SlapSeg04
(Slap Fingerprint Segmentation Evaluation 2004)

Results

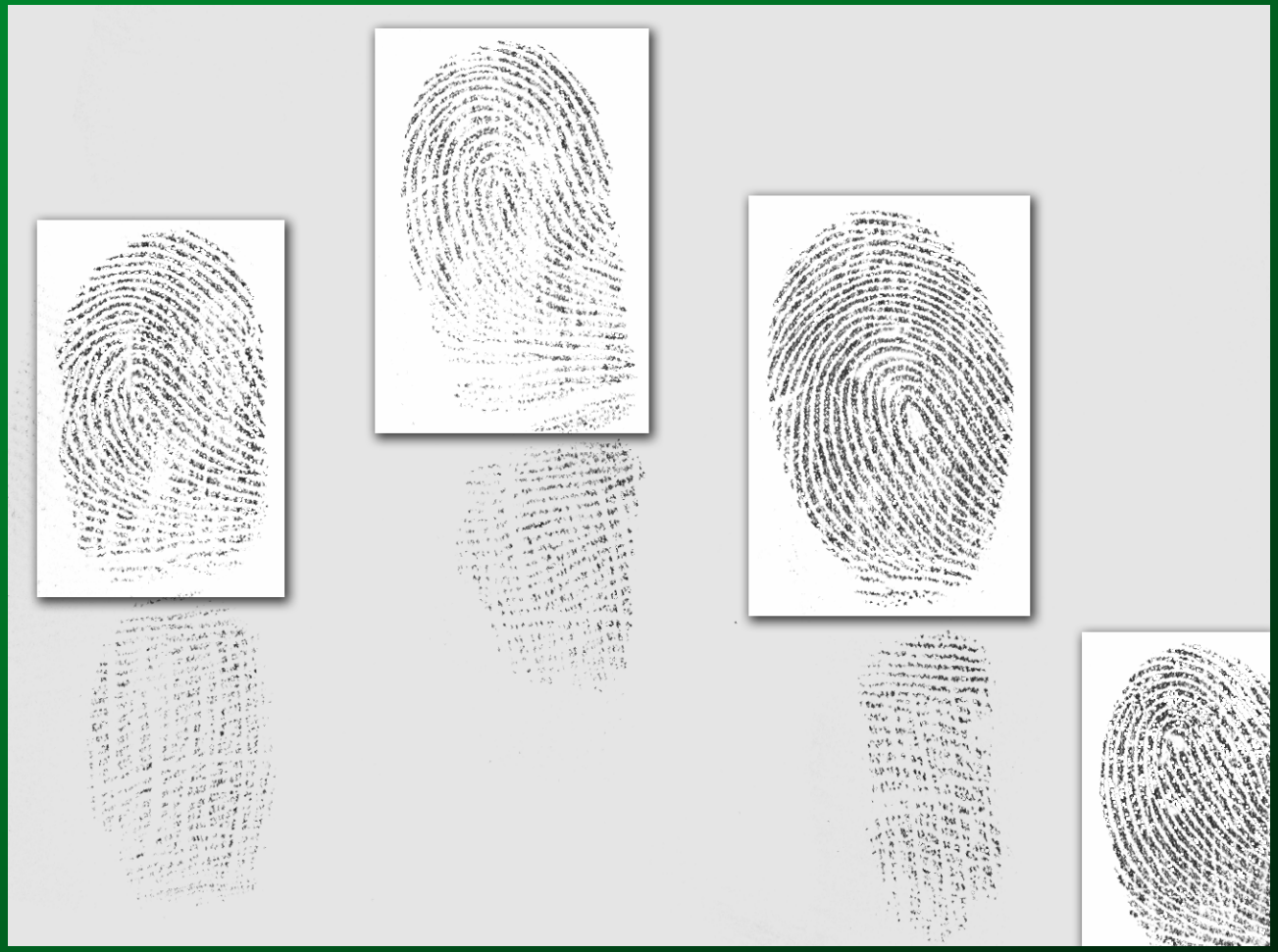
9 March 2005

Bradford Ulery	Mitretek Systems
Austin Hicklin	Mitretek Systems
Craig Watson	NIST
Michael Indovina	NIST
Kayee Kwong	Mitretek Systems

Overview

- The Slap Fingerprint Segmentation Evaluation 2004 (SlapSeg04) was conducted to assess the accuracy of algorithms used to segment slap fingerprint images into individual fingerprint images.
- SlapSeg04 was conducted by the National Institute of Standards & Technology (NIST) and Mitretek Systems on behalf of the Justice Management Division (JMD) of the U.S. Department of Justice.
- SlapSeg04 serves as part of NIST's statutory mandate under section 403c of the USA PATRIOT Act to certify those biometric technologies that may be used in U.S. VISIT.
- SlapSeg04 was announced in July 2004; the evaluations were conducted at NIST facilities at Gaithersburg from October through December 2004.

Slap Segmentation



Purpose of the Study

- This evaluation was conducted to determine the accuracy of existing slap segmentation algorithms on a variety of operational-quality slap fingerprints.

- The study incorporates several subtly different objectives:
  - Measurement of the accuracy of state-of-the-art slap segmentation software
  - Assessment of the practicality of segmenting operational quality slap fingerprints
  - Determination of the factors that cause slap segmentation and matching to fail
  - Assessment of the ability of segmentation algorithms to detect when segmentation was successful

Operational Scenarios

- The study was conducted to determine the practicality of these operational scenarios:
  - Real-time segmentation of livescan slap fingerprints at the time of capture
  - Batch segmentation of large databases of livescan, paper, or mixed livescan/paper slap fingerprints

Background

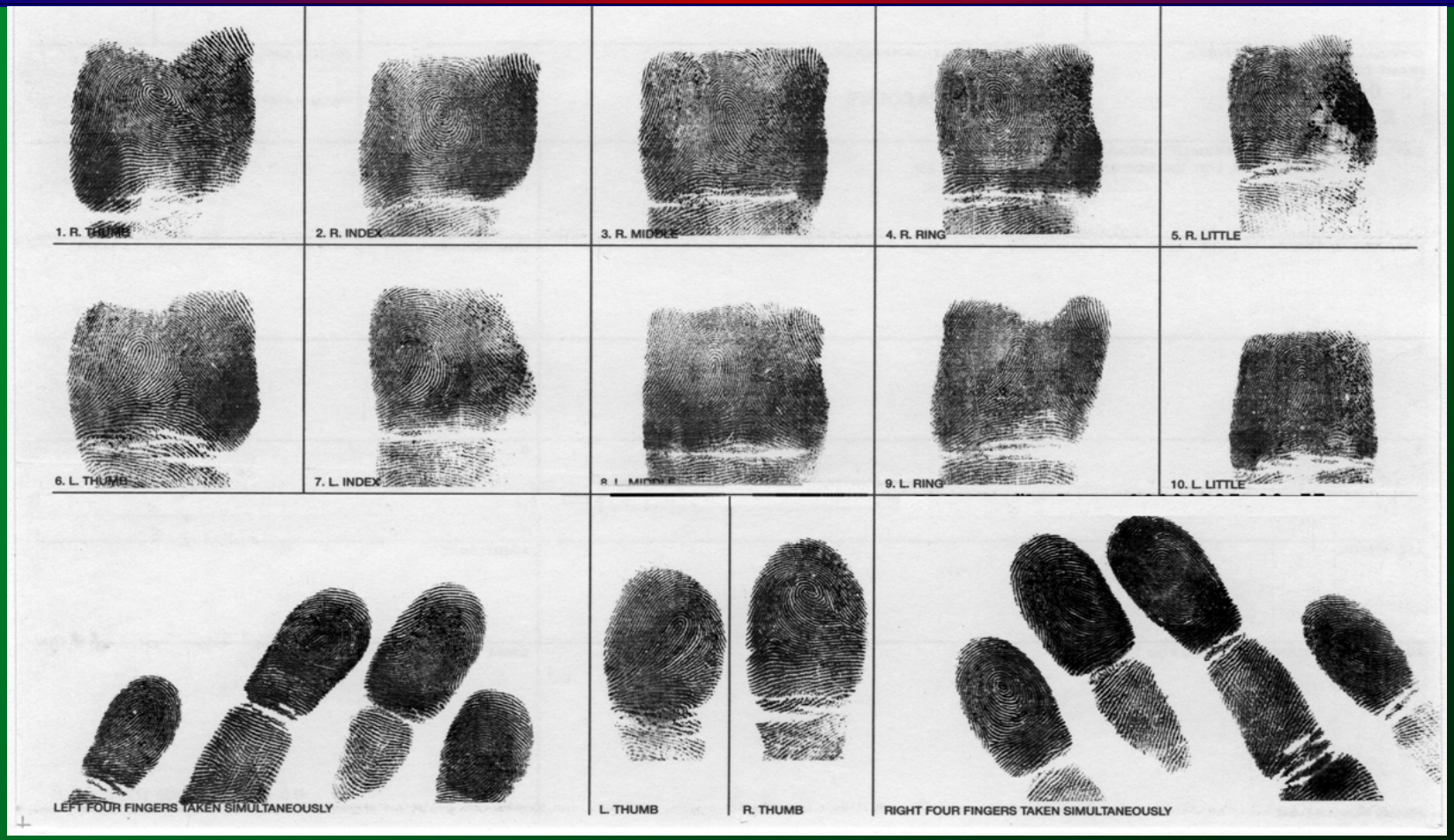
What are slap fingerprints?

