



Digital Image Processing

Image Enhancement (Spatial Filtering 1)

By

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In this session we will look at spatial filtering techniques:

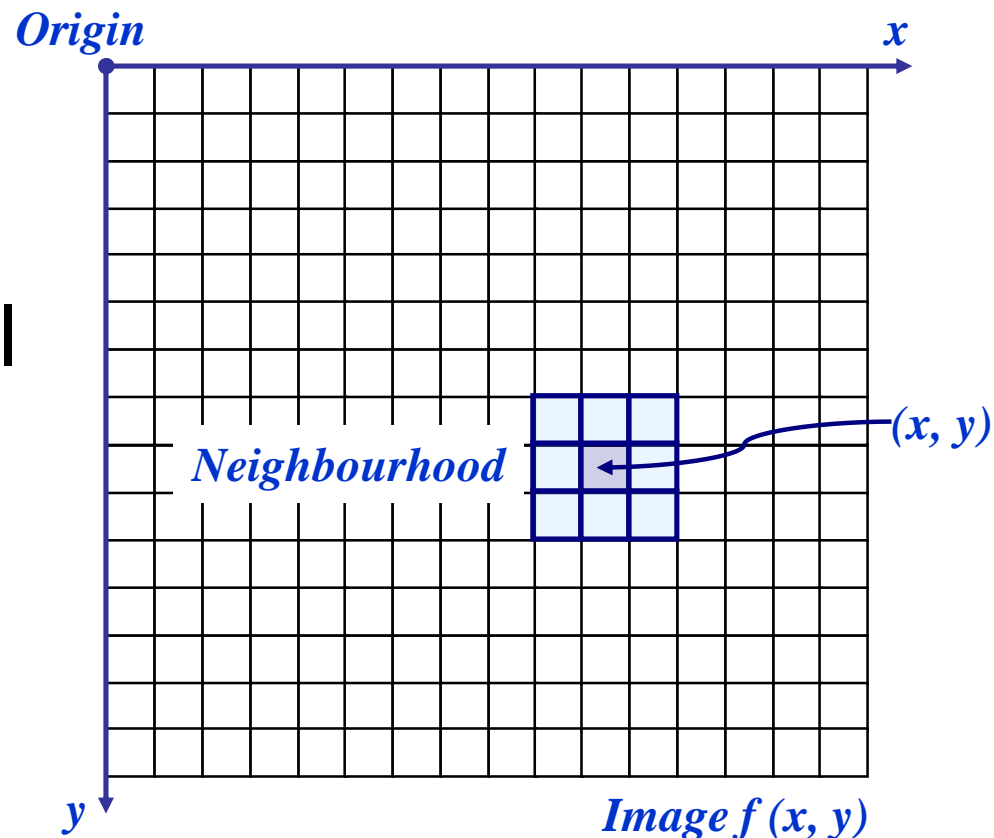
- Neighbourhood operations
- Linear vs Non-Linear Operations
- What is spatial filtering?
- What happens at the edges?
- Smoothing linear operations
- Simple non-linear operations
- Unsharp masking

Neighbourhood Operations

Neighbourhood operations simply **operate on a larger neighbourhood** of pixels than point operations

Neighbourhoods are mostly a rectangle around a central pixel

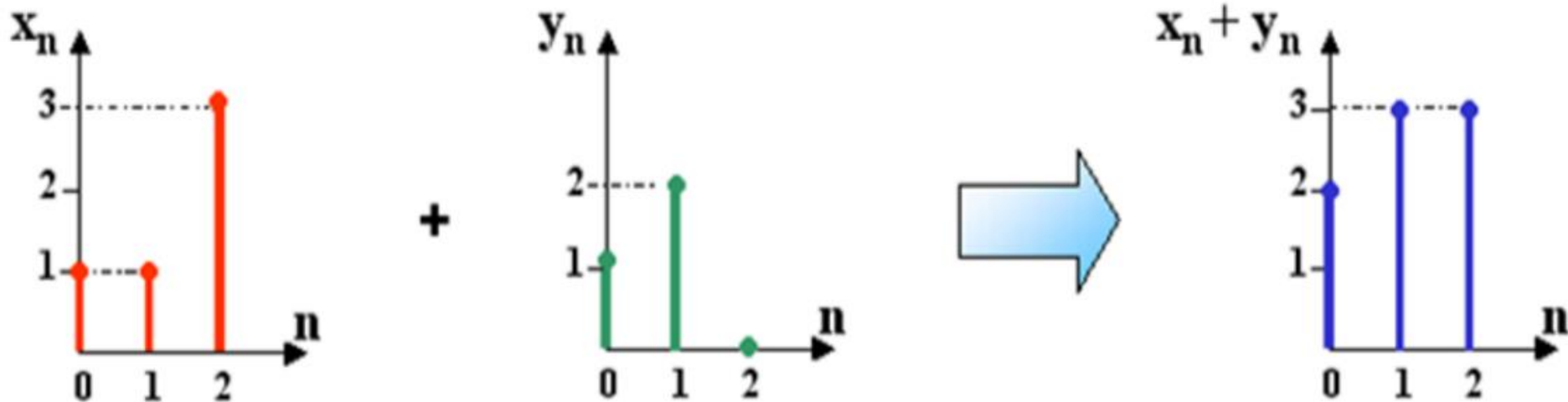
Any size rectangle and any shape filter are possible



Linear vs Non Linear Filters

In mathematics, a linear map or linear function $f(x)$ is a function that satisfies the following two properties:

- **Additivity:** $f(x + y) = f(x) + f(y)$.
- **Homogeneity of degree 1:** $f(\alpha x) = \alpha f(x)$ for all α .



1. $\text{mean}(X_n) + \text{mean}(Y_n) = \text{mean}(X_n + Y_n)$
 $8/3 = 1 + 5/3$ **which is OK, so mean is linear function.**
2. $\text{median}(X_n) + \text{median}(Y_n) = \text{median}(X_n + Y_n)$,
 $1 + 1 = 3$ **which is not true, median is non linear.**

Linear vs Non Linear Filters

Knowing which type of filter to select depends on the goals and nature of the image data.

1. In cases where the input data contains a large amount of noise but the magnitude is low, a linear low-pass filter may suffice.
2. Conversely, if an image contains a low amount of noise but with relatively high magnitude, then a non linear (e.g., median filter) may be more appropriate.

