Challenges of Integrating NFIQ into an Existing Biometric Application

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Homeland Security

US-VISIT
Keeping America's Doors Open and Our Nation Secure

Agenda

§ **Overview**
  - US-VISIT Biometrics Quality Assurance
  - Use of Fingerprint Image Quality Scores in US-VISIT

§ **NFIQ and IDENT Scores**
  - Score Range and Initial Mapping

§ **Where NFIQ Encounters Challenges**
  - Score Mapping and Correlation of NFIQ = 3

§ **Desired Characteristics of an Image Quality Score Algorithm and Its Score Range**
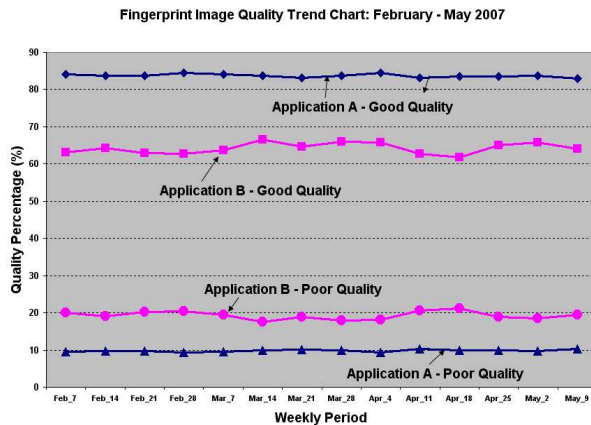
§ **Summary**

IDENT Image Quality Monitoring, Reporting and Analysis

Image Quality Reports:

§ **By application**

§ **By site/terminal**

§ **By capture device**

§ **By new or repeated subject**

§ **By matcher enrollment**

§ **By finger and between fingers**

§ **Trend analysis**

Fingerprint Image Quality Trend Chart: February - May 2007

#	Application	FingerType	TotalImages	Good (Q1-Q4) %	Ave. (Q5-Q6) %	Poor (Q7-Q8) %
1	Application-A	F	9562	91.00	3.44	5.56
2	Application-A	R	490	69.80	11.43	18.78
3	Application-B	F	3554	89.62	3.97	6.42
4	Application-B	R	72	75.00	9.72	15.28
5	Application-C	R	1922	77.84	10.25	11.91
6	Application-D	R	40	17.50	27.50	55.00
7	Application-E	R	500	76.40	11.60	12.00
8	Application-F	F	6962	83.34	6.92	9.74

Summary Report

All Subject Encounters

Application	TotalImages	Q1%	Q2%	Q3%	Q4%	Q5%	Q6%	Q7%	Q8%
	1205636	29.71	21.01	18.35	15.98	3.61	2.41	1.88	7.03

Application	TotalImages	Good % (Q1-Q4)		Average % (Q5-Q6)	Poor % (Q7-Q8)
	1205636	85.06		6.03	8.92

Detailed Report by Site and by Terminal within the Site

SiteCode	SiteName	TerminalID	TotalImages	Good % (Q1-Q4)	Average % (Q5-Q6)	Poor % (Q7-Q8)
Site-A	JFK INTL AIRPORT (TERMINAL 4)	WJFK_A_T1	1338	88.27	5.16	6.58
Site-A	JFK INTL AIRPORT (TERMINAL 4)	WJFK_A_T2	2604	88.17	5.41	6.41
Site-A	JFK INTL AIRPORT (TERMINAL 4)	WJFK_A_T3	3054	88.54	5.40	6.06
Site-A	JFK INTL AIRPORT (TERMINAL 4)	WJFK_A_T4	3066	91.55	4.47	3.98
Site-B	MIAMI INTL AIRPORT	WMIA_B_T1	1690	85.03	6.45	8.52
Site-B	MIAMI INTL AIRPORT	WMIA_B_T2	3726	88.81	5.26	5.93
Site-B	MIAMI INTL AIRPORT	WMIA_B_T3	1572	88.30	4.77	6.93
Site-B	MIAMI INTL AIRPORT	WMIA_B_T4	1624	85.41	5.60	8.99
Site-C	DULLES INTL AIRPORT	WDIA_C_T1	896	78.35	6.36	15.29
Site-C	DULLES INTL AIRPORT	WDIA_C_T1	928	85.02	5.60	9.38
Site-C	DULLES INTL AIRPORT	WDIA_C_T1	984	81.91	6.91	11.18
Site-C	DULLES INTL AIRPORT	WDIA_C_T1	1870	83.74	6.36	9.89