What can they be used for?

What are Slap Fingerprints?

- Slap fingerprints, or “simultaneous plain impressions,” are simply multiple flat fingerprints captured at the same time.

What are Slap Fingerprints?



Why Slap Fingerprints?

- Slap fingerprints have received increasing attention as a compromise between
  - rolled fingerprints and
  - single-finger flat fingerprints.

Rolled Fingerprints

- Rolled fingerprints provide a great deal of information, allowing for accurate searches
- A rolled fingerprint has about twice the area of a flat or segmented slap fingerprint — and correspondingly more information to use in matching

but

- Properly rolling fingerprints is a slow process that requires trained staff
- Operators must hold and twist fingers to capture fingerprints, making subjects feel manhandled

Flat Fingerprints

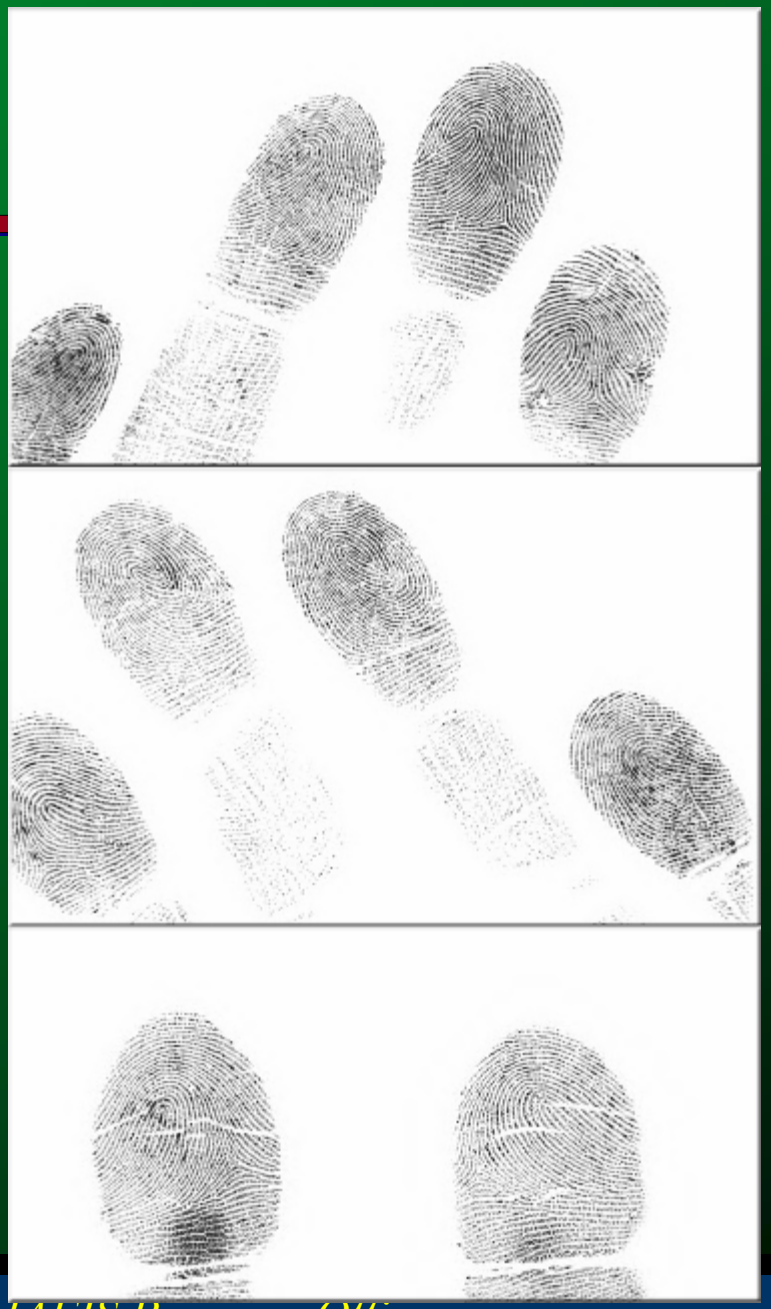
- Single-finger flat fingerprints can be acquired quickly with little training
- Single-finger flat livescan devices are inexpensive

but

- Single-finger flat fingerprints are adequate to use to verify identity, but at least 4 flat fingerprints are needed for accurate searches of very large databases
- As the number of fingers increases, so does the likelihood that they are scanned out of sequence — this is also true of rolls, especially for less-trained operators

Slap Fingerprints

- Slaps are "*simultaneous plain impressions*":
  - Slap fingerprints are simply multiple flat fingerprints captured at the same time
- Capturing multiple fingerprints is easier, faster, and much less error-prone than rolls or single-finger flats
- Two or three slap images include eight or ten fingers, allowing accurate searches of a large system



What is Slap Segmentation?

