Florence 2002

Efficient Coherent Noise Filtering

An application of shift-invariant wavelet denoising

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Scope of the paper

- Ground-roll (surface waves removal)
  - complex issue in land seismic processing
- Recent techniques
  - model based/adaptive
    - Soubaras (EAGE 2001)
  - wavelets/packets/frames/pursuit
    - Deighan & Watts (EAGE 1998)
    - Castagna, Mars, Ulrych
- Focus on 2-D experiments
  - assessment on 3-D geometries coming

Overview

- Some wavelet facts
  - the continuous
  - the discrete (filter bank)
  - the overcomplete: shift-invariant wavelets (SI)
- The results
  - classical wavelets vs. SI-wavelets
  - small challenges: aliasing, gaps, wavelet choice
  - discussion on results
- Conclusions & discussion

A subset of requirements

- Wish list
  - improvements over established f-k filter
  - memory/storage burden
  - computational complexity (vs. Fourier/wavelet)
  - action on unsorted data (X-spread)
  - robustness to aliasing (wavefields)
  - robustness to acquisition gaps
- Some of them will be met
- ... and some not

The wavelet framework

- Continuous wavelets

$$s(t) \cong \sum K_{a,b}\left[1/\sqrt{a}\, w\left(\frac{t-b}{a}\right)\right]$$

- Discrete approximation

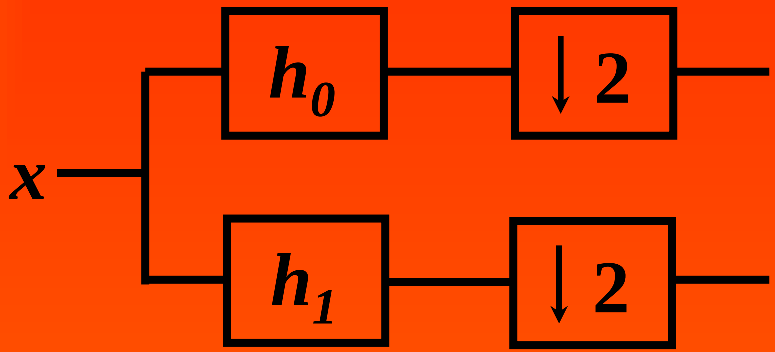
$$a = 2^{j}$$

$$b = 2^{j} n$$

- Filter bank implementation (Mallat, Daubechies)

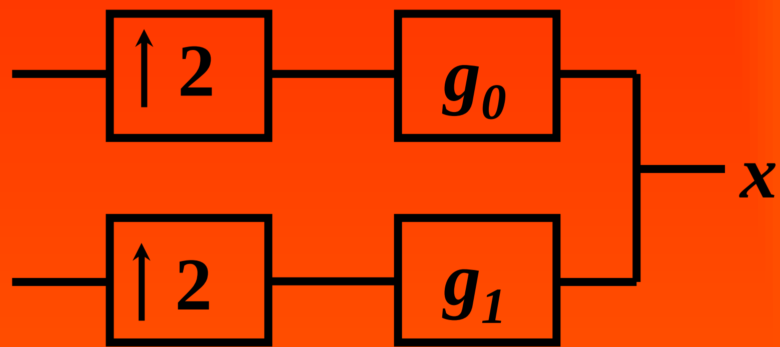
Classical discrete wavelet paradigm

- Analysis filter bank



Aliasing!

