass filtered

Band-stop filtered

Cont…

- There are several standard forms of low pass filters (LPF).
  - Ideal low pass filter
  - Butterworth low pass filter
  - Gaussian low pass filter

Ideal Low pass Filters (ILPFs)

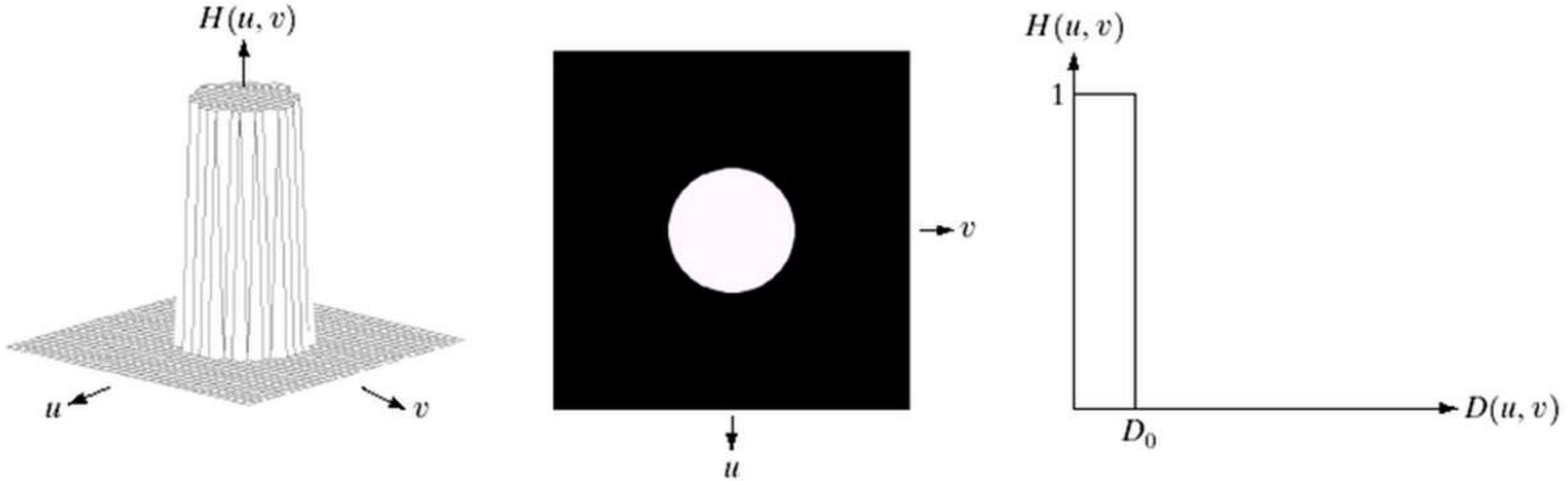
- The simplest low pass filter is a filter that "cuts off" all high-frequency components of the Fourier transform that are at a distance greater than a specified distance D_0 from the origin of the transform.
- The transfer function of an ideal low pass filter

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

where $D(u,v)$: the distance from point (u,v) to the center of their frequency rectangle

