A wavelets based deblocking technique for DCT based compressed materials

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Overview

- Motivation
- Method
  - Wavelet, Translation Invariant Wavelet
  - Deblocking
- Results
  - Normal and Special Domain Comparison
- Summary, Conclusion and Future Improvements

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Motivation

- Wavelet domain is well know for data compression (JPEG2000, Dirac).
- Not a lot of research are done in the field of digital artifacts reduction (only gaussian noise reduction).
- Why wavelet?
- Usually a natural image has more energy at low frequencies and the wavelet transform exploits this.
- Artifacts provided by a DCT based compression usually interest the high frequencies.

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Motivation

Problem due to the high frequencies quantization.

⇨ Blocking Artifacts

Wavelets provide at the same time a frequency and a spatial resolution.

⇩

1. Remove blocks using at the same time frequency and spatial information (blocks location).
2. Iterate only the high frequencies and not change the lower ones, in which the most energy is focused.

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Story of Wavelet

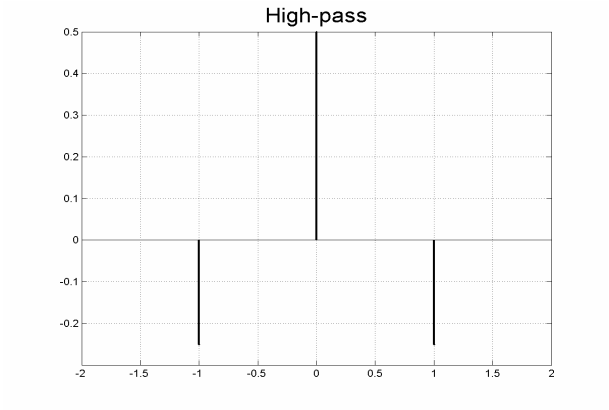
- **Wavelet - Time line**

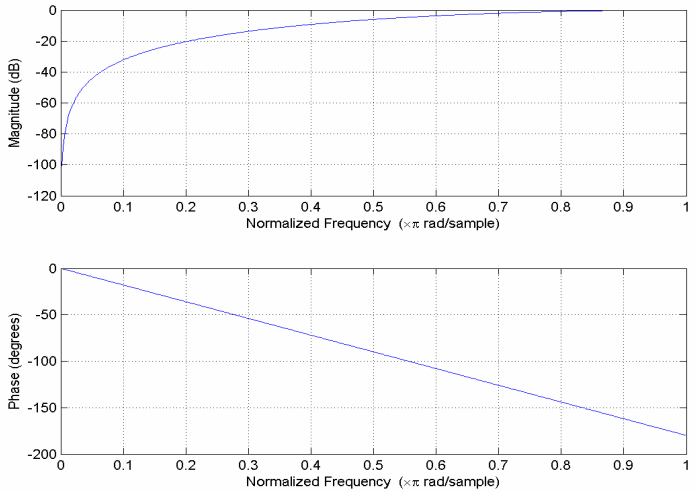
- First wavelet by Alfred Haar (1909)
  - Haar wavelet

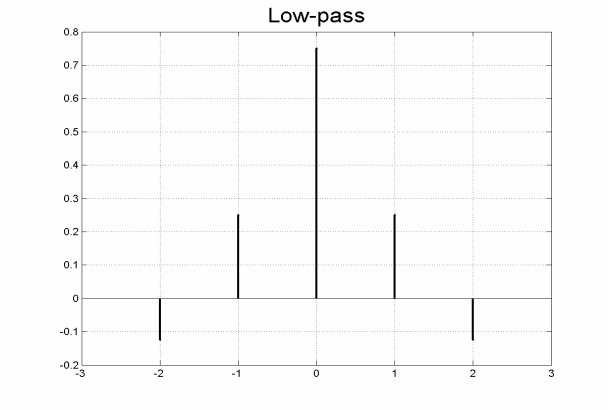
- Since the 1950s: Jean Morlet and Alex Grossman
  - Formulation of what is now known as the CWT (1982)

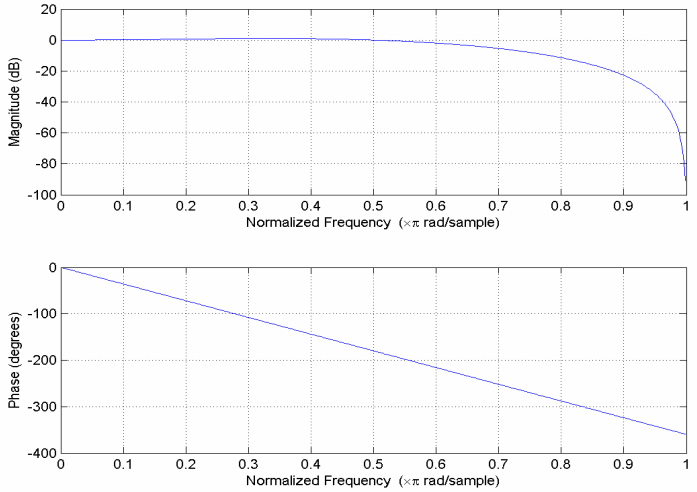
- Since the 1980s: Yves Meyer, Stéphane Mallat, Ingrid Daubechies, Ronald Coifman, Victor Wickerhauser and Strömberg
  - Strömberg's early work on discrete wavelets (1983)
  - Daubechies' orthogonal wavelets with compact support (1988)
  - Mallat's multiresolution framework (1989)
  - Delprat's time-frequency interpretation of the CWT (1991)

Wavelet 1D









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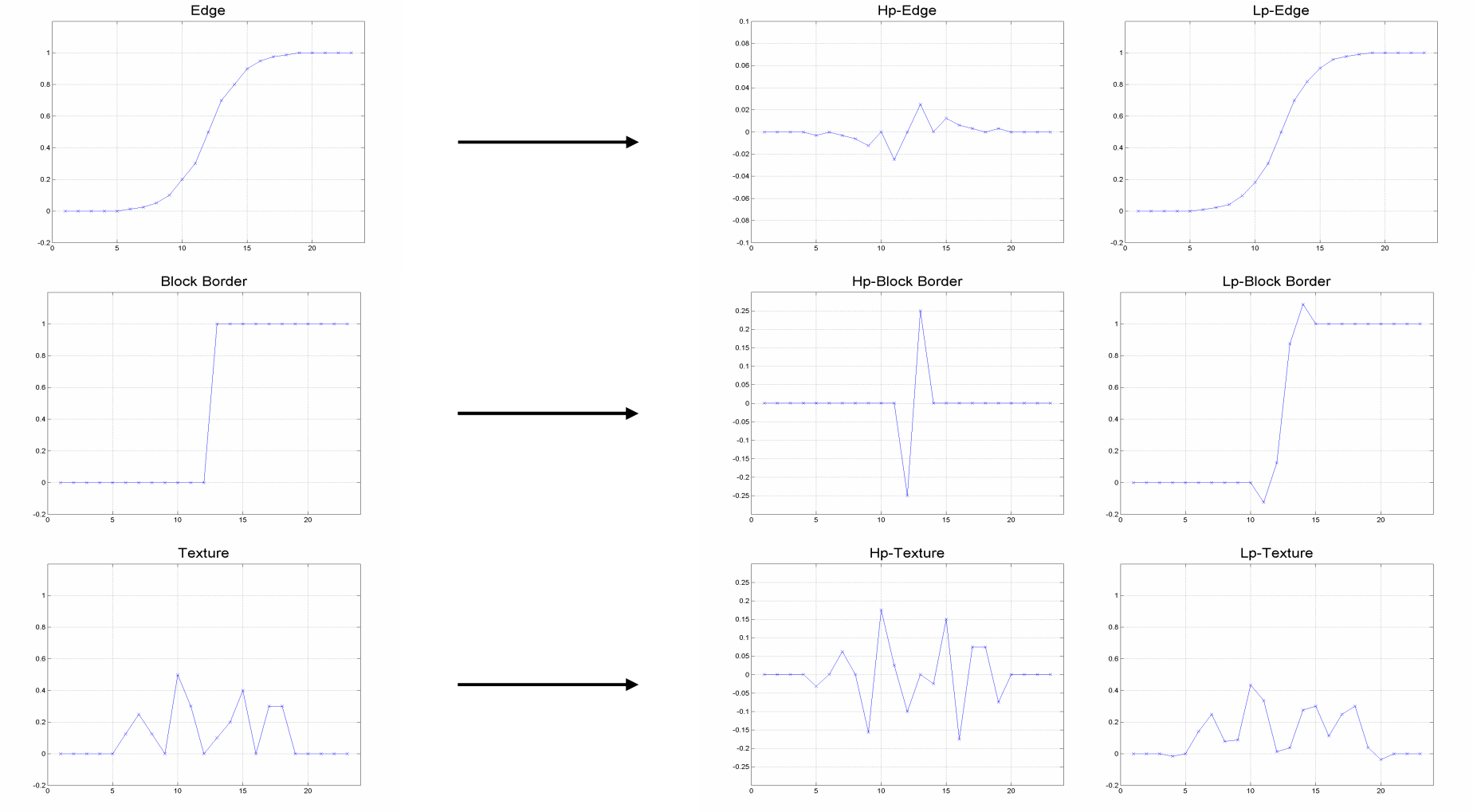
Wavelet 1D



