Pattern Recognition Classification of Early Voting Ballot (EVB) Return Envelope Images for Signature Presence Detection
An Engineering Systems Approach to Identify Anomalies to Advance Integrity of U.S. Election Processes

Dr. Shiva Ayyadurai, MIT PhD
SMVS, SMME, SBEE
701 Concord Avenue | Cambridge, MA 02138
E: vashiva@vashiva.com | P: 617-631-6874

PRESENTED TO

Arizona State Senate

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Agenda

- Executive Summary
- Background
- Maricopa EVB Results
- Scope of Audit & EchoMail Analysis
- EchoMail Results
- Comparative Analysis
- Key Findings and Anomalies
- Questions for Maricopa Election Officials
- Conclusion & Summary
- Conclusions
Executive Summary

• The Early Voting Ballot (EVB) Return Envelope is the protective vehicle by which the EVB is transported and processed
• The authentication/verification of the Signature on the EVB return envelope is critical to reliability of the process
• This audit reveals anomalies raising questions on the verifiability of the Signature Verification Process.
Background
Author’s Expertise & Bio

- Four M.I.T. degrees: PhD, SMME, SMVS, SBEE
- Inventor of Email, Fulbright Scholar, Lemelson-MIT Finalist, Westinghouse Science Honors Recipient
- Nominee for National Medal of Technology & Innovation
- 40+ years of experience in pattern recognition and classification of diverse signals and signatures across industries and applications:
  - Industries: Biology & Medicine; Engineering: Aeronautics, Civil, Electrical; Banking & Finance; Military
  - Applications: Handwriting recognition on bank checks, electronic document e.g. email analysis and categorization, ultrasonic and radar wave signature classification for non-destructive evaluation (NDE), speech analysis for tadoma signature identification, biomarker patterns analysis for efficacy of combination therapy, sleep pattern signature categorization for identification of SIDS patients, signal detection of fluid flow anomalies in fluidized bed reactors
- Winner of White House competition for automatic classification of email
- Seven successful high-tech companies:
  - EchoMail - Pattern recognition classification of documents (1994-Present)
  - CytoSolve - Computational modeling (2007-present)
- Patents, books, and publications in peer-reviewed high-impact journals: IEEE, IJPRAI, Nature Neuroscience, CELL Biophysical, etc.
- Invited Distinguished Lectures: NSF, NIH, FDA, Harvard, MIT Presidential Fellows Lecture

1Dr. Shiva Ayyadurai, Biography and Curriculum Vitae: https://vashiva.com/about-va-shiva-ayyadurai/
2Facts on the invention of email, https://www.inventorofemail.com/thefacts/
Systems and Modeling

Reality

The System
Systems and Modeling

Reality

Model

The System

The Signal
Sudden Infant Death Syndrome
Signature Detection of Abnormal Sleep Patterns to Prevent Baby’s Death (1978 – 1984)

Baby

The System
Sudden Infant Death Syndrome
Signature Detection of Abnormal Sleep Patterns to Prevent Baby’s Death (1978 – 1984)

Baby

Sleep Signature Patterns

The System

The Signal

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Tadoma

Tadoma – Deaf-Blind Communication

The System
Tadoma

Tadoma – Deaf-Blind Communication

Multiple Signals from Mouth

The System

The Signal

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Bridge Deck Deterioration

The System
**Bridge Deck Deterioration**


Bridge Deck

- Buckling of girder flange
- Spalling in abutments
- Deck cracking

**Bridge Deterioration Signatures**

Bridge deck suspected of greater deterioration (see Figure 9).

**The Signal**

**The System**

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Non-Destruction Evaluation

Aircraft Wings

The System
Non-Destruction Evaluation

Aircraft Wings

Aircraft Wing Ultrasonic Signatures

The System

The Signal
Handwritten Numerals on Bank Checks

Bank Checks

The System
**Handwritten Numerals on Bank Checks**

**Bank Checks**

![Image of a bank check with handwritten numerals]

**Detection of Numerals**

![Image of a signal extracted from a bank check]

**The System**

**The Signal**
**Email Message**

Email: Rbrady@oal.com  
Name: Robert Brady  
Subject: slow line

With a 56K Modem operating at 49.3K your web site has terrible response time. Also you are overloaded  
With cookies. I tried to order on the web and the runaround I received when Filling out the informa- 
tion, telling me I did not fill out something that I did, is ridiculous. Someone should be monitoring what 
your response time is, I know for certain I will never again use your on-line ordering, I will use a service 
that is user-responsive as well as user-friendly.

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---

**Email Signals**  
(Attitude, Issue, Product, Request, Customer)

---

**The System**

---

**The Signal**

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CytoSolve®: Discovering Combinations That Work
Signal Detection of Combination Therapies That Alleviate Disease (2007 - Present)

Combination of Foods

The System
CytoSolve®: Discovering Combinations That Work
Signal Detection of Combination Therapies That Alleviate Disease (2007 - Present)

Biomarkers That Reduce Inflammation

Combination of Foods

The System

The Signal

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Systems and Modeling

The System

Reality

Model

The Signal

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Systems and Modeling

The System

Cardiovascular Model

The Signal

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Cardiac Signature Detection & Classification

NORMAL STATE

ABNORMAL STATE(S)
Systems and Modeling

The System

Reality

Model

The Signal

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Early Voting Ballot (EVB) System

The System
Early Voting Ballot (EVB) System

The System

EVB System

EVB Return Envelope Images

The Signal

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Early Voting Ballot (EVB) System

The System

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The Signal

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Early Voting Ballot Return Envelope

Within U.S. - MAIL no later than 6 days prior to Election Day (noted on ballot)
EVB Return Envelope Images
Signature Detection & Classification

NORMAL STATE

Signature

ABNORMAL STATES

Blank
Likely Blank
Scribble
Early Voting Ballot (EVB) System

The System

EVB System

The Signal
Early Voting Ballot (EVB) System

The System

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The Signal

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Maricopa EVB Results
## General Election

