BIOMETRICS & HOW THEY WORK

Dr. Jim Wayman

San Jose State University

www.engr.sjsu.edu/biometrics

biomet@email.sjsu.edu

BEFORE WE START

The real purpose of the scientific method is to make sure Nature hasn't mislead you into thinking you know something you don't actually know. There's not a mechanic or a scientist or a technician alive who hasn't suffered from that one so much that he's not instinctively on guard.

-- Robert Pirsig, Zen and the Art of Motorcycle Maintenance (1974)

COURSE OUTLINE

- Overview
  - Background
  - Scientific Approach
- Technologies
  - Retina Recognition
  - Facial Recognition
- Testing
  - CESG/NPL
  - FRVT2000

PART 1:
OVERVIEW

A MODERN DEFINITION OF BIOMETRIC AUTHENTICATION

The automatic identification or identity verification of living, human individuals based on behavioral and physiological characteristics

MATERIALS

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- Text: National Biometric Test Center Collected Works

  www.engr.sjsu.edu/biometrics/nbtccw.pdf
- Additional Papers available at

  www.engr.sjsu.edu/biometrics/UCLAS/

MATERIALS

- FVC2000

  http://bias.csr.unibo.it/fvc2000

- Sandia Iris Report

infoserve.library.sandia.gov/sand_doc/1996/961033.pdf

- FRVT 2000 and Philips,et al www.dodcounterdrug.com/facialrecognition/FRVT2000/documents.htm

MATERIALS

San José State UNIVERSITY

- CESG/NPL Test and “Best Practices”

www.cesg.gov.uk/technology/biometrics

RESOURCES

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- A. Jain, etal, eds. Biometrics:Personal Security in Networked Society, (Kluwer Academic Press, 1999), 411 pages
- J. Ashbourn , Biometrics: Advanced Identification Technology (Springer, 2000)
- “Special Issue on Biometrics”, IEEE Computer Magazine, Feb. 2000
- “Biometric Technology Today”, Elsevier Science

RESOURCES

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- Biometrics in Human Services Users Group, www.dss.state.ct.us/digital.htm
- International Biometrics Industry Association www.ibia.org
- (US Federal) Biometric Consortium, www.biometrics.org

WHO'S WHO

- DARPA
- Michigan State University
- Sandia National Laboratory
- UK Biometrics Working Group
- German Information Security Agency
- TeleTrusT/WG6/BioTrusT

WHO'S WHO

- IBIA www.ibia.org
- Japanese Biometric Group/Japanese Standards Agency
- European Union 5th Framework
- Korean Information Security Agency
- International Biometrics Group
- University of Bologna

WHO'S WHO

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- US standards activities
  - Driver's licensing: B10.8
  - Financial transactions: X9.84
  - BioAPI
- International standards activities
  - Common Criteria: ISO15408
  - Driver's licensing: ISO SC68
  - Passport: ISO SC68

MODERN HISTORY OF BIOMETRIC ID

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- Bertillion -- 1880

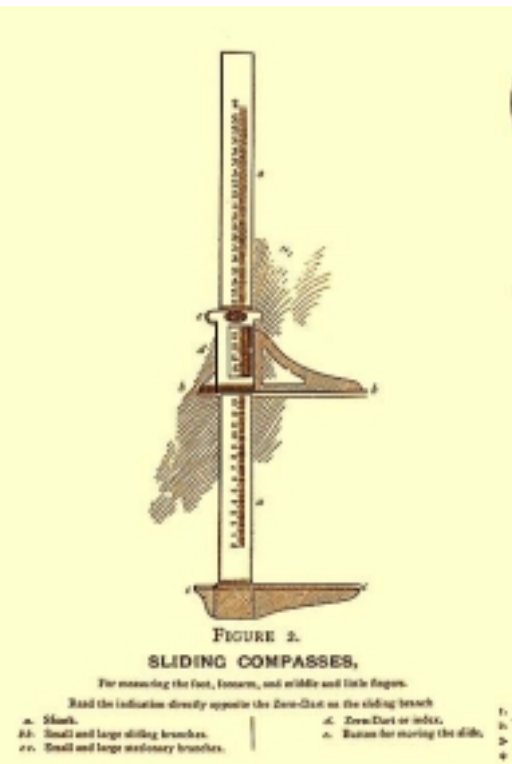

FIGURE 2.

SLIDING COMPASSES,

For measuring the foot, forearm, and middle and little fingers.

Read the indication directly opposite the Zero-Dart on the sliding branch

a. Shank.
bb. Small and large sliding branches.
cc. Small and large stationary branches.
d. Zero-Dart or index.
e. Button for moving the slide.

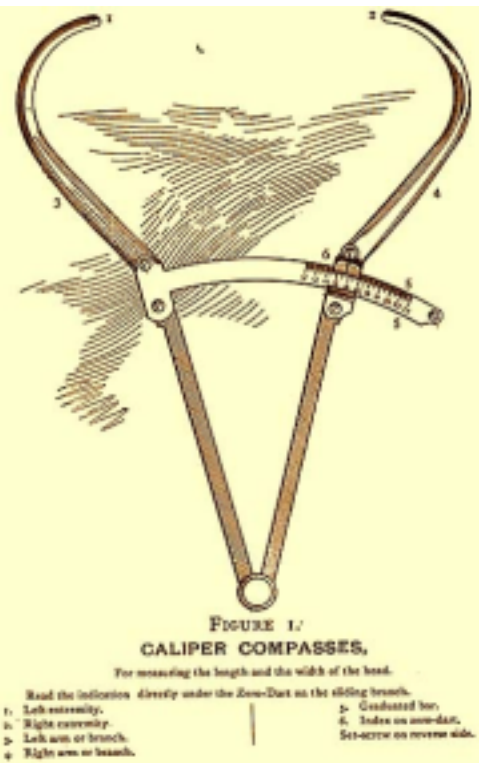

FIGURE 1.

CALIPER COMPASSES,

For measuring the length and the width of the head.

Read the indication directly under the Zero-Dart on the sliding branch.

1. Left extremity.
2. Right extremity.
3. Left arm or branch.
4. Right arm or branch.
5. Graduated bar.
6. Index on zero-dart.

Set-screw on reverse side.

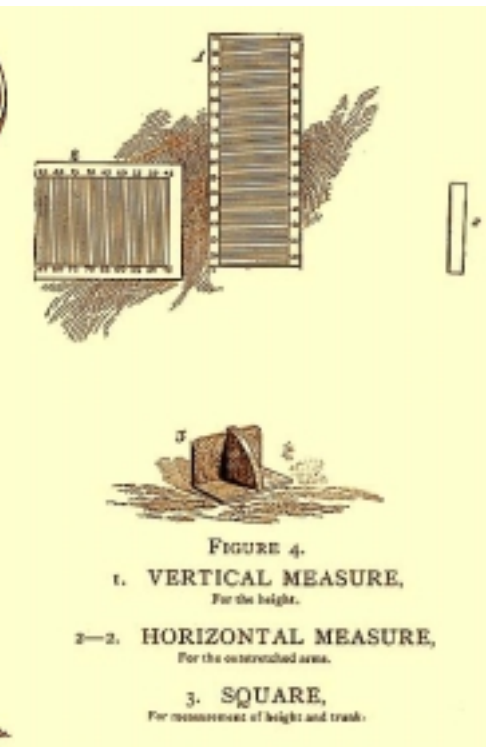

FIGURE 4.

1. VERTICAL MEASURE,
For the height.

2—2. HORIZONTAL MEASURE,
For the outstretched arms.

3. SQUARE,
For measurement of height and trunk.

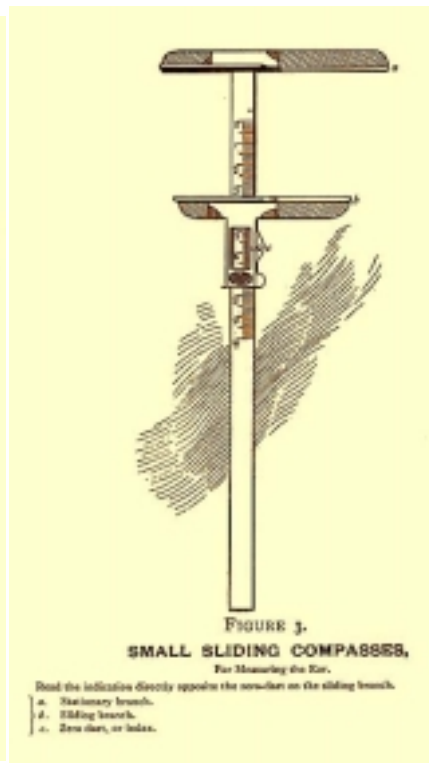

FIGURE 3.

SMALL SLIDING COMPASSES,

For Measuring the Ear.

Read the indication directly opposite the zero-dart on the sliding branch.

a. Stationary branch.
d. Sliding branch.
e. Zero dart, or index.

FINGERPRINTING

- Faulds, Herschel -- 1880
- Galton, “Personal ID and Description” -- 1888
- Vucetich -- 1891
- Galton, Fingerprints, 1892
- Twain, Life on the Mississippi, Pudd’nhead Wilson 1892

GALTON'S CRITICISM OF BERTILLION

There was...a want of fulness in the published accounts of it, while the principle upon which extraordindary large statistical claims to its quasi-certainty had been founded were manifestly incorrect, so further information was desirable. The incorrectness lay in treating the measures of different dimensions of the same person as if they were *independent* variables, which they are not. For example, a tall man is much more likely to have a long arm, foot, or finger, than a short one. The chances against mistake have been overrated enormously owing to this error; still, the system was most ingenious and very interesting. Galton, *Memories of My Life* (1908), p. 251.