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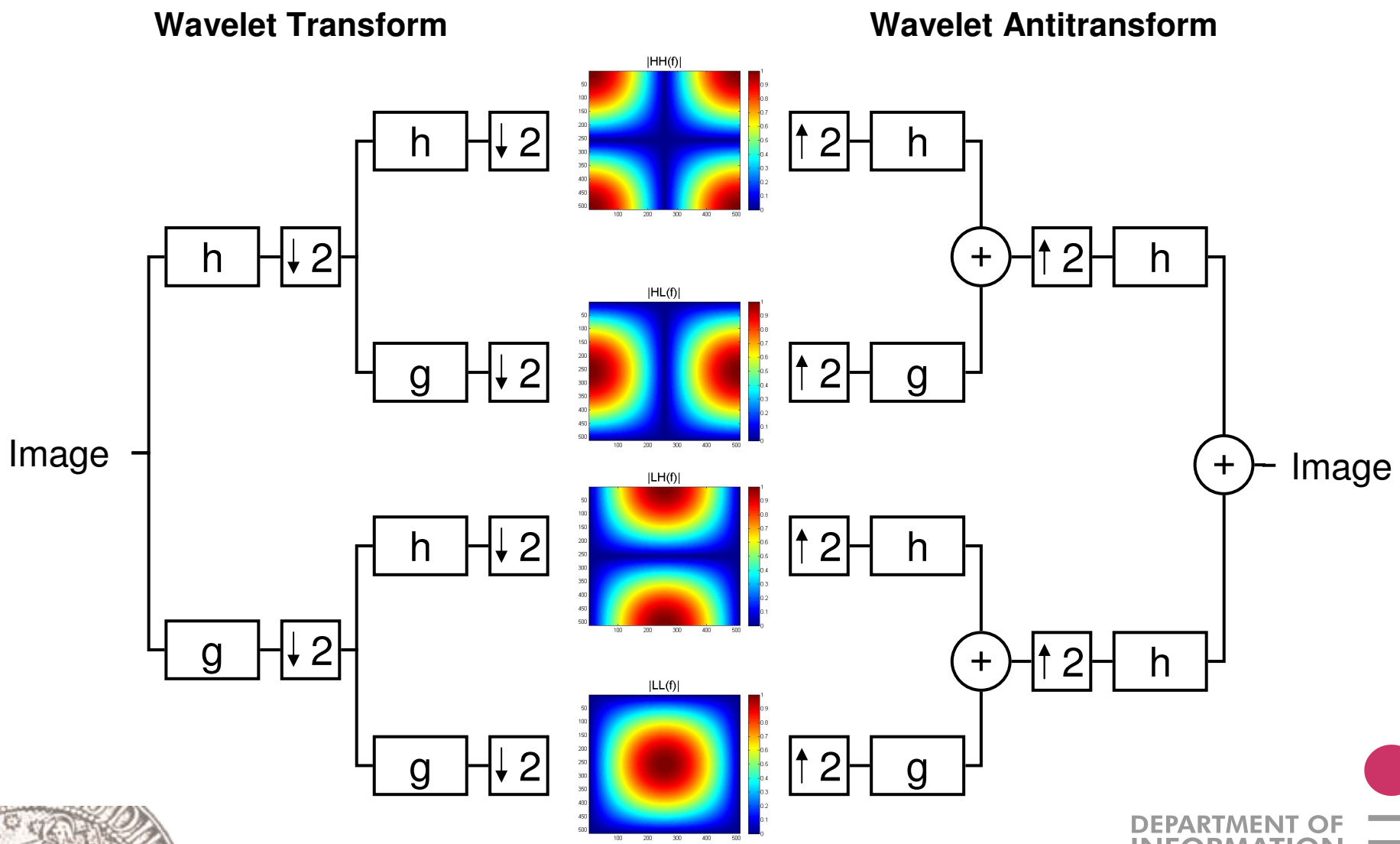
Wavelet 2D



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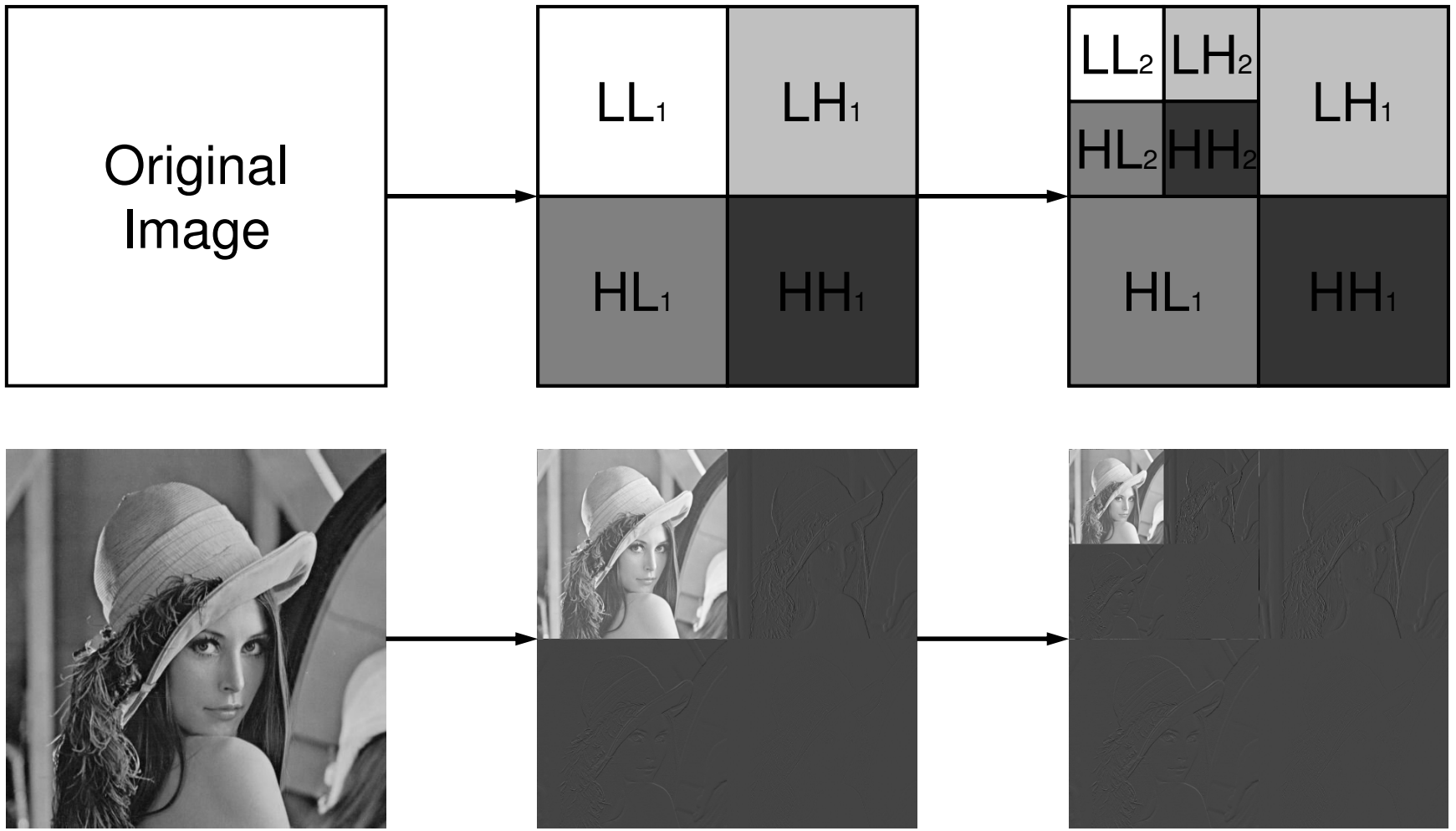
Wavelet 2D



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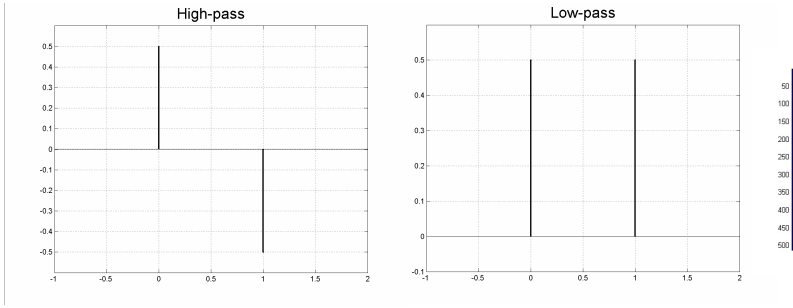
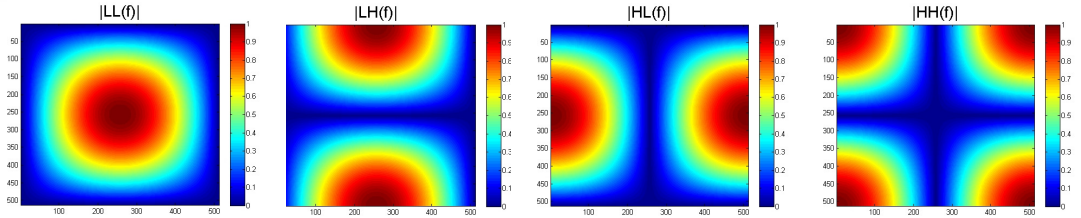
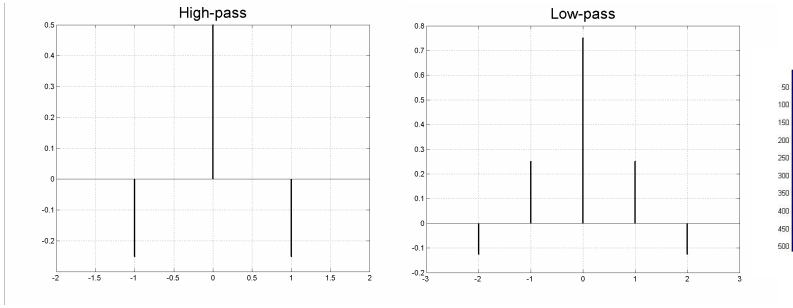
Examples of Wavelet [1]

