A Speckle Reduction Algorithm Using The *À Trous* Wavelet Transform

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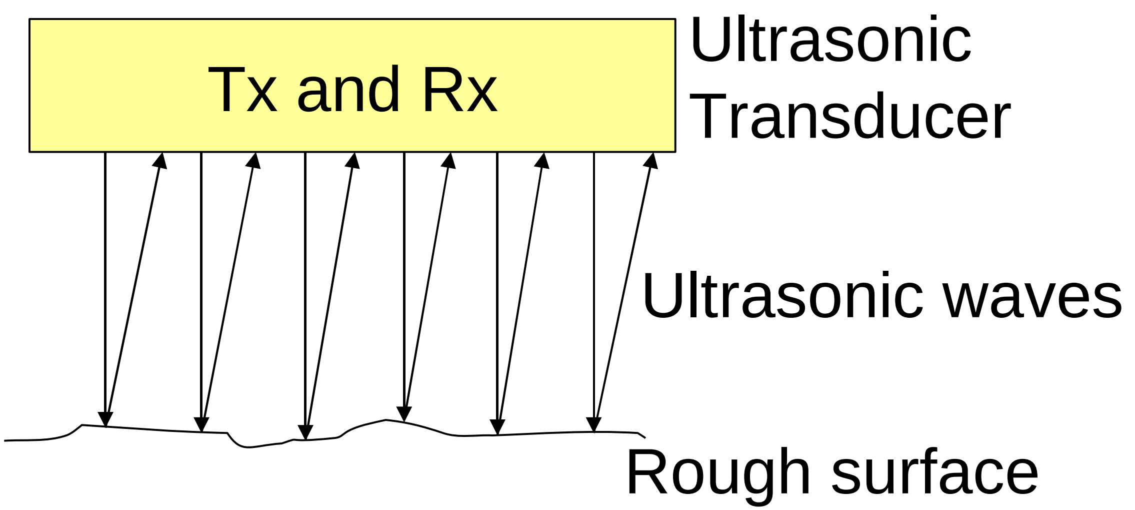
Introduction

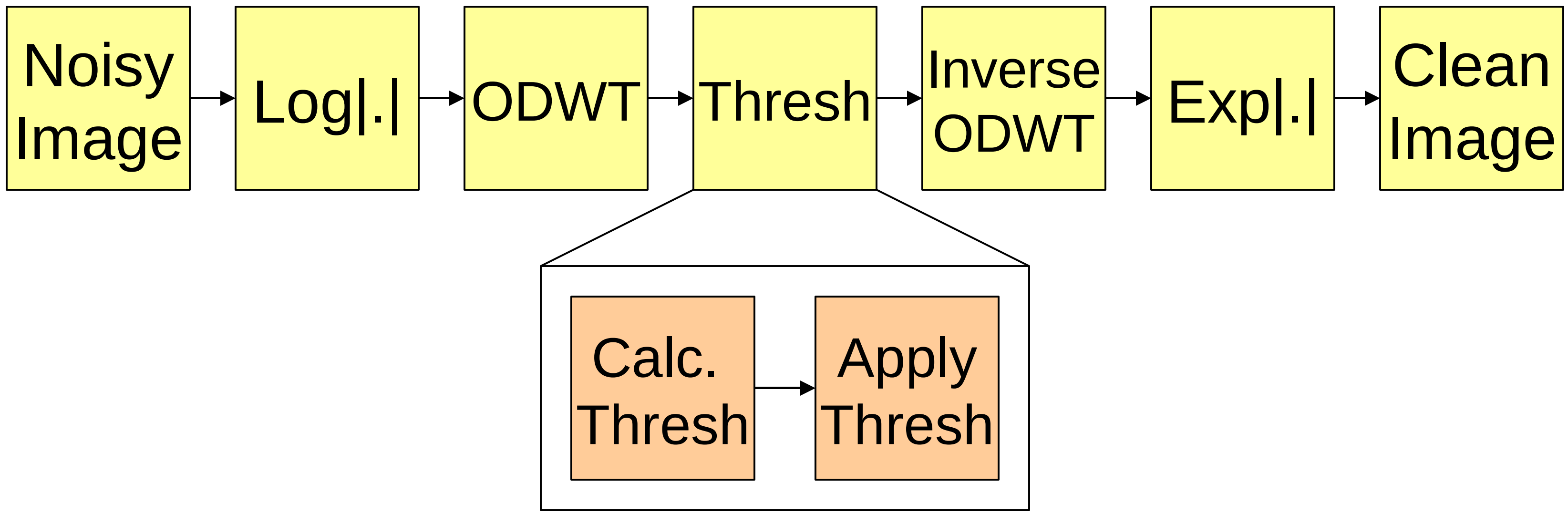
- Speckle noise.
- Speckle reduction using the Orthogonal Discrete Wavelet Transform (ODWT).
- Speckle reduction using the *À Trous* WT.
- Quantitative filter results.
- Conclusions.

Speckle Noise

- Interference of coherent light/waves.
- Ultrasonic imaging, holography and radar.
- ‘Blobs’ of different shape, size and position.
- Engineers regard speckle as form of noise.
- Speckle noise is multiplicative in nature.