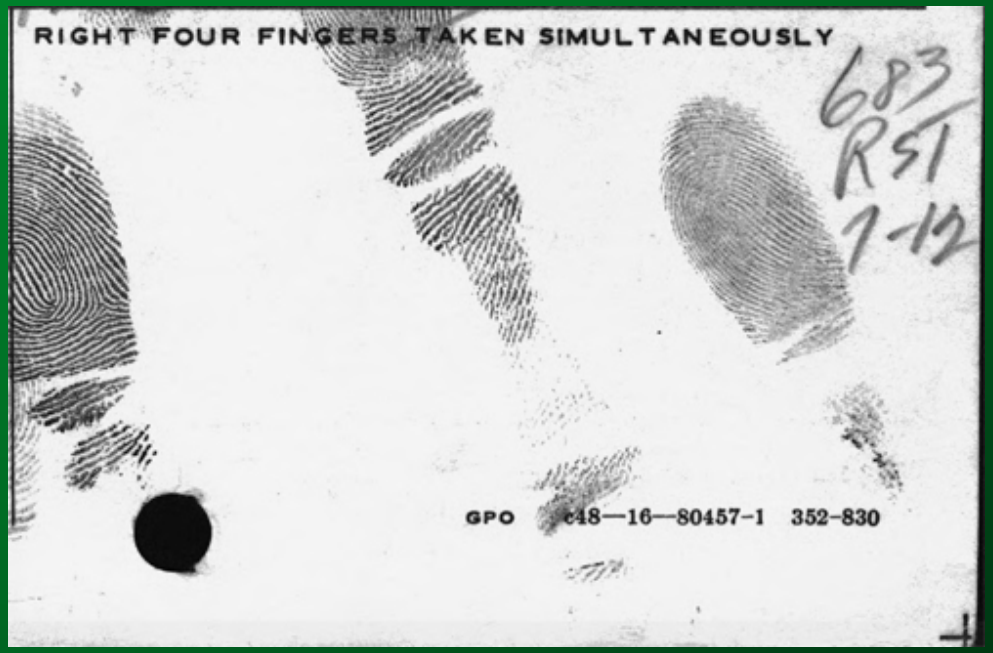
Simple Example of Slap Segmentation

Segmentation of a Problem Slap

Segmentation of a Problem Slap

Examples of Problem Slaps

Examples of Problem Slaps

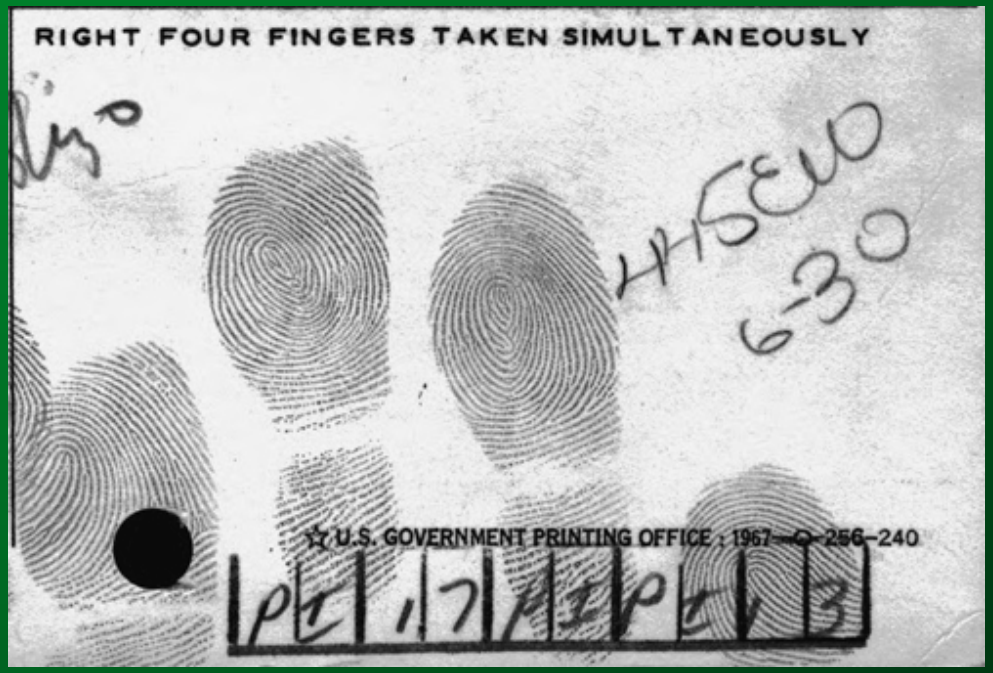


Examples of Problem Slaps

Examples of Problem Slaps

Examples of Problem Slaps

Examples of Problem Slaps



Examples of Problem Slaps

Examples of Problem Slaps

SlapSeg04 Evaluation Methodology

Evaluation Overview

- Participants submitted segmenter software to NIST
  - 13 segmenters from 10 organizations
  - Compliant with API specification
  - Sample data results were verified by NIST
- Each segmenter was run on ~30,000 slap images at NIST

Determining Segmentation Accuracy

- There was no practical way to determine the ideal segmentation for every slap image
- The accuracy of segmentation was determined by how well the slaps matched against the corresponding rolled fingerprints
- Matching was performed using several matchers from the NIST SDK tests
  - Several matchers were used to limit bias or correlations
- NOTE: Accuracy as reported in the study is ALWAYS in terms of the segmentation of fingerprints that matched against the corresponding rolls

Matching Against Rolls




Matching Against Rolls

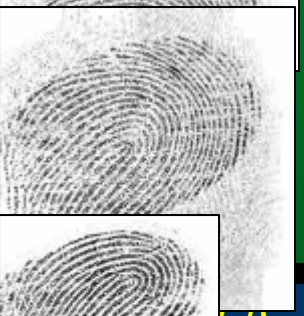
Match
(High Threshold)

Match
(High Threshold)

Match
(High Threshold)

Match
(High Threshold)

Matching Against Rolls



Match
(High Threshold)

Marginal Match
(Low Threshold)

Match
(High Threshold)

Match
(High Threshold)

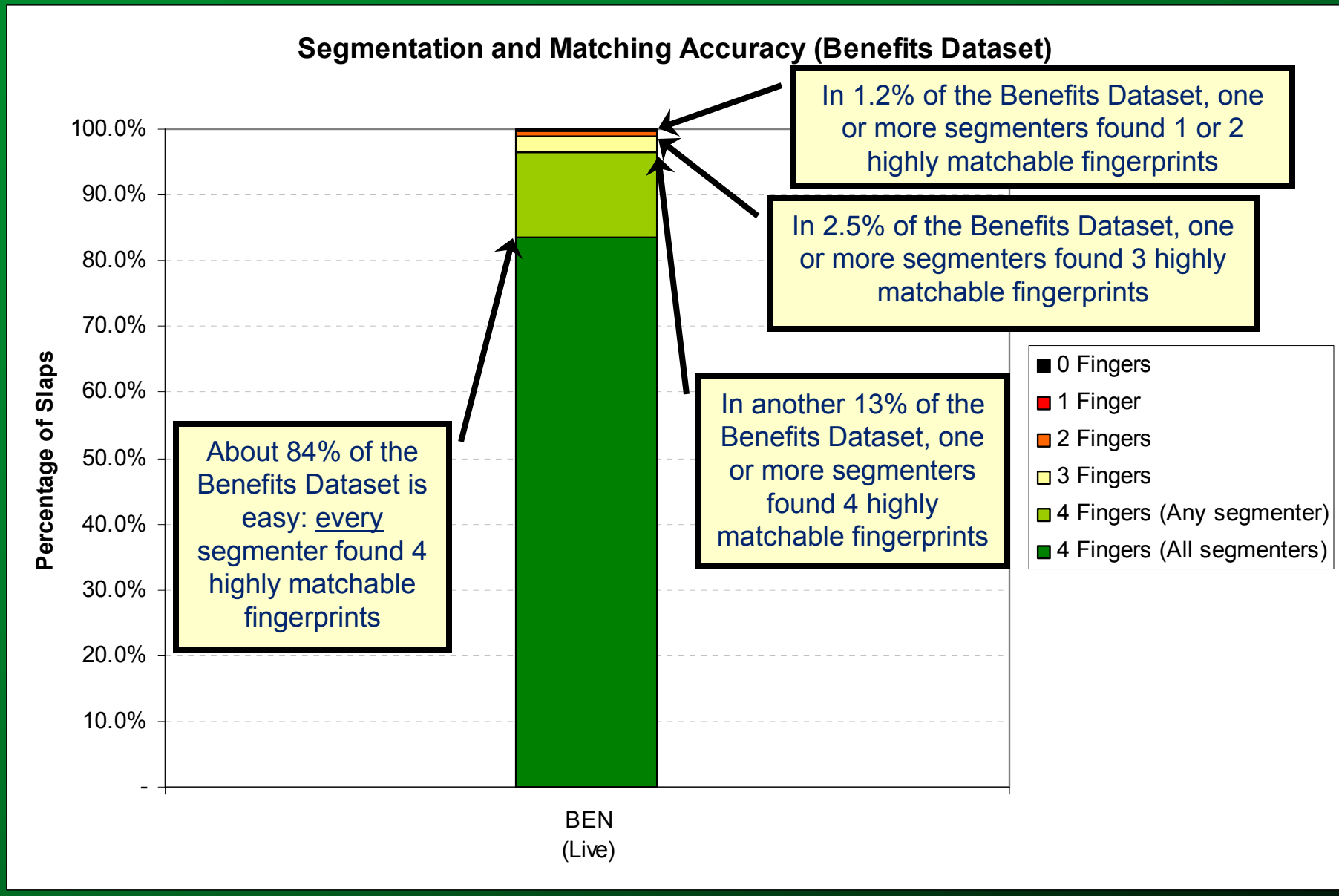
Match
(High Threshold)