Scanner A	Application App-X	TotalImages	Good % (Q1-Q4)	Ave. % (Q5-Q6)	Poor (Q7-Q8)
		862	48.96	24.01	27.03

Scanner B	Application App-X	TotalImages	Good % (Q1-Q4)	Ave. % (Q5-Q6)	Poor (Q7-Q8)
		13644	87.72	6.77	5.50

Scanner C	Application App-X	TotalImages	Good % (Q1-Q4)	Ave. % (Q5-Q6)	Poor (Q7-Q8)
		14346	91.64	4.41	3.95

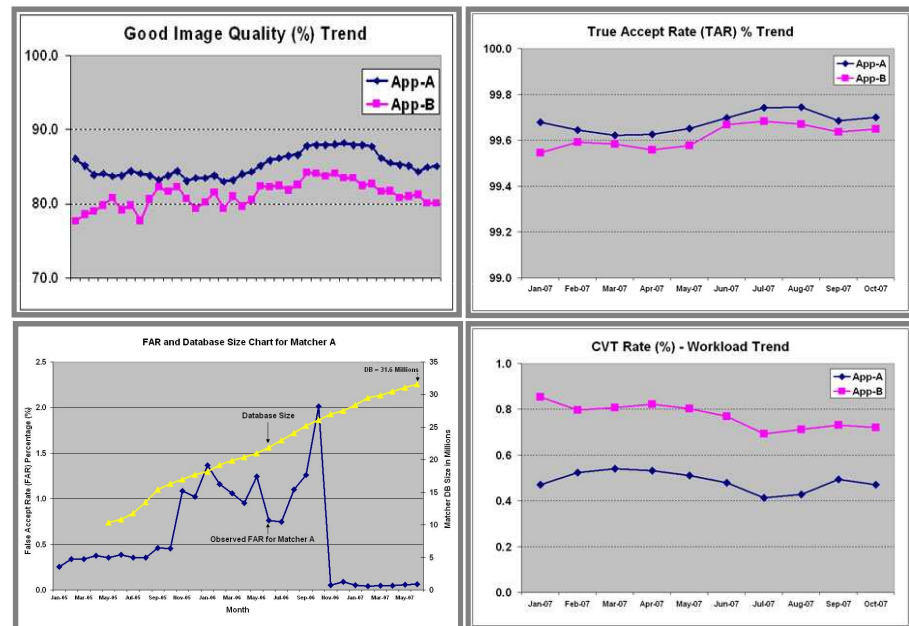|	Good (Q1 - Q4) %	Average (Q5 - Q6) %	Poor (Q7 - Q8) %
Matcher A	76.68	9.14	14.18
Matcher B	87.20	5.77	7.03
Matcher C	88.49	6.06	5.45

IDENT Matcher Accuracy Monitoring, Reporting and Analysis

Accuracy, Performance and Trend:

§ **1:1 True Accept Rate (TAR)**

§ **1:N False Accept Rate (FAR)**

§ **Examiner (CVT) Workload**
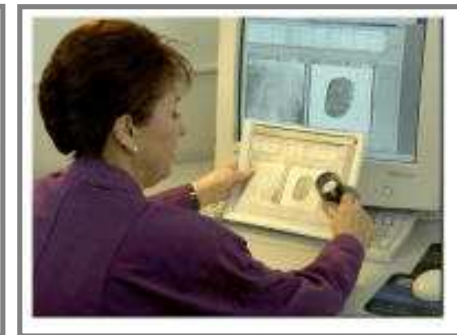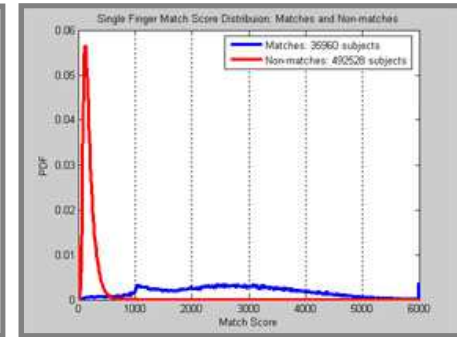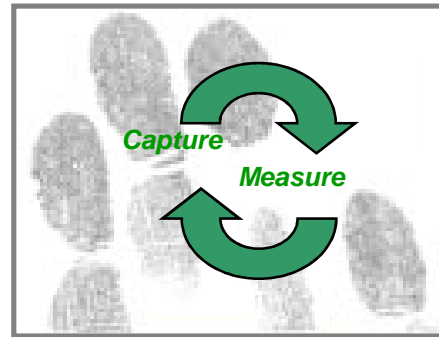
§ **FAR vs. Database Size**