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

Cont…



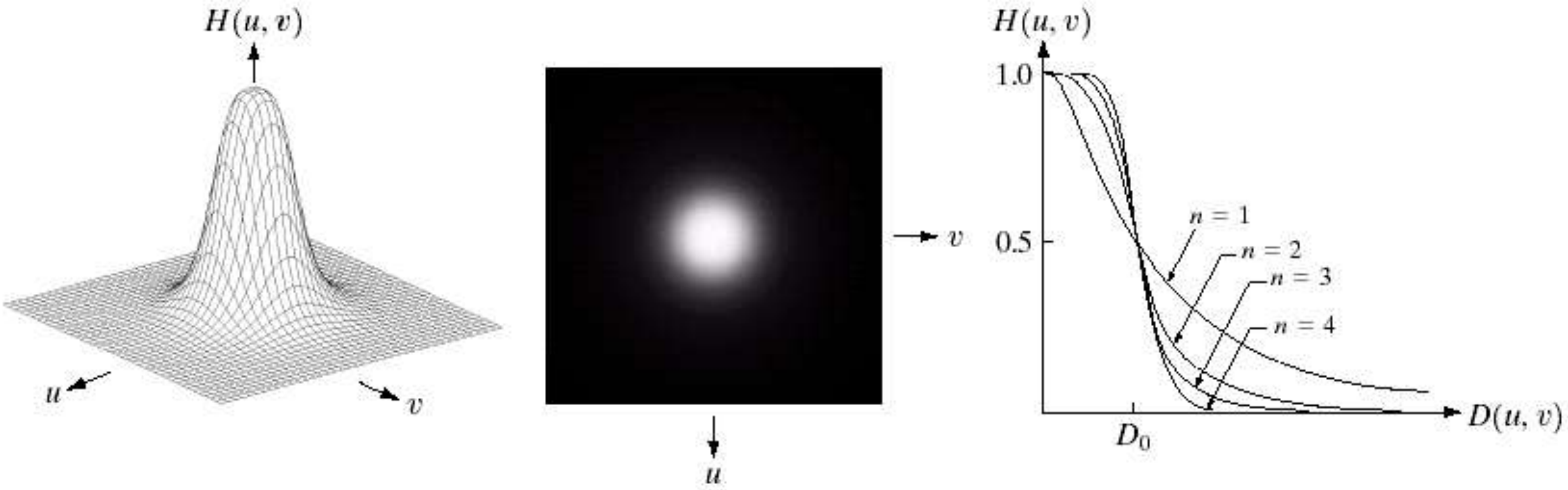
(a) Perspective plot of an ideal lowpass filter transfer function. (b) Filter displayed as an image. (c) Filter radial cross section.

a	b
c	d
e	f

(a) Original image. (b)–(f) Results of ideal lowpass filtering with cutoff frequencies set at radii values of 5, 15, 30, 80, and 230

Butterworth Low pass Filters (BLPFs)