### Voter Turnout

<table>
<thead>
<tr>
<th></th>
<th>2020</th>
<th>2016</th>
</tr>
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<tbody>
<tr>
<td>Voter Turnout</td>
<td>80.51%</td>
<td>74.43%</td>
</tr>
<tr>
<td>Early Ballots Requested</td>
<td>2,160,412</td>
<td>1,497,565</td>
</tr>
<tr>
<td>Early Ballots Verified and Counted</td>
<td>1,915,487</td>
<td>1,251,978</td>
</tr>
<tr>
<td>Rejected Early Ballots</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bad Signatures</td>
<td>587</td>
<td>1,456</td>
</tr>
<tr>
<td>No Signatures</td>
<td>1,455</td>
<td>2,209</td>
</tr>
<tr>
<td>Late Returns</td>
<td>934</td>
<td>1,536</td>
</tr>
</tbody>
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# General Election Voter Turnout 2020

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Total: 1,918,463
Summary of Results from Maricopa County

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Scope of Audit & EchoMail Analysis
Systems Process for Early Voting Ballot (EVB) Return Envelope Processing

Voter Submits Early Voting Ballot (EVB)
Systems Process for Early Voting Ballot (EVB) Return Envelope Processing

1. Voter Submits Early Voting Ballot (EVB)
2. EVB Return Envelopes Are Scanned into Images
Systems Process for Early Voting Ballot (EVB) Return Envelope Processing

Voter Submits Early Voting Ballot (EVB)

EVB Return Envelopes Are Scanned into Images

Six (6) different EVB return envelope formats
Systems Process for Early Voting Ballot (EVB) Return Envelope Processing

Voter Submits Early Voting Ballot (EVB)

EVB Return Envelopes Are Scanned into Images
Systems Process for Early Voting Ballot Return Envelope Processing

Voter Submits Early Voting Ballot (EVB)

EVB Return Envelopes Are Scanned into Images

Standard Image File (SIF)

Name of Voter

Sign Within the Box

Firme Dentro de la Caja

Signature

Within U.S. - Mail no later than 6 days prior to Election Day (dated on ballot)
Systems Process for Early Voting Ballot (EVB) Return Envelope Processing

Voter Submits Early Voting Ballot (EVB)

EVB Return Envelopes Are Scanned into Images

Six (6) different EVB return envelope formats

UOCAVA Image File, Type A (UIF-A)
Systems Process for Early Voting Ballot (EVB) Return Envelope Processing

Voter Submits Early Voting Ballot (EVB)

EVB Return Envelopes Are Scanned into Images

Six (6) different EVB return envelope formats

UOCAVA Image File, Type B (UIF-B)
Systems Process for Early Voting Ballot (EVB) Return Envelope Processing

Voter submits Early Voting Ballot (EVB)

EVB Return Envelopes Are Scanned into Images

Six (6) different EVB return envelope formats

UOCAVA Image File, Type C (UIF-C)
**Systems Process for Early Voting Ballot (EVB) Return Envelope Processing**

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<th>Voter Submits Early Voting Ballot (EVB)</th>
<th>EVB Return Envelope Processing</th>
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<tr>
<td>If the voter is unable to return the ballot to the EVB return envelope, they can mail it back to the EVB Return Center.</td>
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</tr>
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</table>

**Within U.S. - Mail no later than 6 days prior to Election Day (rented on ballot)**

- **Voter**: A resident of any state who has registered to vote in the 2020 General Election in Arizona.
- **EVB Return Envelopes**: Large Print Image File (LIF) format.

**EVB Return Envelope Processing**

1. **Large Print Image File (LIF)**
   - **Name of Voter**
   - **Signature**
   - **Date**
   - **Time**

   **Ballot is not counted without your signature.**

   **Signature Required/Firma Requerida**
Systems Process for Early Voting Ballot (EVB) Return Envelope Processing

Voter submits Early Voting Ballot (EVB)

EVB return envelopes are scanned into images

Six (6) different EVB return envelope formats

Braille Image File, (BIF)
**Total Count of EVB Return Envelope Image Files Received by EchoMail: 1,929,240**

*Breakdown by type of images*

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**Systems Process for Early Voting Ballot Return Envelope Processing**

1. **Voter Submits Early Voting Ballot (EVB)**
2. **EVB Return Envelopes Are Scanned into Images**
3. **Six (6) different EVB return envelope formats**
4. **Removal of Duplicates**
## Duplicates Analysis

<table>
<thead>
<tr>
<th>Type</th>
<th>Total Images</th>
<th>Duplicates</th>
<th>Unique Voters</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Copy Duplicates</td>
<td>33,868</td>
<td>16,934</td>
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<td><strong>17,322</strong></td>
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## EchoMail: Total Unique EVB Return Envelopes

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<tbody>
<tr>
<td>EVB Return Envelopes Received</td>
<td>1,929,240</td>
</tr>
<tr>
<td><strong>Duplicate Analysis</strong></td>
<td></td>
</tr>
<tr>
<td>Duplicates</td>
<td>(17,322)</td>
</tr>
<tr>
<td><strong>Total Unique EVB Return Envelopes</strong></td>
<td>1,911,918</td>
</tr>
</tbody>
</table>
Systems Process for Early Voting Ballot Return Envelope Processing

- Voter Submits Early Voting Ballot (EVB)
- EVB Return Envelopes Are Scanned into Images
- Signature Presence Detection

Six (6) different EVB return envelope formats

Removal of Duplicates


**Systems Process for Early Voting Ballot Return Envelope Processing**

1. **Voter Submits Early Voting Ballot (EVB)**
2. **EVB Return Envelopes Are Scanned into Images**
3. **Signature Presence Detection**
   - Six (6) different EVB return envelope formats
   - Determination of those EVBs **WITH** Signatures in the Signature Region of Return Envelope
4. **Removal of Duplicates**