Use of Fingerprint Image Quality Scores in US-VISIT

Usages:

§ **Fingerprint Recapture**

§ **Updating Prints on Matchers**

§ **Match Accuracy Prediction/Optimization**

Objectives:

§ **Ensure High Quality Fingerprint (Biometrics) Capture**

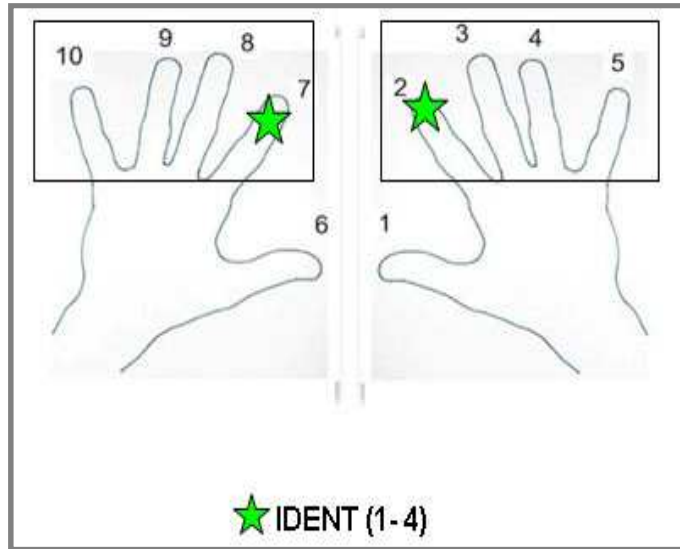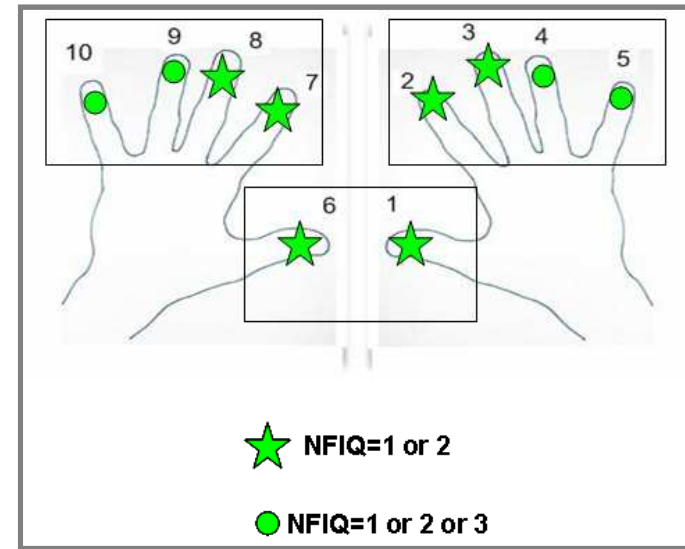§ **Ensure High Fingerprint (Biometrics) Identification Performance**

Fingerprint Recapture

Current 2-Print System

IDENT (1-4)