Evaluation Data

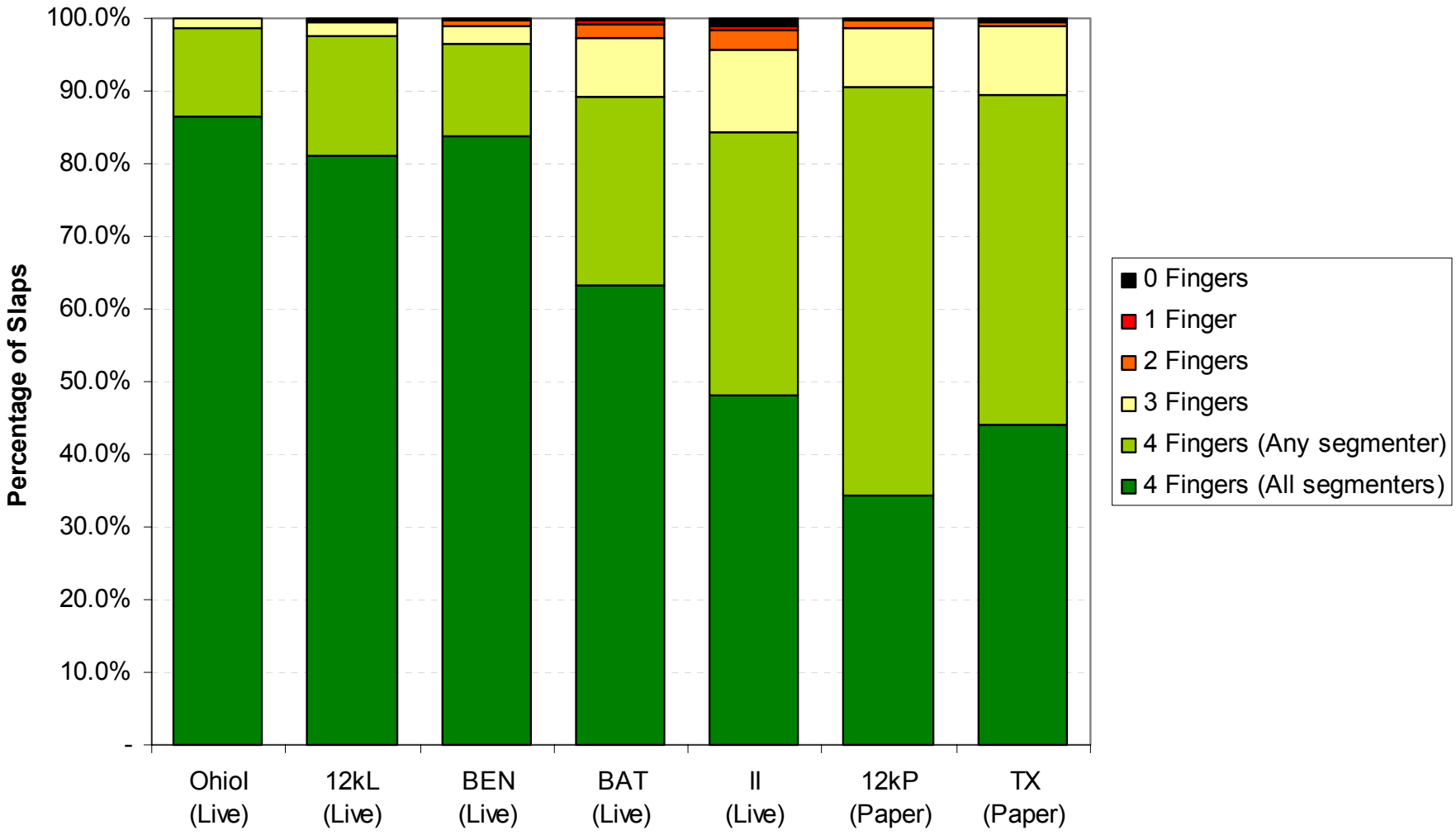
Dataset	Type	Slaps	Comments
Ohio (OhioI)	Livescan	1,850	Fingerprints collected from Ohio prisoners, under carefully controlled conditions. The only non-operational dataset.
FBI 12k Search (12kL)	Livescan	5,000	Criminal and civil livescan fingerprints from IAFIS.
Benefits (BEN)	Livescan	5,000	Fingerprints from DHS/BICE (formerly INS) Benefits data
DoD BAT (BAT)	Livescan	2,634	Fingerprints collected by DoD.
IDENT/IAFIS (II)	Livescan	5,000	Fingerprints collected in secondary processing for IDENT/IAFIS.
FBI 12k File (12kP)	Paper	5,000	Criminal paper fingerprints from IAFIS.
Texas (TX)	Paper	5,000	Criminal fingerprints from Texas Department of Public Safety.
Total		29,484	