Speckle Reduction Using the ODWT

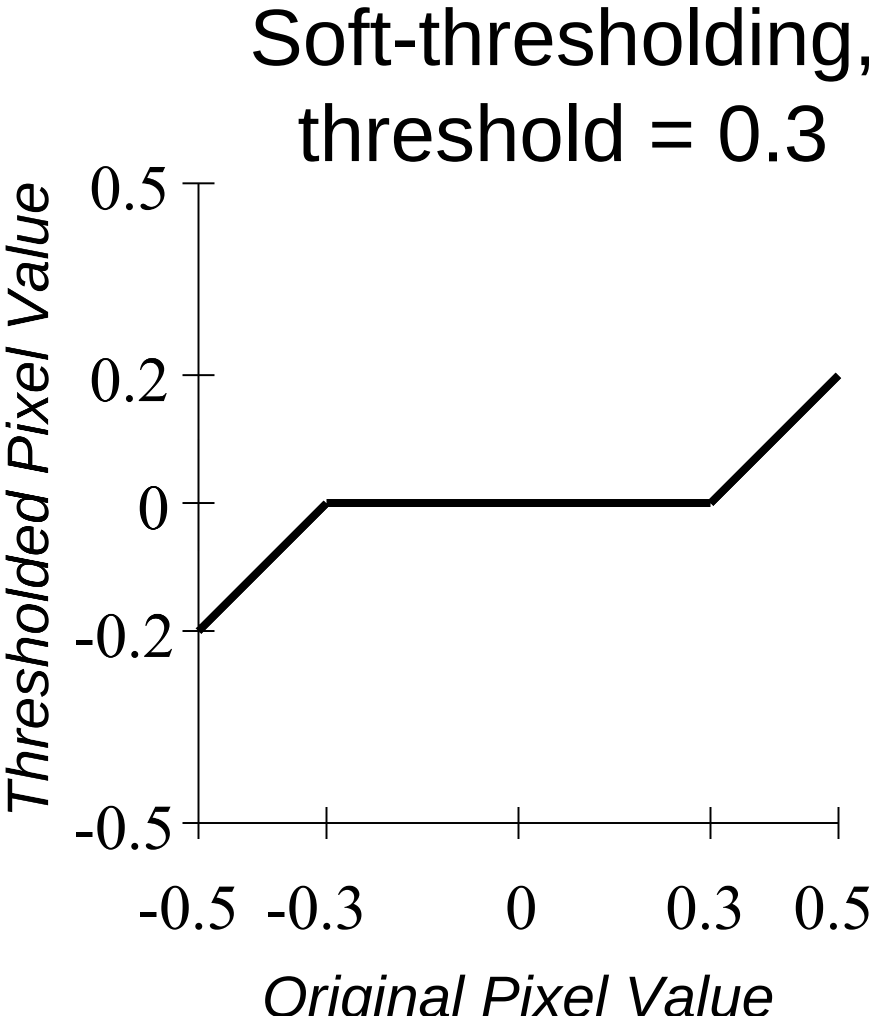


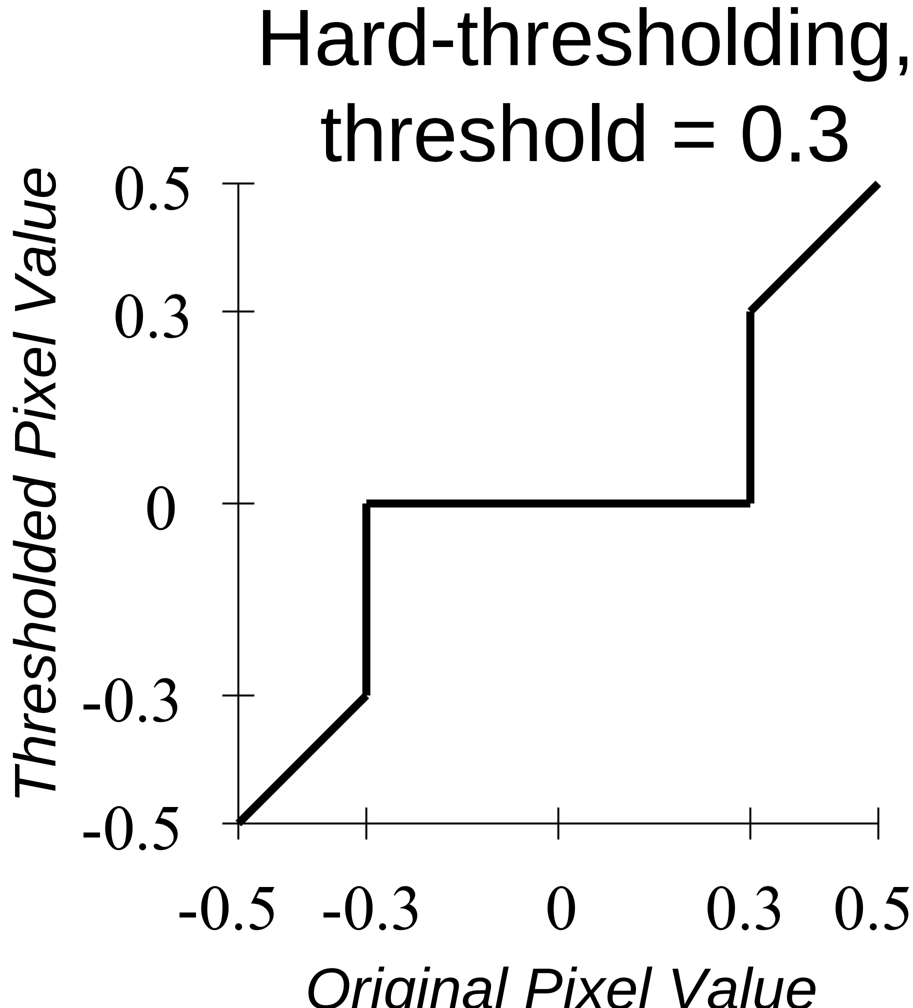
- Log transform, speckle to additive Gaussian noise.
- Donoho’s optimal threshold calculation:

$$t = \gamma\sigma\sqrt{2\log(n)/(n)}$$

- Threshold applied globally to all coefficients.