DÉJÀ VU IN THE 21st CENTURY

DNA -- NRC I and NRC II

1 error in 10^3 vs. 1 error in 10^{10}

Iris Recognition

1 error in 10^{78}

US DOJ at *Daubert* hearing on fingerprinting

1 error in 10^{97}

DAUBERT v. MERRILL DOW PHARMACEUTICAL (509 U.S. 579, 1993)

Admissible as “scientific”if:

- Theory or technique has or can be tested
- Subjected to peer review and publication
- Existence and maintenance of standards for use
- General acceptance in scientific community
- Known potential rate of error

“On the Individuality of Fingerprints”

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- Sharath Pankati, Salil Prabhakar and Anil Jain
- http://biometrics.cse.msu.edu/cvpr230.pdf

THE HISTORY OF AUTOMATIC ID

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- Voice -- 1964
- Hand -- 1972
- Fingerprint -- (1880)/1963/1974
- Retinal -- (1935)/1976
- Signature -- (1929)/1983
- Keystroke -- 1985
- Facial -- (1888)/1972/1987
- Iris -- 1994

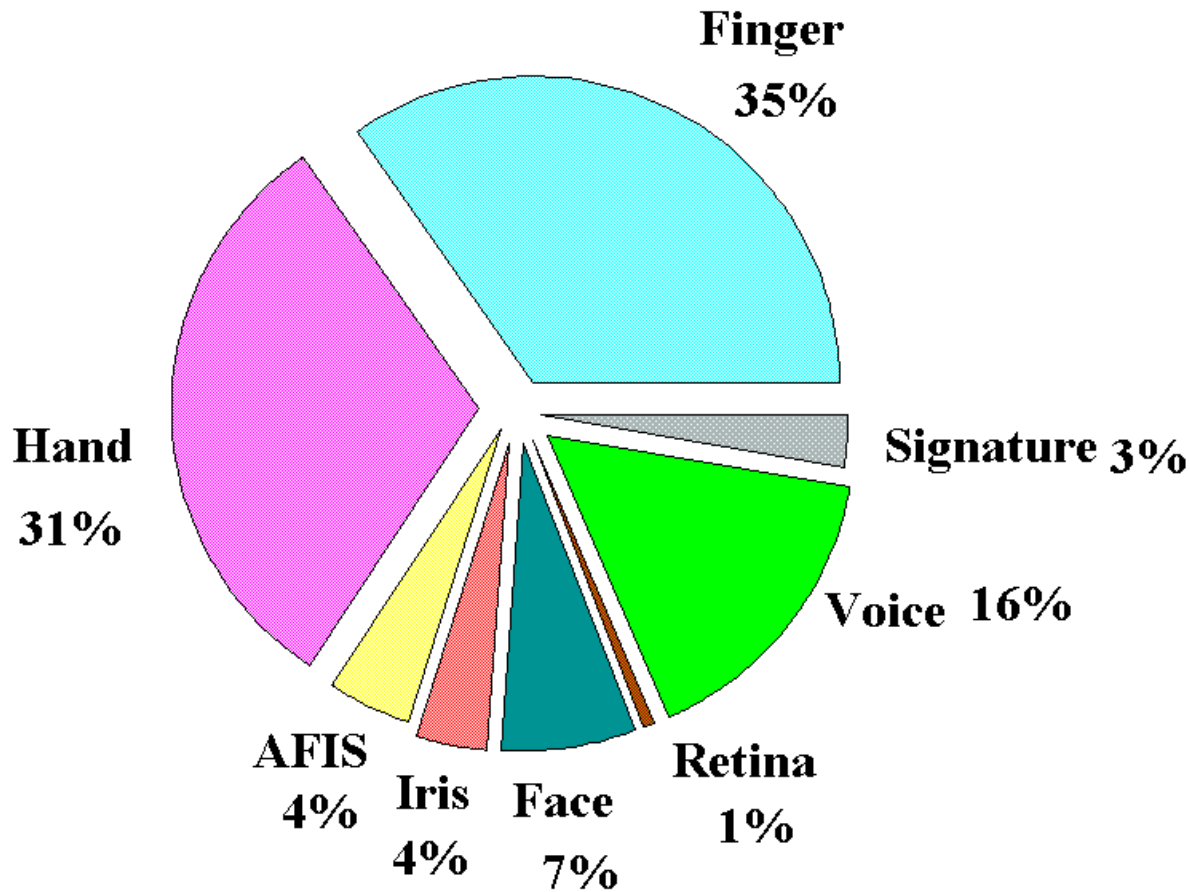
"A LARGE, DIVERSE MARKET"

- Credit systems
- Industrial and military security systems
- Personal locks

Speed, Decentralization, Ultravalidity, Convenience

--Hughes Research Laboratory Report #190, March 1961

TECHNOLOGY OF APPLICATIONS



Source: Biometric Technology Today

INDUSTRY GROWTH

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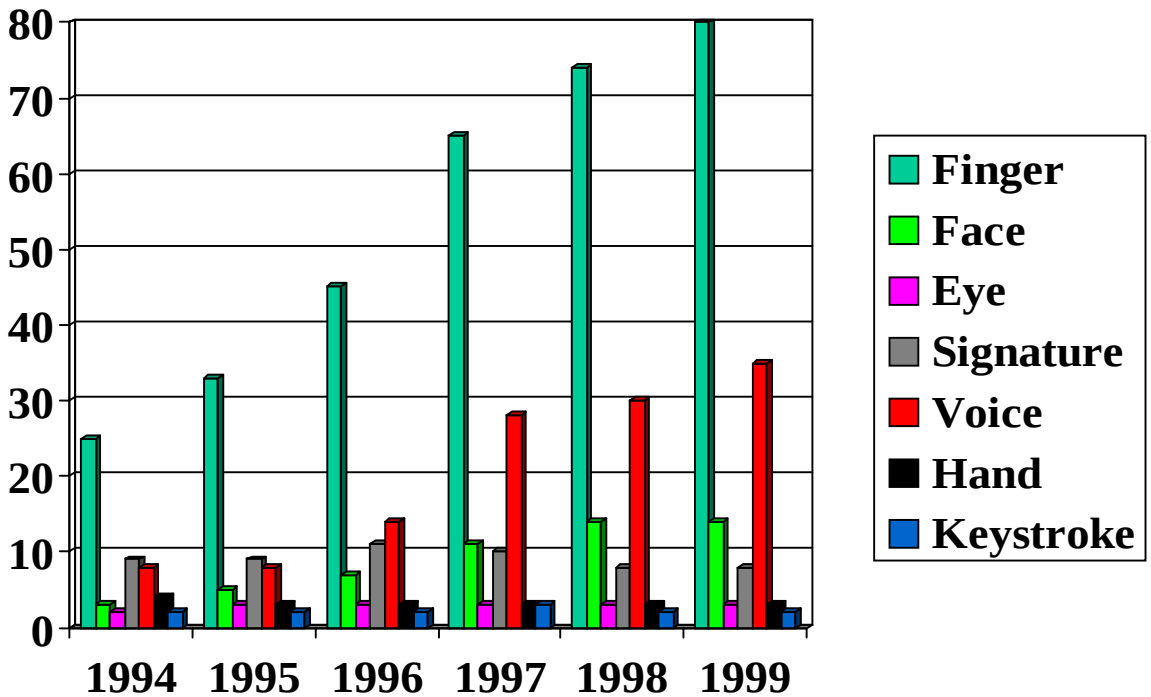
	UNITS	CHANGE	HARDWARE REVENUE ($M)	CHANGE	AVE. PRICE
1990	1,288		$6.6		$5,124
1991	1,675	30%	$7.3	11%	$4,358
1992	1,998	19%	$8.3	14%	$4,154
1993	3,073	54%	$10.1	22%	$3,287
1994	4,829	57%	$12.2	21%	$2,256
1995	6,450	34%	$14.7	21%	$2,279
1996	8,550	33%	$21.2	44%	$2,479
1997	28,391	232%	$33.0	56%	$1,162
1998	55,000	94%	$39.5	20%	$718
1999*	115,000	110%	$63.2	60%	$547

* estimate

Source: *ID WORLD*, Nov/Dec. 1999

COMPETITIVE ENVIRONMENT



Total	52	63	87	125	134	145
Change (%)		21	38	44	7	8

Source: *ID World*, July/Aug 1999

Applications

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- Positive hypothesis
- Negative hypothesis

POSITIVE IDENTIFICATION

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- To prove I am who I say I am
- Prevent multiple users of a single identity
- Matching sample to single stored template
- False match allows fraud
- False non-match is inconvenient
- Multiple alternatives
- Can be voluntary

NEGATIVE IDENTIFICATION

- To prove I am not who I say I am not
- Prevent multiple identities of a single user
- Matching sample to all stored templates
- False non-match allows fraud
- False match is inconvenient
- No alternatives
- Mandatory for all users

"TYPE I" AND "TYPE II" ERRORS

- Type I: Rejecting a true hypothesis
- Type II: Accepting a false hypothesis
- What is the hypothesis?