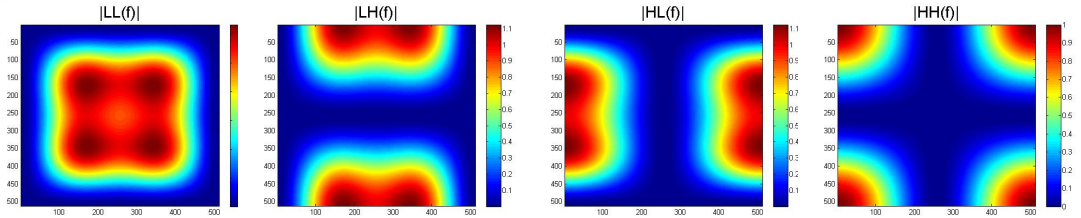
- Haar



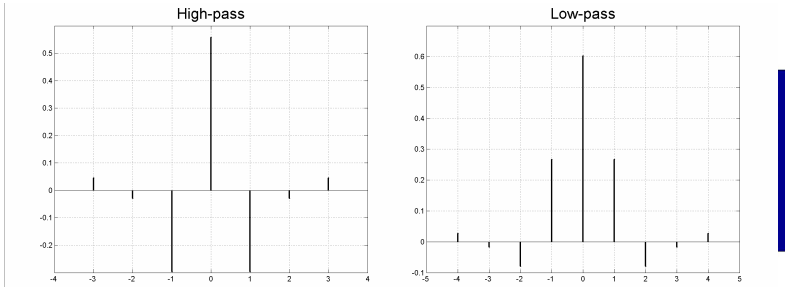


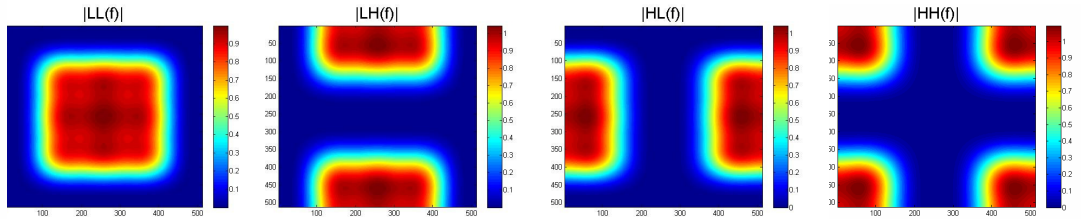
- LeGall 5/3





- Daubechies 9/7





[1] Majid Rabbani, Rajan Joshi, *An overview of the JPEG2000 still image compression standard*, Eastman Kodak Company, Rochester, NY, USA

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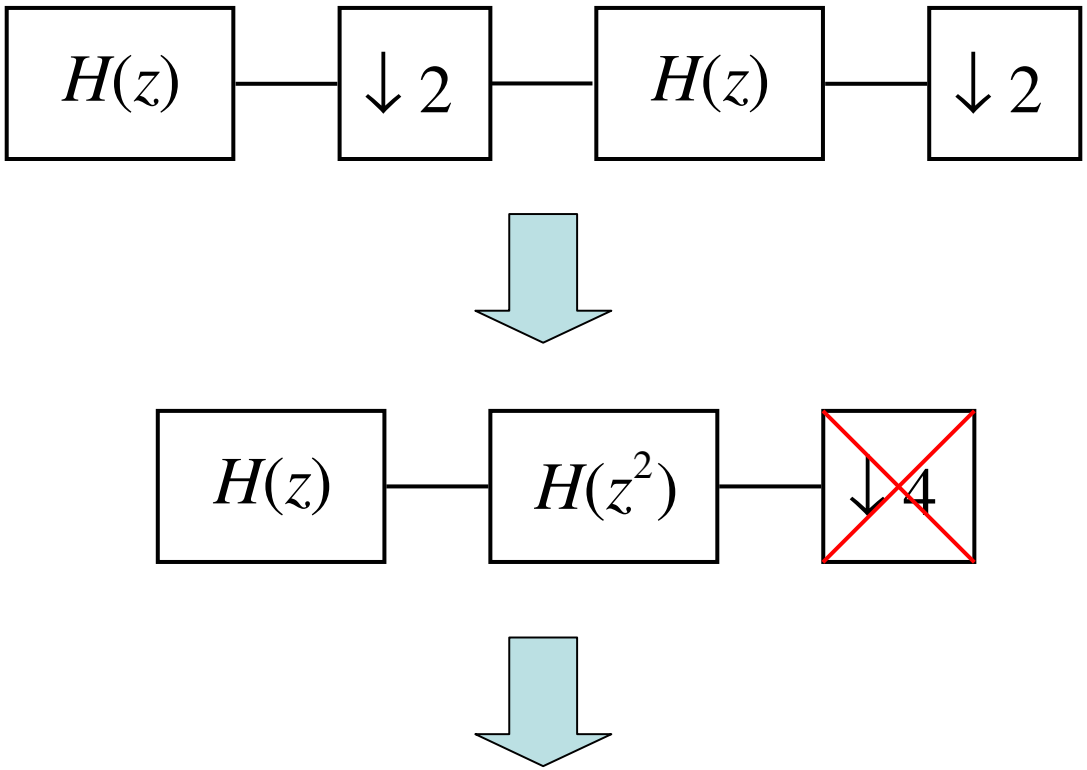
Translation Invariant Wavelet

Cascade of filtering and subsampling.



Equivalent to insert zeros between filters taps [2].

[2] P. P. Vaidyanathan, *Multirate Digital Filters, Filter Banks, Polyphase Networks, and Applications: A Tutorial*, Prentice Hall, IEEE, 1990

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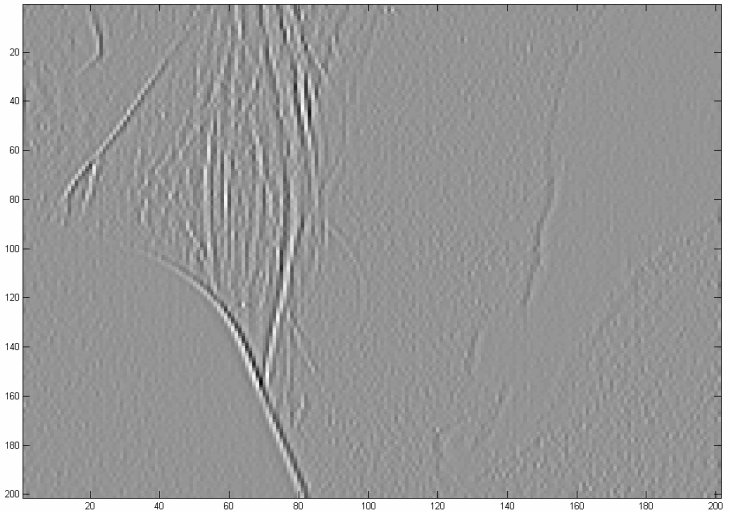
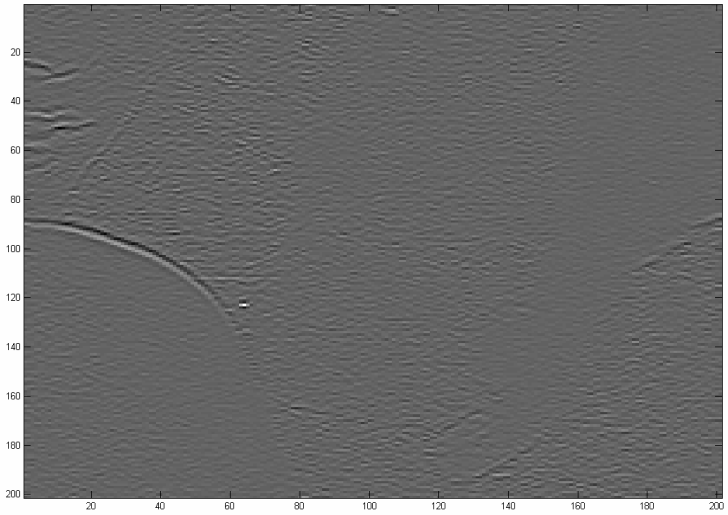
Translation Invariant Wavelet