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Pattern Recognition Classification of Signature Region on Early Voting Ballot (EVB) Return Envelope Images as Blank, Likely Blank, Scribble, or Signature

Signature Presence Detection and Classification

Signature ▶ Blank ▶ Likely Blank ▶ Scribble ▶ Duplicates

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Pattern Recognition Classification of Signature Region on Early Voting Ballot (EVB) Return Envelope Images as Blank, Likely Blank, Scribble, or Signature

Signature Presence Detection and Classification

0% Non-White Pixel Density

Signature
Blank
Likely Blank
Scribble
Duplicates

© 2021 Dr. Shiva Ayyadurai
Pattern Recognition Classification of Signature Region on Early Voting Ballot (EVB) Return Envelope Images as Blank, Likely Blank, Scribble, or Signature

Signature Presence Detection and Classification

- Signature
- Blank
- Likely Blank
- Scribble

0% to 0.1% Non-White Pixel Density
Pattern Recognition Classification of Signature Region on Early Voting Ballot (EVB) Return Envelope Images as Blank, Likely Blank, Scribble, or Signature

Signature Presence Detection and Classification

Signature
Blank
Likely Blank
Scribble

Duplicates

>0.1%+ to 1%
Non-White Pixel Density

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Pattern Recognition Classification of Signature Region on Early Voting Ballot (EVB) Return Envelope Images as Blank, Likely Blank, Scribble, or Signature

Signature Presence Detection and Classification

>1%+ and greater Non-White Pixel Density
%Non-White Pixel Density vs. EVB Return Envelope Volume
%Non-White Pixel Density vs. EVB Return Envelope Volume

![Graph showing %Non-White Pixel Density vs. EVB Return Envelope Volume](image-url)
Systems Process for Early Voting Ballot Return Envelope Processing

Voter Submits Early Voting Ballot (EVB)

EVB Return Envelopes Are Scanned into Images

Signature Presence Detection

Signature Verification

Six (6) different EVB return envelope formats

Removal of Duplicates

Determination of those EVBs WITH Signatures in the Signature Region of Return Envelope
Systems Process for Early Voting Ballot Return Envelope Processing

1. Voter Submits Early Voting Ballot (EVB)
2. EVB Return Envelopes Are Scanned into Images
3. Signature Presence Detection
4. Signature Verification
5. Opening of EVB Return Envelopes and Tabulation of EVBs
6. Six (6) different EVB return envelope formats
   - Removal of Duplicates
   - Determination of those EVBs **WITH** Signatures in the Signature Region of Return Envelope
   - Validate Signatures on EVB Return Envelopes
Signature Presence Detection
EVB Return Envelope Image

Automatic EVB Envelope Classification
Automatic EVB Envelope Classification

- EVB Return Envelope Image
- Detection of Signature Region & OCR of Name
- Duplicate Recognition
- Duplicates
Automatic EVB Envelope Classification

Detection of Signature Region & OCR of Name

Duplicate Recognition

Duplicates

Pattern Recognition Classification of Signature Region

- EchoMail SIF Classifier
- EchoMail UIF-A Classifier
- EchoMail UIF-B Classifier
- EchoMail MIF-C Classifier
- EchoMail LIF Classifier
- EchoMail BIF Classifier

EVB Return Envelope Image

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EchoMail, Inc. Proprietary and Confidential.
Detection of Signature Region & OCR of Name

Pattern Recognition Classification of Signature Region

- EchoMail SIF Classifier
- EchoMail UIF-A Classifier
- EchoMail UIF-B Classifier
- EchoMail MIF-C Classifier
- EchoMail LIF Classifier
- EchoMail BIF Classifier

Duplicate Recognition

EVB Return Envelope Image

Automatic EVB Envelope Classification

Signature
Blank
Likely Blank
Scribble
## Non-Duplicate Signature Presence Detection Results

<table>
<thead>
<tr>
<th>Classification of Non-Duplicate EVB Return Envelope Images</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signature</td>
<td>1,890,500</td>
<td>99.77%</td>
</tr>
<tr>
<td>Scribble</td>
<td>2,420</td>
<td>0.13%</td>
</tr>
<tr>
<td>Blank</td>
<td>1,771</td>
<td>0.09%</td>
</tr>
<tr>
<td>Likely Blank</td>
<td>101</td>
<td>0.01%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1,894,792</strong></td>
<td><strong>100.00%</strong></td>
</tr>
</tbody>
</table>
**Non-Duplicate Signature Presence Detection Results**

- **Scribbles**
  - 2,420 Scribbles

- **Blanks i.e. “No Signatures”**
  - 1,771
  - 101
  - 1,872 Blanks

<table>
<thead>
<tr>
<th>Non-Duplicate Image Classification</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signature</td>
<td>1,890,500</td>
</tr>
<tr>
<td>Scribble</td>
<td>2,420</td>
</tr>
<tr>
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<td>101</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1,894,792</strong></td>
</tr>
</tbody>
</table>
EchoMail Pattern Recognition Methodology & Process for 2-Copy Duplicate Classification

**LEGEND**
- Signature/Signature (SS)
- Signature/Blank (SB)
- Signature/Likely Blank (SL)
- Signature/Scribble (SC)
- Scribble/Blank (CB)
- Scribble/Likely Blank (CL)
- Scribble/Scribble (CC)
- Blank/Blank (BB)
- Blank/Likely Blank (BL)
- Likely Blank/Likely Blank (LL)
EchoMail Pattern Recognition Methodology & Process for 2-Copy Duplicate Classification

Duplicate Recognition

Duplicates

LEGEND
- Signature/Signature (SS)
- Signature/Blank (SB)
- Signature/Likely Blank (SL)
- Signature/Scribble (SC)
- Scribble/Blank (CB)
- Scribble/Likely Blank (CL)
- Scribble/Scribble (CC)
- Blank/Blank (BB)
- Blank/Likely Blank (BL)
- Likely Blank/Likely Blank (LL)
EchoMail Pattern Recognition Methodology & Process for 2-Copy Duplicate Classification

