

# Signature Authentication Using Wavelets and Fourier Analysis

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**Mentoring through Critical Transition Points, 2013**

# Purpose

- Is it possible for a machine to authenticate a signature?

# Outline

- 1 Introduction
  - Data Collection
- 2 Authentication Process
  - Original Data
  - Wavelets
  - Fourier Transformation
- 3 Data Comparison
  - Further Example
  - Signatures Outside of the Basis Set
  - Error Problems
- 4 Conclusion
  - Applications and Outlook

# Data Collection

- We each selected two names and then signed four “original” signatures
- Other group members then “forged” each signature
- The following are the names we used

- |               |                 |
|---------------|-----------------|
| ① Alicia Keys | ⑥ John Williams |
| ② Amy Pond    | ⑦ Matt Smith    |
| ③ Adam Savage | ⑧ Paul Trisko   |
| ④ Babe Ruth   | ⑨ Tom Hanks     |
| ⑤ Joe Jonas   | ⑩ Yogi Berra    |

# The Data We Used

- We started with a sheet of signatures
- Four genuine signatures and four forgeries



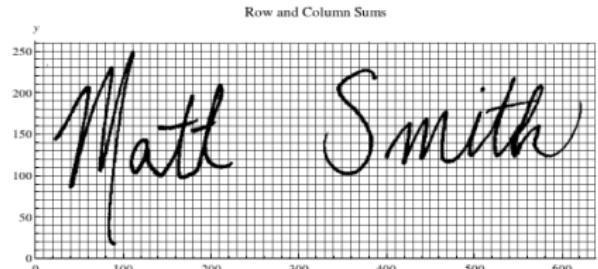
# Single Signature

- We cut out individual signatures
- Converted all of them to bitmap files
- Then imported them into Matlab

A handwritten signature in black ink that reads "Matt Smith". The signature is written in a cursive style, with "Matt" on the top line and "Smith" on the bottom line.

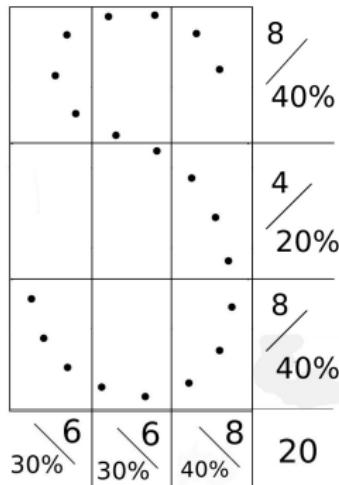
# Analyzing Original Data

- The data from bitmap files was used for row and column sums
- We then partitioned the rows and columns to find the distribution percentages
- By calculating percentages in partitions, different sized signatures can be compared



## Original Data

## Example



- $\vec{v} = < 40, 20, 40, 30, 30, 60 >$
- The first half of the vector  $\vec{v}$  is the column percentages
- The rest is the row percentages

## Calculating Error for Original Data

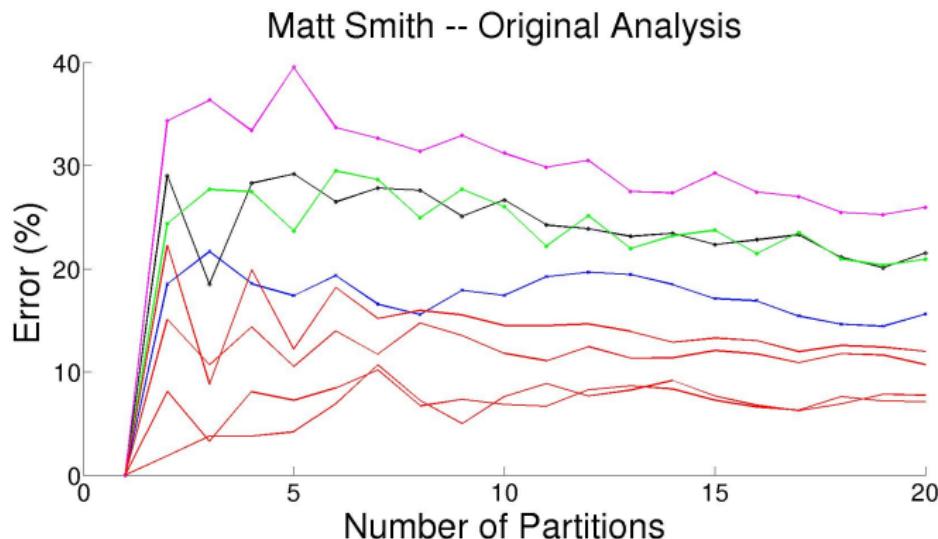
- We then averaged the four genuine signatures
- We then calculated error for all signatures

