Large-Scale Evaluation of Biometric Algorithms

Elaine M. Newton, PhD
Computer Security Division
Information Technology Laboratory

National Institute of Standards and Technology (NIST)
Department of Commerce
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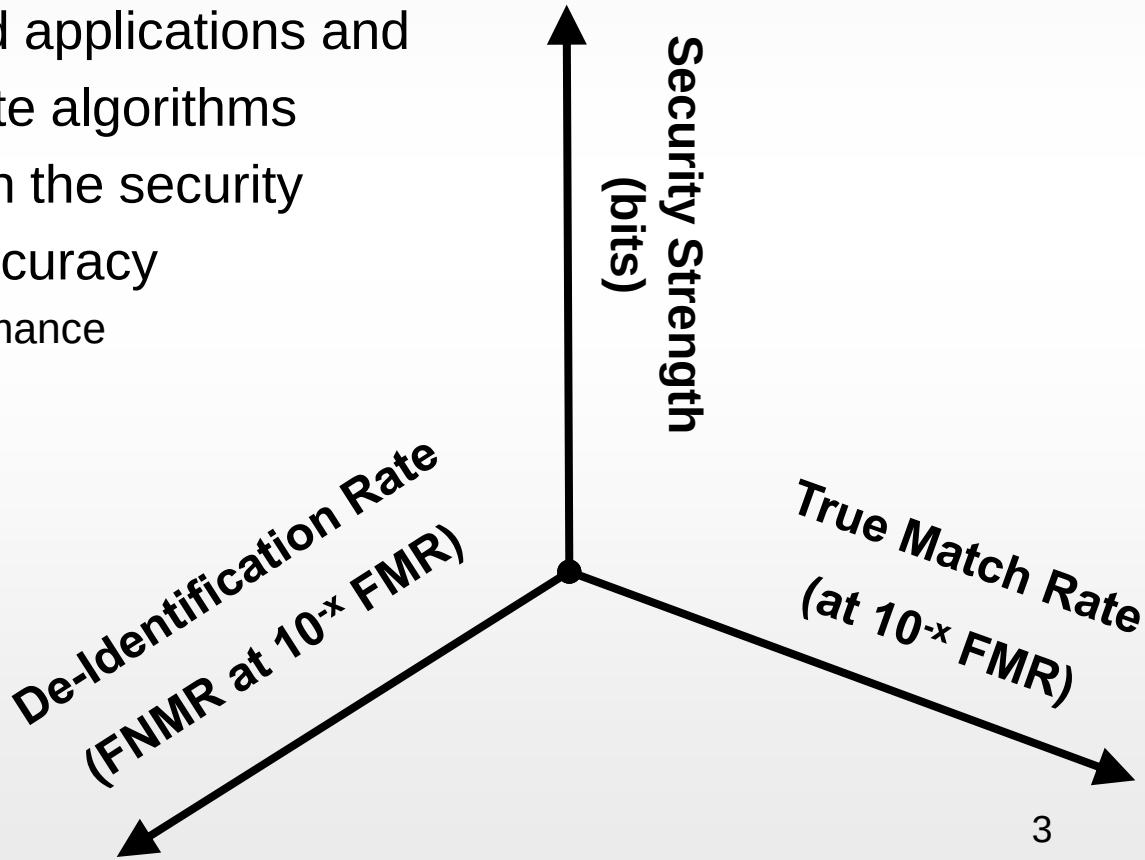
Why do we test?

- To assess the state-of-the-art
- To determine if products are interoperable
- To balance the asymmetry of information in the market place
- To give consumers confidence

➢ Ultimately, to provide a basis for trust in systems relying on the technology

Take Home Message

- Next steps for template protection testing will need to address
  - scale for intended applications and
  - metrics to evaluate algorithms incorporating both the security properties and accuracy
    - Biometric Performance
    - De-Identification
    - Irreversibility
    - Others



Evaluation of Technology

Principles

- Testing organization is an independent party.
- Sequestered data is used for evaluation.
- Results are published by testing organization.
- Testing methods are made publicly available to so that consumers of the results can assess the
  - technical merits of the methods used and
  - applicability to their needs.

