CS 414 – Multimedia Systems Design

Lecture 9 – JPEG 2000 Compression (Part 4)

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Administrative

- MP1 deadline today, February 9
- Demonstrations, Monday, February 9, 5-7pm in 0216 SC
- MP2 will be posted tonight, February 9
- MP2 deadline, Monday, March 2

JPEG-2000

Original (uncompressed TIF 116KB

JPEG (8:1, 14KB)

JPEG-2000 (8:1, 14KB)

http://www.photographical.net/jpeg2000.html

JPEG-2000

- Created in 2000 by JPEG committee
- File extension:
  - jp2 for ISO/IEC 15444-1 conforming files
  - image/jp2 for MIME type

JPEG-2000 Features

- Low bit rate compression performance
  - Current standards offer excellent rate-distortion performance in mid and high bit rates
  - Low bit rate distortions become unacceptable
- Lossless and lossy compression
  - Current standard does not provide superior lossless and lossy compression in a single code-stream

JPEG-2000

- Large Images
  - Current standard does not allow for images larger than 64Kx64K pixels without quality degradation
- Single decompression architecture
  - Current standard has 44 modes (application specific, and not used by majority JPEG coders)
  - Single common decompression architecture can provide greater interchange between applications

JPEG-2000 Features

- Transmission in noisy environment
  - Current standard has provision for restart intervals, but image degrades badly when bit errors occur.
- Computer generated imagery (Graphics)
  - Current standard is optimized only for natural imagery
- Compound documents
  - Current standard is not applied to compound documents because of its poor performance when applied to text imagery

JPEG-2000 Criteria

- Superior low bit rate performance
  - Below 0.25 bits per pixel for highly detailed grey-scale images
- Lossless and lossy compression
  - Lossless compression uses progressive decoding (i.e., difference image encoding) for medical imaging
- Progressive transmission by pixel accuracy and resolution
  - Reconstruction of images is possible with different resolutions and pixel accuracy for different target devices

JPEG-2000 Criteria

- Random code-stream access and processing
  - Needed in case images have parts that are more important than others
  - User defines “regions-of-interest” in the image to be randomly accessed and/or decompressed with less distortion than the rest of images
  - random code-stream processing allows operations: rotation, translation, filtering, feature extraction, scaling,…