$$\sigma_n = \sqrt{(a - a_1)^2 + (b - b_1)^2 + (c - c_1)^2 + \dots}$$

Original Data

# Error Analysis Using Original Data

- This graph shows the error for tested signatures



## Original Data

# Accepted vs Rejected Signatures

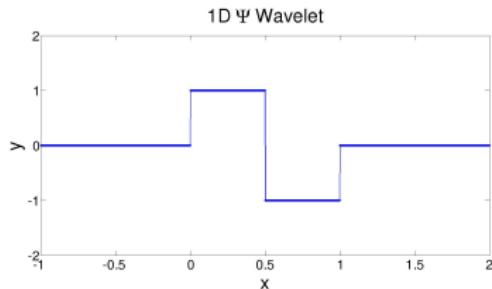
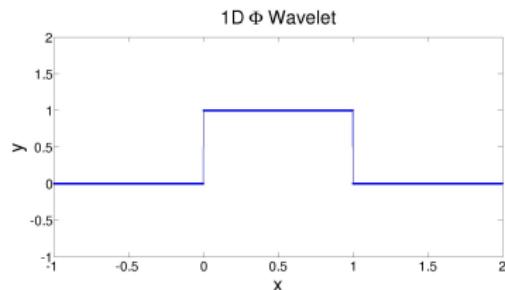
- This table shows the percent of signatures that would be accepted by the program at various cutoffs

$$\sqrt{(\sigma_1)^2 + (\sigma_2)^2 + (\sigma_3)^2 + \dots}$$

Total Error	40	50	60	70	80
Genuine	32.5%	50%	60%	70%	72.5%
Forgery	0%	2.5%	5%	15%	25%

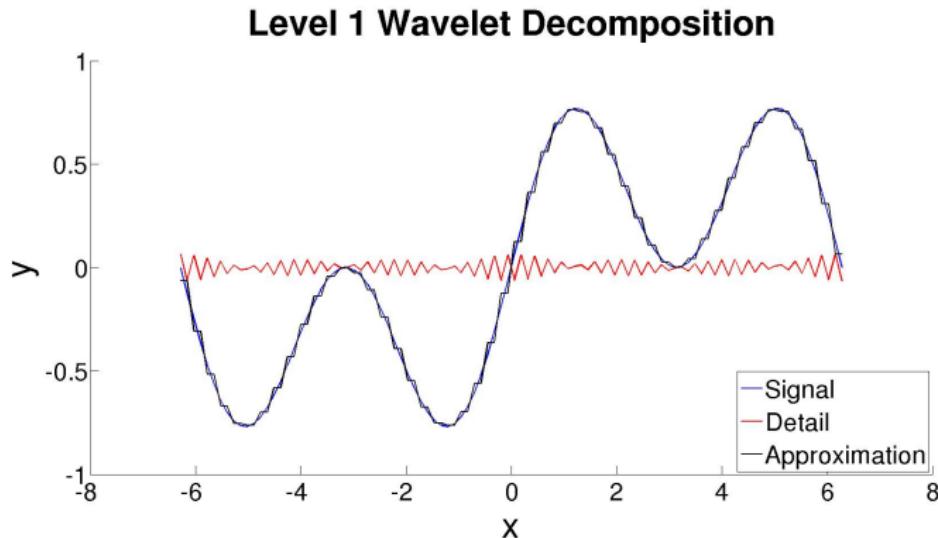
Wavelets

# Haar Wavelet Decomposition



## Wavelets

# Example of Wavelet Decomposition



Introduction  
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Authentication Process  
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Data Comparison  
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Conclusion  
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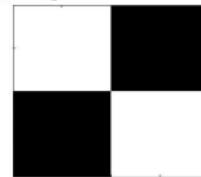
Wavelets