Threshold Application





De-noised Images

Original

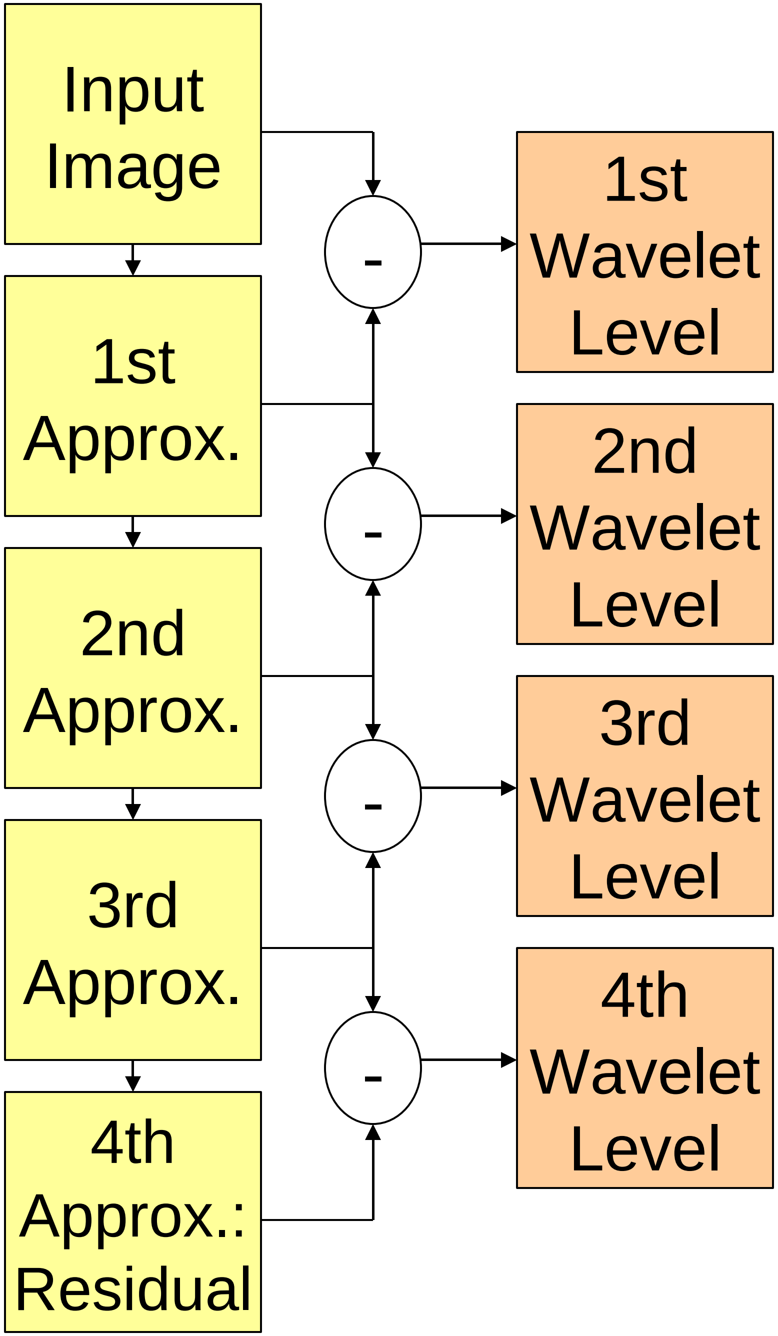
Noisy

Hard Thresh

Soft Thresh

The *À Trous* WT

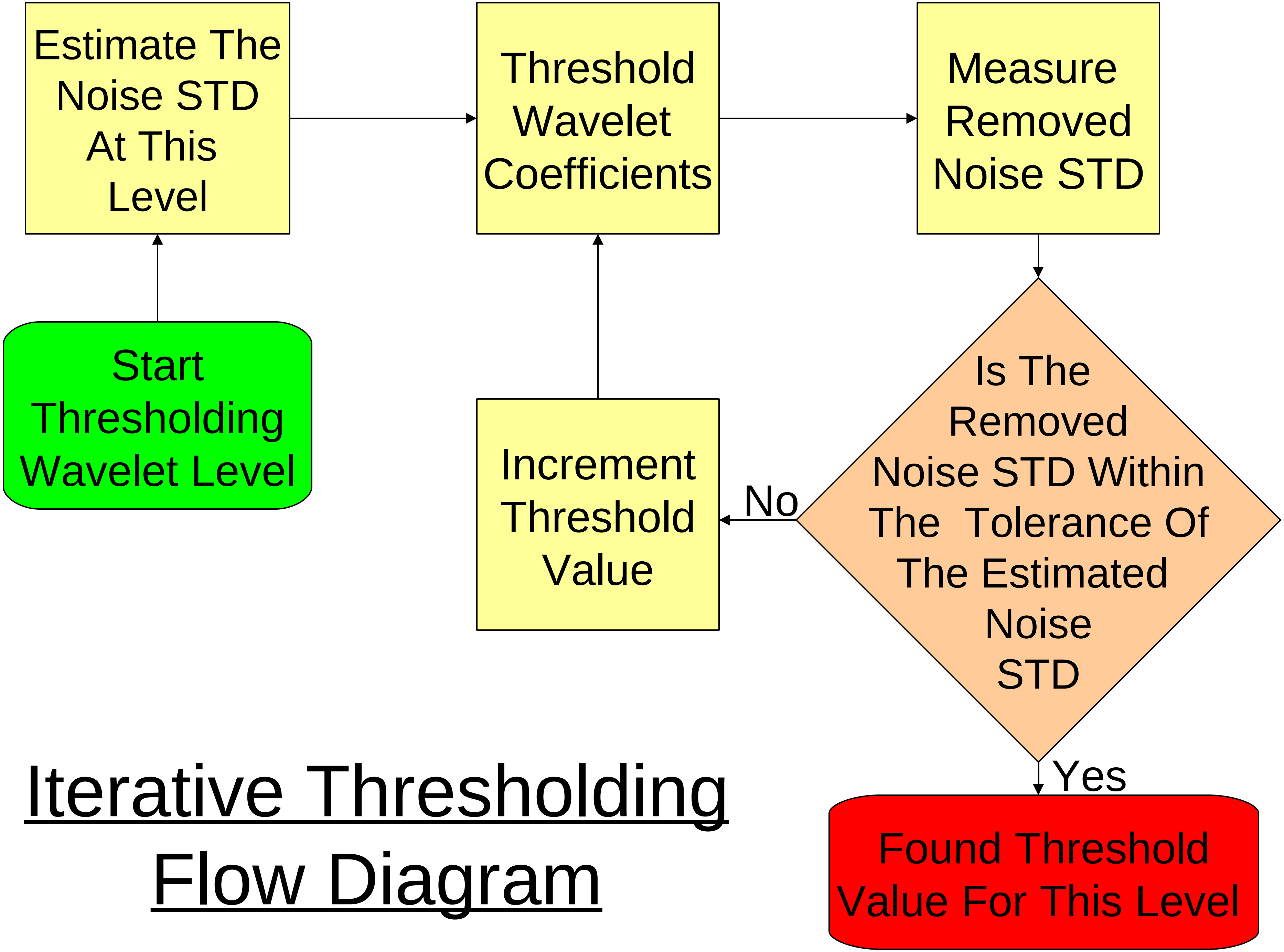
- No decimation performed.
- B_3-spline scaling function used to smooth image.
- Sampling distance of the scaling function increases.
- Reconstruction: Residual+WL4+WL3+ WL2+WL1 = Input Image.



Noise in the *À Trous* Wavelet Domain

- No decimation and smoothing performed.
- Noise measure within wavelet levels decreases as analysis becomes coarser.
- Global threshold inappropriate.
- Threshold for each wavelet level *j* required.
- Calculated by passing simulated noise image (STD = 1) through *À Trous* WT:

$$\sigma_j = \sigma_I \sigma_j^s$$



Iterative Thresholding Flow Diagram

Quantifying Speckle Reduction

- Manually select a 7×7 box within a homogeneous region in the test image.