Duplicate Recognition

Duplicates

SS  SB  SL  SC

Signature

LEGEND

- Signature/Signature (SS)
- Signature/Blank (SB)
- Signature/Likely Blank (SL)
- Signature/Scribble (SC)
- Scribble/Blank (CB)
- Scribble/Likely Blank (CL)
- Scribble/Scribble (CC)
- Blank/Blank (BB)
- Blank/Likely Blank (BL)
- Likely Blank/Likely Blank (LL)
EchoMail Pattern Recognition Methodology & Process for 2-Copy Duplicate Classification

LEGEND
- Signature/Signature (SS)
- Signature/Blank (SB)
- Signature/Likely Blank (SL)
- Signature/Scribble (SC)
- Scribble/Blank (CB)
- Scribble/Likely Blank (CL)
- Scribble/Scribble (CC)
- Blank/Blank (BB)
- Blank/Likely Blank (BL)
- Likely Blank/Likely Blank (LL)

Duplicate Recognition

Duplicates

SS  |  SB  |  SL  |  SC  |  CB  |  CL  |  CC

Signature

Scribble
EchoMail Pattern Recognition Methodology & Process for 2-Copy Duplicate Classification

Duplicate Recognition

Duplicates

SS  SB  SL  SC  CB  CL  CC  BB  BL  LL

Signature
Scribble
Blank

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Duplicate (Signed & Signed - SS)

NOV 3 2020 GENERAL ELECTION

SIGN WITHIN THE BOX
FIRME DENTRO DE LA CAJA

Name of Voter

Signature

Phone Number 10/13/2020

(>PHONE, if signature is questioned) (DATE/FECHA)

Within U.S. - MAIL no later than 6 days prior to Election Day (noted on ballot)

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Duplicate (Signed & Blank - SB)

- **Name of Voter**
- **Signature**
- **Phone Number**

**NOV 3 2020 GENERAL ELECTION**

- **SIGN WITHIN THE BOX**
- **FIRME DENTRO DE LA CAJA**

**BALLOT WILL NOT BE COUNTED WITHOUT YOUR SIGNATURE.**
**POWERS OF ATTORNEY are not valid for voting purposes.**
**LA BOLETA NO SE TRAVIITAR SIN SU FIRMA.**
**PODER DE ABOGADO no es válido para fines de votación.**

Within U.S. - MAIL no later than 6 days prior to Election Day (noted on ballot)

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Duplicate (Signed & Likely Blank - SL)
Duplicate (Signed & Scribble - SC)
Duplicate (Scribble & Blank - CB)
Signature Region with Blank is Being Approved
**Duplicate (Scribble & Likely Blank - CL)**

**Signature Region with Scribble is Being Approved**

---

**NOV 3 2020 GENERAL ELECTION**

**Name of Voter**

BALLOT WILL NOT BE COUNTED WITHOUT YOUR SIGNATURE. POWERS OF ATTORNEY are not valid for voting purposes. LA BOLETA NO SE TRAMITAR SIN SU FIRMA. PODER DE ABOGADO no es válido para fines de votación.

**Within U.S. - MAIL no later than 6 days prior to Election Day (stated on ballot)**

---

**NOV 3 2020 GENERAL ELECTION**

**Name of Voter**

BALLOT WILL NOT BE COUNTED WITHOUT YOUR SIGNATURE. POWERS OF ATTORNEY are not valid for voting purposes. LA BOLETA NO SE TRAMITAR SIN SU FIRMA. PODER DE ABOGADO no es válido para fines de votación.

**Within U.S. - MAIL no later than 6 days prior to Election Day (stated on ballot)**
**Duplicate (Scribble & Scribble - CC)**

- **Name of Voter**
- **Phone Number**

Within U.S. - MAIL no later than 6 days prior to Election Day (noted on ballot)

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Duplicate (Blank & Blank - BB)
Signature Region with Blank is Being Approved
Duplicate (Blank & Likely Blank - BL)
Signature Region with Likely Blank is Being Approved

*Orientation of Name of Voter varies between the two duplicates, thought the exact same image. Appears as if name was overlaid differently from one image to another.
Duplicate (Likely Blank & Likely Blank - LL)
Signature Region with Likely Blank is Being Approved
## 2-Copy Duplicate Signature Presence Detection Results

<table>
<thead>
<tr>
<th>Image Copy I</th>
<th>Image Copy II</th>
<th>Classification</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signature</td>
<td>Signature</td>
<td>SS</td>
<td>15,288</td>
</tr>
<tr>
<td>Signature</td>
<td>Blank</td>
<td>SB</td>
<td>1,348</td>
</tr>
<tr>
<td>Signature</td>
<td>Likely Blank</td>
<td>SL</td>
<td>26</td>
</tr>
<tr>
<td>Signature</td>
<td>Scribble</td>
<td>SC</td>
<td>72</td>
</tr>
<tr>
<td>Scribble</td>
<td>Blank</td>
<td>CB</td>
<td>6</td>
</tr>
<tr>
<td>Scribble</td>
<td>Likely Blank</td>
<td>CL</td>
<td>7</td>
</tr>
<tr>
<td>Scribble</td>
<td>Scribble</td>
<td>CC</td>
<td>142</td>
</tr>
<tr>
<td>Blank</td>
<td>Blank</td>
<td>BB</td>
<td>36</td>
</tr>
<tr>
<td>Blank</td>
<td>Likely Blank</td>
<td>BL</td>
<td>5</td>
</tr>
<tr>
<td>Likely Blank</td>
<td>Likely Blank</td>
<td>LL</td>
<td>4</td>
</tr>
</tbody>
</table>

**TOTAL** 16,934

### Signatures for Verification
- Signature
- Likely Blank

### Scribbles
- Scribble
- Blank

### Blanks “No Signatures”
- Blank
- Likely Blank

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2-Copy Duplicate Signature Presence Detection Results

