High-Pass and Band-Pass Filtering

CS 450: Introduction to Digital Signal and Image Processing

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Sharpening

Blurring is low-pass filtering, so deblurring is high-pass filtering.

- Explicit high-pass filtering
- Unsharp Masking
- Deconvolution
- Edge Detection

Tradeoff:

- Reduces blur, but
- Increases noise

High-Pass Filtering

Ideal: $H(u) = \begin{cases} 1 & \text{if } u > u_c \\ 0 & \text{otherwise} \end{cases}$

Gaussian: $H(u) = 1 - e^{-\frac{1}{2}u^2/{u_c}^2}$

Butterworth: $H(u) = \frac{1}{1+\left({u_c}^2/u^2\right)^n}$

High-Pass Filters

Ideal

Butterworth

Gaussian

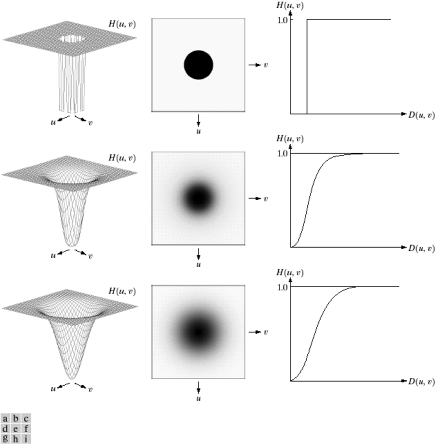
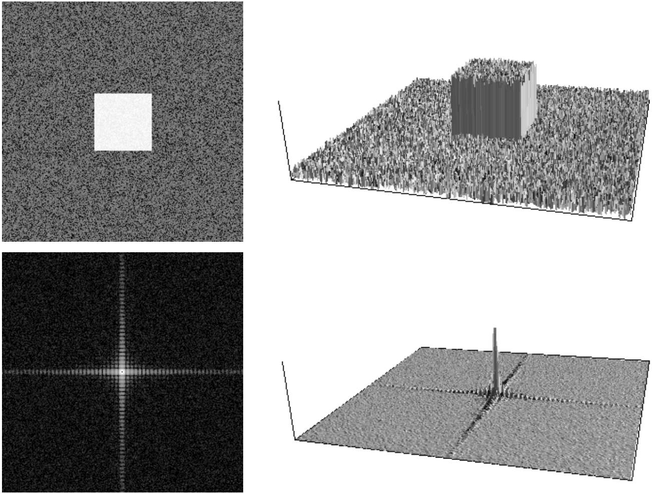
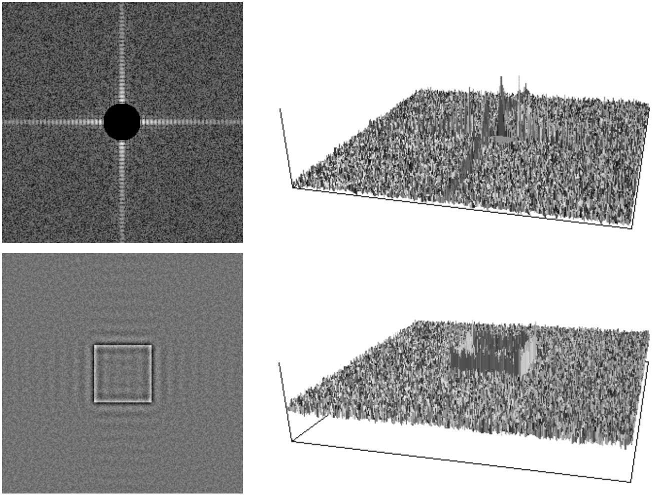


FIGURE 4.22 Top row: Perspective plot, image representation, and cross section of a typical ideal highpass filter. Middle and bottom rows: The same sequence for typical Butterworth and Gaussian highpass filters.

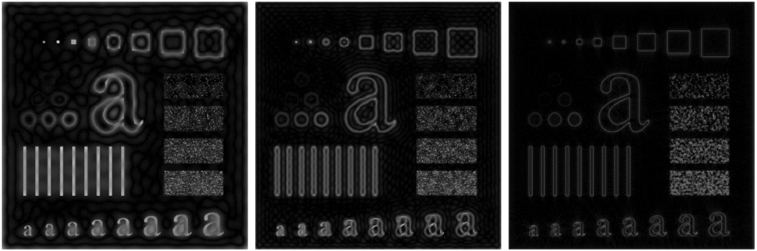
Ideal Filters and Ringing



Ideal Filters and Ringing (cont'd)



Ideal Filters and Ringing

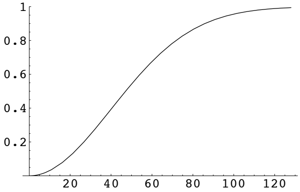


a b c

FIGURE 4.24 Results of ideal highpass filtering the image in Fig. 4.11(a) with $D_0 = 15$, 30, and 80, respectively. Problems with ringing are quite evident in (a) and (b).

