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# Biometrics: How do you know they work?

***"Garbage in Garbage Out"***

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# How do you know biometrics work?

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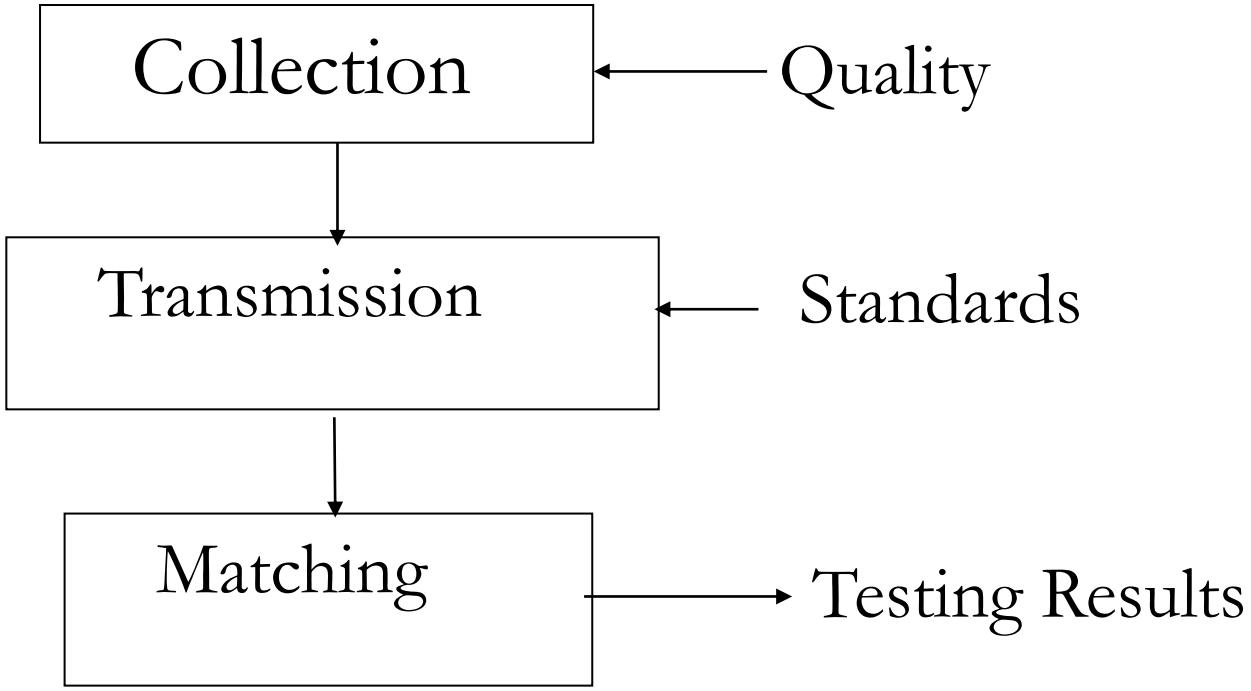
- **Most biometrics work some of the time. If you never got a hit why bother?**
- **Both hits and misses are based on probabilities.**
- **You never know what your miss probability is unless you test.**
- **The testing process is well understood.**
- **To test you need a realistic test sample.**
  - –Big enough to get statistical numbers
  - –As close to your work load as possible
- **At every stage in the system quality is important. NIST Fingerprint Image Quality (NFIQ) is used here.**

# Issues


Collection
Quality
Transmission
Standards
Matching
Testing Results

# Topics

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- **Standards**
- **Matching and Quality**
  - 10-finger Quality Measures
  - Difference in Transaction  Used by the FBI
  - Accuracy is a Function of Quality
- **Standardization of System Testing**
  - Any AFIS could be setup to be tested .
  - This includes operational systems.
  - All that is needed is candidate lists with scores.
- **Multimodal Biometrics**
  - Usability - All biometric modes have image quality issues that are sensitive to acquisition procedures.
  - Fusion - How much would score level fusion improve biometric accuracy? How should it be done?

# Standards

- **Standards needed for interoperability**
  - Ensure a high-level quality for captured images
  - Process fingerprints and other biometrics from dissimilar systems
- **Required types of standards**
  - Data format standards
  - Image quality standards
  - Performance standards
  - Conformance standards
- **Standards development organizations**
  - ANSI/NIST
  - M1/SC 37
  - Application Profile Interfaces (API)

# ANSI/NIST–ITL Standard

- **Key transmission standard used by federal, state, & local law enforcement agencies**
  - FBI, DHS, PIV, DoD
  - De facto international standard (EURODAC, INTERPOL, UK, CA, etc.)
- **Updated versions developed to accommodate evolving biometrics and needs.**
- **A single standard used for the exchange of a subject's descriptive, demographic and biometric information**
- **Biometrics include fingerprint, face, iris, DNA, etc.**
- **Traditional and XML versions developed**
- **FBI EBTS 9.1 and DoD EBTS are 2.0 APIs based on standard**

# MOBILE ID Devices

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- Handheld or portable devices used to capture a subject's biometrics on the street, in a warzone, at a border, etc.
- Functions include enrollment, identification, and verification
- Applications include as physical/logical access control, border crossing, and checkpoint operations
- Capture and matching of biometrics in near real time with no transportation of subject and zero transit time
- Functions for enrolment, identification, & verification
- Best Practice Recommendation (BPR) lists progressively more stringent sets of image capture settings for the device
- BPR provides guidance on settings to be used based on function of device and risk to public safety.

# CONFORMANCE

- **Data format conformance establishes confidence that an implementation fulfills the standard's requirements**
  - Syntactic conformance: correct structure, values, and bits for each field
  - Semantic conformance: faithful representation of captured biometric
- **Conformance requirements are part of the ANSI/NIST-ITL**
- **Hardware conformance**
  - FBI EBTS Appendix F specifies requirements for fingerprint live scan and field deployed mobile ID devices
  - Qualified products are listed on public website