- Speckle strength defined as STD/mean ratio.
- Speckle Reduction (*SR*) given by:

$$SR = 1 - \frac{Speckle\ strength\ after\ \ filtering}{Speckle\ strength\ before\ \ filtering}$$

Quantifying Edge Sharpness

- Manually select a 7×7 box about an edge in the test image.
- Calculate the mean values either side of the edge.
- Edge sharpness (*ES*) defined as the absolute difference between means; quantified by:

$$ES = \frac{Edge\ sharpness\ after\ filtering}{Edge\ sharpness\ before\ filtering}$$

Quantifying Filter Performance

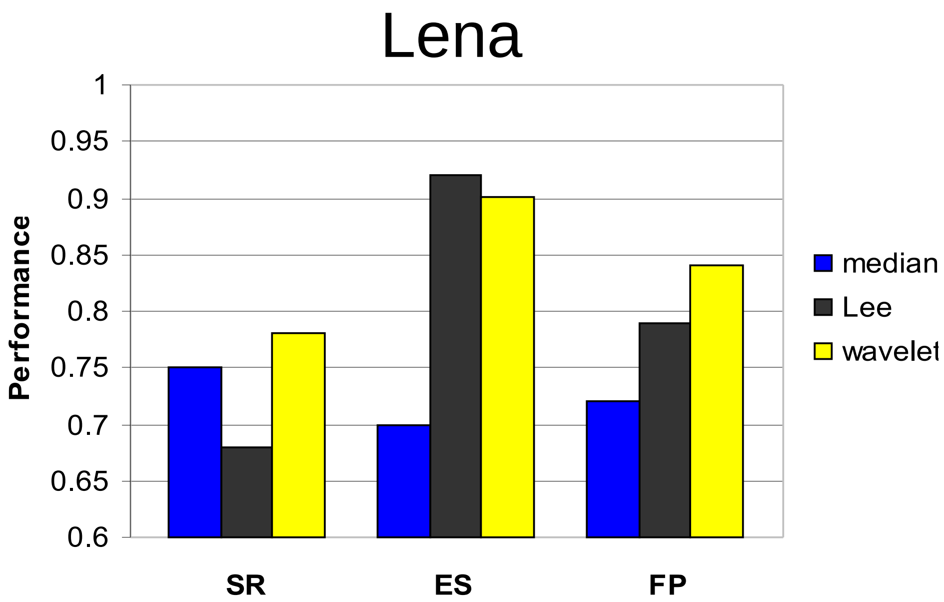
- Measure *SR* and *ES* three times in each image.
- Average each, giving $\overline{SR}$ and $\overline{ES}$.
- Both $\overline{SR}$ and $\overline{ES}$ will be bounded to range 0-1.
- Hence, the overall ability of a filter to reduce speckle and preserve edges can be quantified via the filter performance (*FP*):

