Lectures Remote Sensing

DIGITAL FILTERS

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Digital Filters

- Purpose
- Operator
- Examples
- Properties

(L&K pp. 494-499 and section 7.5)

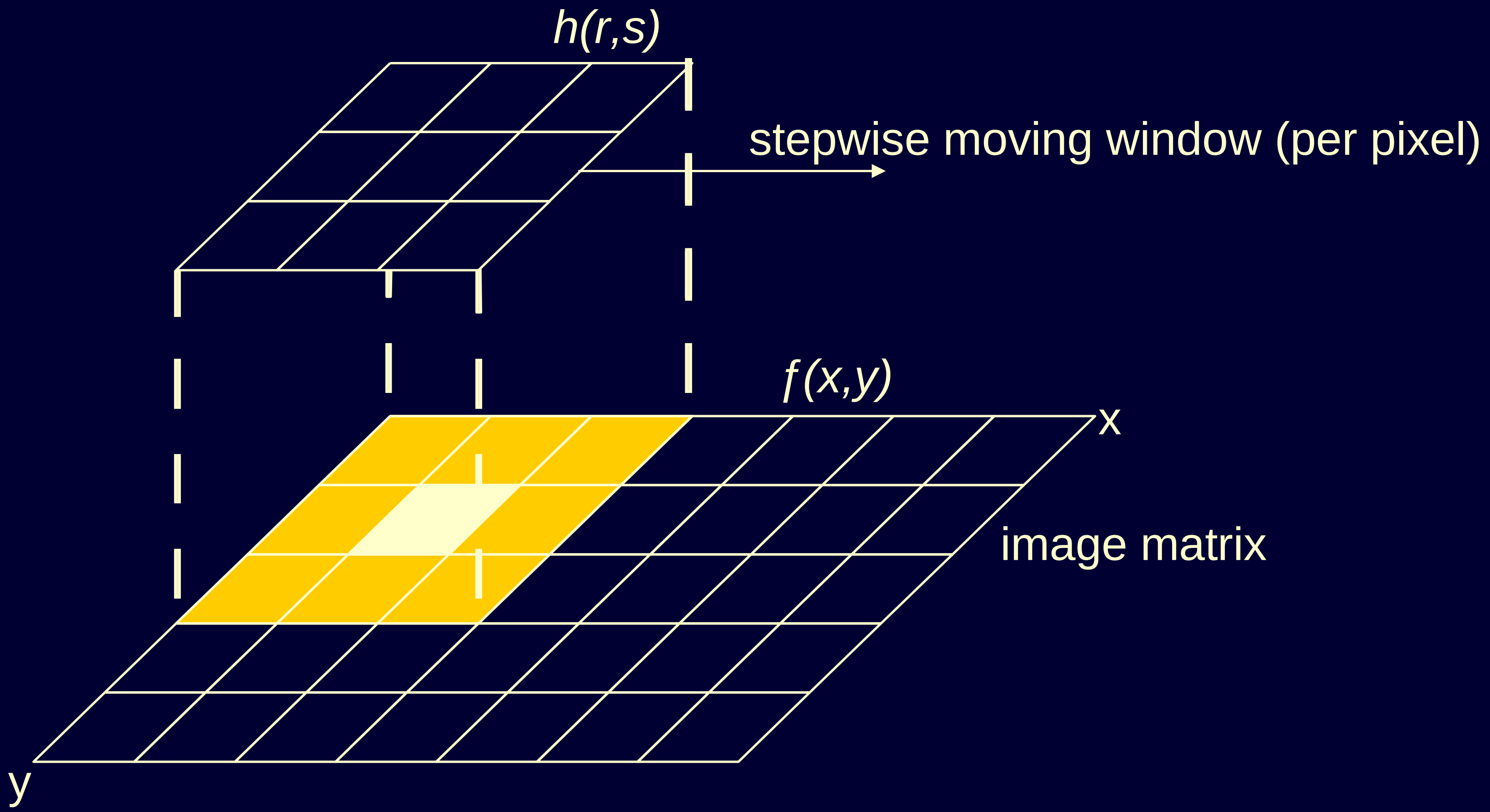
Digital Filters and RS Images

Local operation by "mask" or "window" or "template" with some algorithm ("kernel")

Purposes:

- Image improvement or restoration
  - elimination of disturbances in points and/or lines
  - noise suppression
  - image enhancement (sharpening)
  - edge detection of line structures
- preprocessing before spectral classification
  - averaging of field units
  - elimination of local disturbances
- discover spatial patterns (enhancement)
  - distinguish area, line and point objects through window operations

E.g. 3 x 3 filter window:



Input to algorithm: 9 pixel values from the input image

Output to **central** pixel: **1** filter result value in the output image

Filter Definition

Filter: operation scheme (mask) $h(r,s)$, which moves over the image $f(x,y)$.

→ size mask = N • N window

→ pixel to pixel transformation

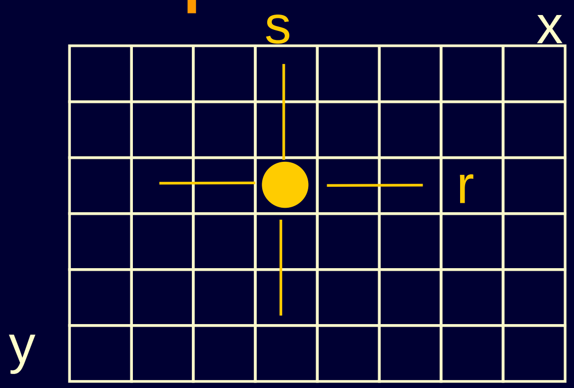
→ neighbourhood dependent (local operator)

- the central pixel value is replaced by the filter result
- the window moves pixel by pixel, line by line across the image

2 classes of filter operators:

- linear filters
- non-linear filters

Operation of Digital Filters



$f(x,y)$ = image pixel value as
a function of position
(in original image)

The concept **convolution** is used with **linear filtering**:

$$g(x,y) = f(x,y) \bullet h(r,s)$$

$g(x,y) \rightarrow$ filter result

$h(r,s) \rightarrow$ operation scheme

x,y: central window coordinates in the image to be filtered $f(x,y)$

r,s: number of steps relative to the centre, that is to say the coordinates

N = 3: $\overbrace{-1\ 0\ 1}^{r \text{ or } s}$

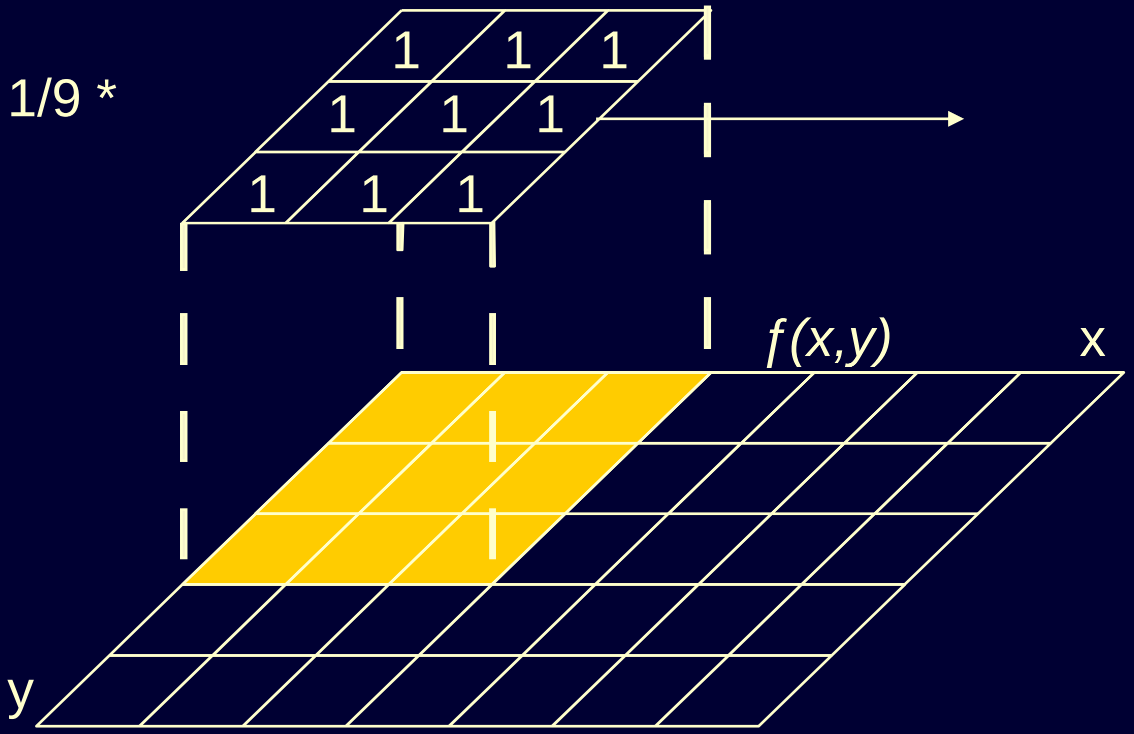
N = 5: -2 -1 0 1 2

N = 7: -3 -2 -1 0 1 2 3

N = size of the window
(preferably **odd**)

Examples

h(r,s) with N = 3:

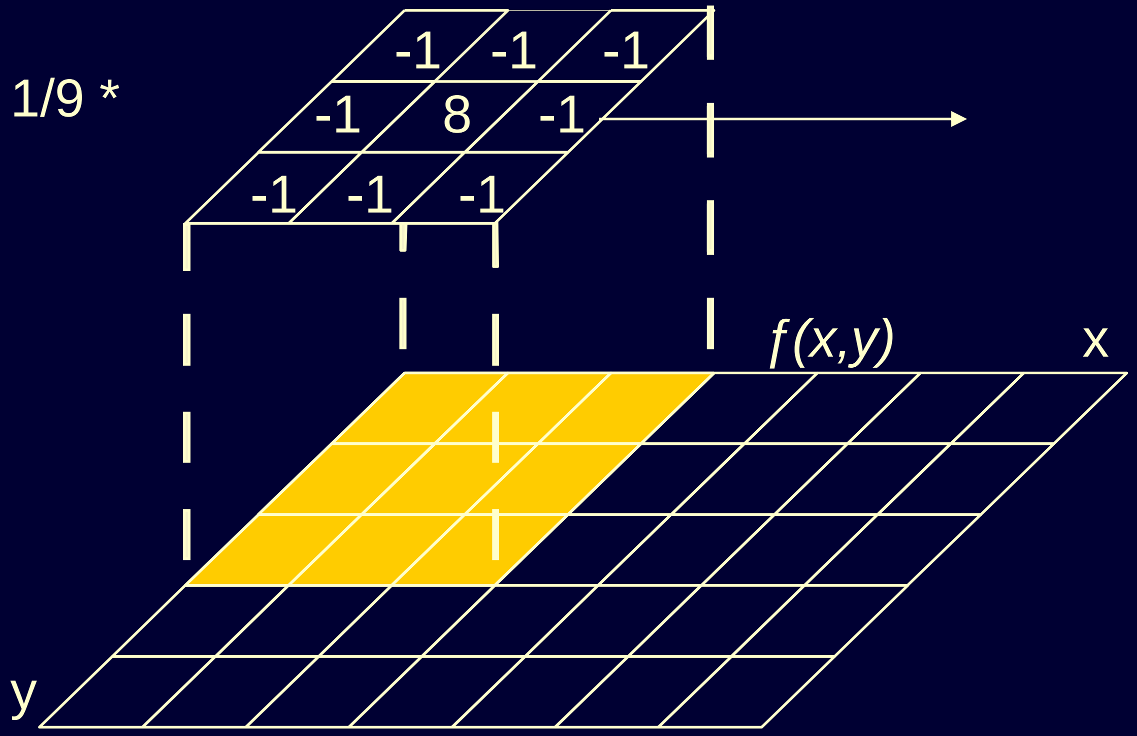


Low pass filter

(moving average)

shows
long periodic
fluctuations
→ trends

High pass filter



-1	-1	-1
-1	8	-1
-1	-1	-1

shows
short periodic
fluctuations
→ local transitions

Low pass + high pass = original image!!

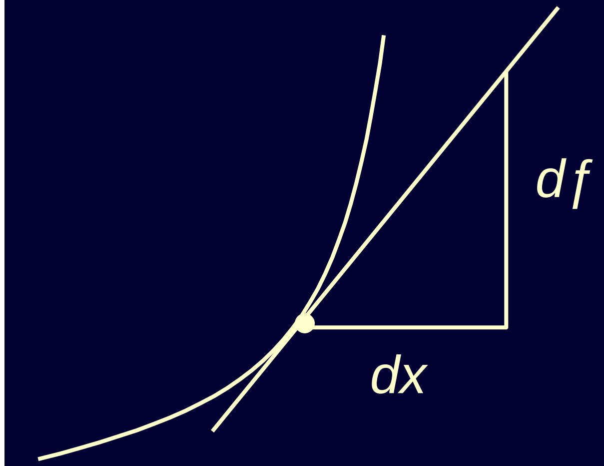
Example TM image, band 5

Result low pass filter, 3x3 window

Result high pass filter, 3x3 window

Gradient filter:

first derivative of *f(x,y)* in a chosen direction



clear edge → *df* / *dx* large

weak edge → *df* / *dx* small

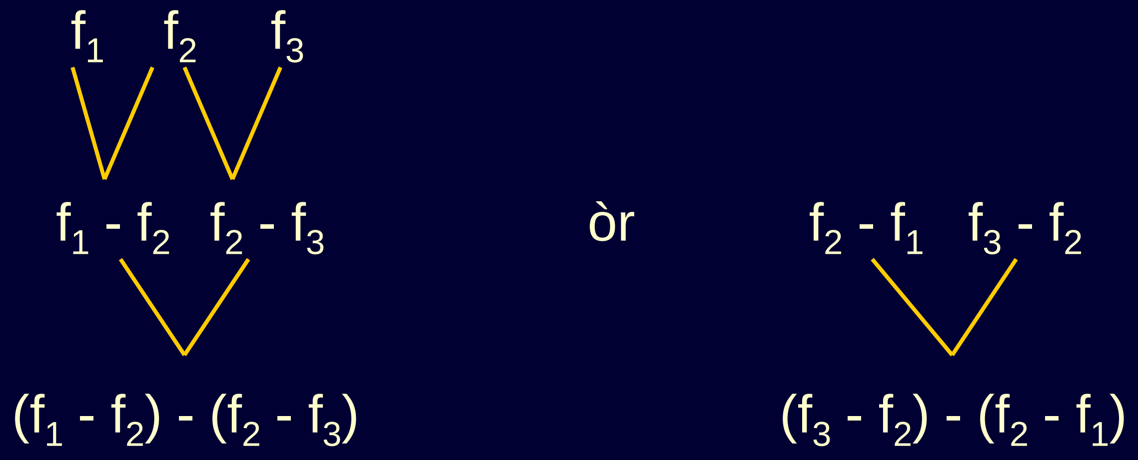
One may consider this as a 3 • 3 convolution:

$$\begin{pmatrix} 0 & 0 & 0 \\ -1 & 0 & 1 \\ 0 & 0 & 0 \end{pmatrix} ; \qquad \text{also } (45^o): \begin{pmatrix} 0 & 0 & 1 \\ 0 & 0 & 0 \\ -1 & 0 & 0 \end{pmatrix} \qquad \text{etc.}$$

Laplace filter:

$d^2 f / dx^2$: second derivative of $f(x,y)$

in x ànd y directions simultaneously



f_1 f_2 f_3

$f_1 - f_2$ $f_2 - f_3$ òr $f_2 - f_1$ $f_3 - f_2$

$(f_1 - f_2) - (f_2 - f_3)$

$= f_1 - 2 f_2 + f_3$

$= d^2 f / dx^2$

$(f_3 - f_2) - (f_2 - f_1)$

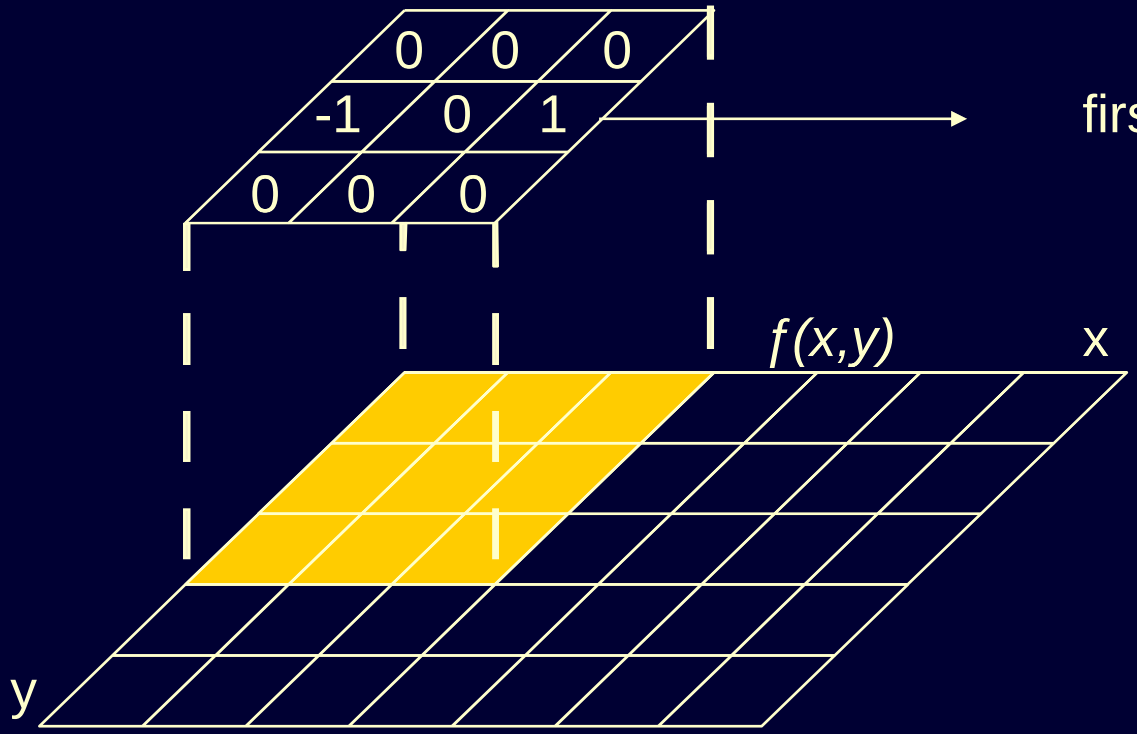
$= f_1 - 2 f_2 + f_3$

$= d^2 f / dx^2$

Filter operation scheme is $-d^2 f / dx^2$:

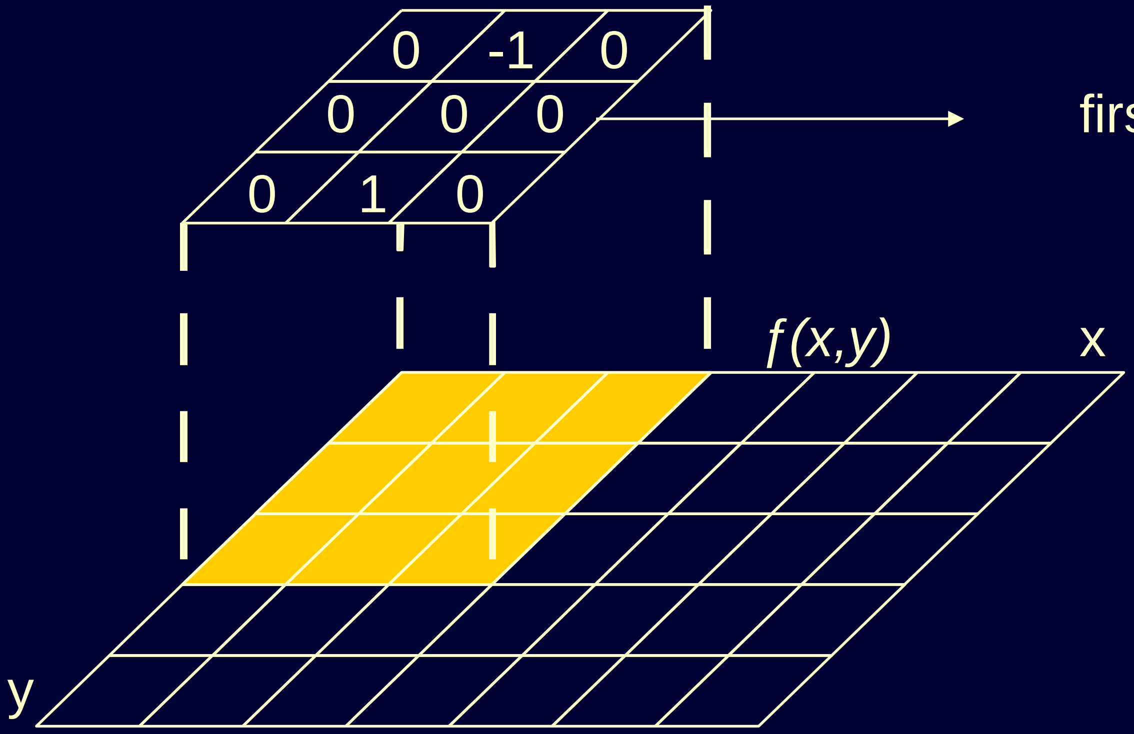
$$\begin{pmatrix} -1 \\ 2 \\ -1 \end{pmatrix}$$ and (-1 2 -1) together.