Supported by:

- Testing standards (e.g. ISO/IEC 19795)
- Accreditation programs (e.g. NVLAP)

Large-Scale Biometric Testing

In collaboration

with Dr. Jonathon Phillips

NIST Biometric Testing/Data

- Fingerprint
  - Ongoing Proprietary Fingerprint Test (PFTII) and MINEX (MINutiae EXchange) testing using various databases of 120K+ subjects
  - Software development kit (SDKs) –based testing
- Face
  - Data from grand challenges and vendor tests
  - DOS Database of 37K subjects
  - Algorithm-based testing
- Iris
  - Data from grand challenges and vendor tests
  - Algorithm-based testing

And we can see improvements over time…

Progress in Fingerprint Recognition

FVC

	2000	2002	2006
Top 10% Mean	0.03640	0.00173	0.00074
Top 10% Median	0.03640	0.00170	0.00095
Top 10% Range	0.03640	0.14% to 0.21%	0.021% to 0.121%
Top Quartile Mean	0.04337	0.00599	0.00131
Top Quartile Median	0.04010	0.00605	0.00137
Top Quartile Range	3.64% to 5.36%	0.14% to 1.18%	0.021% to 0.237%

PFT

	POEBVA	DOS	DHS2
2006 Mean	0.0373	0.0437	0.0967
2007 Mean	0.0079	0.0095	0.0429

Progress in Face Recognition

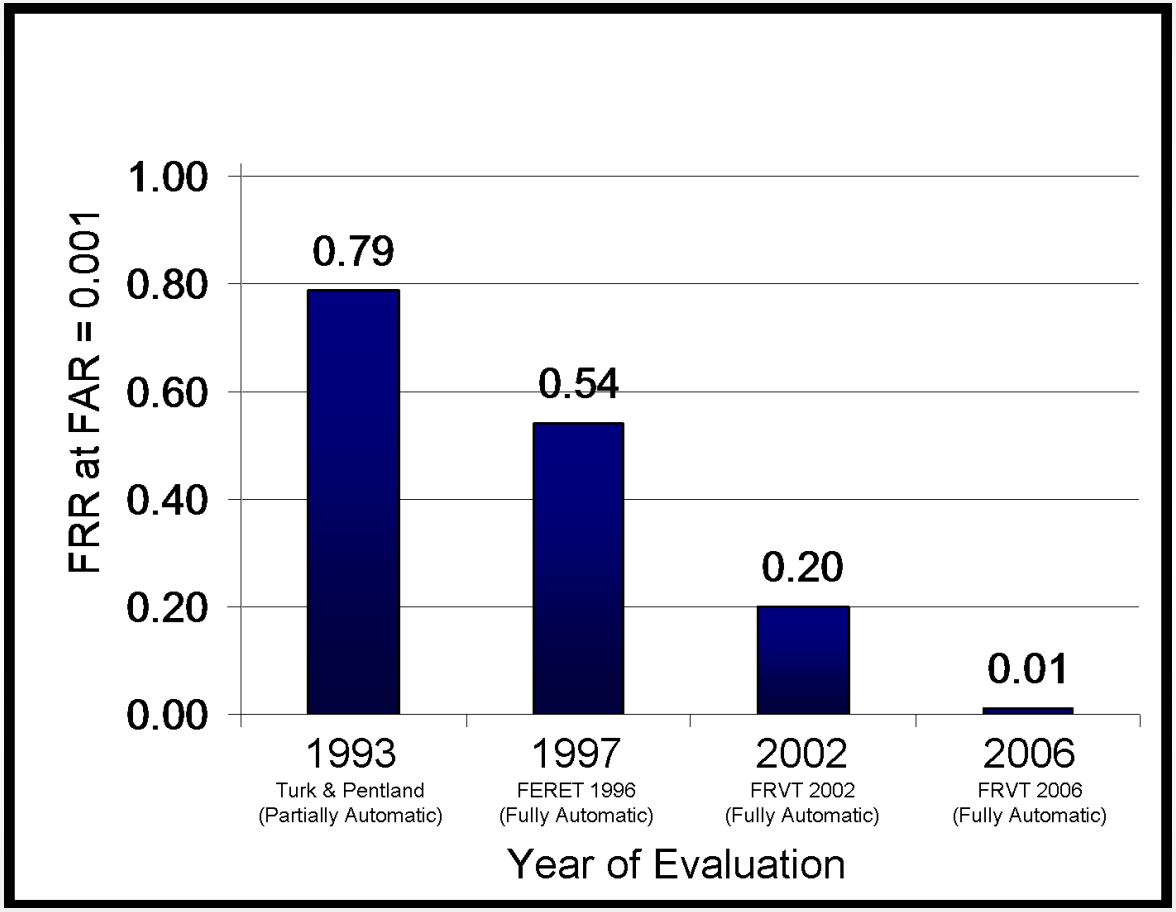