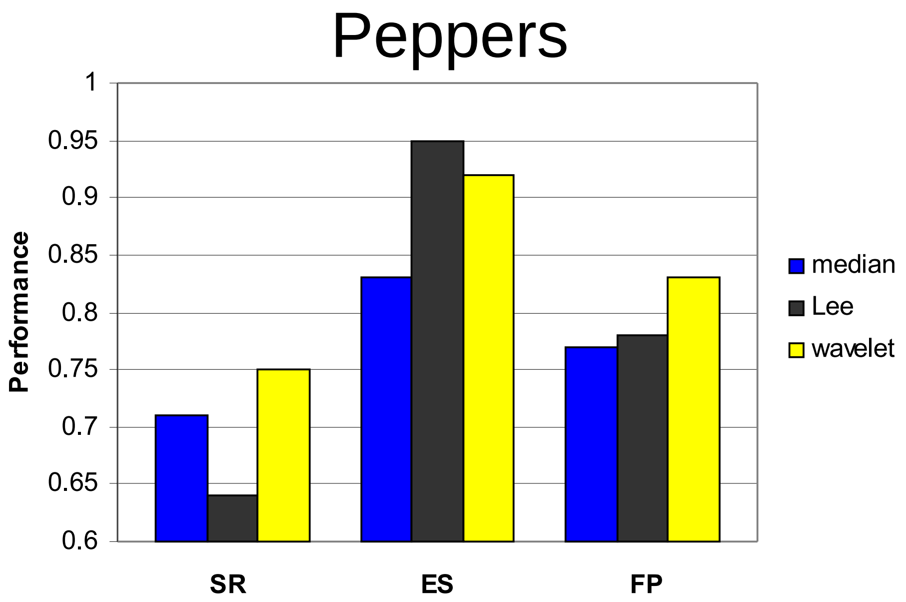
$$FP = \sqrt{\overline{SR} \bullet \overline{ES}}$$

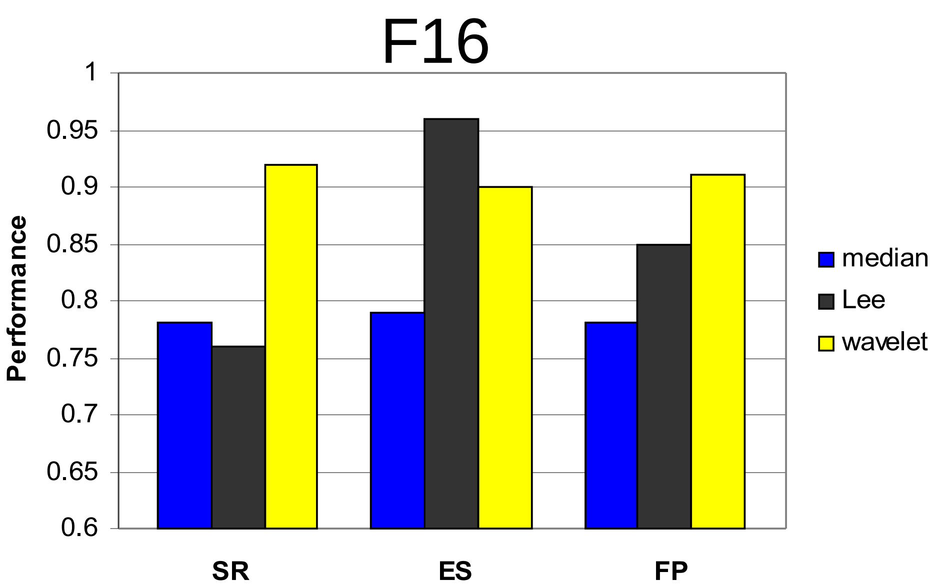
Parameters for Tested Filters

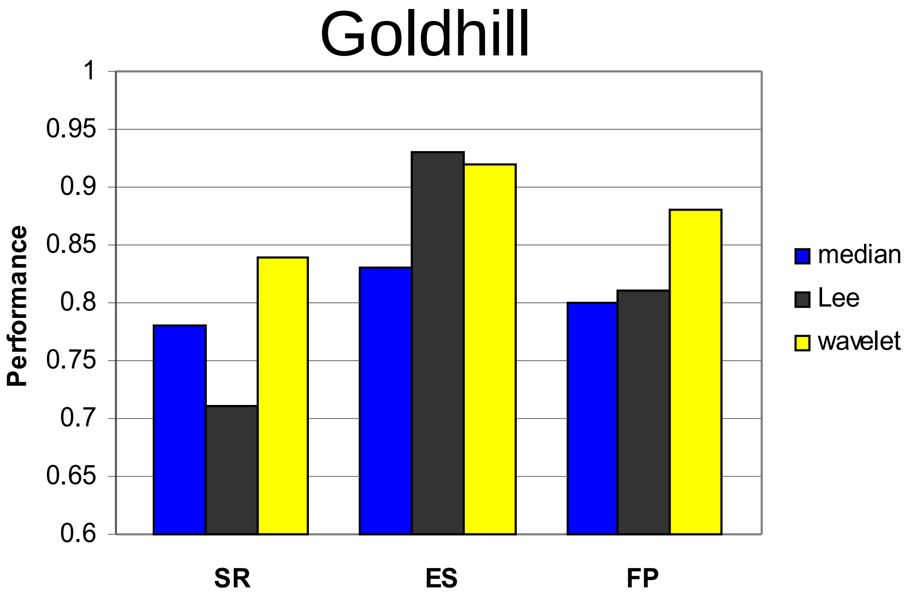
- Median filter parameters chosen to maximize the image smoothing.
- Lee and wavelet filter parameters chosen to give de-noised images that are visually clean and unblurred.
- De-noised images using Lee and wavelet filters have identical PSNR values.

