



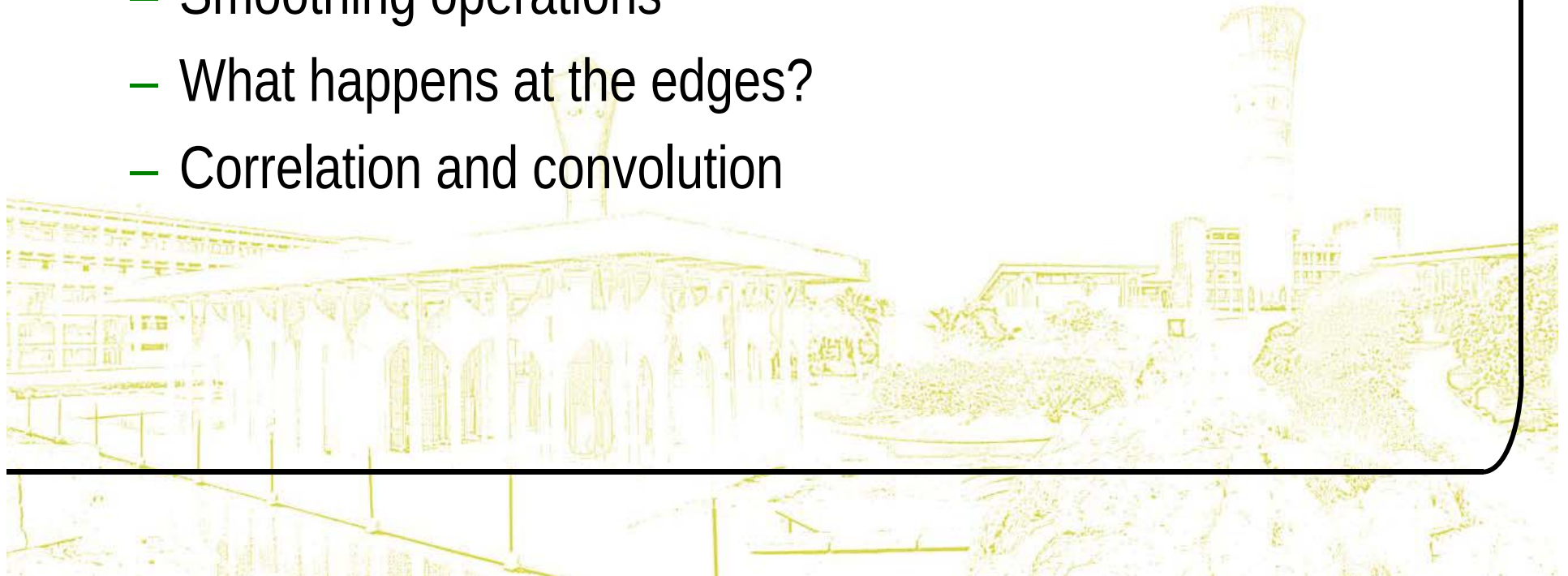
Image Enhancement (Spatial Filtering 1)

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Contents



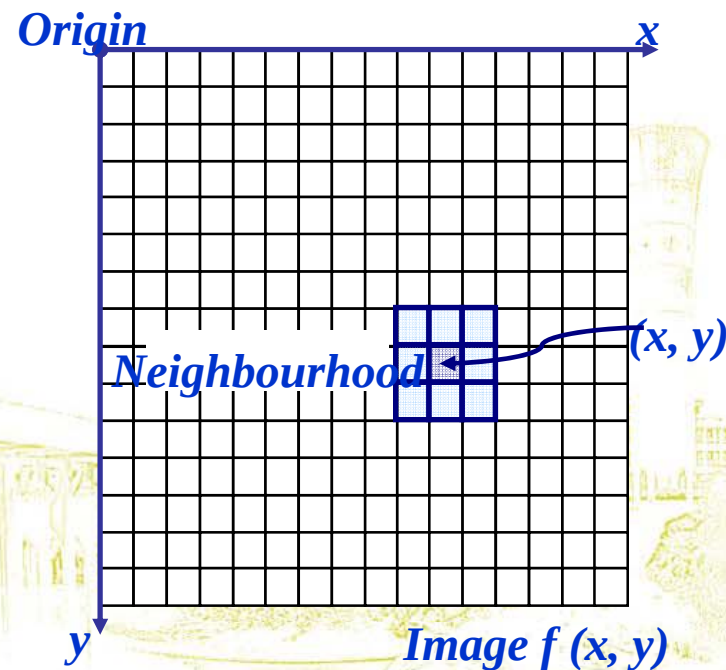
- In this lecture we will look at spatial filtering techniques:
 - Neighbourhood operations
 - What is spatial filtering?
 - Smoothing operations
 - What happens at the edges?
 - Correlation and convolution



Neighbourhood Operations



- Neighbourhood operations simply operate on a larger neighbourhood of pixels than point operations
- Neighbourhoods are mostly a rectangle around a central pixel
- Any size rectangle and any shape filter are possible



Simple Neighbourhood Operations



- Some simple neighbourhood operations include:
 - **Min:** Set the pixel value to the minimum in the neighbourhood
 - **Max:** Set the pixel value to the maximum in the neighbourhood
 - **Median:** The median value of a set of numbers is the midpoint value in that set (e.g. from the set [1, 7, 15, 18, 24] 15 is the median). Sometimes the median works better than the average



Simple Neighbourhood Operations Example

Original Image

123	127	128	119	115	130	• • •
140	145	148	153	167	172	
133	154	183	192	194	191	
194	199	207	210	198	195	
164	170	175	162	173	151	
• • •						

Enhanced Image

						• • •
• • •						

The Spatial Filtering Process



Origin

x

y

Simple 3*3
Neighbourhood

Image $f(x, y)$

3*3 Filter

a	b	c
d	e	f
g	h	i

Original Image
Pixels

r	s	t
u	v	w
x	y	z

Filter

$$e_{processed} = v * e + r * a + s * b + t * c + u * d + w * f + x * g + y * h + z * i$$

The above is repeated for every pixel in the original image to generate the filtered image