Emerging 10-Print System

★ NFIQ=1 or 2

● NFIQ=1 or 2 or 3

Client Image Quality Checks

- Quality check of individual fingers
- Recapture requested if the specified thresholds for the individual fingers are not met
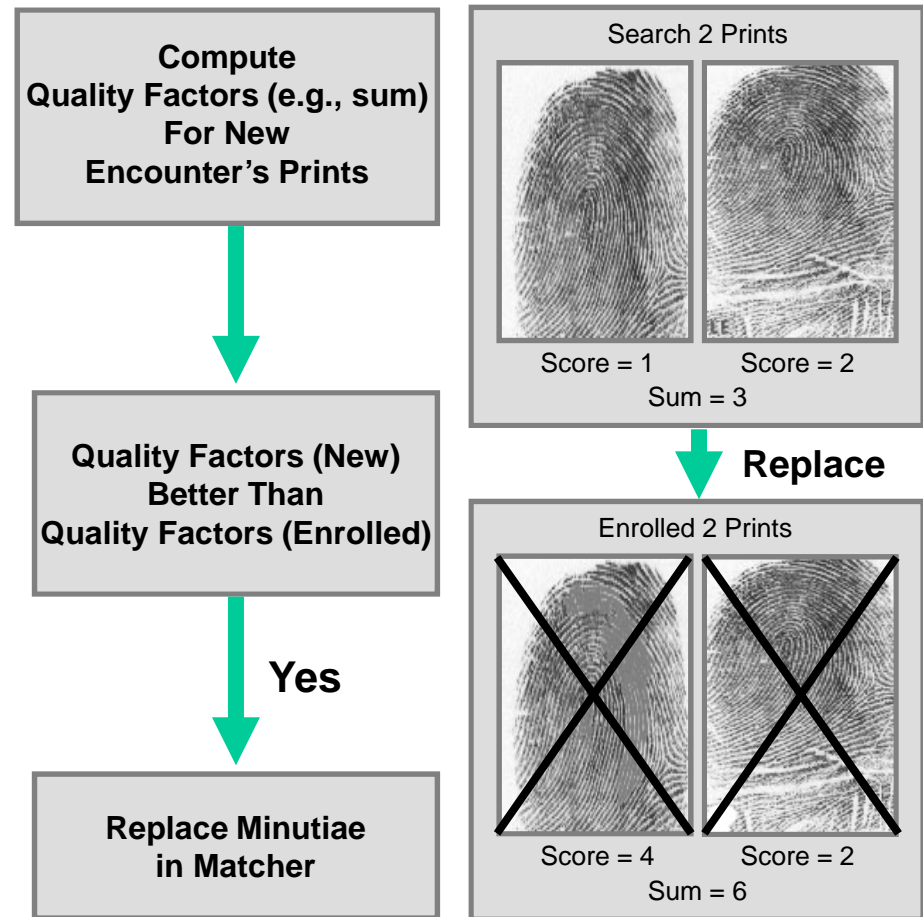
Fingerprint Updating Based on Quality

Existing Implementation:

§ **Perform best quality fingerprint updates when the sum of the IDENT quality scores is less than the sum of the scores of the enrolled prints**

Proposed Implementation:

§ **When using NFIQ, similar replacement rules need to be developed**

Compute
Quality Factors (e.g., sum)
For New
Encounter's Prints

↓

Quality Factors (New)
Better Than
Quality Factors (Enrolled)

Yes ↓

Replace Minutiae
in Matcher

Search 2 Prints
Score = 1   Score = 2
Sum = 3

Replace ↓

Enrolled 2 Prints
Score = 4   Score = 2
Sum = 6

NFIQ and IDENT Image Quality

IDENT Quality:

- **Scores range from 1 to 127**
  - **1 is the highest quality**
  - **127 is the lowest quality**
- **Thresholds were created based on match accuracy**

Good   Fair   Poor

1, 2, 3, 4, 5, 6, 7, 8, 9, …, 127

NFIQ:

- **Scores range from 1 to 5**
  - **1 is the highest quality**
  - **5 is the lowest quality**
- **Similar thresholds were created to map to existing IDENT Quality thresholds***

Good   Fair Poor

1, 2, 3, 4, 5

*NFIQ thresholds were based on the following:
- NIST IR 7151 – "Fingerprint Image Quality"
  - NFIQ Scores 1,2,3,4,5
  - Excellent, Very Good, Good, Fair, Poor.
- NIST SP 800-76-1 – "Biometric Data Specification for Personal Identity Verification"
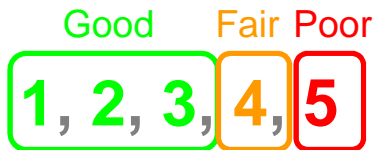 - "NFIQ values of 1,2, or 3 (i.e., good quality)"