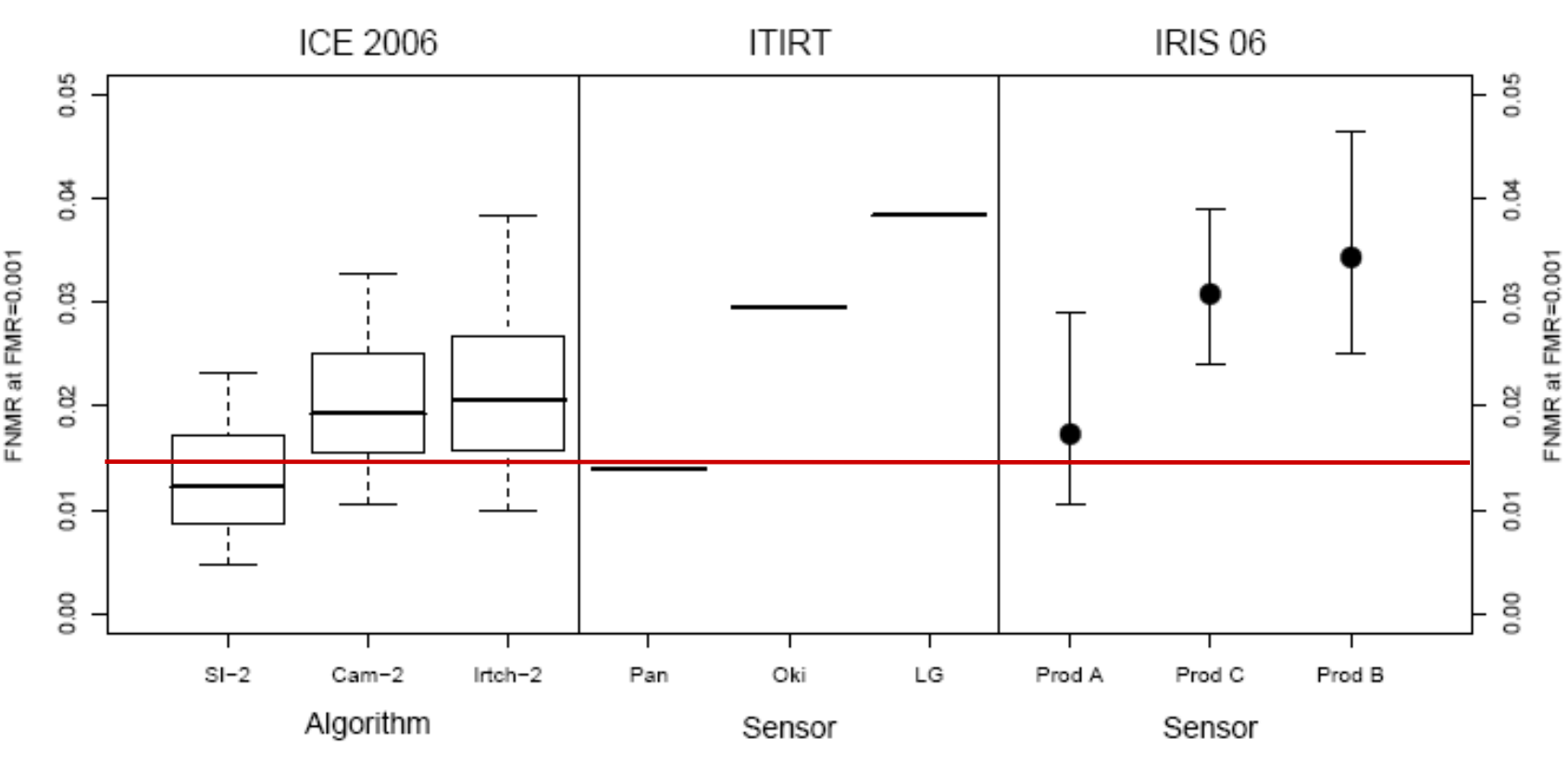
Figure is from the FRVT 2006 Report.

Three Recent Iris Evaluations

- ICE 2006
  - NIST
  - Results released in 2007
- ITIRT
  - Independent Test of Iris Recognition Technology
  - International Biometric Group
  - Results released in 2005
- IRIS06
  - Authenti-Corp
  - Results released in 2007

Analysis of Best Performers

- **Average FNMR = 0.0146**
- **Average Absolute Difference = 0.004**



Relevant use cases

Scenario Name:	**Personal Security**		**Forensics**		**Watchlist**		**Large-Scale ID**	
Operational FMR:	0.01		0.0001		1.E-07		1.E-07	
Min|Max E[Subjects]	1	10	1000	1E+09	10	1.E+05	1.E+07	1E+09

Gap in Testing Large-Scale Applications

- Large-scale (150K and greater) verification and/or identification performance, especially at very low error rates.
  - What is currently understood about the accuracy of biometric systems through empirical study?
  - Is testing answering questions relevant to anticipated uses of biometrics, such as personal security, forensic ID, watchlists, and large-scale ID?
  - Can current testing methods be leveraged to fill the gaps between current testing and anticipated needs?