waveletAC n=1

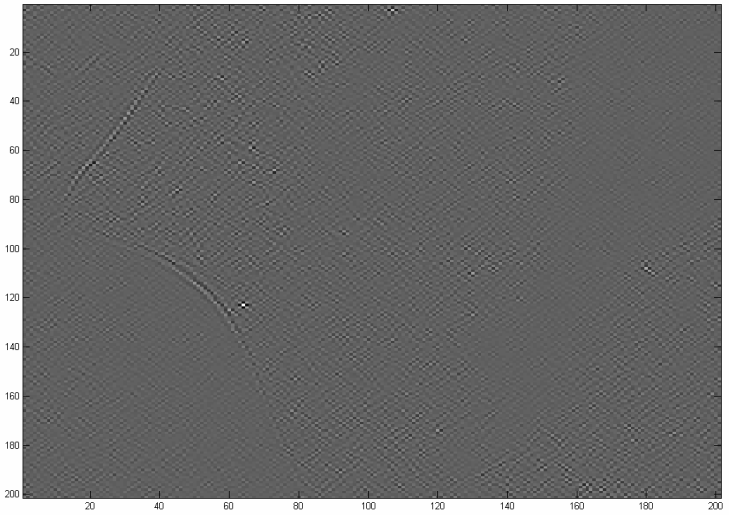
waveletVC n=1



waveletOC n=1

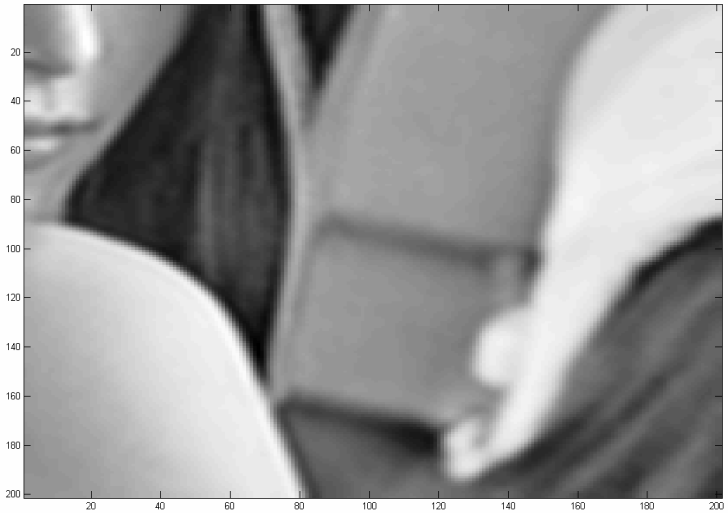


waveletDC n=1

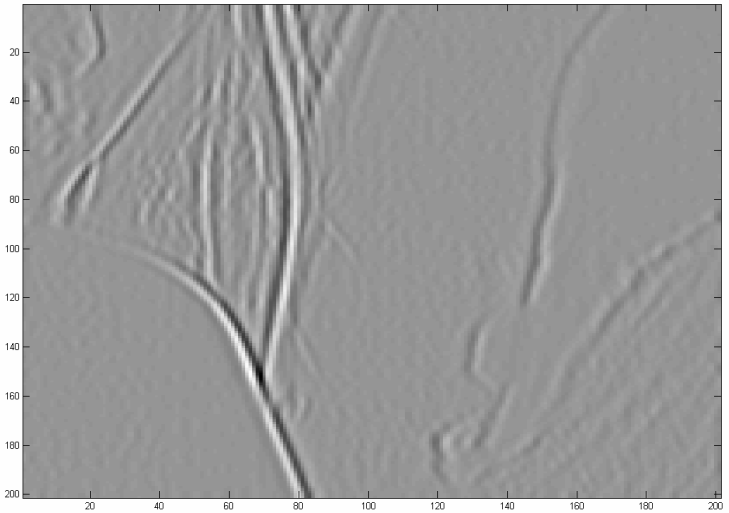


Translation Invariant Wavelet

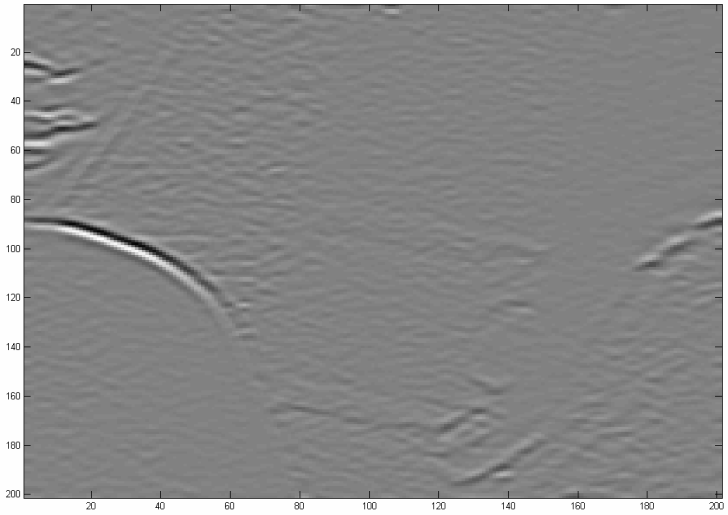
waveletAC n=2



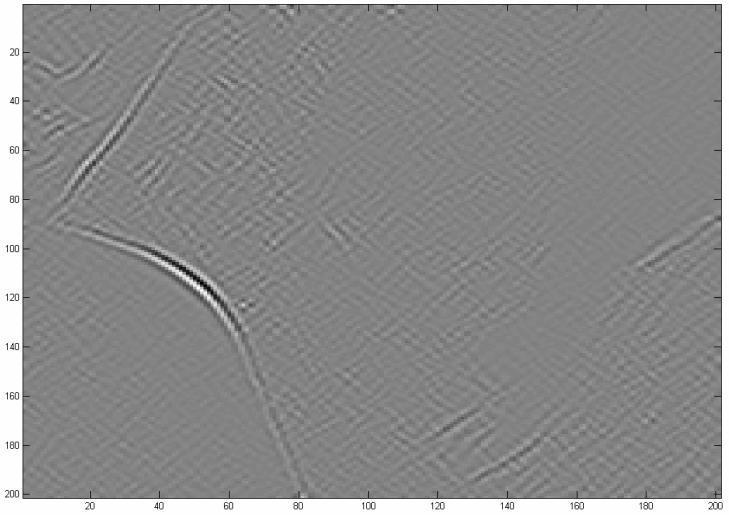
waveletVC n=2



waveletOC n=2

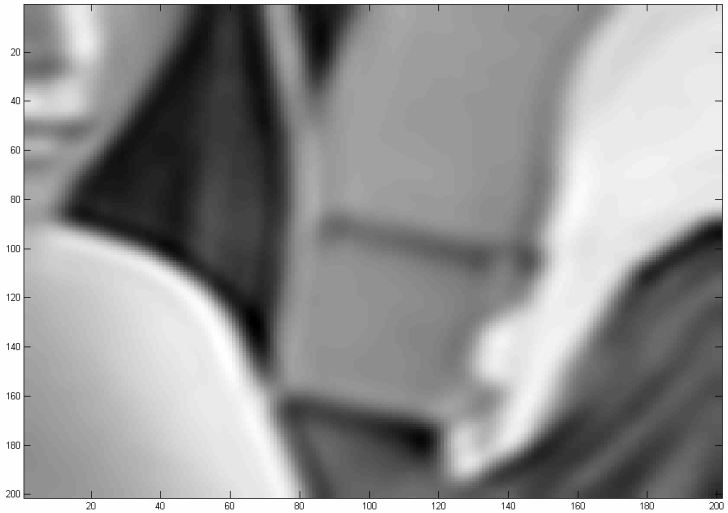


waveletDC n=2

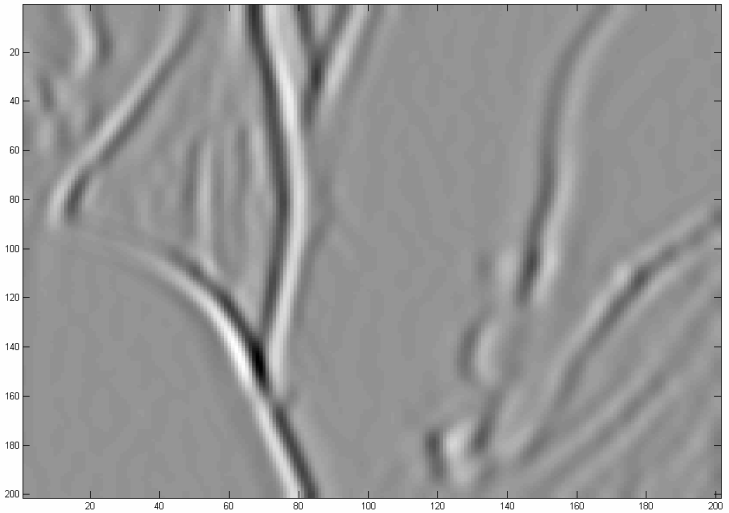


Translation Invariant Wavelet

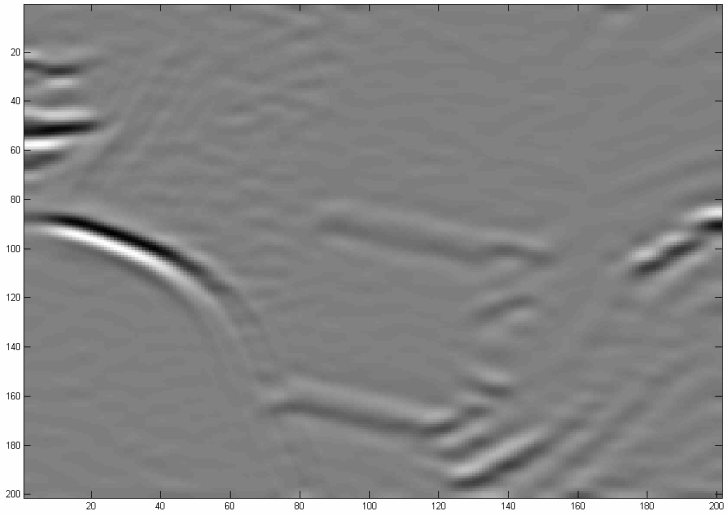
waveletAC n=3



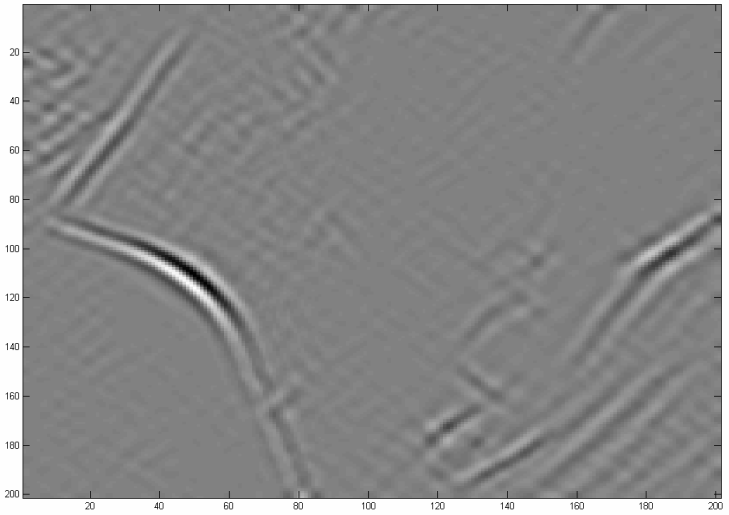
waveletVC n=3



waveletOC n=3

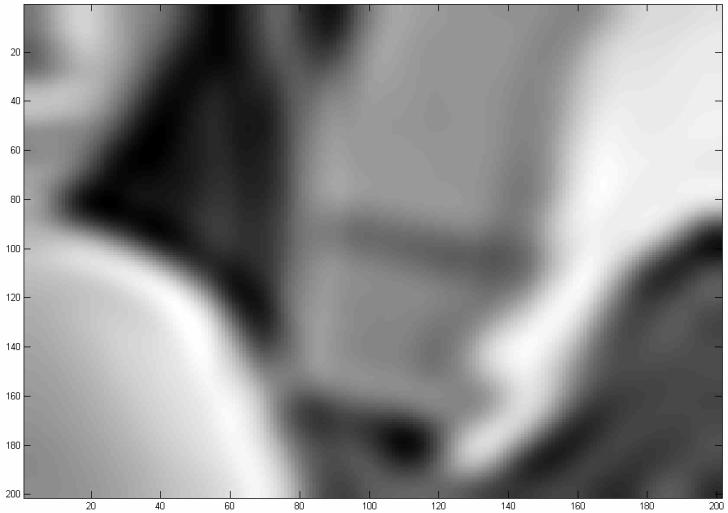


waveletDC n=3