# Objective of NIST Fingerprint Image Quality (NFIQ)

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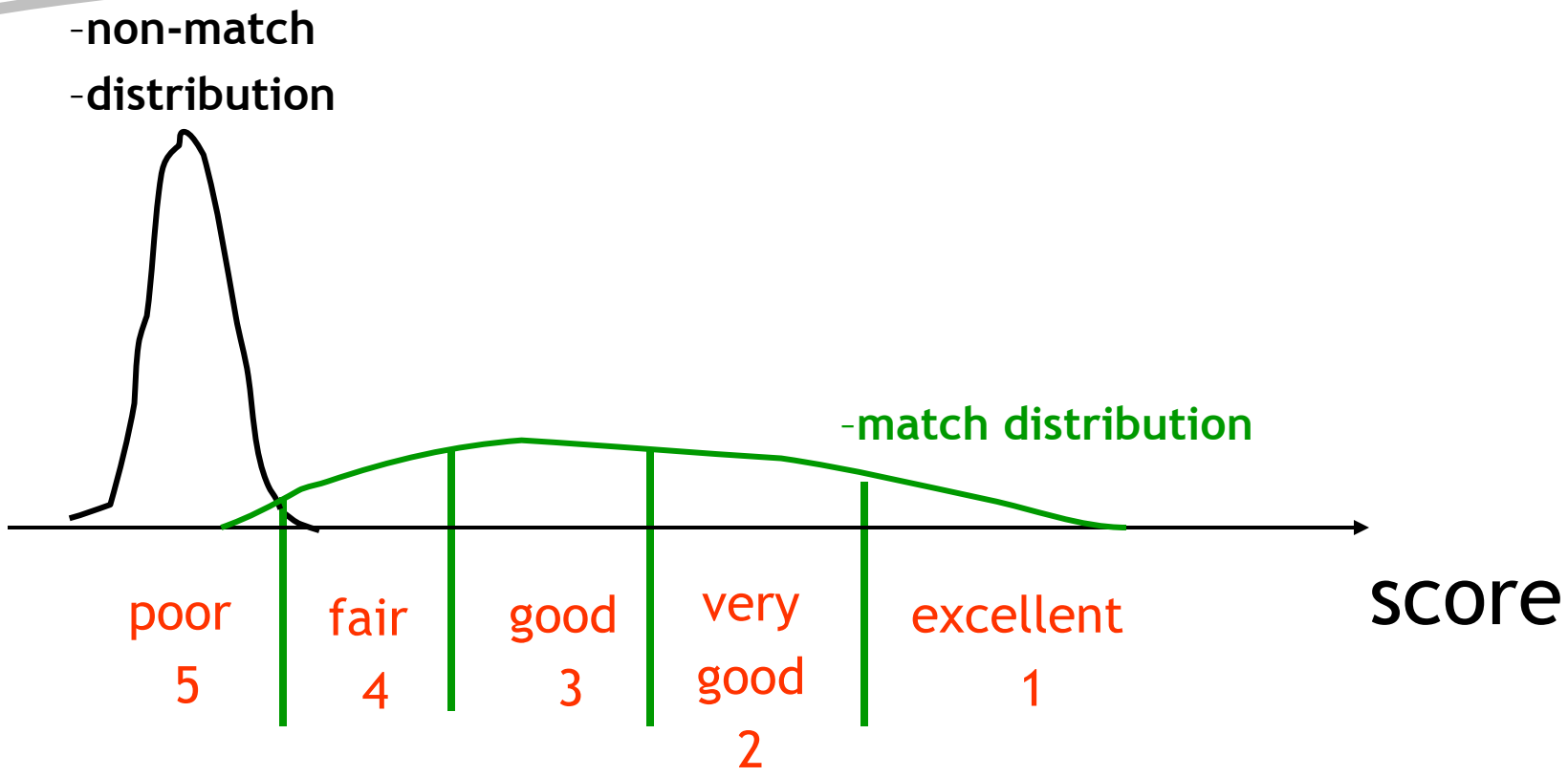
- Define and develop a fingerprint image quality measure that can predict fingerprint recognition performance.
- Use ROC curves to check the quality of the new algorithm.

# NFIQ Performance Score Prediction




Bin boundaries selected based on expected match score distribution

# Analysis of FBI IAFIS Metadata

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- This analysis took what was learned from many years of NIST tests and applied it to IAFIS performance
- Addressed quality issues
- Addressed the difference in quality between different subsamples and different TOTs (Types of Transactions)
- Addressed workload variation caused by quality

# Sample Size Used in this work

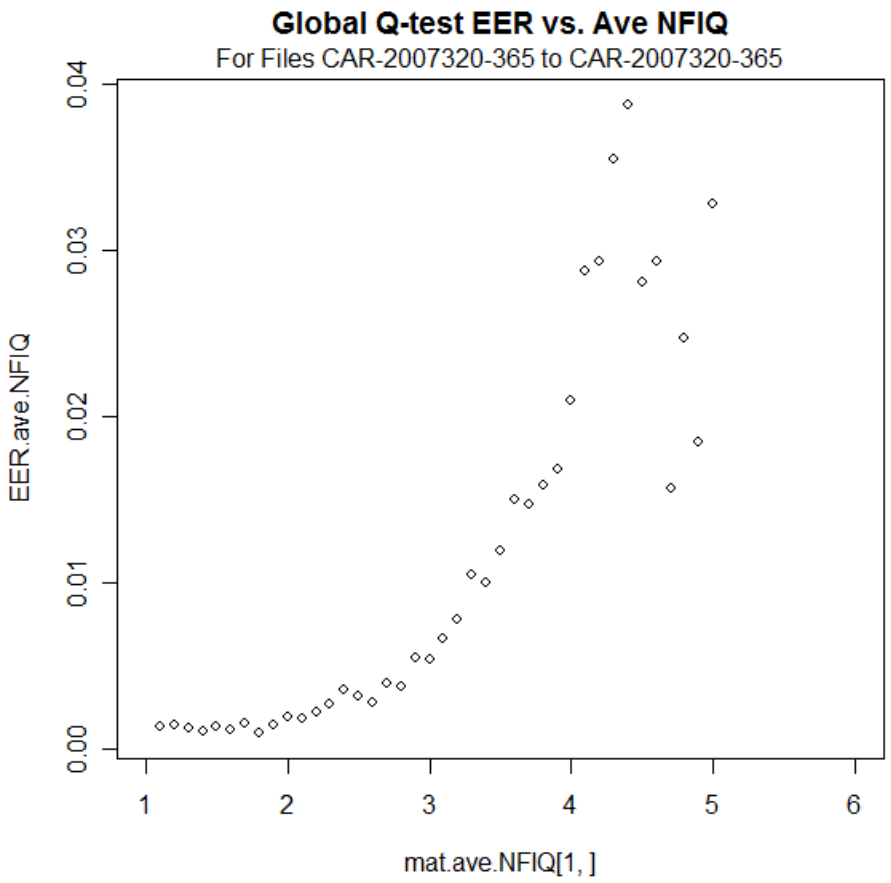
- All FBI submissions days between Nov. 11, 2007 and Dec. 31, 2008
- 45.9M samples, an average of 111K per Day
- Idents (valid Matches) 10.5M,
- Nonidents (No matches found) 28.9M
- 21.8GB of ASCII data
- Rolled
  - Idents 10.25M
  - Nonidents 15.63M
- Flat
  - Idents 309K
  - Nonidents 13.37M

