

Lecture 5

Reading: Image Transform, G&W Chap 4, Jain Chap 5.1-5.6, 5.11



Digital Image Processing

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<http://www.ee.columbia.edu/dvmm>

Most images are downloaded from the web site of the Gonzalez/Woods textbook

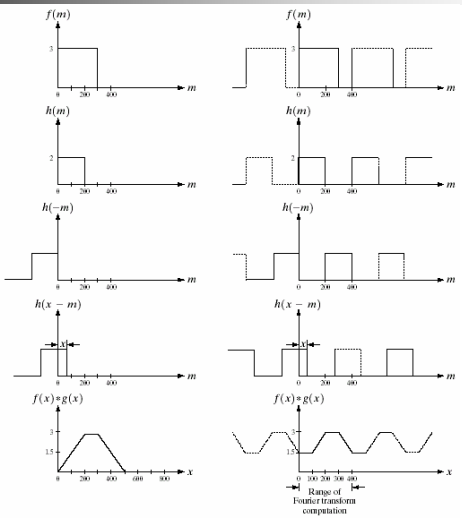


Convolution



a f
b g
c h
d i
e j

FIGURE 4.36 Left: convolution of two discrete functions. Right: convolution of the same functions, taking into account the implied periodicity of the DFT. Note in (j) how data from adjacent periods corrupt the result of convolution.



Correlation and Template Matching

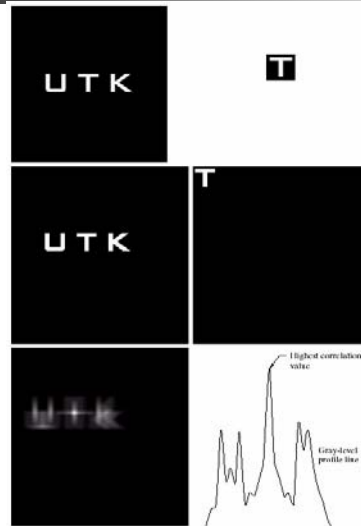
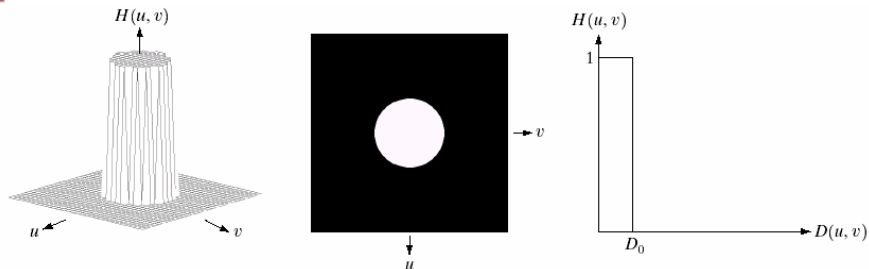


FIGURE 4.41
 (a) Image
 (b) Template
 (c) and
 (d) Padded
 images
 (e) Correlation
 function displayed
 as an image
 (f) Horizontal
 profile line
 through the
 highest value in
 (c), showing the
 point at which the
 best match took
 place.



Ideal LPF



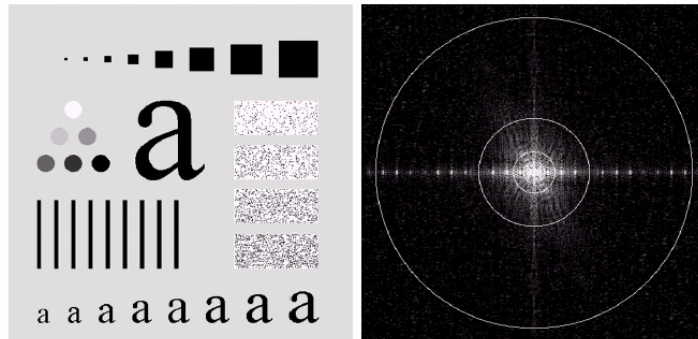
a b c

FIGURE 4.10 (a) Perspective plot of an ideal lowpass filter transfer function. (b) Filter displayed as an image. (c) Filter radial cross section.

- Assume original shifting (i.e., $(-1)^{x+y}$) has been done



Power Distribution



a b

FIGURE 4.11 (a) An image of size 500×500 pixels and (b) its Fourier spectrum. The superimposed circles have radii values of 5, 15, 30, 80, and 230, which enclose 92.0, 94.6, 96.4, 98.0, and 99.5% of the image power, respectively.