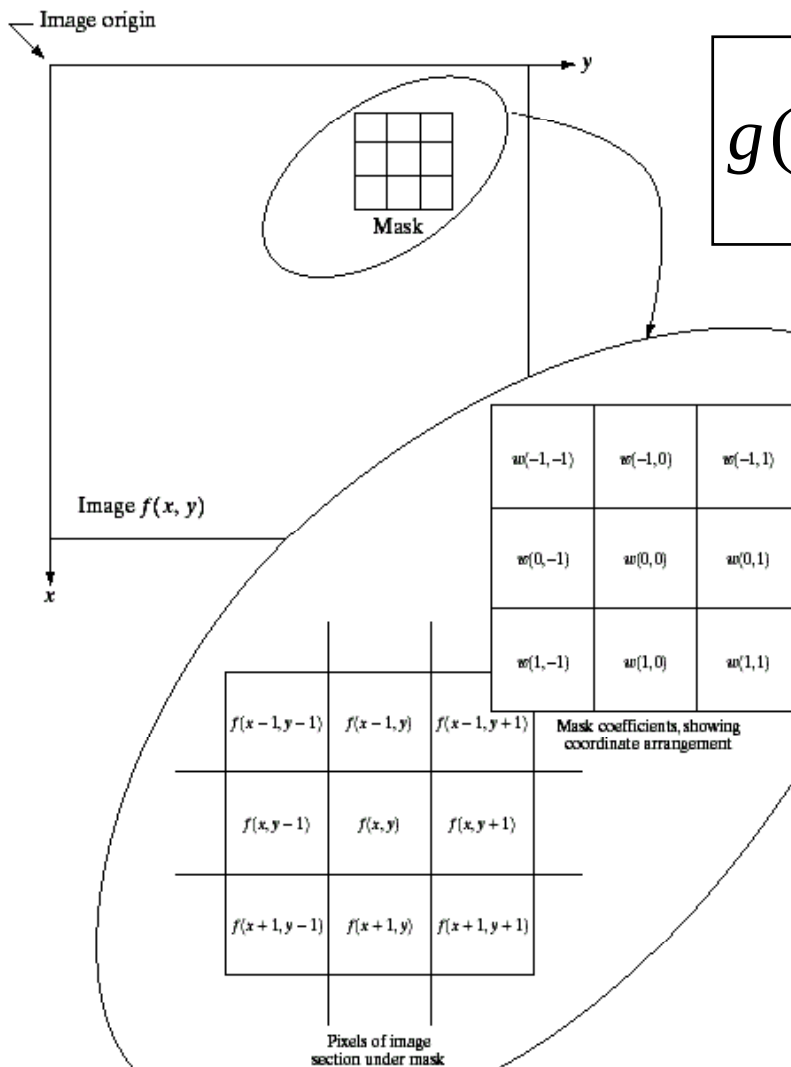
Spatial Filtering: Equation Form



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

Filtering can be given in equation form as shown above

Notations are based on the image shown to the left





Smoothing Spatial Filters

- One of the simplest spatial filtering operations we can perform is a smoothing operation
 - Simply average all of the pixels in a neighbourhood around a central value
 - Especially useful in removing noise from images
 - Also useful for highlighting gross detail

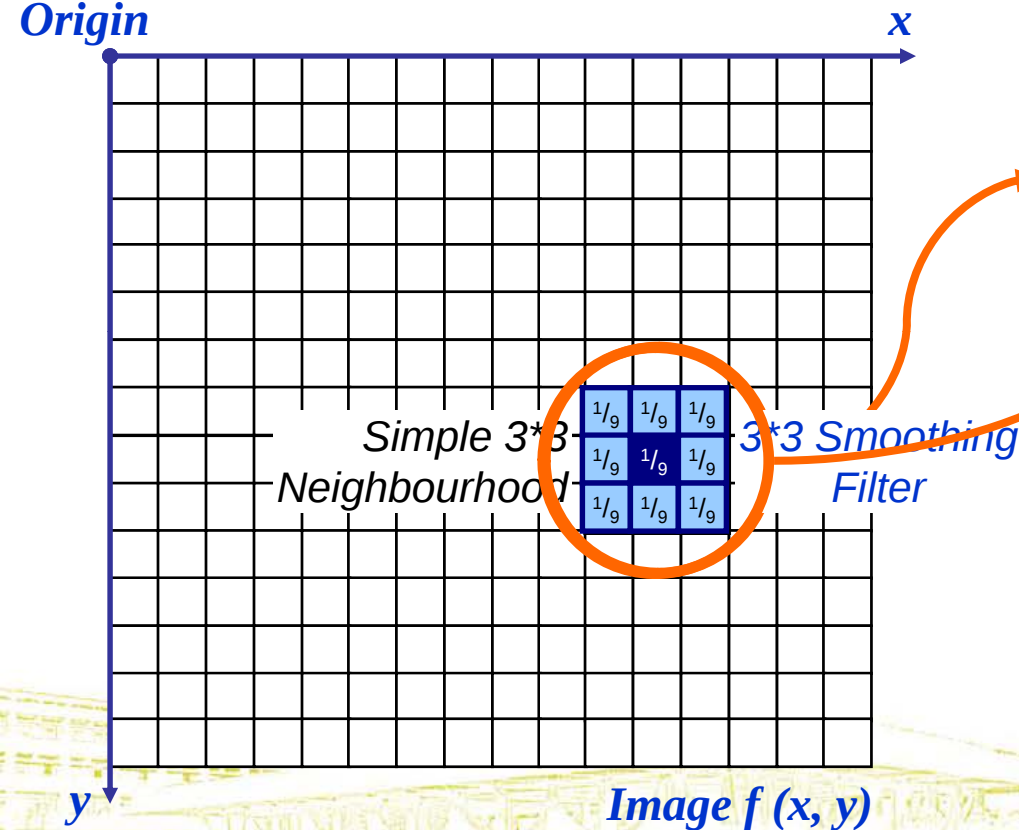
$1/9$	$1/9$	$1/9$
$1/9$	$1/9$	$1/9$
$1/9$	$1/9$	$1/9$

Simple
averaging
filter

Smoothing Spatial Filtering



Origin



104	100	108
99	106	98
95	90	85

Original Image
Pixels

$1/9$	$1/9$	$1/9$
$1/9$	$1/9$	$1/9$
$1/9$	$1/9$	$1/9$

Filter

$$\begin{aligned}
 e &= \frac{1}{9} * 106 + \\
 &\frac{1}{9} * 104 + \frac{1}{9} * 100 + \frac{1}{9} * 108 + \\
 &\frac{1}{9} * 99 + \frac{1}{9} * 98 + \\
 &\frac{1}{9} * 95 + \frac{1}{9} * 90 + \frac{1}{9} * 85 \\
 &= 98.3333
 \end{aligned}$$

The above is repeated for every pixel in the original image to generate the smoothed image

Image Smoothing Example



- The image at the top left is an original image of size 500*500 pixels
- The subsequent images show the image after filtering with an averaging filter of increasing sizes
 - 3, 5, 9, 15 and 35
- Notice how detail begins to disappear