BIOMETRIC DEVICES CANNOT DIRECTLY DETERMINE:

- Name
- Age
- Race
- Birth place
- Health
- Citizenship
- Gender
- Income

POSSIBILITY OF DATA FUSION

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- No general biometric databases
- Biometrics on the internet?
- “Strong” identifier required for biometric-only identification
  - Recommend two fingerprints

NEITHER UNIQUE NOR TIME-INVARIANT

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DAN, RON AND PETER

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PETER

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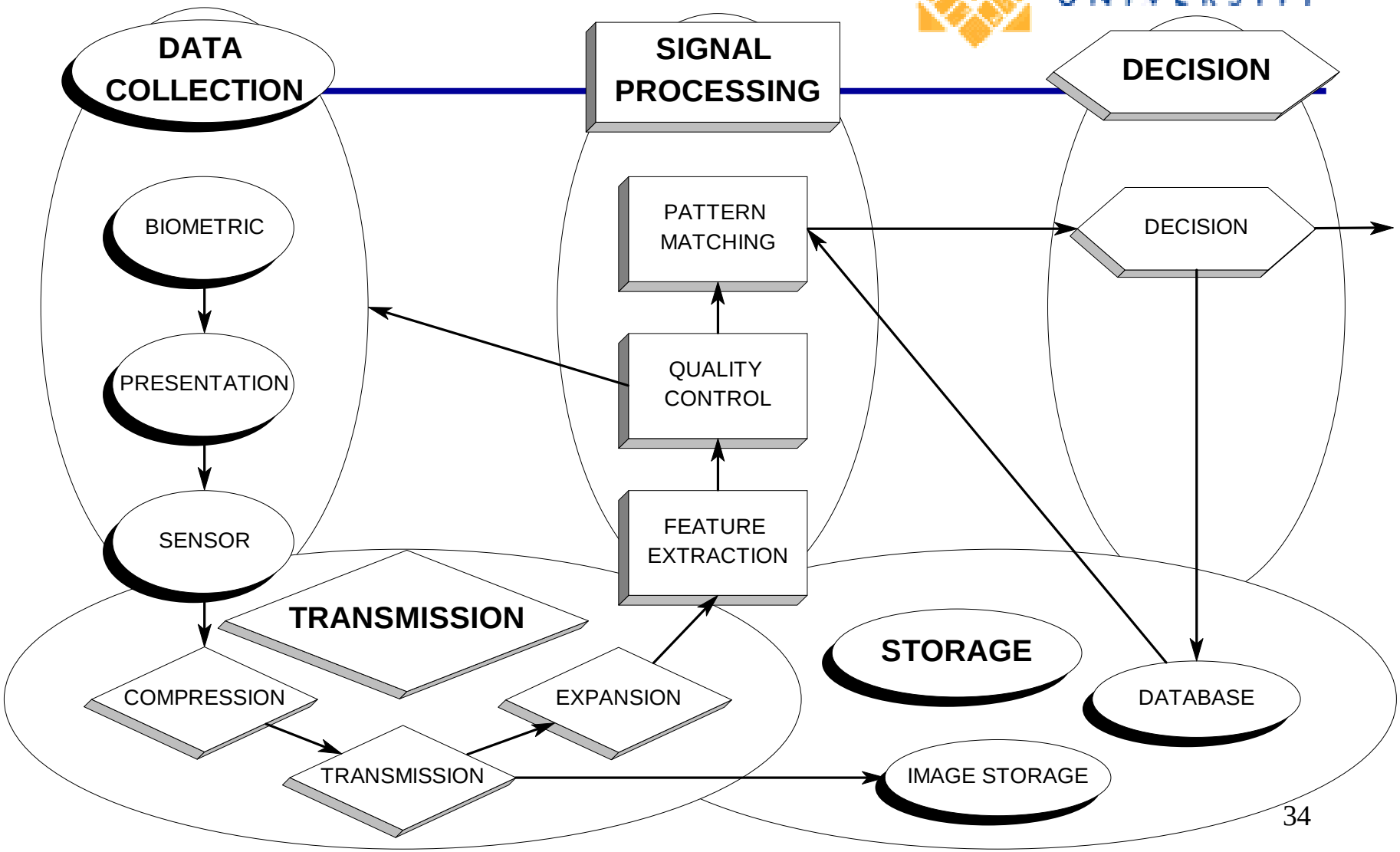
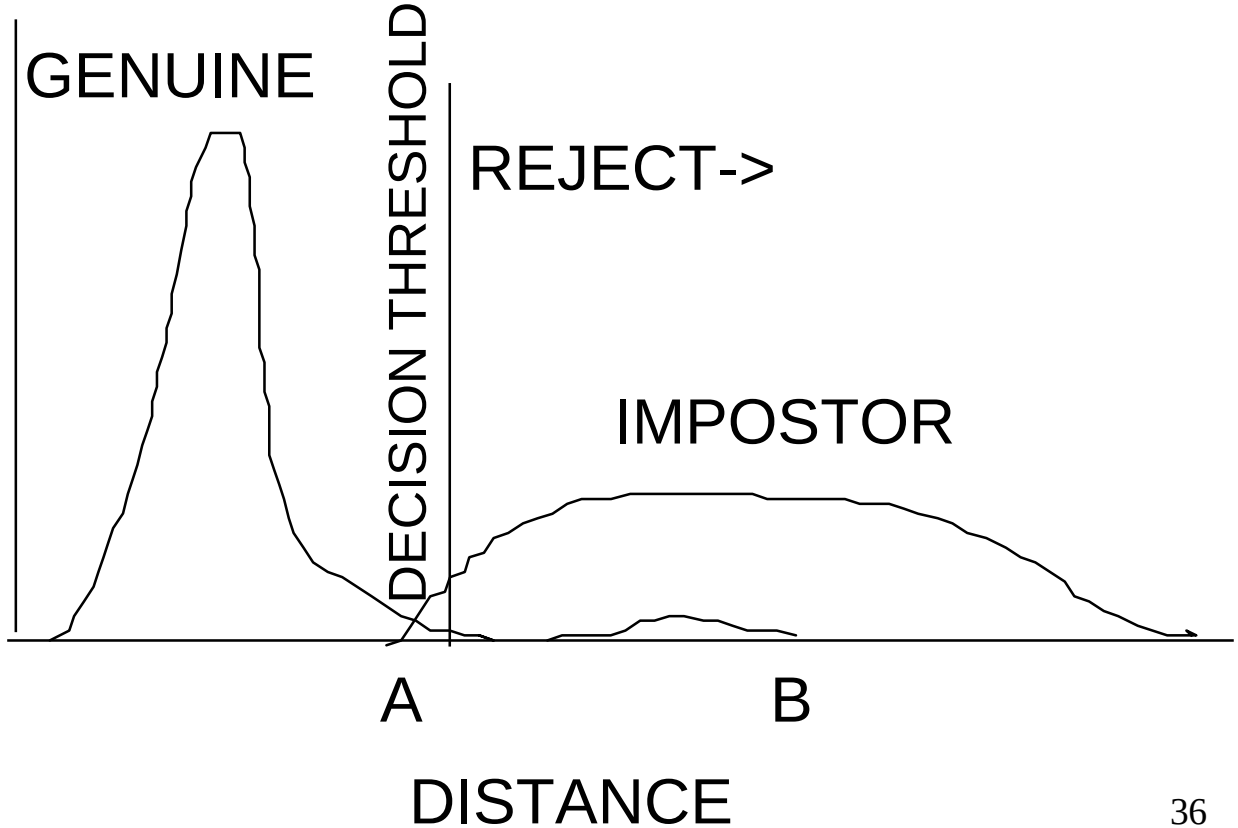
SYSTEM DESCRIPTION



TEMPLATE SIZES

- Fingerprint -- 200+ bytes
- Hand Geometry -- 9 bytes
- Finger Geometry -- 14 bytes
- Iris -- 512 bytes
- Face -- 100 - 3.5 kbytes
- Voice -- 6k bytes