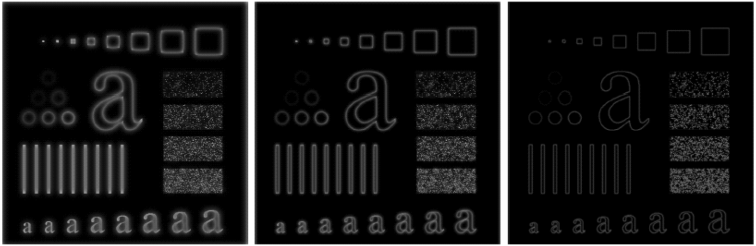
Gaussian High-Pass Filters

$$H(u) = 1 - e^{-\frac{1}{2}u^2/u_c{}^2}$$



Sound familiar?
This is what we did with unsharp masking to get the edges!

Gaussian High-Pass Filters



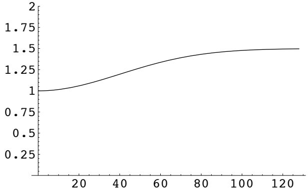
a b c

FIGURE 4.26 Results of highpass filtering the image of Fig. 4.11(a) using a GHPF of order 2 with $D_0 = 15$, 30, and 80, respectively. Compare with Figs. 4.24 and 4.25.

High-Boost Filtering

$$H(u) = 1 + \alpha \, HP(u)$$

- $HP(u)$ is a high-pass filter
- α controls how much to boost the higher frequencies

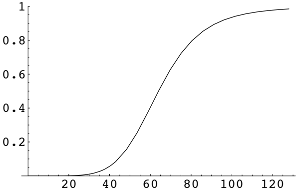


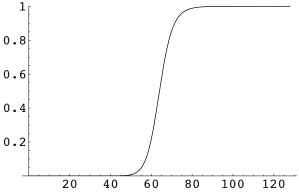
This is why unsharp masking in the spatial domain works!

Butterworth High-Pass Filter

Controllable sharpness of the frequency-domain cutoff u_c:

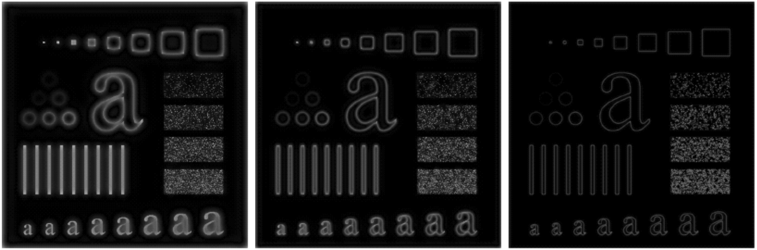
$$H(u) = \frac{1}{1 + \left(u_c^2 / u^2\right)^n}$$





- The “cutoff” frequency u_c controls where the cutoff occurs.
- The parameter n controls the sharpness of the cutoff.

Butterworth High-Pass Filters



a b c

FIGURE 4.25 Results of highpass filtering the image in Fig. 4.11(a) using a BHPF of order 2 with $D_0 = 15$, 30, and 80, respectively. These results are much smoother than those obtained with an ILPF.