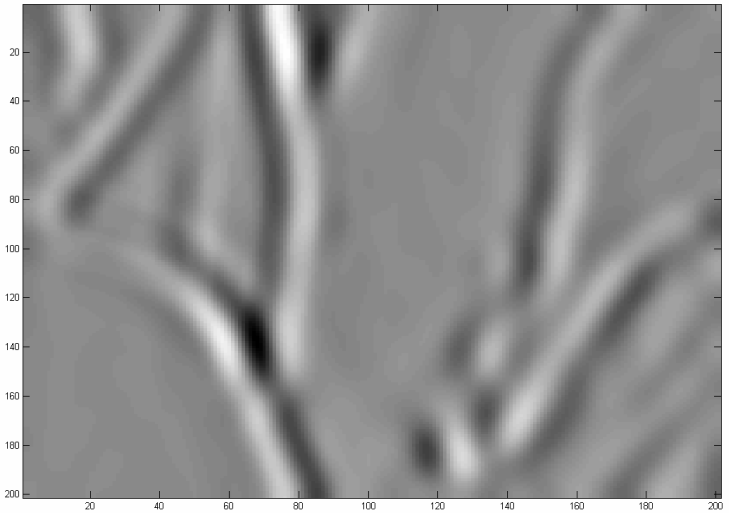


Translation Invariant Wavelet

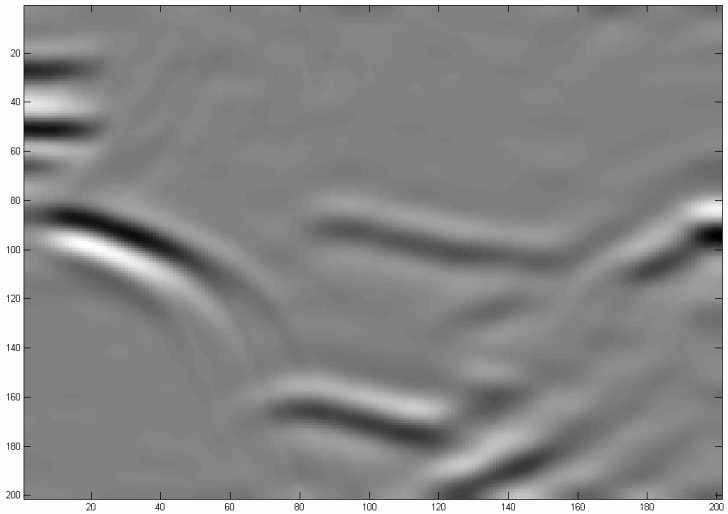
waveletAC n=4



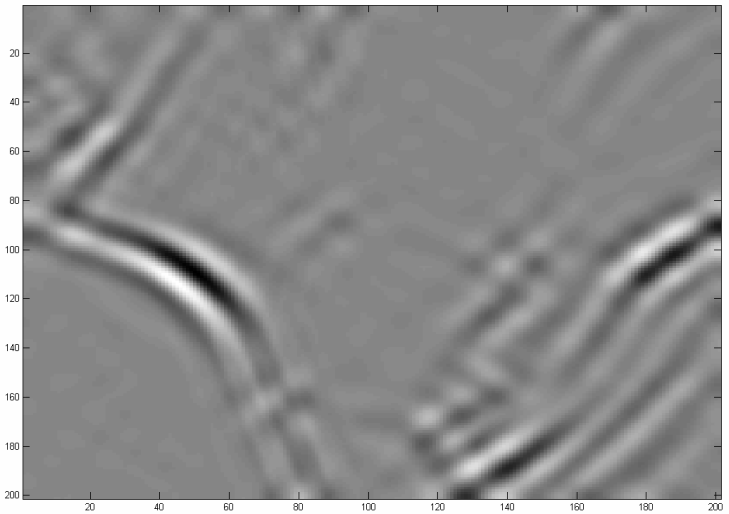
waveletVC n=4



waveletOC n=4



waveletDC n=4



Translation Invariant Wavelet

Wavelet Decomposition → Linear Operations

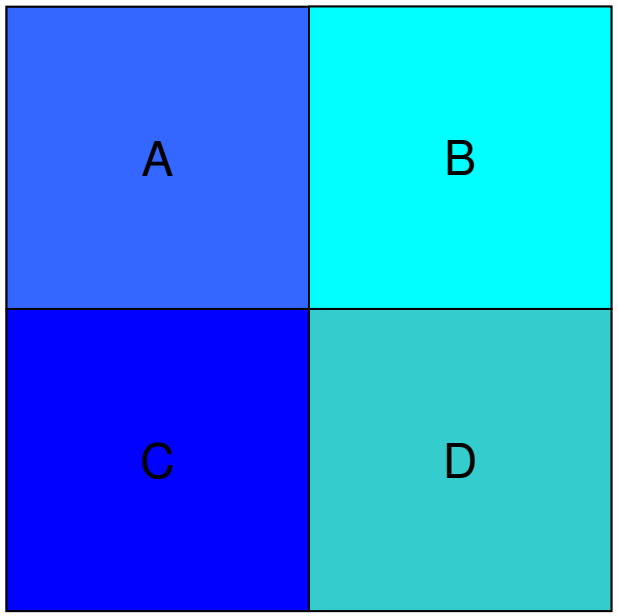
Deblocking → Not Linear Operators

Perfect reconstruction with subsample is not always possible in the presence of not linear operations

- **Cons:**
  - More Memory is needed.

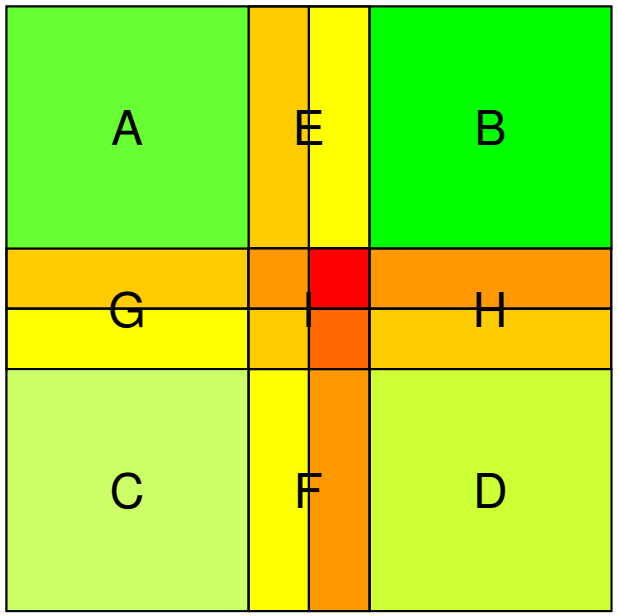
- **Pro:**
  - Exploit the correlation between the pixels.
  - The subsampling can cause problems in a video sequence in which the object is moving.

