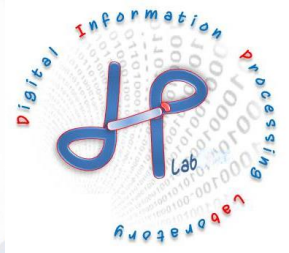
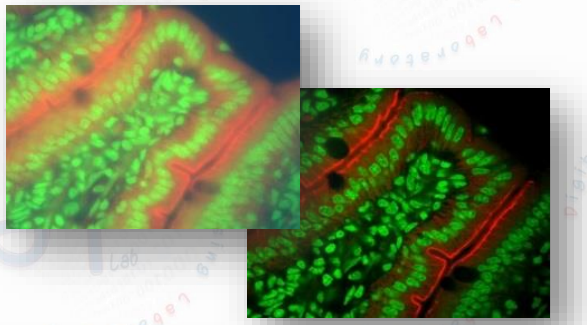
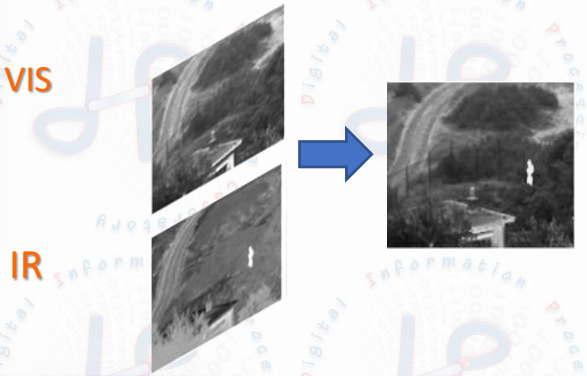
Classical multiscale analysis@DIPLab

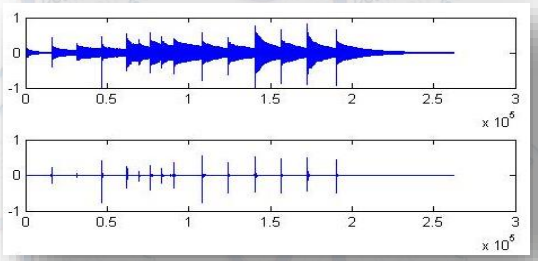


Tools

- ✓ Multiscale of models and methods for
  - ✓ *quality enhancement* (*denoising, deblurring, fusion*);
  - ✓ *data compression*
  - ✓ feature extraction:
    - ✓ *image segmentation*
    - ✓ *edge detection*
    - ✓ *transients detection*

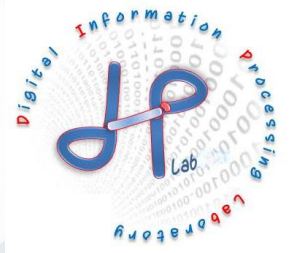






Classical multiscale analysis@DIPLab:

… a bit of theory



Wavelets in signal and image processing

Different problems…..

- ***de-noising***: $g(t) = f(t) + \nu(t) \quad t \in \mathbf{R}$

  to separate original information f from noise ν

  - *for recovering original data: classical denoising problem*
  - *for extracting noise*

- ***image enhancement***: *better image quality (image deblurring, contrast adjustment)*

- ***signal and image compression:*** *to select few and representative elements*

- ***image segmentation, features extraction, object tracking:***

  to detect those elements subjected to some constraints

……one common goal

best transform/expansion basis (*sparse representation)*

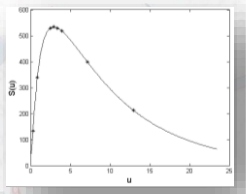
…lets family

Nice wavelet properties

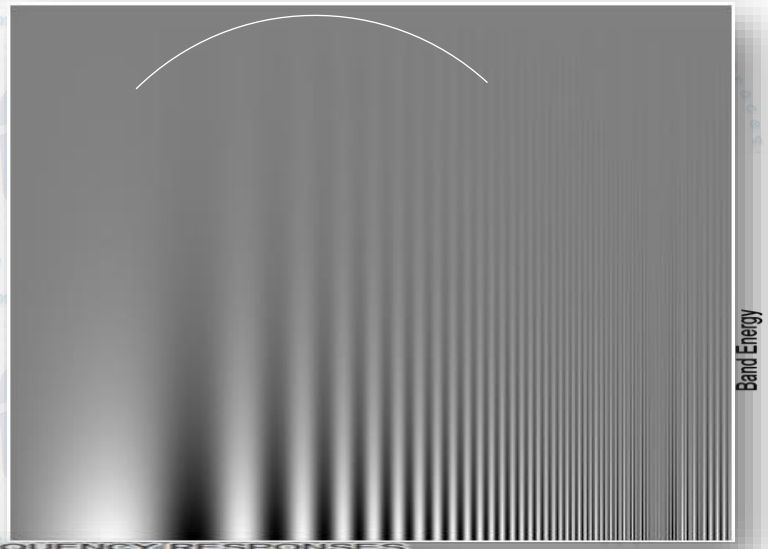
- Compact support → local information
- Vanishing moments and regularity → singularities characterization
- MultiResolution Analysis -MRA (filter bank) → fast implementation

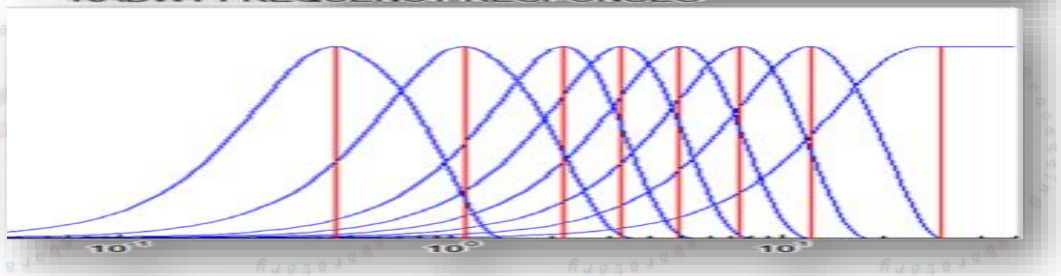
… but

Real-world requires adaptive frequency/scale

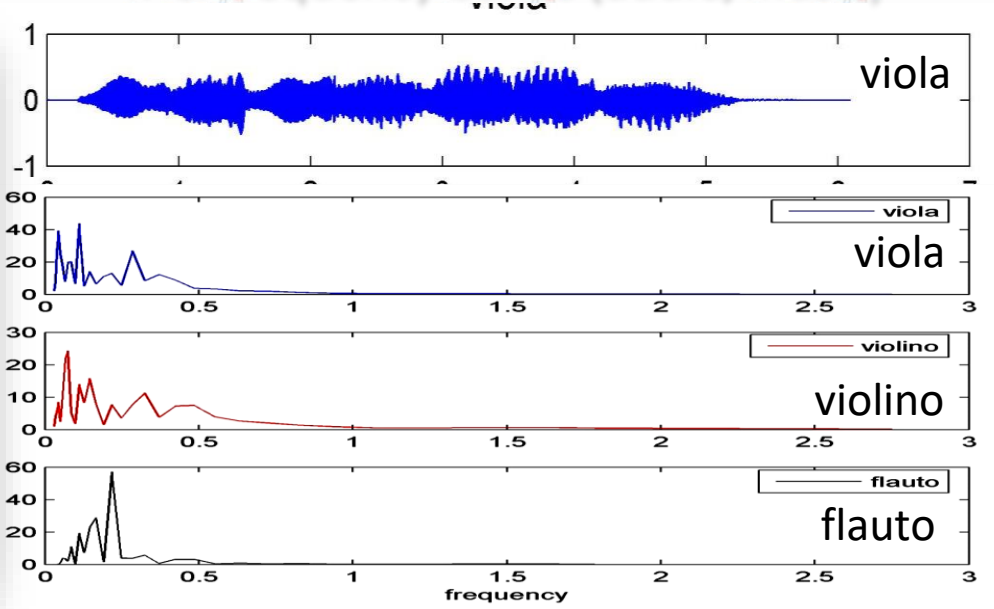


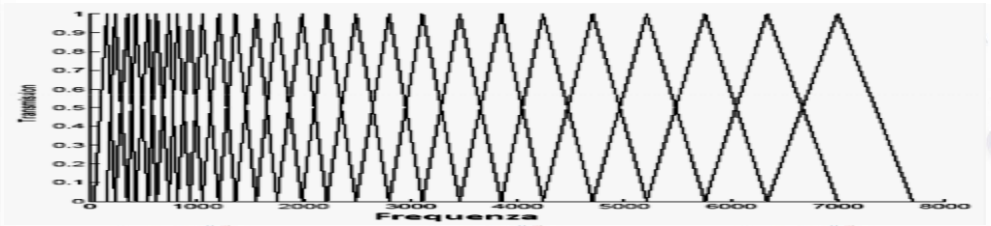
Contrast sensitivity (vision)