# 10-Finger Quality Measures

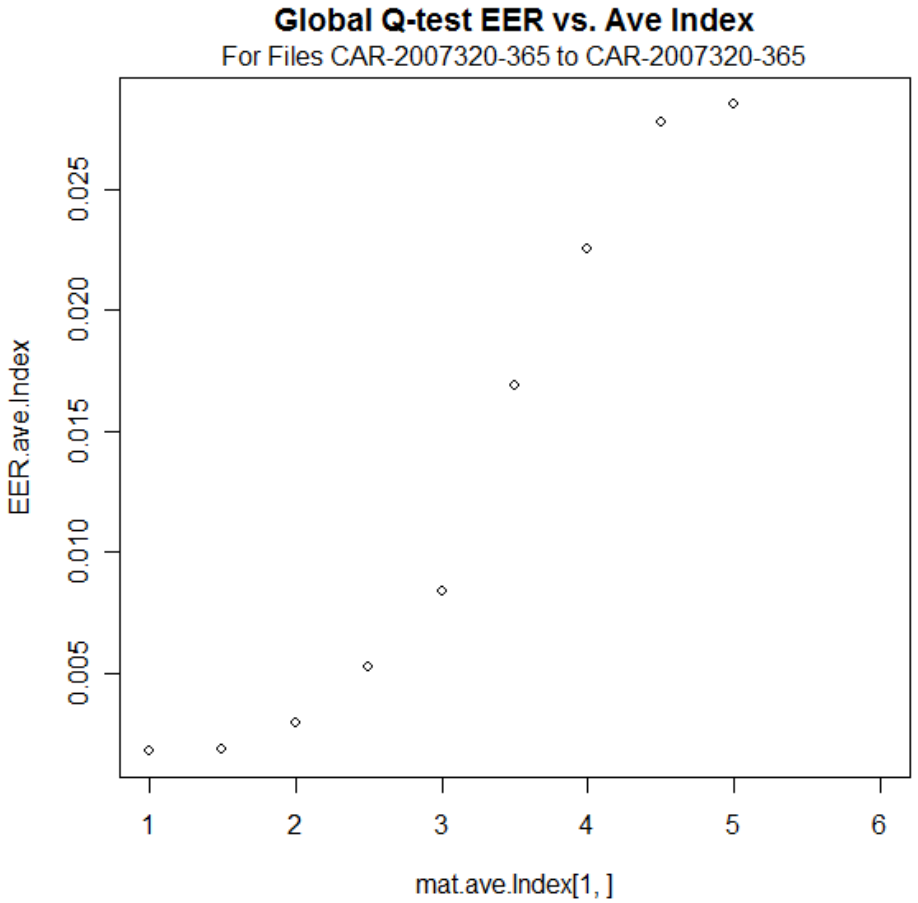
- **Seven different measures were tested**
- **Averages**
  - –All 10 fingers
  - –Index Fingers
  - –Average of 8
  - –Average of 6
- **Best N fingers of 10**
  - –Best of 5,4, or 3
- **Equal Error Rate (EER) is the point at which False Match Rate (FNR) equals the False Nonmatch Rate (FNMR)**

# Equal Error Rate for Average of 10 Fingers and Index Fingers

10 Fingers




Index Fingers



# EER for Average of 8 and Average of 6

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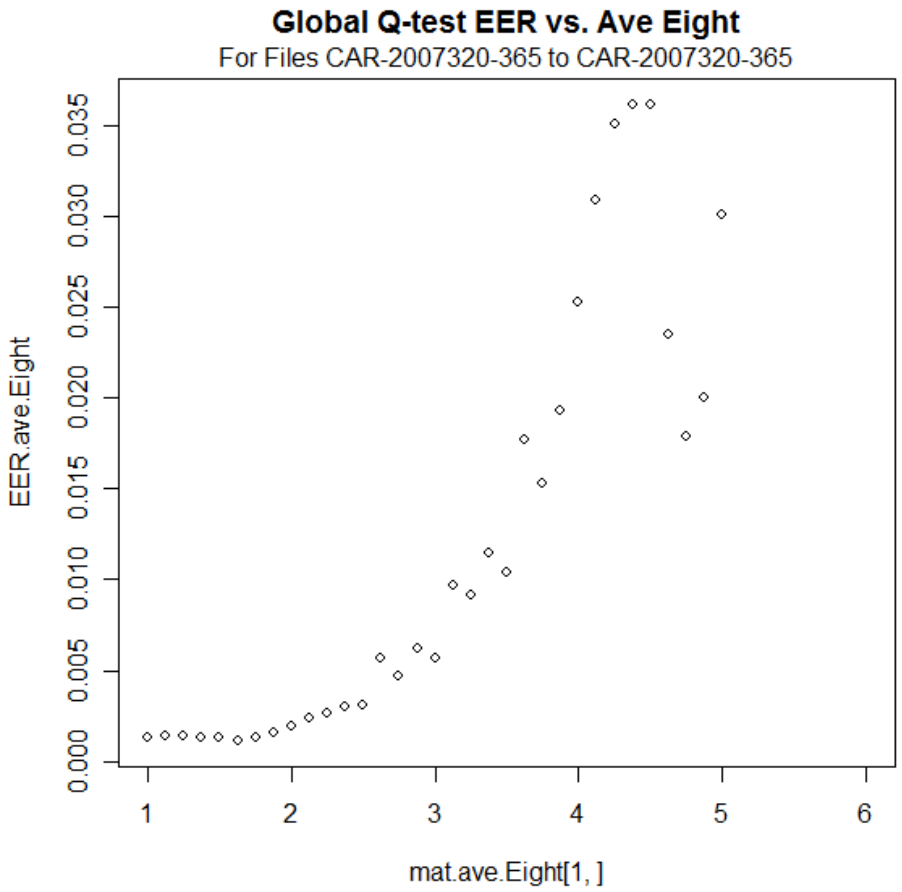
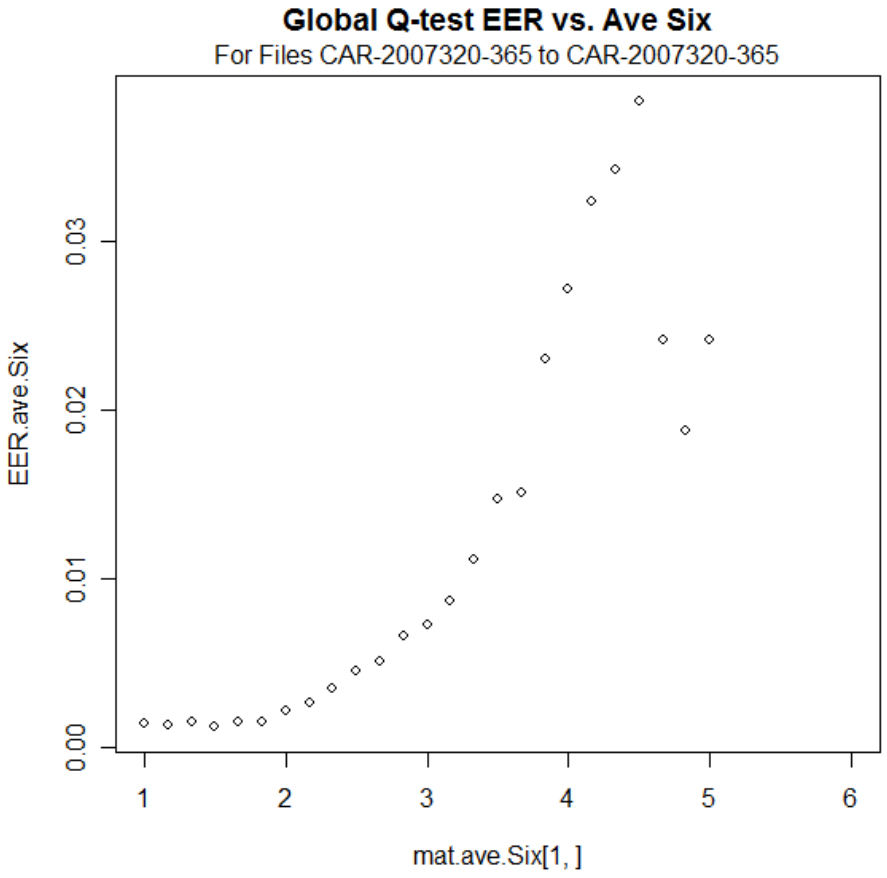
## 8 Fingers