Horizontal gradient filter



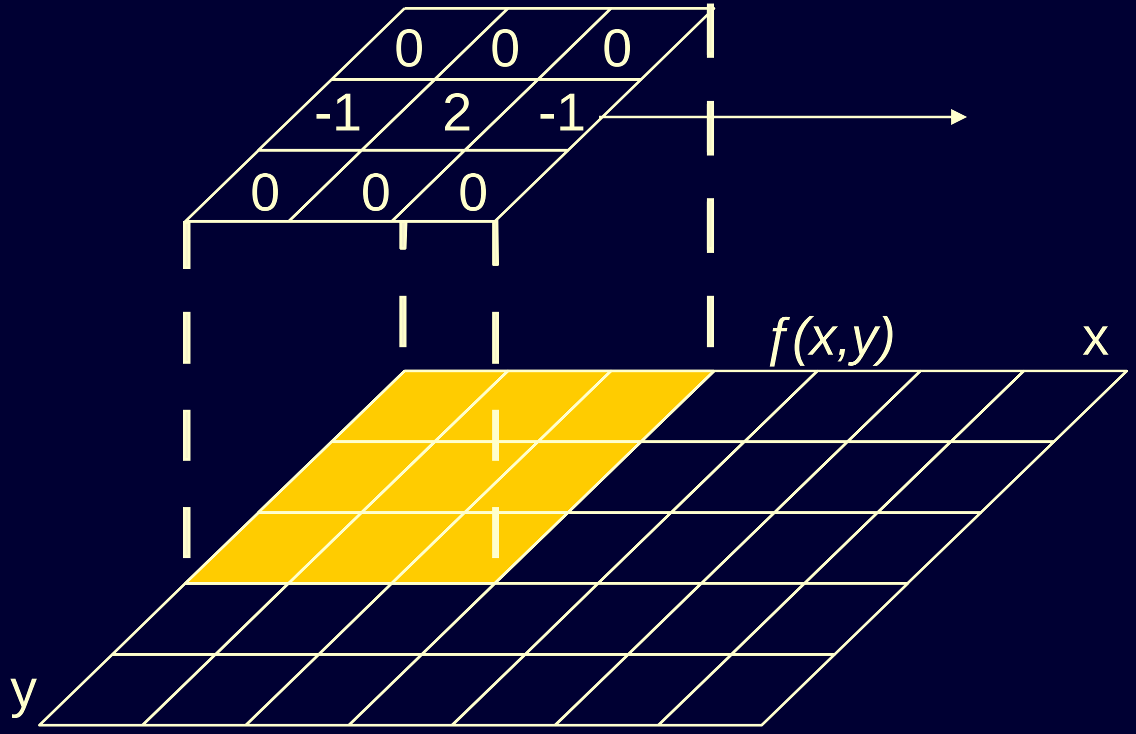
first derivative *x* direction

Vertical gradient filter

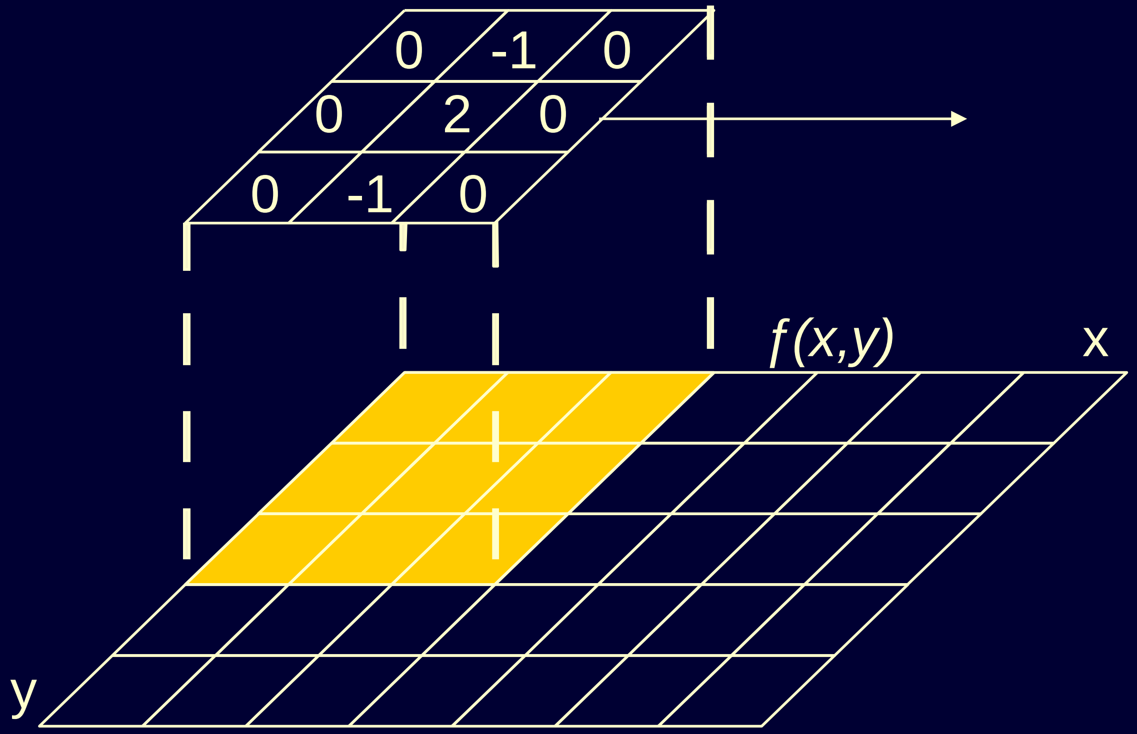


first derivative *y* direction

Horizontal Laplace filter



Vertical Laplace filter



Laplace filter

$$(-1 \;\; 2 \;\; -1) \text{ with } \begin{pmatrix} -1 \\ 2 \\ -1 \end{pmatrix} \text{ gives } \underbrace{\begin{pmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{pmatrix}}_{\text{Laplace}}$$