5



■ Note the blurring and ringing effect

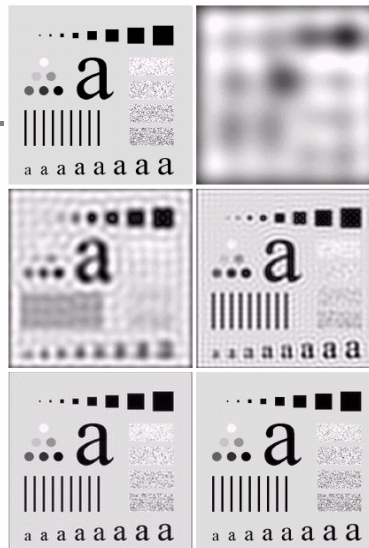


FIGURE 4.12 (a) Original image. (b)–(f) Results of ideal lowpass filtering with cutoff frequencies set at radii values of 5, 15, 30, 80, and 230, as shown in Fig. 4.11(b). The power removed by these filters was 8, 5.4, 3.6, 2, and 0.5% of the total, respectively.

6



Tradeoff between blur and ring

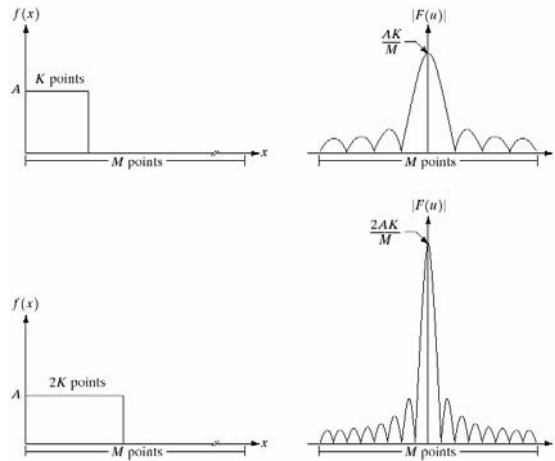


FIGURE 4.2 (a) A discrete function of M points, and (b) its Fourier spectrum. (c) A discrete function with twice the number of nonzero points, and (d) its Fourier spectrum.

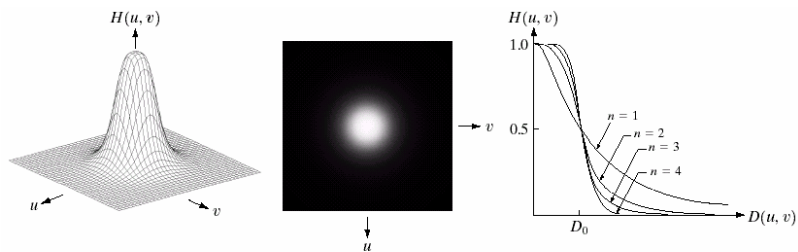
7



Butterworth LPF

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

- D_0 controls the cutoff frequency



a b c

FIGURE 4.14 (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.

8





- Order = 2
- No ringing

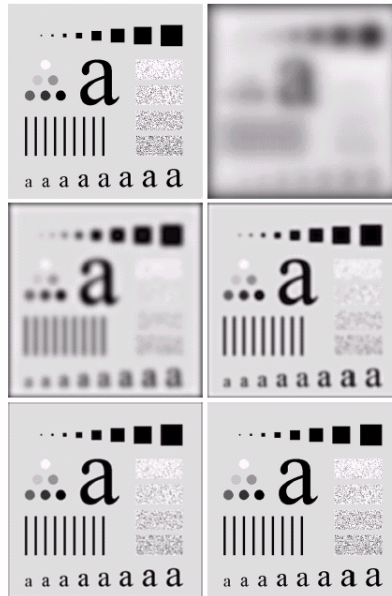


FIGURE 4.15 (a) Original image. (b)–(f) Results of filtering with BLPFs of order 2, with cutoff frequencies at radii of 5, 15, 30, 80, and 230, as shown in Fig. 4.11(b). Compare with Fig. 4.12.



Effect of the order

- When order=20, close to Ideal LPF

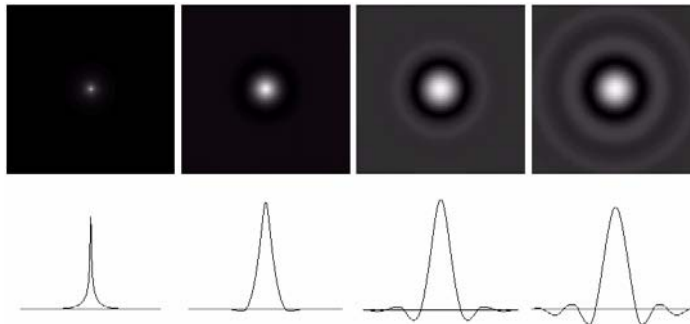
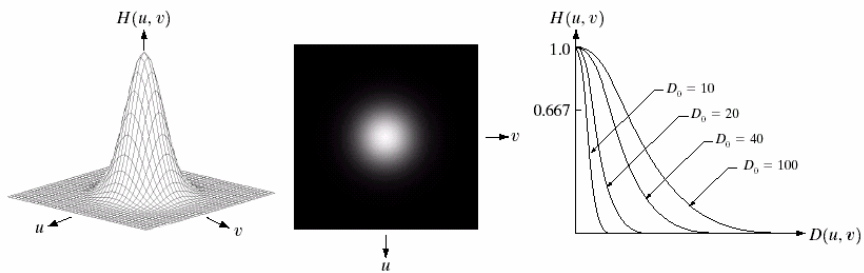