SCORE DISTRIBUTIONS



DETECTION ERROR TRADE-OFF CURVES

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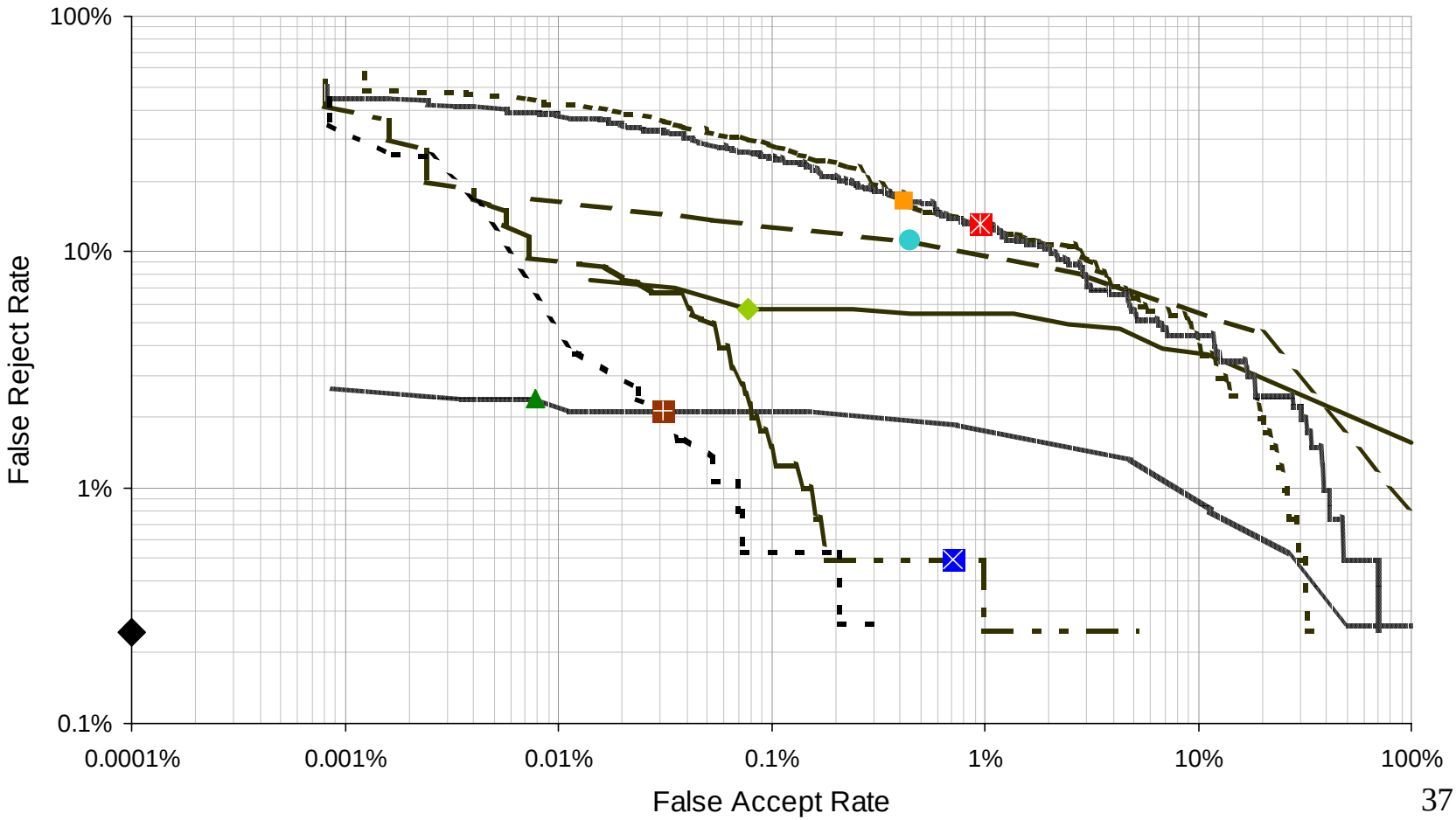

OTHER MEASURES OF INTEREST

- “Failure to acquire” rate
- “Failure to enroll” rate
- Throughput
- System cost

APPLICATION DEPENDENCY OF ALL MEASURES

WHOOPS!

Our total inability to predict performance in one environment from measures in another

TAXONOMY OF APPLICATIONS

- Public/Private
- Open/Closed
- Attended/Unattended
- Habituated/Non-habituated
- Overt/Covert
- Standard/Non-standard Environment

PART 3: TECHNOLOGIES

2-D FILTERING

1	0	–1	0	1	5	6	5	6	7
0	–1	–2	0	1	5	5	5	6	7
0	–2	–3	–1	2	5	6	6	6	8
–1	–1	–2	0	3	6	7	7	7	8
0	0	–1	0	4	7	8	8	8	8
0	0	0	0	5	6	7	8	8	9
0	0	0	1	6	6	6	8	8	9
1	1	1	1	7	7	7	7	7	8
2	2	1	2	8	8	8	7	8	7
2	2	2	2	9	9	9	9	9	8

–1	0	1
–1	0	1
–1	0	1

- **Image**

Filter

Retinal Recognition

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- Commercial come-back?
- Vascular patterns on retina
- Near infra-red illumination and imaging
  - Invisible
  - Lasers have never been used
- Circular scan of contrast measures

Retinal Recognition

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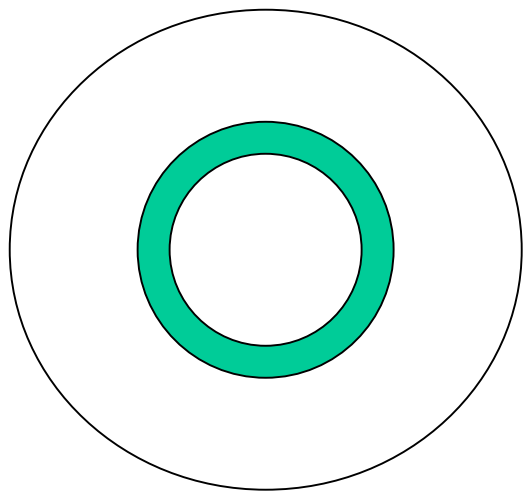
- Contrast filter
- Filter output or FFT-based comparisons



Retinal Recognition

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- No known way to extract health information from filtered annulus
- Pattern instability could be due to:
  - Retinal changes
  - Presentation inconsistency
  - Sensor variation

Facial Recognition

Applications

- INS Otay Mesa Border Crossing (discontinued)
- Newham, London town monitoring
- NBTC Lab door
- Las Vegas casinos
- Check cashing kiosks

Facial Recognition

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- **Presentation**
  - Facial expression
  - Glasses, jewelry
  - Hats
  - Facial hair (including bangs)
  - Lighting
  - Template “aging”
  - Pose angle
  - Head height
  - Distance/Resolution

Facial Recognition

- Sensors
  - CCD camera
  - Some AAMVA, INS and NIST standards
  - Still or motion imagery

Facial Recognition

- NIST “Best Practices”
  - Pose angle -- “full frontal”
  - Background -- 18% gray scale
  - Illumination -- 3 point frontal
  - Resolution -- 480 x 640 pixels (face width 50% of horizontal)
- www.itl.nist.gov/iaui/894.03/face/face.html

Segmentation

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- Is there a face?
- Where?

Pre-processing

- Find eyes
- “Normalize” interocular distance
- Contrast: “Normalize” gray-scale histogram

Facial Recognition

- Signal Processing
  - Eigen-faces
  - Elastic nets
  - Shape from shading
  - “Holographic Quantum Neural Networks”

EIGENFACES

Say what??

COVARIANCE MATRICES

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$$\vec{\mu} = \frac{1}{M}\sum_{i=1}^{M}\vec{x}_i$$

$$[\vec{x}-\vec{\mu}]^T[\vec{x}-\vec{\mu}] = \begin{bmatrix} (x_1-\mu_1)^2 & (x_1-\mu_1)(x_2-\mu_2) & \\ (x_2-\mu_2)(x_1-\mu_1) & \ddots & \\ \vdots & & \\ (x_N-\mu_N)(x_1-\mu_1) & & (x_N-\mu_N)^2 \end{bmatrix}$$

$$\frac{1}{M}\sum_{i=1}^{M}[\vec{x}_i-\vec{\mu}_i]^T[\vec{x}_i-\vec{\mu}_i] = C \text{ (covariance matrix)}$$

COVARIANCE MATRICES

What does it mean?

Diagonal elements are variances of the components of x

Off-diagonal elements are covariances between different components

If components are independent, the covariance ~ 0

If all components are independent and have equal variance,

C = c I , where I is identity matrix

A GENERIC EXAMPLE

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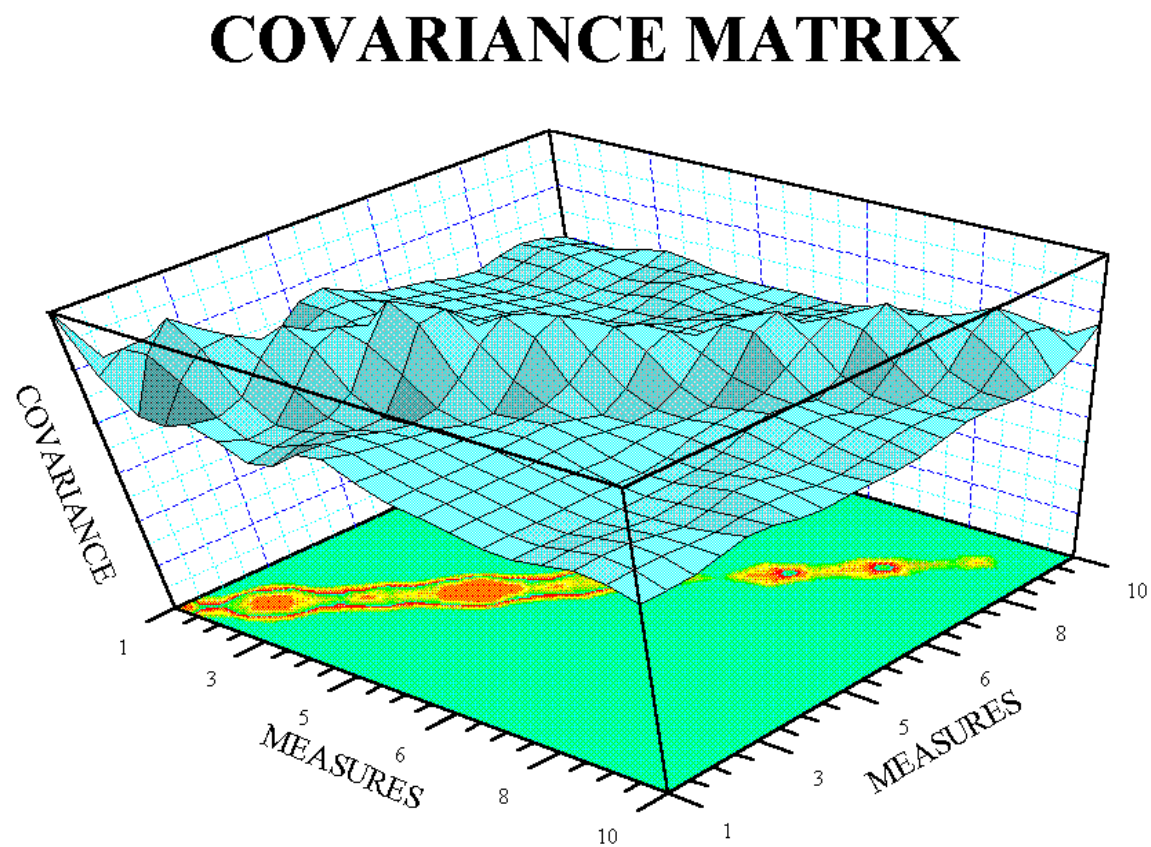


