# Digital Image Processing

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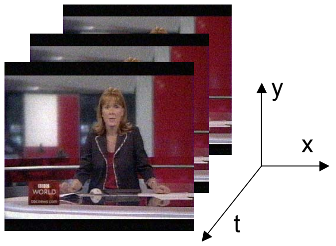
INSTITUUT VOOR PERMANENTE VORMING

# Video Denoising

# - Repeating -

# Introduction to video processing




Video can be described as 3-dimensional data

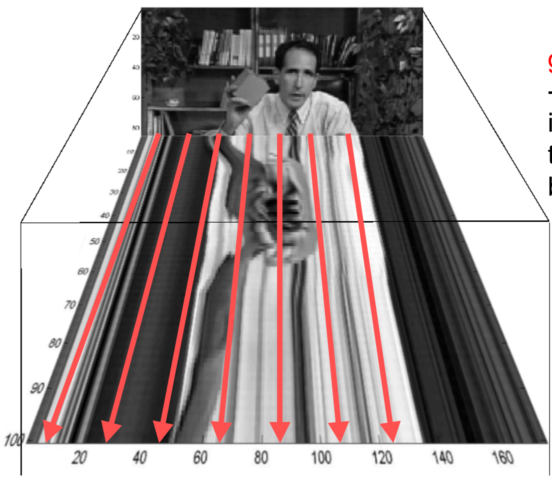
There is a great spatial and temporal redundancy in video

- In static areas noise is removed best by temporal filtering (no spatial bluring occurs)
- A key of any successful video processing method is motion detection and/or motion estimation
- Most often real-time processing is required and hence the algorithms need to be of low-complexity and/or hardware-friendly
- In some applications (e.g., restoration of old movies) the processing is off-line and the involved algorithms can be more complex



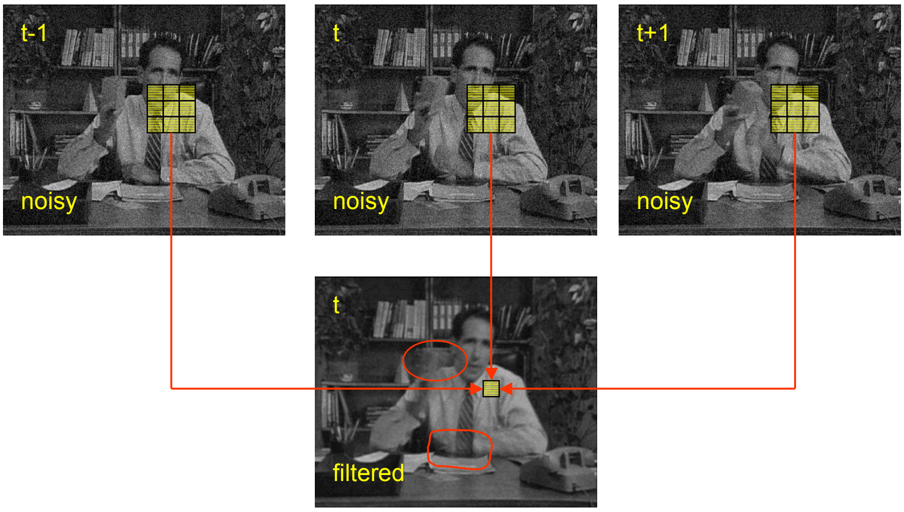


# Temporal filtering




Probleem: in moving areas ghost artefacts -
- structures that are not present in the current frame appear or the actual structures dissapear being filtered out