# 2D Haar Wavelet

Approximation      Horizontal Detail

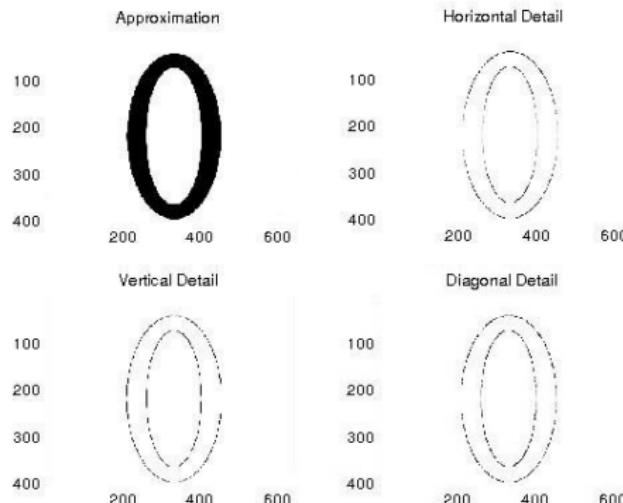


Vertical Detail      Diagonal Detail



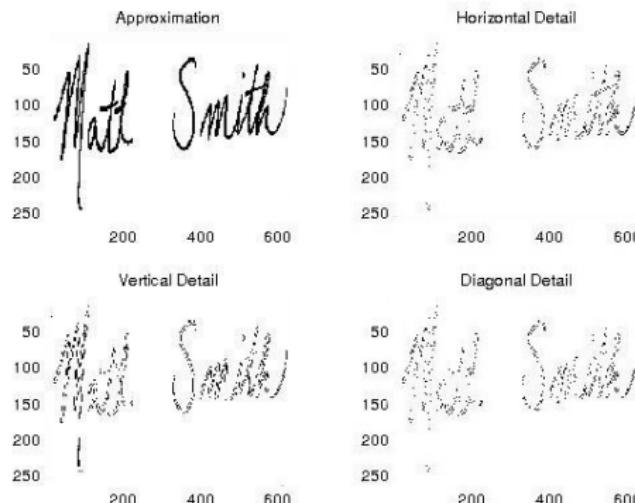
## Wavelets

# Simple 2D Haar Wavelet



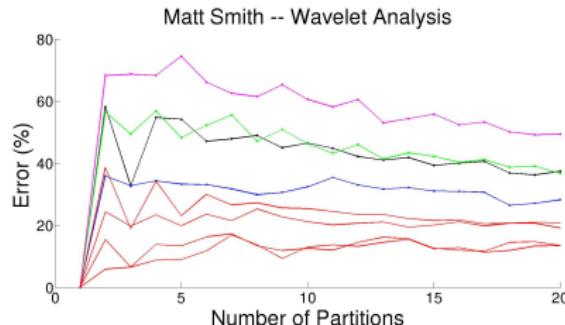
Wavelets

# Example of a Level One Wavelet Decomposition



# Error Analysis Using Wavelets

- The coefficients for the Vertical, Horizontal, and Diagonal were used for analysis
- Summed the rows and columns
- Compared each signature to the average genuine signature



## Accepted vs Rejected Signatures

- This table shows the percent of signatures that would be accepted by the program at various cutoffs

Total Error	75	100	105	110	115
Genuine	65%	65%	65%	65%	70%
Forgery	0%	2.5%	5%	20%	20%

# Discrete Fourier Transformation

Using the equation

$$f(x) = \sum_{n=-\infty}^{\infty} \beta_n e^{inx}$$

for discrete functions,  $\beta_n$  is

$$\beta_n = \sum_{j=0}^{n-1} \beta_i \cdot \bar{\omega}^{-jk}, \quad \omega = e^{\frac{j2\pi}{n}}$$