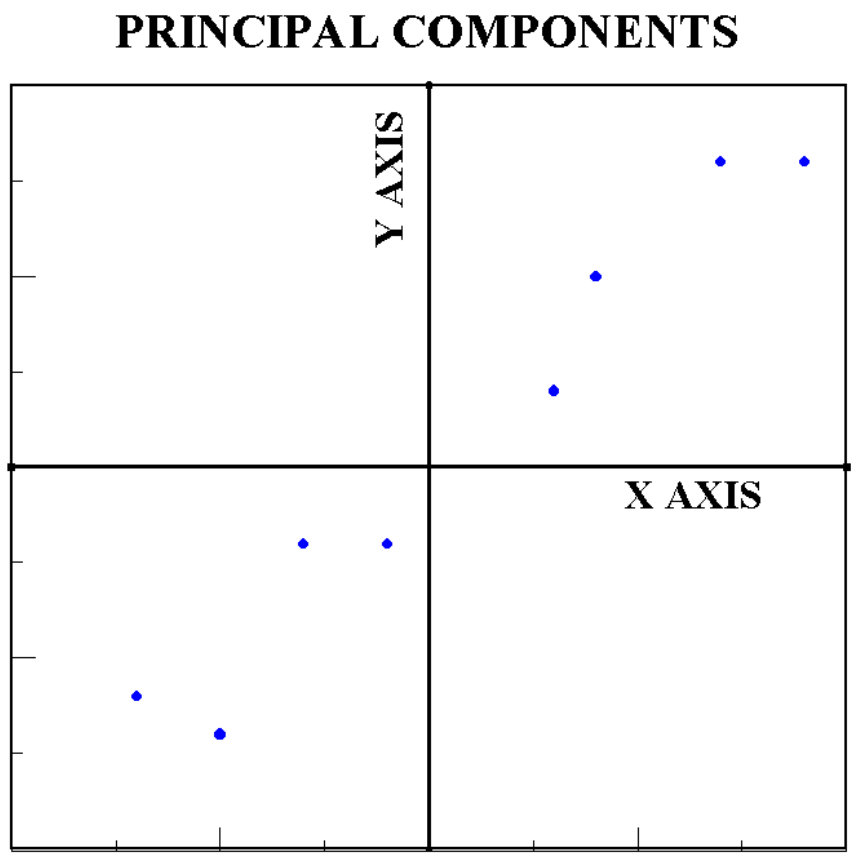
EIGEN-SYSTEMS & PRINCIPAL COMPONENT ANALYSIS

- Extract the R eigenvalues
- Order them from largest to smallest, $\lambda_1, \lambda_2 \ldots \lambda_r$
- Order corresponding eigenvectors

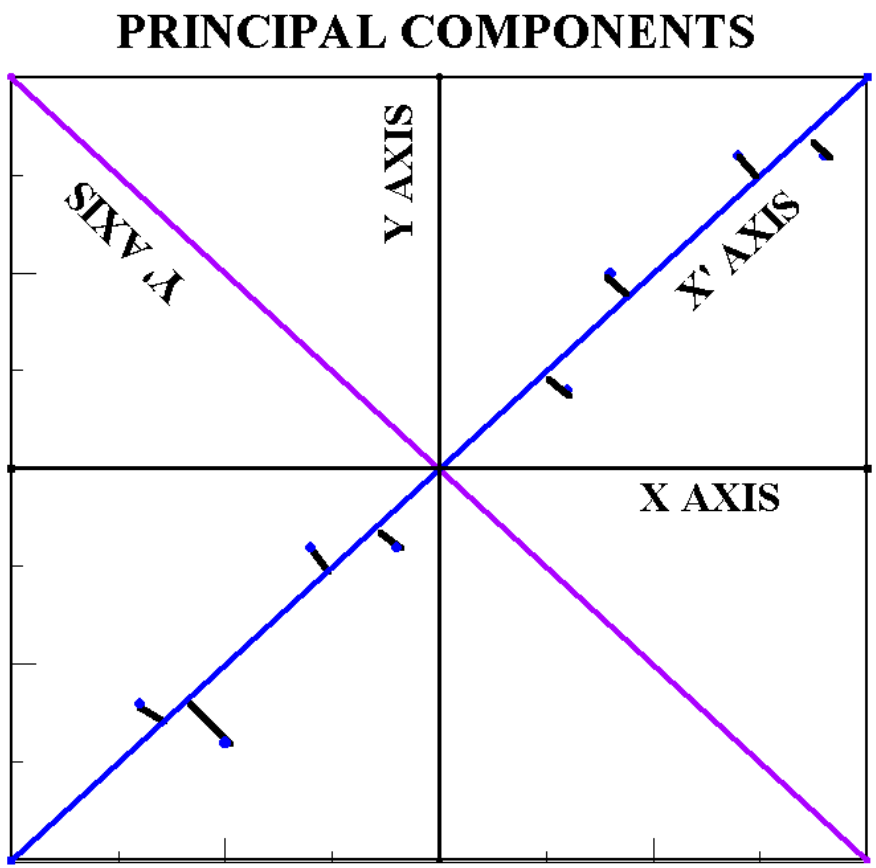
$$\vec{v}_1, \vec{v}_2, \ldots \vec{v}_R$$

- These are “principal components”

EIGEN-SYSTEMS & PRINCIPAL COMPONENT ANALYSIS



EIGEN-SYSTEMS & PRINCIPAL COMPONENT ANALYSIS



Facial Recognition

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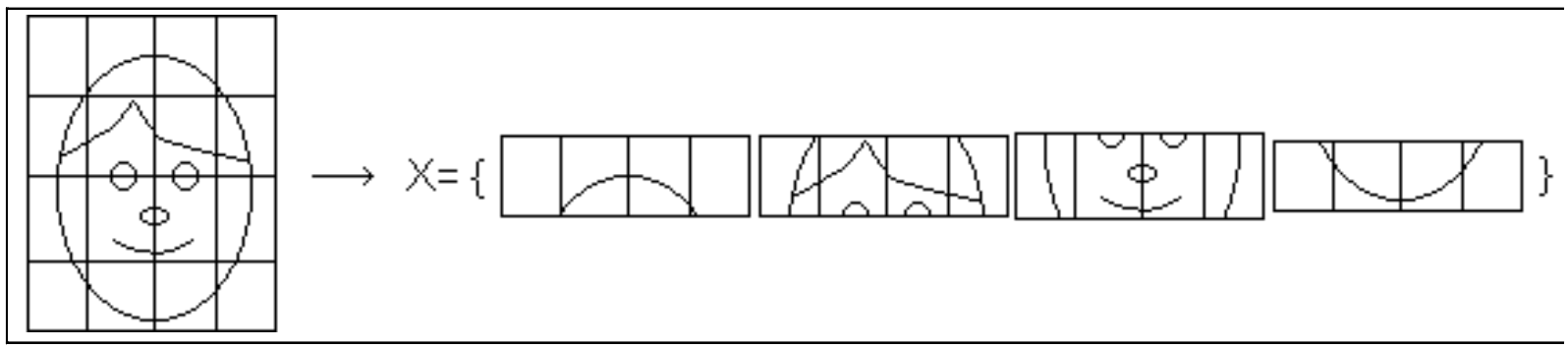
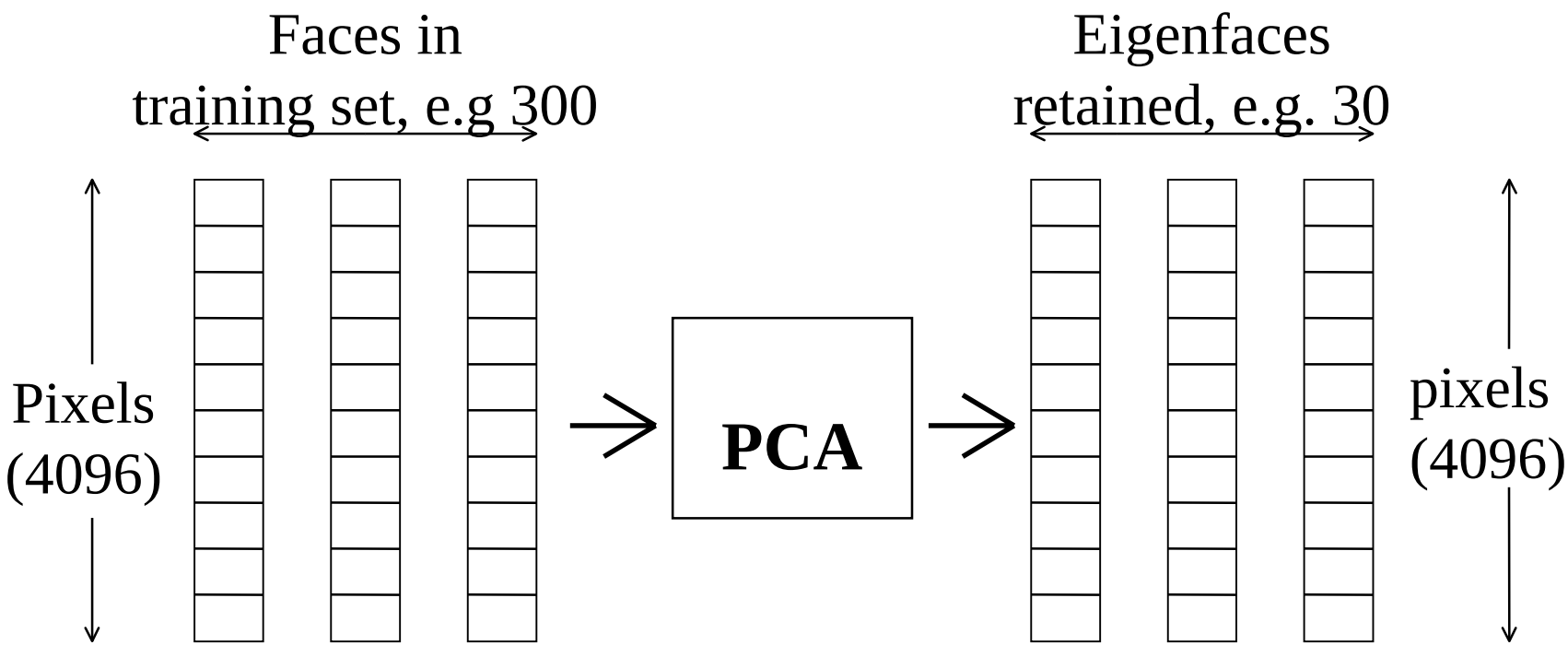
- Eigenfaces