Deblocking



Normal Image

Deblocking



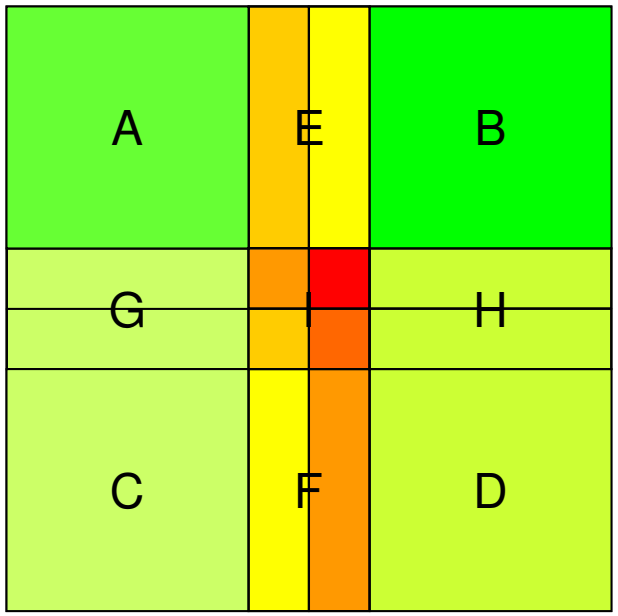
First Wavelet Iteration

Block borders are expanded and they have more activity than the neighbours

Equalize this activity as the absolute moment of the first order

This equalization is at the same time block border and neighbour contenent dependent

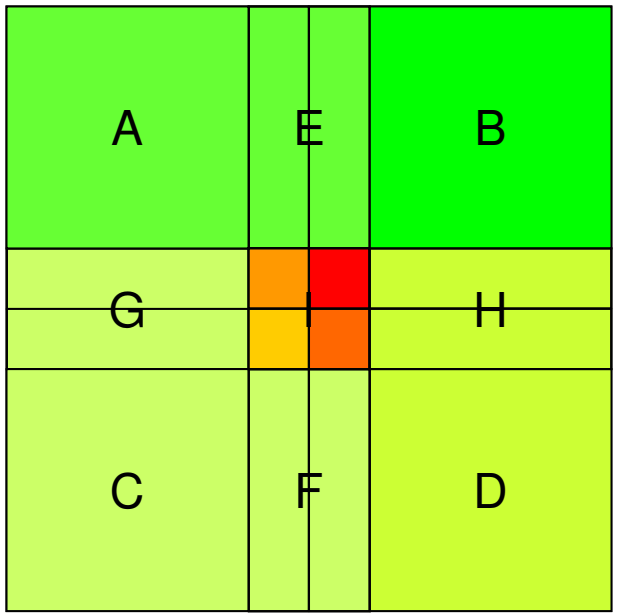
Deblocking



Equalize the activity in G taking a combination between A and C

Equalize the activity in H taking a combination between B and D

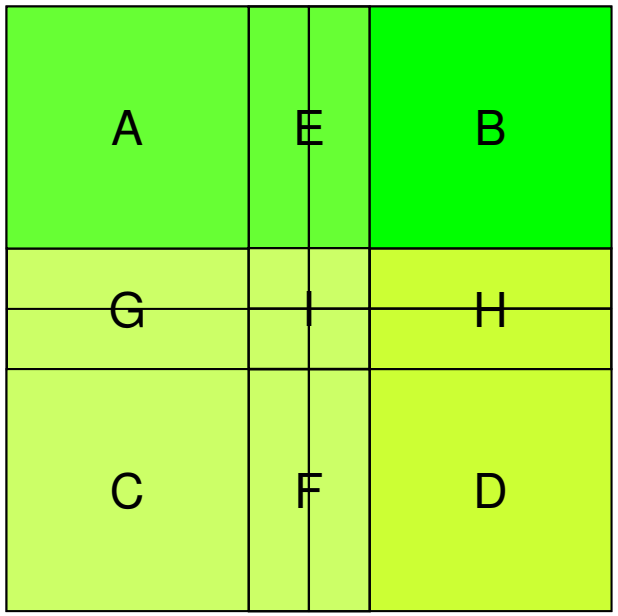
Deblocking



Equalize the activity in E taking a combination between A and B

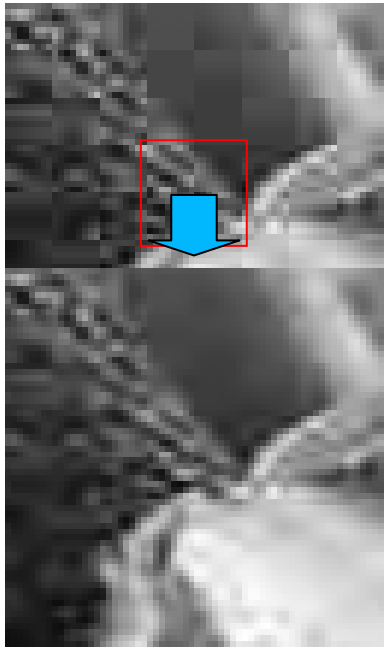
Equalize the activity in F taking a combination between C and D

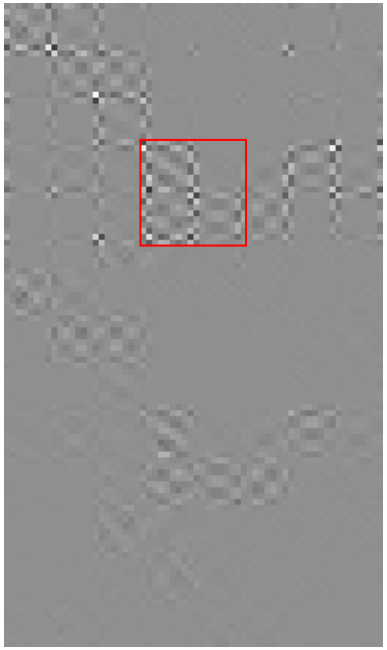
Deblocking

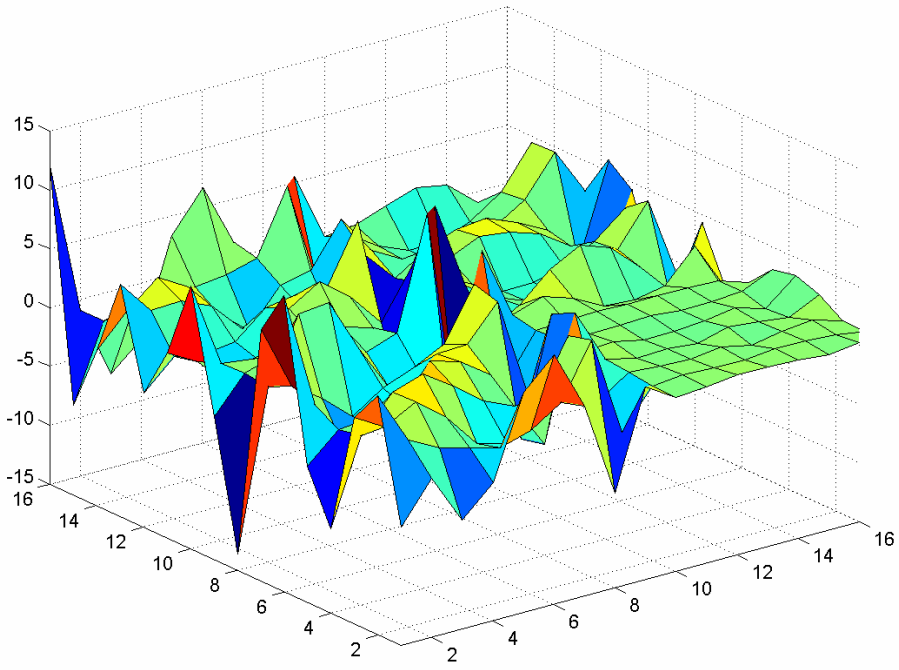


Equalize the activity in I taking a combination between A, B, C and D

Deblocking







Diagonal Details (Wavelet Domain)