Introduction  
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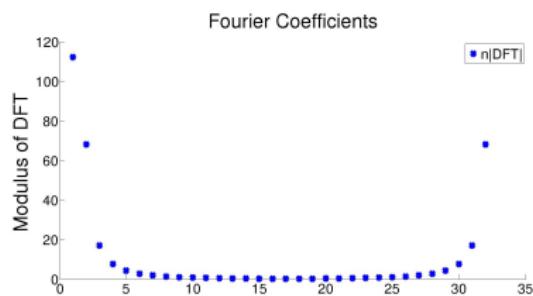
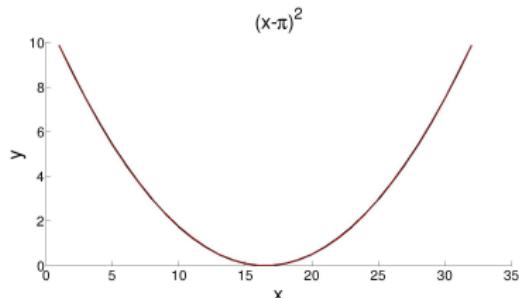
Authentication Process  
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Data Comparison  
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Conclusion  
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Fourier Transformation

# Simple Fourier Transform



Introduction  
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Authentication Process  
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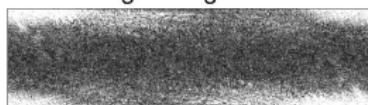
Data Comparison  
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Conclusion  
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Fourier Transformation

# Fourier Space

Matt Smith -- Fourier Transform  
Original Signature



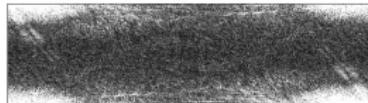
Matt Smith

Forgery 1



Matt Smith

Forgery 2

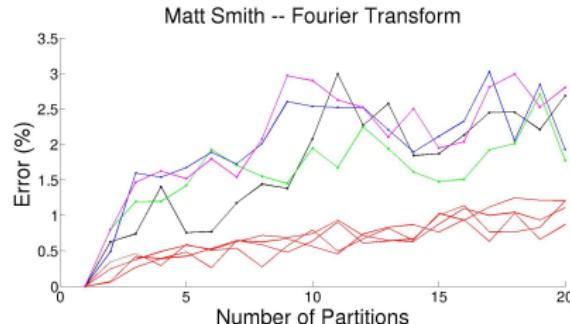


Matt Smith

Fourier Transformation

## Error Analysis Using Fourier Transformation

- The Discrete Fourier Transformation coefficients were used for analysis
- Summed the rows and columns
- Compared each signature to the average genuine signature



## Accepted vs Rejected Signatures

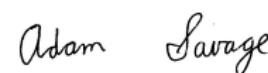
- This table shows the percent of signatures that would be accepted by the program at various cutoffs

