Denoising with Spatial Filters

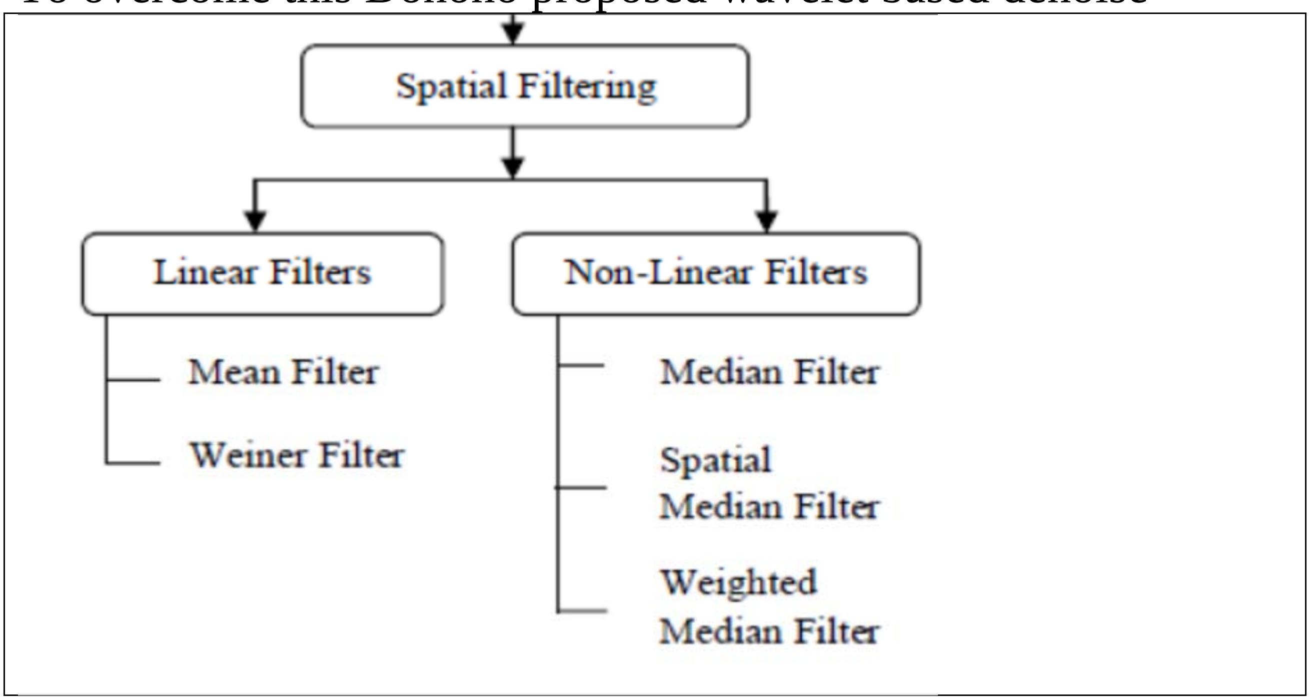
- Denoising considered a fundamental image processing problem
- First approaches were spatial domain
- Advantage is speed of processing
- Disadvantage is unable to preserve edges
- Sees edges as discontinuities

- Linear filters
- Mean filter: takes moving average of 3x3 or large
- A 3x3 mean filter has the kernel

$$\frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

- Used as a convolution moving average
- Is the optimum for Gaussian noise by mean square error
- Problem is smooths out image details

- Wiener Filter
- Requires information on spectra of noise and original signe
- Performs well only if the underlying signal is smooth
- To overcome this Donoho proposed wavelet based denoise



Mean Filter Image

- Image with Gaussian Noise
- 3x3 with mean filter
- However note loss of image details