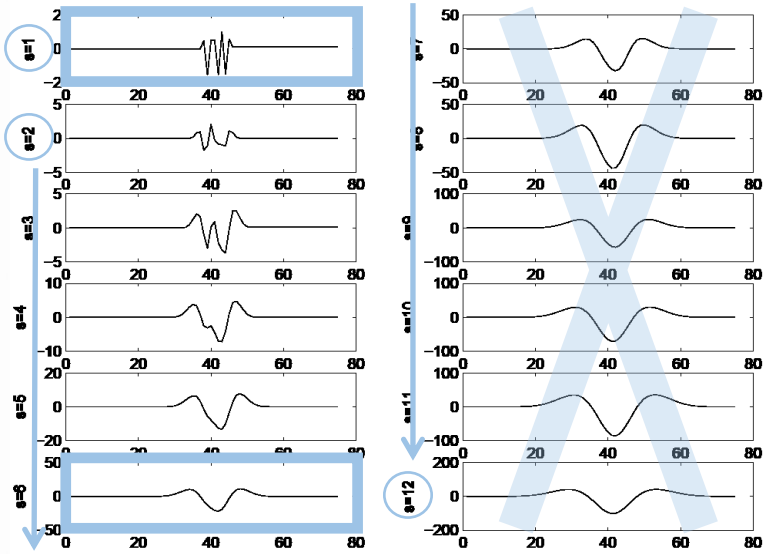


Mel frequency bands (audio/music)





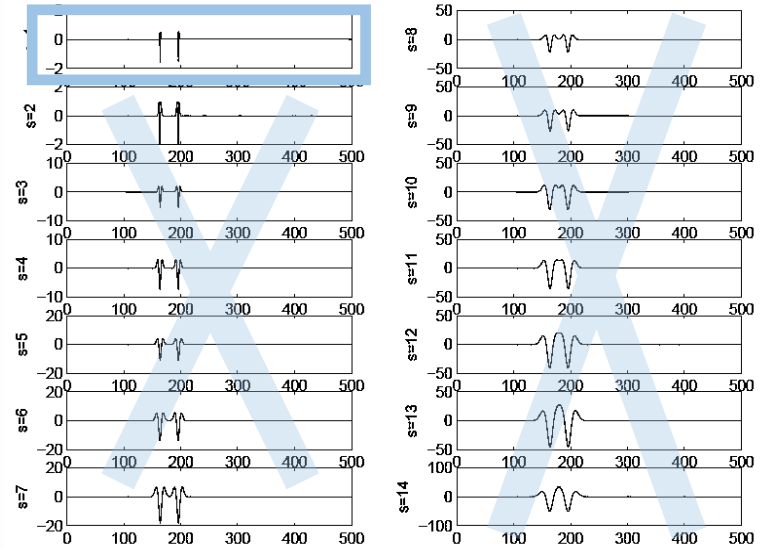
Solutions?



scale redundancy

New wavelets families

scale-dependent support length
and/or number of vanishing moments
while preserving MRA



Non linear transform

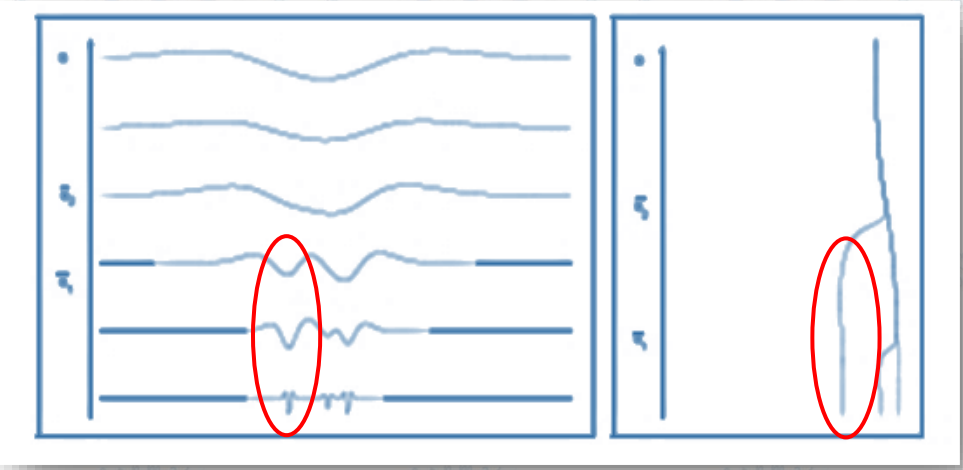
non linear/non local operators
applied to the transfom

(both in scale and time)

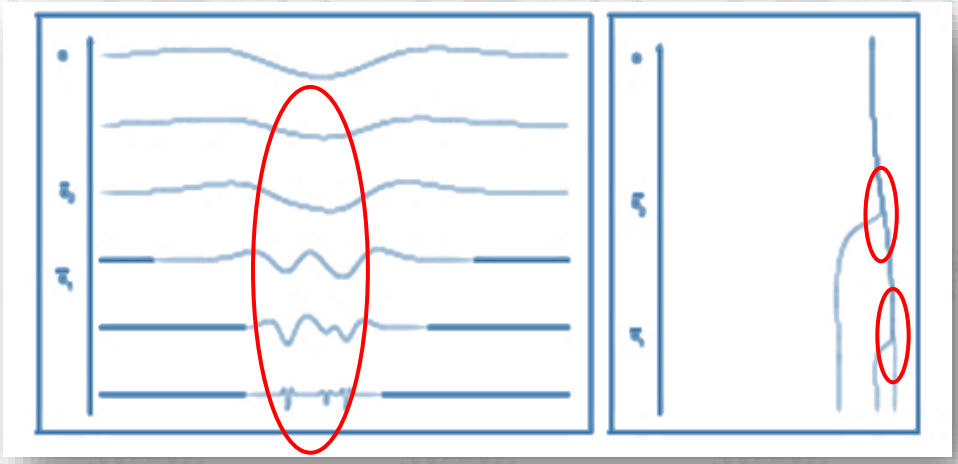
Maxima chains

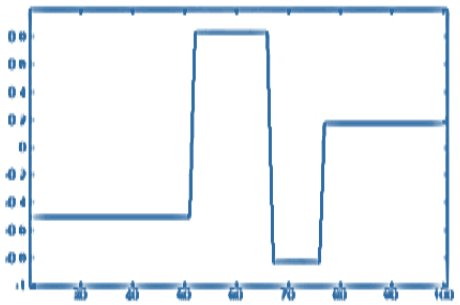
Points characterization through the multiscale behaviour

isolated



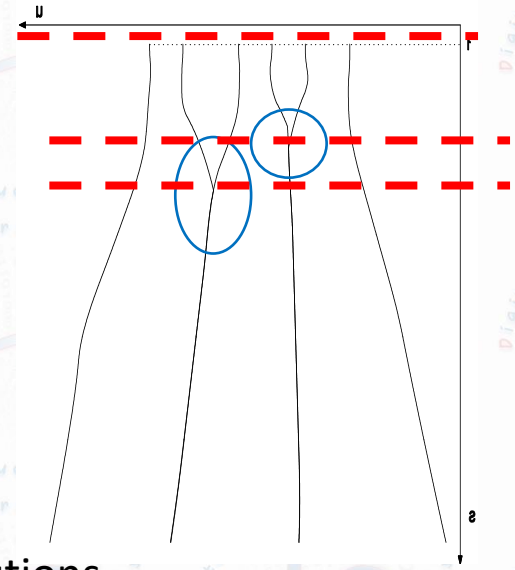
interfering





Exploit time-scale interactions:

- **self similarities**
- **scale prediction**
- **adaptive scale selection**
- slowing interaction

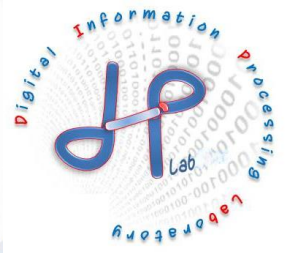


Advantages:

- ✓ Combine information at different resolutions
- ✓ Compaction properties
- ✓ Extraction of features of interest
- ✓ Optimized computational methods

Classical multiscale analysis@DIPLab:

some applications

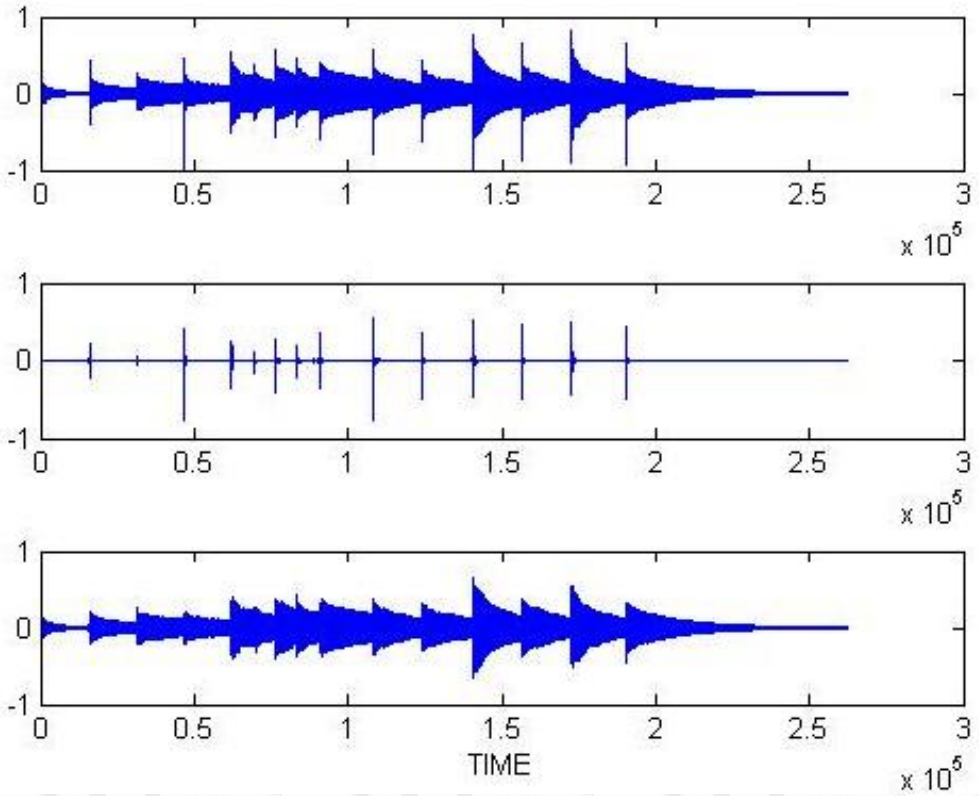


Transients detection in audio signals

Maxima chains for:
- **adaptive scale selection**
- **scale prediction**

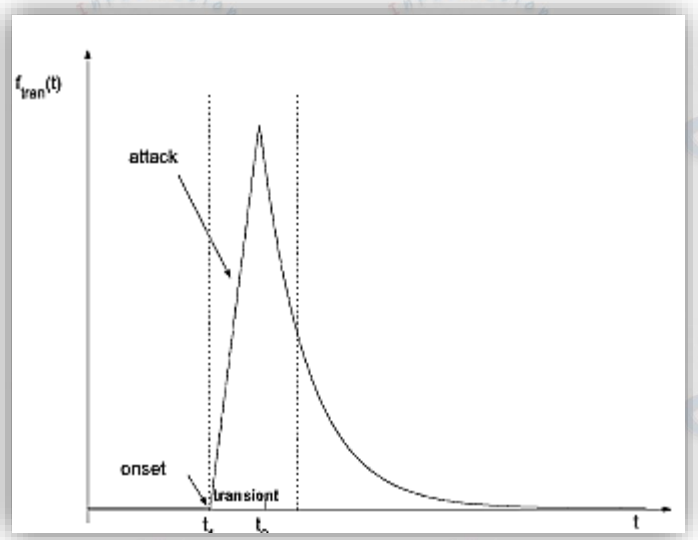
Audio signals

- *Transients: attack of the notes or abrupt changes in the sound*
- *Tonal: harmonic nature of the signal*



Original signal

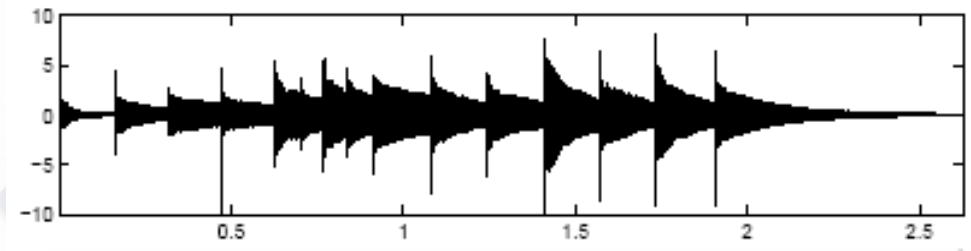
Transients

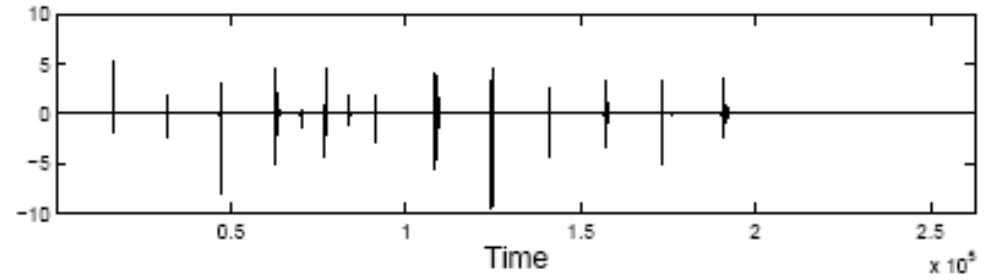


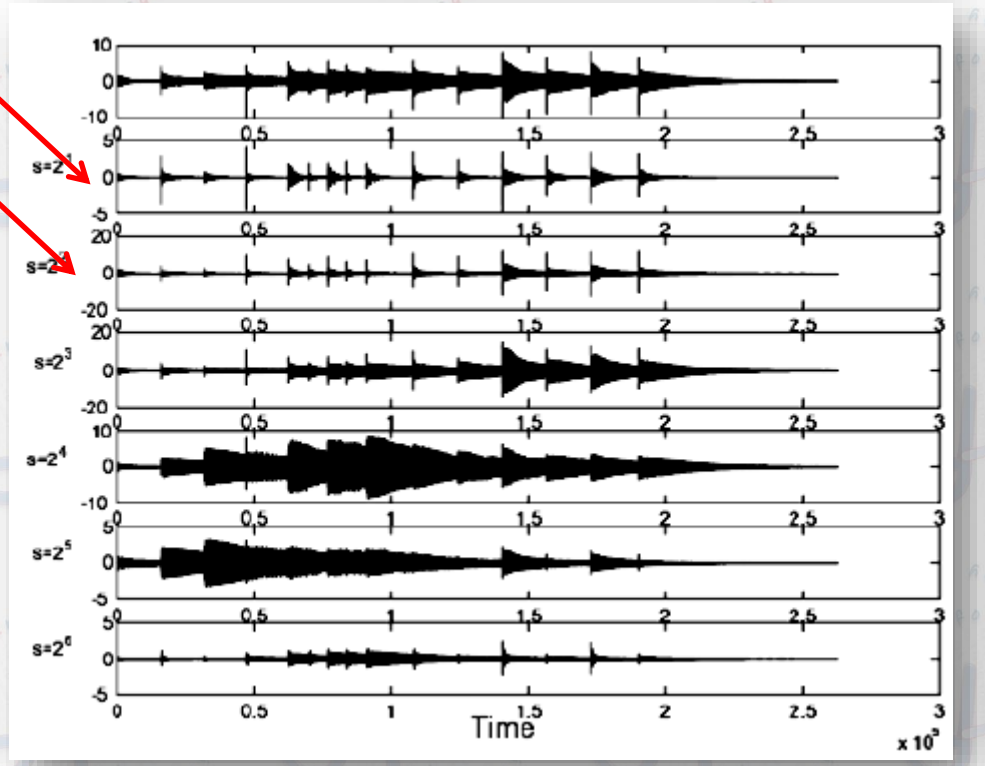
Tonal component

Maxima chains for:
- adaptive scale selection
- scale prediction

multi-scale characterization of transients







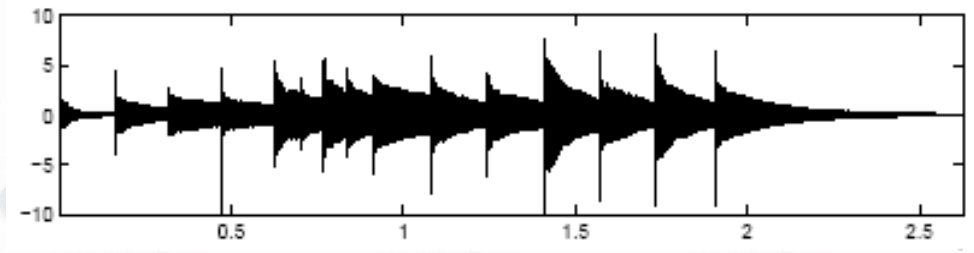
Transients are isolated singularities in the original signal

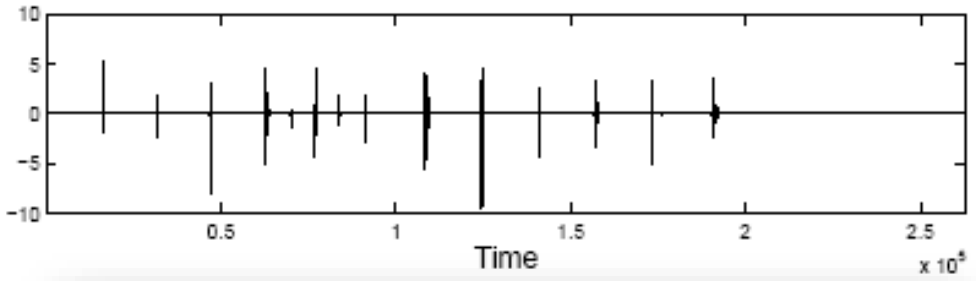
Time-scale behaviour is localized inside the cone of influence