Simple Neighbourhood Operations

Example

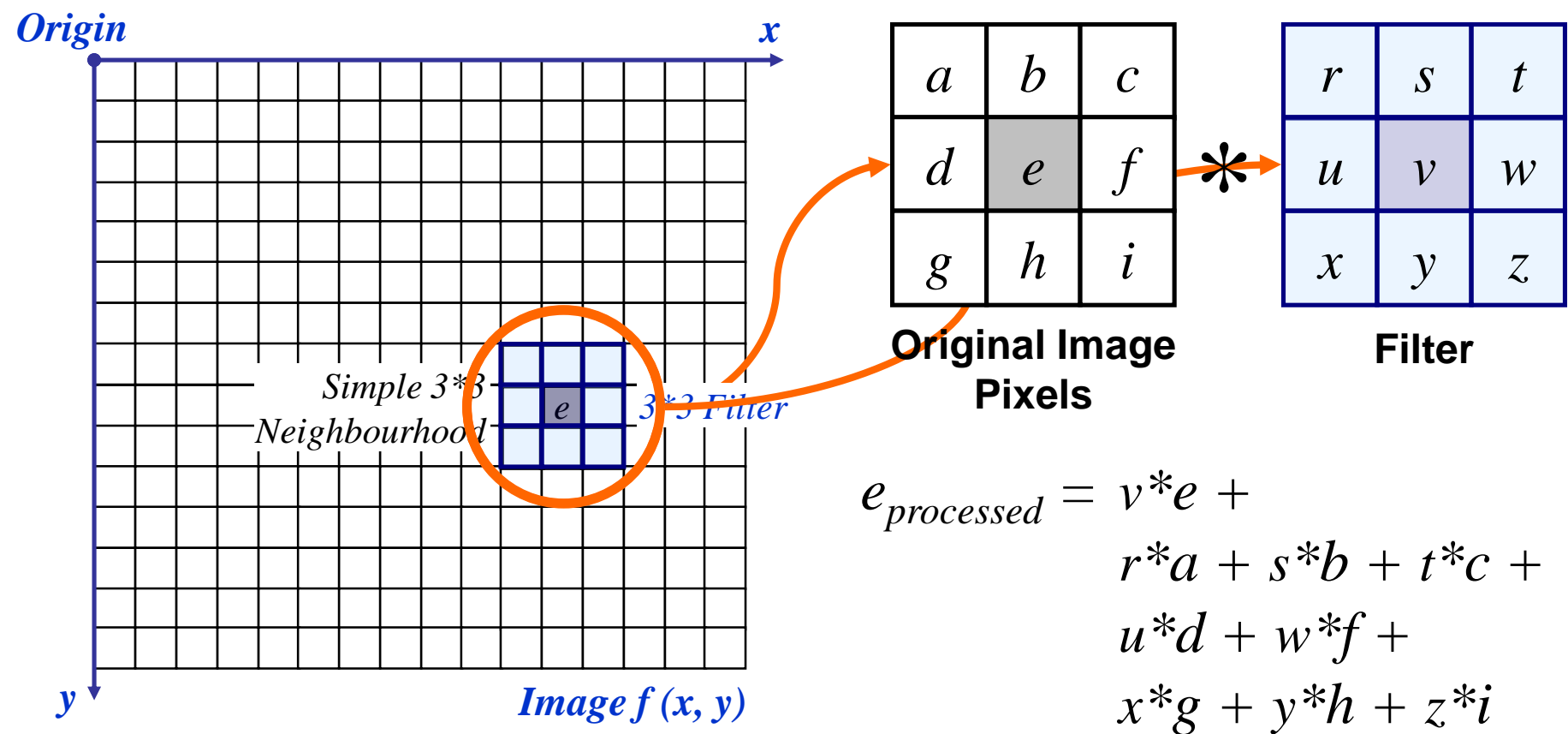
Original Image

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

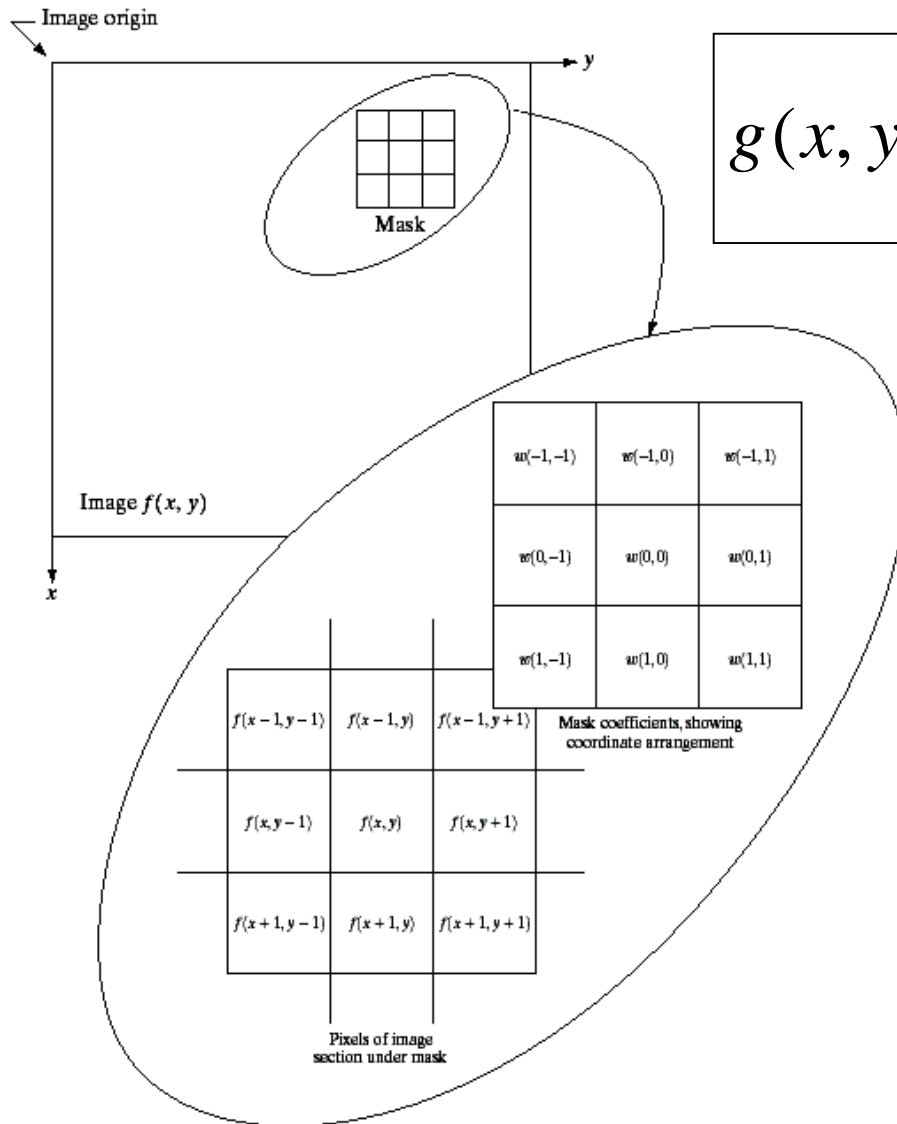
						• • •
• • •						

The Spatial Filtering Process



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

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

a	b	c
d	e	e
f	g	h

Original Image
Pixels

$*$

r	s	t
u	v	w
x	y	z

Filter

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

For symmetric filters it makes no difference

Properties of Convolution

There are a number of important mathematical properties associated with convolution.

1. Convolution is commutative .

$$c = a \otimes b = b \otimes a$$

2. Convolution is associative.

$$c = a \otimes (b \otimes c) = (a \otimes b) \otimes c = a \otimes b \otimes c$$

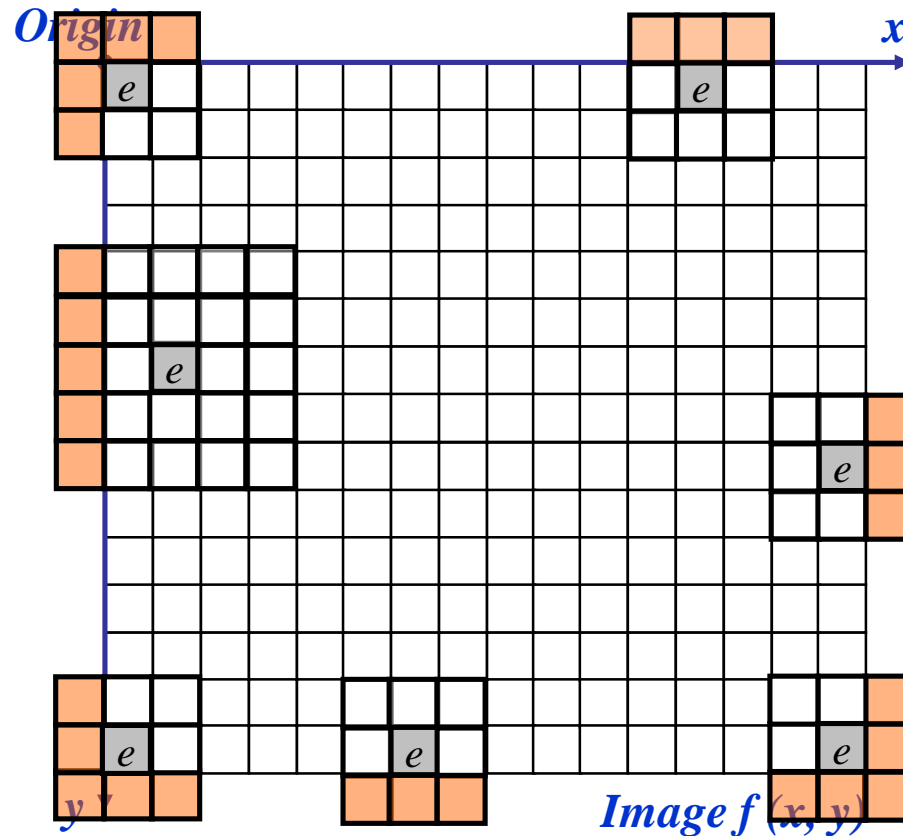
3. Convolution is distributive.

$$c = a \otimes (b + d) = (a \otimes b) + (a \otimes d)$$

where a, b, c, and d are all images, either continuous or discrete.

Strange Things Happen At The Edges!

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

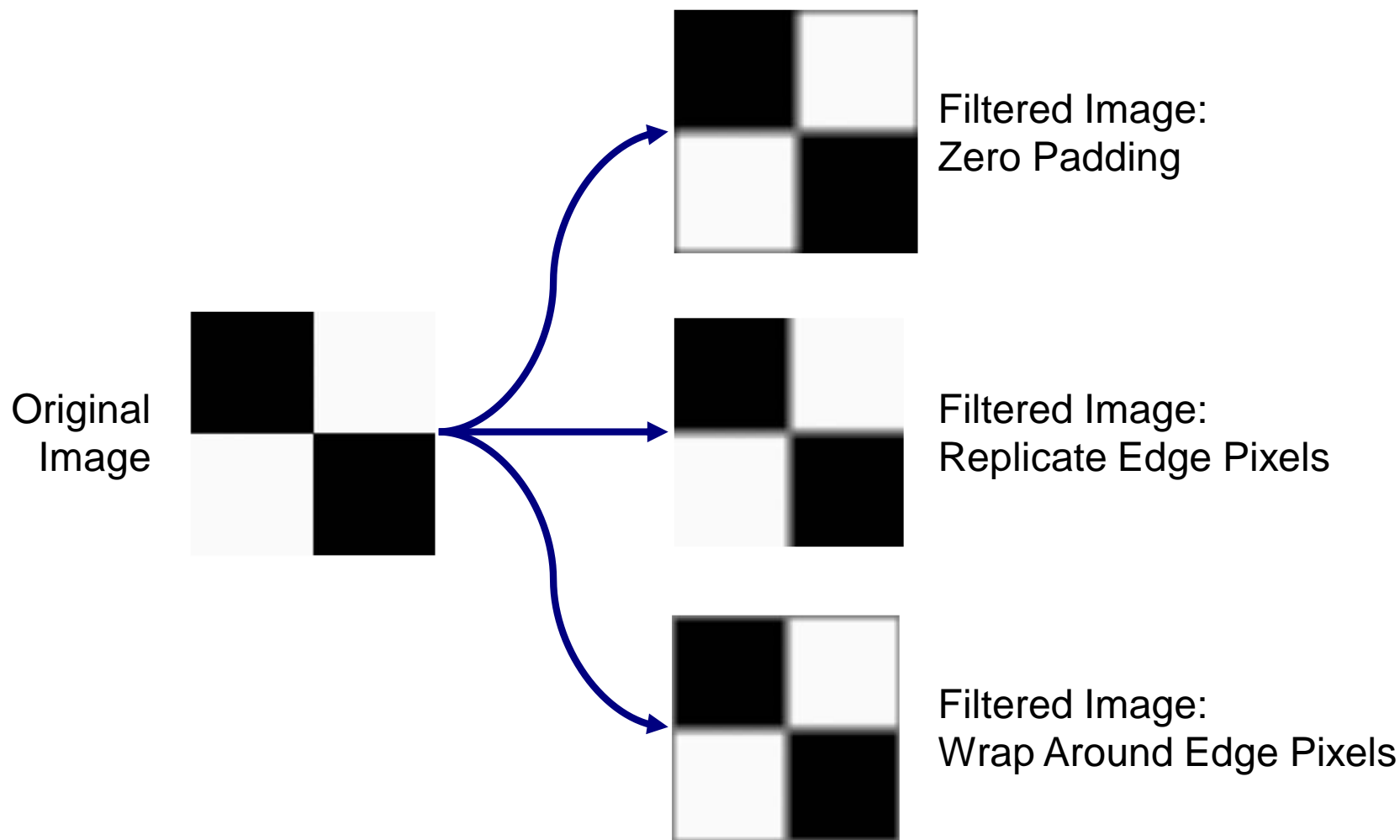


Strange Things Happen At The Edges! (cont...)