$$H(u,v) = \frac{1}{1 + [D(u,v)/D_0]^{2n}}$$



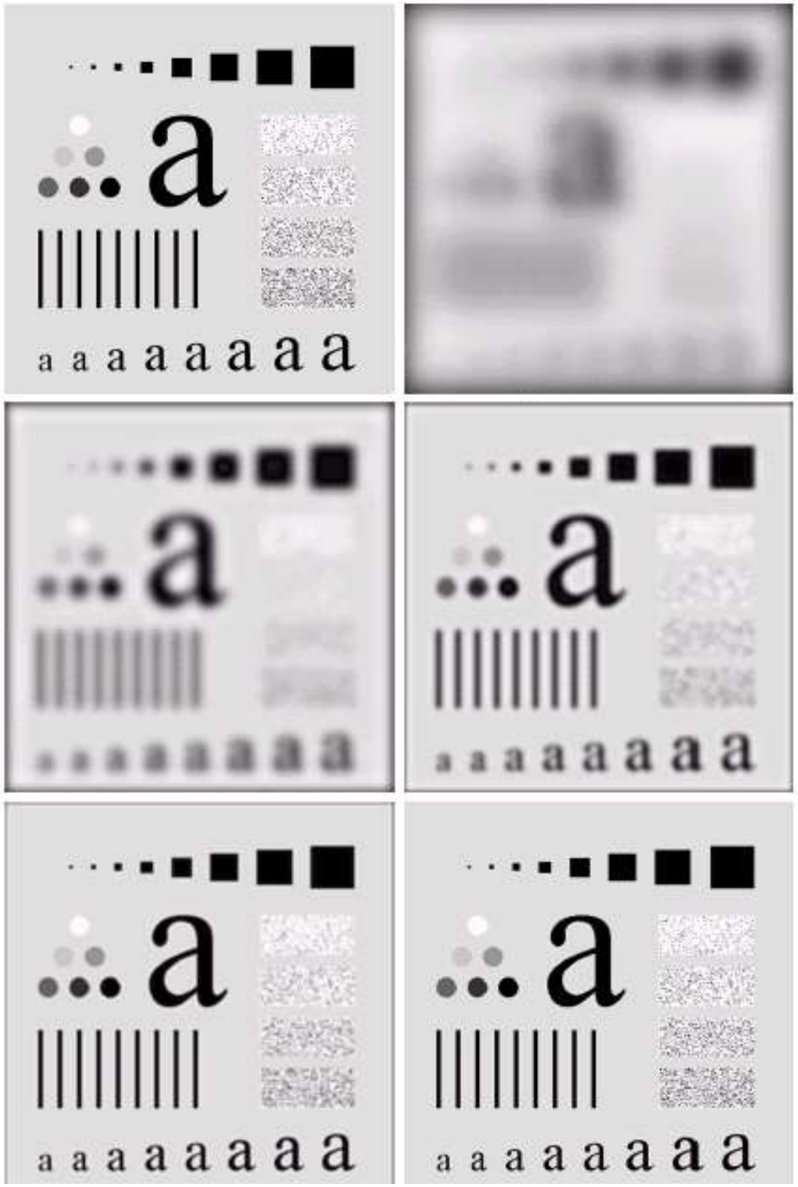
a b c

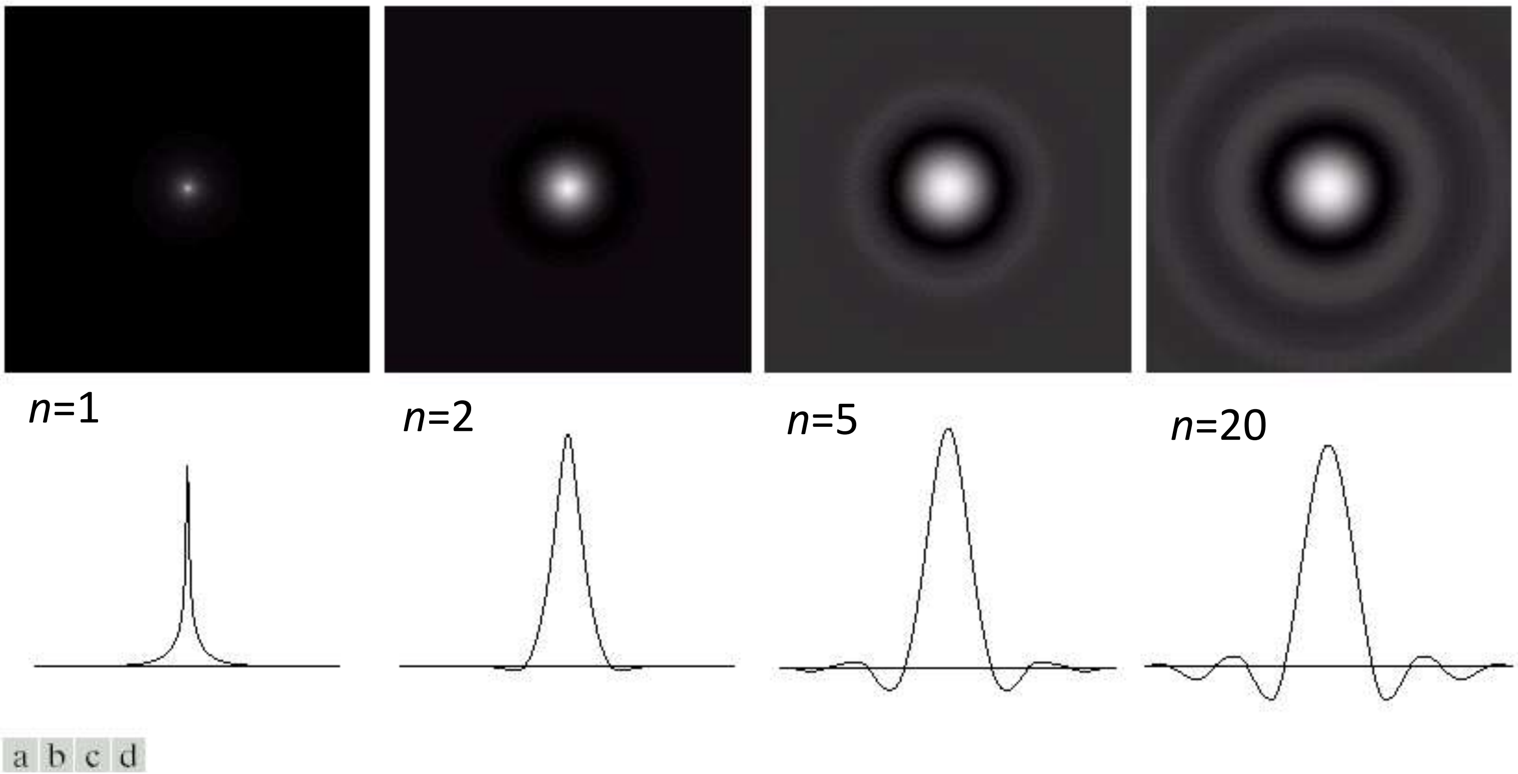
(a) Perspective plot of a Butterworth lowpass filter transfer function. (b) Filter displayed as an image. (c) Filter radial cross sections of orders 1 through 4.