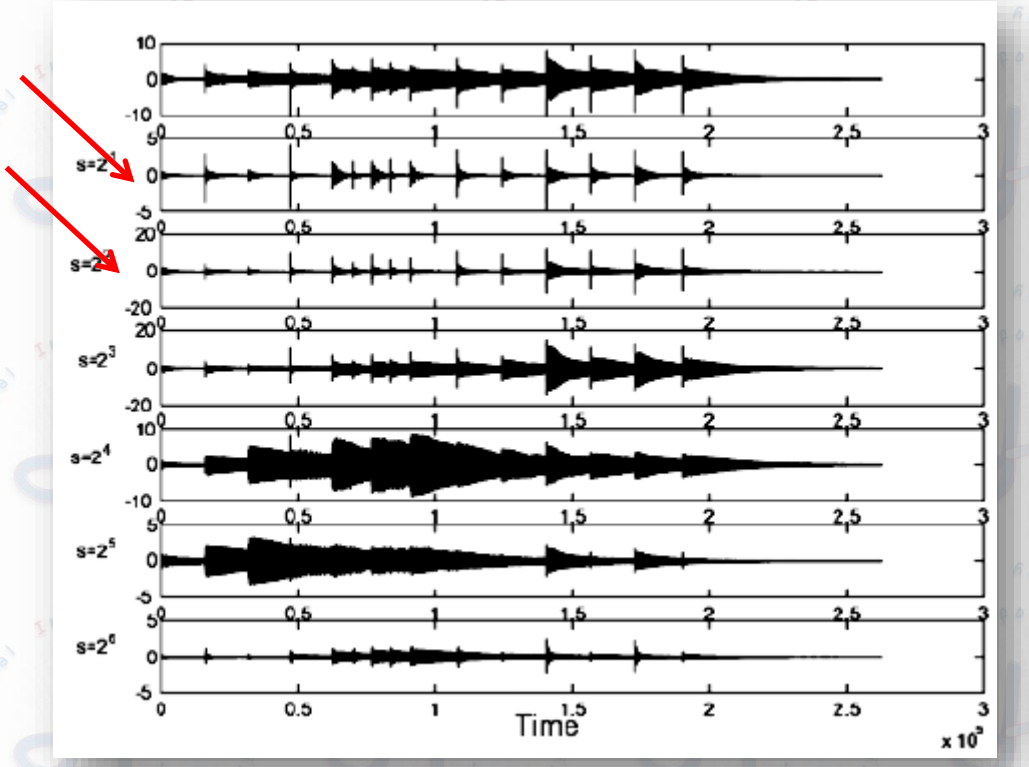
- ✓ Transients detection at «good» scales
- ✓ Prediction of transients contribution at the remaining scales

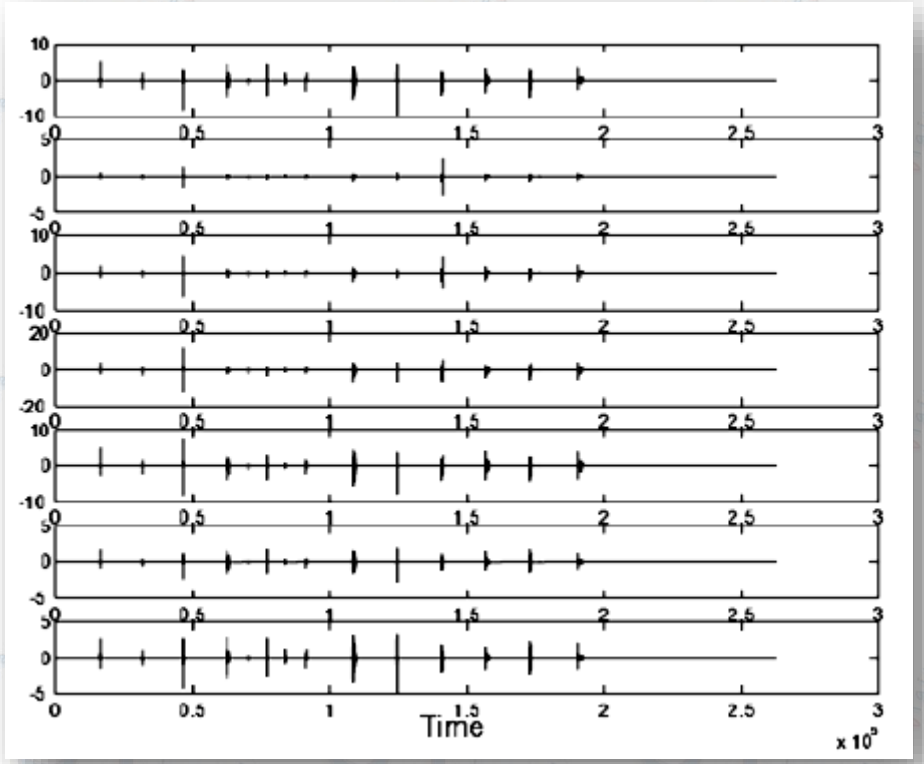
Maxima chains for:
- adaptive scale selection
- scale prediction

multi-scale characterization of transients









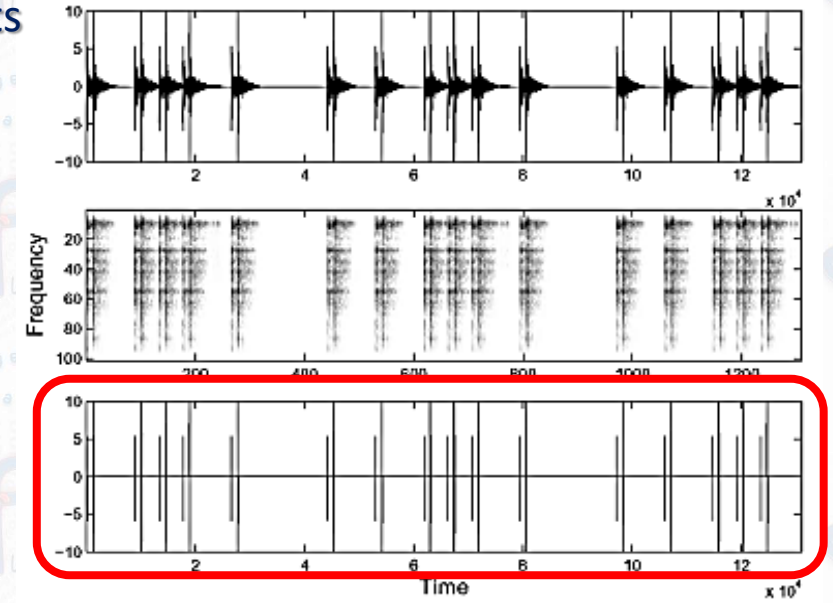
Maxima chains for:
- **adaptive scale selection**
- **scale prediction**