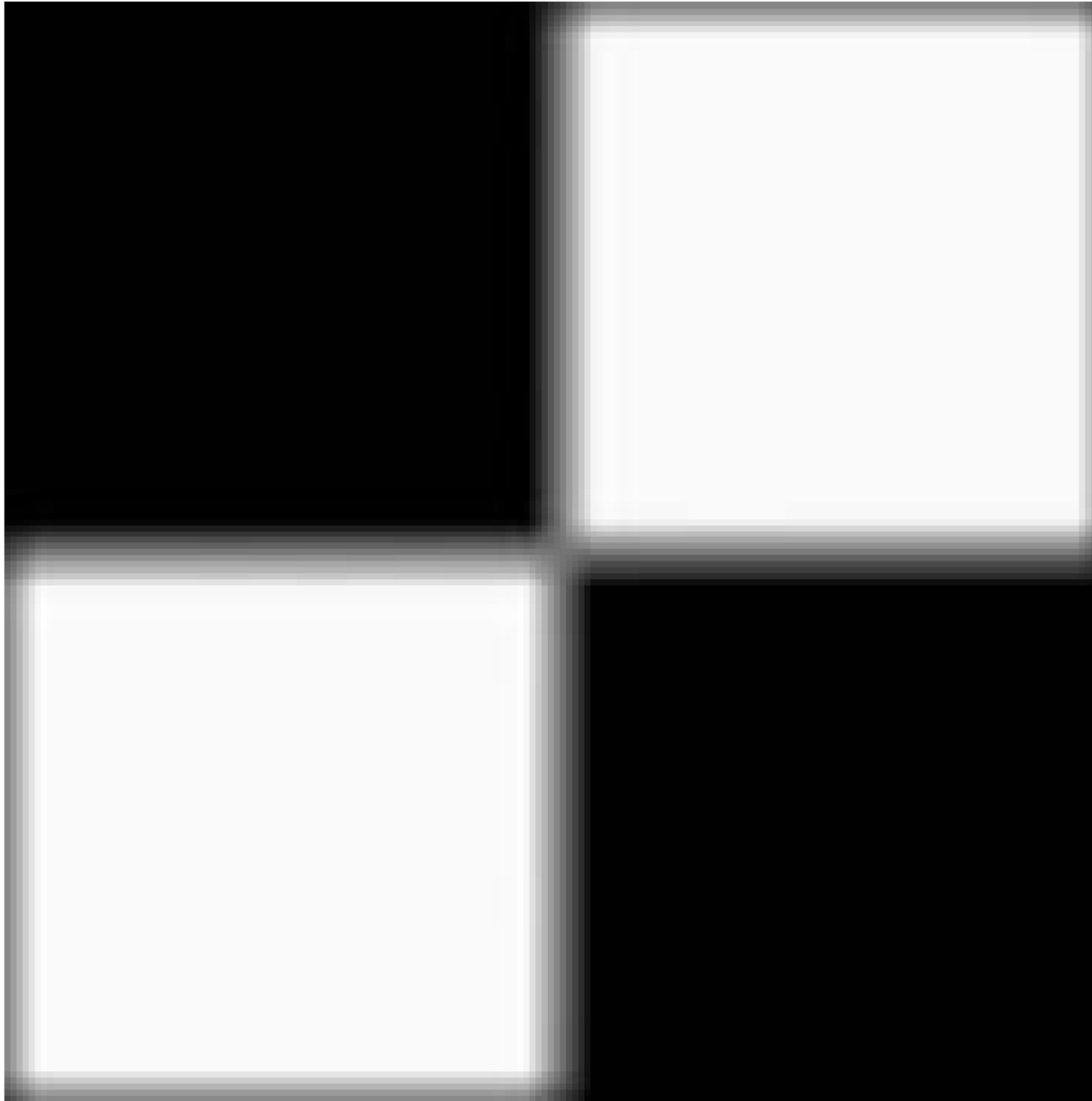
There are a few approaches to dealing with missing edge pixels:

- 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, *only if borders are not important.*
- Allow pixels *wrap around* the image
 - Can cause some strange image artefacts

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

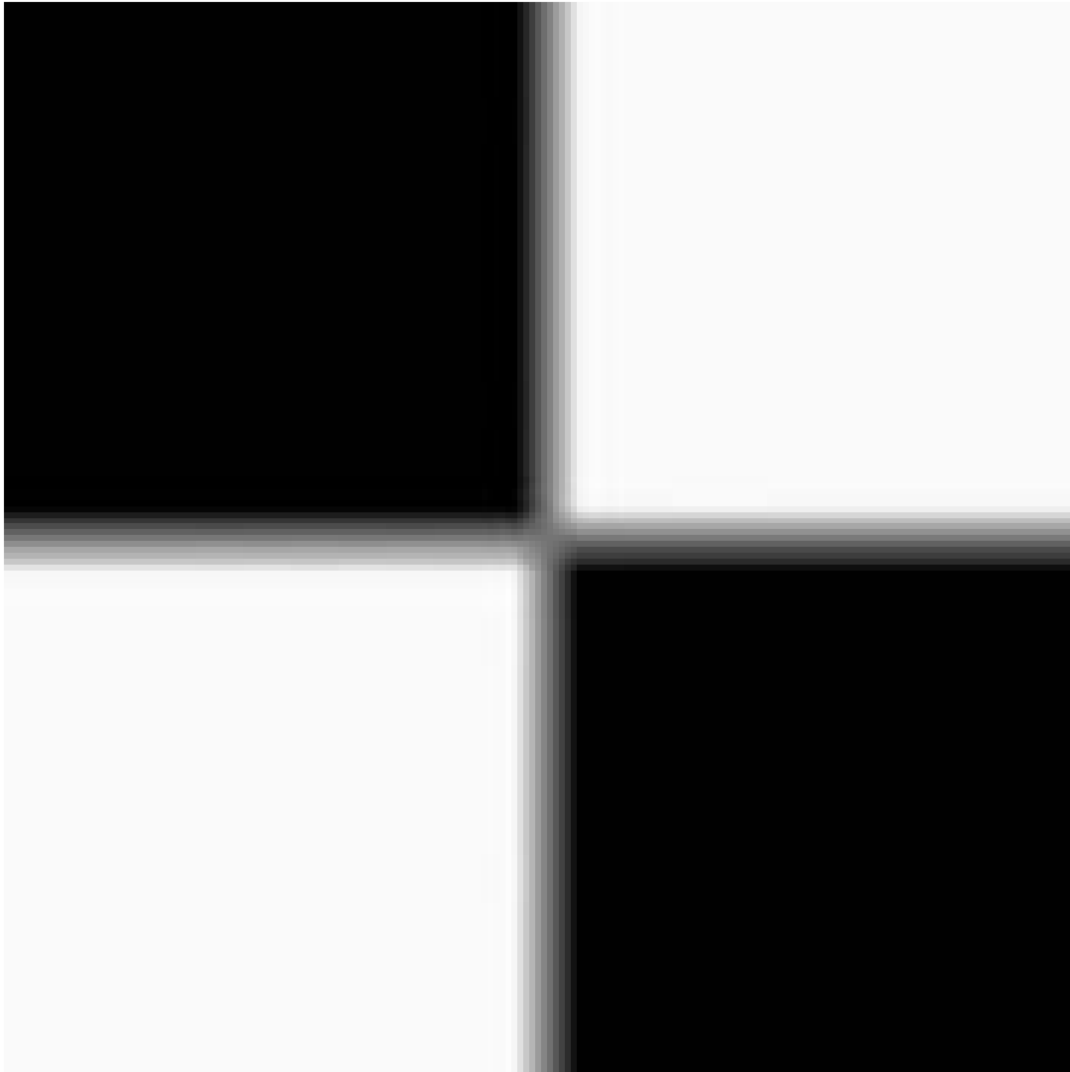


Strange Things Happen At The Edges! (cont...)