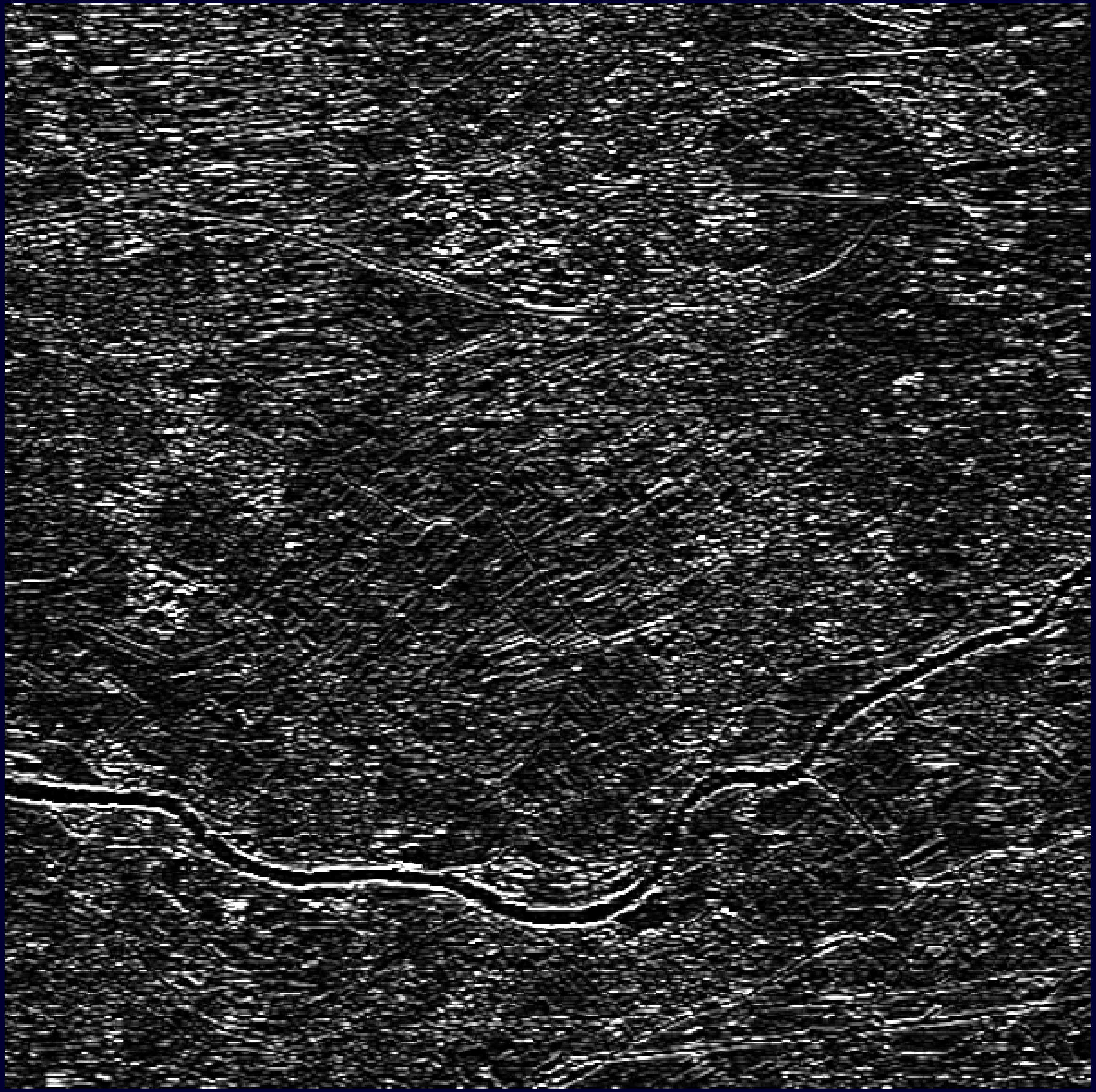
Blurred image (original) + Laplace filter → Sharper image

$$\begin{pmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{pmatrix} + \begin{pmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{pmatrix} = \begin{pmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{pmatrix}$$