- Scribbles
  - CB + CL + CC
  - $6 + 7 + 142$
  - 155 Scribbles
- Blanks i.e. “No Signatures”
  - BB + BL + LL
  - $36 + 5 + 4$
  - 45 Blanks

<table>
<thead>
<tr>
<th></th>
<th>Image Copy I</th>
<th>Image Copy II</th>
<th>Classification</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signature</td>
<td>Signature</td>
<td>SS</td>
<td></td>
<td>15,288</td>
</tr>
<tr>
<td>Signature</td>
<td>Blank</td>
<td>SB</td>
<td></td>
<td>1,348</td>
</tr>
<tr>
<td>Signature</td>
<td>Likely Blank</td>
<td>SL</td>
<td></td>
<td>26</td>
</tr>
<tr>
<td>Signature</td>
<td>Scribble</td>
<td>SC</td>
<td></td>
<td>72</td>
</tr>
<tr>
<td>Scribble</td>
<td>Blank</td>
<td>CB</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Scribble</td>
<td>Likely Blank</td>
<td>CL</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Scribble</td>
<td>Scribble</td>
<td>CC</td>
<td></td>
<td>142</td>
</tr>
<tr>
<td>Blank</td>
<td>Blank</td>
<td>BB</td>
<td></td>
<td>36</td>
</tr>
<tr>
<td>Blank</td>
<td>Likely Blank</td>
<td>BL</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Likely Blank</td>
<td>Likely Blank</td>
<td>LL</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>16,934</strong></td>
</tr>
</tbody>
</table>
3-Copy, and 4-Copy Duplicate Signature Presence Detection Results

<table>
<thead>
<tr>
<th>Type</th>
<th>Definitive Blanks</th>
<th>Likely Blanks</th>
<th>Scribbles</th>
<th>Signatures</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-Copy</td>
<td>40</td>
<td>2</td>
<td>16</td>
<td>506</td>
<td>564</td>
</tr>
<tr>
<td>4-Copy</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>14</td>
<td>16</td>
</tr>
</tbody>
</table>

**Table 9:** Three- & Four-Copy Duplicate Signature Presence Detection Results.
Three-Copy Duplicate Scribble
459562.tiff

PBSigVar_1377_RTNIMAGOUT_10122020_0007/459562.tiff

PBSigVar_1377_RTNIMAGOUT_10152020_0037/459562.tiff

PBSigVar_1377_RTNIMAGOUT_10262020_0107/459562.tiff
EchoMail Results
### Total Number of Blanks Calculation

<table>
<thead>
<tr>
<th></th>
<th>Blanks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Duplicate Blanks</td>
<td>1,872</td>
</tr>
<tr>
<td>2-Copy Duplicate Blanks</td>
<td>45</td>
</tr>
<tr>
<td>3-Copy Duplicate Blanks</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1,919</td>
</tr>
</tbody>
</table>
### Total Number of Scribbles Calculation

<table>
<thead>
<tr>
<th>Type</th>
<th>Scribbles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Duplicate Scribbles</td>
<td>2,420</td>
</tr>
<tr>
<td>2-Copy Duplicate Scribbles</td>
<td>155</td>
</tr>
<tr>
<td>3-Copy Duplicate Scribbles</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2,580</strong></td>
</tr>
</tbody>
</table>

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**EchoMail Results Summary**

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>EVB Return Envelopes Received</td>
<td>1,929,240*</td>
</tr>
<tr>
<td>Duplicate Analysis</td>
<td></td>
</tr>
<tr>
<td>Duplicates</td>
<td>(17,322)</td>
</tr>
<tr>
<td>Unique EVB Return Envelopes</td>
<td>1,911,918</td>
</tr>
<tr>
<td>Signature Presence Detection</td>
<td></td>
</tr>
<tr>
<td>No Signature Ballots</td>
<td>(1,919)</td>
</tr>
<tr>
<td>Scribbles</td>
<td>(2,580)</td>
</tr>
<tr>
<td>EVBs Ready for Signature Verification</td>
<td>1,907,419</td>
</tr>
</tbody>
</table>
Comparative Analysis
## Comparative Analysis of EchoMail and Maricopa Reported

<table>
<thead>
<tr>
<th>Metric</th>
<th>EchoMail Analysis</th>
<th>Maricopa Reported</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>EVB Return Envelopes Received</td>
<td>1,929,240*</td>
<td>Unknown</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Duplicate Analysis</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duplicates</td>
<td>(17,322)</td>
<td>Un-reported</td>
<td>NA</td>
</tr>
<tr>
<td>Unique EVB Return Envelopes</td>
<td>1,911,918</td>
<td>1,918,463**</td>
<td>(6,545)</td>
</tr>
<tr>
<td><strong>Signature Presence Detection</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Signature Ballots</td>
<td>(1,919)</td>
<td>(1,455)</td>
<td>(464)</td>
</tr>
<tr>
<td>Scribbles</td>
<td>(2,580)</td>
<td>NA</td>
<td>(2580)</td>
</tr>
<tr>
<td>EVBs Ready for Signature Verification</td>
<td>1,907,419</td>
<td>1,917,008</td>
<td>(9,589)</td>
</tr>
<tr>
<td><strong>Signature Verification</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“Bad Signatures”</td>
<td>NA</td>
<td>(587)</td>
<td>NA</td>
</tr>
<tr>
<td>“Late Returns”</td>
<td>NA</td>
<td>(934)</td>
<td>NA</td>
</tr>
<tr>
<td>Total EVBs Verified and Counted</td>
<td>NA</td>
<td>1,915,487</td>
<td>NA</td>
</tr>
</tbody>
</table>

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Key Findings and Anomalies
EchoMail Key Findings