Total Error	4.5	5	5.5	6
Genuine	82.5%	87.5%	95%	97.5%
Forgery	0%	2.5%	7.5%	10%

Further Example

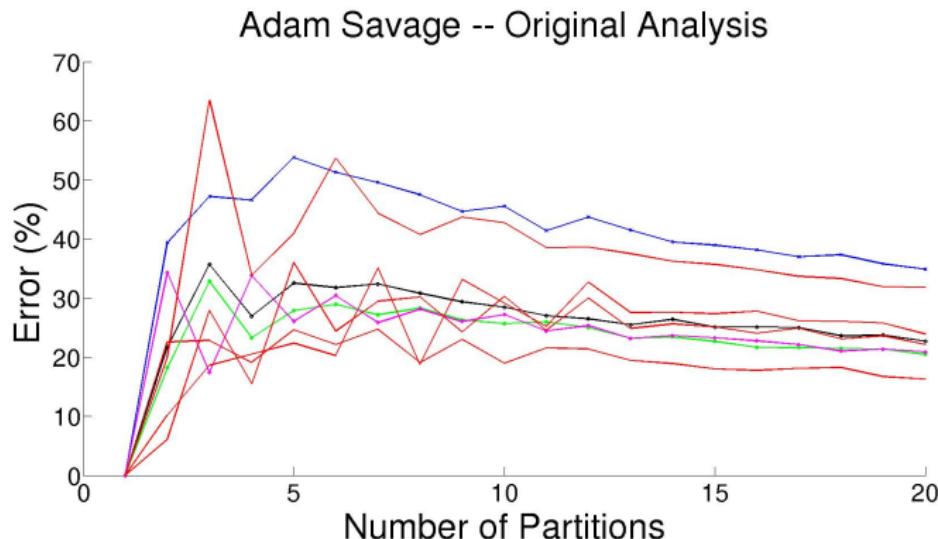
## Close Signatures

- The genuine signatures have variations
- Some of the forgeries are fairly close to the genuine signatures

A handwritten signature of "Adam Savage" in black ink.A handwritten signature of "Adam Savage" in black ink, very similar to the first one.A handwritten signature of "Adam Savage" in black ink.A handwritten signature of "Adam Savage" in black ink, very similar to the second one.A handwritten signature of "Adam Savage" in black ink.A handwritten signature of "Adam Savage" in black ink, very similar to the third one.A handwritten signature of "Adam Savage" in black ink.A handwritten signature of "Adam Savage" in black ink, very similar to the fourth one.