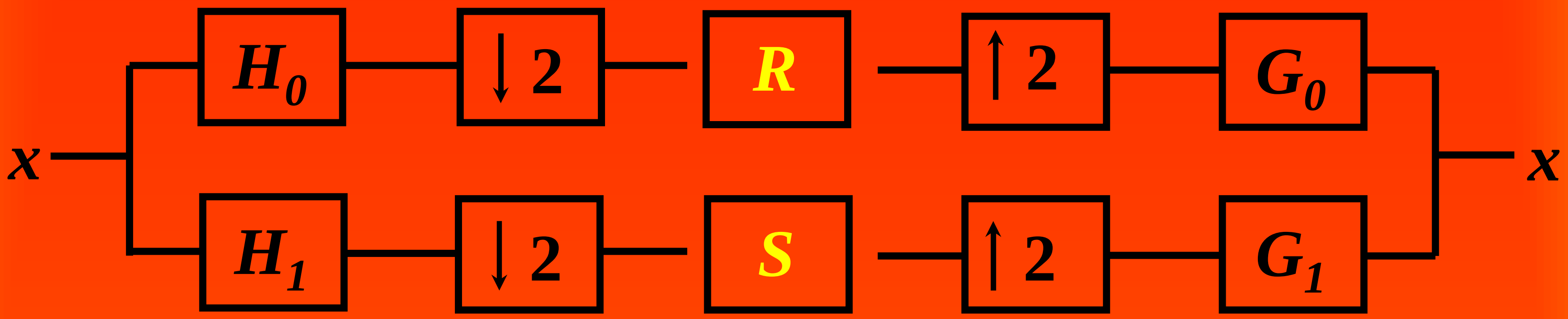
- Synthesis filter bank



Aliasing removed

- **Warning! No processing allowed in between**

DWT + denoising (1)



- With wavelet denoising...
  - (almost) everything breaks down:

    $G_0(z)H_0(z) + G_1(z)H_1(z) = 2z^{-d}$

    $G_0(z)H_0(-z) + G_1(z)H_1(-z) = 0$
  - gives

    $X(-z)H_0(-z)H_1(-z)[R(z^2) - S(z^2)] = 0$

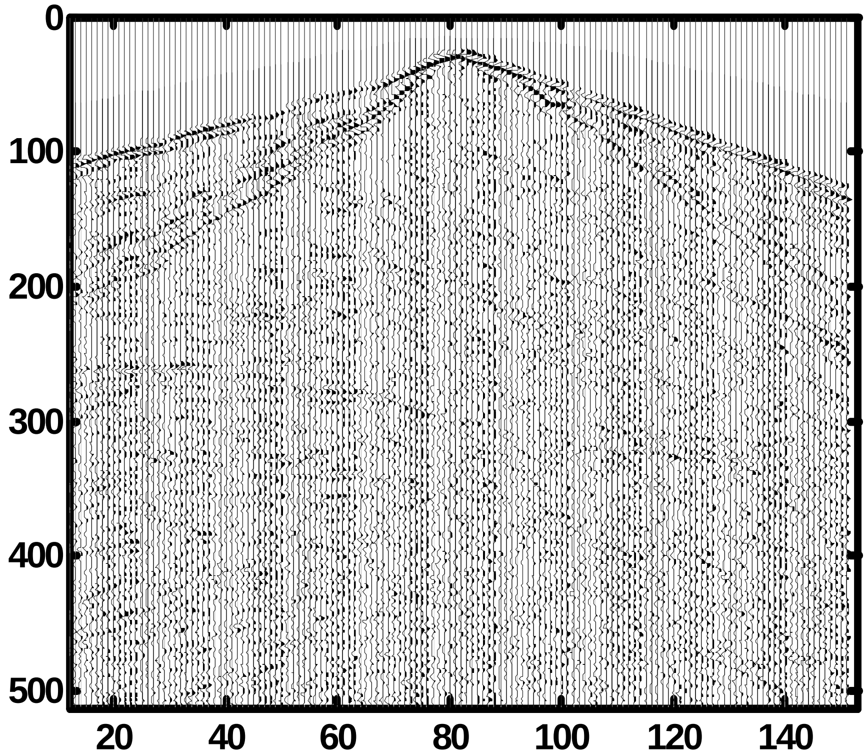
DWT + denoising (2)

- New solutions would be
  - filter dependant
  - signal dependant
  - scale dependant

- A simple choice would be
  - give up dependancy (for more freedom)
  - forget dowsampling/aliasing
  - redundant/denser wavelet approximation