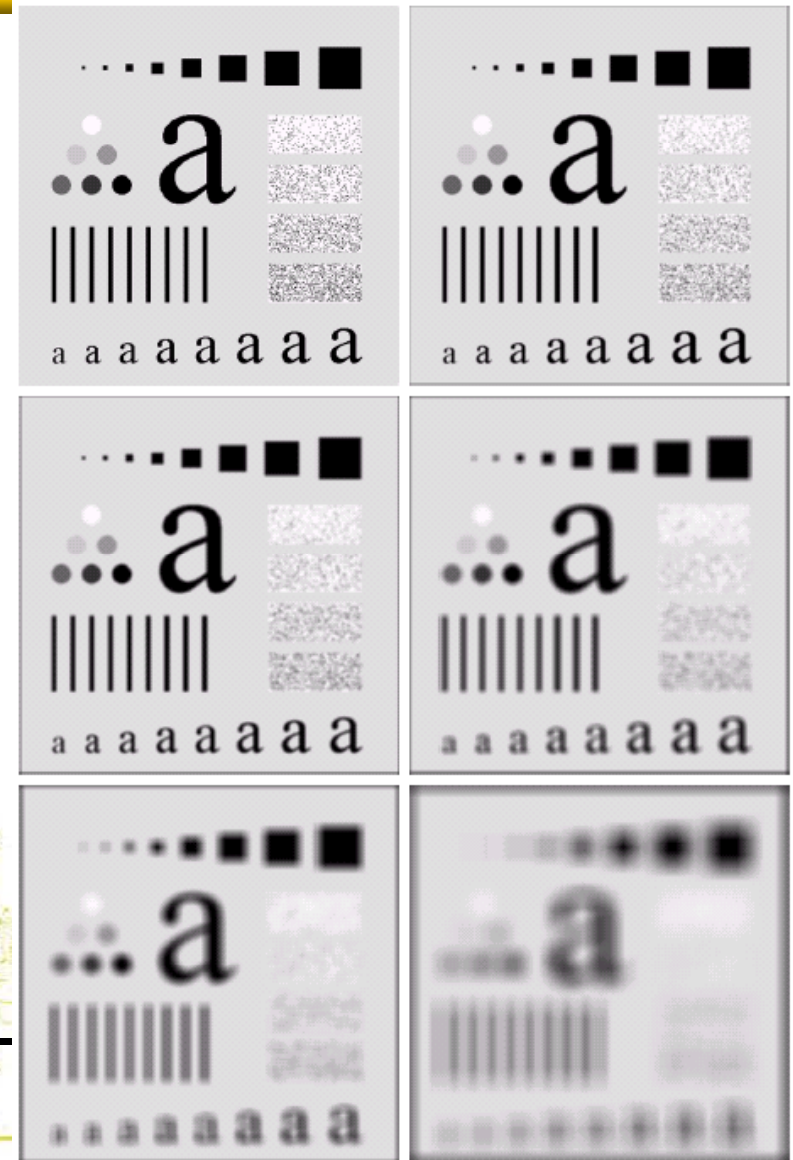


Image Smoothing Example

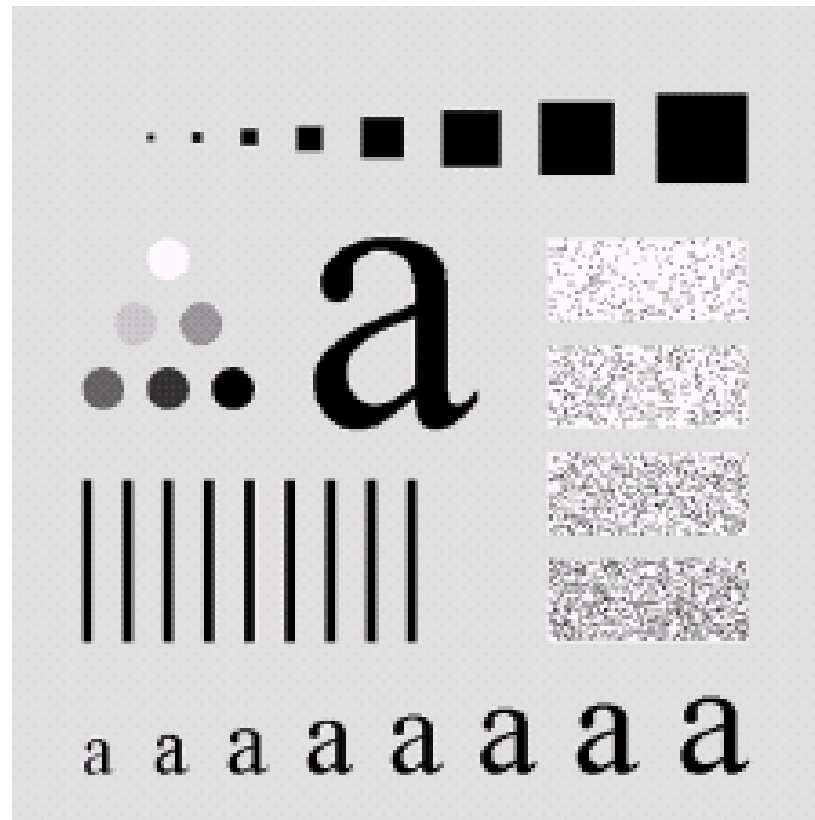


Image Smoothing Example

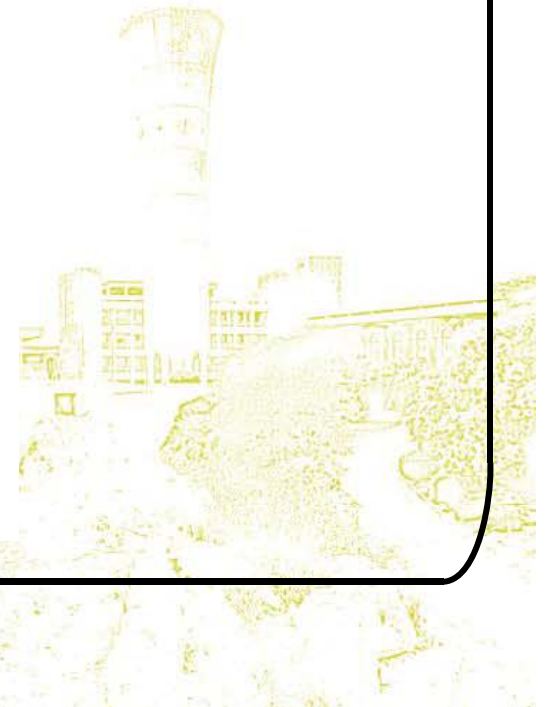
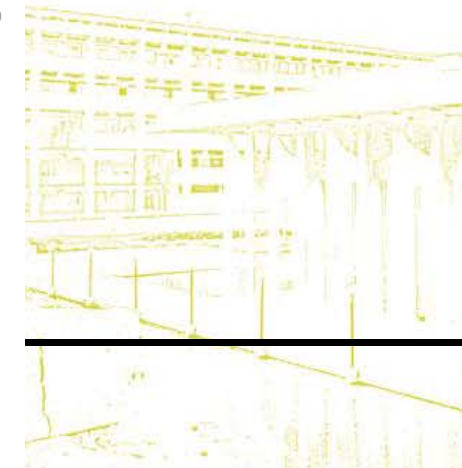
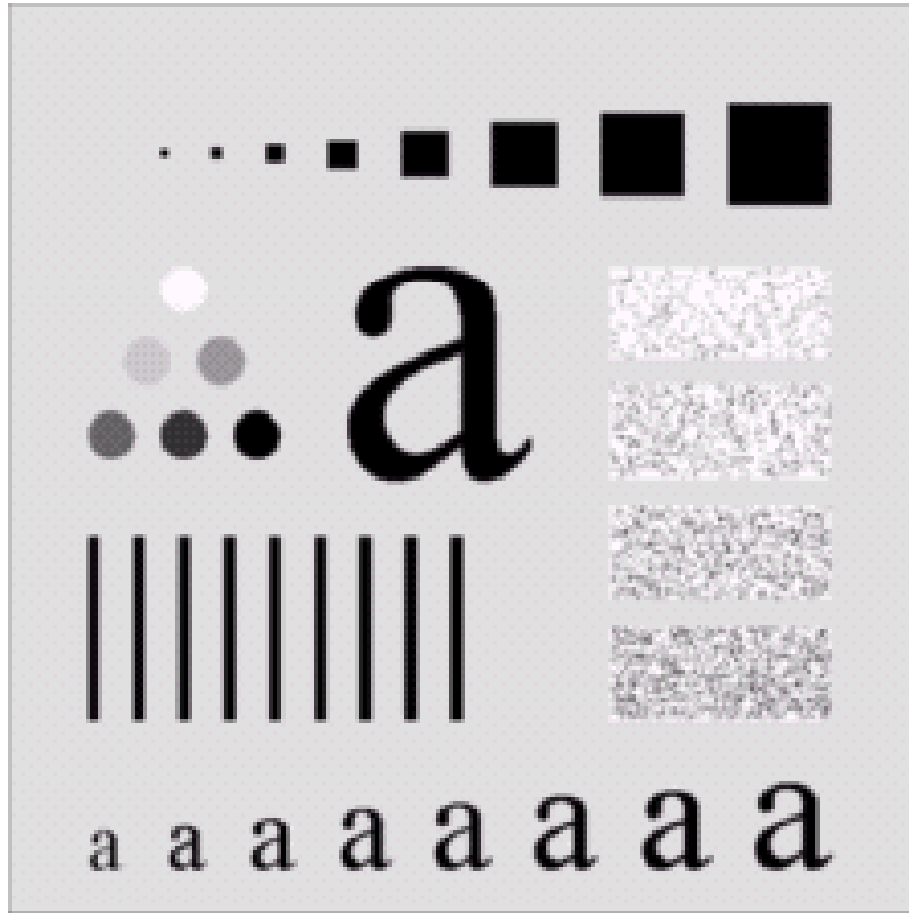