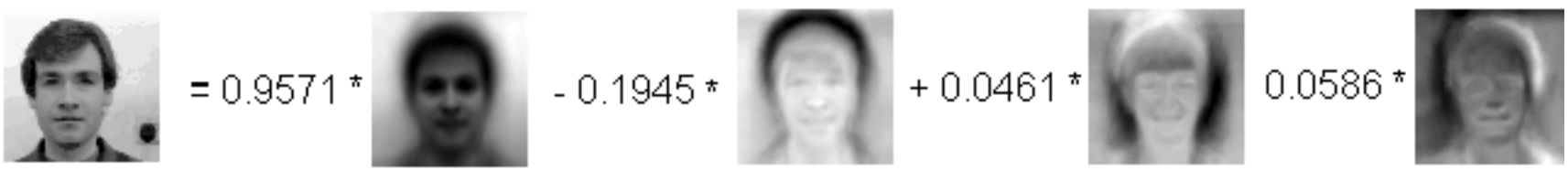


Facial Recognition



Facial Recognition

- Set of basic eigenfaces



- Express new face as linear combination

Facial Recognition

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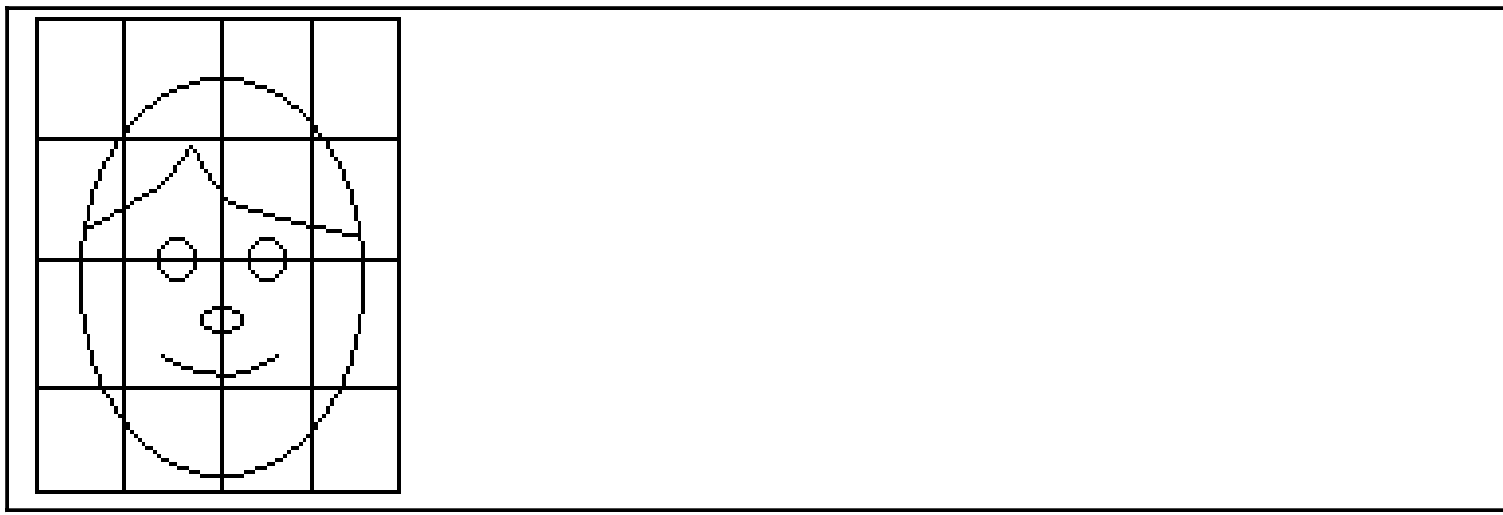
- Elastic Nets



Shape from Shading

- Enrollment
  - Assume generic 3-D model
  - Use shadows to estimate direction of light source
  - Use length of shadows to estimate 3-D information
  - Refine model by multiple images with varying lighting directions

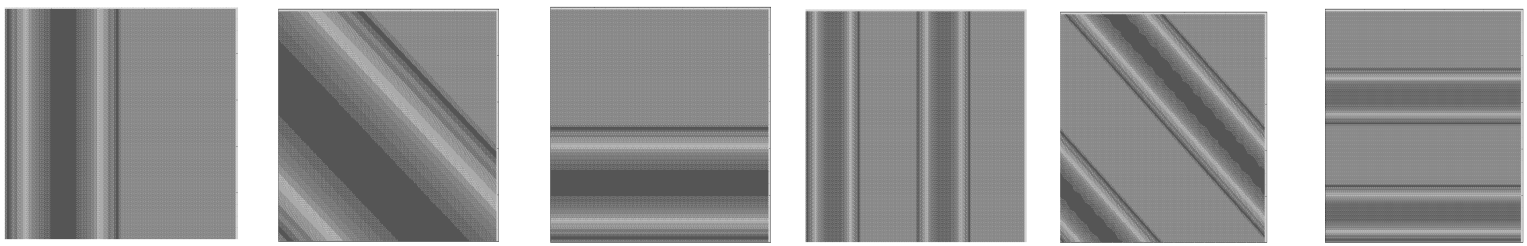
Shape from Shading

- Verification
  - Use shadows to estimate direction of light source
  - Apply light source to 3-D template to produce image
  - Compare images

HNet

- Inputs to the cell are simply the frequency domain coefficients of the raw image, with some prior normalization applied. Running the learning process over 100 synaptic pruning and regrowth cycles (i.e. neural plasticity) takes approximately 10 seconds, and achieves virtually a 100% classification accuracy in recognizing faces vs. non-faces. http://www.acsysbiometrics.com/

FOURIER TRANSFORM BASIS FUNCTIONS



PART 3:
TESTING

TESTING STANDARDS

- U.K. BWG Testing “Best Practices”