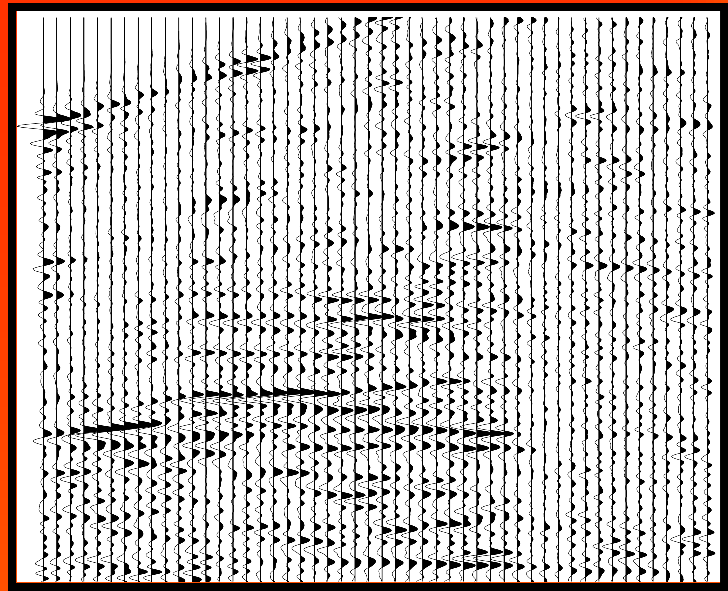
Results - Introduction- The data

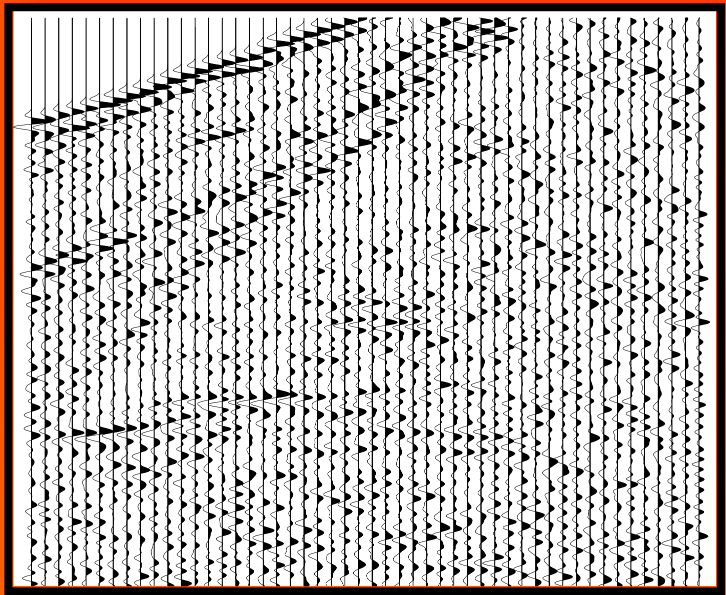
- Ground roll removal on a shot gather
- Challenges over classical wavelet
  - aliasing
  - gaps
  - wavelet sensitivity