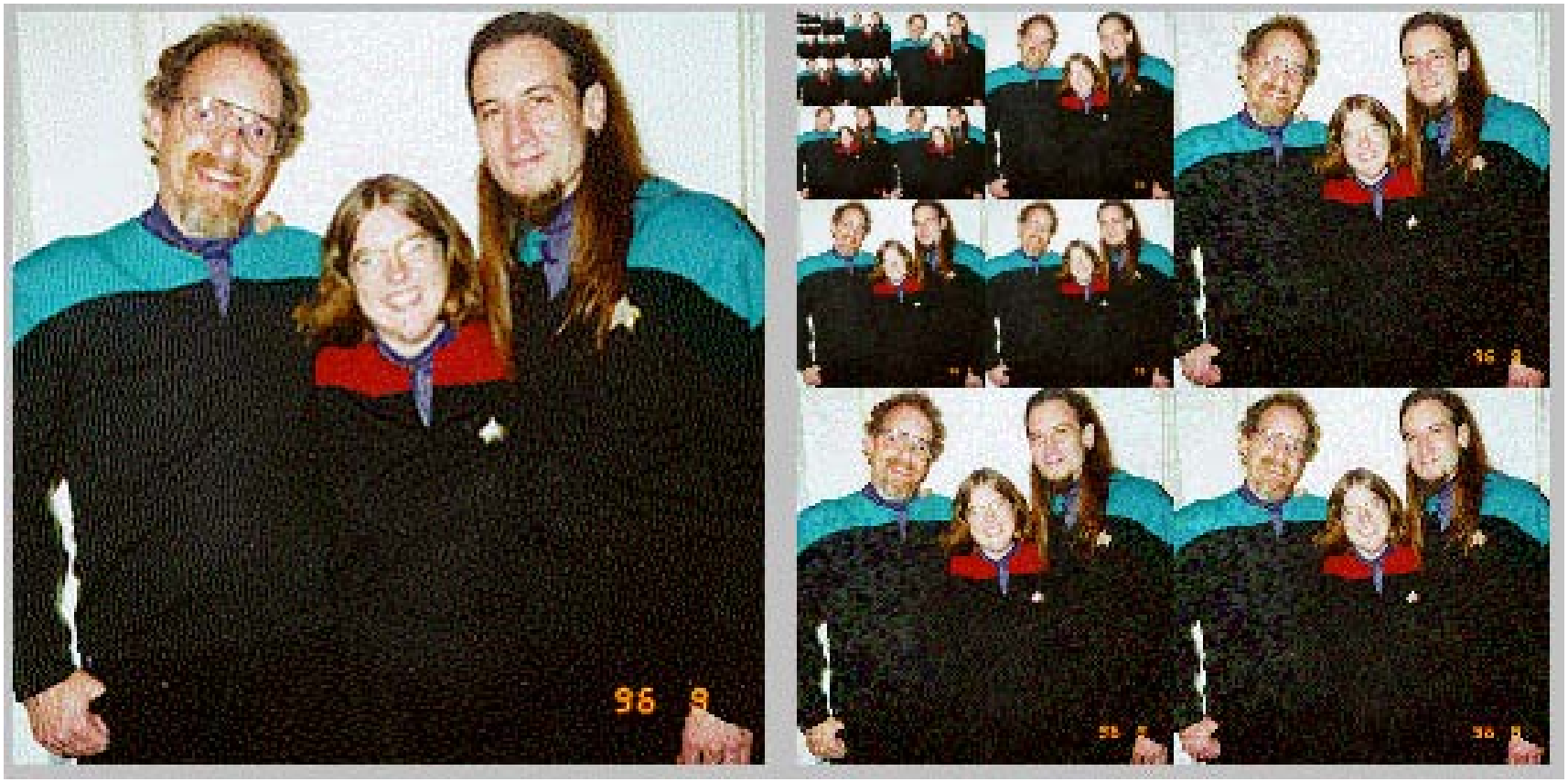
Methods of Compression

- DCT-based coder
  - New baseline JPEG algorithm required for backward compatibility with existing JPEG
- Wavelet-based coder
  - This method permits coding of still images with high coding efficiency as well as spatial and SNR (signal-to-noise ratio) scalability at fine granularity

Wavelet Transform

- JPEG-2000 uses two different wavelet transforms:
  - Irreversible: it introduces quantization noise that depends on precision of the decoder
  - Reversible: it uses only integer coefficients, so the output does not need quantization (used in lossless coding)

2D Wavelet Transform for Image Progressive Transmission



Wavelet Transform

- DWT (Discrete Wavelet Transform) extracts information from the source image at different scales, locations and orientations
- JPEG-2000 uses 2D wavelets and multi-scale transforms
- Wavelet is defined as a set of basic functions, derived from the same prototype function
- Prototype function is known as "mother wavelet"
  - Examples: "Mexican Hat" wavelet, Haar wavelet

Wavelet Coding Method

Integral 1D wavelet transform defined as :

$$W(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{+\infty} f(x)\psi^* \left(\frac{x-b}{a} \right) dx$$

- *W(a,b)* is the wavelet coefficient of the function *f(x)*
- *ψ (x)* is the analyzing wavelet
- *a (> 0)* is the scale parameter
- *b* is the position parameter