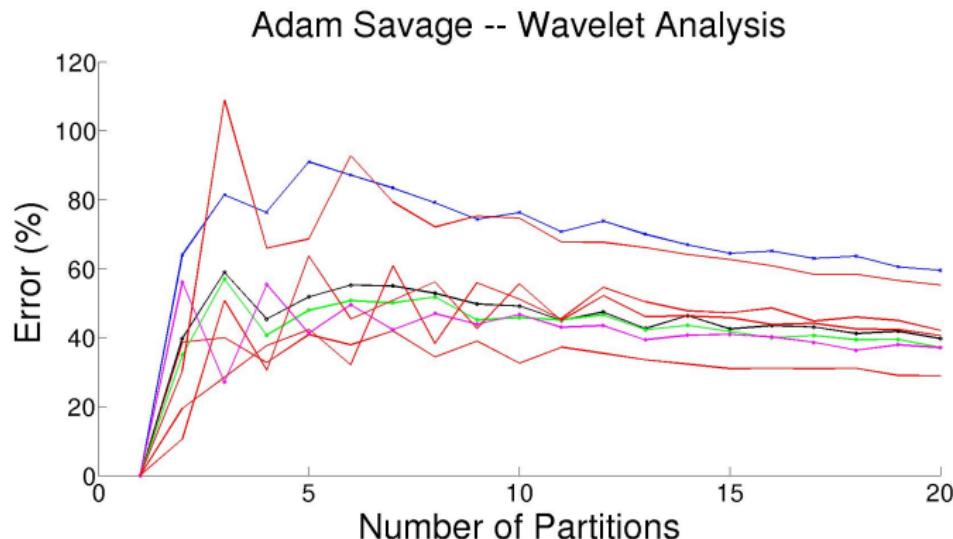
Further Example

# Adam Savage Original Data



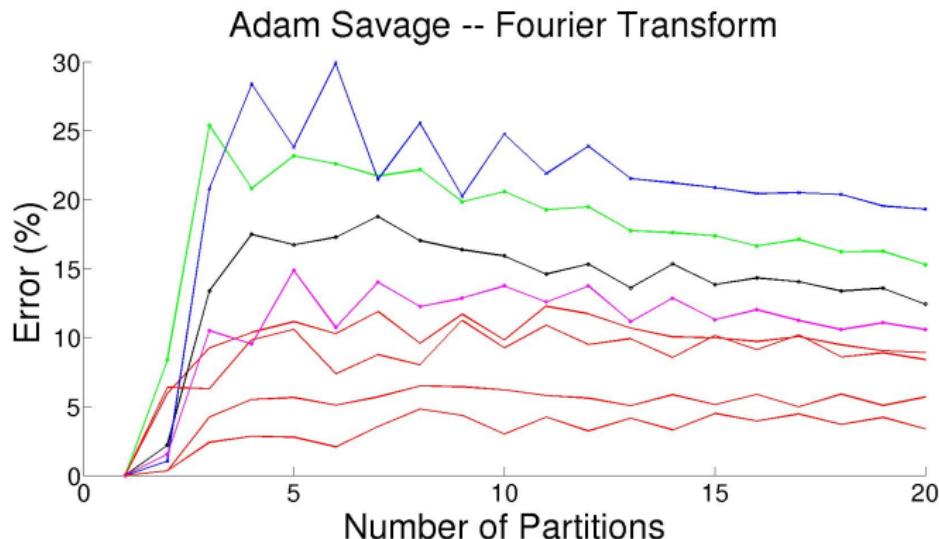
Further Example

# Adam Savage Wavelet



Further Example

# Adam Savage DFT



Introduction  
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Authentication Process  
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Data Comparison  
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○○○○

Conclusion  
○○○○

Further Example

## Cut Off Comparison

Original Data	40	50	60	70	80
Genuine	32.5%	50%	60%	70%	72.5%
Forgery	0%	2.5%	5%	15%	25%

Wavelet	75	100	105	110	115
Genuine	65%	65%	65%	65%	70%
Forgery	0%	2.5%	5%	20%	20%

DFT	4.5	5	5.5	6
Genuine	82.5%	87.5%	95%	97.5%
Forgery	0%	2.5%	7.5%	10%

Further Example

# Conjectures

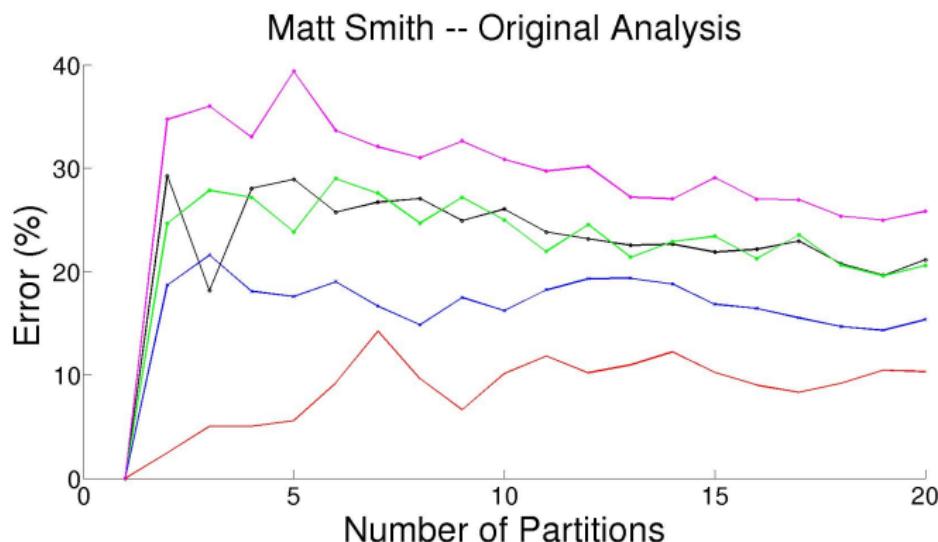
- Fourier Transform
  - Recognizes patterns in the signatures
  - Removes noise and small variations in the signatures
  - Identifies rhythms in the signature

# Comparing Signatures Outside of the Basis Set

- The next section we only compared genuine signatures outside of our average
- We averaged 3 genuine signatures for our base line
- We then compared the 4<sup>th</sup> genuine and 4 forgeries in the following graphs