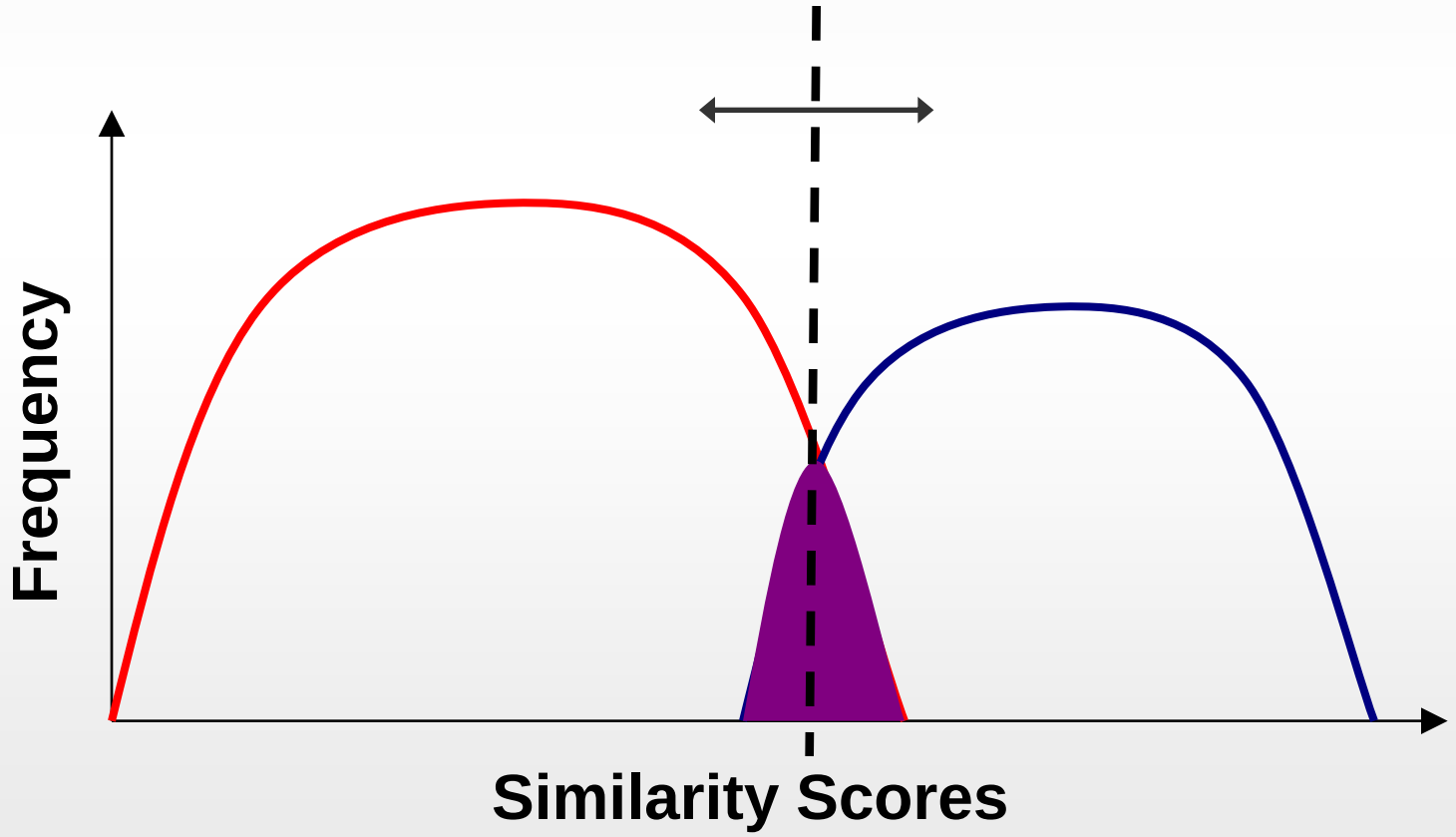
i→I Experiment (1)