Zero Padding

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



**Replicate Edge
Pixels**

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



**Wrap Around
Edge Pixels**

Smoothing Spatial Filters

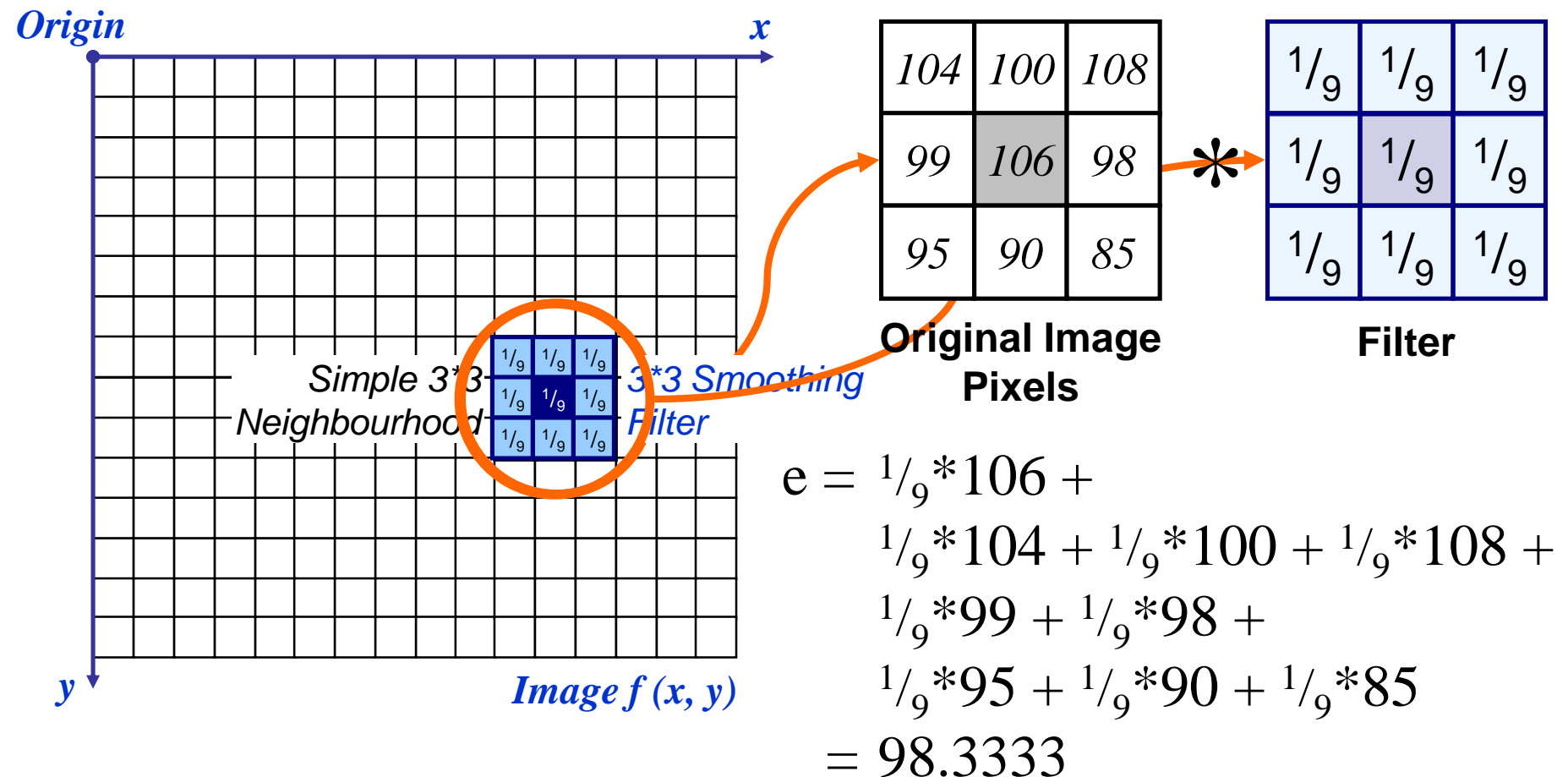
One of the simplest spatial filtering operations we can perform is a smoothing operation