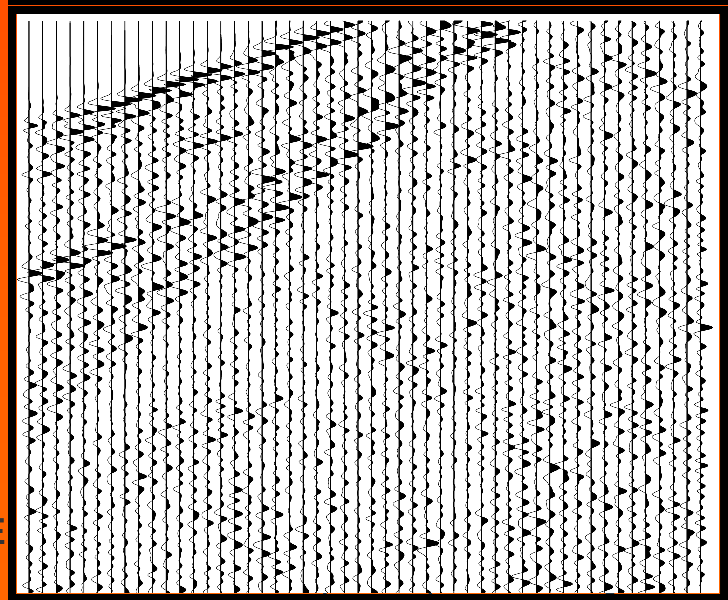
Results: signal/noise separation

Signal





Data

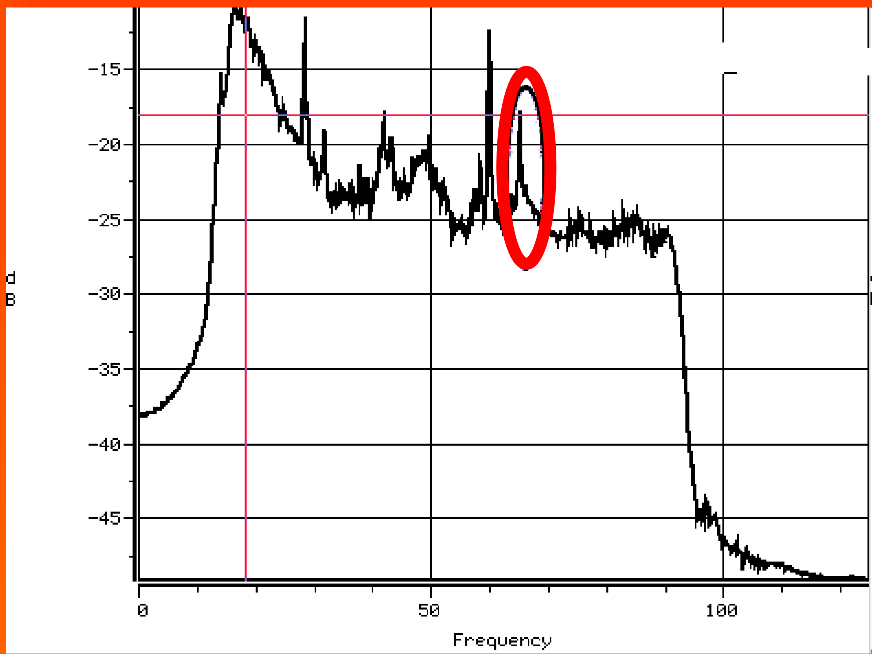


Noise

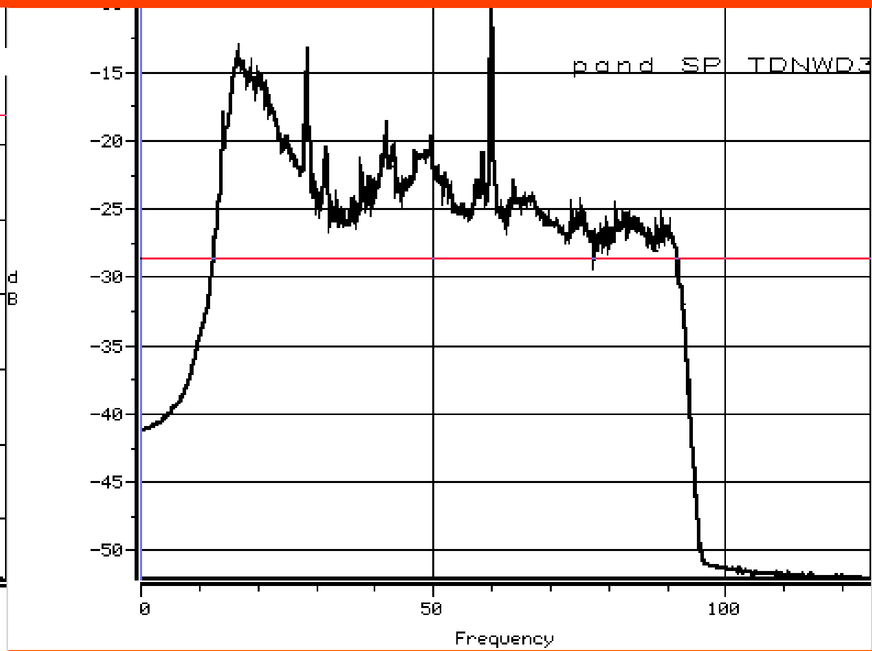
EAGE

Results: anti-aliasing breakdown

- 60 Hz aliasing in unfolded at 65 Hz

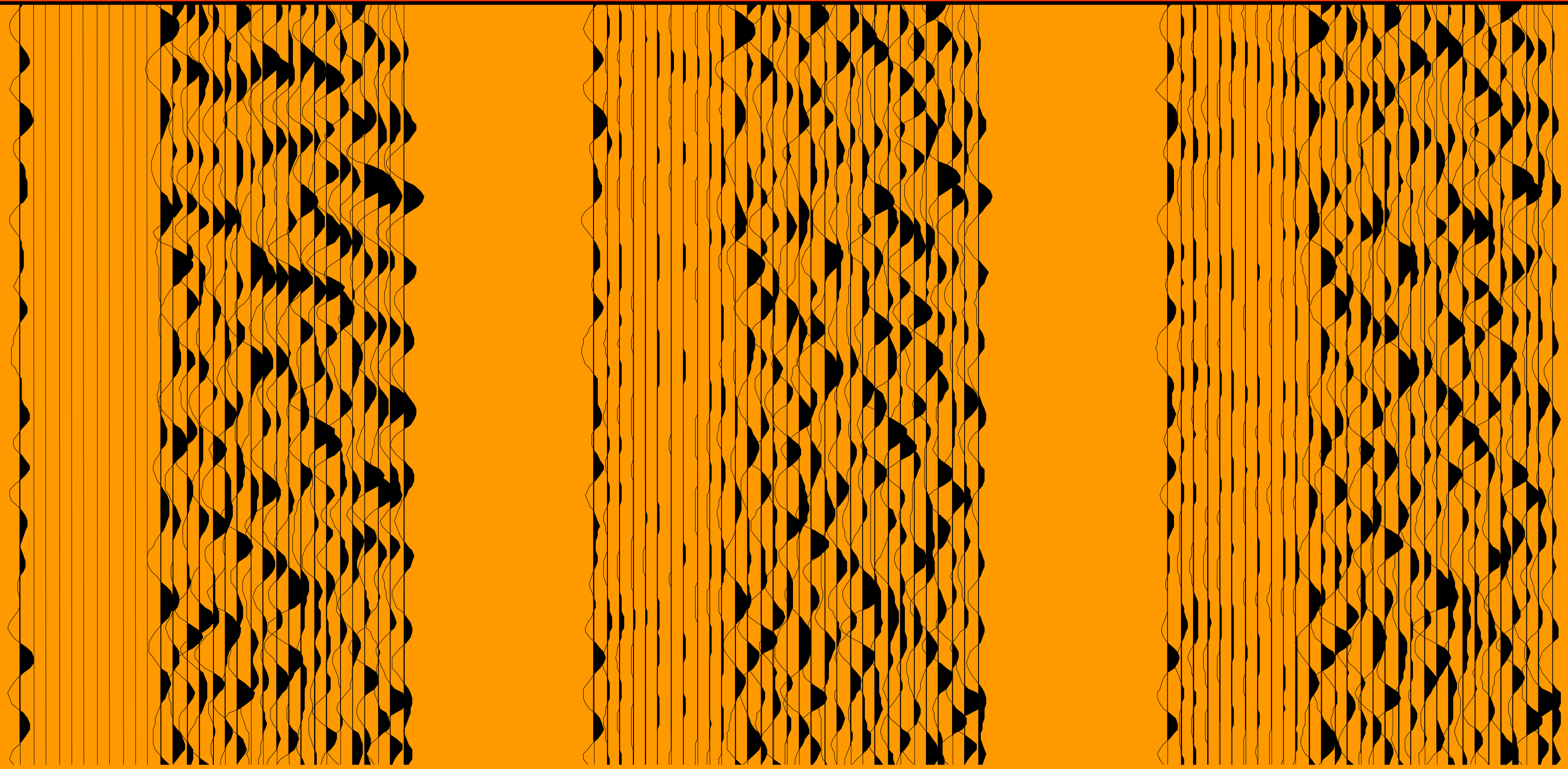


Classical wavelet



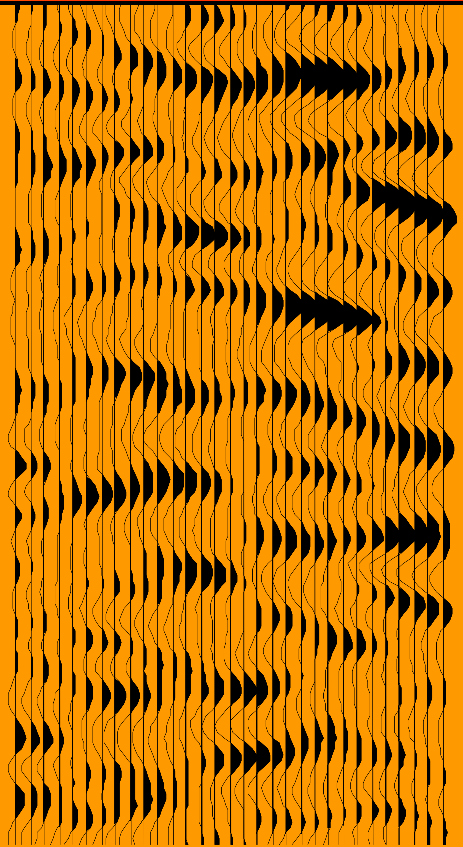
SI-wavelet