- Department of State database with 36,000 subject's faces

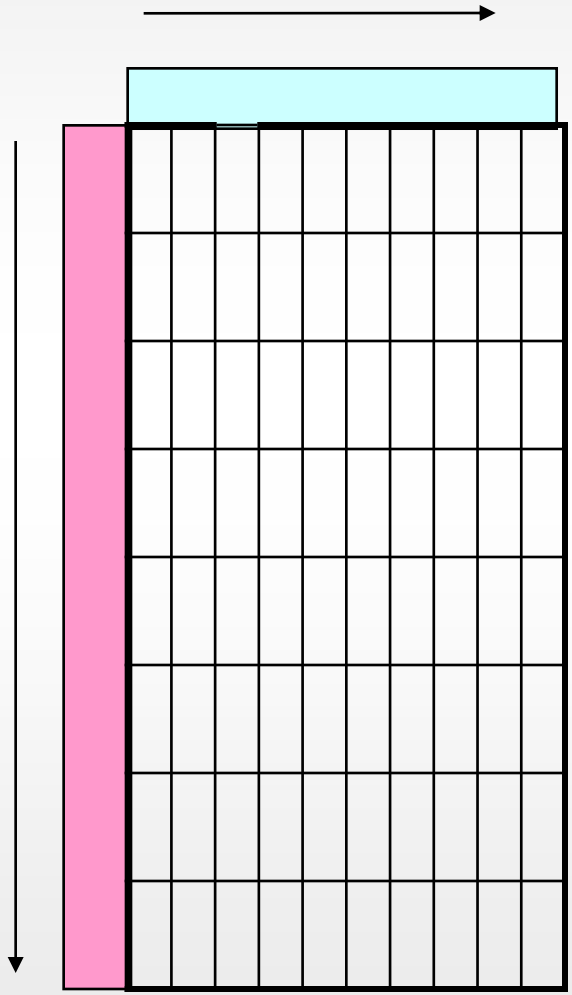
- Ran open-set identification tests to observe the effect of small scale testing on large-scale scenarios.

i→I Experiment (2)

- Tested two FMR levels: FMR = 0.01 and FMR = 0.001. Observing change in threshold.



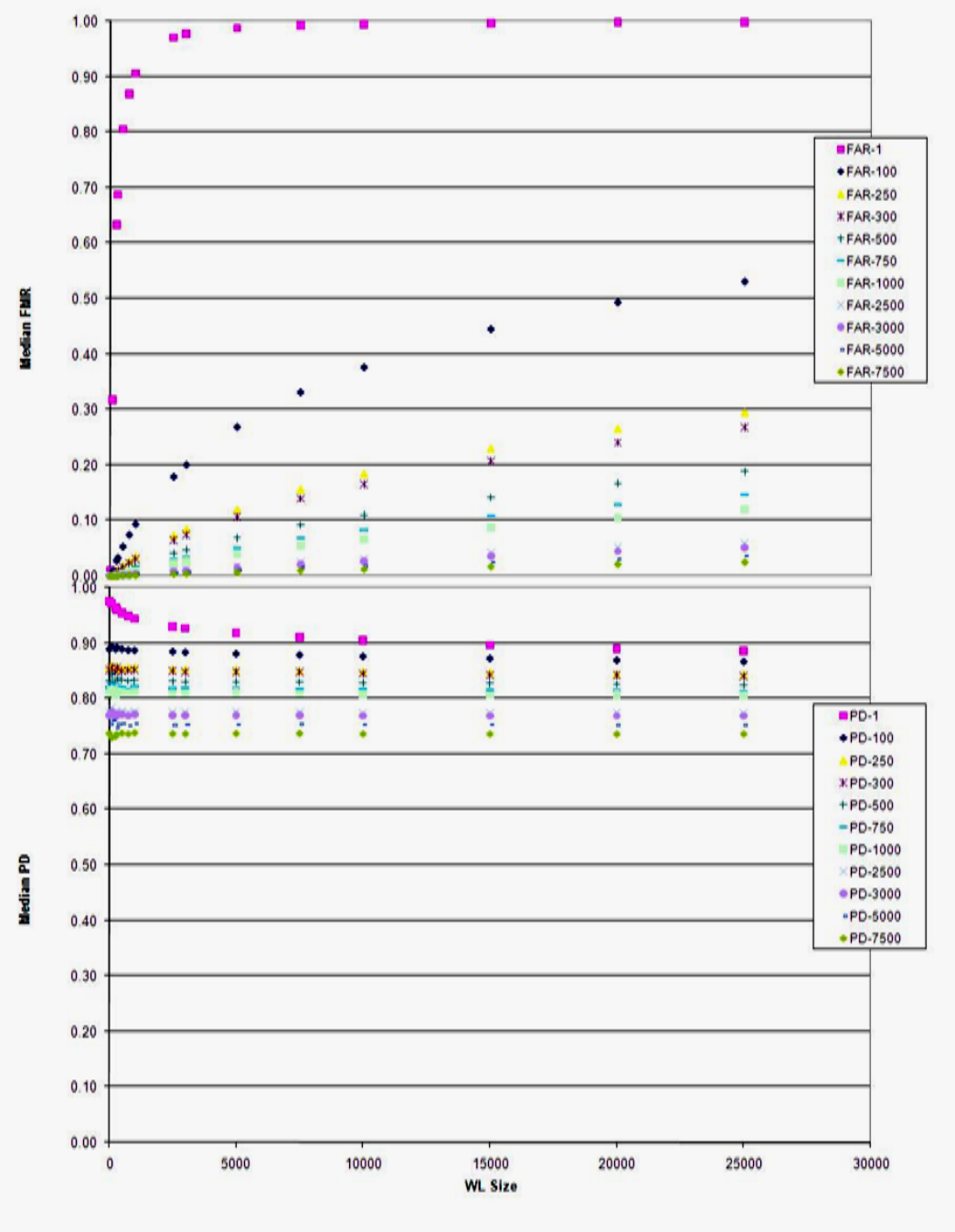
i→I Experiment



- Ran trials with 10,000 imposters (rose) against different size galleries (blue)
  - Varied gallery size
  - Top match retrieved from similarity scores
  - Repeated 100 times