Quantitative Results









Conclusions

- An iterative filtering algorithm for the shift-invariant *À Trous* WT introduced.
- Filter performance metric established.
- Overall, the introduced filter algorithm was shown to outperform the Lee and median filters.

De-noised Lena Images

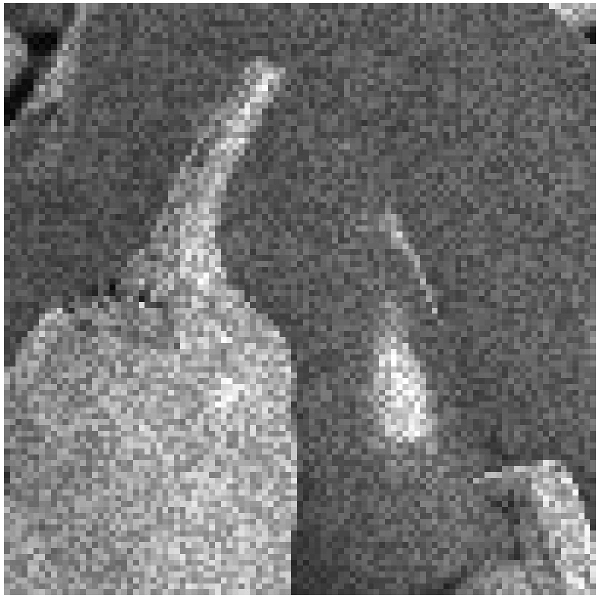