- 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



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

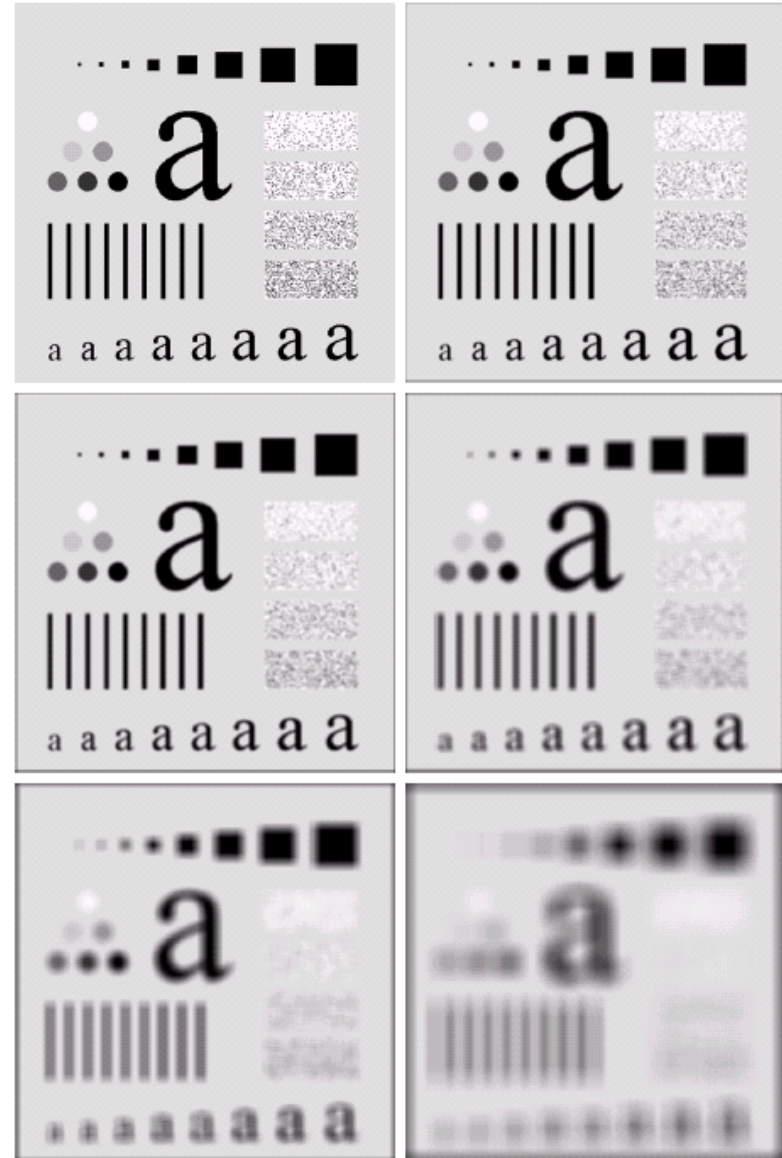


Image Smoothing Example

Original Image

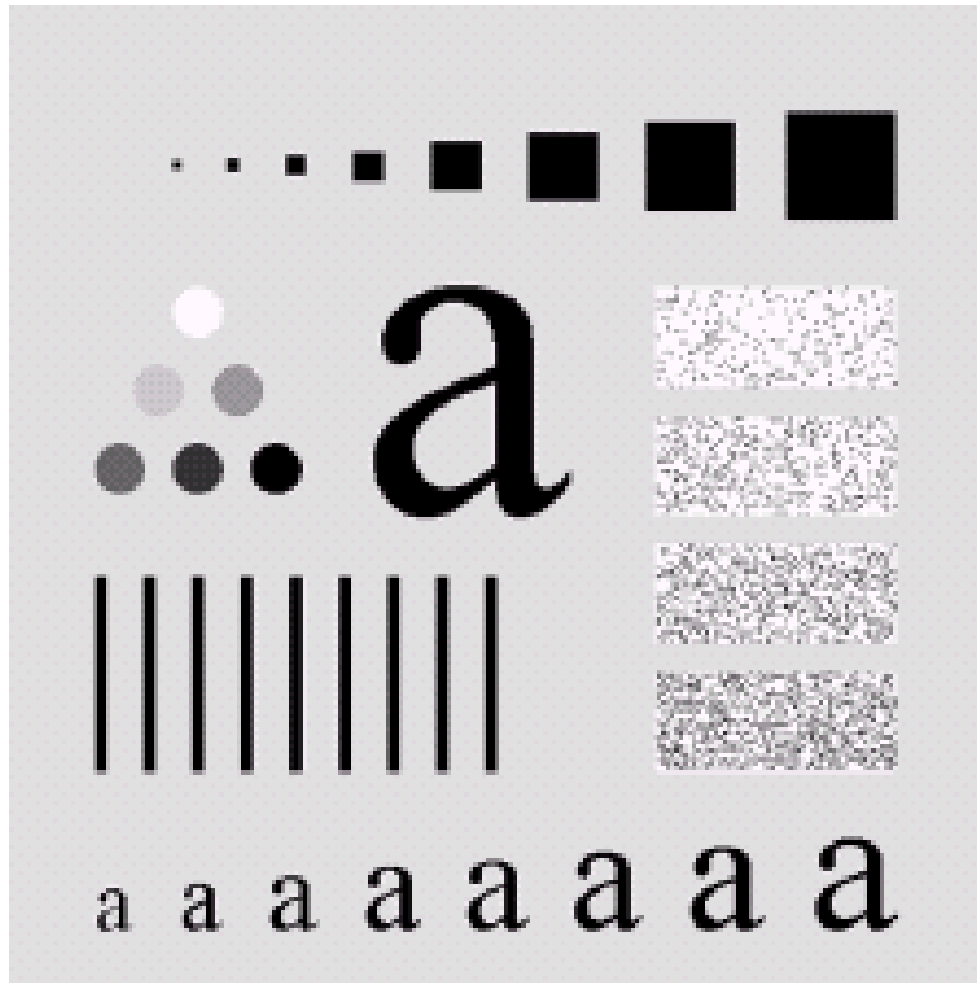


Image Smoothing Example

3x3 Average Filter

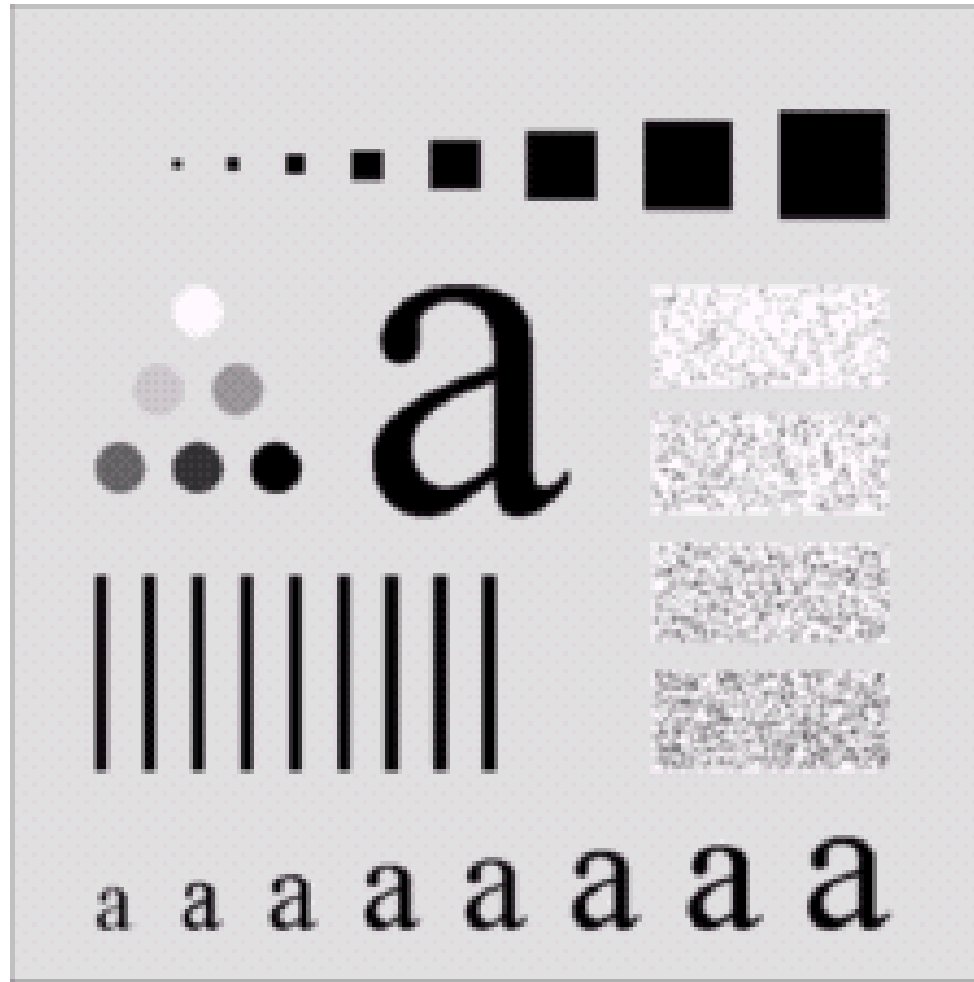


Image Smoothing Example

5x5 Average Filter

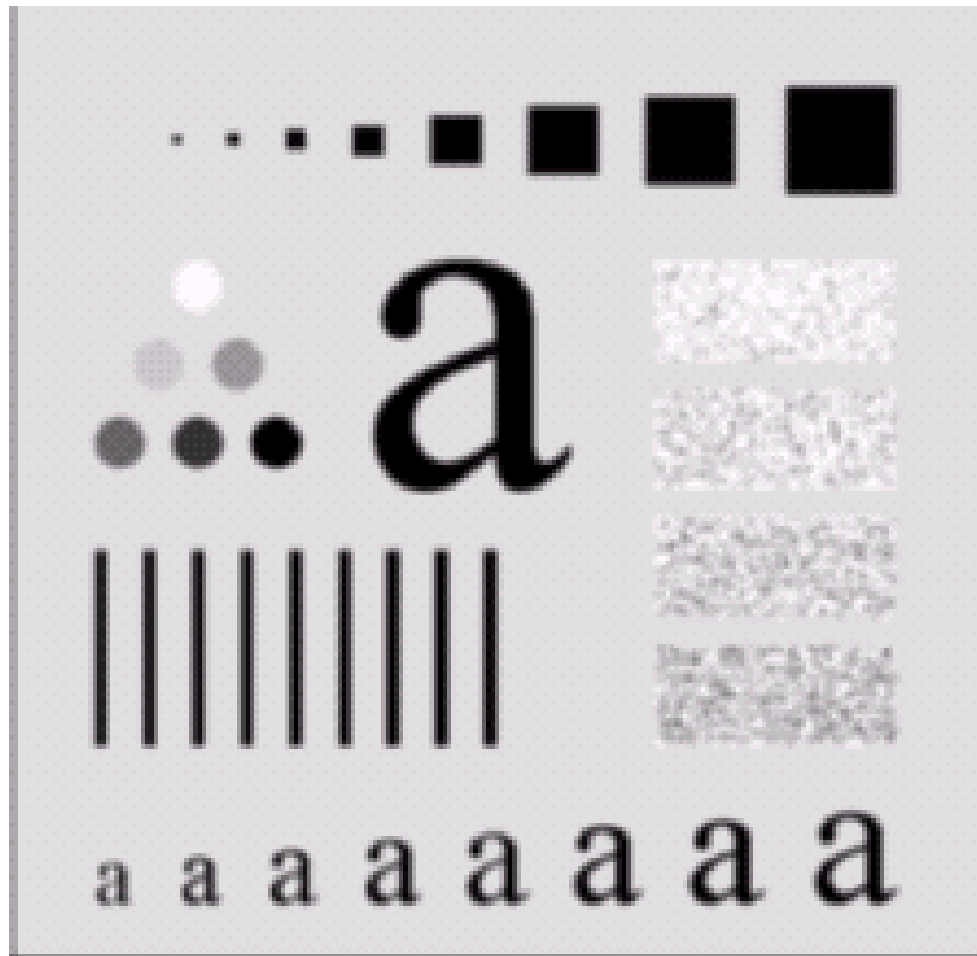


Image Smoothing Example

9x9 Average Filter

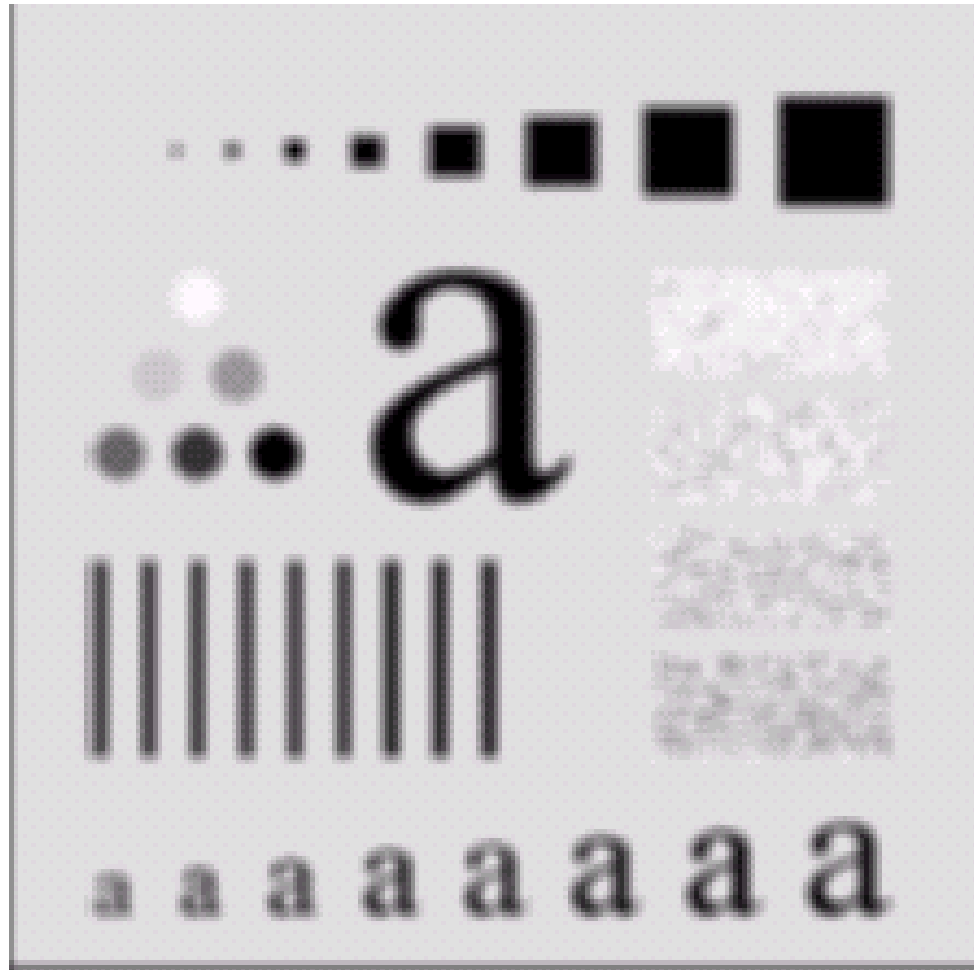


Image Smoothing Example

15x15 Average Filter

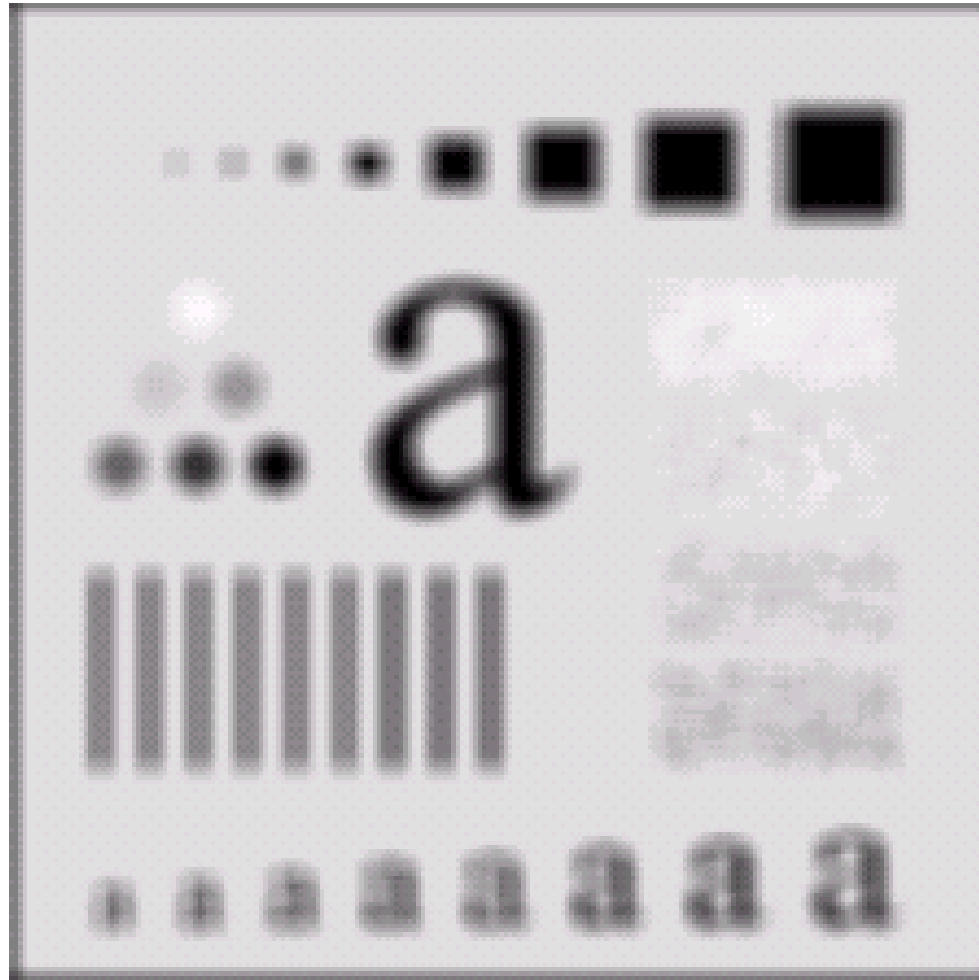
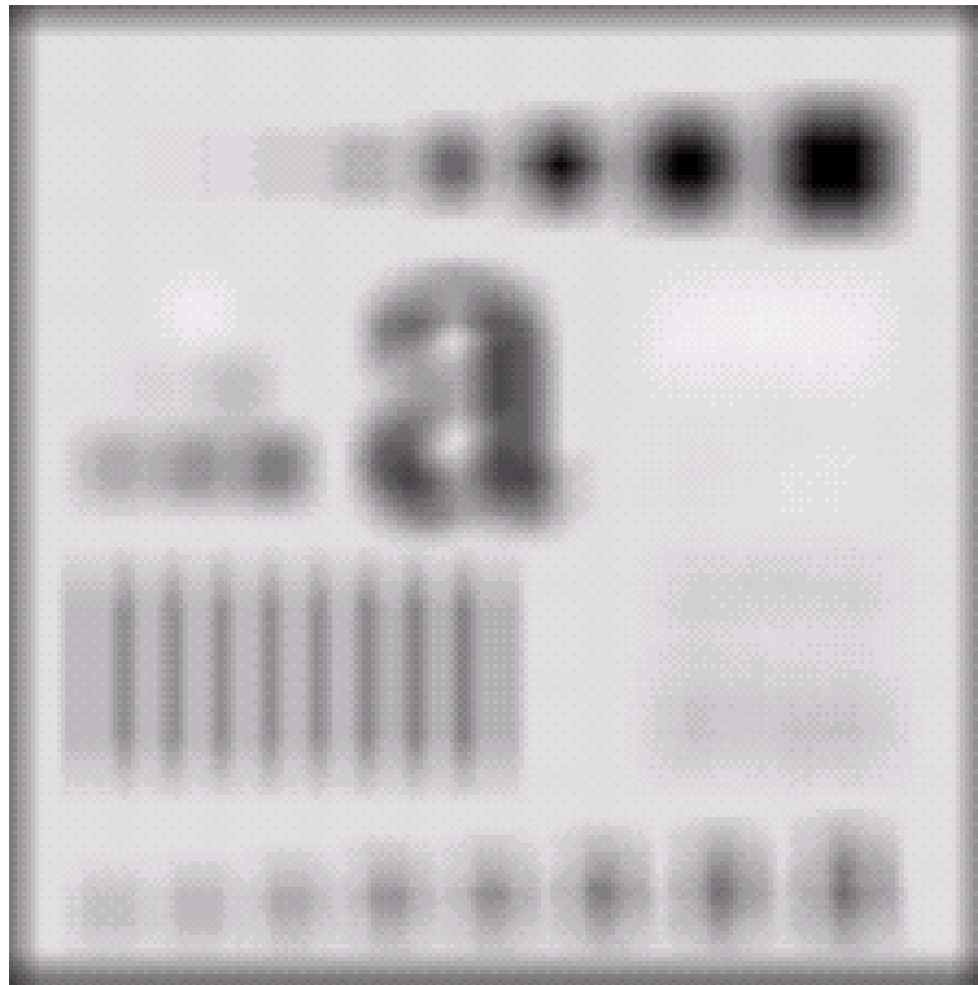