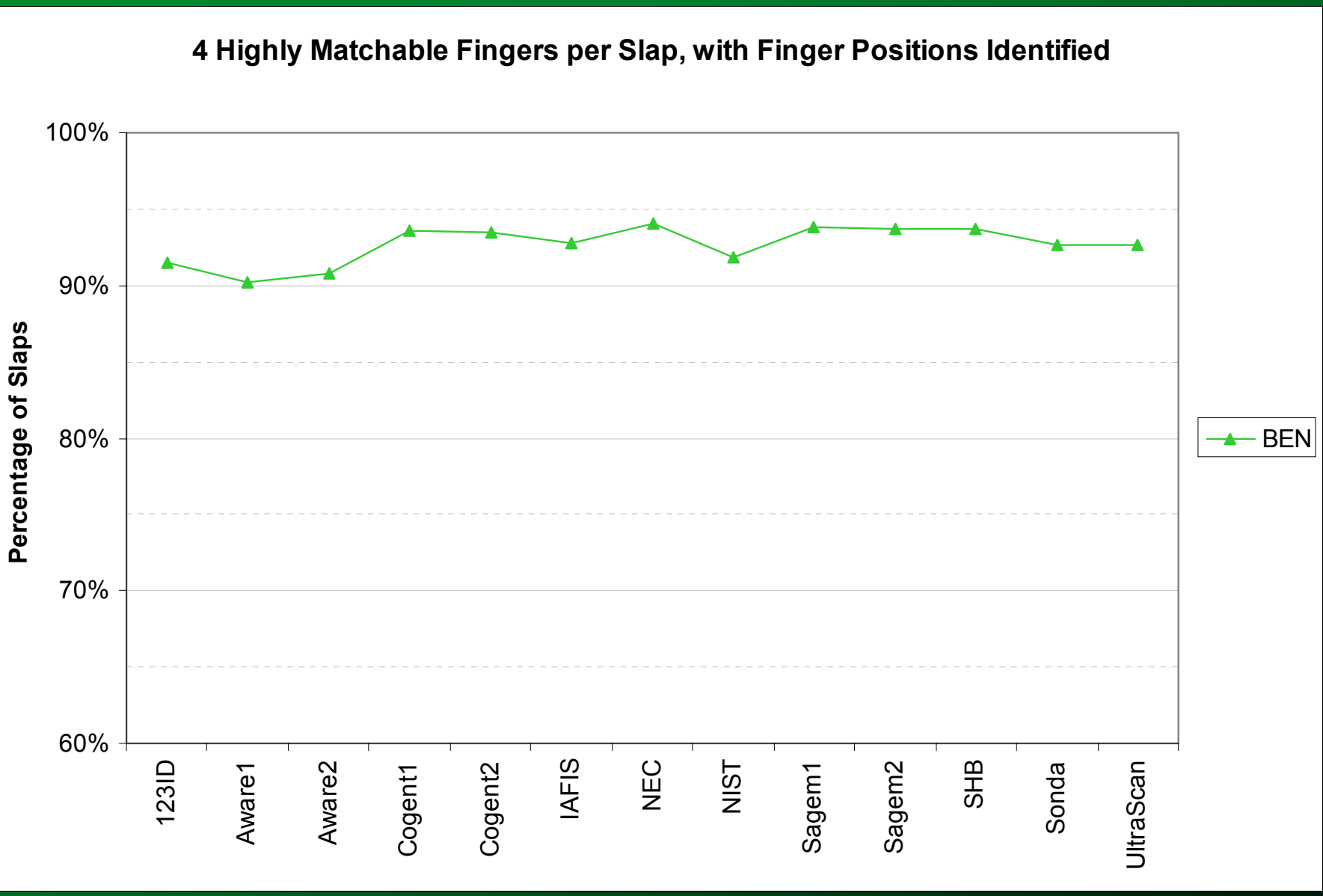
SlapSeg04

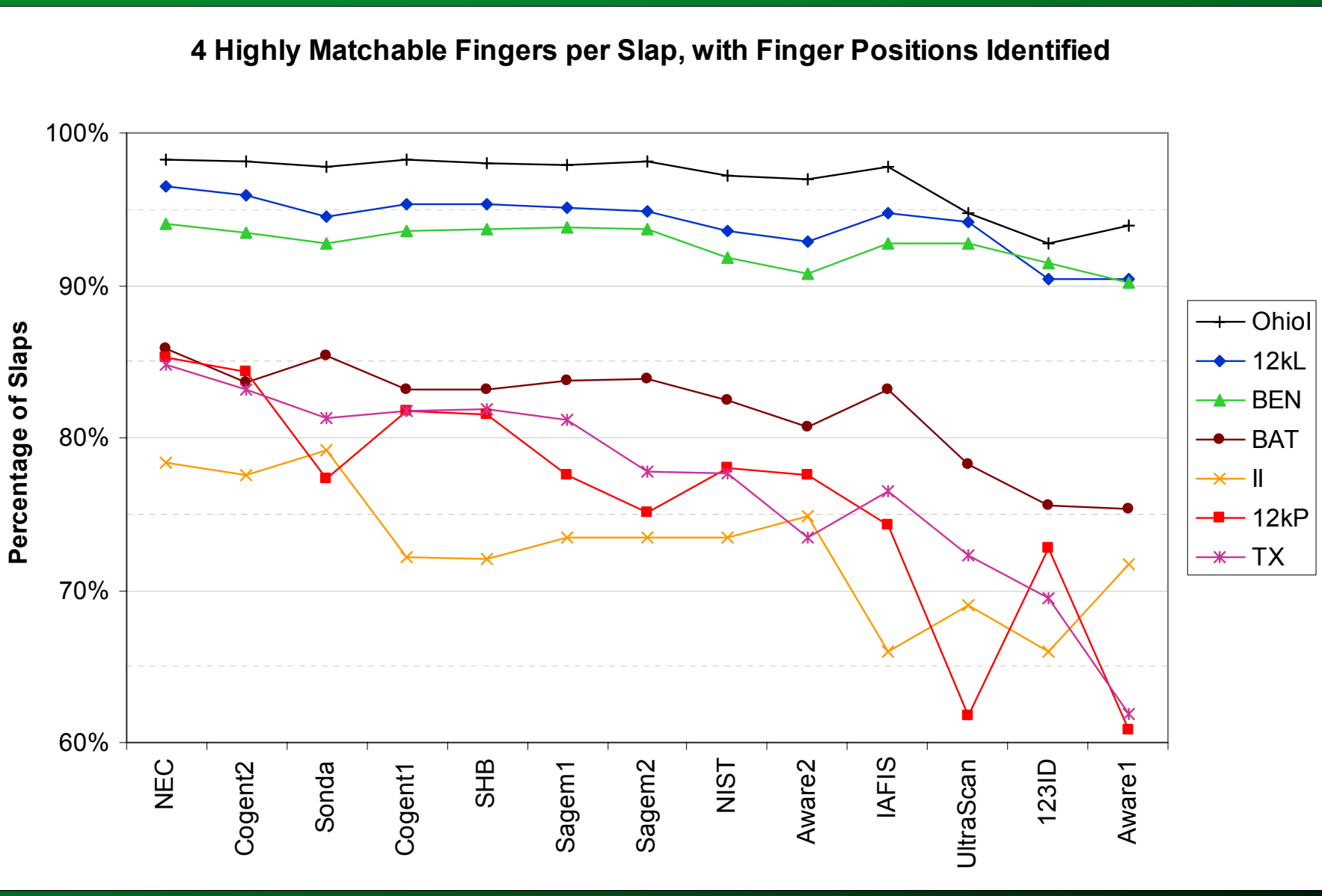
Results

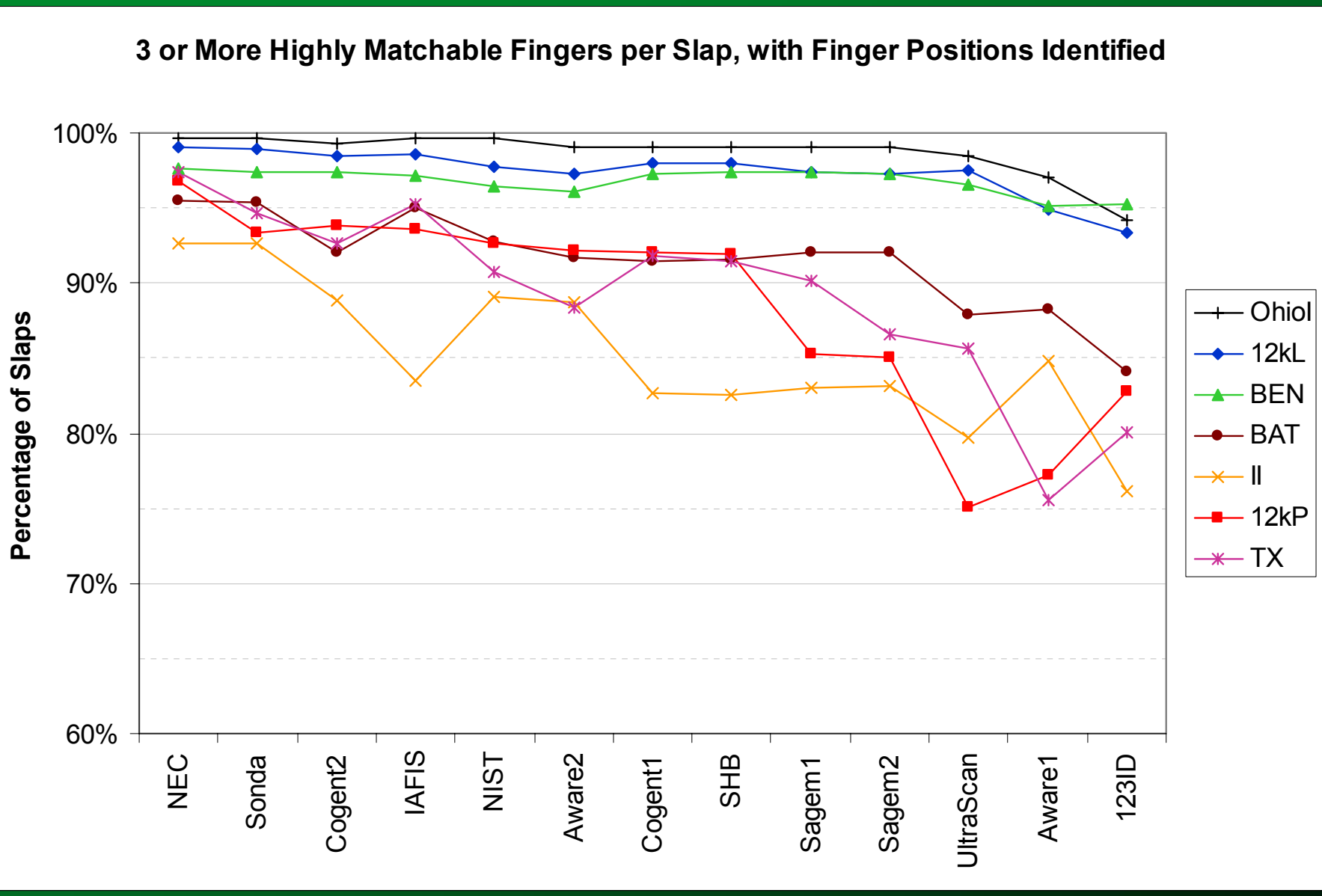

Segmentation and Matching Accuracy (Benefits Dataset)
In 1.2% of the Benefits Dataset, one or more segmenters found 1 or 2 highly matchable fingerprints
In 2.5% of the Benefits Dataset, one or more segmenters found 3 highly matchable fingerprints
In another 13% of the Benefits Dataset, one or more segmenters found 4 highly matchable fingerprints
About 84% of the Benefits Dataset is easy: every segmenter found 4 highly matchable fingerprints
Percentage of Slaps
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
-
BEN
(Live)
0 Fingers
1 Finger
2 Fingers
3 Fingers
4 Fingers (Any segmenter)
4 Fingers (All segmenters)

Segmentation and Matching Accuracy across Datasets

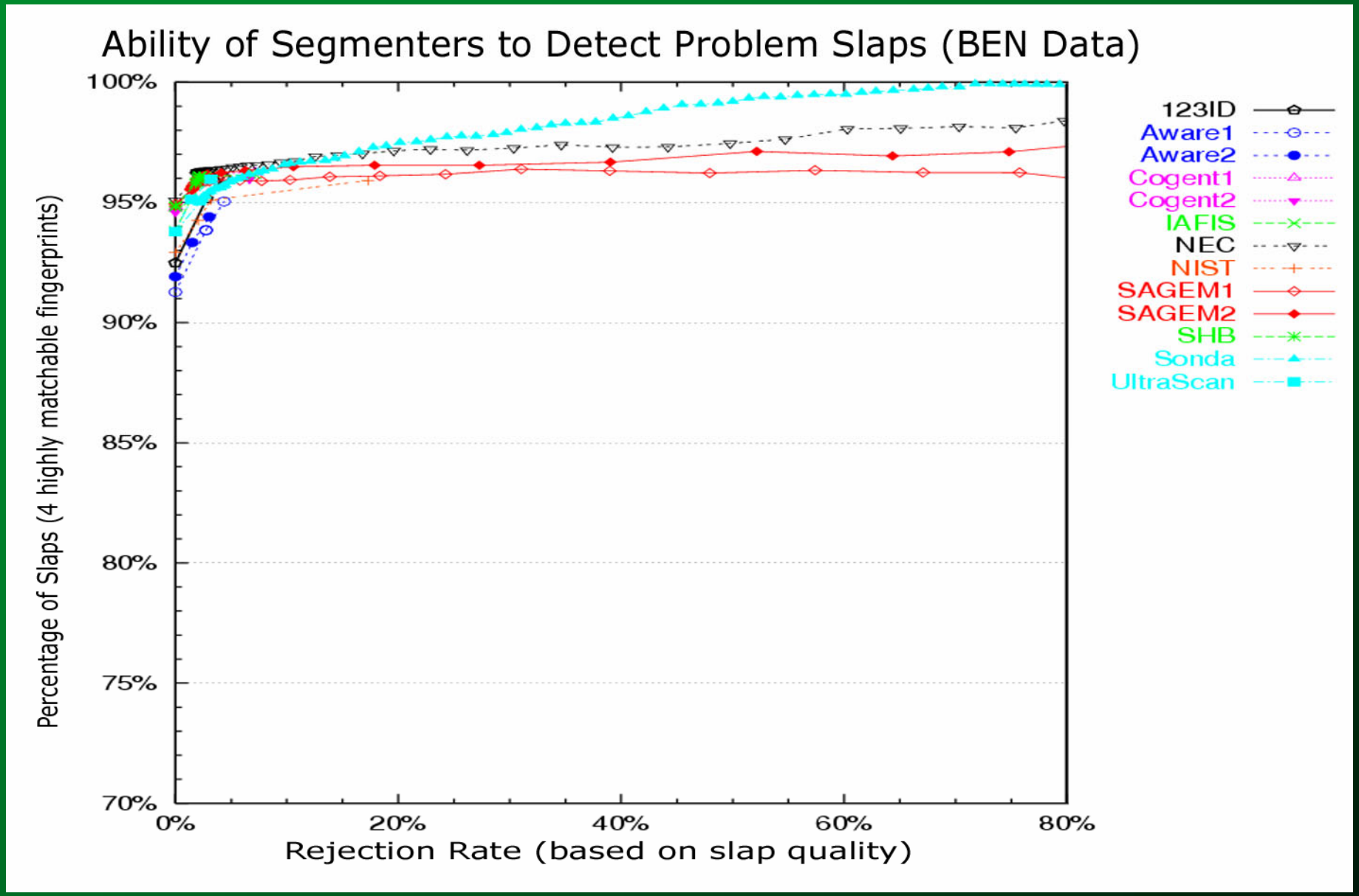



4 Highly Matchable Fingers per Slap, with Finger Positions Identified
Percentage of Slaps
100%
90%
80%
70%
60%
123ID
Aware1
Aware2
Cogent1
Cogent2
IAFIS
NEC
NIST
Sagem1
Sagem2
SHB
Sonda
UltraScan
BEN


4 Highly Matchable Fingers per Slap, with Finger Positions Identified
Percentage of Slaps
100%
90%
80%
70%
60%
NEC
Cogent2
Sonda
Cogent1
SHB
Sagem1
Sagem2
NIST
Aware2
IAFIS
UltraScan
123ID
Aware1
OhioI
12kL
BEN