Butterworth Low pass Filters (BLPFs)

n=2

D_0=5,15,30,80,and 230

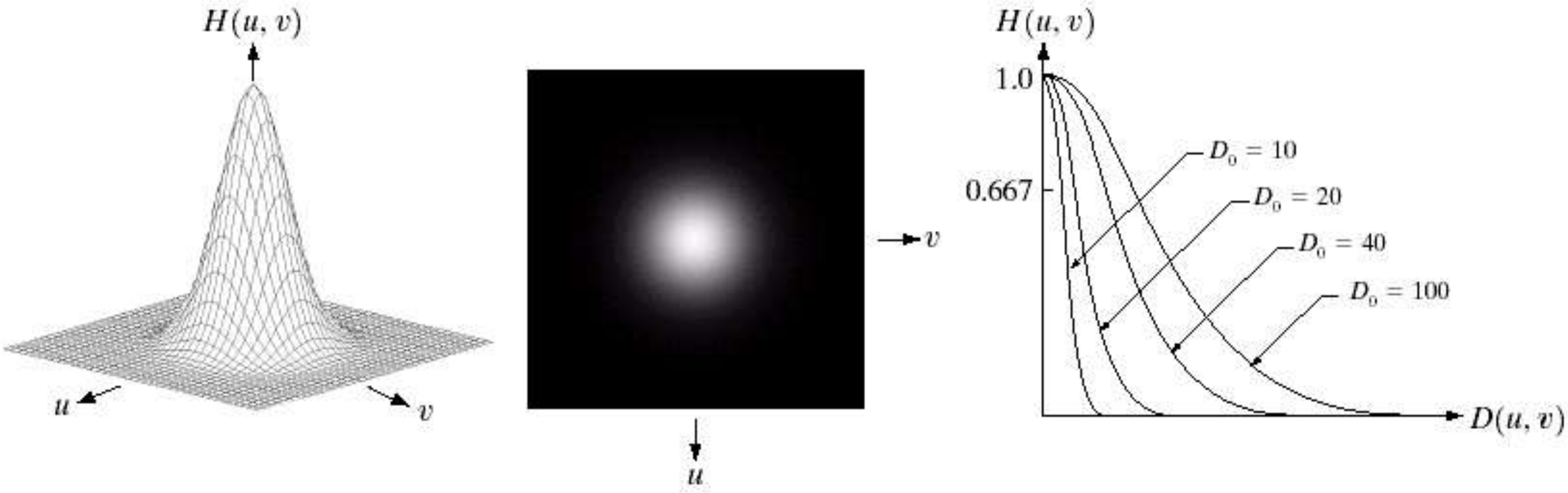




(a)–(d) Spatial representation of BLPFs of order 1, 2, 5, and 20, and corresponding gray-level profiles through the center of the filters (all filters have a cutoff frequency of 5). Note that ringing increases as a function of filter order.