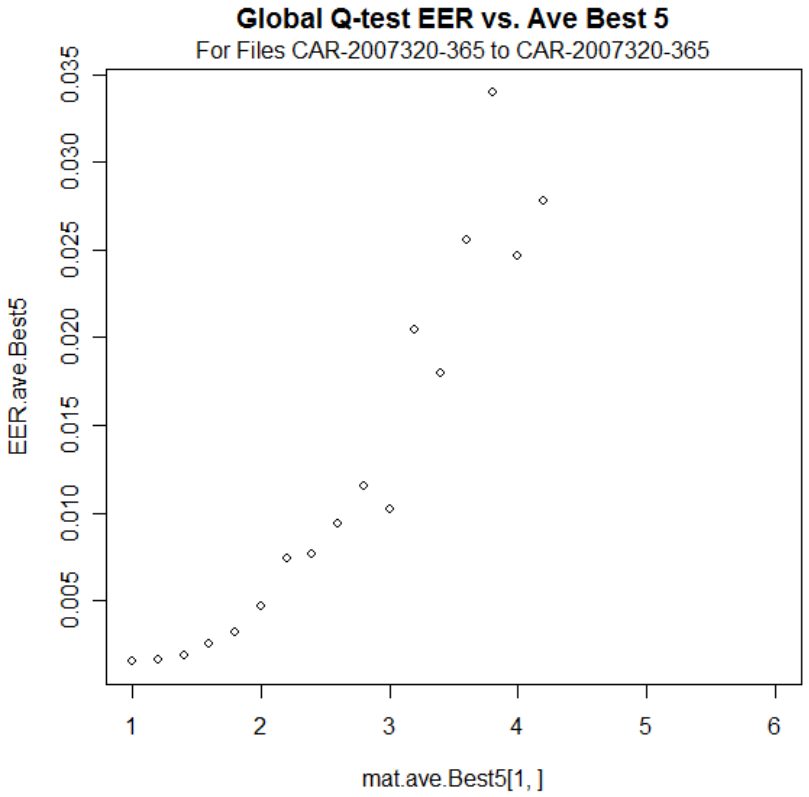



## 6 Fingers

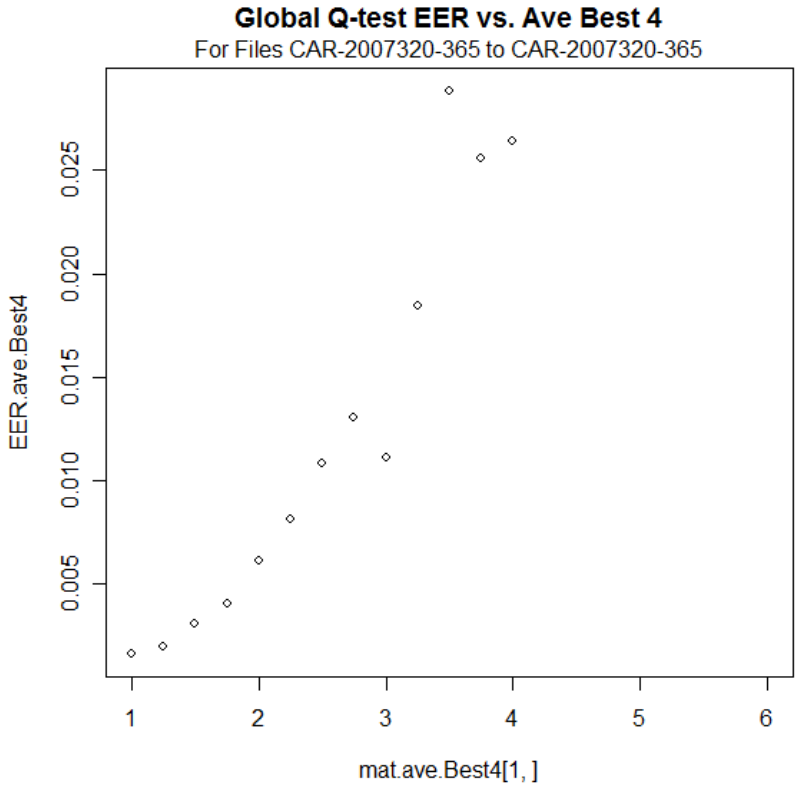


# EER for Best 5 and Best 4

Best 5

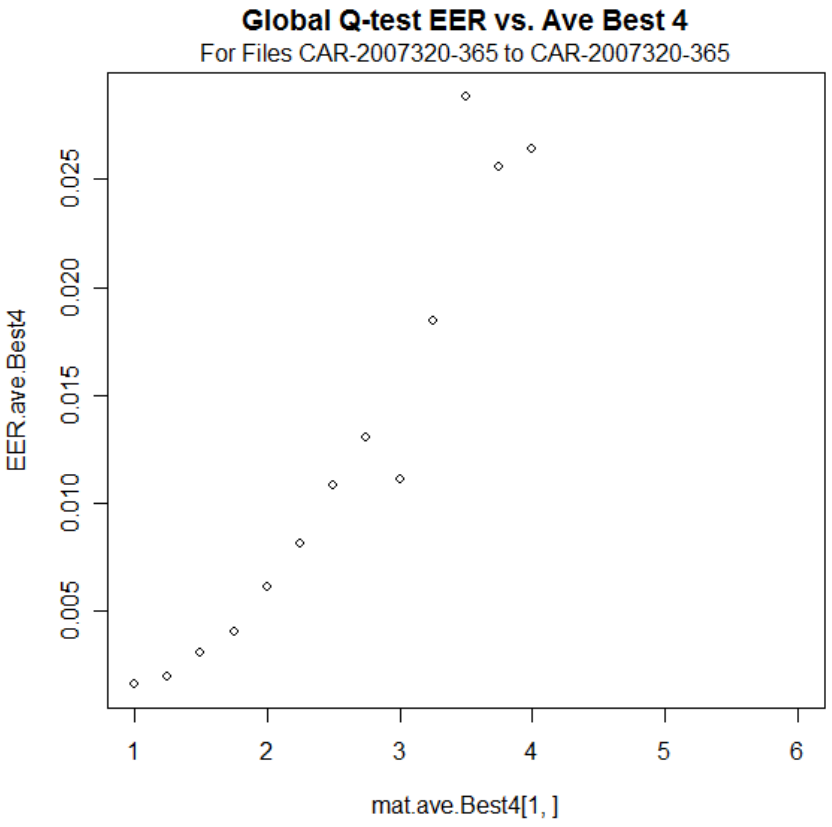



Best 4