BAT
II
12kP
TX


3 or More Highly Matchable Fingers per Slap, with Finger Positions Identified
Percentage of Slaps
100%
90%
80%
70%
60%
NEC
Sonda
Cogent2
IAFIS
NIST
Aware2
Cogent1
SHB
Sagem1
Sagem2
UltraScan
Aware1
123ID
Ohiol
12kL
BEN
BAT
II
12kP
TX


Ability of Segmenters to Detect Problem Slaps (II Data)
Percentage of Slaps (4 highly matchable fingerprints)
100%
95%
90%
85%
80%
75%
70%
0%
20%
40%
60%
80%
Rejection Rate (based on slap quality)
123ID
Aware1
Aware2
Cogent1
Cogent2
IAFIS
NEC
NIST
SAGEM1
SAGEM2
SHB
Sonda
UltraScan


Ability of Segmenters to Detect Problem Slaps (BEN Data)
Percentage of Slaps (4 highly matchable fingerprints)
100%
95%
90%
85%
80%
75%
70%
0%
20%
40%
60%
80%
Rejection Rate (based on slap quality)
123ID
Aware1
Aware2
Cogent1
Cogent2
IAFIS
NEC
NIST
SAGEM1
SAGEM2
SHB
Sonda
UltraScan

Groundtruthing

- Data errors and quality problems were identified through automated and manual reviews.
- Image quality of every rolled image and every segmented slap image was automatically assessed.
- Unexpected results were flagged for possible human review
  - Example: no segmenter could find the little finger for a particular slap
- Over 1000 slap/roll sets were reviewed (3.7% of the total)
  - Essentially all of the egregious errors were identified