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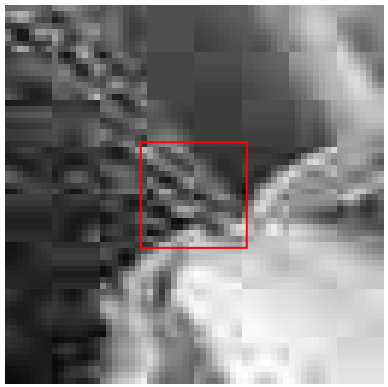
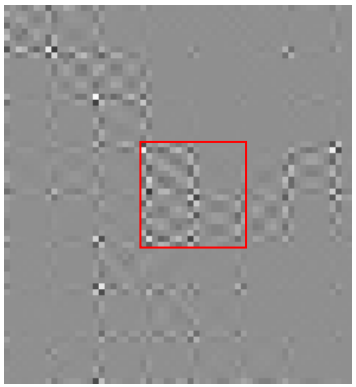
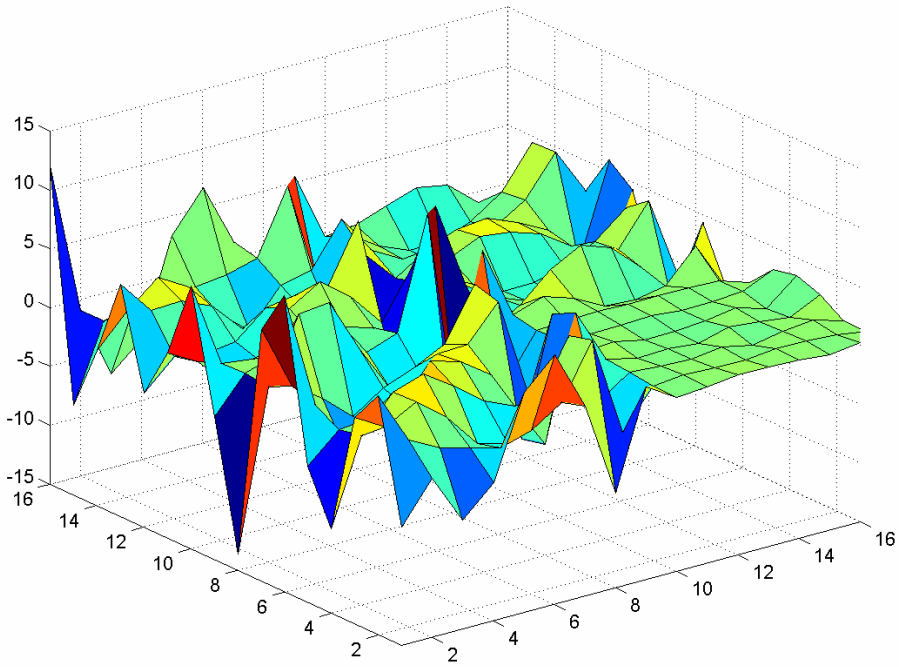
Deblocking







Diagonal Details (Wavelet Domain)

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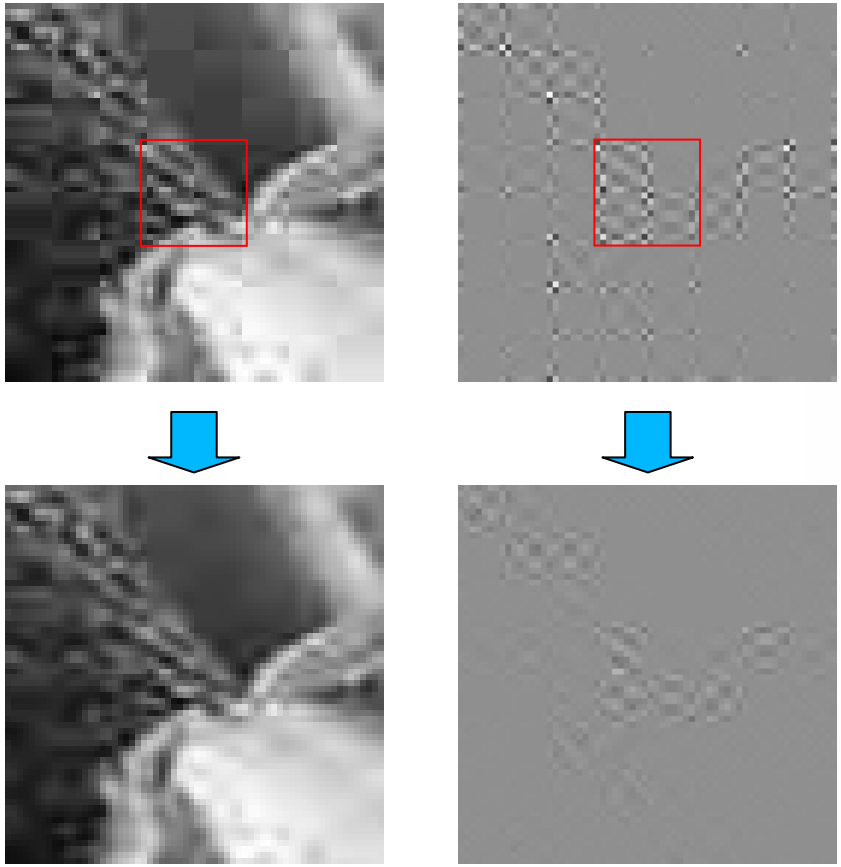
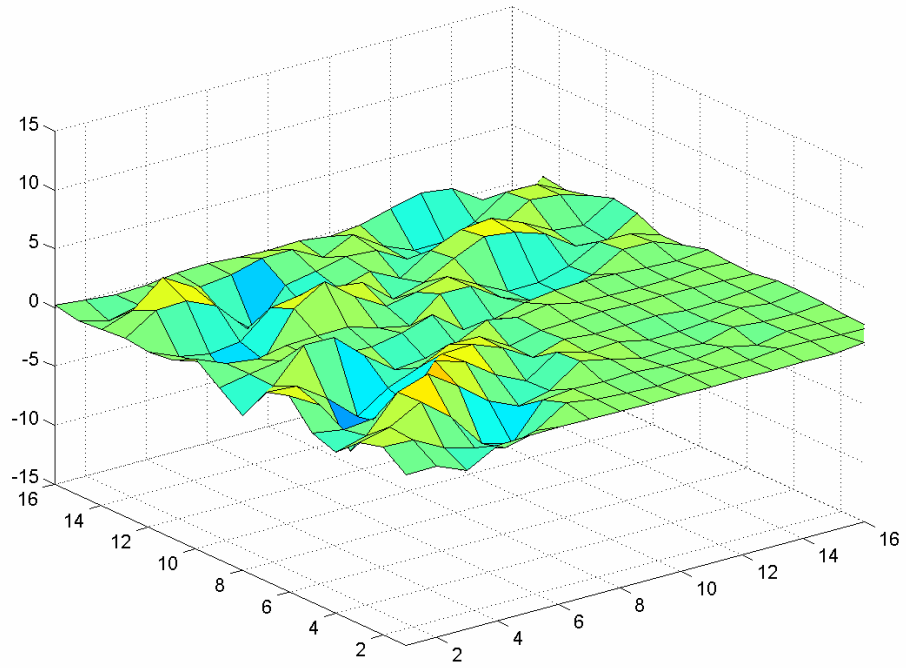
Deblocking





Diagonal Details (Wavelet Domain)

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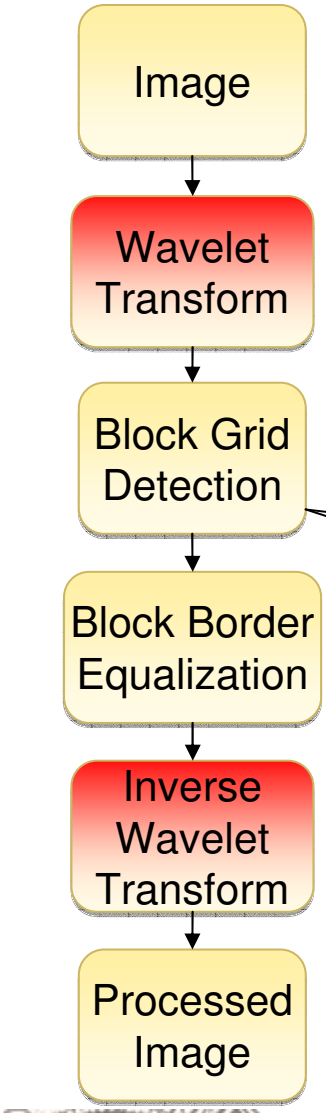
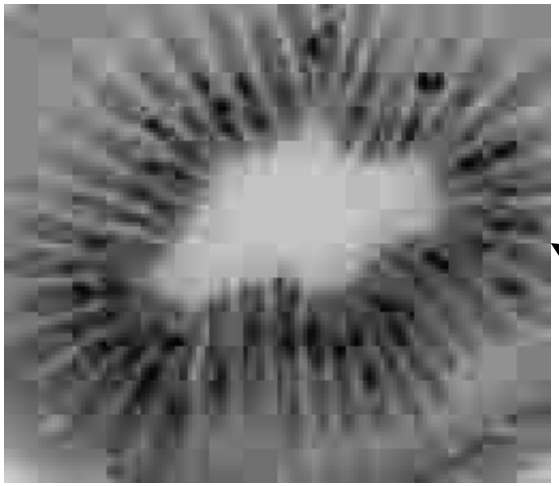
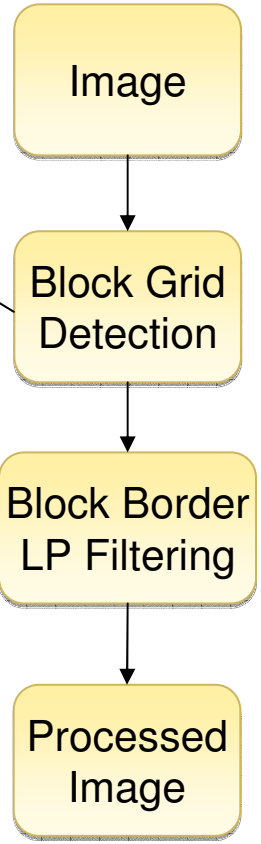
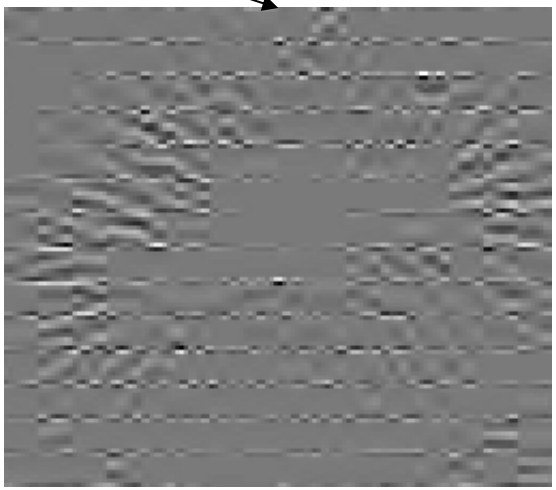
Normal and Special Domain Comparison