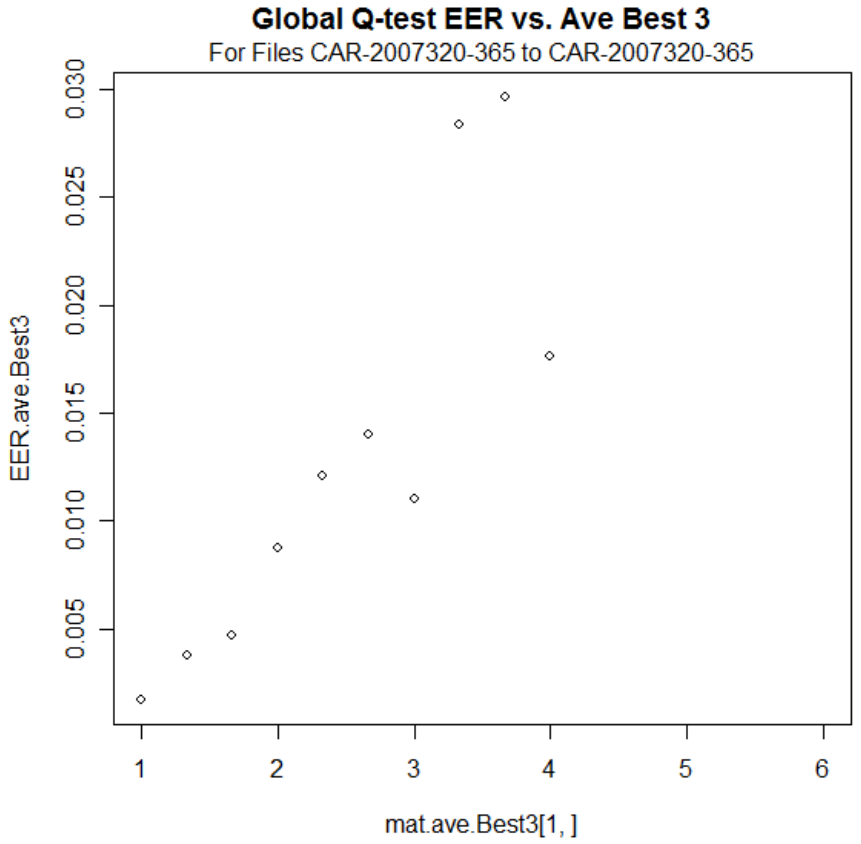


# EER for Best 4 and Best 3

Best 4




Best 3



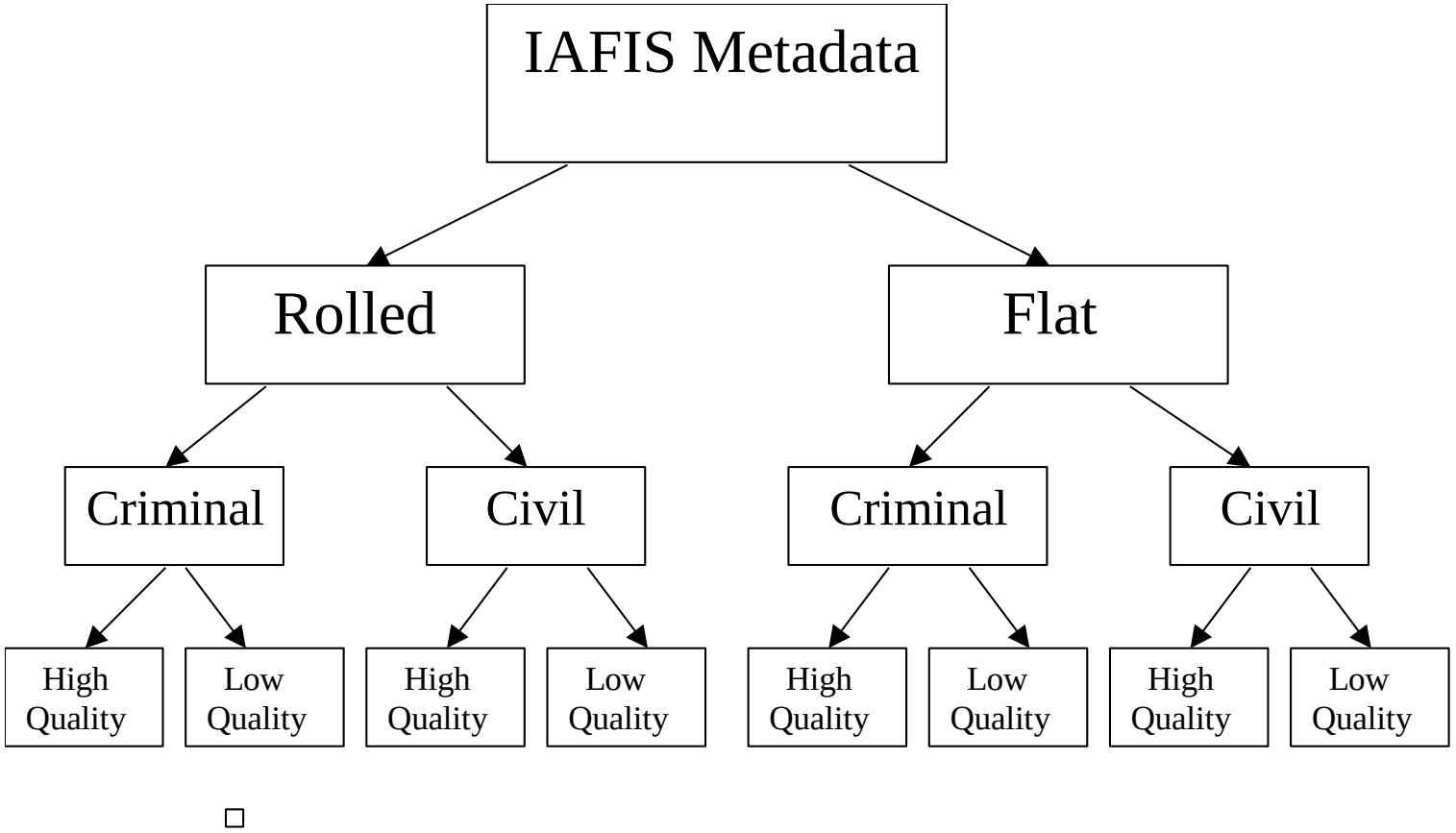
# The Number of good fingers and the Quality Required for A Given EER Are Correlated