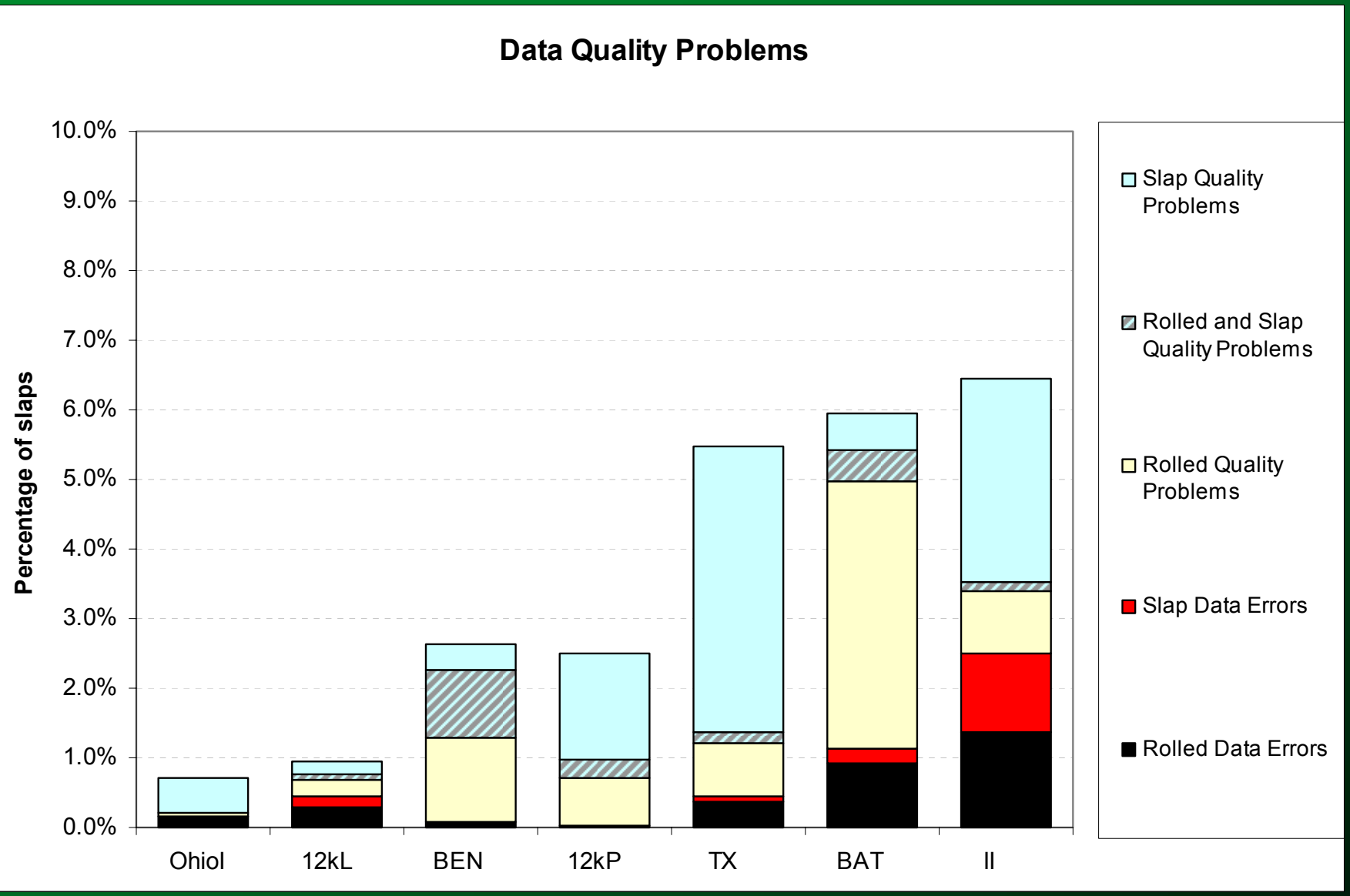
Data Errors and Quality Problems

- Data Errors
  - Invalid fingerprints
  - Sequence errors or Swapped hands

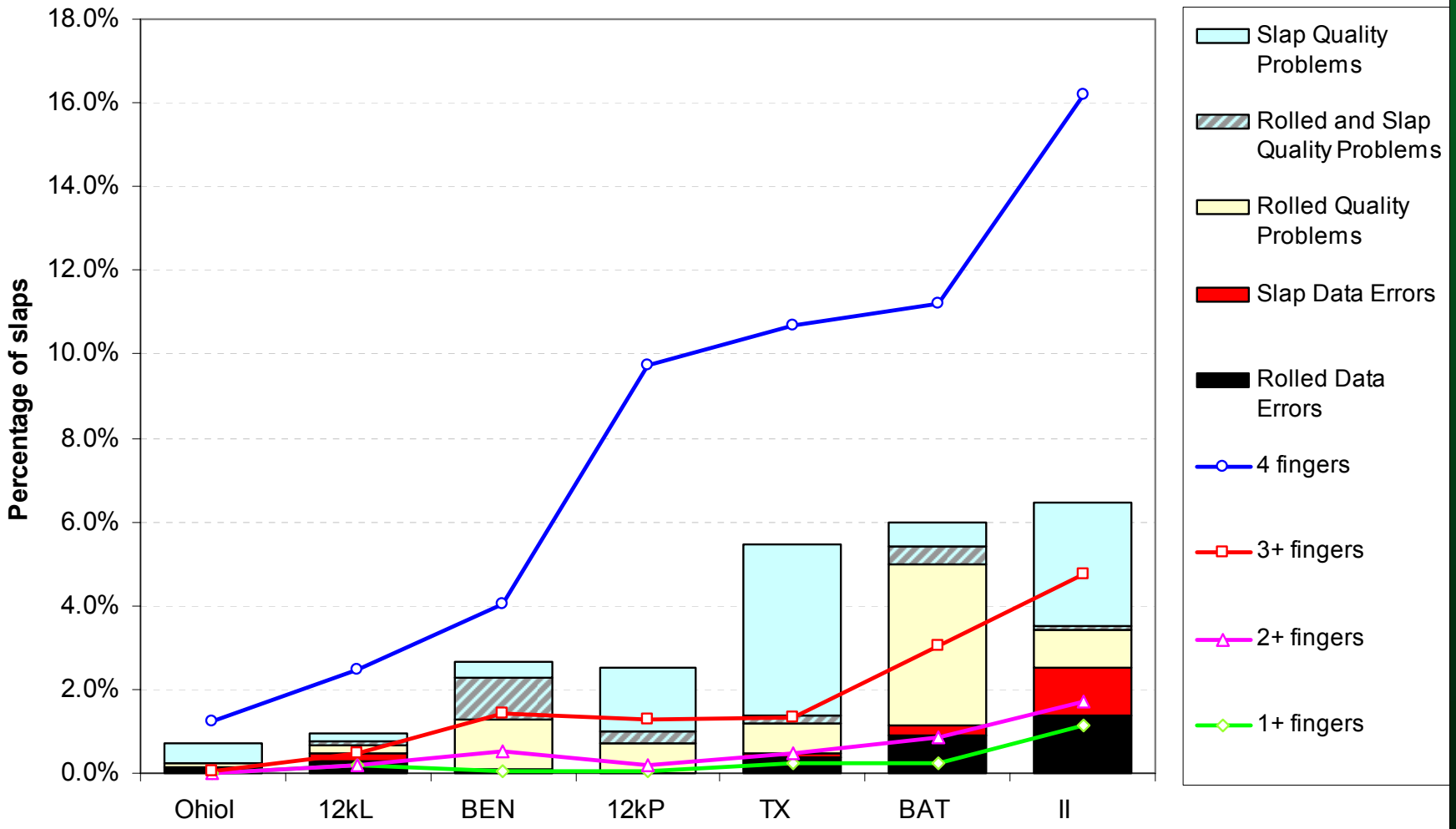
- Quality Problems
  - Partial, Missing, or Extra prints
  - Exceptionally poor quality fingerprints