Differences Between NFIQ and IDENT Image Quality

NFIQ Algorithm (1 to 5):

Good   Fair   Poor

1, 2, 3, 4, 5

- § Direction map
- § Contrast map
- § Flow map
- § High curve map

Quality	1	2	3	4	5
Accuracy	99.4	98.4	88.1	59.4	27.8

IDENT Algorithm (1 to 127):

Good   Fair   Poor

1, 2, 3, 4, 5, 6, 7, 8, 9, ..., 127

- § Noise level of useful area of image
- § Image contrast information
- § Size of useful area of image
- § Core position and confidence
- § Poor quality image area percentage
- § Average quality level for minutiae
- § Number of minutiae and deleted low confidence minutiae
- § Percentage of background image area

Quality	1	2	3	4	5	6	7	8-127
Accuracy	99.4	99.2	99.1	98.2	95.2	89.3	83.0	53.6

* Statistics from NIST IR 7110. "Matching Performance for the US-VISIT IDENT System Using Flat Fingerprints". Values are TAR at FAR 1.0%.
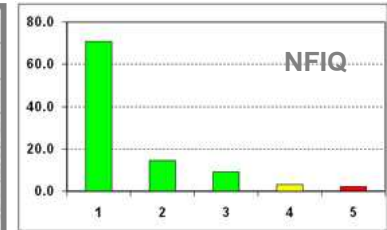
Score Mapping and Correlation: IDENT vs. NFIQ

§ **Nice mapping in Very Good and Poor images**

§ **Ambiguities occur in good and fair images (NFIQ = 3 and 4)**

	F2+F7: Total 7364 fingerprints				
	NFIQ Score				
	1	2	3	4	5
IDENT Score — Mean	2.4	3.3	7.6	9.9	15.2
Median	2	3	7	10	16
Std.Dev.	1.5	1.9	2.9	3.4	2.8

Good Fair Poor
1, 2, 3, 4, 5

NFIQ

Count	F2+F7: Total 7364 fingerprints					
	NFIQ Score					
	1	2	3	4	5	
IDENT Score 1	1419	143	2	0	0	1564
2	1816	274	8	4	0	2102
3	1072	250	25	4	0	1351
4	497	168	62	4	0	731
5	198	107	63	11	0	379
6	91	62	93	19	0	265
7	58	30	125	23	0	236
8	28	18	89	24	3	162
9	10	13	70	15	4	112
10	4	4	49	22	2	81
11	3	4	37	26	9	79
12	1	0	26	27	8	62
13	1	1	14	23	16	55
14	1	0	15	21	15	52
15	0	0	5	7	21	33
16	0	0	3	5	29	37
17	0	0	5	0	23	28
18	0	0	0	1	12	13
19	0	0	1	0	10	11
20	2	0	0	1	8	11
	5201	1074	692	237	160	

%tage	F2+F7: Total 7364 fingerprints					
	NFIQ Score					
	1	2	3	4	5	
IDENT Score 1	19.3	1.9	0.0	0	0	21.2
2	24.7	3.7	0.1	0.1	0	28.5
3	14.6	3.4	0.3	0.1	0	18.3
4	6.7	2.3	0.8	0.1	0	9.9
5	2.7	1.5	0.9	0.1	0	5.1
6	1.2	0.8	1.3	0.3	0	3.6
7	0.8	0.4	1.7	0.3	0	3.2
8	0.4	0.2	1.2	0.3	0.0	2.2
9	0.1	0.2	1.0	0.2	0.1	1.5
10	0.1	0.1	0.7	0.3	0.0	1.1
11	0.0	0.1	0.5	0.4	0.1	1.1
12	0.0	0	0.4	0.4	0.1	0.8
13	0.0	0.0	0.2	0.3	0.2	0.7
14	0.0	0	0.2	0.3	0.2	0.7
15	0	0	0.1	0.1	0.3	0.4
16	0	0	0.0	0.1	0.4	0.5
17	0	0	0.1	0	0.3	0.4
18	0	0	0	0.0	0.2	0.2
19	0	0	0.0	0	0.1	0.1
20	0.0	0	0	0.0	0.1	0.1
	70.6	14.6	9.4	3.2	2.2	