- Unknown how many EVB return envelopes were originally received by Maricopa
- 34,448 Duplicates from 17,126 Unique Voters. Maricopa reported NO Duplicates in CANVASS report.
- 464 **more** “No Signature” EVB Return Envelopes Identified by EchoMail
- 6,545 **more** unique EVB Return Envelopes processed by Maricopa
- 2,580 Scribbles in Signature Region i.e. “Bad Signatures”
  - Maricopa reported 587 “Bad Signatures” that is 0.031% of total EVBs received
- 9,589 **more** net EVBs submitted for Signature Verification by Maricopa versus EchoMail EVB return envelope images
- 25% Surge of Duplicates in Last Six Days
- Blanks of Duplicates being stamped **“VERIFIED & APPROVED MCTEC”**
- Stamps of **“VERIFIED & APPROVED MCTEC”** in Blank Signature Regions
- **“VERIFIED & APPROVED MCTEC”** Stamps Appearing “BEHIND” Envelope Triangle
- Two Different Voter-IDs, having Same Address/Phone/Name, with Matching Signatures
Anomaly #1
Anomaly #1

Maricopa Reported Only 587 "Bad Signatures" Out of 1,918,463 (0.031%)
Anomaly #1

ONE “Bad Signature” for EVERY 3,268 EVBs
Anomaly #1

ONE “Bad Signature” for EVERY 3,268 EVBs

1,918,463 EVBs

630 feet
Anomaly #1

ONE “Bad Signature” for EVERY 3,268 EVBs

1,918,463 EVBs

630 feet
Anomaly #1

ONE “Bad Signature” for EVERY 3,268 EVBs

1,918,463 EVBs

630 feet

2.31 inches

557 “Bad Signatures”
Anomaly #1

ONE “Bad Signature” for EVERY 3,268 EVBs

0.0306% of All EVB Return Envelopes

1,918,463 EVBs

630 feet

2.31 inches

557 “Bad Signatures”
Anomaly #2

ECHOMAIL
2,580 “Bad Signatures” e.g. Scribbles Out of 1,911,918 (0.135%)
**Anomaly #2**

**ECHOMAIL**

2,580 “Bad Signatures” e.g. Scribbles Out of 1,911,918 (0.135%)

EchoMail was commissioned to identify presence of Blanks, Scribbles, Signatures in Signature Region, **NOT** to perform Signature Verification/Matching. If Scribbles ALONE were considered “Bad Signatures,” then EchoMail ITSELF identified 335% more “Bad Signatures” than Maricopa did from its **ENTIRE** Signature Verification process.
### State of Arizona: 2016 General Election Signature Mismatch Rejection Rate

<table>
<thead>
<tr>
<th></th>
<th>State of Arizona 2016 General Election</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mail-In Ballots</td>
<td>2,017,722</td>
</tr>
<tr>
<td>Rejection from</td>
<td></td>
</tr>
<tr>
<td>Signature Mismatch</td>
<td>2,657</td>
</tr>
<tr>
<td>Signature Mismatch</td>
<td></td>
</tr>
<tr>
<td>Rejection Rate</td>
<td>0.131%</td>
</tr>
</tbody>
</table>
%Non-White Pixel Density vs. EVB Return Envelope Volume
Anomaly #3

ECHOMAIL

3% to 97% Increased Illegibility Rate of Signatures 4 days After Election Day
Signatures 4-Weeks BEFORE Election Day

~95% Legible Signatures
~5% Illegible Signatures
Signatures 4-Days AFTER Election Day

~5% Legible Signatures
~95% Illegible Signatures
Random Sampling of Signatures:
4-Weeks **Before** Election vs. 4-Days **After** Election

4-Weeks **Before** Election
Random Sampling of Signatures:

4-Weeks Before Election vs. 4-Days After Election

4-Weeks Before Election

4-Days After Election

Illegible

Legible
Anomaly #4

As EVBs Increased by 53% from 2016 to 2020 in Maricopa, “Bad Signatures” Decreased by 56%
**Inverse Pattern: Increase in EVBs with Decrease in Signature Mismatch Rate**

<table>
<thead>
<tr>
<th>Maricopa County 2016 General Election</th>
</tr>
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<tr>
<td>EVB Return Envelopes</td>
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### Inverse Pattern: Increase in EVBs with Decrease in Signature Mismatch Rate

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<th>Maricopa County, AZ 2020 General Election</th>
<th>Maricopa County 2016 General Election</th>
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<tr>
<td>EVB Return Envelopes</td>
<td>1,918,463</td>
<td>1,257,179</td>
</tr>
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<td>Rejection from Signature Mismatch</td>
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<td>1,456</td>
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Anomaly #5
Anomaly #5

MARICOPA

No Mention of Duplicates in Maricopa CANVASS Report
### Anomaly #5

**MARICOPA**

**No Mention of Duplicates in Maricopa CANVASS Report**

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voter Turnout</td>
<td>80.51%</td>
</tr>
<tr>
<td>Early Ballots Requested</td>
<td>2,160,412</td>
</tr>
<tr>
<td>Early Ballots Verified and Counted</td>
<td>1,915,487</td>
</tr>
<tr>
<td>Rejected Early Ballots</td>
<td></td>
</tr>
<tr>
<td>Bad Signatures</td>
<td>587</td>
</tr>
<tr>
<td>No Signatures</td>
<td>1,455</td>
</tr>
<tr>
<td>Late Returns</td>
<td>934</td>
</tr>
</tbody>
</table>

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Anomaly #5

MARICOPA

No Mention of Duplicates in Maricopa CANVASS Report

ECHOMAIL

17,126 Voters Sent in TWO or More Ballots (“Duplicates”)
## Anomaly #5

<table>
<thead>
<tr>
<th>Type</th>
<th>Total Images</th>
<th>Duplicate Images</th>
<th>Unique # of Voters</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Copy Duplicates</td>
<td>33,868</td>
<td>16,934</td>
<td>16,934</td>
</tr>
<tr>
<td>3-Copy Duplicates</td>
<td>564</td>
<td>376</td>
<td>188</td>
</tr>
<tr>
<td>4-Copy Duplicates</td>
<td>16</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>34,448</strong></td>
<td><strong>17,322</strong></td>
<td><strong>17,126</strong></td>
</tr>
</tbody>
</table>
Anomaly #6
Anomaly #6