Castanets

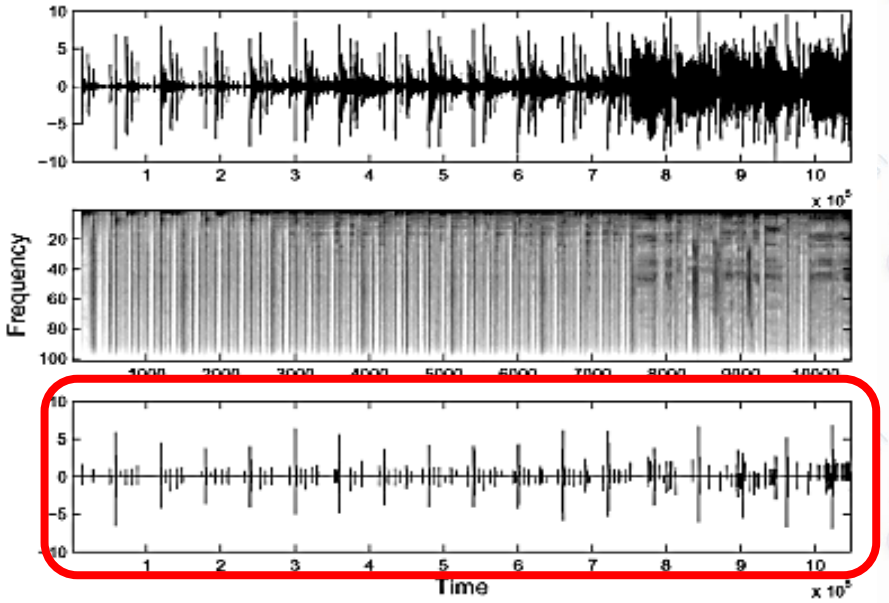
Original signal

Time-frequency distribution

Extracted transients



Mamavatu

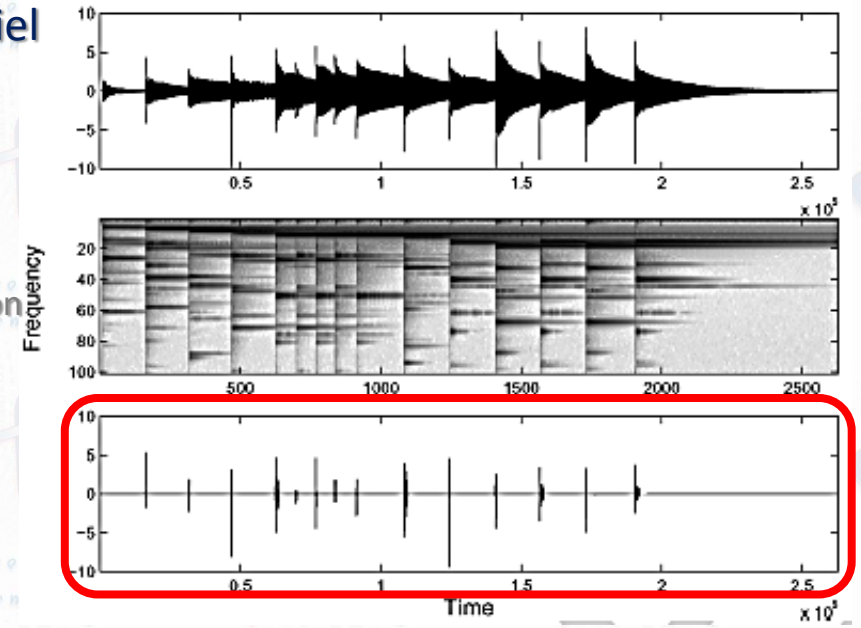


Glockenspiel

Original signal

Time-frequency distribution

Extracted transients



Xylophone

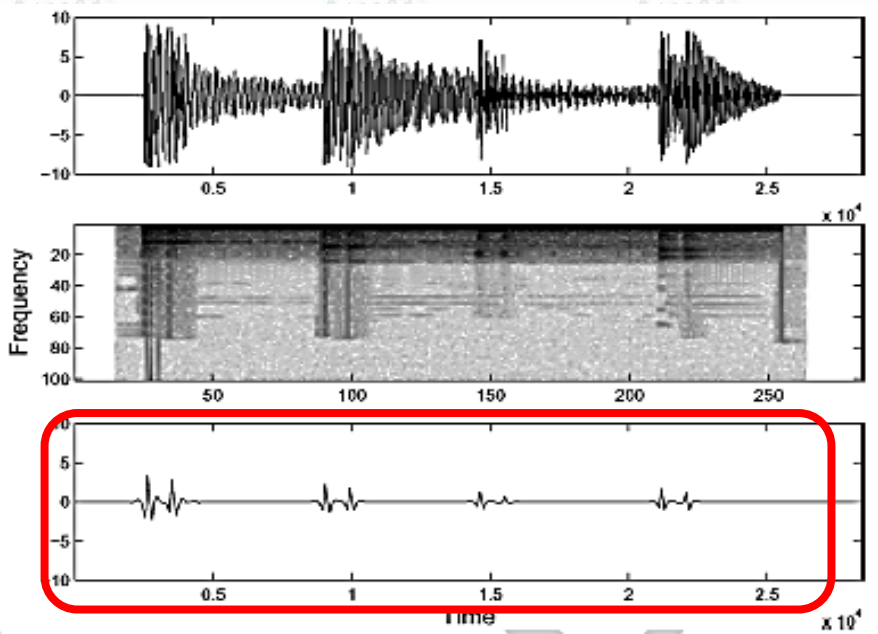


Image denoising

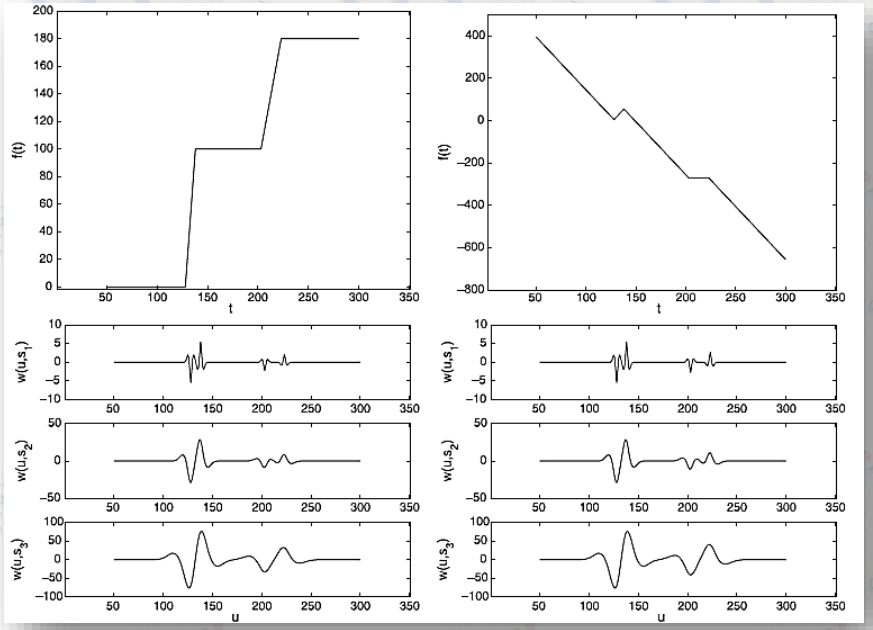
Noise: global degradation

Maxima chains for:
- **self similarities**
- **scale prediction**

Maxima chains for

- **self similarities**
- **scale prediction**

different signals same wavelet details → Similarities in the time-scale plane



Modulus maxima trajectory depends on

- ✓ the distance from neighbouring atoms
- ✓ the ratio between their amplitudes
- ✓ the difference between their growing exponents

Advantages:

- ✓ multiscale restoration
- ✓ edges and texture preservation
- ✓ reduced oversmoothing

Noisy image (σ=25)
(PSNR = 20.01db)

Noisy image
(σ=20)
(PSNR = 22.06db)

Denoised image
(PSNR = 31.51db)

Denoised image
(PSNR = 32.45db)

Maxima chains for:
- **self similarities**
- **scale prediction**

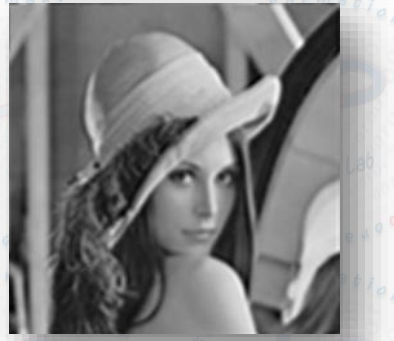
Advantages:
- ✓ multiscale restoration
- ✓ edges preservation
- ✓ texture preservation
- ✓ reduced oversmoothing

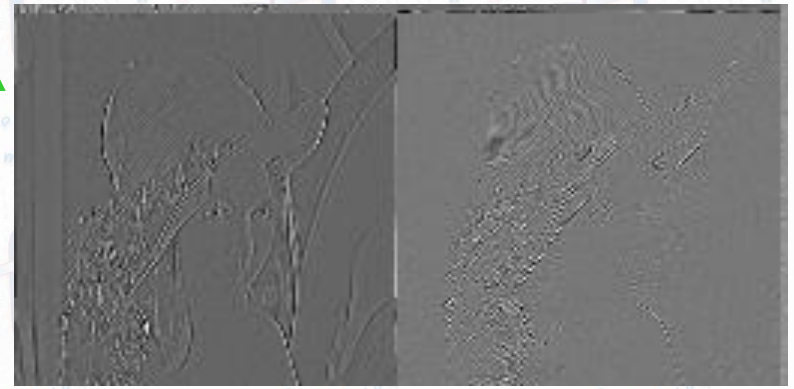
Image compression

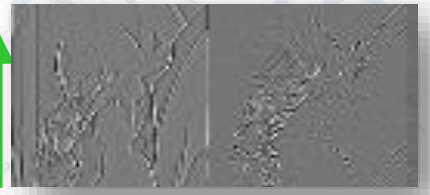
Maxima chains for

- **scale prediction**

Maxima chains for:
- **scale prediction**







s_{n-1}

$s_{n-1}+\Delta s$

s_n

Evolution law

$s_n+\Delta s$

from coarse to fine scales

Advantages:

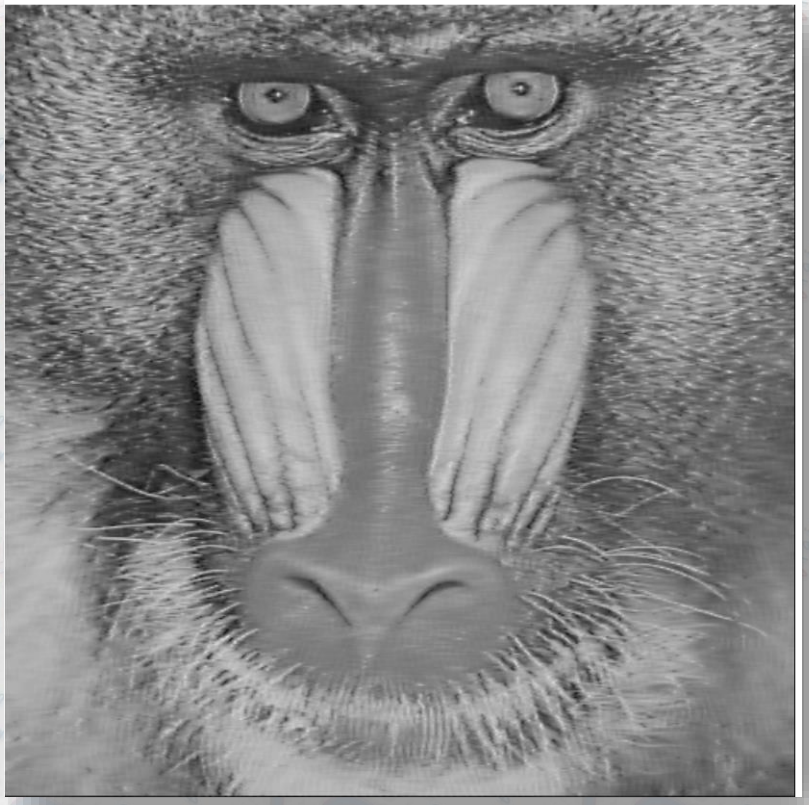
- ✓ progressive algorithm
- ✓ details preservation