Original image

With Gaussian Noise added

Mean filter

Nonlinear Spatial Filters

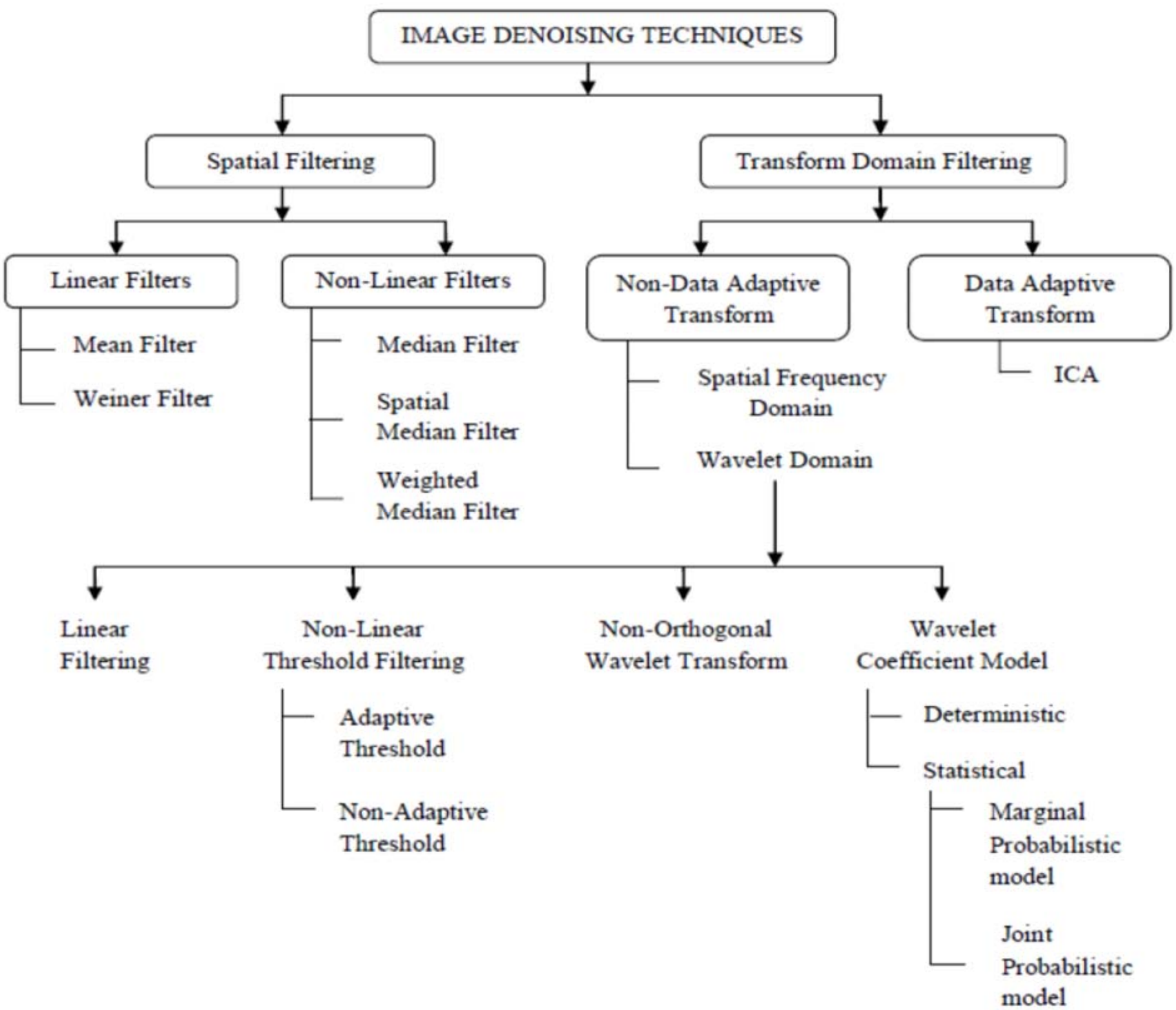
- Employ low pass filter on groups of pixels
- Assumption is that the noise is the high frequency spectrum
- Thus noise removed without identifying it
- Removes noise but at the cost of blurring
- Makes edges invisible
- Median Filter – is the simplest
- For a given area eg 3x3 order the data from low to high
- Find the median – ie the point midway in the order
- Ie the 50% point (statistical median)
- Weighted Median filter
- Gives more weight to some values
- Center weighted median gives more weight to the central point