25%+ of Duplicates Came In During Nov. 4-9, 2020
Anomaly #6
Anomaly #6

[Graph showing daily totals for EVBRE, Blanks, Scribbles, and Duplicates over a period from 10/9/20 to 11/9/20]
Anomaly #6
Anomaly #7
Anomaly #7

ECHOMAIL

EV33 System Had Only 9,382 Voters Who Submitted Duplicates vs. 17,126 Voters Identified by EchoMail
Anomaly #7

ECHOMAIL

EV33 System Had Only 9,382 Voters Who Submitted Duplicates vs. 17,126 Voters Identified by EchoMail

ECHOMAIL

Of the 9,382 in EV33, ONLY 2,138 Voters Matched with Voters Among the 17,126
Anomaly #8
Anomaly #8

ECHOMAIL

Duplicate BLANKS were “VERIFIED & APPROVED”
Duplicate Blanks
Stamped and Approved – Example #1

Within U.S. - MAIL no later than 6 days prior to Election Day (noted on ballot)
Duplicate Blanks
Stamped and Approved - Example #2
Duplicate Blanks
Stamped and Approved - Example #3

Within U.S. - MAIL no later than 6 days prior to Election Day (noted on ballot)
Duplicate Blanks
Stamped and Approved - Example #4
Three-Copy Duplicate Blanks (2 Approved)
Three-Copy Duplicate Blanks

Within U.S. - MAIL no later than 6 days prior to Election Day (noted on ballot)

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Anomaly #9

ECHOMAIL

“VERIFIED & APPROVED” in Blank Signature Region
Within U.S. - MAIL no later than 6 days prior to Election Day (noted on ballot)
Within U.S. - MAIL no later than 6 days prior to Election Day (noted on ballot)
Within U.S. - MAIL no later than 6 days prior to Election Day (noted on ballot)
Anomaly #10

Two Different Voter-Ids with Same Name/Address Phone Number with MATCHING Signatures
Same Name/Address/Signature/Phone, Two Different Voter IDs

Within U.S. - MAIL no later than 6 days prior to Election Day (noted on ballot)
 Same Name/Address/Signature/Phone, Two Different Voter IDs

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EchoMail, Inc. Proprietary and Confidential.
Same Name/Address/Signature/Phone, Two Different Voter IDs
Anomaly #11

ECHOMAIL

“VERIFIED & APPROVED STAMP” Behind Envelope Triangle
Within U.S. - MAIL no later than 6 days prior to Election Day (noted on ballot)
Your signature is required. Powers of attorney are not valid for voting purposes.
Questions to Maricopa Election Officials
Questions for Maricopa

• Did Maricopa County receive any duplicate EVBs
  – EchoMail identified 34,448 EVB return envelope images being 2-copy, 3-copy and 4-copy Duplicates originating from 17,126 unique voters, while no Duplicates were reported in Maricopa’s CANVASS report

• Is the reason that EchoMail has more “No Signatures” than reported by Maricopa because EchoMail analyzed solely the Signature Region? If not, why?
  – EchoMail identified 1,919 Blanks in Signature Region of EVB return envelopes
  – Maricopa reported 1,455 “No Signatures” in EVB return envelopes
Questions for Maricopa

• Why did EchoMail detect more Scribbles than Maricopa’s reporting of “Bad Signatures”?
  – EchoMail identified 2,580 Scribbles in Signature Region of EVB return envelopes
  – Maricopa reported 587 “Bad Signatures” from its Signature Verification
  – Had EchoMail been commissioned to identify “Bad Signatures,” at least 2,580
    Scribbles would have been classified as “Bad Signatures;” 1,993 more “Bad
    Signatures” than the 587 identified by Maricopa

• Are the date stamps on the directories for SIFs, in the data set provided to
  EchoMail, the date in which the Maricopa election officials received the EVB return
  envelopes?
Questions for Maricopa

- Why does the approval stamp, “VERIFIED & APPROVED MCTEC” appear to exist only on a relatively small subset of EVB return envelopes?

- Did Maricopa stamp some EVB return envelopes as “VERIFIED & APPROVED MCTEC” even though Signature Region is blank, since they found a signature elsewhere i.e. outside of the Signature Region, during Signature Verification?

- What is the Standard Operating Procedure (“SOP”) for the EVB processing?

- What is the SOP for Signature Verification and curing of questionable signatures?

- What is the Chain of Custody for EVB return envelopes?
Questions for Maricopa

• Why is the surge in Duplicates (and Blanks and Scribbles) during 11/04/2020 to 11/09/2020 incongruent with the trend of EVBRE daily counts during the same period?

• Why is the “VERIFIED & APPROVED MCTEC” stamp appearing “behind” the printed envelope triangle?

• Can Two Voter-IDs be associated with the same person at the same address with matching signatures?

• Why are Blanks being stamped as “VERIFIED & APPROVED MCTEC?”

• Why is the stamp “VERIFIED & APPROVED MCTEC” appearing in a blank Signature Region?
Conclusion & Summary
**Conclusion & Summary**

- The EVB Return Envelope IS the CONTAINER of the Ballot

- Significant opportunities to enhance:
  - Precision
  - Verifiability
  - Reliability
  - Auditability
  - Reproducibility
Future Research