Band-Pass Filtering

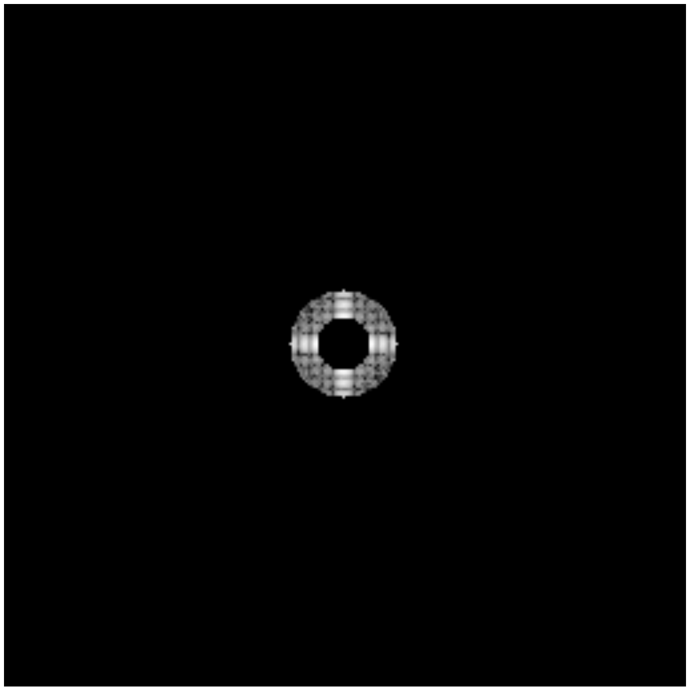
Tradeoff: Blurring vs. Noise

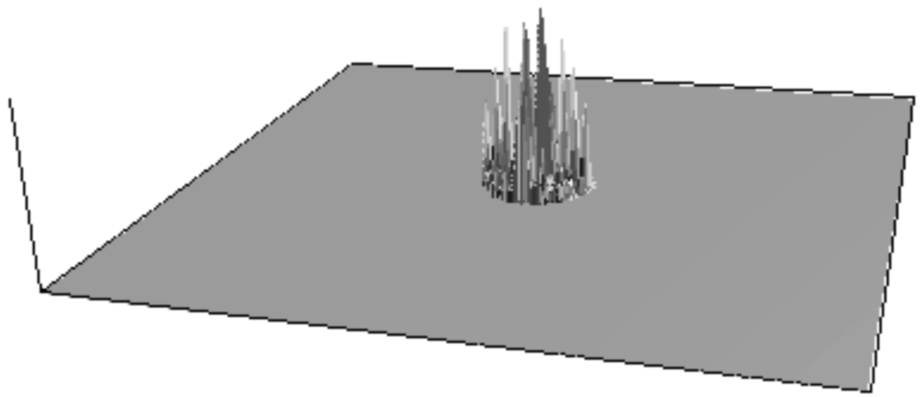
- Low-pass reduces noise but accentuates blurring
- High-pass reduces blurring but accentuates noise

A compromise:

Band-boost filtering boosts certain midrange freqencies and partially corrects for blurring, but does not boost the very high (most noise corrupted) frequencies.