Image Smoothing Example

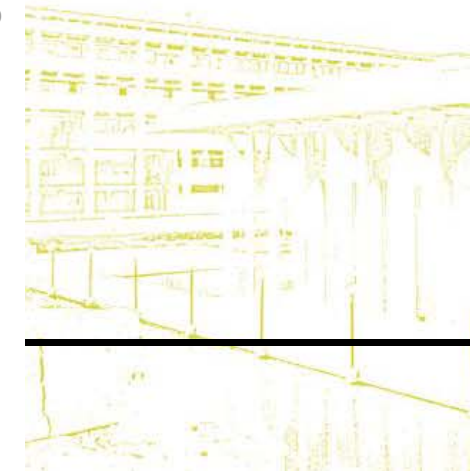
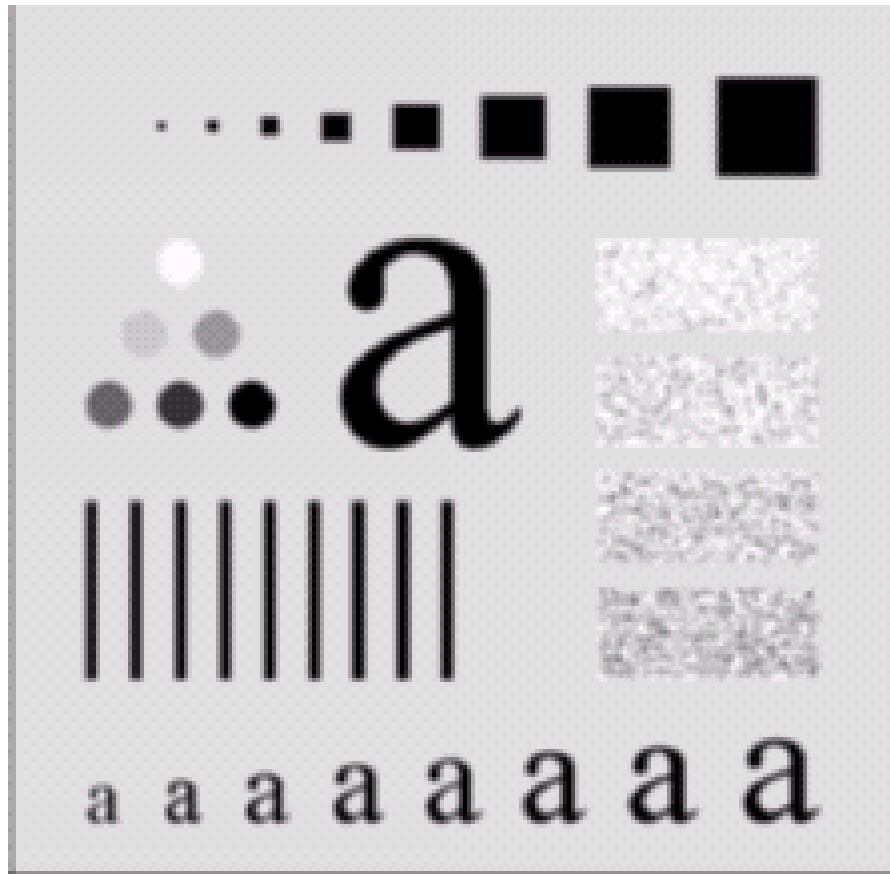