i→I Experiment

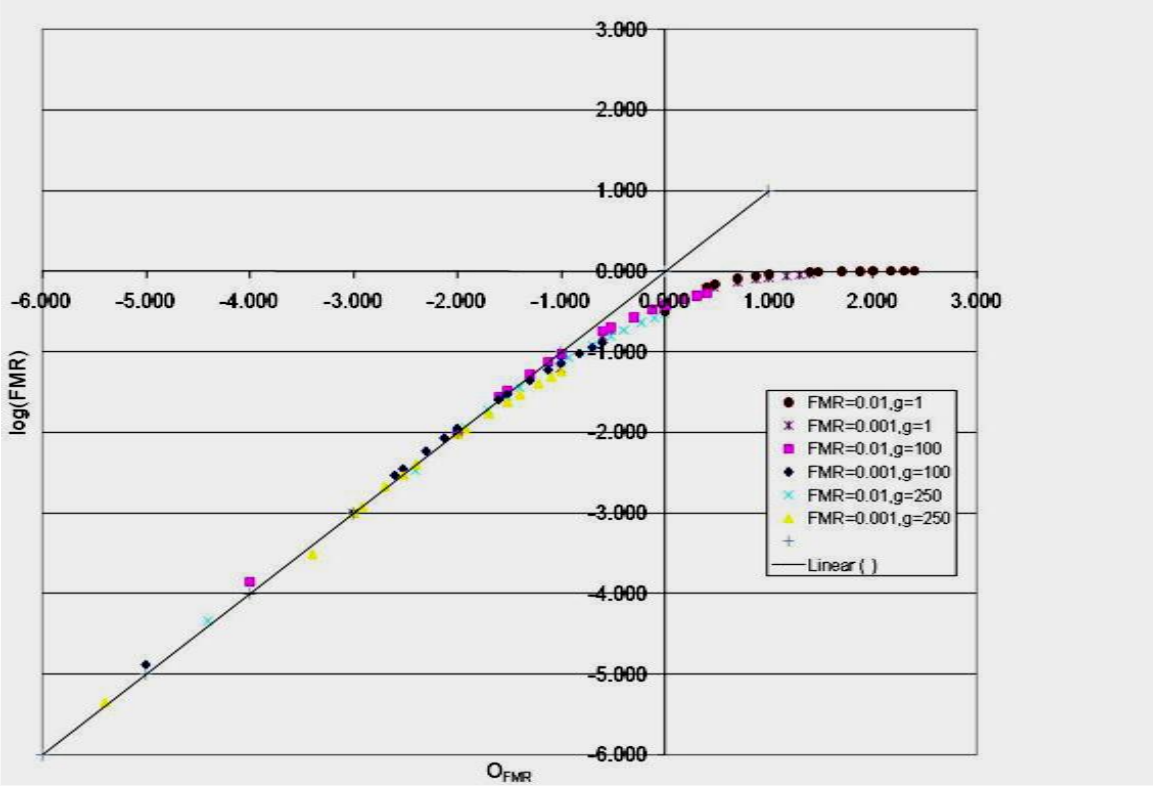
- For each gallery size *g*, there are 100 similarity scores corresponding to the tested FMR level FMR_{Λ} (0.01 or 0.001)
  - Median similarity score assigned to $\tilde{T}_g^{FAR_{\Lambda}}$
- For every *g* for FMR_{Λ} , $\tilde{T}_g^{FAR_{\Lambda}}$ was reapplied to each trial matrix to determine the FMR and P_D
  - Varied scenario watchlist size from 1 to 25,000


Median FMR
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
FAR-1
FAR-100
FAR-250
FAR-300
FAR-500
FAR-750
FAR-1000
FAR-2500
FAR-3000
FAR-5000
FAR-7500
Median PD
PD-1
PD-100
PD-250
PD-300
PD-500
PD-750
PD-1000
PD-2500
PD-3000
PD-5000
PD-7500
0
5000
10000
15000
20000
25000
30000
WL Size

i→I Results

- When applying the median threshold for FMR-level 0.01 from experiments of WL=100 to WL=10,000, the observed-median-FMR is 0.38.
  - 38 times greater FMR for change in gallery size of 2 orders of magnitude.
  - For WL = 25,000, applying the median threshold when g = 100, FMR=0.53.
  - For WL = 25,000, applying the median threshold when g = 1, FMR is nearly 100%.
- When applying the median threshold for FMR-level 0.001 from experiments of WL=100 to WL=10,000, the observed-median-FMR is 0.07.
  - 70 times greater FMR for change in gallery size of 2 orders of magnitude.
  - For WL=25,000, applying the median threshold when g = 100, FMR=0.13.
  - For WL = 25,000, applying the median threshold when g = 1, FMR=0.91.