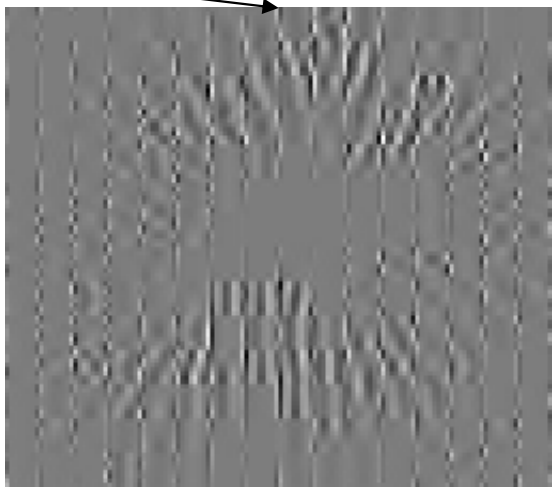


Input Image.





Horizontal Details.



Vertical Details.

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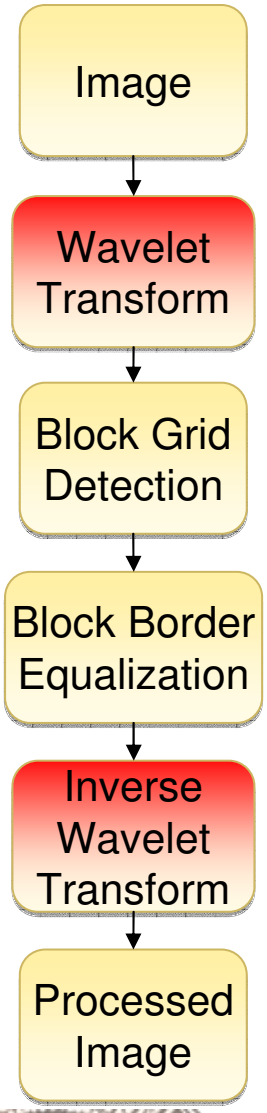
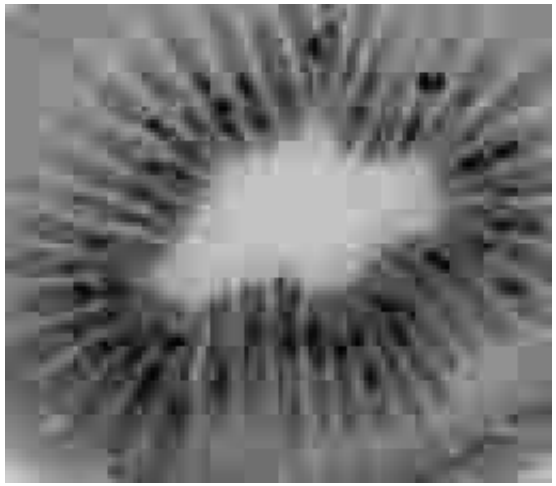
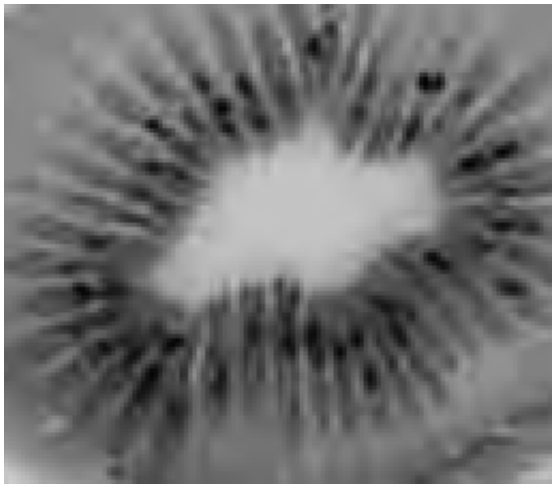
Normal and Special Domain Comparison

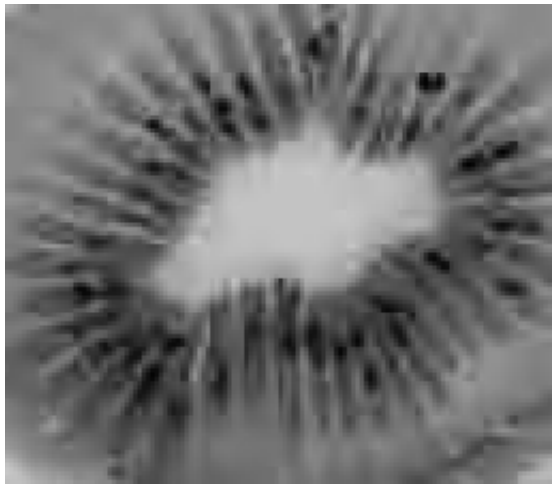




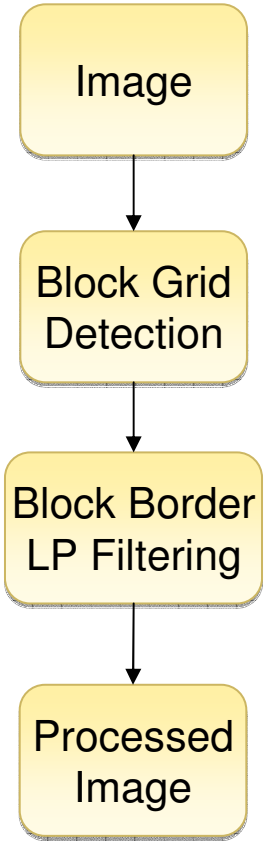
Input Image.



Wavelet Deblocking.



Internal Reference.



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Normal and Special Domain Comparison

Wavelet Decomposition

Cons:

- More operations to implement the wavelet decomposition.

Pros:

- It highlights the artifacts ➔ simpler detection.
- It is possible to process only the needed frequencies.
- It provide the possibility of simpler solution.
- Decomposition already suitable for others image enhancement process (Sharpness, Contrast, Hue, Saturation, …) [3].

Conclusion:

- It represents the right trade-off if you have to operate more than a single process.

[3] Barry E. Mapen, *Image Enhancement in the Wavelet Domain,* Information Display Magazine, 2008

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Results

Original

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Results

Deblocked

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Results

Original

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Results

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Results

Original

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Summary and Conclusion

- Wavelet
  - Implementation, Block Diagram, Filter Spectrum.
- Method
  - Translation invariant wavelet to exploit the correlation between the pixels.
  - Equalization of the block borders in the wavelet domain for Deblocking.
- Results
  - Comparison with the wavelet deblocking and the internal one.
  - Some examples for normal and cartoon images.
- Future Improvement
  - Implementation of a block grid detection in the wavelet domain.
  - Implementation of a wavelet based deringing.
  - Implementation of a wavelet based edge detection.
  - Implementation of a wavelet based sharpness enhancement.

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Bibliography

[1] Majid Rabbani, Rajan Joshi, *An overview of the JPEG2000 still image compression standard*, Eastman Kodak Company, Rochester, NY, USA

[2] P. P. Vaidyanathan, *Multirate Digital Filters, Filter Banks, Polyphase Networks, and Applications: A Tutorial*, Prentice Hall, IEEE, 1990

[3] Barry E. Mapen, *Image Enhancements in the Wavelet Domain*, Information Display Magazine, 2008

[4] Anil K. Jain, *Foundamental of Digital Image Processing*, Prentice Hall, Englewood Cliffs, New Jersey, 1989

[5] Rafael C. Gonzalez, Richard E.Woods, *Digital Image Processing, 2/E*, Prentice Hall, Upper Saddle River, New Jersey, 2002

[6] C. S. Burrus,R. A. Gopinath, H. Guo, *Introduction to Wavelets and Wavelet Transforms*, Prentice Hall, Upper Saddle River, New Jersey, 1998

[7] L. Prasad, S. S. Iyengar, *Wavelet Analysis with Applications to Image Processing*, CRC Press, Boca Raton, Fla, 1997

[8] Gabriel Peyré, Stéphane Mallat, *A review of Bandlet methods for geometrical image representation*, Numer Algor, 2007

[9] Stéphane Mallat, *Geometrical grouplets*, CMAP, École Polytechnique, Palaisau Cedex, France, 2008

[10] Yen-Yu Chen, Ying-Wen Chang, Wen-Chien Yen, *Design of a De-ringing Filter for Wavelet-based Compressed Image*, The 23rd International Technical Conference on Circuits/Systems, Computers and Communication (ITC-CSCC 2008)

Summary and Conclusion

Thanks for your attention!

Any Question?