Image Smoothing Example

35x35 Average Filter



Weighted Smoothing Filters

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

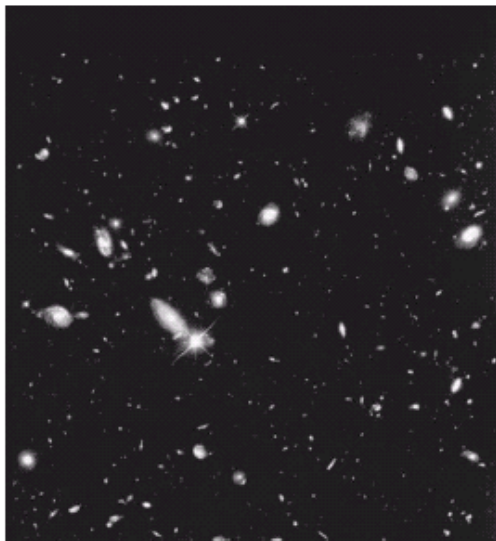
- Pixels closer to the central pixel are more important
- Often referred to as a *weighted averaging*

$1/16$	$2/16$	$1/16$
$2/16$	$4/16$	$2/16$
$1/16$	$2/16$	$1/16$

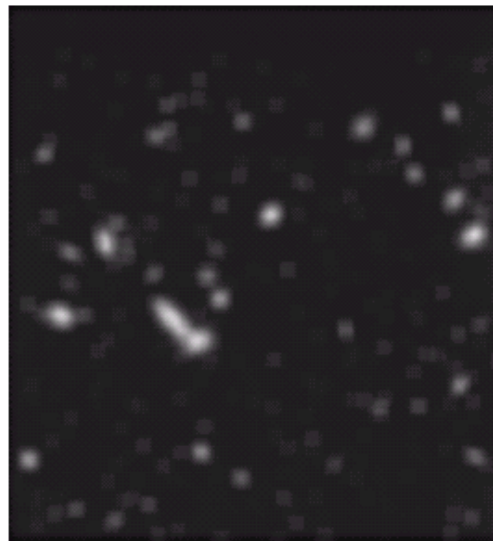
Weighted
averaging filter

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



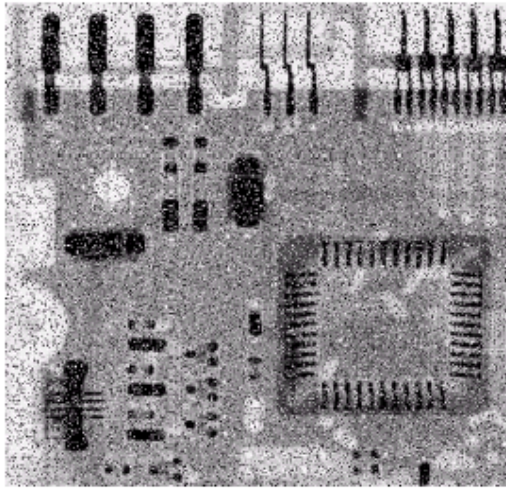
Thresholded Image

Simple Non-Linear Operations

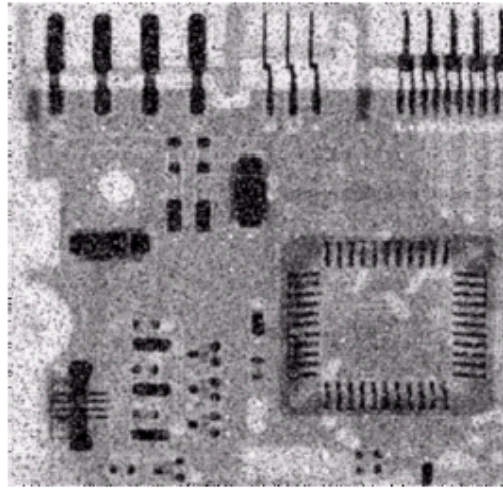
Some simple **non linear** neighbourhood operations include:

- **Min (erosion)**: Set the pixel value to the minimum in the neighbourhood
- **Max (dilation)**: 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

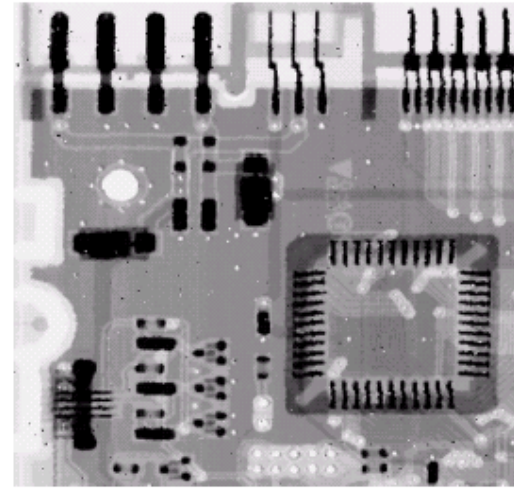
Averaging Filter Vs. Median Filter Example



**Original Image
With Noise**



**Image After
Averaging Filter**



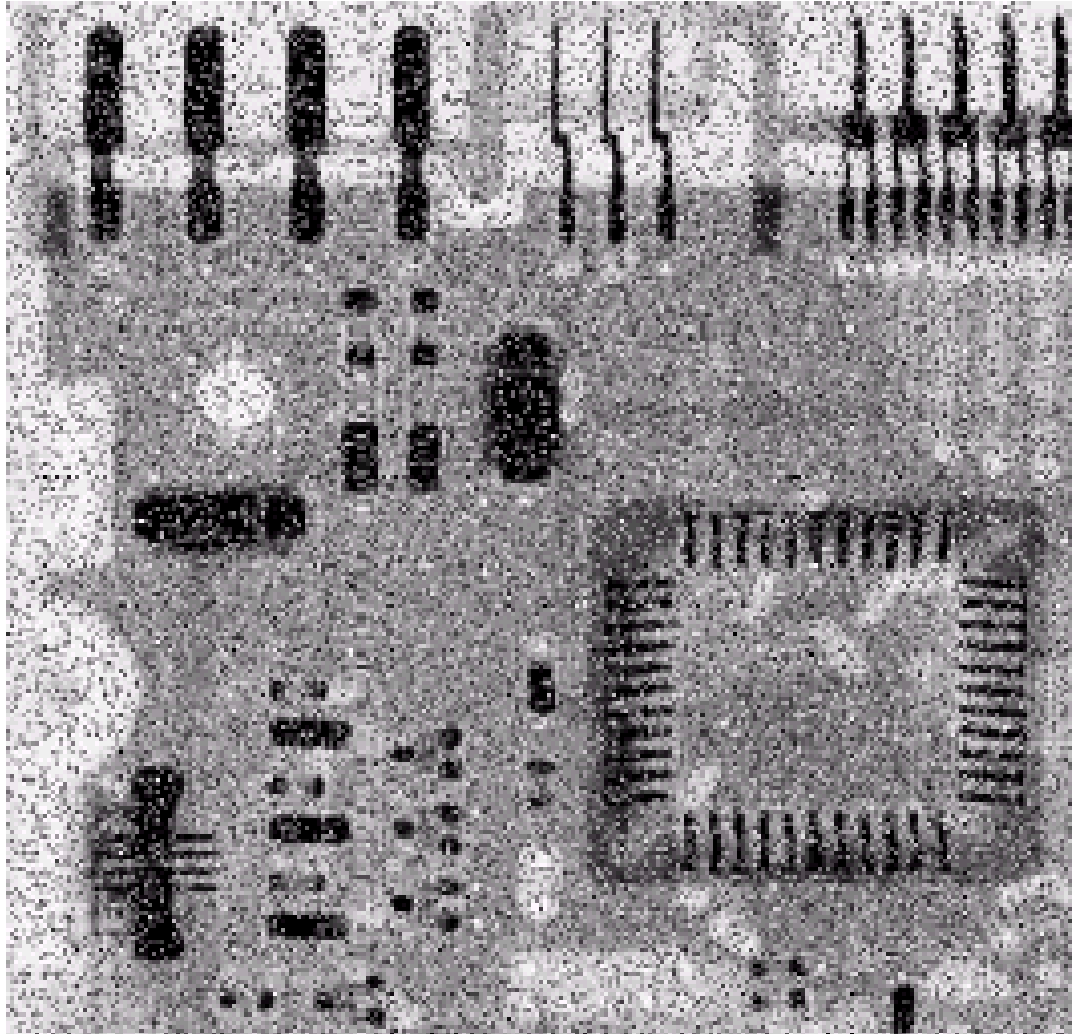
**Image After
Median Filter**

Filtering is often used to remove noise from images

Sometimes a median filter works better than an averaging filter

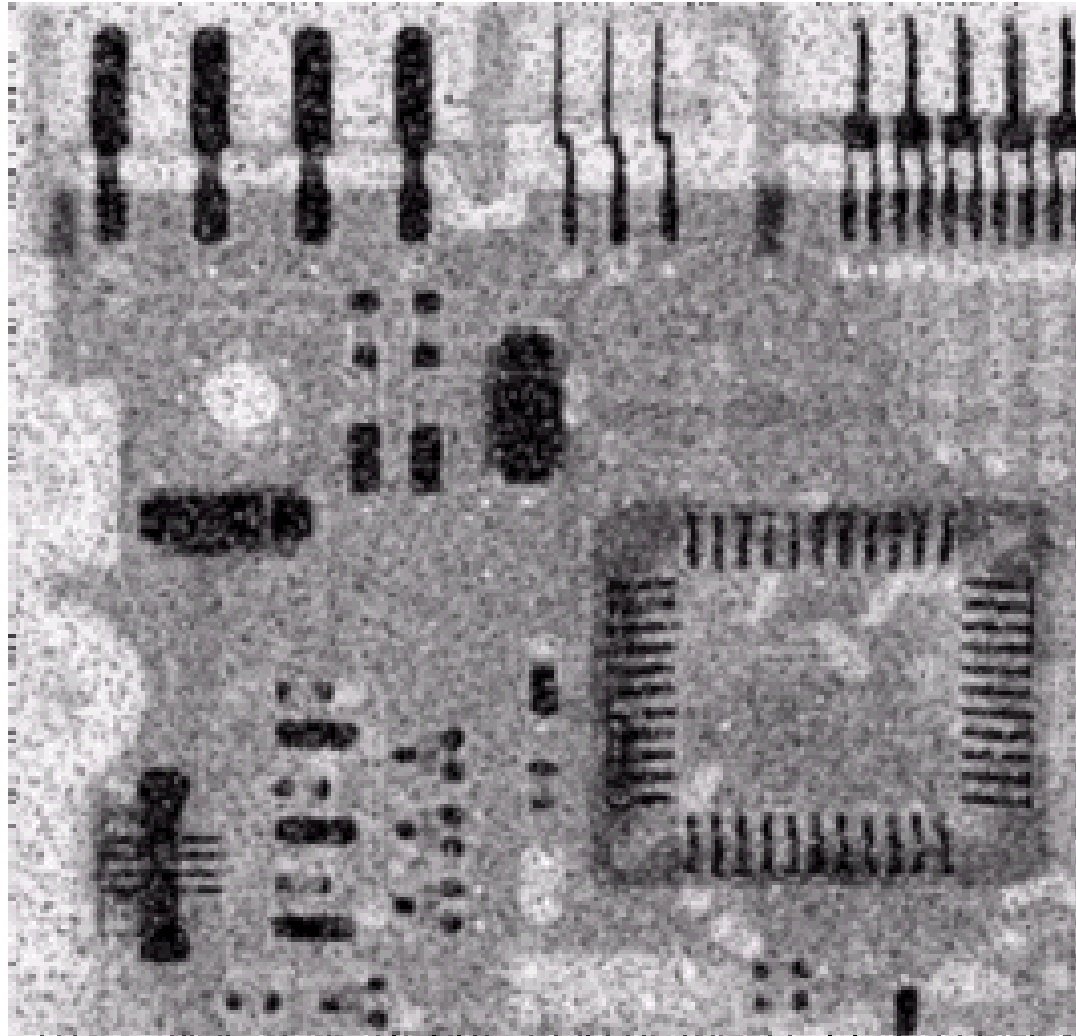
Averaging Filter Vs. Median Filter Example