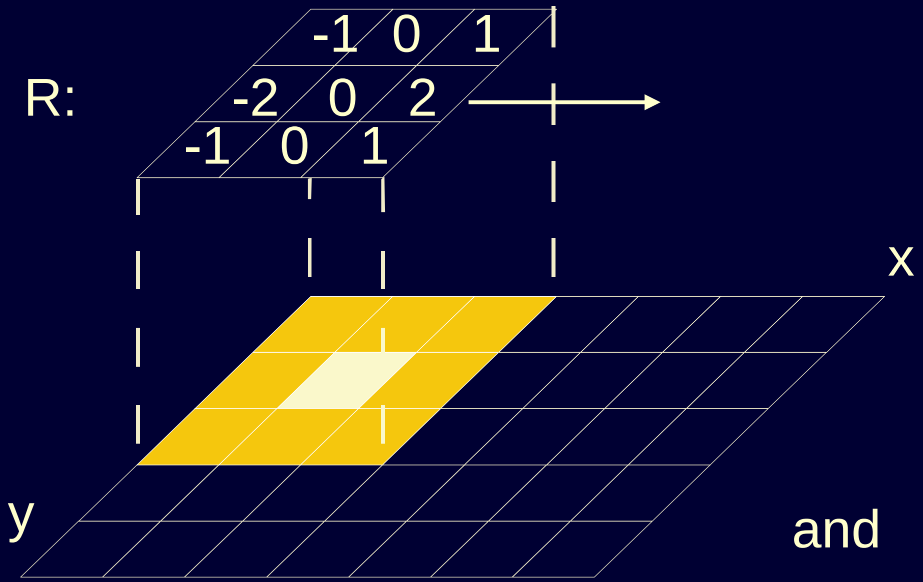
Example TM image, band 5

Result Laplace + original, 3x3 window

Result vertical gradient filter, 3x3 window



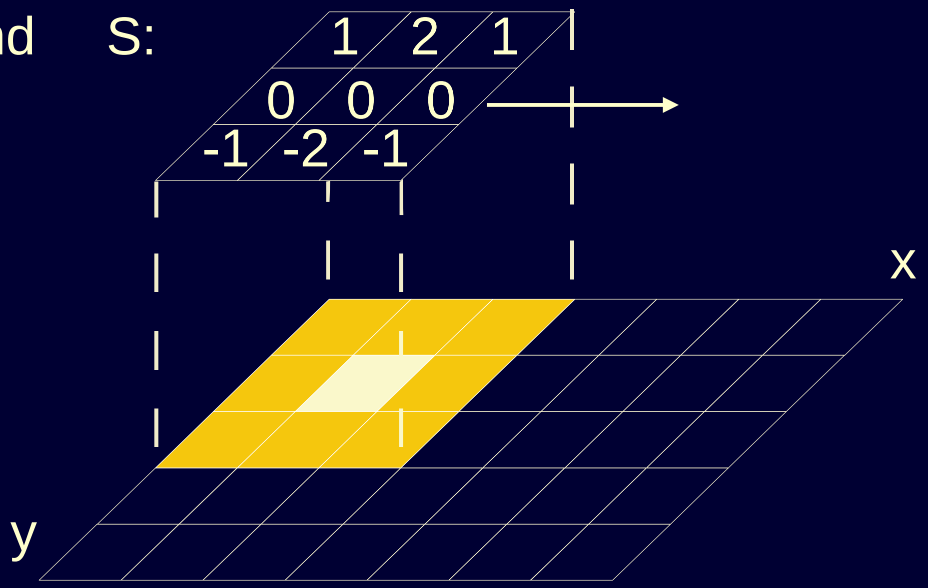
Edge Detection



Sobel filter

filter value = $\sqrt{(R^2 + S^2)}$

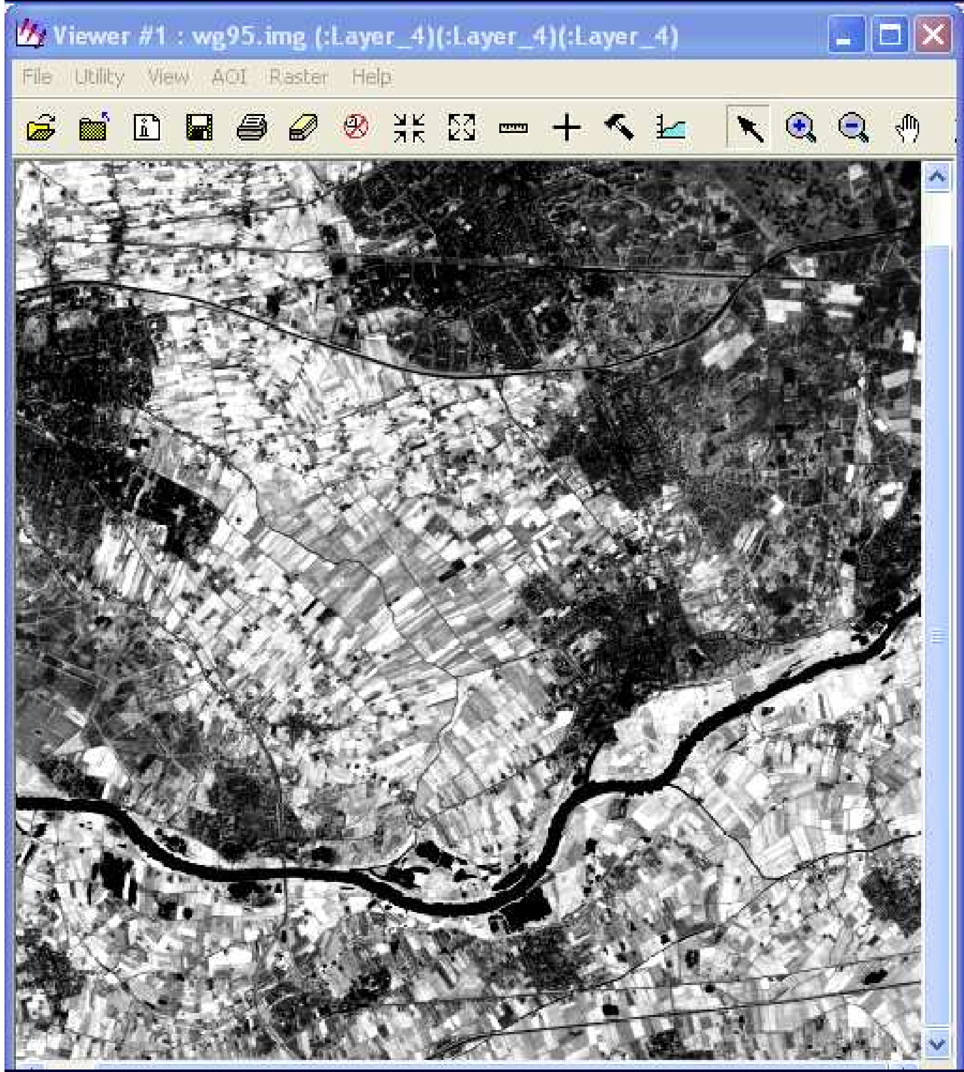
and

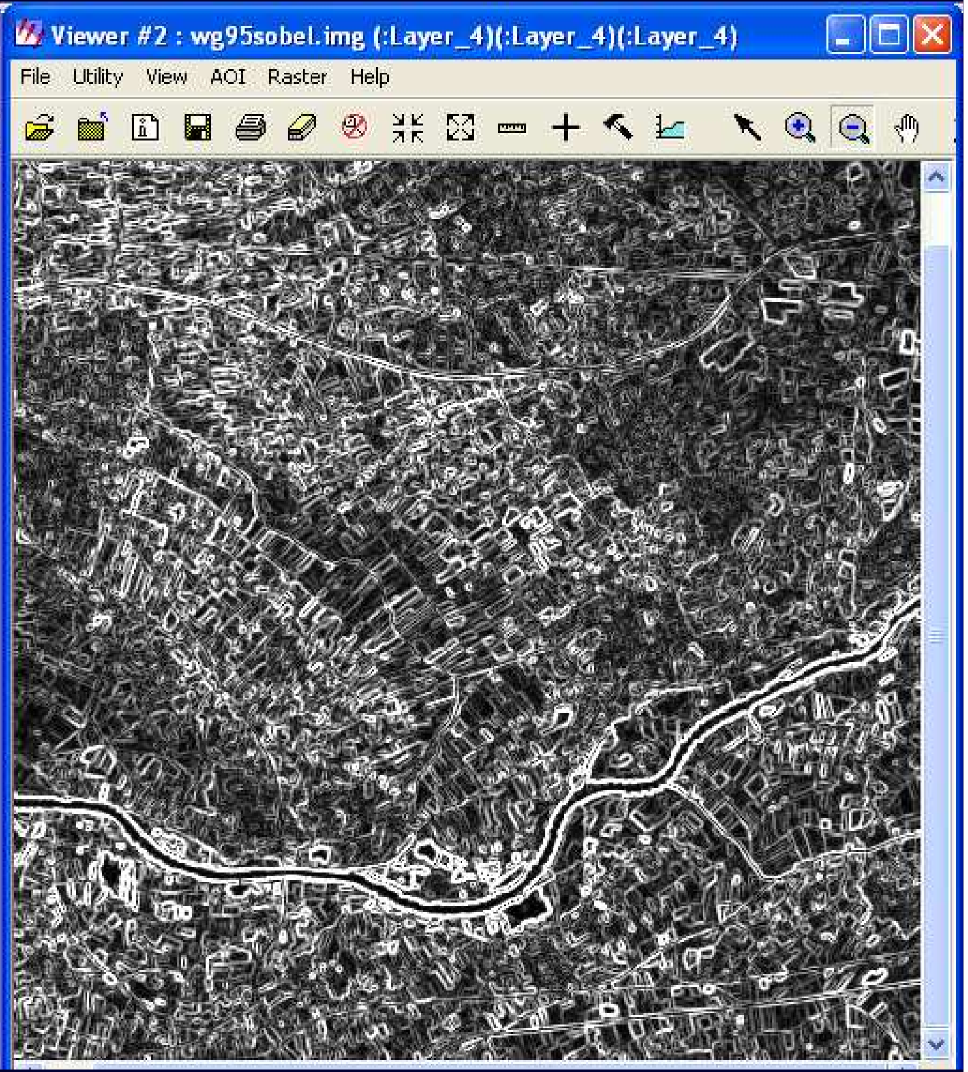


The direction of the **edge** is:

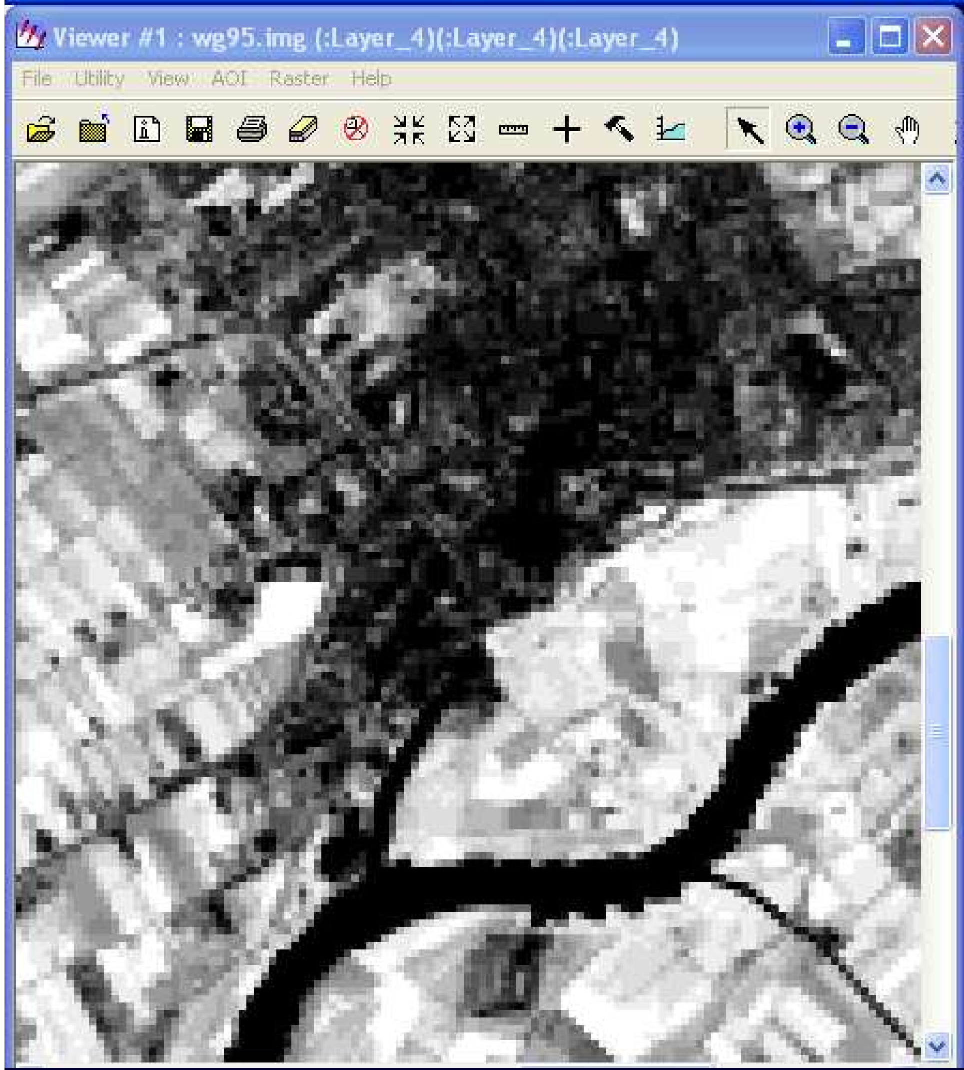
arctan (S/R)

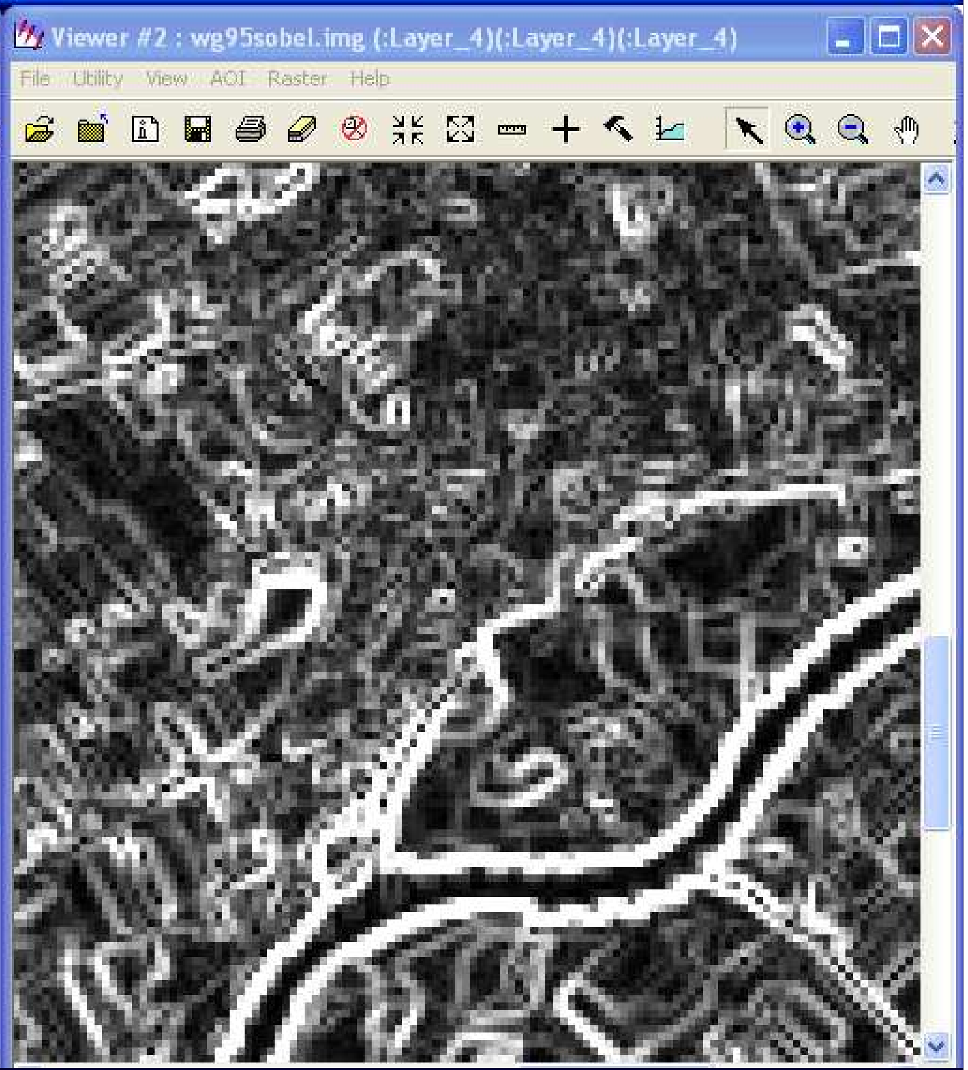
Example Sobel filtering





Example Sobel filtering





Median filter

f_1	f_2	f_3
f_4	f_5	f_6
f_7	f_8	f_9

E.g.:

12	7	8
10	32	5
9	13	17

Median filter: the 9 pixel values are ordered

$$f_6 \quad f_2 \quad f_3 \quad f_7 \quad \boxed{f_4} \quad f_1 \quad f_8 \quad f_9 \quad f_5$$

pixel value f_4 is now assigned to the central pixel

Properties of Filters

Linear filters

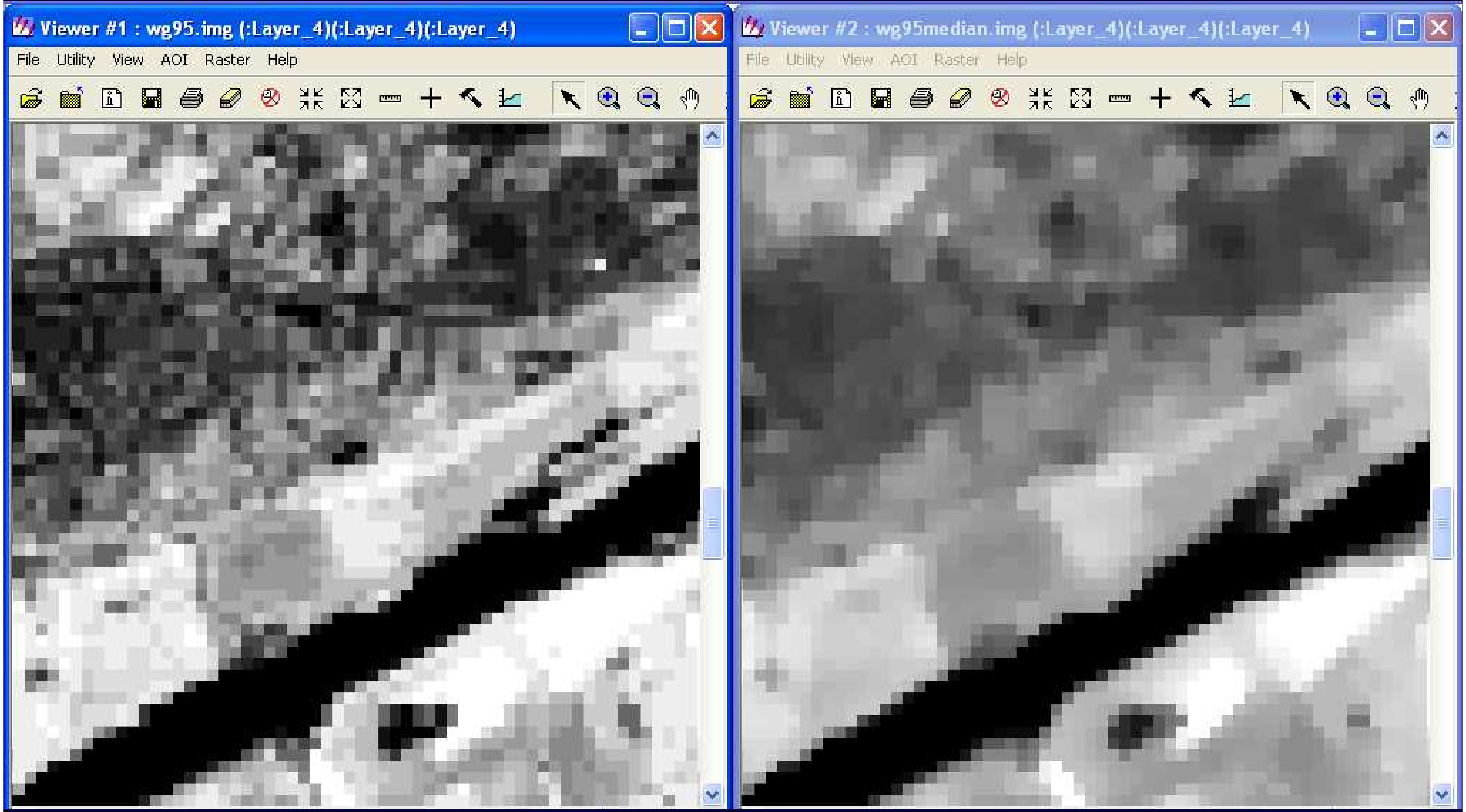
Low pass:	averaging small fluctuations in image values; random noise suppression; smoothing however: image fading (blurring)
High pass:	enhancing details (also noise); emphasizing edges
Gradient:	directional filter for line structures
Laplace: (+ original)	improving image sharpness, enhancing details

Properties of Filters -2-

Non-Linear filters

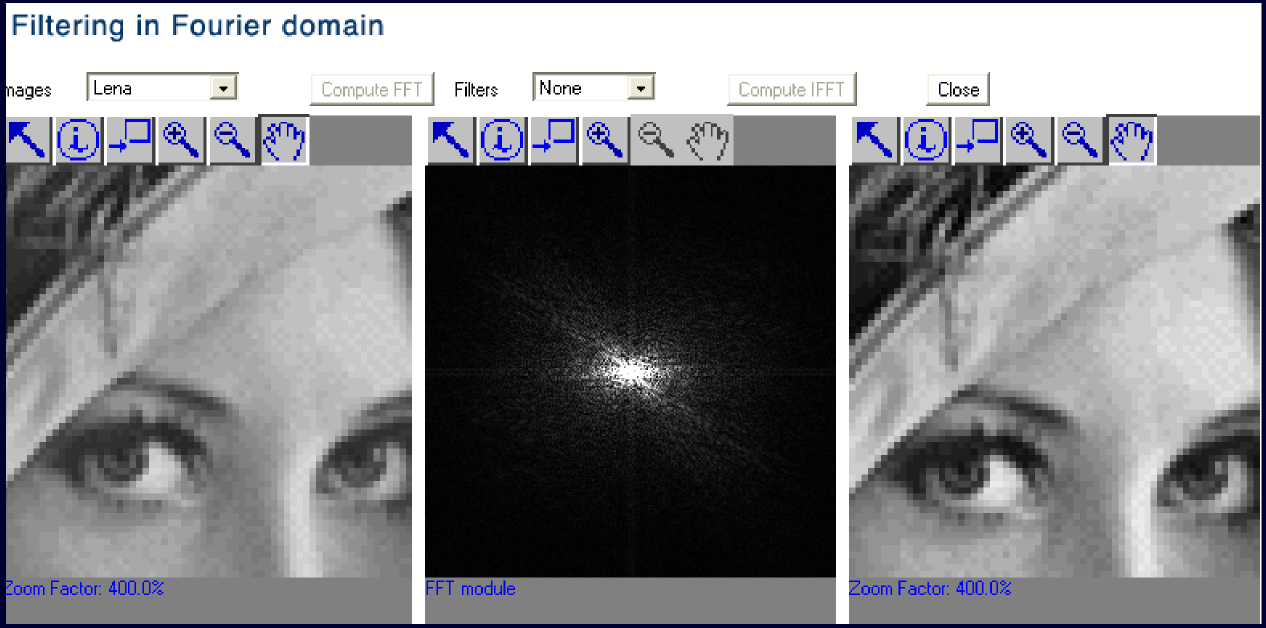
Median:	suppressing isolated noise or peaks; preserving edges however: rounding off corners of fields
Prewitt Sobel Kirsch :	edge detectors; exaggerate edges even

Example Median filtering



New filtering techniques

- Fourier analysis: spatial frequency decomposition



http://bigwww.epfl.ch/demo/fourierfilter/

- Wavelet analysis
- Kalman filter: recursive filter which estimates the state of a dynamic system from a series of incomplete and noisy measurements

Spatial aggregation

Dutch land use data base (LGN)

25 m + 39 classes aggregated to 300 m + 9 classes