Image Smoothing Example

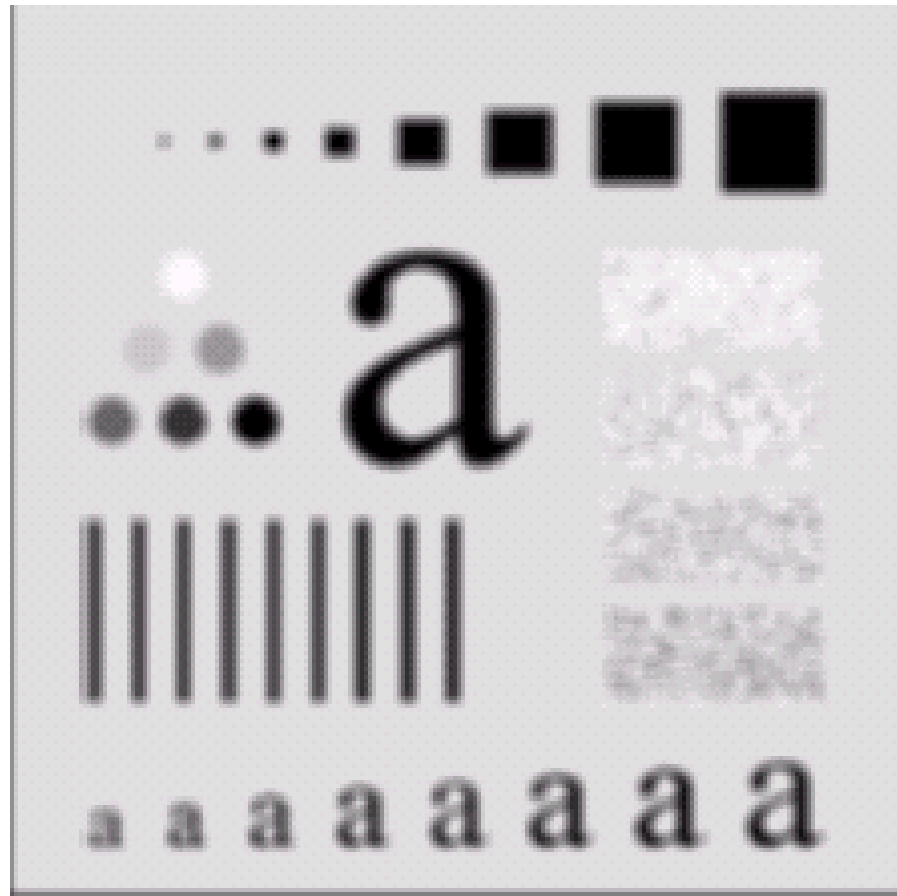


Image Smoothing Example

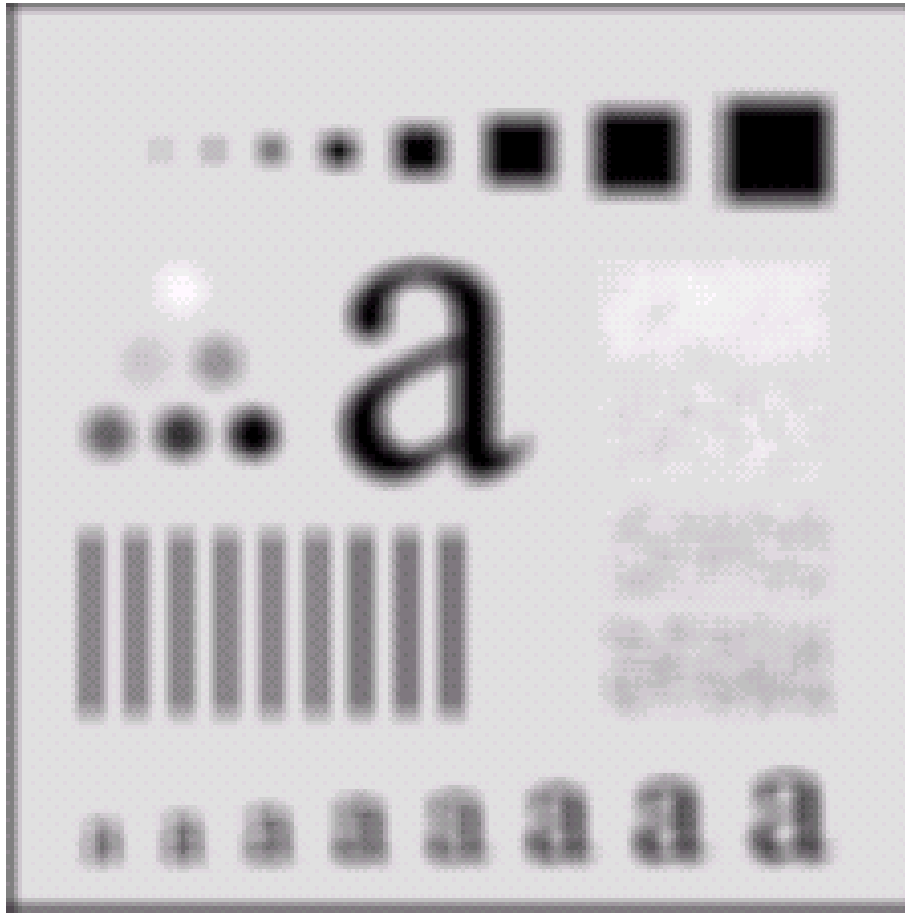
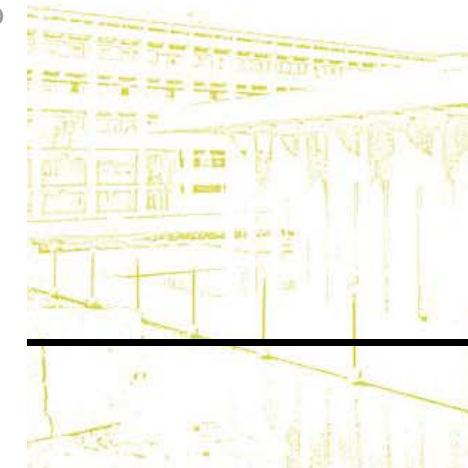
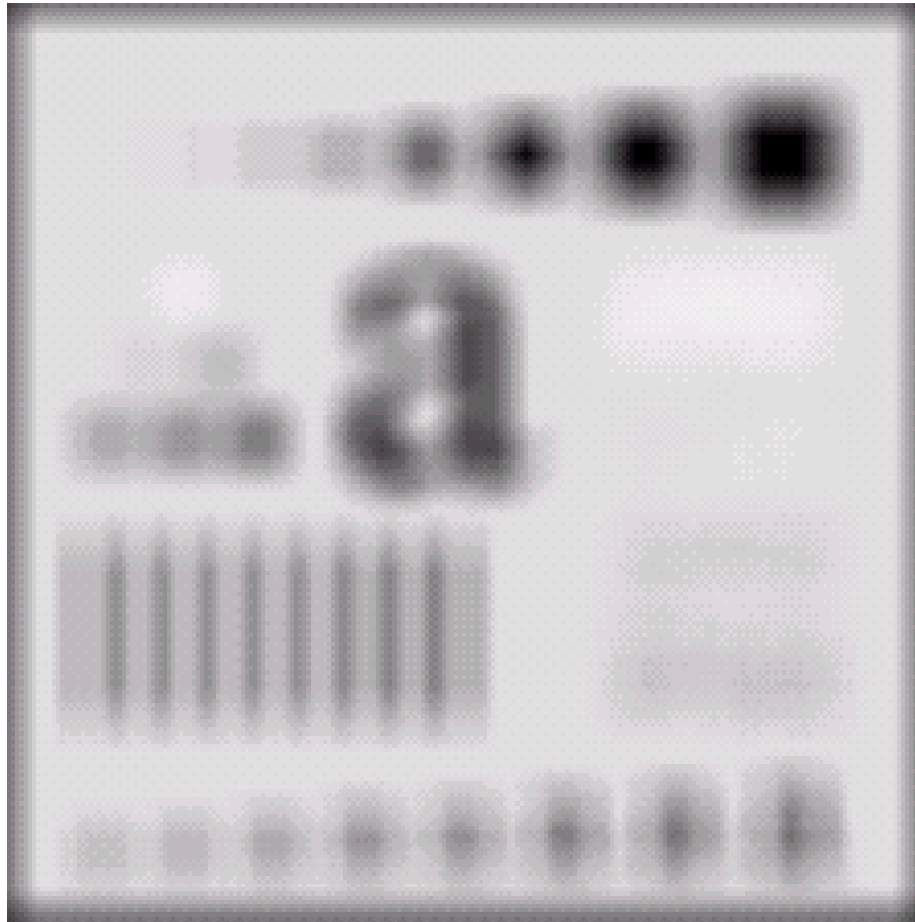


Image Smoothing Example



Weighted Smoothing Filters



- More effective smoothing filters can be generated by allowing different pixels in the neighbourhood different weights in the averaging function

- Pixels closer to the central pixel are more important
- Often referred to as a *weighted averaging*

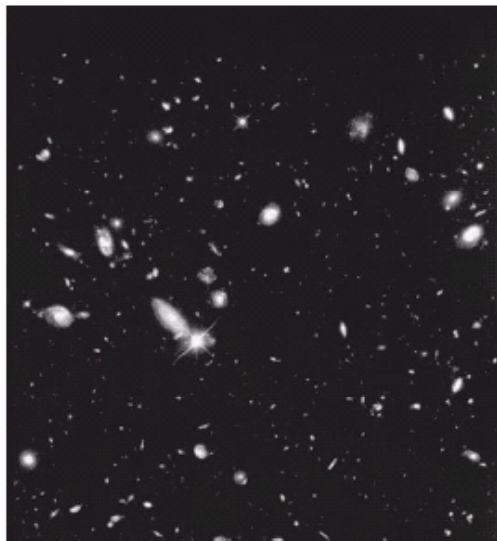
$\frac{1}{16}$	$\frac{2}{16}$	$\frac{1}{16}$
$\frac{2}{16}$	$\frac{4}{16}$	$\frac{2}{16}$
$\frac{1}{16}$	$\frac{2}{16}$	$\frac{1}{16}$