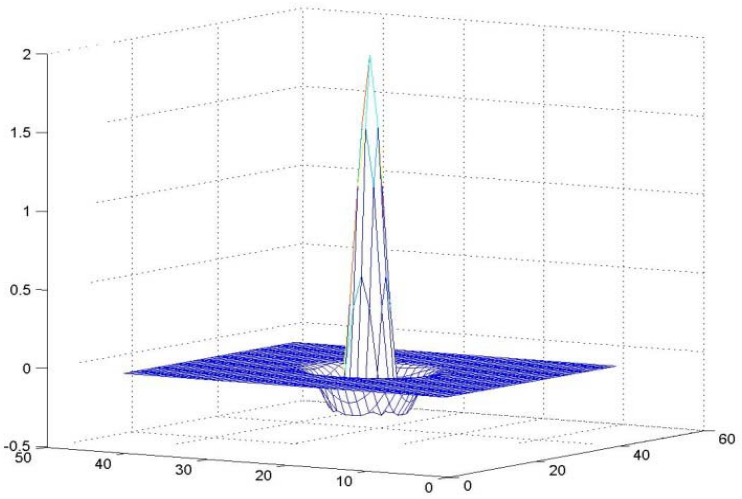
http://jstarck.free.fr/transf.htm

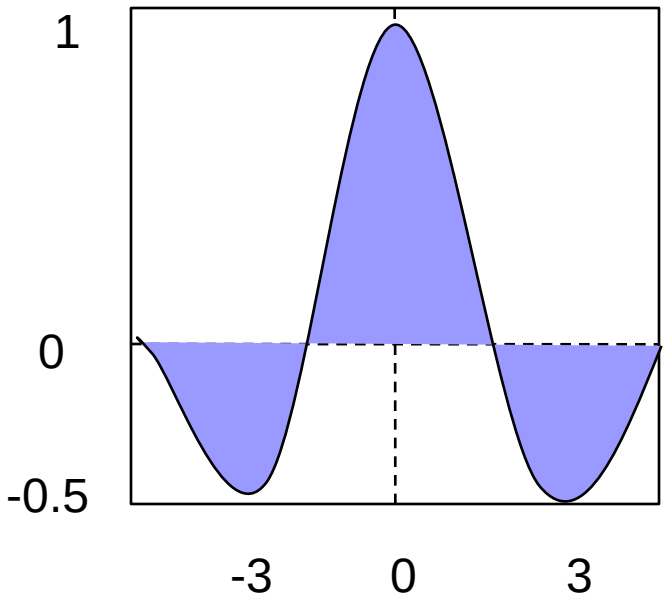
1D/2D Mexican Hat wavelet

Time domain

$$\Psi(x,y) = (x^2 + y^2 - 2)e^{-\frac{1}{2}(x^2+y^2)}$$

$$\psi(x) = (1 - \frac{x^2}{\sigma^2})e^{-\frac{x^2}{2\sigma^2}}$$

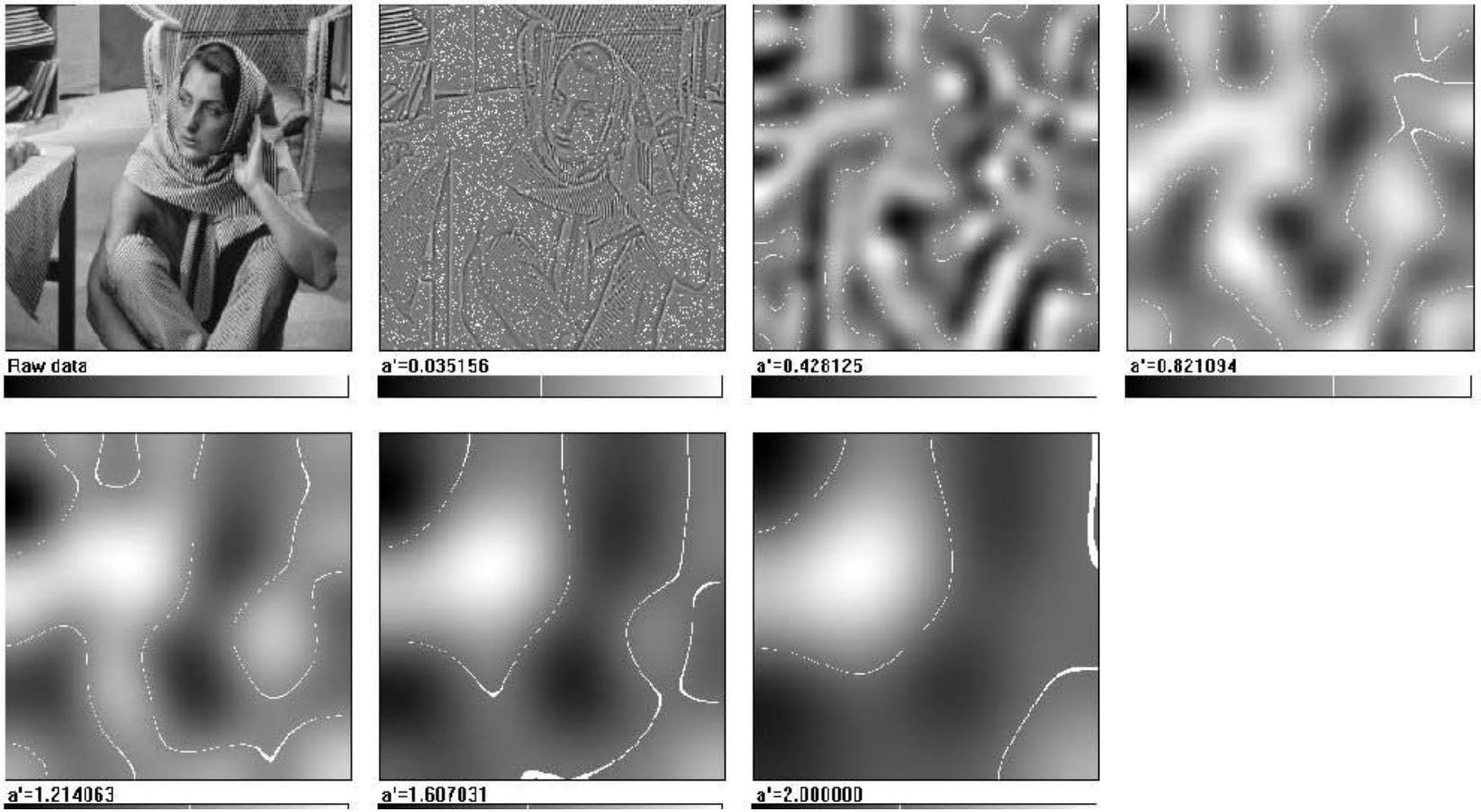




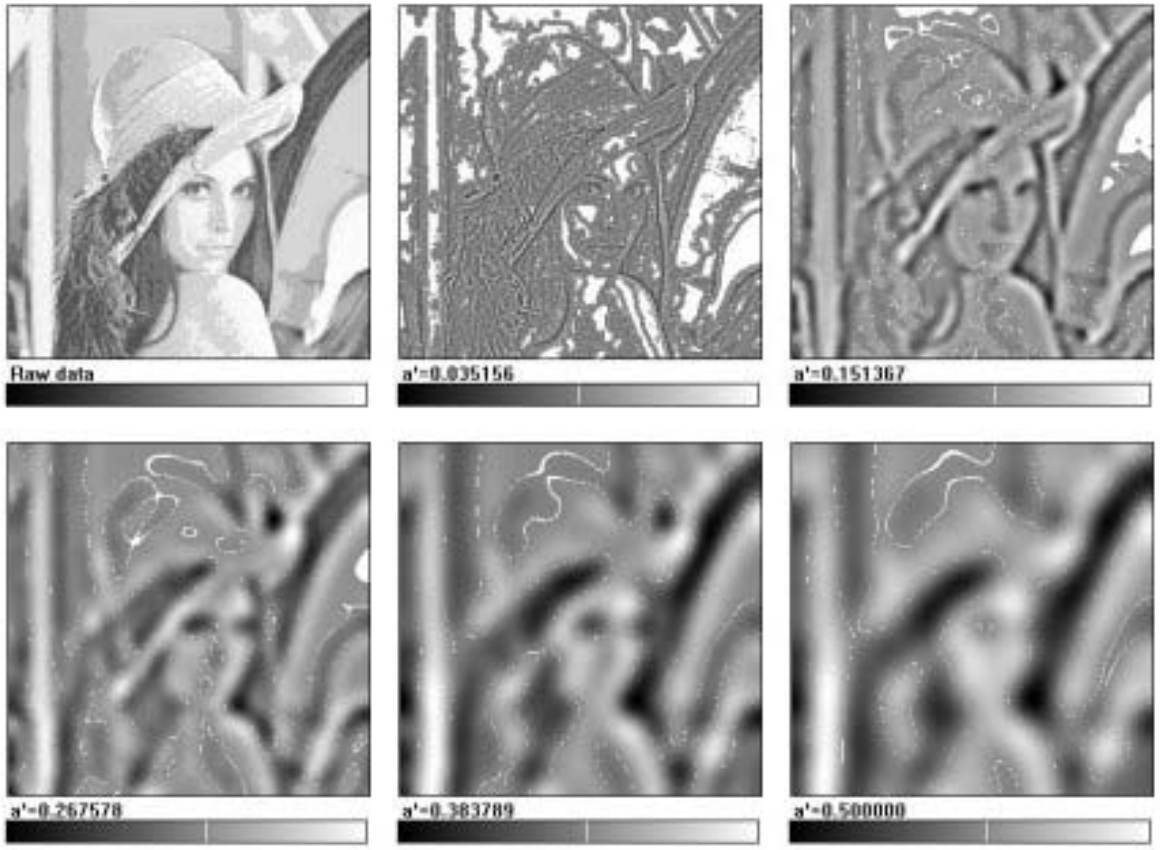
Wavelet Transform Properties

- Wavelet transform coders process high and low frequency parts of image independently
  - DCT methods have difficulties with high-frequency information
- Wavelet method transforms image as a whole (not subdivided into pixel blocks)
  - No blocking artifacts occur
  - Wavelet coders degrade gracefully