Image compression

Maxima chains for

- **scale prediction**

512x512 *Lena image*
bpp = 0.3 PSNR = 35.59 db
Compression factor: **27:1**



512x512 *Baboon image*
bpp = 0.24 PSNR = 24.90 db
Compression factor: **33:1**

Advantages:

- ✓ progressive algorithm
- ✓ details preservation

Image forgery detection

Maxima chains for:
- self similarities

Original image

Forged image

Forged regions

Forgery is detected as points having the same time-scale characterization

Advantages:

- **precision (local method)**
- **reduced number of features**
- **low computing time**

Maxima chains for:
- self similarities

Input image

Feature extraction from the image blocks

Feature matching and filtering

Detection result

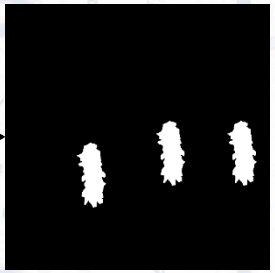
Image transformation

Partition into overlapping blocks

Features extraction

Matching process for block pairs

Post processing (Morphological operations)



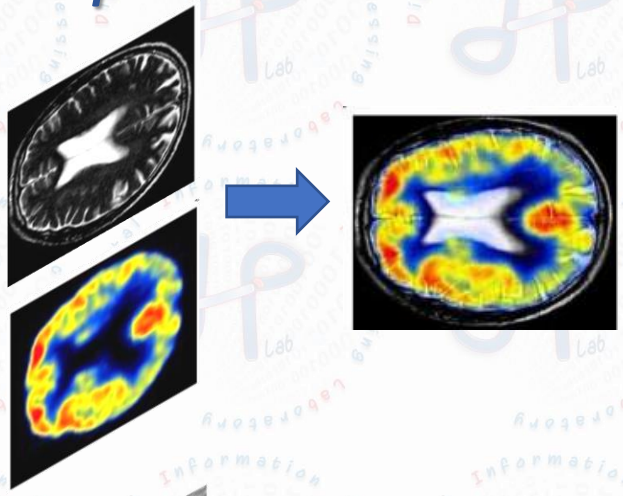
Forgery is detected as points having the same time-scale characterization

The image fusion problem

Maxima chains for:
- adaptive scale selection

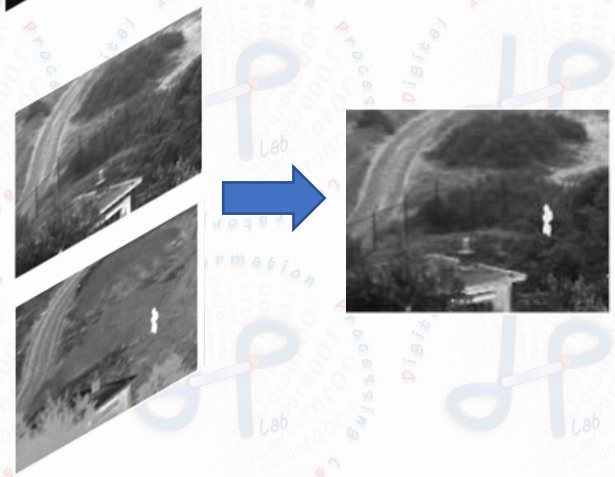
MRI

PET



Visible

Infrared

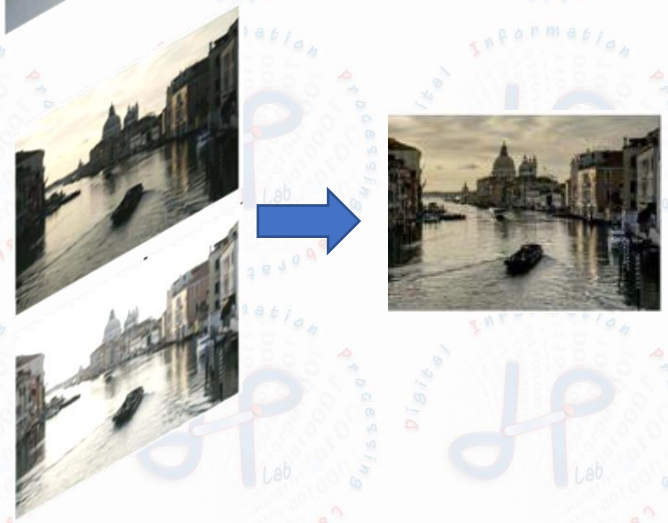


Day

Night

Under exposure

Over exposure



N source images

different sensors ,
acquisition modes/ conditions/time, ….

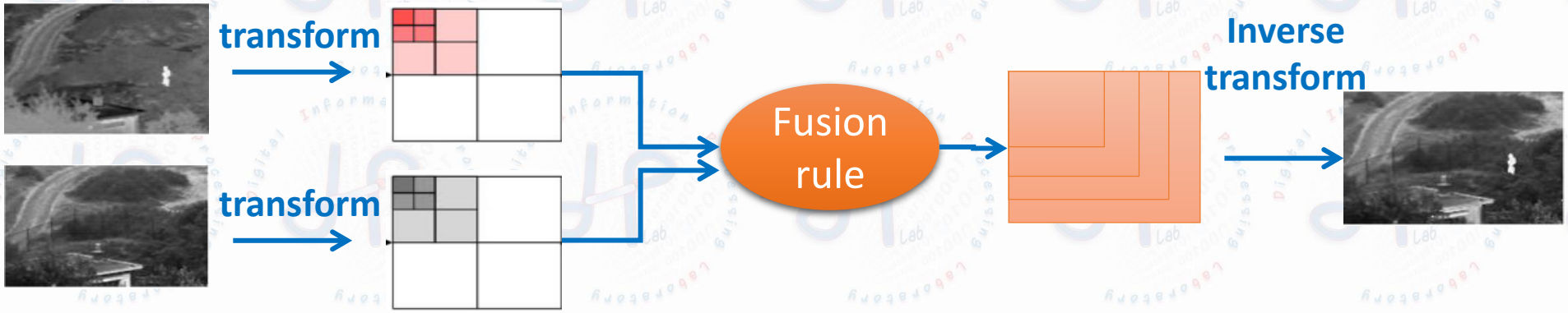
ONE image

more accurate and detailed
data description

Fusion method: Multiscale/time-frequency transforms

IR-VI image fusion

Maxima chains for:
- adaptive scale selection



IR and VI images have different:

- **spectral distribution**
- **visual content**
- **local activity**

✓ Adaptive multiscale transform
✓ Visual dependent frequency axis partition
✓ Proper local activity weights for the fusion rule

Multiscale Lipschitz regularity

RDWT
(Rational dilation wavelet transform)
+
CSF
(Contrast Sensitivity Function)

Maxima chains for:
- adaptive scale selection

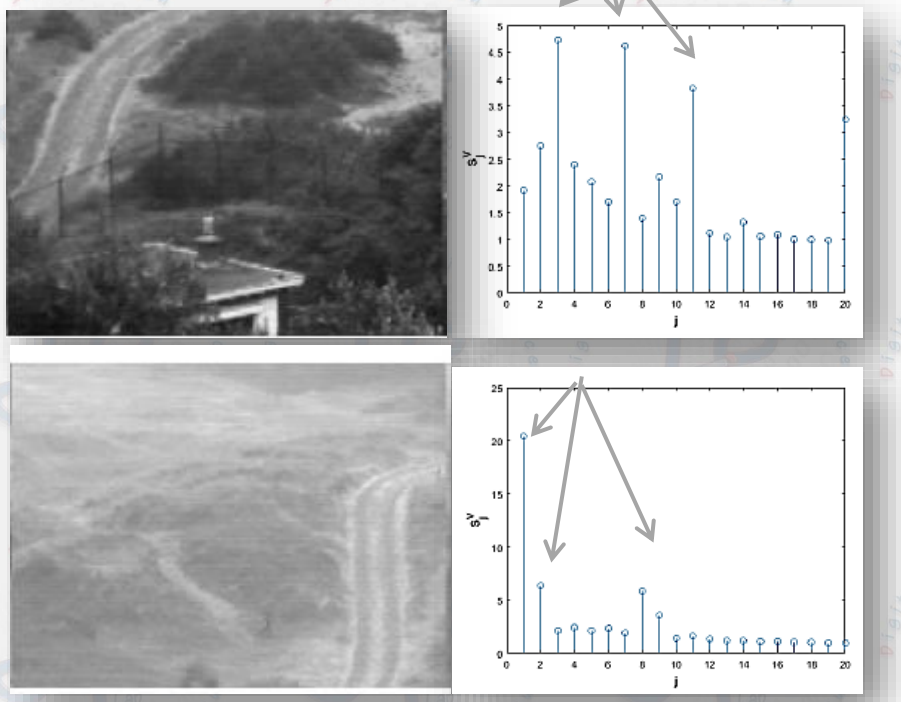
Multiscale local activity for adaptive RDWT