CESG/NPL TEST PROGRAM

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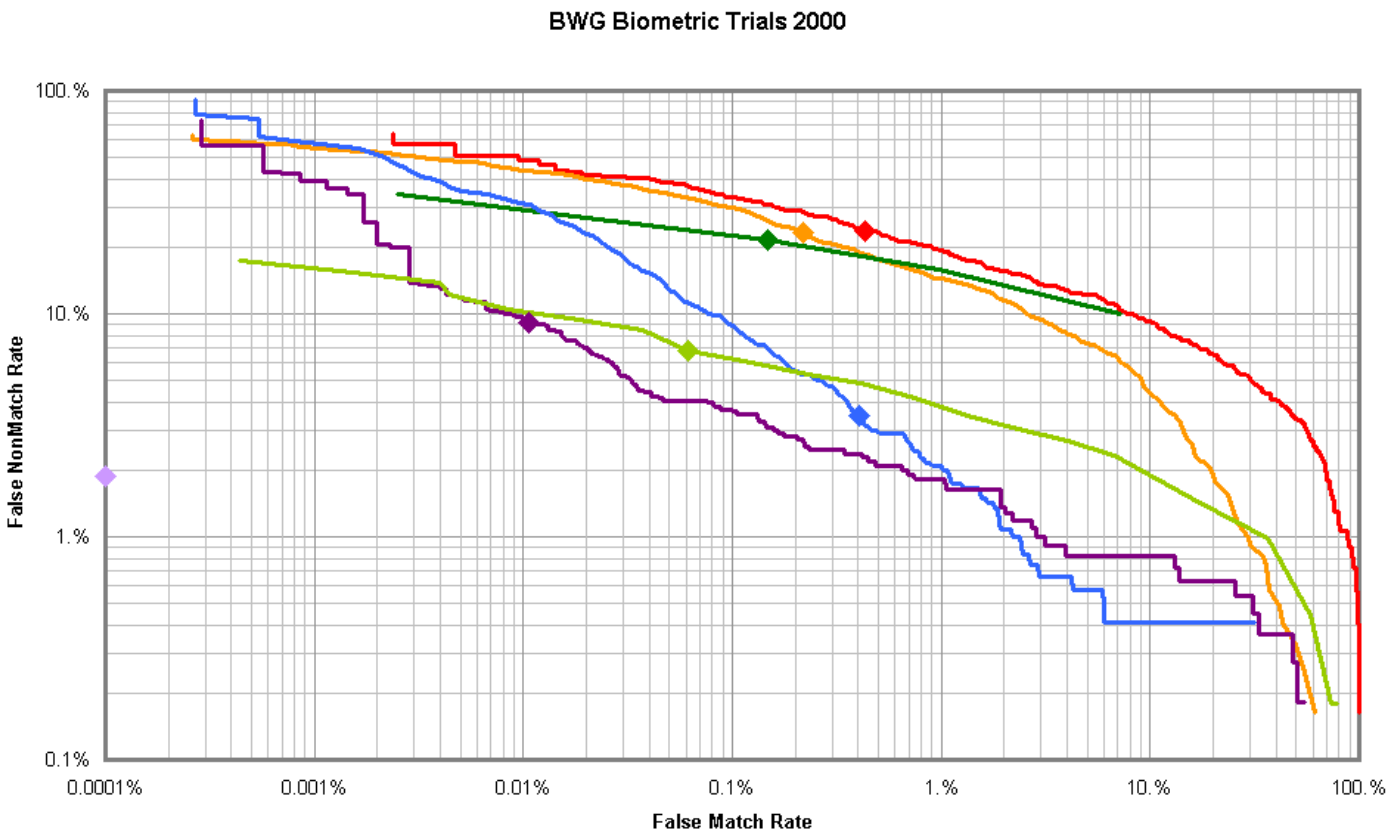

“BEST OF THREE” DET

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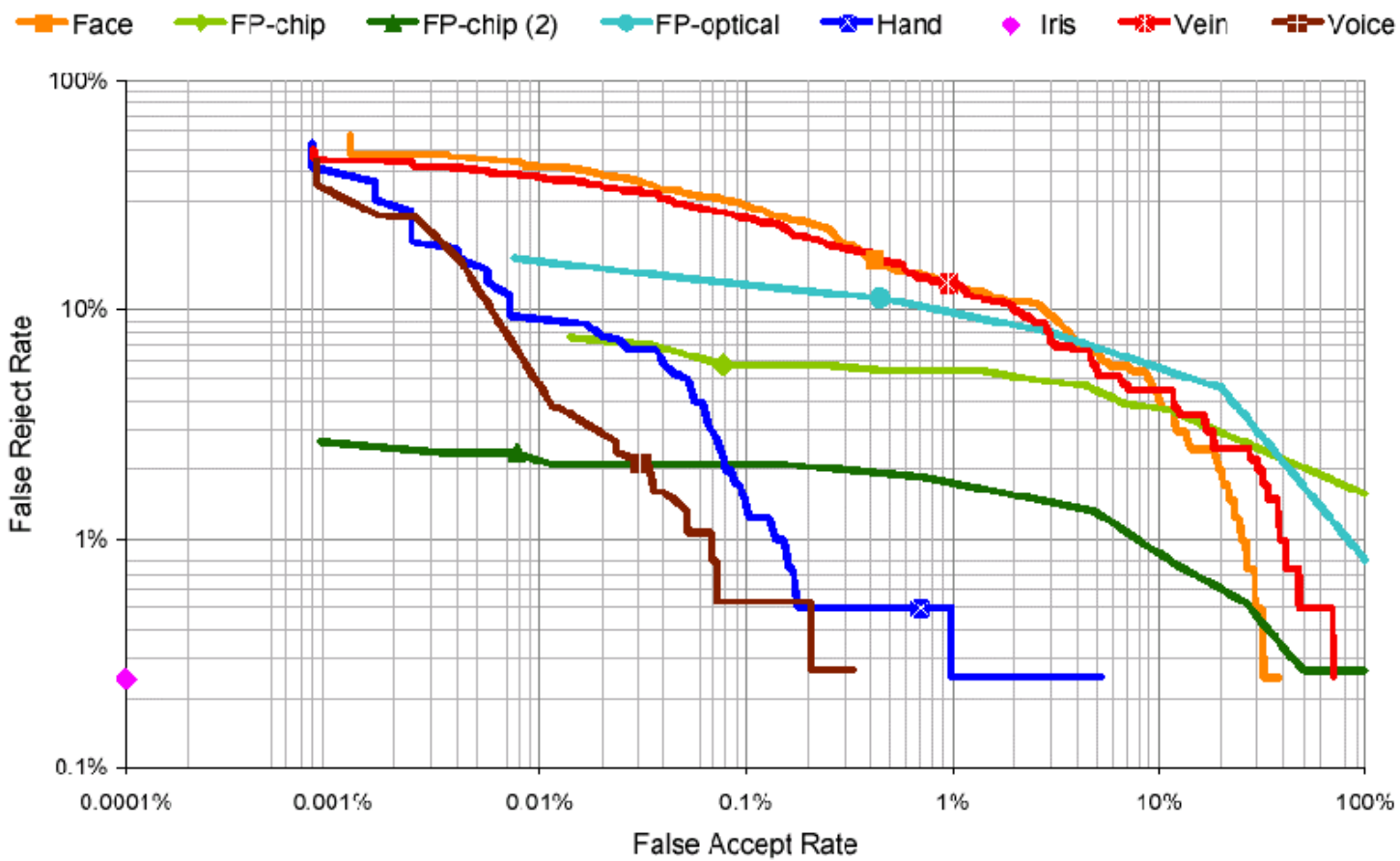

Figure 6. Detection error trade-off: Best of 3 attempts

SYSTEM EQUATIONS

- Number of false matches = number of independent comparisons x Prob(false match on a single comparison
- Number of false non-matches ≅ number of uses x [Prob(false non-match or failure-to-acquire on max number of comparisons)+Failure-to-enroll rate]

HUMAN FACE RECOGNITION

Pike, Kemp and Brace, “Psychology of Human Face Recognition”, IEE Conference on Visual Biometrics, 2 March 2000, Savoy Place, London

Same Day FAA = 34% FRR = 7%

Facial Recognition Vendor Test 2000

- DoD Counterdrug Technology Program Office, DARPA, Crane NSWC, Dahlgren NSWC
- www.dodcounterdrug.com/facialrecognition/FRVT2000/documents.htm