Weighted
averaging filter

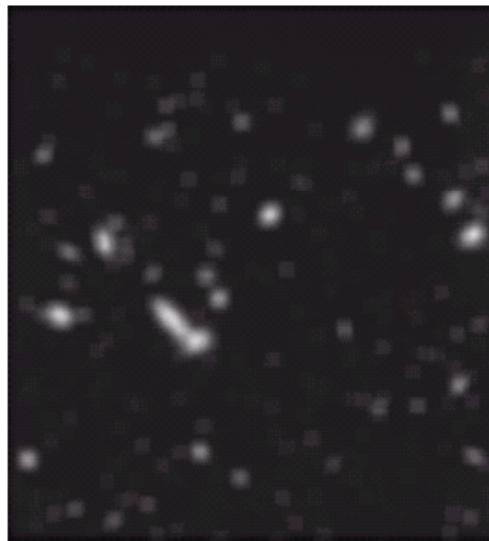
Another Smoothing Example



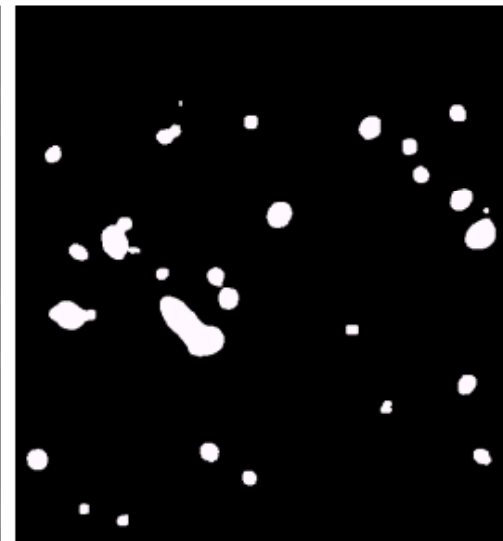
- By smoothing the original image we get rid of lots of the finer detail which leaves only the gross features for thresholding



Original Image

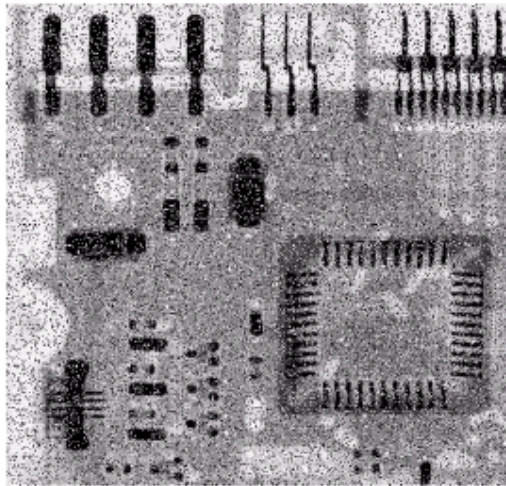


Smoothed Image

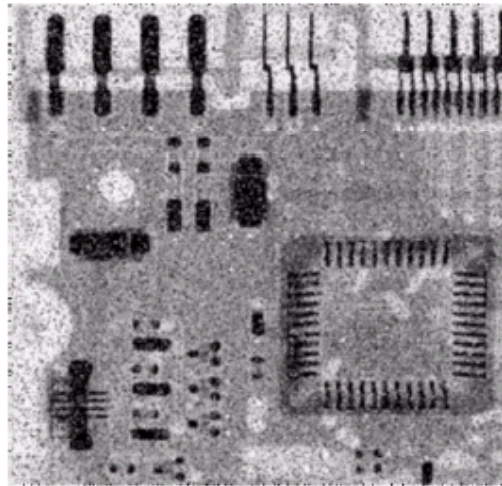


Thresholded Image

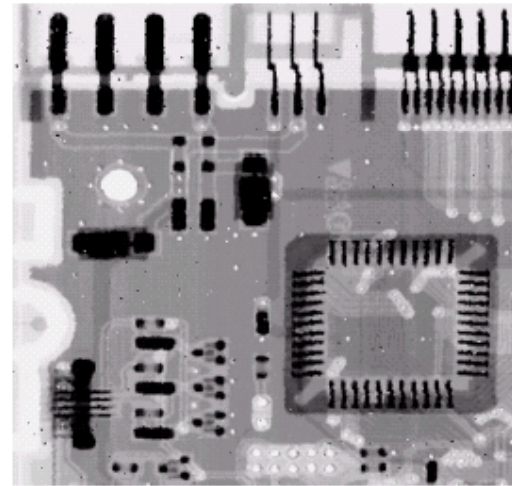
Averaging Filter Vs. Median Filter Example



**Original Image
With Noise**



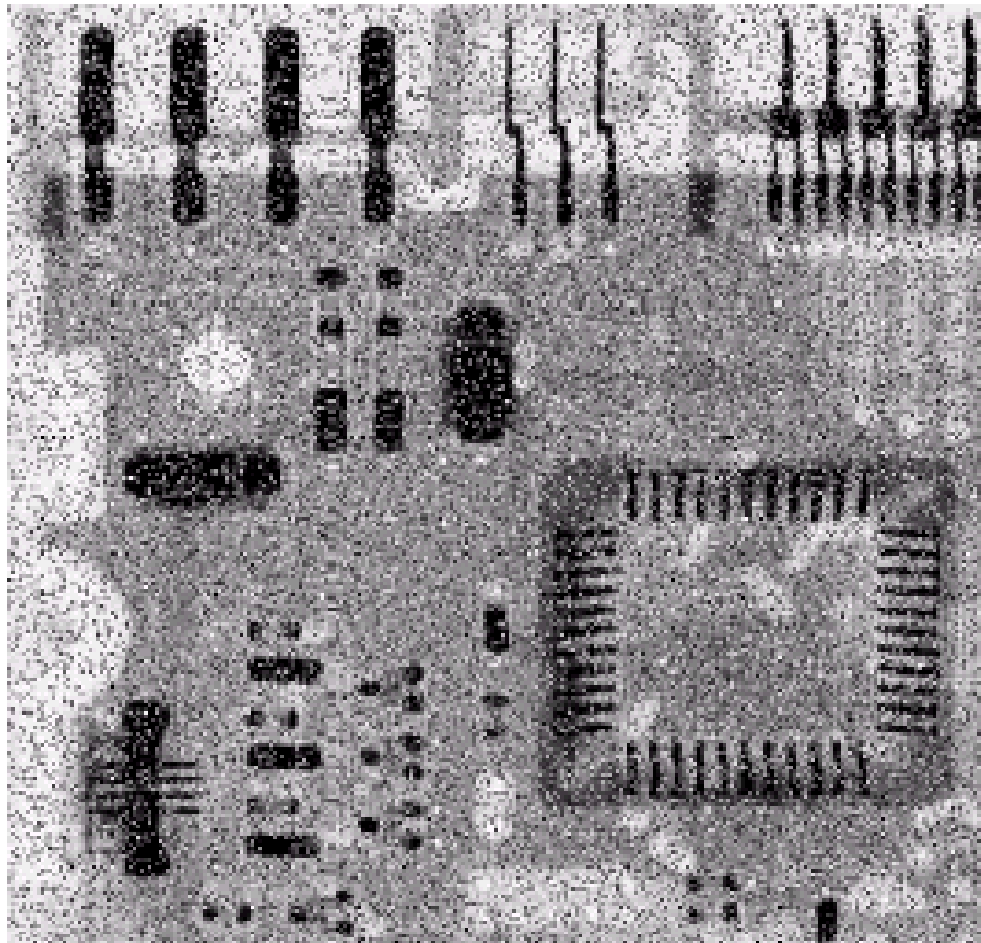
**Image After
Averaging Filter**



**Image After
Median Filter**

- Filtering is often used to remove noise from images
- Sometimes a median filter works better than an averaging filter