# Motion blur due to temporal filtering

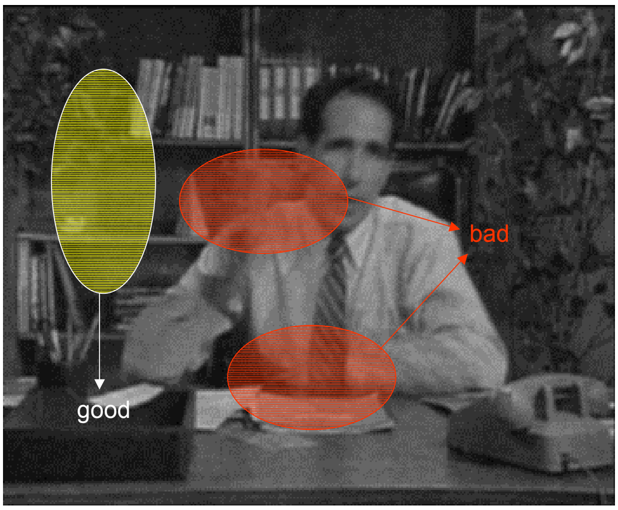




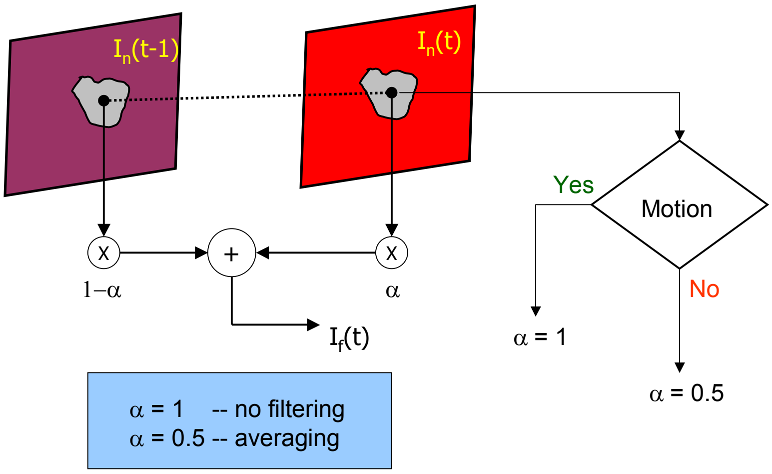




# Motion blur due to temporal filtering



# Motion adaptive temporal averaging

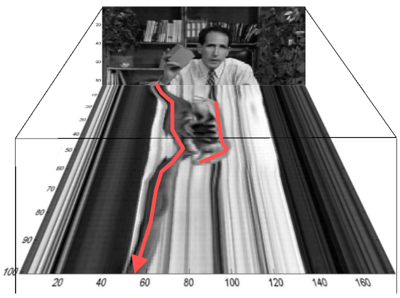








# Filtering along the motion trajectory



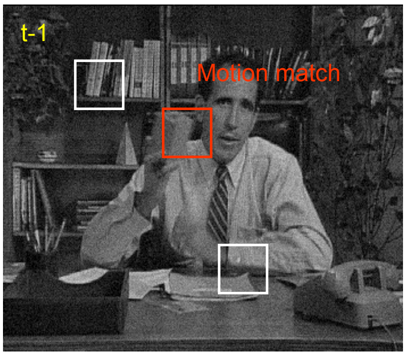
Advanced temporal filters for video filter along the estimated motion trajectory – this is called motion compensated filtering

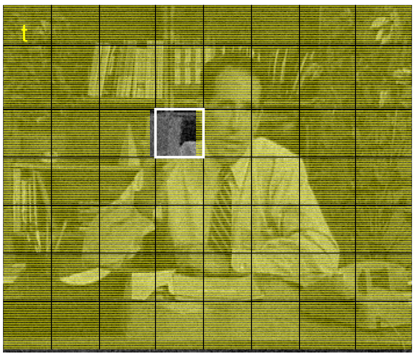
Problem: motion estimation is never perfect!

A possible solution: estimate the reliability of the motion estimates and filter more where reliability of the motion estimates is higher

Even advanced, temporal filtering alone is in general not sufficient for a superior quality. Spatio-temporal (“3-D” filtering) yelds best performance