Signatures Outside of the Basis Set

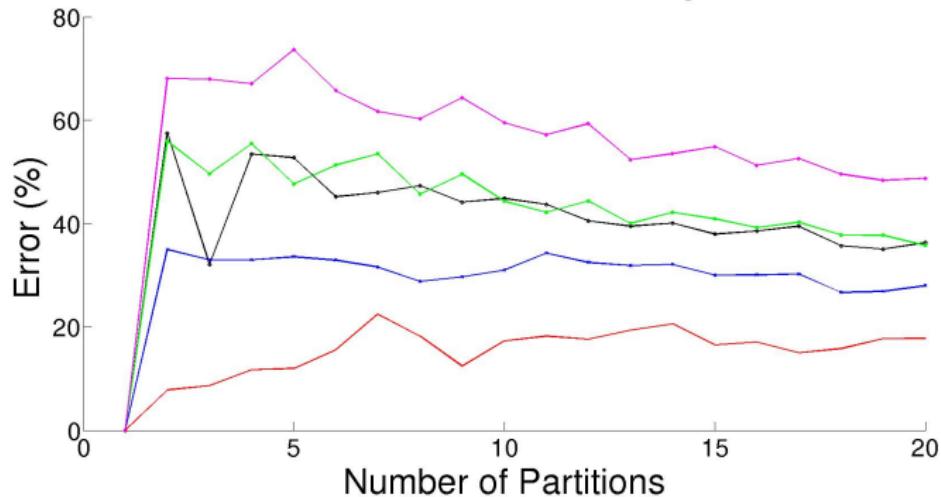
# Original Data



Signatures Outside of the Basis Set

# Wavelets

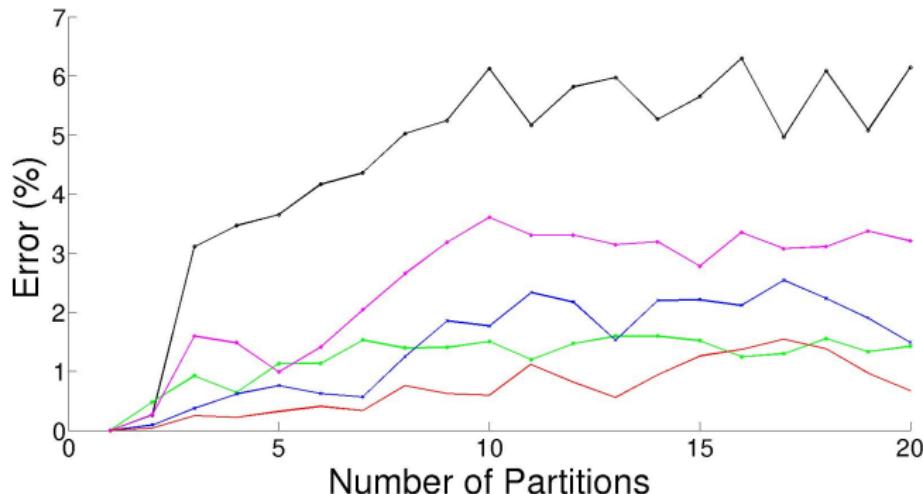
Matt Smith -- Wavelet Analysis



Signatures Outside of the Basis Set

# DFT

Matt Smith -- Fourier Transform



# Original – Advantages and Disadvantages

- Advantages
  - Shortest processing time
    - About 4 seconds for 80 signatures
- Disadvantages
  - Sensitive to variation

# Wavelets – Advantages and Disadvantages

- Advantages
  - High level of detail
- Disadvantages
  - Sensitive to variation
  - Approximately three times the processing time as original data
    - About 13 seconds for 80 signatures

# Fourier – Advantages and Disadvantages

- Advantages
    - Recognizes patterns
    - Filters noise
  - Disadvantages
    - Approximately twice the processing time as original data
      - About 8 seconds for 80 signatures

# Problems and Possible Error Sources

- Signatures were not “real”, therefore more inconsistent than actual signatures.
- None of our methods were 100% effective at both rejecting forgeries and accepting original signatures.
- Does not take into account pressure
- Does not take into account the effects of aging
- Non flat surfaces may be difficult to analyze

## Applications and Outlook

# Applications

- Banks and businesses
- Memorabilia
- Qualification Exams



# Other Methods Used Today

- Human eyes
- Video Spectral Comparator
  - Finds errors in ink, pressure, and other markings
- Radio Carbon Dating
  - For aging purposes
- Computational
  - Compare Individual Letters Using a Gray scale

# Outlook

- Use a collection of actual signatures
- Use different wavelet families
- Compress data using different techniques
- Applying this to hand writing samples
- Analysing non-flat surfaces

## Applications and Outlook

# Thank You