Note these apply both to the slaps and rolls

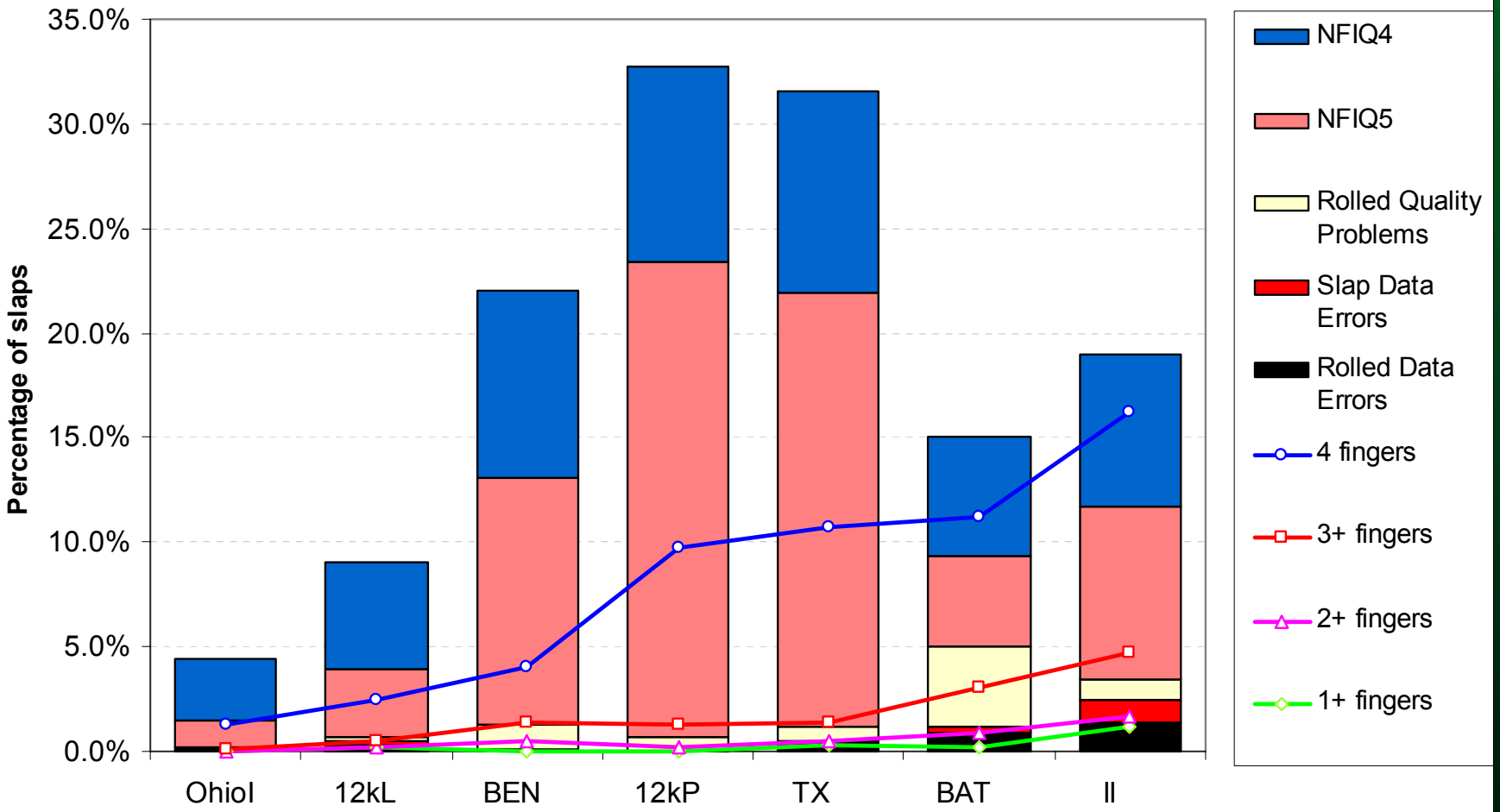

Data Quality Problems
Percentage of slaps
10.0%
9.0%
8.0%
7.0%
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
BEN
Slap Quality Problems
Rolled and Slap Quality Problems
Rolled Quality Problems
Slap Data Errors
Rolled Data Errors


Data Quality Problems
Percentage of slaps
10.0%
9.0%
8.0%
7.0%
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
Ohiol
12kL
BEN
12kP
TX
BAT
II
Slap Quality Problems
Rolled and Slap Quality Problems
Rolled Quality Problems
Slap Data Errors
Rolled Data Errors

Data Quality Problems and Unsuccessful Segmentation



Data Quality Problems and Unsuccessful Segmentation (Using NFIQ instead of Null Image Quality)



SlapSeg04

Conclusions

Conclusions (1 of 6)

- The source of data had more of an effect on segmentation and matching accuracy than any other factor.

Conclusions (2 of 6)

- The relative accuracy of segmenters depends on the criteria and data used.
- Most of the segmenters achieved comparable accuracies on the better quality data, but there were significant differences on poor quality data.

Conclusions (3 of 6)

- Segmentation and matching accuracy can be defined in a variety of ways, based on the number of fingers required for success, and matcher score thresholds.
- There is no single measure of accuracy that is appropriate for all possible uses. Reported accuracies depend greatly on which measure is used.
- Two definitions of accuracy likely to be of general use are
  - the ability of a segmenter to segment four highly matchable fingerprints from a slap, or
  - the ability of a segmenter to segment three or more highly matchable fingerprints from a slap, with all finger positions correctly identified.

Conclusions (3 of 6) continued

- Segmentation accuracy, if defined as four highly matchable fingerprints per slap with finger positions correctly identified, ranged from 61% to 98% depending on the source of data. The three most accurate segmenters ranged from 77% to 98%.
- Segmentation accuracy, if defined as three or more highly matchable fingerprints per slap with finger positions correctly identified, ranged from 75% to over 99%. The two most accurate segmenters ranged from 93% to over 99%.
- Segmentation accuracy rates would be higher than those stated here if less restrictive matcher thresholds were used, which may be appropriate in some operational scenarios.

Conclusions (4 of 6)

- Segmenters are capable of identifying many, but not all, cases where they fail to produce highly matchable segmented images.
  - Some slaps that could not be successfully segmented and matched were not identified by any segmenter or by image quality measures.
  - The ability to identify problem slaps varies greatly among segmenters, resulting in great variation in expected recapture/reject rates.
  - Some segmenters can accurately determine whether a slap came from a right or left hand, and therefore could identify many cases in which the slaps were swapped left for right.
  - The implications of recapture or rejection of data depend on operational requirements.

Conclusions (5 of 6)

- Two characteristics of the fingerprints that might have been expected to have an obvious effect on segmentation and matching accuracy were found to have little or no such effect:
  - Livescan versus paper — Other factors (such as data quality) clearly outweighed whether images were from livescan or paper sources.
  - Slap orientation — The orientation (angle of rotation) of the slap images was found to have little or no effect on overall accuracy.

- We did not have data to measure
  - The effect of large livescan platens/slap image sizes
  - The effect of different scanner types
  - Note, however, that some of the better results came from the 12kL and BEN datasets, which used small platen scanners that were certified at a lower image quality (EFTS Appendix G, not F)
  - This does not mean that platen size and livescan image quality do not matter; it means that other characteristics (notably operational quality control) outweigh platen size and livescan image quality.

Conclusions (6 of 6)

- The causes of segmentation and matching failure vary depending on the dataset.
- Database errors, such as invalid slap images or out-of-sequence rolled fingerprints, were found in between 0.1% and 2.5% of data, depending on the dataset.
- Partial, missing, and exceptionally poor quality fingerprints were found in between 0.4% and 4.8% of data, depending on the dataset.
- Database errors and quality problems limit segmentation and matching accuracy for all datasets.
- Some failures to segment and match were due to marginal fingerprint quality rather than poor fingerprint quality per se.

For more information, see
http://fingerprint.nist.gov/SlapSeg04/

Austin Hicklin
Mitretek Systems
hicklin @ mitretek.org