Median filter

Mean filter

Transform Domain Filtering

- Applies transforms to the filtering
- Tends to preserve edges better
- Broken into Non adaptive and adaptive forms
- In non adaptive
- Spatial Frequency Filtering
- Transform domain filtering
- Low Pass Filter used by FFT (fast fourier transform)
- Noise done by adapting a cut-off frequency
- Then designing a frequency domain filter
- Very time consuming



Wavelet Filtering

- Wavelet is an oscillation
- Begins at zero
- Increase to max
- Decreases back to zero
- Wavelets us a
- time-frequency representation for continuous-time (analog) signals

$$\psi(t) = 2\ \mathrm{sinc}(2t) - \ \mathrm{sinc}(t) = \frac{\sin(2\pi t) - \sin(\pi t)}{\pi t}$$

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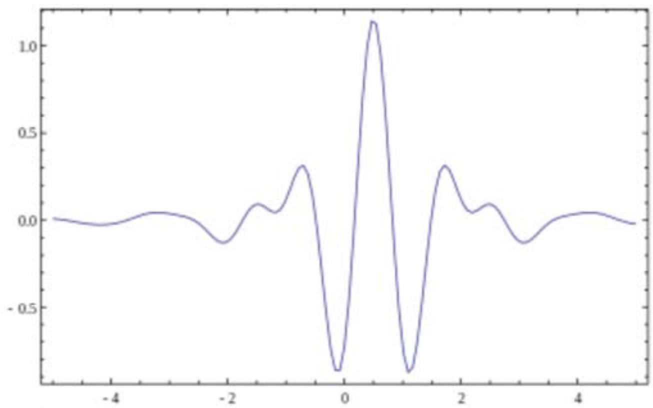
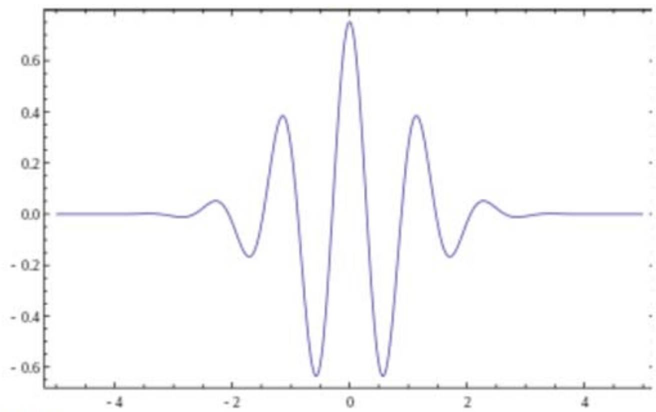
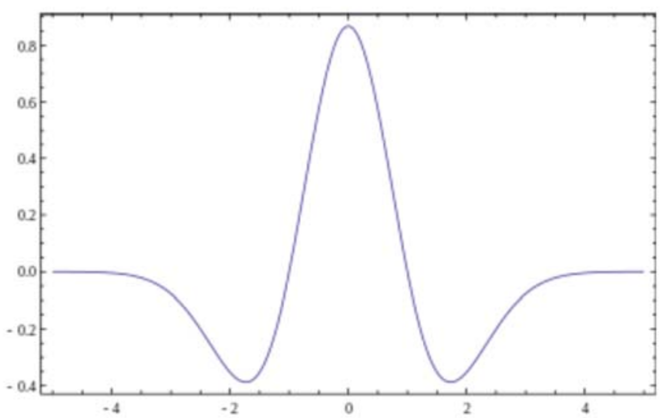
- Many different wavelet transfoms



Meyer



Morlet



Mexican hat

Various forms of denoising

Figure 5. Denoising experience on a natural image. From left to right and from top to bottom: noisy image (standard deviation 20), Gauss filtering, anisotropic filtering, Total variation, Neighborhood filtering and NL-means algorithm. The removed details must be compared with the method noise experience, Figure 4.