Original Image



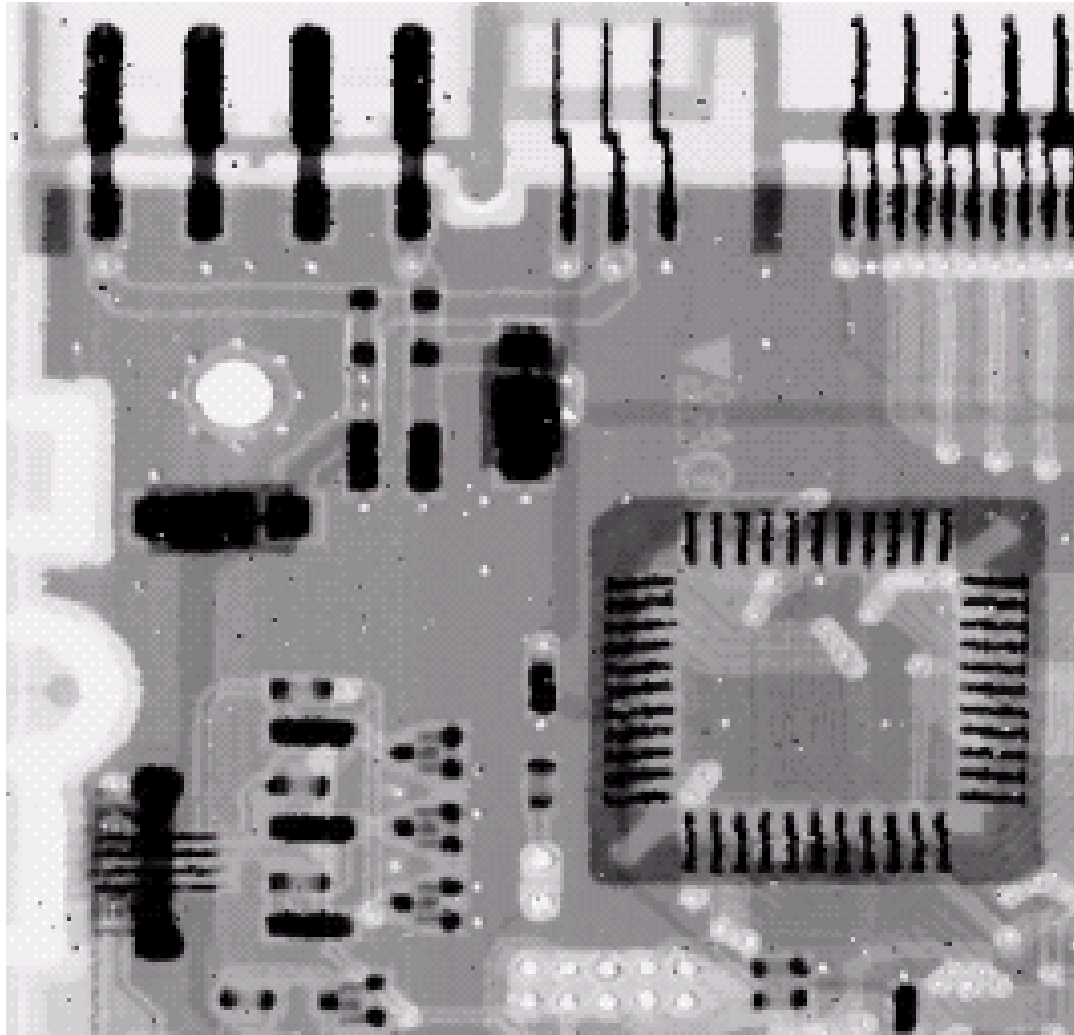
Averaging Filter Vs. Median Filter Example

Average Filter



Averaging Filter Vs. Median Filter Example

Median Filter



sharpen !

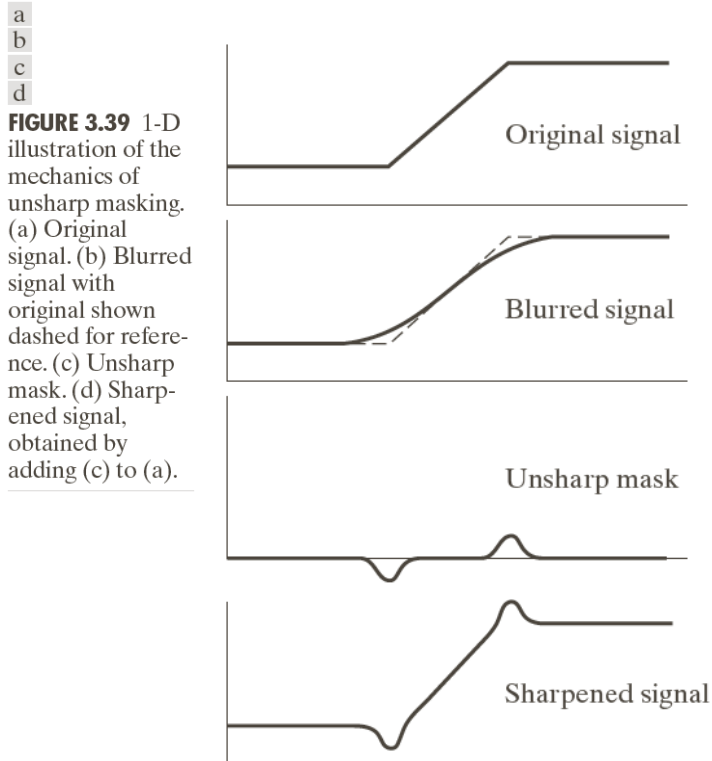


Unlike smoothing the principal objective of **sharpening** is to **highlight transition in intensity.**

http://flickr.com/photos/t_schnitzlein/87607390/

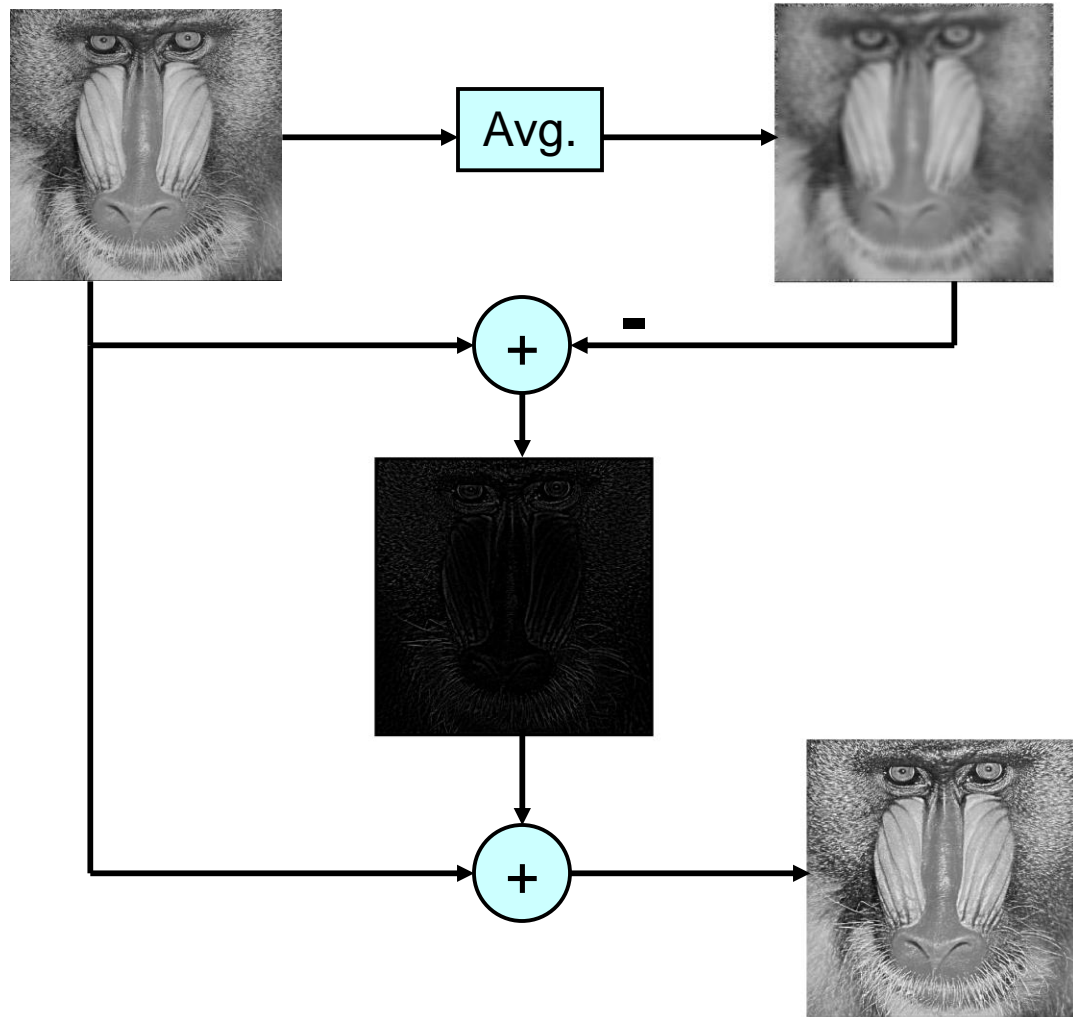
unsharp masking

- **Unsharp masking** is an image manipulation technique for increasing the apparent sharpness of photographic images.
- The "unsharp" of the name derives from the fact that the technique uses a blurred, or "unsharp", positive to create a "mask" of the original image. The unsharp mask is then combined with the negative, creating a resulting image sharper than the original.



- **Steps**
 1. Blur the image
 2. Subtract the blurred version from the original (this is called the *mask*)
 3. Add the "mask" to the original

high-boost filtering



Let $f'(x)$ is the blurred image.

$$g_{mask}(x, y) = f(x, y) - f'(x, y)$$

$$g(x, y) = f(x, y) + A * g_{mask}(x, y)$$

Unsharp mask:

high-boost with $A=1$

unsharp mask example

The Moon 25th August 2005 1:19 GMT

☆ ADD TO FAVES
📄 BLOG THIS
🔍 ALL SIZES



Waning Gibbous Moon, 1:19 GMT Location Edinburgh, Scotland, UK
20.6 days old. Mirror Image!

The Moon with unsharp mask applied

☆ ADD TO FAVES
📄 BLOG THIS
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Similar to last nights picture but with some unsharp masking and turned into a greyscale picture. Do you think it helps?

Waning Gibbous Moon, 1:19 GMT Location Edinburgh, Scotland, UK
20.6 days old. Mirror Image! 25th August 2005 1:19 GMT

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
- Unsharp Masking

Next time we will look at sharpening filters using image derivatives as well as more on filtering and image enhancement