Averaging Filter Vs. Median Filter Example

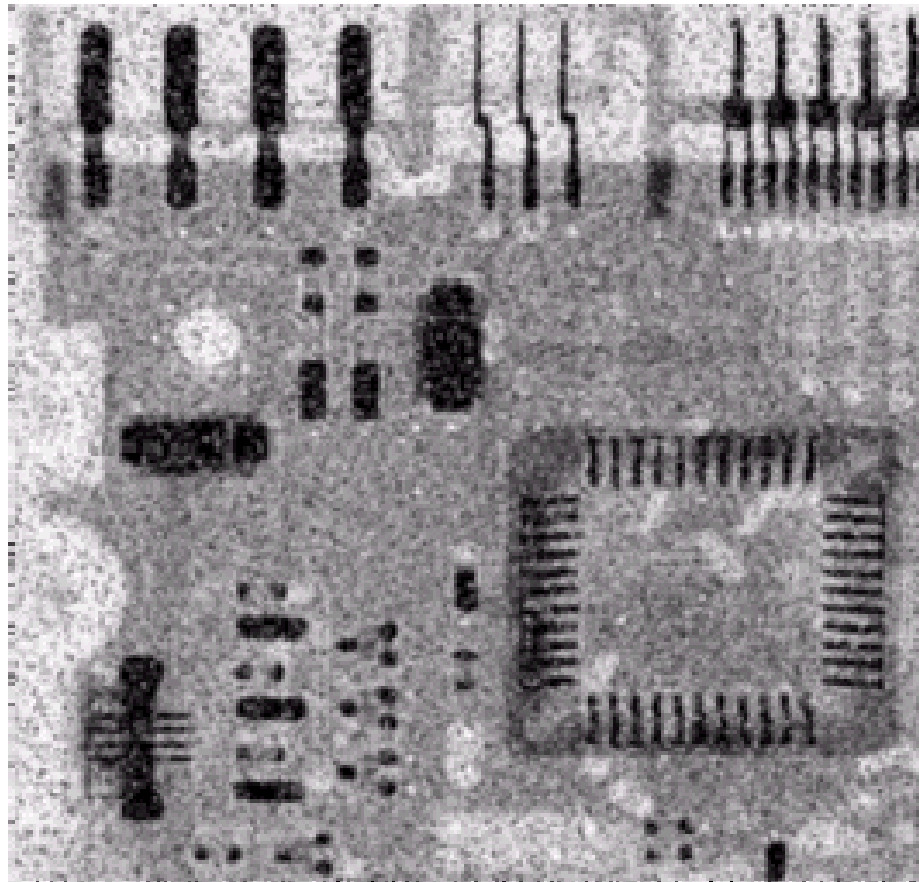


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Averaging Filter Vs. Median Filter Example

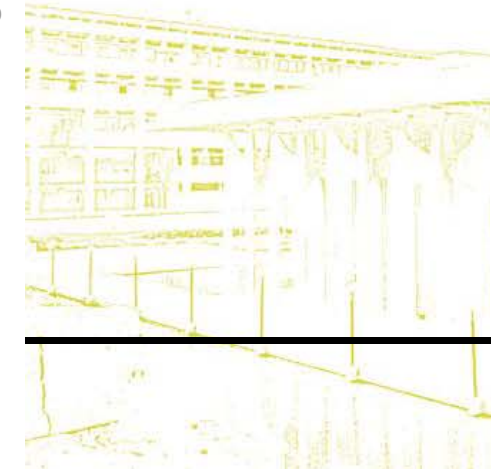
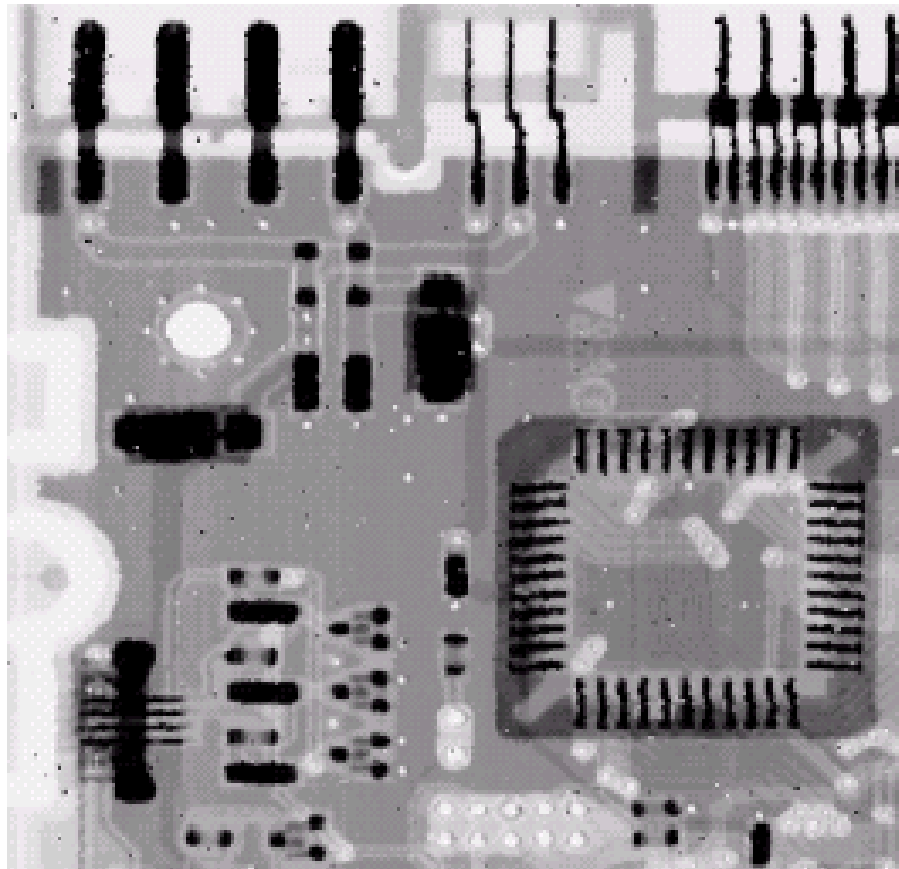


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Averaging Filter Vs. Median Filter Example