Original
Lena

Lee
Filter

Median
Filter

Wavelet
Filter

De-noised Pepper Images



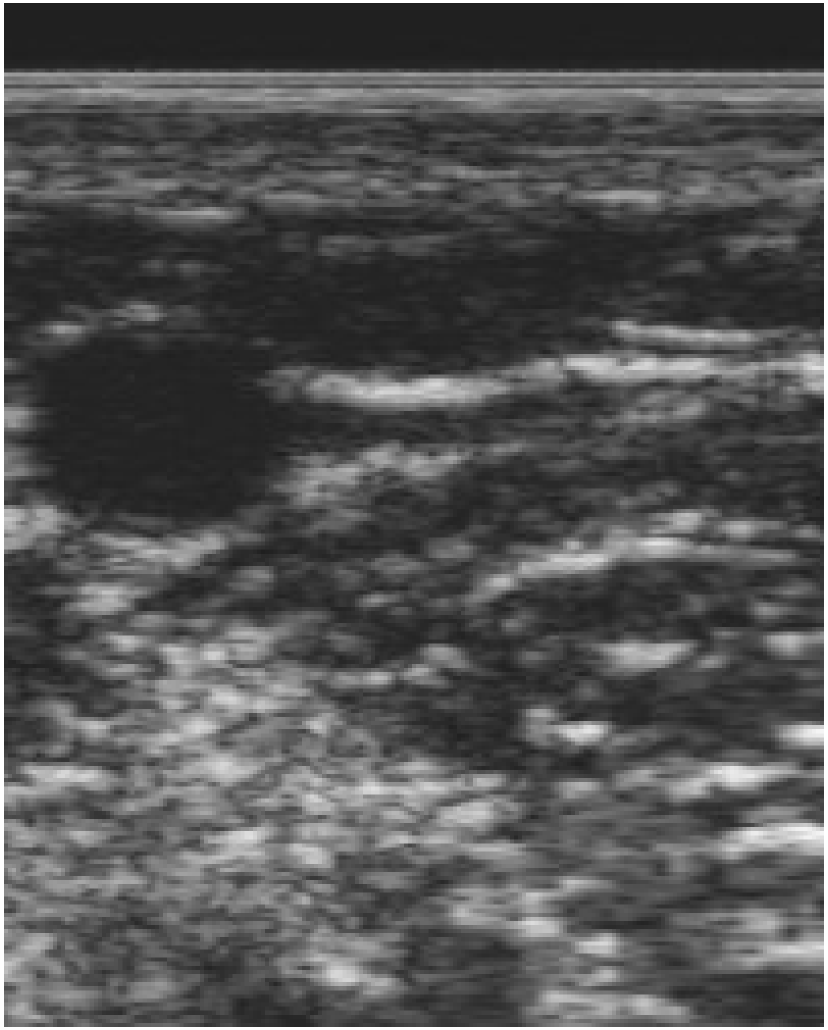
Original
Peppers

Lee
Filter

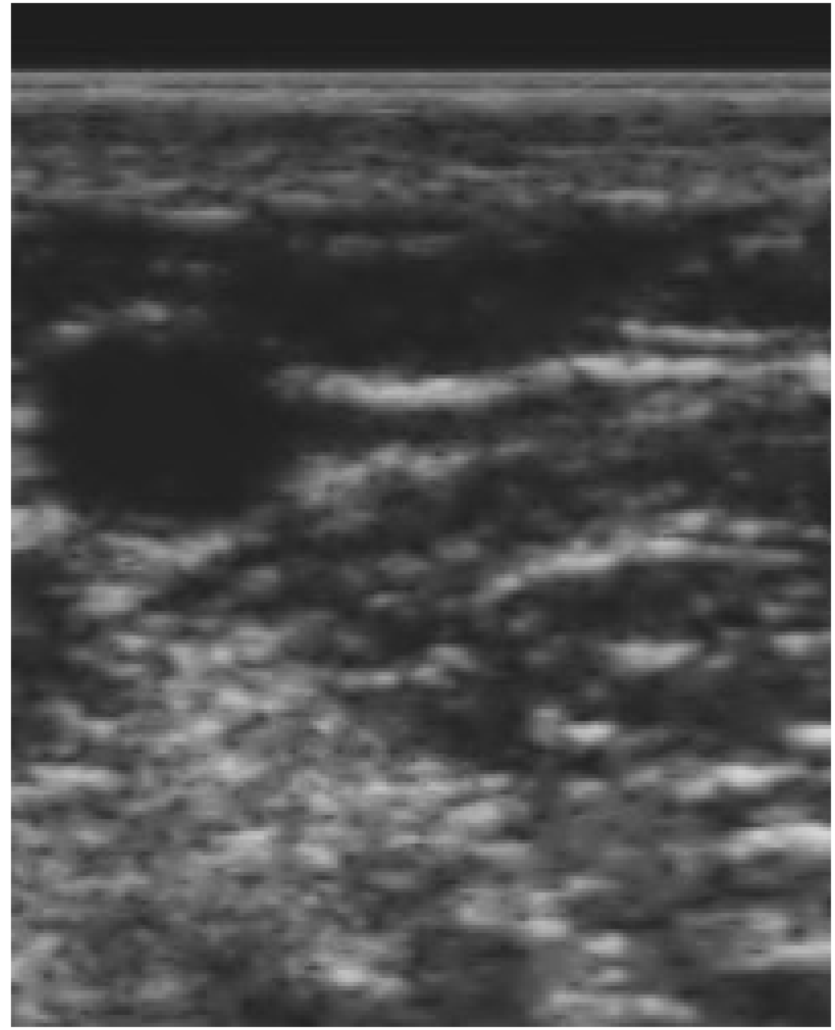
Median
Filter

Wavelet
Filter

De-noised Ultrasound Images

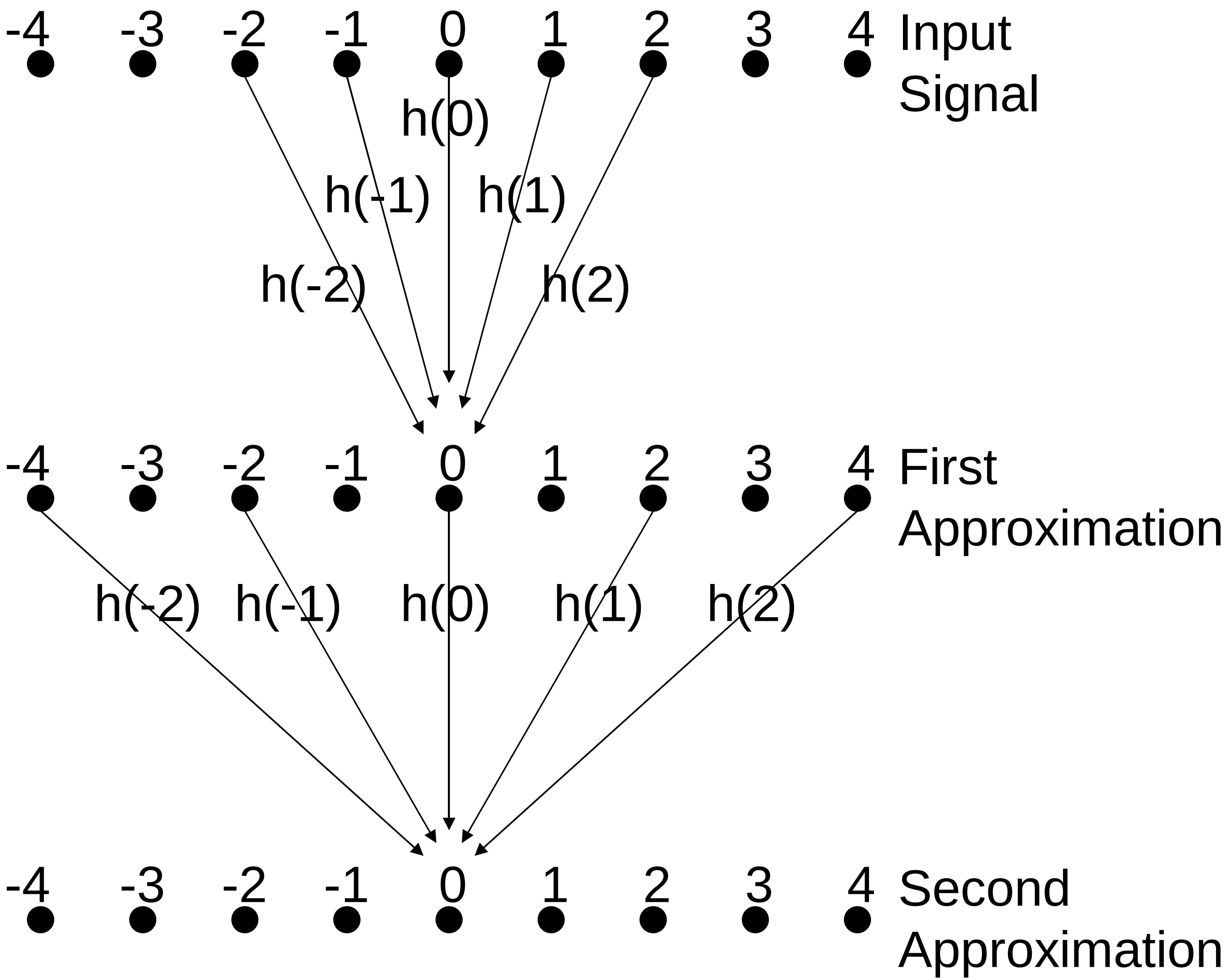


Original