Model for FMR v. FMR Results



$$E\left[\mathrm{E}_{FMR}\right] \approx \frac{WL_O}{g_\Lambda} FMR_\Lambda \quad \text{when } E[\mathrm{E}_{FMR}] \leq 0.10$$

FMR levels to test to determine operating points for scenarios

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Operational FMR:	0.01		0.0001		1.E-07		1.E-07	
Min|Max E[Subjects]	1	10	1000	1E+09	10	1.E+05	1.E+07	1E+09
g (Subjects)								
200								
400								
36,000								
60,000								

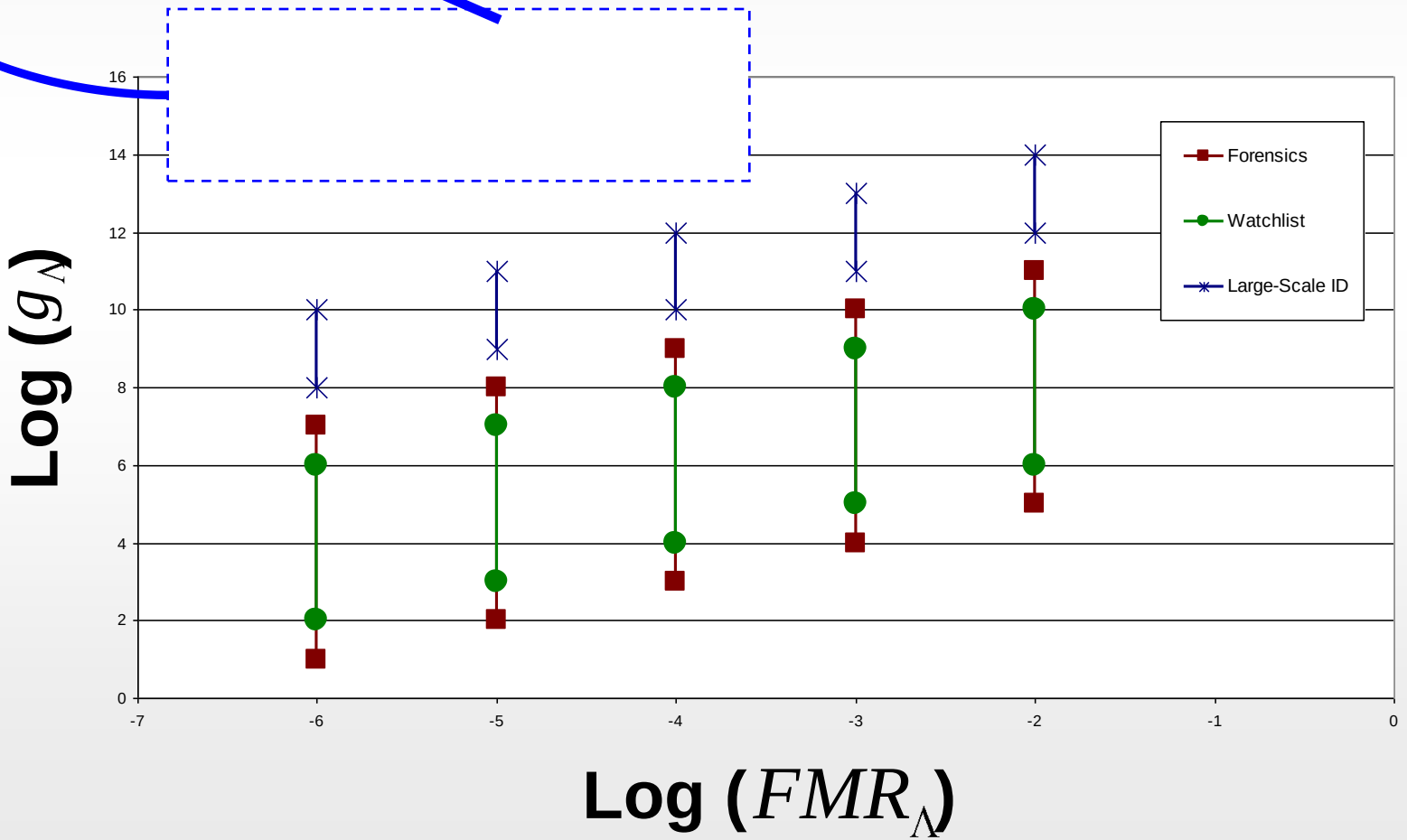
Red = FMR-level can not be tested for this image set size.