LIGHTING VARIATION

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- Mug shot - overhead

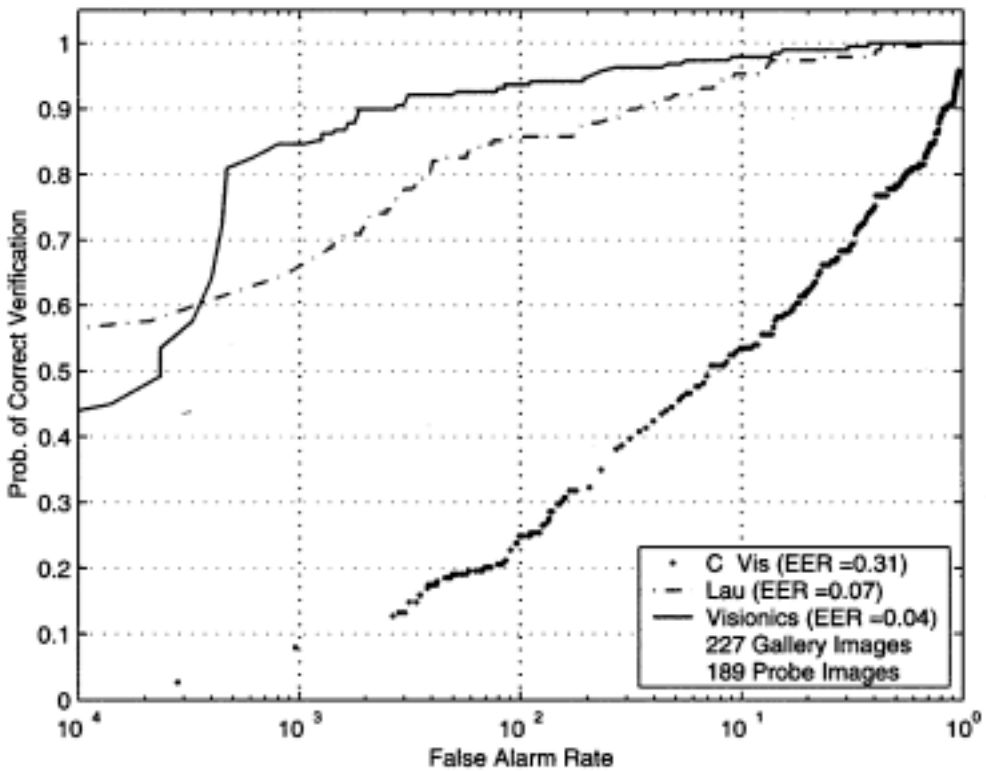

Figure M–43: *Verification Scores—Illumination I1*

EXPRESSION CHANGE

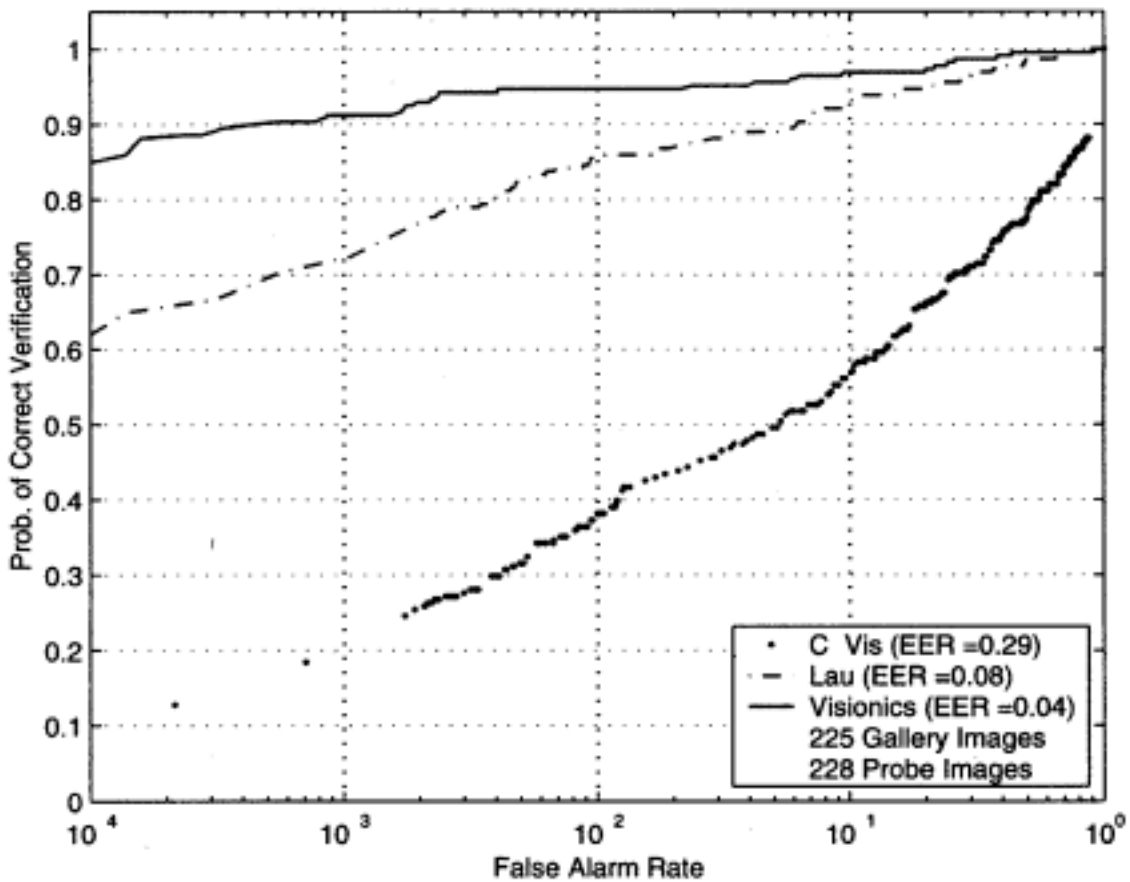

Figure M–41: *Verification Scores—Expression E1*

POSE VARIATION

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- Outdoors
- Mug shot - 45º
- Same session

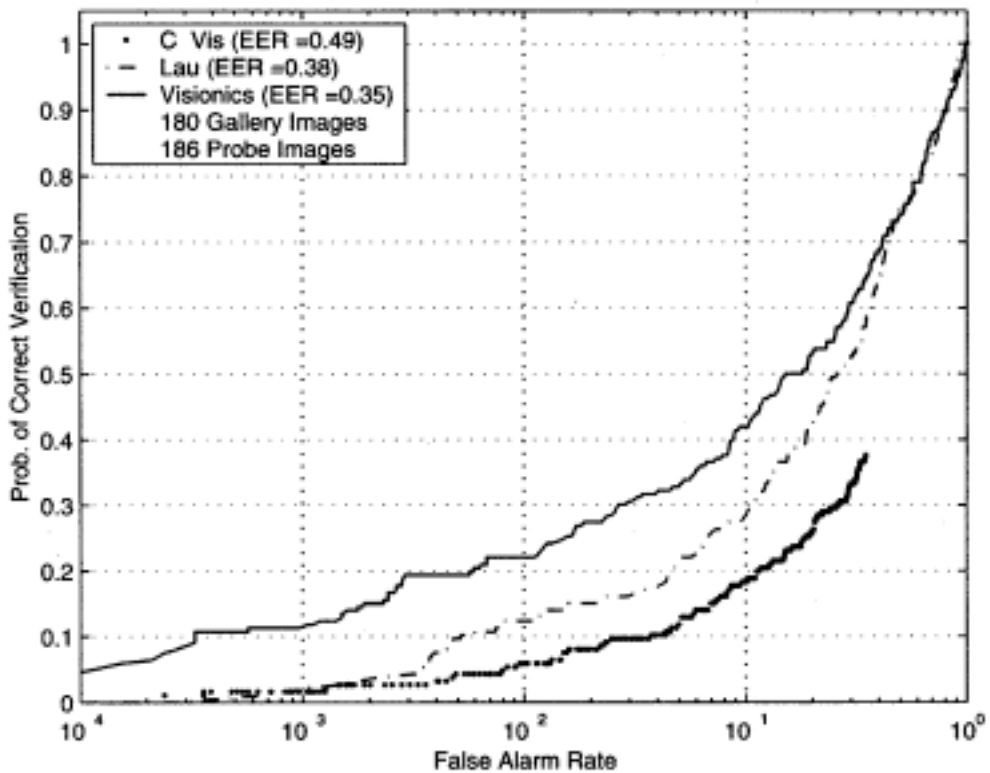

Figure M–48: *Verification Scores—Pose P5*

ONE YEAR AGING

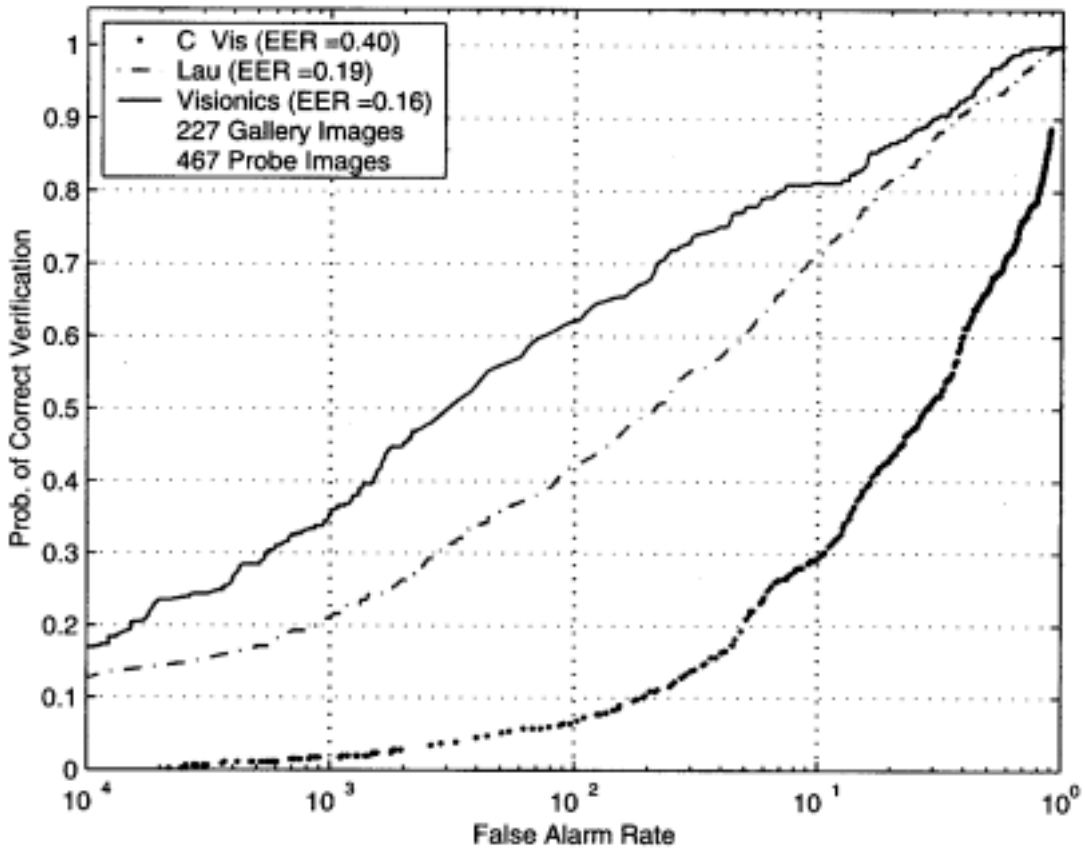

Figure M–54: *Verification Scores—Temporal T4*

CONCLUSIONS

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- Biometric identification has a 120 year history
- Biometrics is not fool-proof because people are not fool-proof
- Positive ID applications are motivated by convenience
- Negative ID applications are motivated by necessity

CONCLUSIONS

- Every project is a custom application
- One size does not fit all
- This is not “plug and play”
- Integration, integration, integration