- **For a fixed 1% EER (Equal Error Rate):**
  - –Five finger require average NFIQ of 2.7
  - –Four finger require average NFIQ of 2.4
  - –Three finger require average NFIQ of 2.0
- **The fewer fingers you have the better they need to be for a given error.**
- **This test can be run on most operational systems.**

# Average of 10-finger Works

- It is simple.
- It is fast – one line of code.
- It works well in the IAFIS application.
- Other measures can be used to get additional insight into system performance.

# FBI Image Classes



# Each Image Class Has Different Quality

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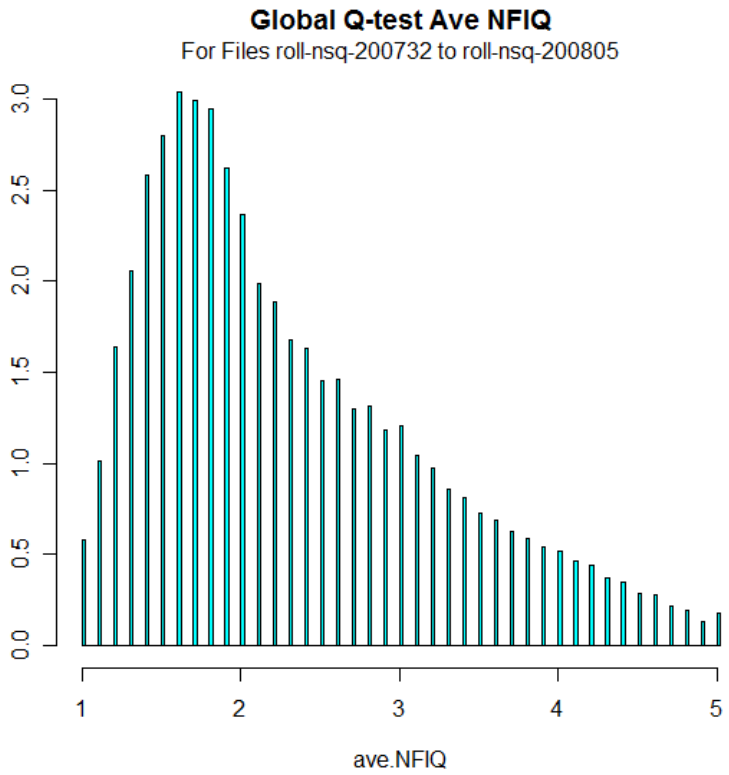
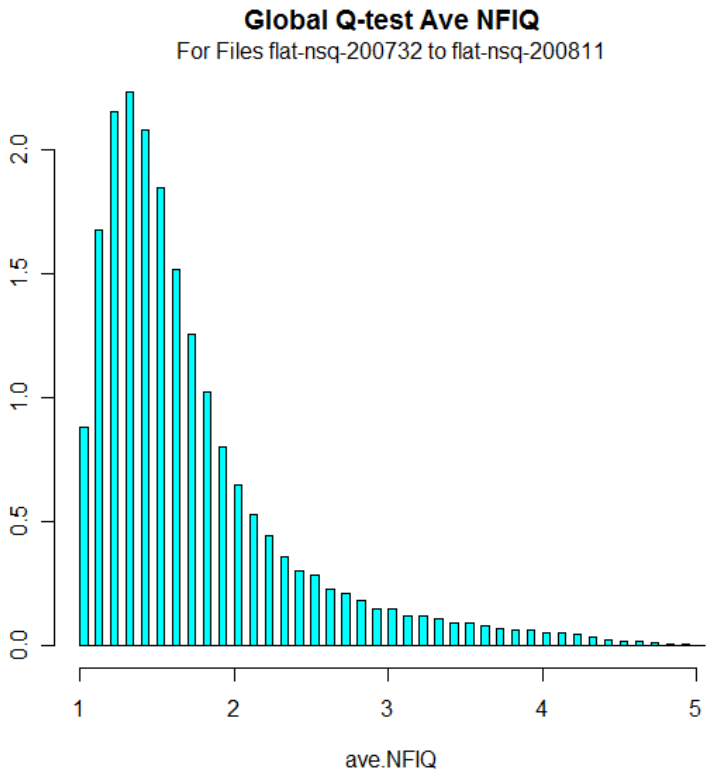
## Rolled Verification Search