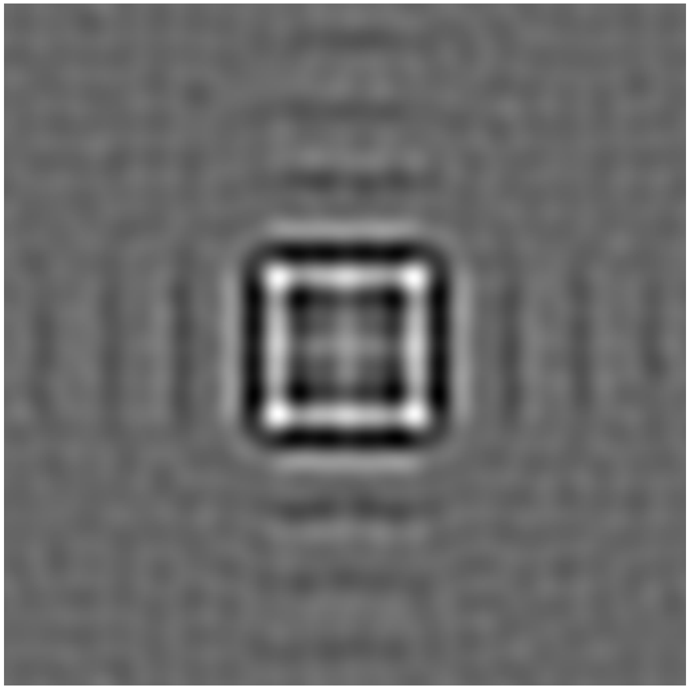
Band-Pass Filtering

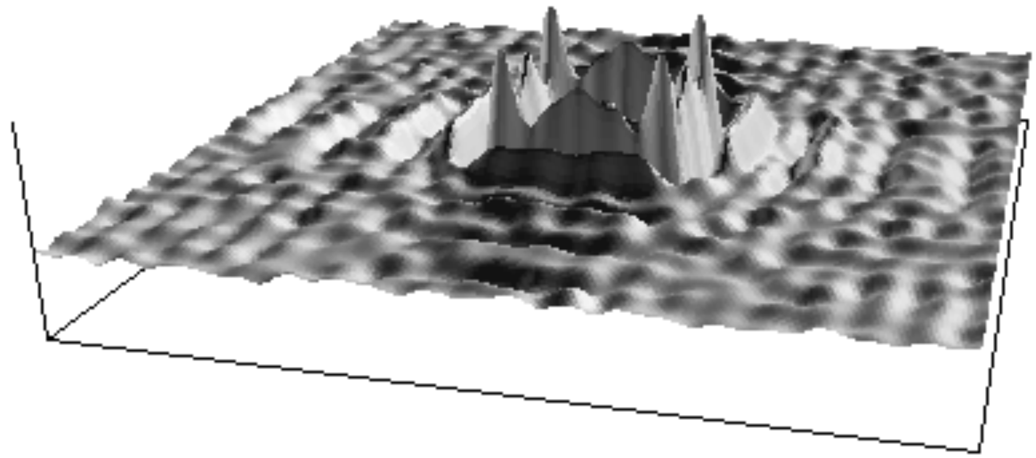




Band-Pass: Frequency Domain
(http://paulbourke.net/miscellaneous/imagefilter/)

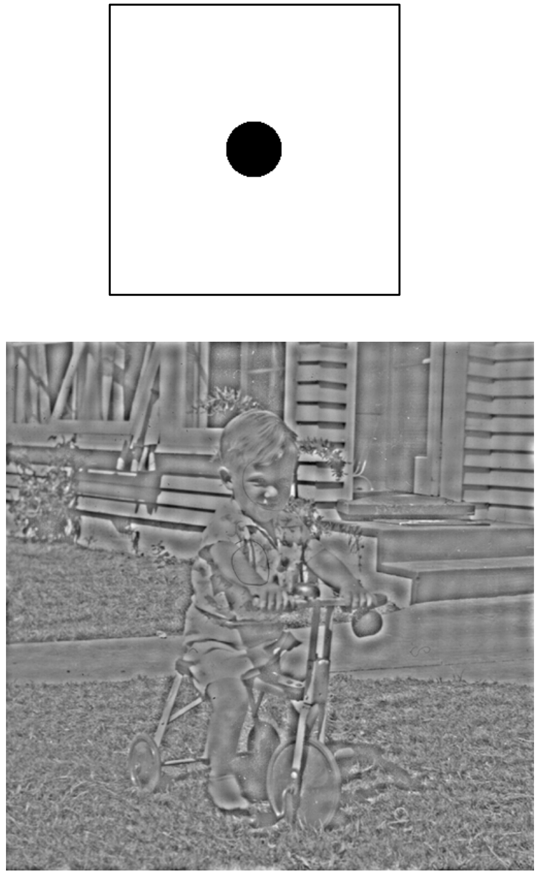
Band-Pass Filtering



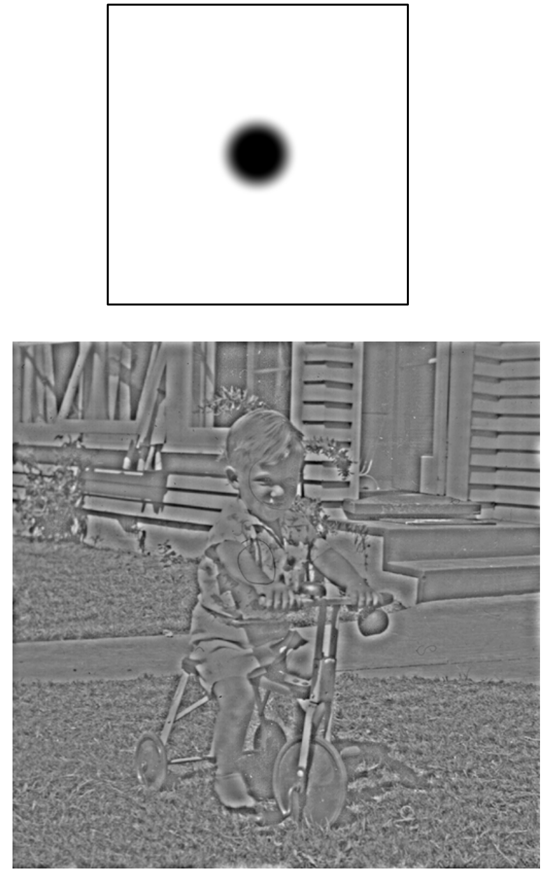


Band-Pass: Space Domain
(http://paulbourke.net/miscellaneous/imagefilter/)

High-Pass Filtering Example



Ideal (Sharp) Cut-Off: Note Ringing



Smooth cut-off: ringing reduced

(http://paulbourke.net/miscellaneous/imagefilter/)

Summary: Filtering

Consider what you want to do in the frequency domain
(the shape of the filter)

Convert signal to/from frequency domain	Convert filter to equivalent convolution operations
THEN	THEN
Implement in the frequency domain	Implement in the spatial domain