FIGURE 4.16 (a)–(d) Spatial representation of BLPFs of order 1, 2, 5, and 20, and corresponding gray-level profiles through the center of the filters (all filters have a cutoff frequency of 5). Note that ringing increases as a function of filter order.



Gaussian LPF

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



a b c

FIGURE 4.17 (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 → Gaussian
- No ringing effect in spatial domain

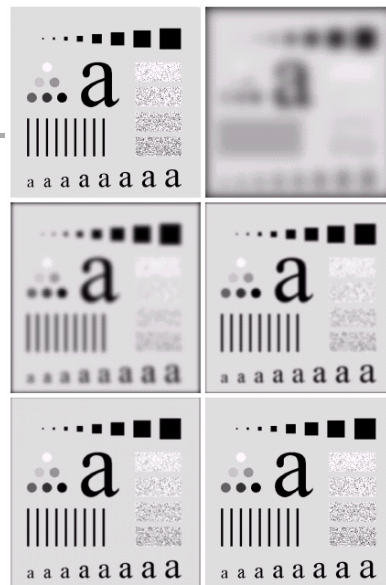


FIGURE 4.18 (a) Original image. (b)-(f) Results of filtering with Gaussian lowpass filters with cutoff frequencies set at radii values of 5, 15, 30, 80, and 230, as shown in Fig. 4.11(b). Compare with Figs. 4.12 and 4.15.

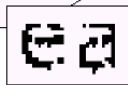
a b
c d
e f

Text Smoothing

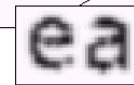
a b

FIGURE 4.19
 (a) Sample text of poor resolution (note broken characters in magnified view).
 (b) Result of filtering with a GLPF (broken character segments were joined).

Historically, certain computer programs were written using only two digits rather than four to define the applicable year. Accordingly, the company's software may recognize a date using "00" as 1900 rather than the year 2000.



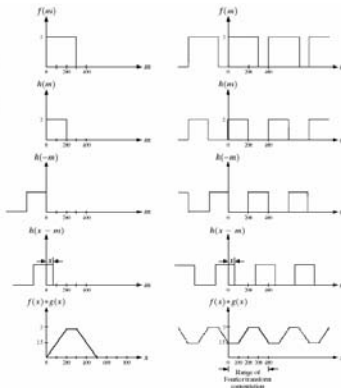
Historically, certain computer programs were written using only two digits rather than four to define the applicable year. Accordingly, the company's software may recognize a date using "00" as 1900 rather than the year 2000.



Zero padding

U
T
B
E
C
H
Q
I
S
J

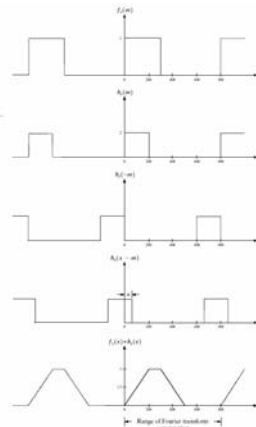
FIGURE 4.16 Left: convolution of two discrete functions. Right: convolution of the same functions, taking into account the implied periodicity of the DFT. Note in (j) how data from adjacent periods corrupt the result of convolution.



■ without padding

U
T
B
E
C
H
Q
I
S
J

FIGURE 4.17 Result of performing convolution with extended functions. Compare Figs. 4.16(a) and 4.16(c).



- with padding
- Extended size = $A+B-1$

Example of padding

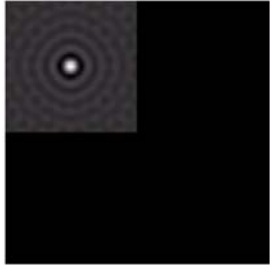


FIGURE 4.39 Padded lowpass filter in the spatial domain (only the real part is shown).

- Note origin shifting

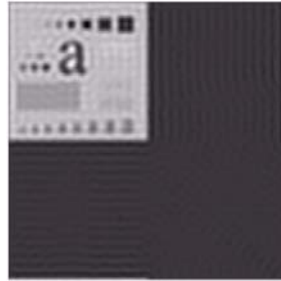


FIGURE 4.40 Result of filtering with padding. The image is usually cropped to its original size since there is little valuable information past the image boundaries.