# Motion estimation: block matching



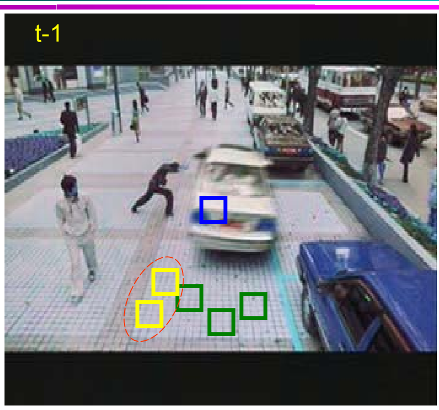




$$MAD_W^{(1)} = \frac{1}{N_x N_y} \sum_s |W(s,t) - W(s - \mathbf{v}, t-1)|$$






# Reliability of motion estimation



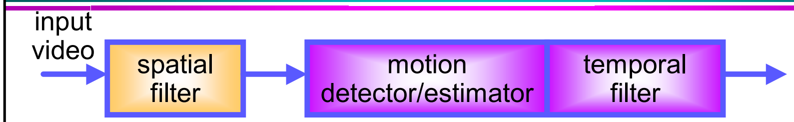


In uniform regions (green squares) motion cannot be accurately estimated

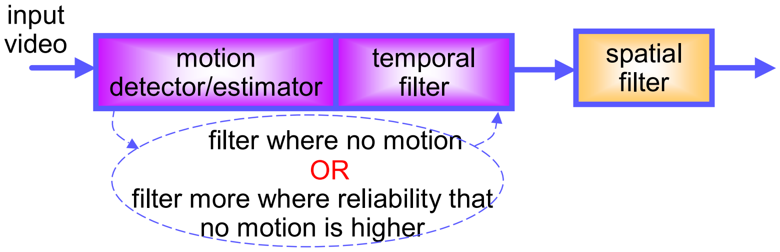
Along edges (yellow boxes) motion reliability is also low, unless motion is perpendicular to the edge

Reliability of motion estimates is highest for blocks that contain corners (blue squares)

# Separable filtering: sequential approach…




+ motion det./est. can be quite simple because noise is suppressed
- spatial blurring is introduced even at static places (where it could have been avoided by using temporal filter only)



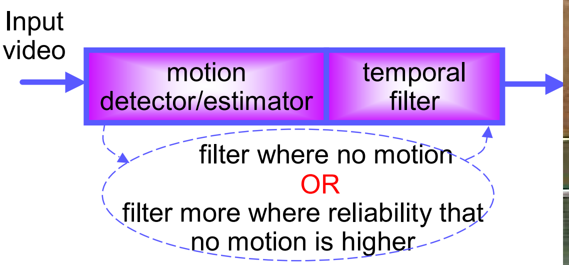

+ less spatial blurring
- spatial filtering more difficult – deals with non-stationary noise
- motion estimation/detection more difficult due to input noise






# …Separable filtering: sequential approach…

More noise remains in the moving areas

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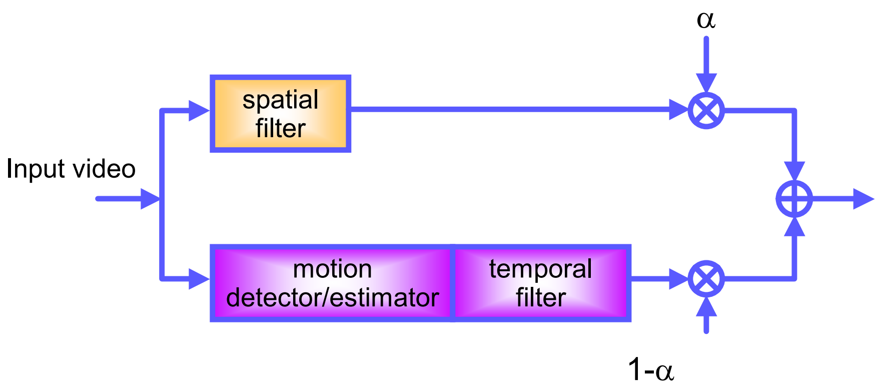
## …Separable filtering: sequential approach