• Full Signature Verification Audit is Necessary
• Systems analysis needed to quantify efficacy of the current Signature Verification process
  – Acquire Maricopa County’s SOP for signature verification
  – Acquire Maricopa County’s 27-point analysis algorithm for signature comparison
  – Replicate signature verification process to scientifically calculate false positives, false negatives, error rate to determine a true confidence value of the signature verification of EVBs
• Need to review Chain of Custody
  – How were the signatures verified in communications
  – Phone/Email
Dr. Shiva Ayyadurai, MIT PHD, SMME, SMVS, SBEE, the inventor of email and polymath, holds four degrees from MIT, is a world-renowned engineer, systems scientist, inventor and entrepreneur. He is a Fulbright Scholar, Lemelson-MIT Awards Finalist, India’s First Outstanding Scientist and Technologist of Indian Origin, Westinghouse Science Talent Honors Award recipient, and a nominee for the U.S. National Medal of Technology and Innovation. He holds multiple patents, is the author of twenty books, and has published original research, in leading peer-reviewed high-impact scientific journals including IEEE, IJPRAI, Nature Neuroscience, CELL Biophysical Journal, that have received thousands of citations. He has started seven successful high-tech companies, received numerous industry awards, consults for Global 2000 organizations and government, and has been invited to present Keynote and Distinguished lectures at leading institutions such as NSF, NIH, FDA, Harvard, and at MIT, where he delivered the Presidential Fellows Lecture.1

In 1978, as a 14-year-old, he was recruited as a Research Fellow by the University of Medicine and Dentistry of New Jersey (UMDNJ), in Newark, NJ after graduating with Honors from a special program in Computer Science at the Courant Institute of Mathematical Science at NYU. At UMDNJ, he invented email – the system as we know it today – when he was the first to convert the old-fashioned interoffice paper-based mail system consisting of the Inbox, Outbox, Memo (To:, From:, Date:, Subject:, Cc:, Bcc:), Attachments, Folders, etc. into its electronic equivalent by writing 50,000 lines of code to create a software system, which he named “Email,” – a term never used before in the English language – and went on to be awarded the first U.S. Copyright TXu 111-775 for “EMAIL, COMPUTER PROGRAM FOR ELECTRONIC MAIL SYSTEM” recognizing him as the inventor of email at a time when Copyright was the only legal mechanism to protect software inventions. Only in 1994 did the Federal Circuit recognize software as a "digital machine" allowing for software patents. Email is not the simple exchange of text messages. Dr. Shiva has never claimed to be the inventor of electronic messaging, which predates email - the system that he created in 1978.2,3

Recognizing his talents in software programming, UMDNJ gave him the opportunity to conduct medical research focused on developing pattern recognition classification methods for categorization of sleep signature patterns from babies with Sudden Infant Death Syndrome (SIDS). His research was published in IEEE and presented at the IEEE-EMBS conference in Espoo, Finland. Since that time and for more than forty years, his research and development efforts in academia and industry have been focused in the field of pattern recognition classification systems, systems science, and development of large-scale computational systems for analysis of diverse signals and signatures across a range of industries: biology and medicine, engineering (e.g. aeronautical, civil, mechanical, electrical), banking, finance, and, government, as well as across a diversity of applications including handwriting recognition of courtesy amounts on bank checks, automatic analysis and classification of electronic documents e.g. email, ultrasonic and radar wave signature classification for

1Dr. Shiva Ayyadurai, Biography and Curriculum Vitae, https://vashiva.com/about-va-shiva-ayyadurai/
2Facts on the invention of email, https://www.inventorofemail.com/thefacts/
Author’s Bio

non-destructive evaluation (NDE), signals analysis of Tadoma feature identification, biomarker analysis for determining signatures of efficacy for multi-combination therapies, image analysis for cardiology, and signal detection of fluid flow anomalies in fluidized bed reactors.

He earned a Bachelors in Electrical Engineering and Computer Science, a Masters in Mechanical Engineering, and another Masters in Visual Studies from the MIT Media Laboratory. In the midst of his PhD research in 1993, where he aimed to create a generalized platform – Information Cybernetics – for pattern recognition, he won an industry-wide competition sponsored by the White House, Executive Office of the President, to automatically analyze and classify President Clinton’s email, resulting in his developing EchoMail® - a platform for automatic classification of electronic documents -, and subsequently launching EchoMail, Inc., a company that grew to nearly $200 million in market valuation. EchoMail today applies its technologies across a diversity of applications.

In 2003, he returned to MIT complete his doctoral work in systems biology in the department of Biological Engineering where he developed CytoSolve®, a scalable computational systems biology platform for mathematically modeling the whole cell. Following his PhD, Dr. Shiva was selected for a Fulbright Fellowship returning him to India where he discovered the systems theoretic basis of eastern systems of medicine resulting in Systems Health®, a new educational program that provides a scientific foundation for integrative medicine. In 2012, Dr. Shiva launched CytoSolve, Inc. with the aim of modeling complex diseases and biomolecular processes to discover multi-combination medicines. His efforts led to CytoSolve earning an FDA allowance for a multi-combination therapy for pancreatic cancer in a record eleven months, developing innovative nutraceutical products, and garnering numerous industry and academic partnerships.

As an educator dedicated to the field of systems science and systems thinking, Dr. Shiva pioneered Systems Visualization, a course he taught at MIT to graduate and undergraduate students, which integrated systems theory, narrative story telling, metaphors, and data science to provide a pedagogy for visualization of complex systems. He founded the International Center for Integrative Systems, a research and educational institution and home to Innovation Corps and R.A.W./C.L.E.A.N. Food Certified, for broader applications of systems science. 

Dr. Shiva has appeared in The MIT Technology Review, TIME, The Wall Street Journal, New York Times, NBC News, USA Today and other major media. Dr. Shiva was named Top 40 Under 40 in the Improper Bostonian. He continues his passion for entrepreneurialism as Managing Director of General Interactive to incubate, mentor and fund new startups in various areas including healthcare, media, biotechnology, information technology, to name a few.

Dr. Shiva is a member of Sigma-Xi, Eta Kappa Nu, and Tau Beta Pi.
Pattern Recognition Classification of Early Voting Ballot (EVB) Return Envelope Images for Signature Presence Detection

An Engineering Systems Approach to Identify Anomalies to Advance Integrity of U.S. Election Processes

Dr. Shiva Ayyadurai, MIT PhD
SMVS, SMME, SBEE
701 Concord Avenue | Cambridge, MA 02138
E: vashiva@vashiva.com | P: 617-631-6874

PRESENTED TO

Arizona State Senate

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