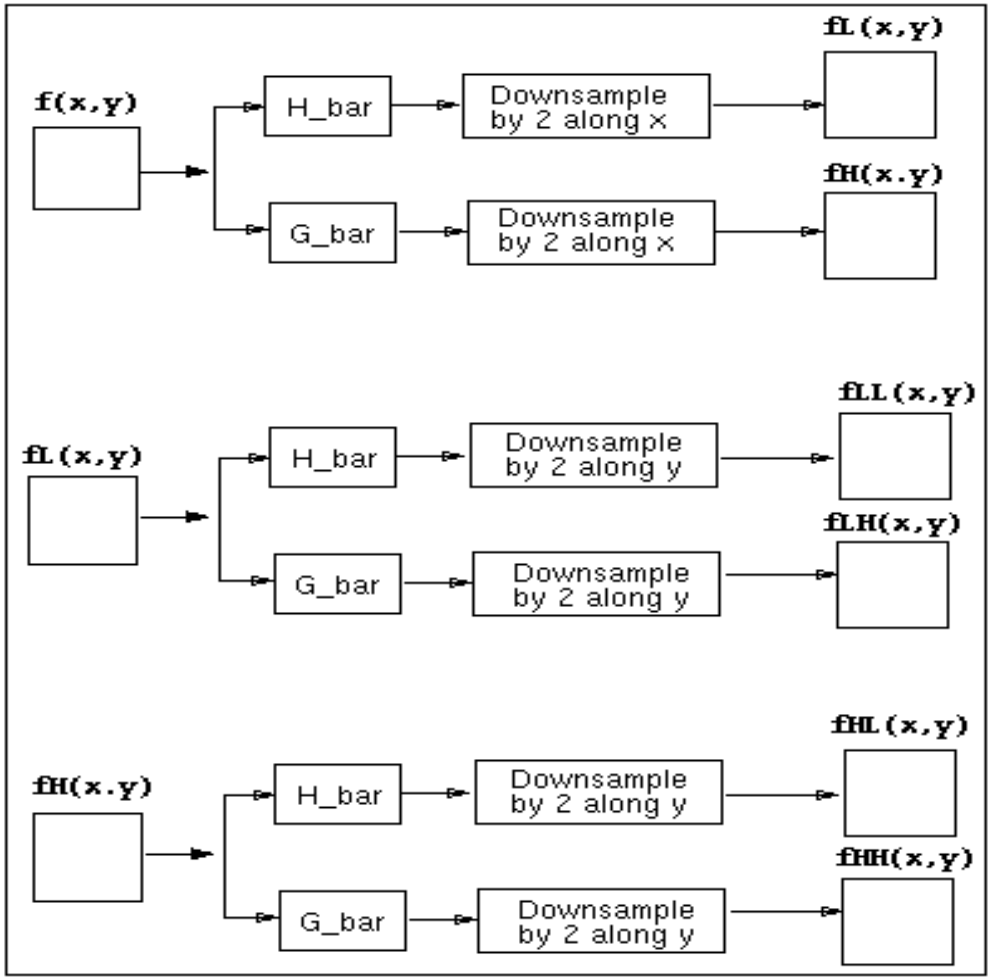
Example of artifacts produced by wavelet transform