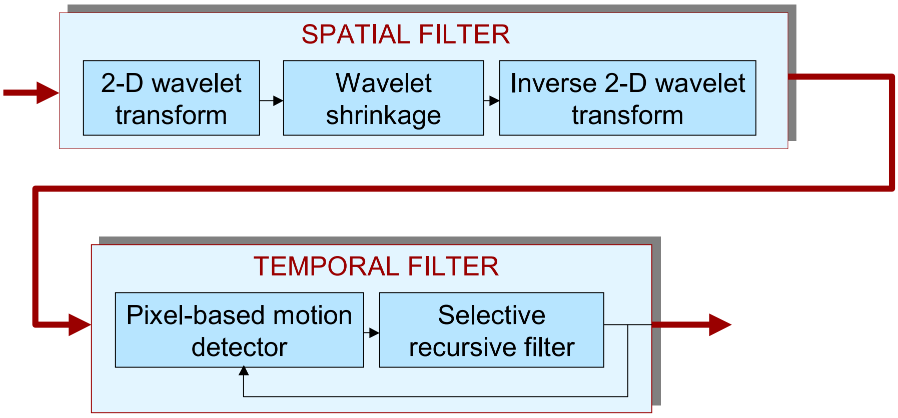

0<α<1 and α should be bigger where motion is bigger and/or where reliability to the estimated motion is smaller

+ potentially most powerful
- How to combine the outputs of the spatial and the temporal filter ? (multiple chices for weighting factors)



## Wavelet domain video Denoising

# SEQWT filter




Sequential wavelet domain and temporal filtering (Pizurica et al., 2003)

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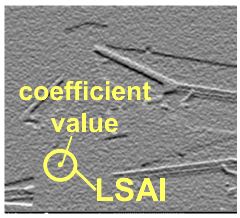
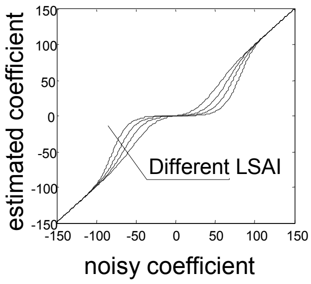
# SEQWT filter: spatial filtering part

- Define **signal of interest** as *noise-free* coefficient component exceeding noise standard deviation

- Estimate the **probability** that a coefficient presents a signal of interest based on
  - **Coefficient value**
  - **Local spatial activity indicator** (**LSAI**) locally averaged magnitude
  - **Global statistical distribution** of the coefficients in a given subband



# SEQWT filter: temporal filtering part

Selective recursive time filtering of spatially filtered frames

**Step 1**: pixel based motion detection

from $f_l^{2D,k}$ – pixel $l$ in $2D$ filtered frame $k$

to $f_l^{3D,k-1}$ – pixel $l$ in $3D$ filtered frame $k-1$

$$m_l^k = \begin{cases} 0, & \text{if } |f_l^{2D,k} - f_l^{3D,k-1}| < T \\ 1, & \text{otherwise} \end{cases}$$

**Step 2**: motion -> **no change**. No motion -> **weighted average**

$$f_l^{3D,k} = \overbrace{m_l^k f_l^{2D,k}} + \overbrace{(1-m_l^k)[a\, f_l^{2D,k} + (1-a)\, f_l^{3D,k-1}]}$$

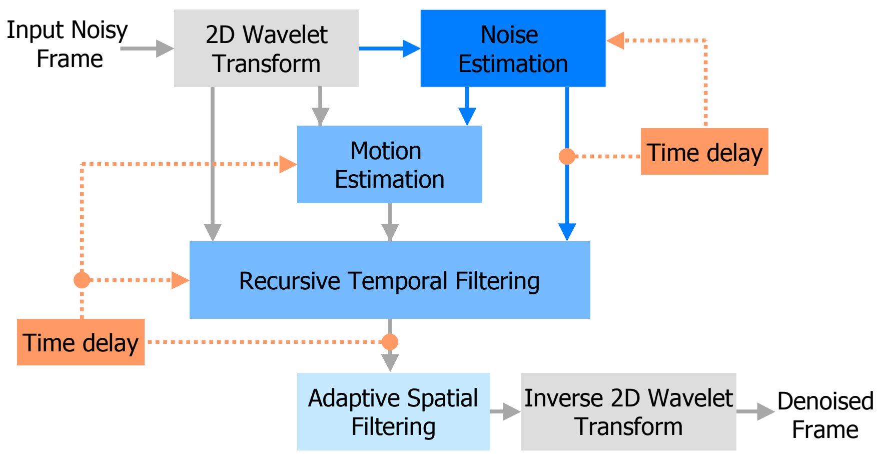


# Advanced filters: motion compensated wavelet domain video denoising

Some parts based on Ph. D. thesis of V. Zlokolica and engineering thesis of Bart Goossens

