Zero Domain Filtering

David M. Stavens ’02
dstavens@cs.princeton.edu

Ken Steiglitz and Perry Cook, Advisors

Schedule

- ✓ Deliverable by the checkpoint:
  - ✓ Design and implementation of:
    - ✓ A simple culling method.
    - ✓ A simple zero moving filter.
    - ✓ Advanced culling methods.
  - ✓ Identification and analysis of data dependent research problems that may benefit from our filtering approach.

- Deliverable by the end of the term:
  - Design and implementation of zero moving filters for the data associated with the research problems.
  - Evaluation of our approach.

Culling Methods

- Simple Iterated Method:
  - Cull the zero Z furthest from the unit circle.
  - If Z is complex, cull its conjugate too.

- Advanced Iterated Method:
  - Cull the zero Z that is furthest zero from the unit circle that also has property P.
  - If Z is complex, cull its conjugate too.

Analysis of Culling Methods

- Property P can be lots of things:
  - A particular frequency response.
  - A certain density of other zeros in the area.

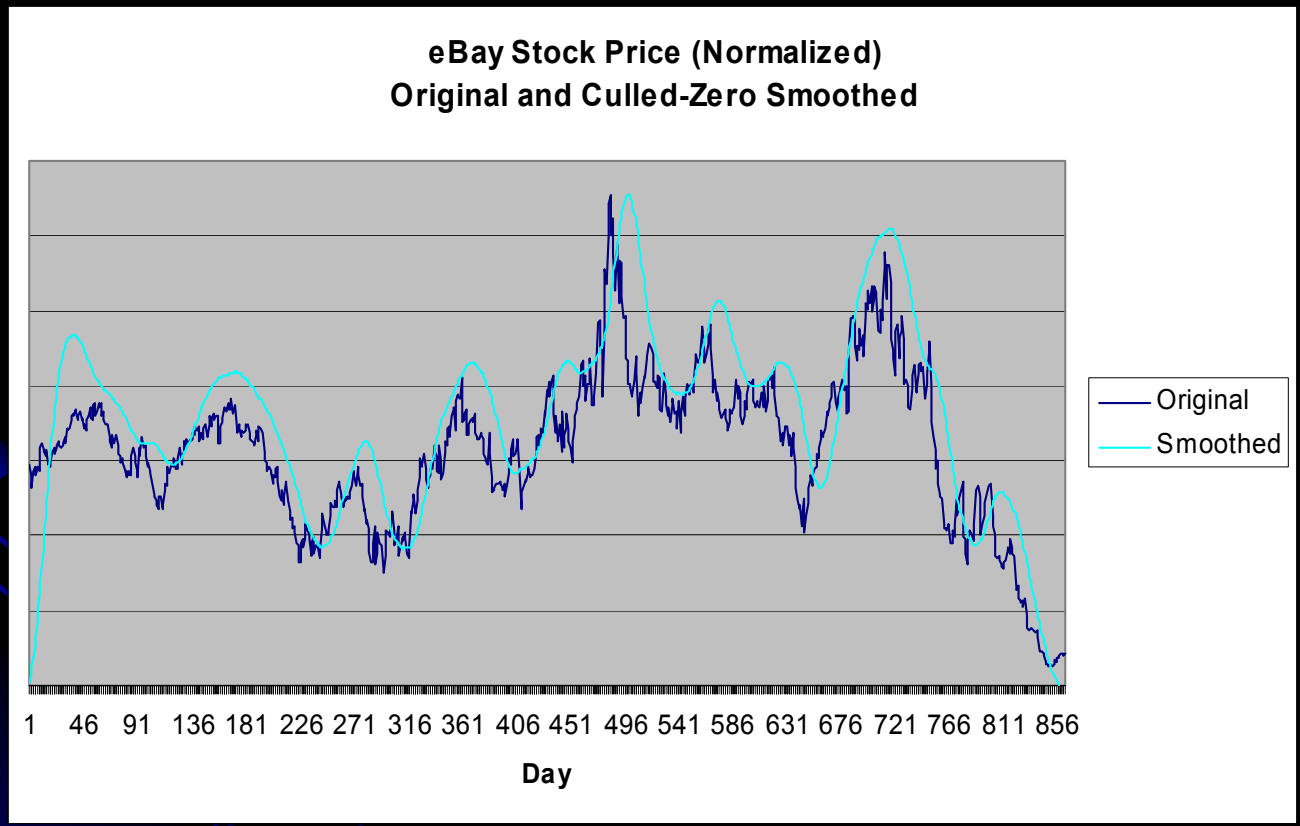
- The simple method seems to be the best.
  - Because, for example, when P is a particular frequency response which we increment, the effect is to put poles throughout the spectrum.
    - This acoustically “tunnels” the signal.

A Simple Zero Moving Filter

- We started with an audio file.
- We culled 50 zeros.
- We embedded a 50^{th} order low pass filter.
  - A 50^{th} order filter is very powerful.
- It worked. Success!

Smoothing Filters

- Our method does an excellent job smoothing:



Selected Research Problem

- We feel that there is a cryptographic application of our filtering method.

- Preliminary Idea:
  - Generate a random z-Transform, K.
    - K is the secret key.
  - Multiply the input signal by K, resulting in E.
  - E is the encrypted version of the input signal.
  - To decrypt, divide E by K.

Zero Domain Encryption

- We need to show this is difficult to break.
  - We have several ideas as to why it is.
- One reason we like the idea of zero domain encryption is that we may be able to accomplish it without having to factor the entire signal.
  - This addresses the “Additional Challenge” mentioned in the proposal talk.

New Insights

- Along the way, we gained new insights into zero domain operations.
- For example, we now know the effect of moving every zero E units closer to or farther from the unit circle.
- We have several small but important results like this.

Setbacks

- Some signals' zeros are all so close to the unit circle that culling any zero drastically changes the signal.
  - Thus, zero domain filtering could not be used.
- Our zero domain smoothing technique does a fantastic job when normalized.
  - But conventional smoothing methods do an excellent job too.

For The Rest of the Term

- Pursue the cryptography idea.
- Continue to work on underlying signal processing issues:
  - Generate the minimum phase version of a signal using zero domain folding.
    - There is no other way to do this.
    - This has never been done.
  - Build zero domain Causal Wiener Filters.