Yellow = FMR-level may testable with image set size, but may still be weak with respect to statistical significance.

Green = FMR-level can be tested with this image set size.

Gallery size to test at tested FMR level, for scenarios operating points

Scenario Name:	**Forensics**		**Watchlist**		**Large-Scale ID**	
Operational FMR:	0.0001		1.E-07		1.E-07	
Min|Max E[Subjects]	1000	1E+09	10	1.E+05	1.E+07	1E+09



Conclusions (1 of 3)

- Major gap in testing biometric systems for larger scale applications
  - largest tests performed on <200,000. Most in verification mode.
- Model for testing shows that
  - Gaps can lead to massive number of false matches.
  - Testing needs to be performed on size relevant to scenario for a reasonable prediction on FMR.
  - FNMR is relatively stable, regardless of gallery/watchlist size.

Conclusions (2 of 3)

- The FMR levels that need to be tested for several common applications can not be supported by the size of tests today.
- To adequately test these, the number of subjects needed exceeds current database sizes, and it would be prohibitively costly to collect for R&D.
- Use of tests for comparison of alternatives on smaller test sets can still be useful.

Conclusions (3 of 3)

- Next steps for template protection testing will need to address
  - scale for intended applications and
  - metrics to evaluate algorithms incorporating both the security properties and accuracy
    - Biometric Performance
    - De-Identification
    - Irreversibility
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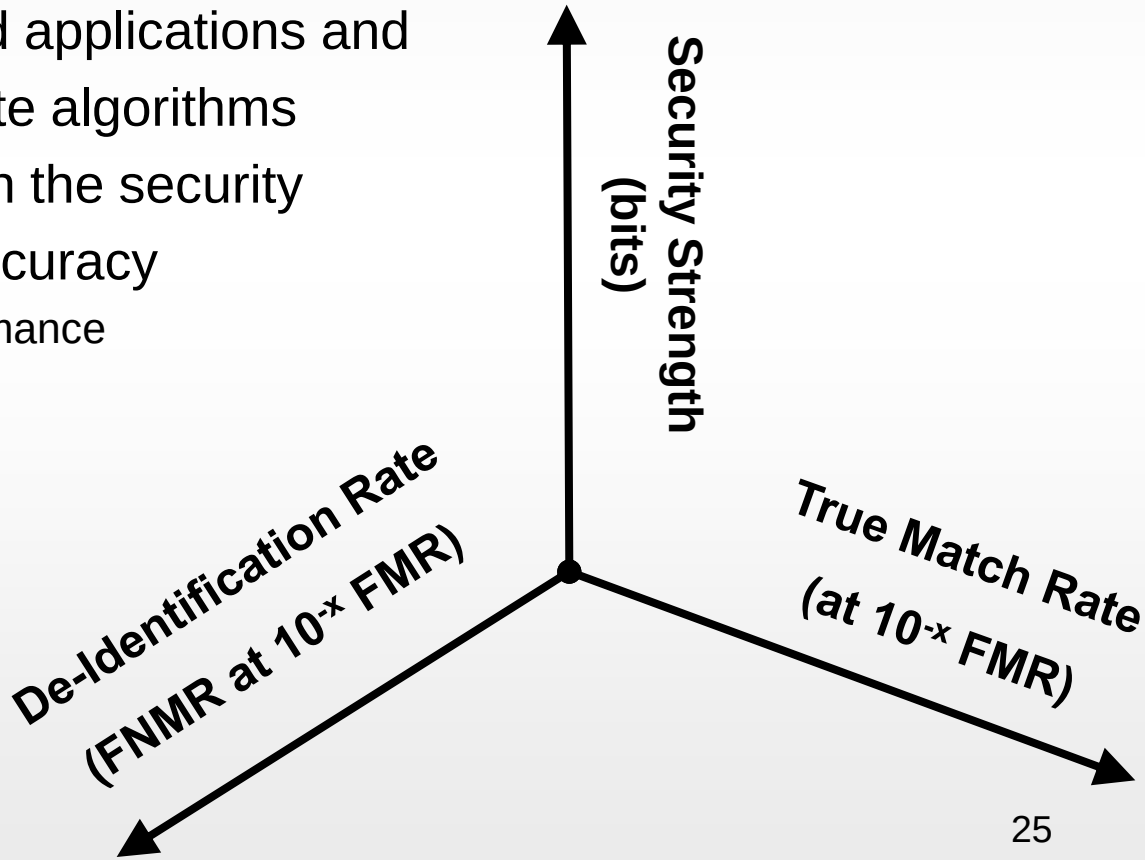

Thank you