Design a filter bank with bandwidths adapted to subband activity

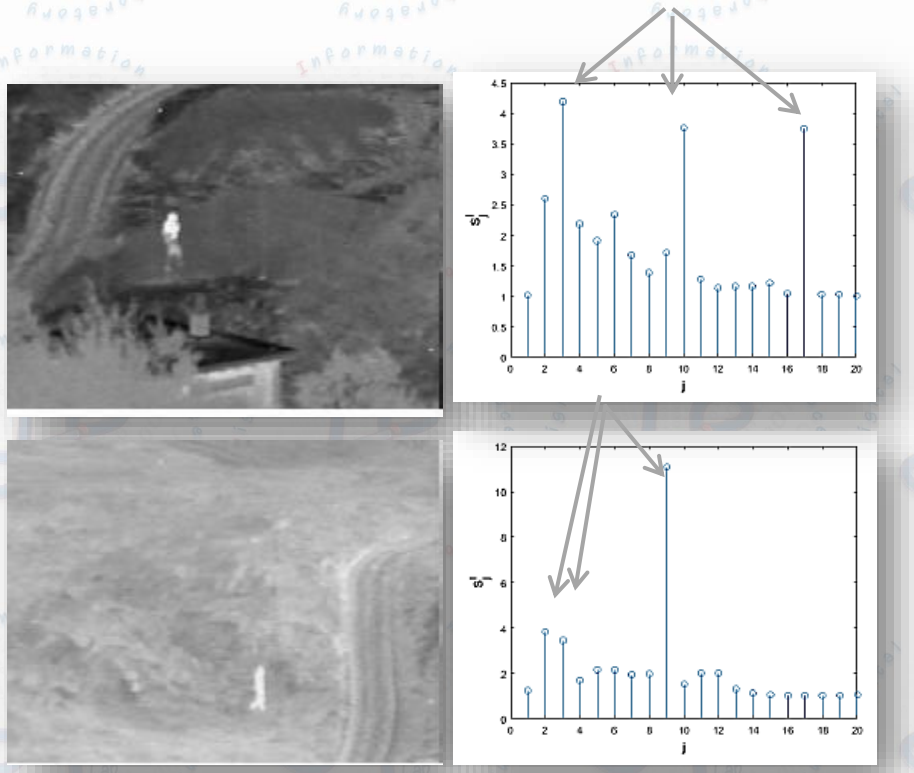
Reduce subband redundancy

RDWT with non constant dilation factor

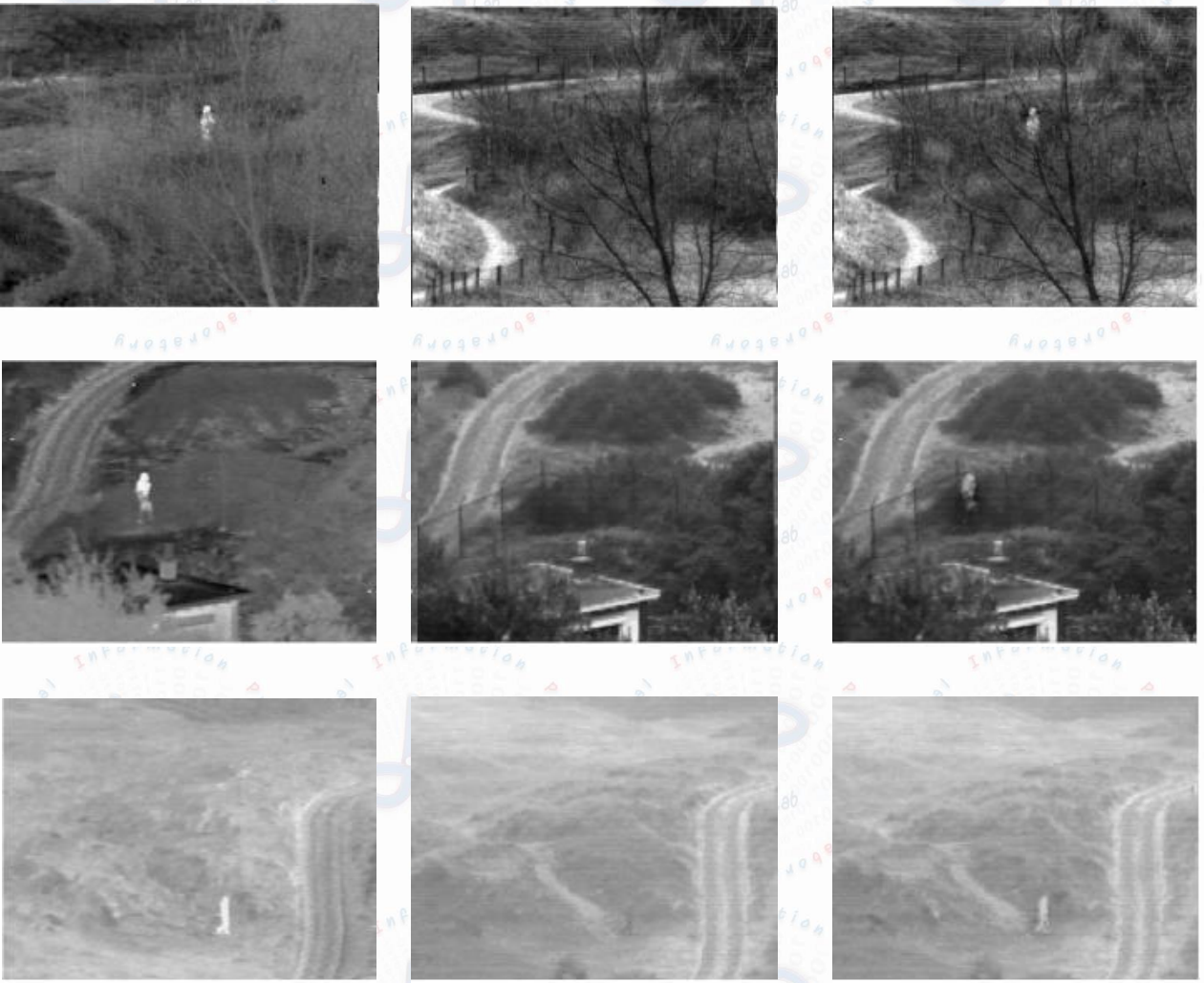
Significant subbands



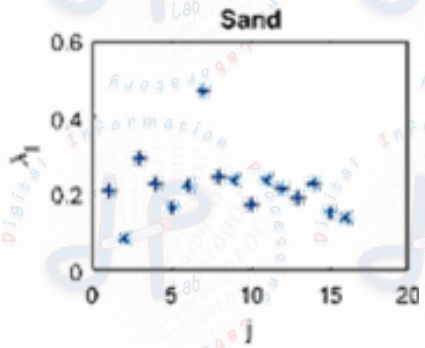
Significant subbands

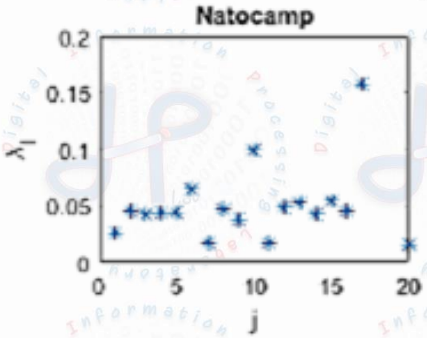


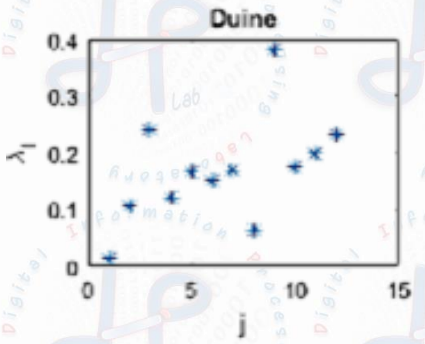
IR **VI** **Fused**



Weights depend on image content







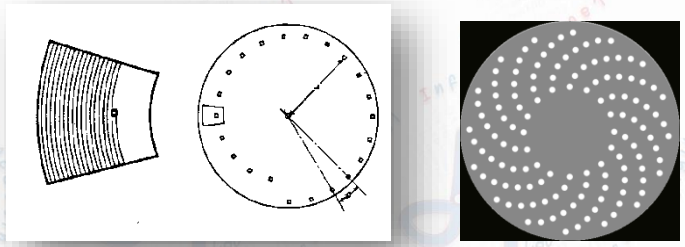
Maxima chains for:
- **adaptive scale selection**

Advantages:

- ✓ *small but significant objects from IR image are preserved*
- ✓ *visible information is preserved*
- ✓ *halo or ringing artifacts are missing*