Good Fair Poor
1, 2, 3, 4, 5, 6, 7, 8, ... 127
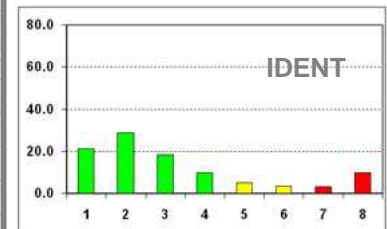
IDENT

Score Mapping and Correlation: NFIQ = 3

§ **NFIQ Score 3 has a wide distribution across IDENT Quality Scores**

§ **For this reason US-VISIT Capture Guidelines differ from NIST PIV Capture Guidelines**

§US-VISIT does not recommend acceptance of NFIQ Score 3 on most important fingers (thumbs, index, and middle)

IDENT Quality Score Distribution of NFIQ=3 Samples

IDENT Score Value
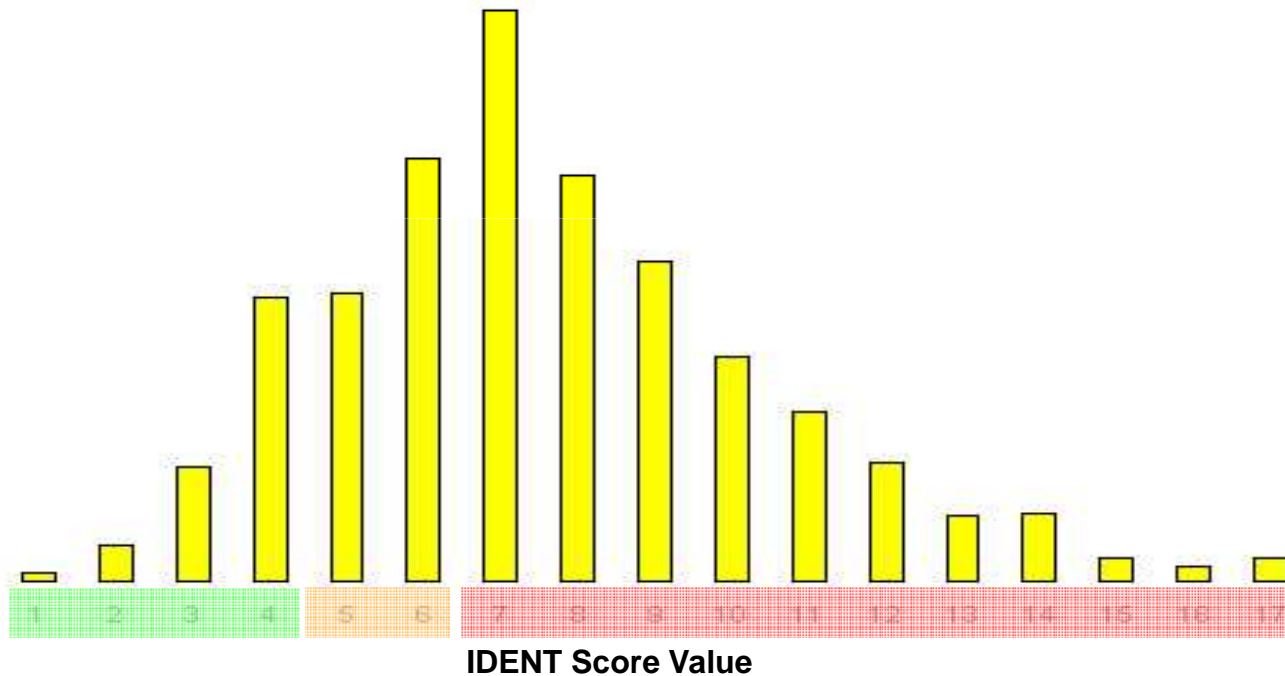
Approximately 10% of images in the study are NFIQ=3

Desired Characteristics of a Fingerprint Image Quality Algorithm and its Score Range