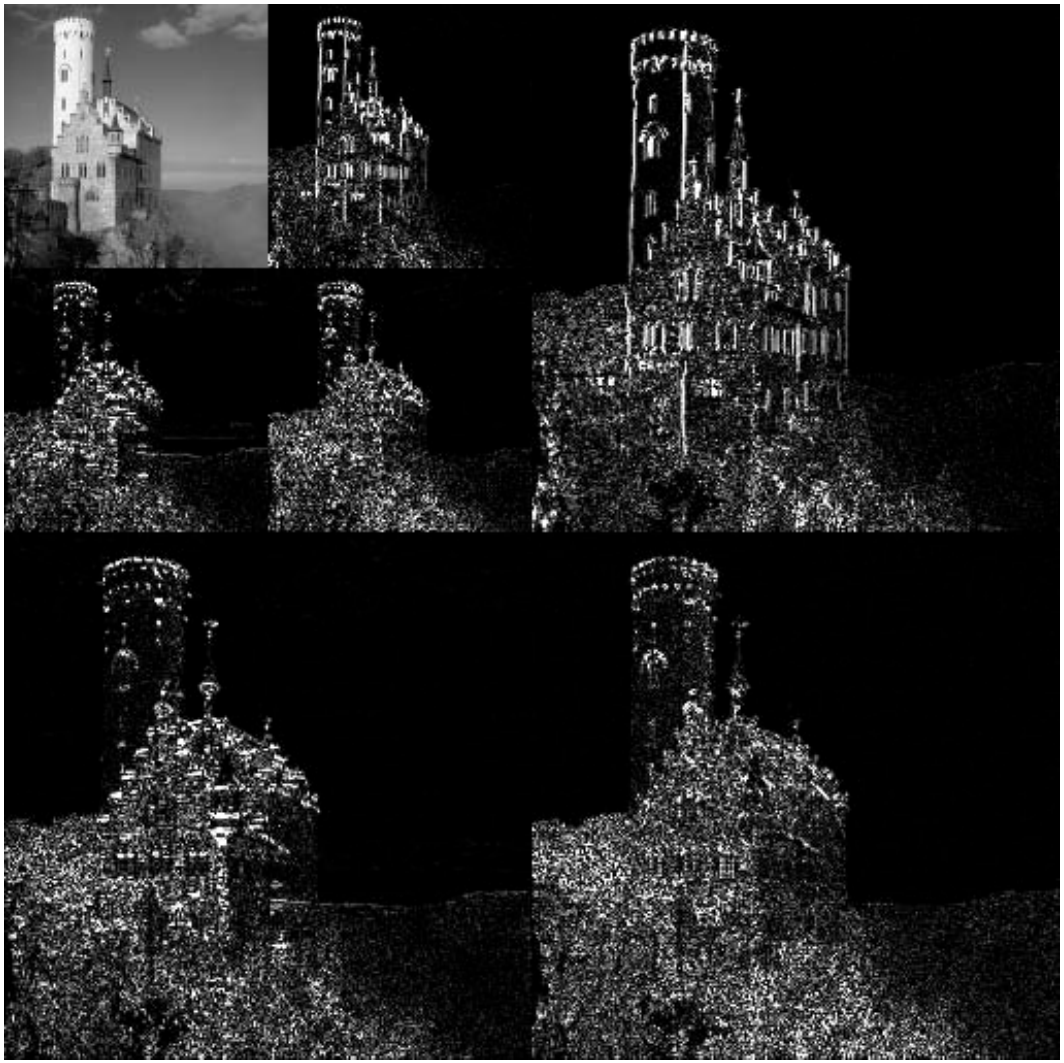
Example of artifacts produced by wavelet transform