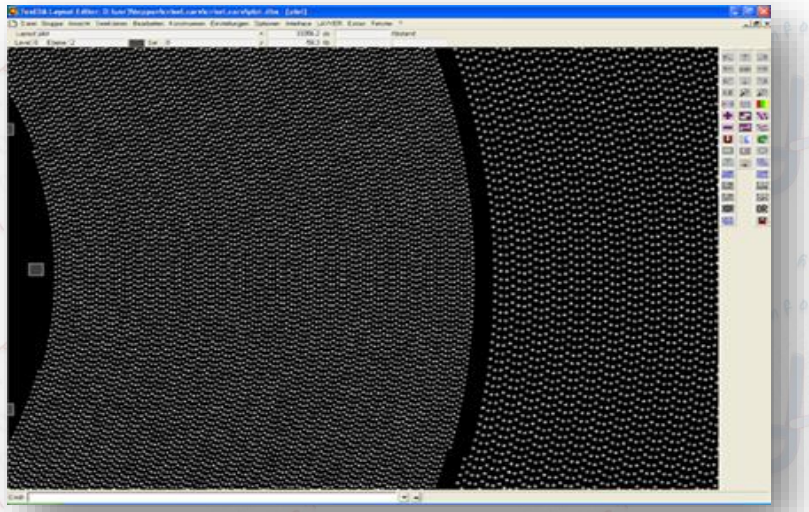
Confocal microscopy

- Design of novel patterns for the spinning disk (novel grid on the disk)



- Definition of a protocol for image acquisition

- Development of enhancement methods for increasing image resolution



✓ Acquisition replicates approximation bands of a wavelet transform

✓ Processing consists of blind deconvolution with exact PSF estimation

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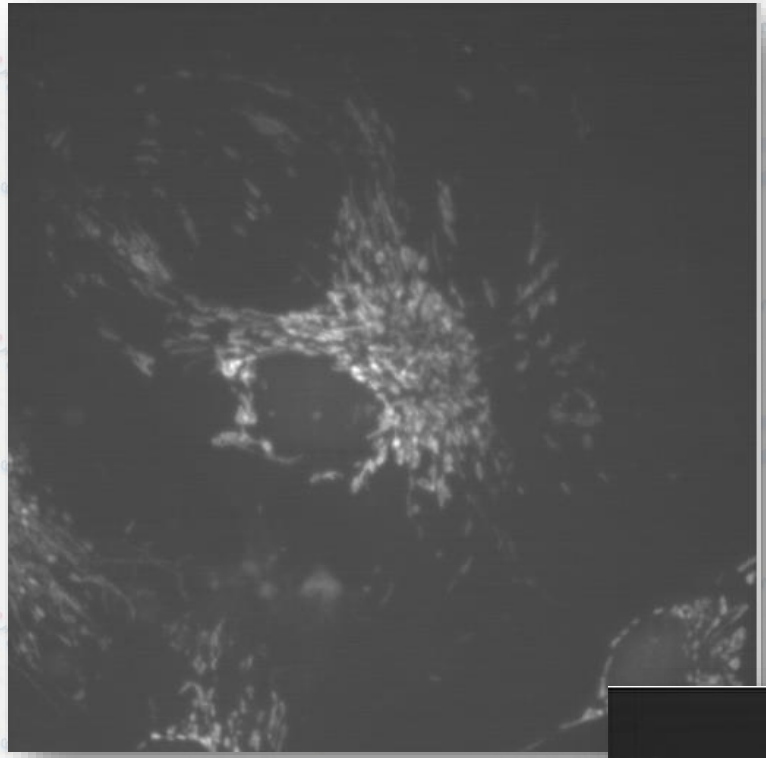
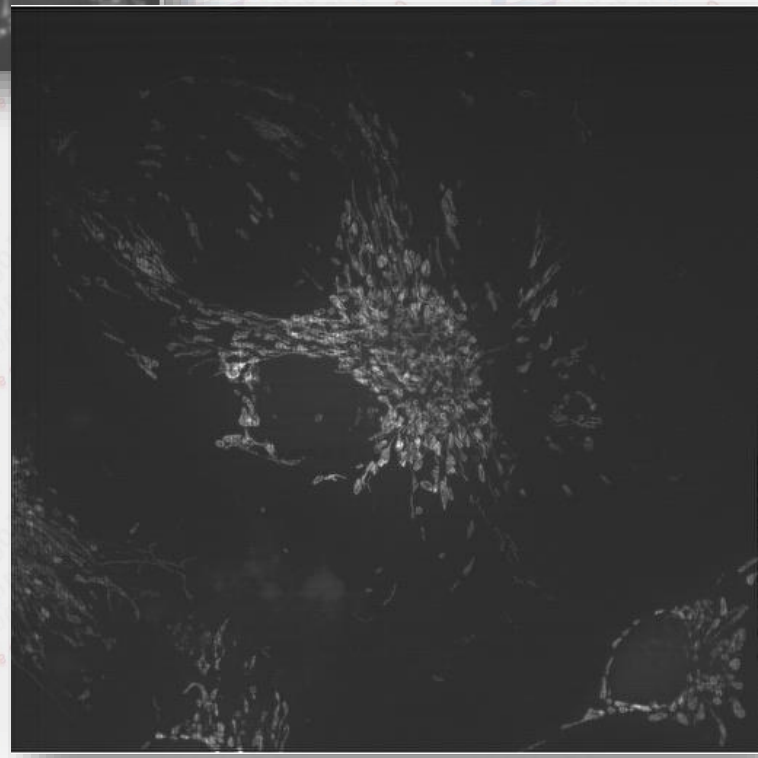
Confocal microscope and related process of acquiring and processing images

- Design of novel patterns for the spinning disk (novel grid on the disk)
- Definition of a protocol for image acquisition
- Development of enhancement methods for increasing image resolution



standard spinning disk

novel pattern + data processing method



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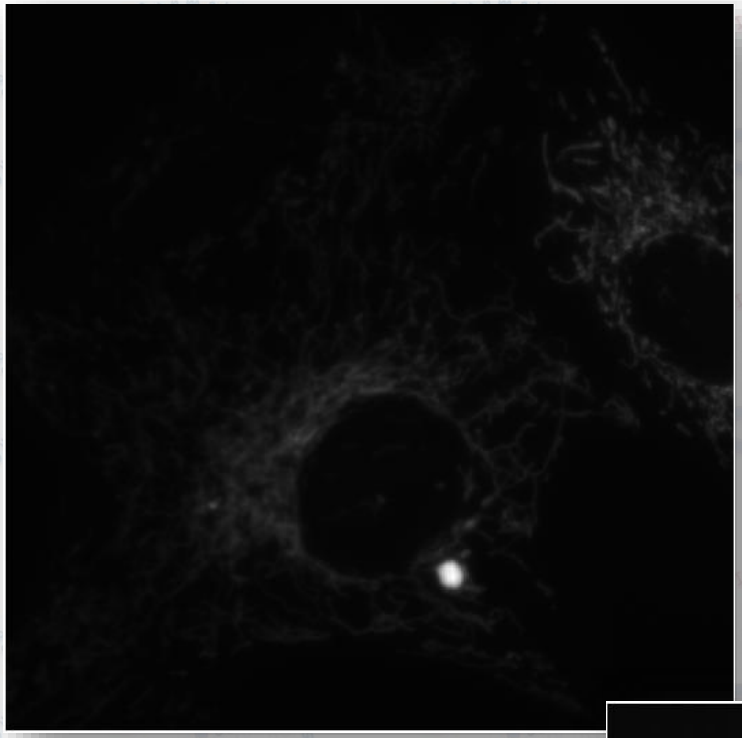
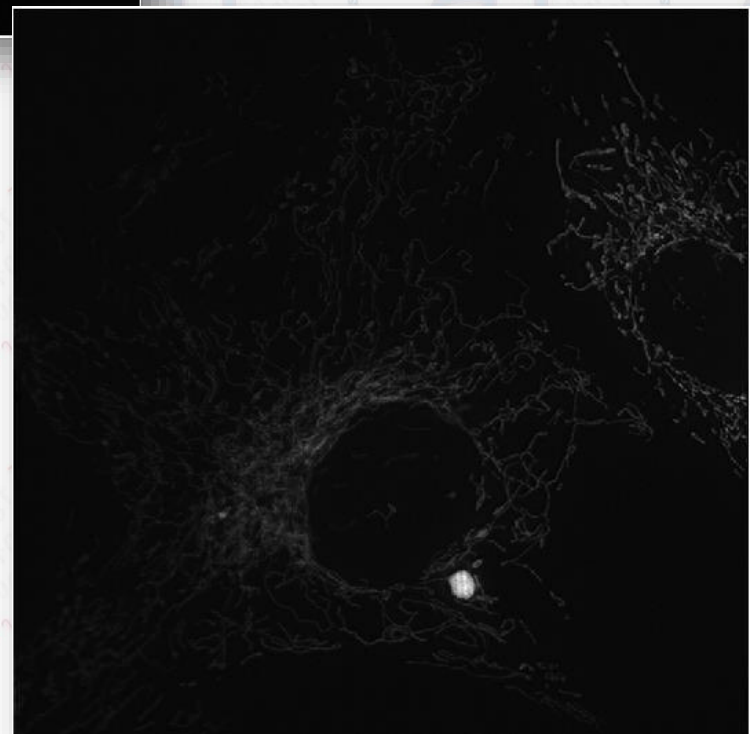


novel pattern

novel pattern +
data processing method



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