Gaussian Lowpass Filters (FLPFs)

$$H(u,v) = e^{-D^2(u,v)/2D_0^2}$$

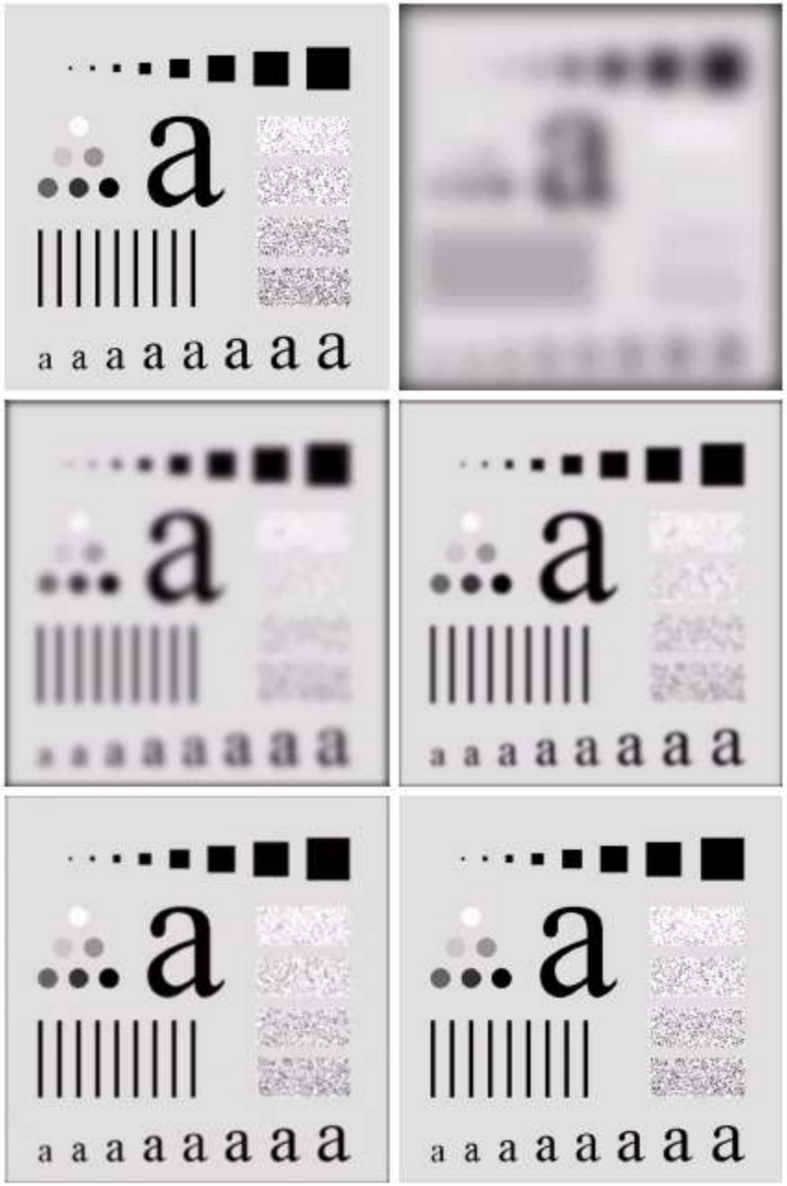


a b c

(a) Perspective plot of a GLPF transfer function. (b) Filter displayed as an image. (c) Filter radial cross sections for various values of D_0.

Gaussian Low pass Filters (FLPFs)

D_0=5,15,30,80,and 230



Conclusion

- Image smoothing 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.

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THANK YOU
FOR YOUR ATTENTION !