Ghent University

# Motion compensated wavelet domain denoising




Developed by V. Zlokolica, Ghent University



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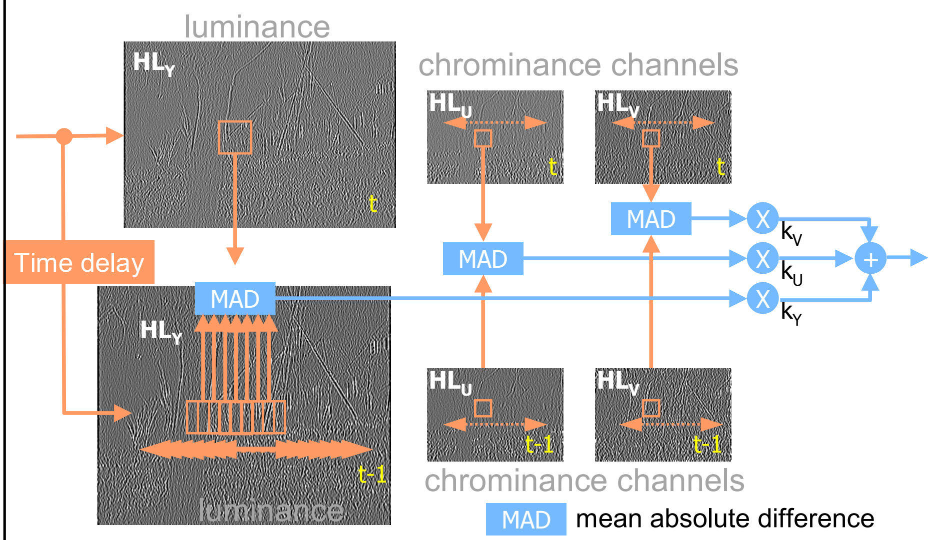
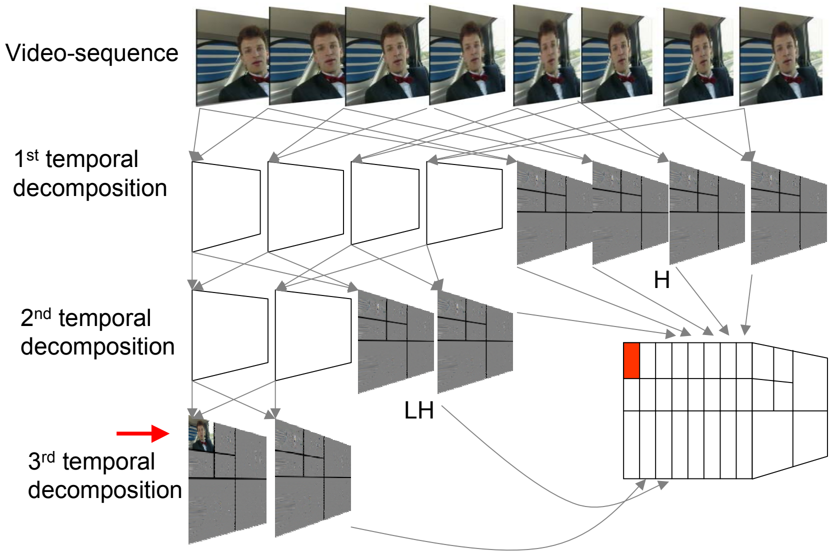
# Wavelet domain block matching



# Motion compensated 3D wavelet lifting

B. Goossens, master thesis, Ghent University







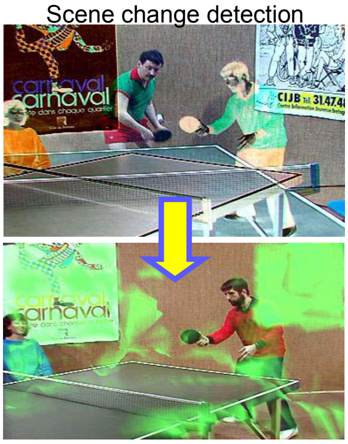


# Motion compensated 3D wavelet lifting

Some challanges:

Ghost artefact reduction

Scene change detection



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