Results: gap sensitivity

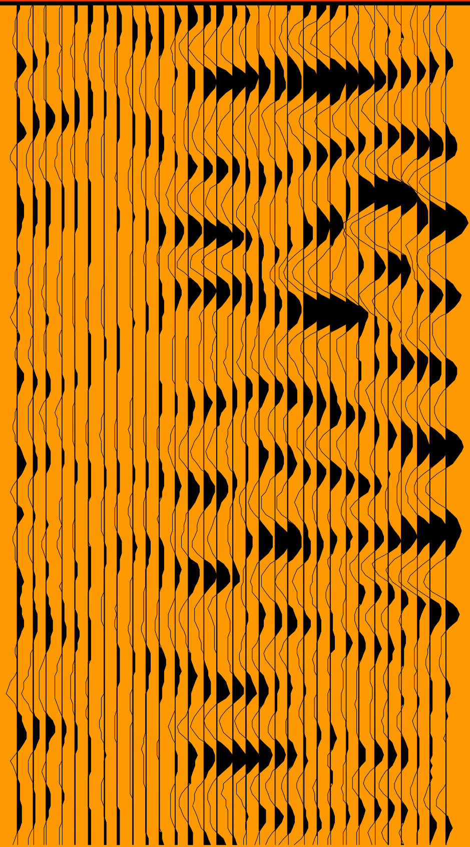


Shot with a 10-trace gap | Wavelet noise residual | SI-Wavelet noise residual

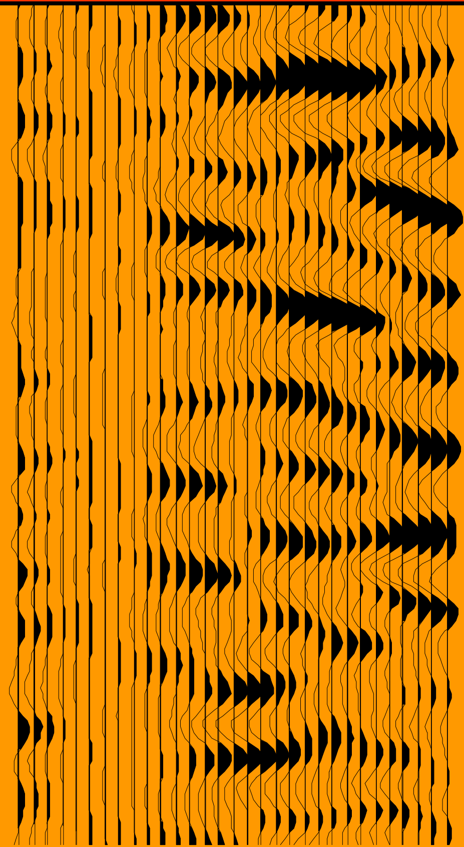
Results: gap sensitivity



Reference shot denoising

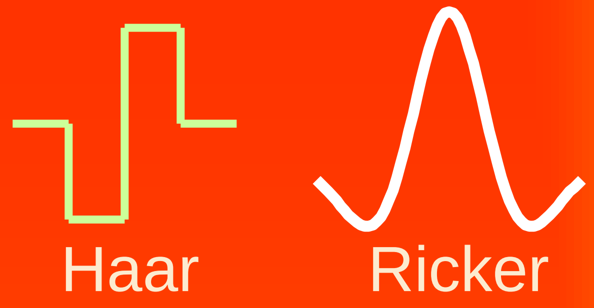


Wavelet denoising

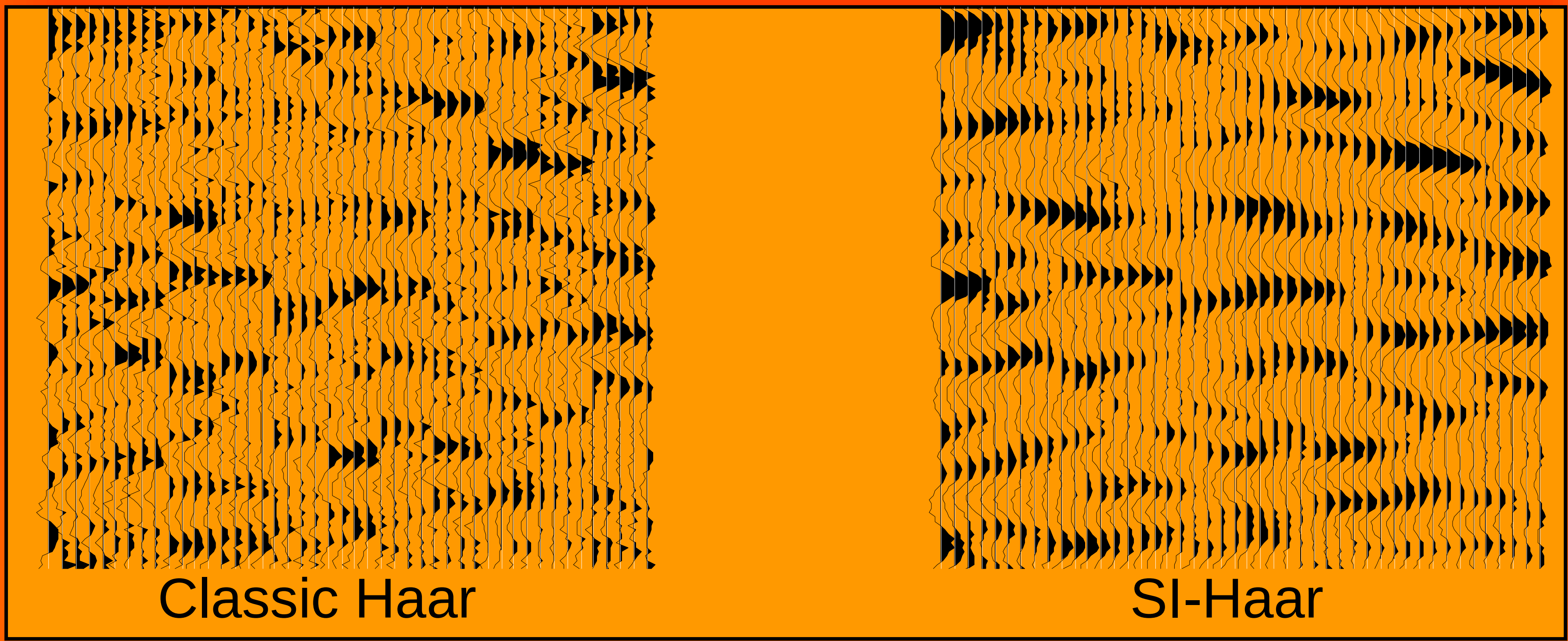


SI-Wavelet denoising

Results - Wavelet sensitivity



- GR filtering for the poor
- Haar wavelet SI effectiveness



Pros and cons

"When a toolbox only contains one hammer, every problem met is nail-shaped" **(Juran)**

- Some drawbacks
  - – memory expensive
  - – computational cost (O(n.*ln*(n)) inst. of O(n) for DWT)
  - – more freedom
- Some advantages
  - – less ringing and aliasing artifact
  - – less "wavelet" sensitive
  - – less gap sensitive than f-k
  - – random noise removal
  - – more freedom (in processing)

Conclusions

- Conclusion
  - an application of the shift-invariant wavelet
  - somewhat complex but effective
  - resist to aliasing
  - resist to gaps
- Coming: 3D geometries
- Contacts
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- Discussion