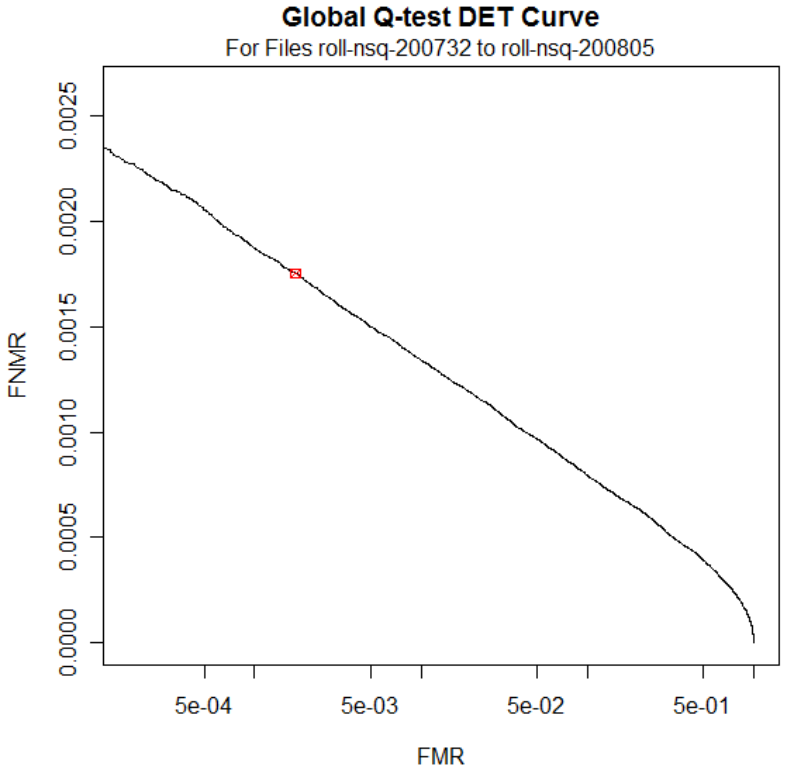



## Flat Verification Search

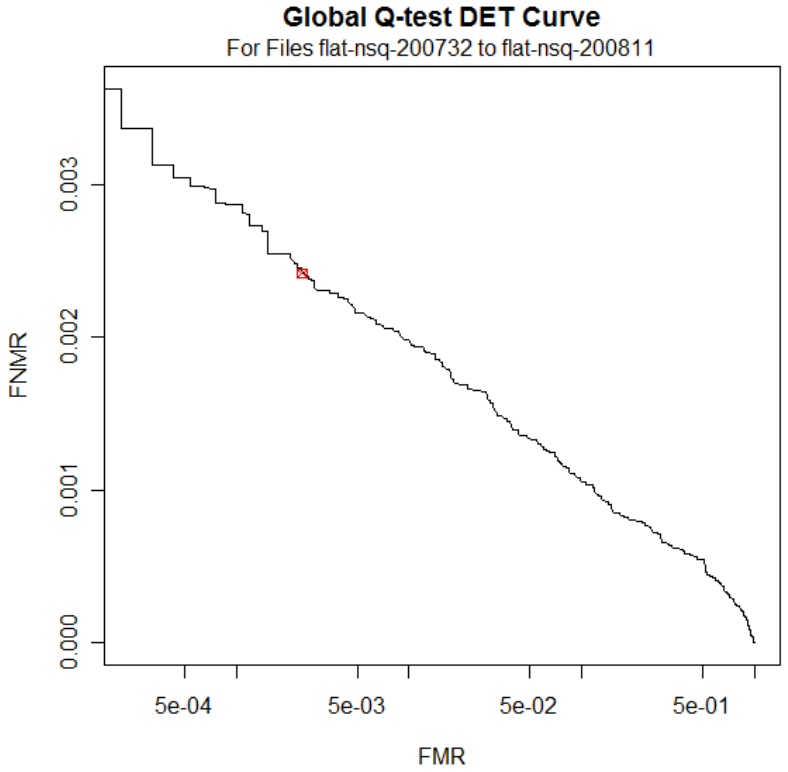


# Each Dataset Has different March Accuracy

## Rolled Verification Search




## Flat Verification Search




These DETS show that flats are harder to match than rolled.

# Error Rates Are Strongly Dependent on Quality

| Type of Data | Equal Error Rate |
|---|---|
| Roll data | 0.00175 |
| Flat data | 0.00242 |
| Criminal data | 0.0013 |
| Civil data | 0.0037 |
| Criminal data quality1 | 0.00012 |
| Criminal data quality5 | 0.011 |
| Civil data quality 1 | 0.00023 |
| Civil data quality 5 | 0.026 |

# Transaction Analysis

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- 10-finger average NFIQ can be used effectively to separate transaction types differences.
- The distribution of NFIQ values allows the fraction of difficult matches, NFIQ ≥ 4.2, to be evaluated.
- The difficult cases account for most of the missed cases.

# Seven Transactions Dominate the FBI Workload

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- Seven high-volume transaction account for 88% of the FBI IAFIS workload .
- 8.77% of the metadata items are for information requests or generate error responses.
- The seven transaction types which represent 1% or more of the work load represent 96.8% of all data items when information requests and errors are accounted for.

# Quality of the Seven Major TOTs

| Transaction | Criminal-Civil | Flat-Rolled | Per Cent of Metadata | Average Daily Volume | 10 finger Mean NFIQ | NFIQ 4.2 or Greater in Percent |
|---|---|---|---|---|---|---|
| CAR | Criminal | Rolled | 26.69 | 29,000 | 1.95 | 3.00 |
| NFUF | Civil | Flat & Rolled | 28.08 | 34,600 | 2.00 | 5.21 |
| NFUE | Civil | Flat | 8.67 | 11,900 | 1.46 | 0.84 |
| CPNU | Criminal | Flat | 6.93 | 9,900 | 1.67 | 2.17 |
| FAUF | Civil | Rolled | 11.14 | 10,700 | 2.13 | 5.50 |
| TPRS | Criminal | Rolled | 4.16 | 4,800 | 1.85 | 2.15 |
| FANC | Criminal | Rolled | 2.36 | 2,300 | 2.04 | 3.87 |
| | | | 88.03 | 103,200 | | |

**Transactions using identical equipment get widely varying quality**

# Each TOT Has a Different DET Curve

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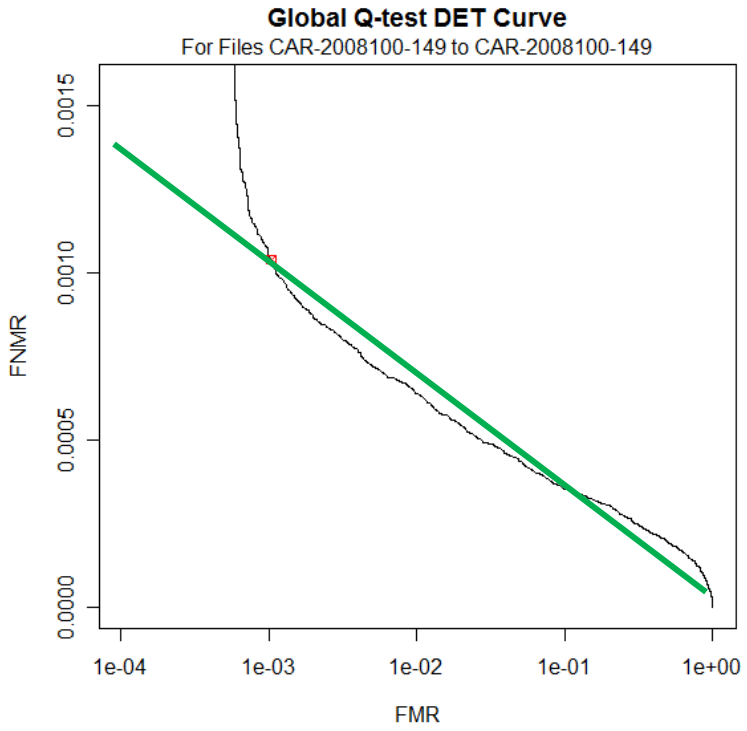
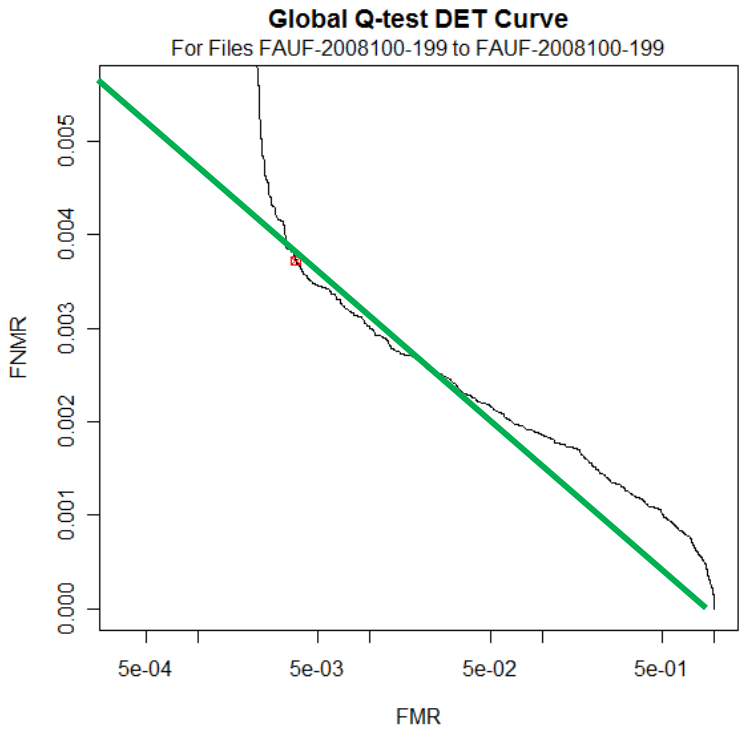
Criminal DET