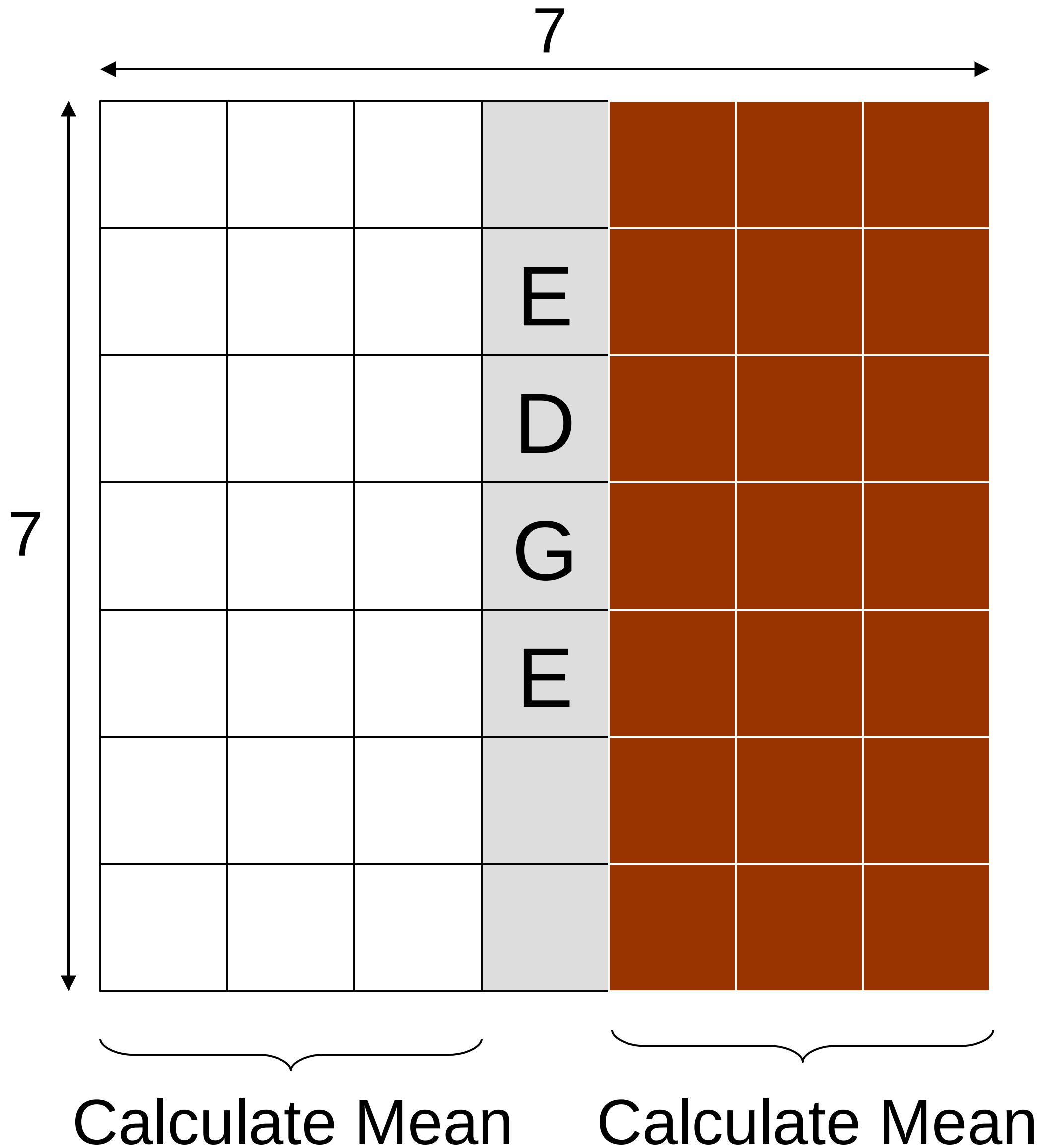


Wavelet Filter

Approximation (With Holes)



Edge Sharpness



PSNR Values for the Images

	Lena	Peppers	F16	Goldhill
original	**24.16**	**22.9**	**19.94**	**23.59**
median	**25.03**	**24.35**	**21.91**	**23.63**
Lee	**29.32**	**28.22**	**25.92**	**26.75**
wavelet	**29.32**	**28.22**	**25.92**	**26.75**