APMA990 Final Project: Wavelets for Audio Compression

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Wavelets

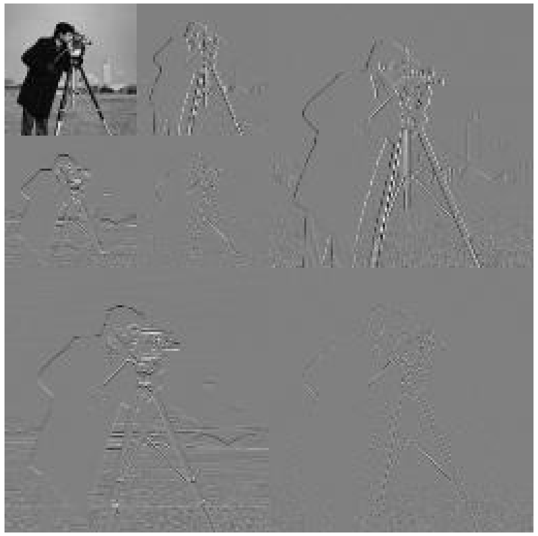
- A *wavelet transform* separates a signal into *smooth* components and *detail* components.

- The detail components form a hierarchy of progressively finer details relative to the smooth component.

- The original signal can be *reconstructed* by beginning with the smooth part and applying the details.

Applying the Wavelet Transform to an Image

Here we recursively apply a Haar wavelet transform to the smooth (top-left) component of an image.

 $\Rightarrow$  $\Rightarrow$ 

Reconstruction of Original Image

From the wavelet transform, we can recover the original image

$\Rightarrow$

Wavelets for Compression

- Wavelets lead to a very natural idea for signal compression:

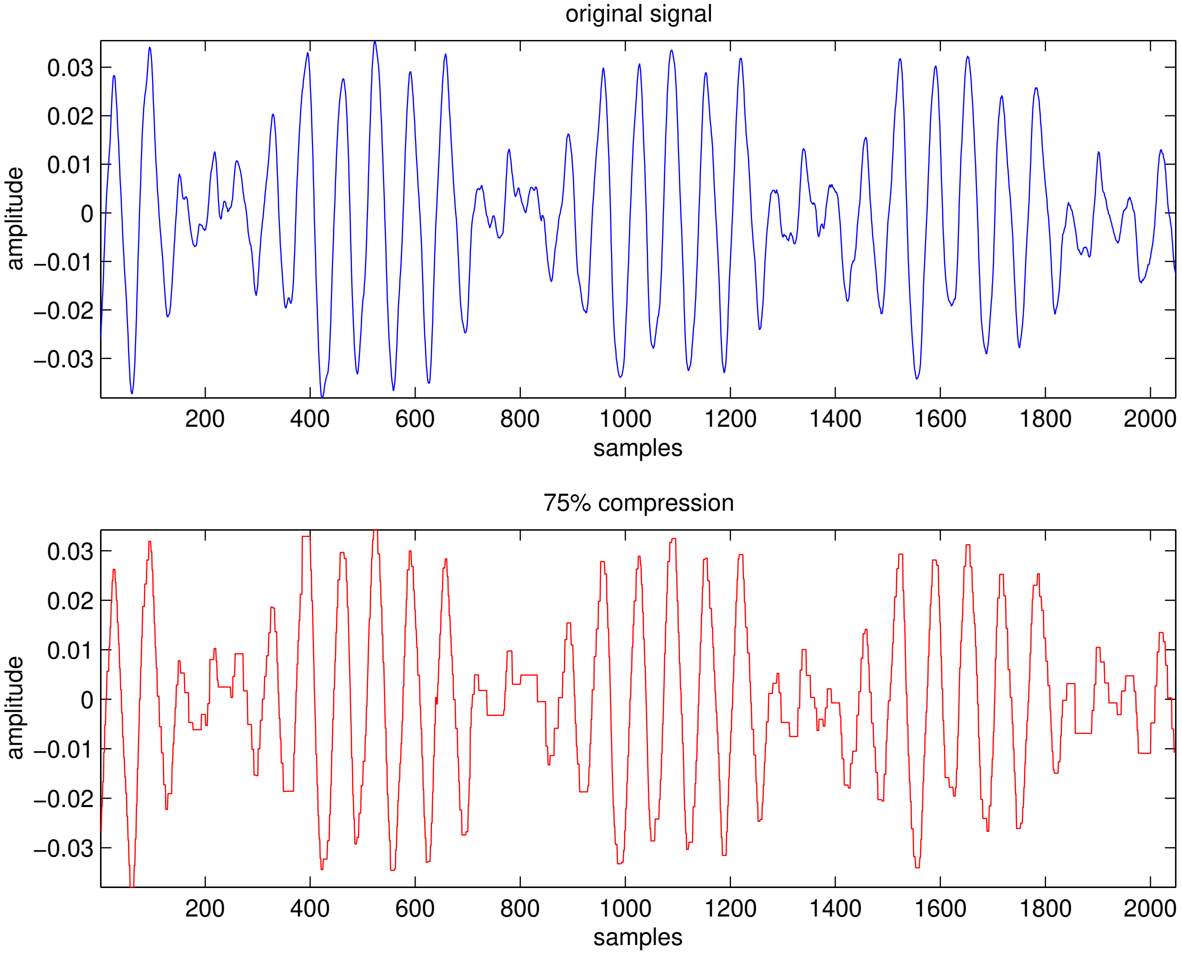
- *Throwing away the small coefficients of the detail corresponds to throwing away the small details in the signal.*

- We will apply this technique to music compression.

An Audio Signal

- 1-D signal.
- "CD quality" (44100 samples/sec, 16 bits/sample, mono (1 channel)).
- *Long signals* (300+ seconds) $\Rightarrow$ process the data in *blocks*. Each block consists of 2^J samples.

2^{11}-Sample Block from Typical Audio Signal



Wavelet Transforms on Audio Signals

We treat each block as an indepdent signal and apply to following:

- Calculate the (Haar) wavelet transform.
- Compress by throwing away the smallest $p\%$ of the detail coefficients.
- (Optionally) store the block using $p\%$ less storage.
- Reconstruct the block.

Some Test Signals

- Tori Amos - *Winter* (piano, vocals, strings)
- Dream Theater - *Learning To Live* (progressive metal - heavy electric guitar, loud drums, bass, keyboard, vocals)
- Pearl Jam - *Jeremy* (alternative rock - guitars, bass, drums, vocals)

Results

- At 50% compression (50% of detail coefficients removed), the compressed signal was virtually indistinguishable from the original. (exception: *Winter*)

- At 65% - 75% compression, noticeable artifacts appear – most notably a “metallic hiss” riding on top of the signal.

- At 95% compression, the signals were still easy recognizable thought not particularly enjoyable to listen to ;-)

Future Work

- Using a *Daubechies filter* instead of the Haar filter might prevent the compressed signal from becoming piecewise constant. This could reduce noise in the reconstructed signal.

- *Variable Bit-Rate Encoding*: The criteria for compression could be varied between blocks. Blocks with less "information" could then be compressed to a higher degree.

Acknowledgments

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References:

- G. Strang, T. Nguyen, *Wavelets and Filter Banks*.
- E. Stollnitz, T. DeRose, D. Salesin, *Wavelets for Computer Graphics: A Primer*.