Forward Wavelet Transform



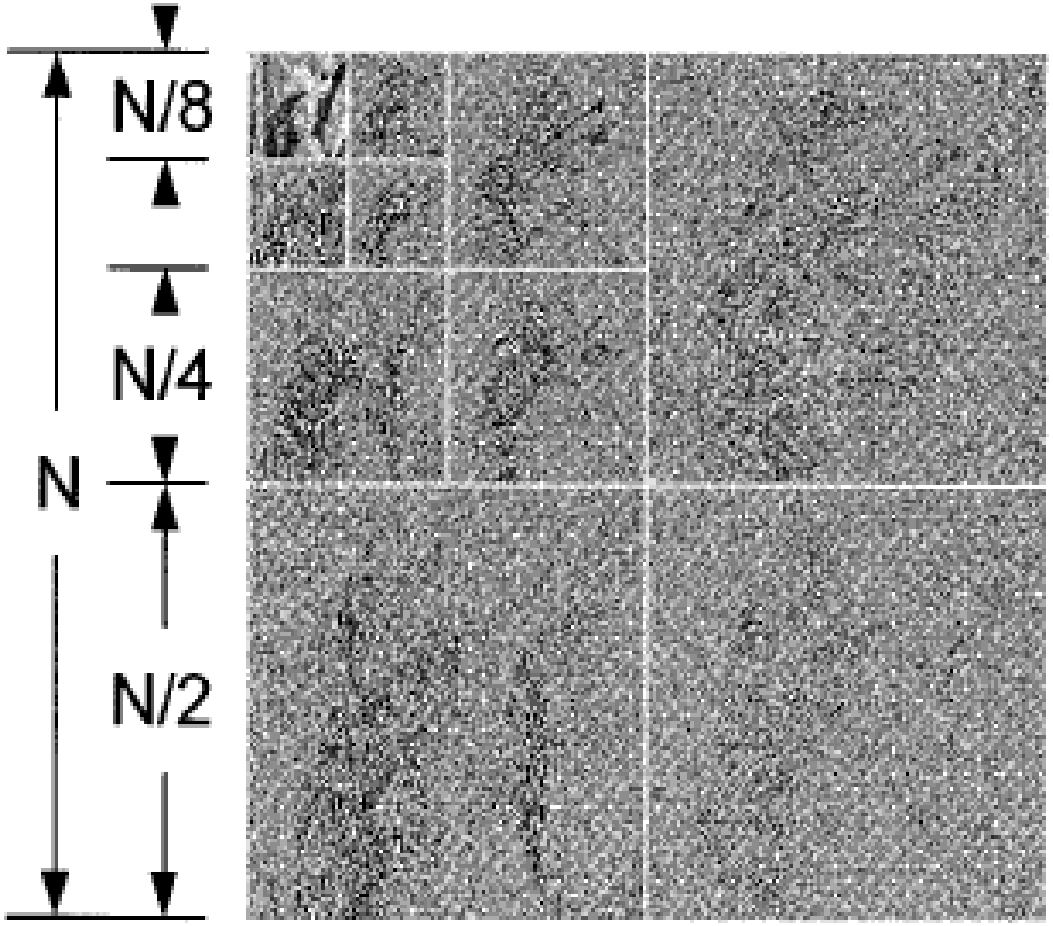
- Image is first filtered along the x dimension, resulting in low-pass and high-pass image
- Since bandwidth of both low pass and high pass image is now half that of the original image, both filtered images can be down-sampled by factor 2 without loss of information
- Then both filtered images are again filtered and down-sampled along the y dimension resulting in four sub-images



An example of the 2D discrete wavelet transform that is used in JPEG2000. The original image is high-pass filtered, yielding the three large images, each describing local changes in brightness (details) in the original image. It is then low-pass filtered and downscaled, yielding an approximation image; this image is high-pass filtered to produce the three smaller detail images, and low-pass filtered to produce the final approximation image in the upper-left.

(Source: wikipedia)

Result of Lena Image after 3-level 2-D DWT

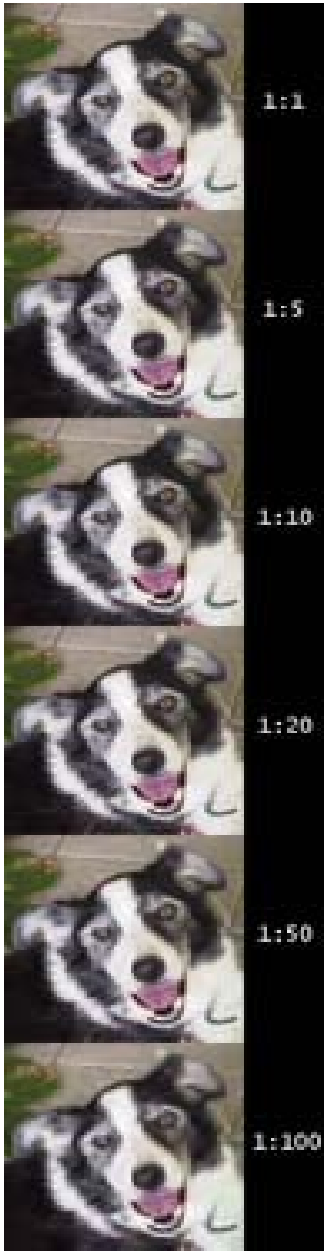


JPEG-2000 Performance

- Gain up to about 20% compression performance to the first JPEG standard
- Applications of JPEG-2000
  - Large images
  - Images with low-contrast edges (e.g., medical images
  - In printers, scanners, facsimile
  - HD satellite images

Applications of Motion JPEG2000

- Leading digital film standard
- Supported by Digital Cinema Initiatives for storage, distribution and exhibition of motion pictures
- Considered by Library of Congress to be the digital archival format



Conclusion

Artifacts of JPEG-2000 Compression

- Compression 1/20 size is without incurring visible artifacts

- If artifacts occur they can be seen as Smoothing rather than squares or mosquito noise