§ **High Scale Resolution**
e.g., [0, …, 100] scale range

§ Easier to map between quality algorithms

§ ANSI/NIST-ITL 1-2007

§ **Linear and Uniform Scale**

Score difference could indicate both machine matching and human examiner inspection difference in linear and uniform scale
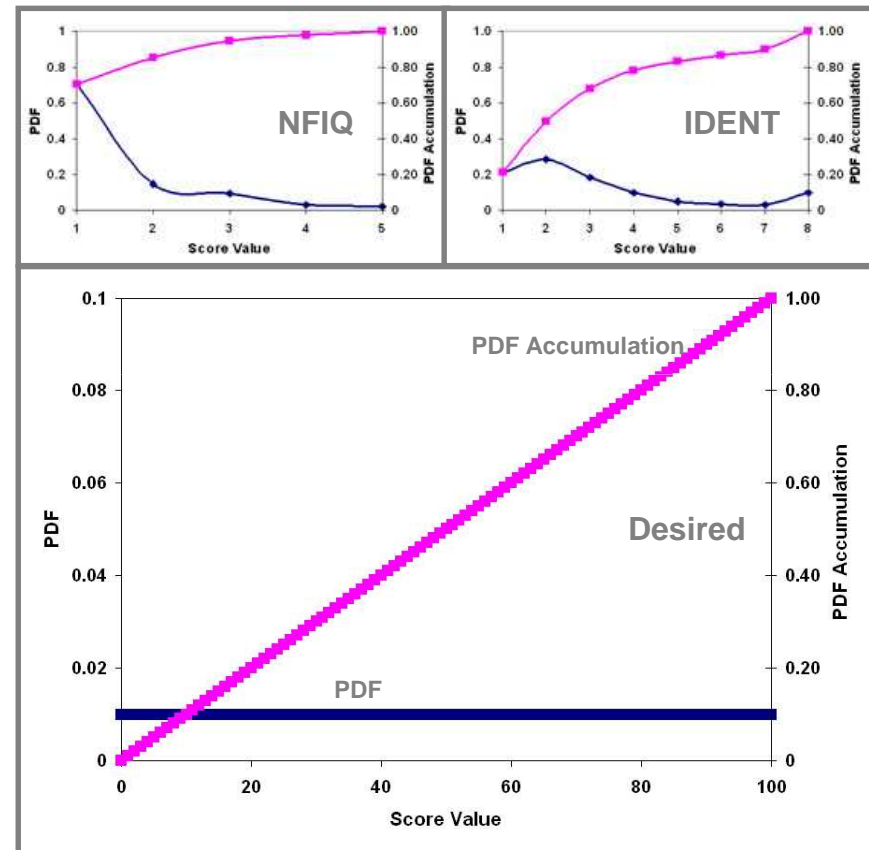
Summary

§ **In US-VISIT Fingerprint Quality Scores are primarily used for Fingerprint Recapture and Updating Prints on Matchers**

§ **Currently integrating NFIQ into the IDENT system**

§ **Challenges have been encountered when attempting to correlate scores**

§ **More distinct quality levels will improve ability to correlate different quality algorithm scores**

§ **Additional work is required for achieving interoperability of quality measures**
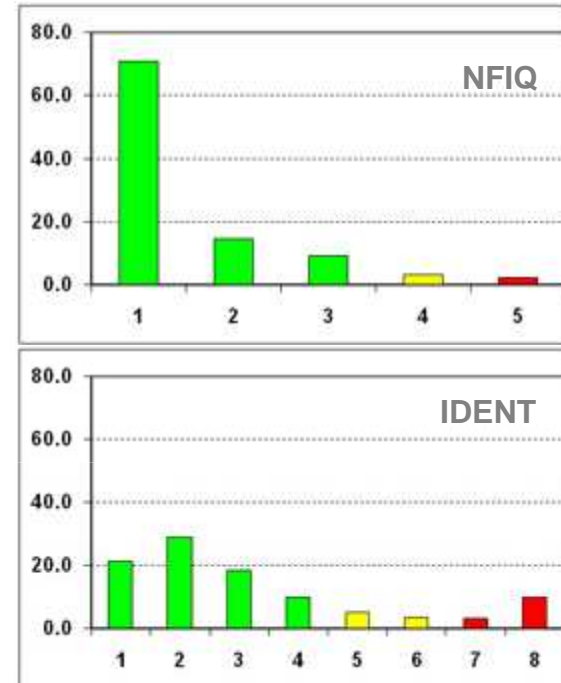
Comments or Questions?

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