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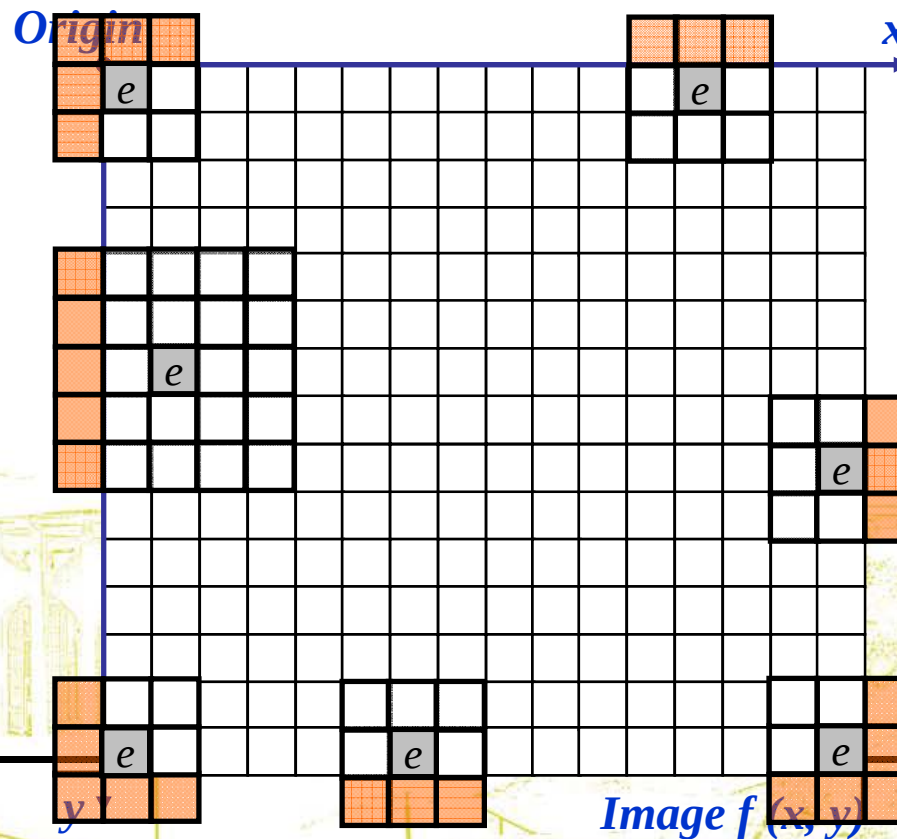
Simple Neighbourhood Operations Example

123	127	128	119	115	130	
140	145	148	153	167	172	
133	154	183	192	194	191	...
194	199	207	210	198	195	
164	170	175	162	173	151	

Strange Things Happen At The Edges!



At the edges of an image we are missing pixels to form a neighbourhood



Strange Things Happen At The Edges! (cont...)



- There are a few approaches to dealing with missing edge pixels:
 - Omit missing pixels
 - Only works with some filters
 - Can add extra code and slow down processing
 - Pad the image
 - Typically with either all white or all black pixels
 - Replicate border pixels
 - Truncate the image
 - Allow pixels *wrap around* the image
 - Can cause some strange image artefacts



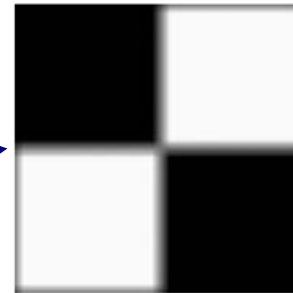
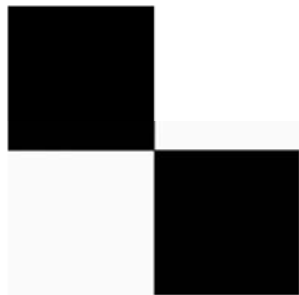
Simple Neighbourhood Operations Example

123	127	128	119	115	130	
140	145	148	153	167	172	
133	154	183	192	194	191	...
194	199	207	210	198	195	
164	170	175	162	173	151	
						...

Strange Things Happen At The Edges! (cont.)



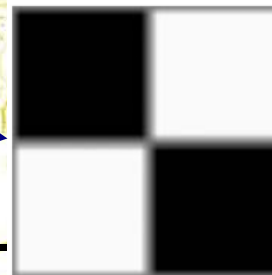
Original
Image



Filtered Image:
Zero Padding

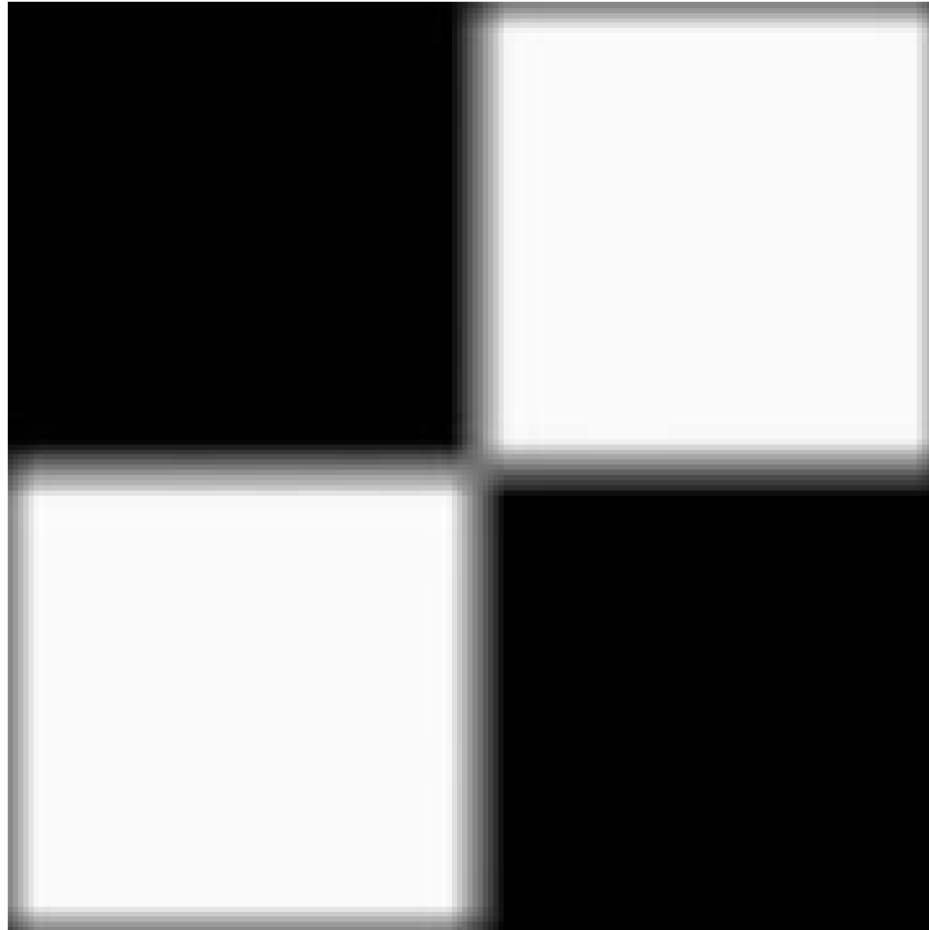


Filtered Image:
Replicate Edge Pixels



Filtered Image:
Wrap Around Edge Pixels

Strange Things Happen At The Edges! (cont.)



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Strange Things Happen At The Edges! (cont.)



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Strange Things Happen At The Edges! (cont.)



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Correlation & Convolution



- The filtering we have been talking about so far is referred to as *correlation* with the filter itself referred to as the *correlation kernel*
- *Convolution* is a similar operation, with just one subtle difference

<i>a</i>	<i>b</i>	<i>c</i>
<i>d</i>	<i>e</i>	<i>e</i>
<i>f</i>	<i>g</i>	<i>h</i>

Original Image
Pixels

$*$

<i>r</i>	<i>s</i>	<i>t</i>
<i>u</i>	<i>v</i>	<i>w</i>
<i>x</i>	<i>y</i>	<i>z</i>

Filter

$$e_{processed} = v * e + \\ z * a + y * b + x * c + \\ w * d + u * e + \\ t * f + s * g + r * h$$

- For symmetric filters it makes no difference

Summary



- In this lecture we have looked at the idea of spatial filtering and in particular:
 - Neighbourhood operations
 - The filtering process
 - Smoothing filters
 - Dealing with problems at image edges when using filtering
 - Correlation and convolution
- Next time we will looking at sharpening filters and more on filtering and image enhancement