Civil DET




Note the 3X difference in the scale of the errors.

# Standardization of System Testing

- Any AFIS could be setup to be tested as IAFIS has been. This includes operational systems.
- All that is needed is candidate lists with scores.
- If this were done every match could return a probabilities on accuracy of hits and misses.
- This is the only way to know what is being missed.
- If search size equivalent information were available workload vs. quality can also be included

# Multimodal Biometrics

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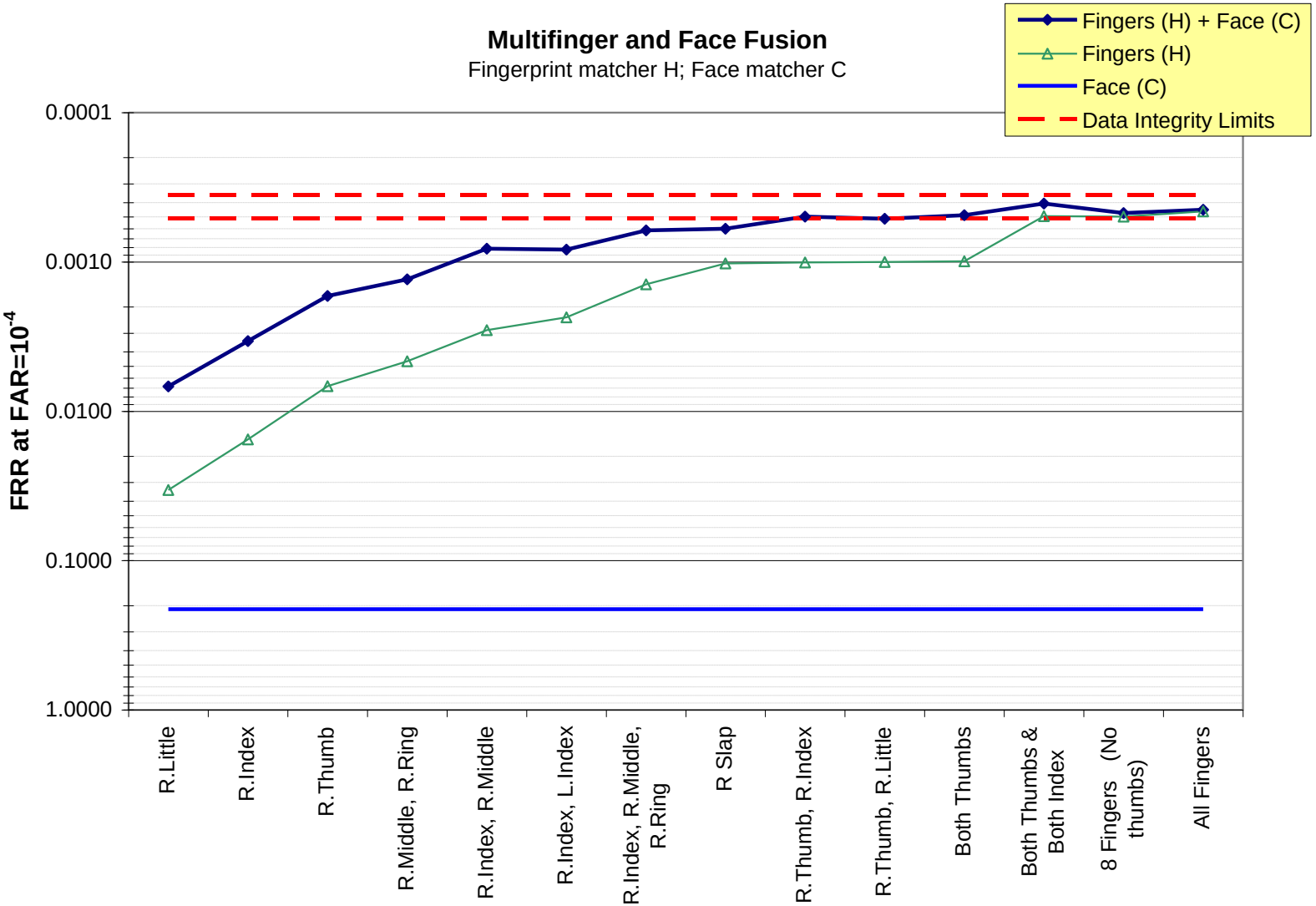
- Usability - All biometric modes have image quality issues that are sensitive to acquisition procedures.

- How the match scores are combined is important. How much would score level fusion improve biometric accuracy? How should it be done?

# Combinations of Fingers + Face



# General Observations

- **Whether the benefits of fusion can be realized in practice depends on**
  - Availability of multi-biometric data and/or multiple matchers
  - The accuracy of the matchers
  - The correlation of the scores
  - Sample similarity and quantity of training data

# Current Status

- Testing has barely scratched the surface of multimodal applications.
- Relatively simple methods can provide significant accuracy gains.
- Lack of correlation between biometric modes should be tested not assumed.

# Conclusions

- **Garbage in Garbage Out**
  - –Very low quality data sharply reduces hits and increases misses
  - –Low and high quality data have sharply different matching characteristics
- **It can be improved.**
  - –Better input quality means more hits and fewer misses
  - –Multimodal matching can improve accuracy.

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