Ongoing MINEX Report Card

Matcher B

National Institute of Standards and Technology
U.S. Department of Commerce

Last Updated: October 9, 2015

Note: This report card is for MINEX III compliance criteria only. Ongoing MINEX never released report cards, but instead published two tables: one for all participants and one for compliant participants.

This report card shows results for an algorithm originally submitted to Ongoing MINEX being re-evaluated based on the MINEX III compliance criteria. If this report says that an algorithm has failed, it means that the algorithm did not meet the MINEX III compliance criteria and will not be included on the MINEX III Compliant Submissions list. For historical records, the old Ongoing MINEX Compliant Submissions list is still available.

Ongoing MINEX tested for compliance of NIST Special Publication 800-76-1, which was withdrawn July 2013. MINEX III tested for compliance of NIST Special Publication 800-76-2, and added additional semantic checks for compliance of ANSI/INCITS 378-2004.

Participant Details

Company: Dermalog Identification Systems GMBH
Date Submitted: 2/1/2005
Date Validated: 3/15/2005
Date Completed: 3/21/2006

Library	Size (bytes)	MD5 Checksum
DermalogMinEx04.dll	5193728	5a53ab6e7a109208986aa4179f6c75d2
DermalogMinEx04_GCC.lib	4580	866cd0dd8230385eae31aa5eb70154d9

NOTE: NIST plans to decertify Windows-based libraries in MINEX III.

Compliance Test Results

The following presents **PIV compliance** results per the criteria detailed in NIST Special Publication 800-76-2: Biometric Specifications for Personal Identity Verification.

PIV Level One: FAIL

- Must match templates from all certified template generators with an $\text{FNMR}_{\text{FMR}}(0.01) \leq 0.01$ using two fingers (4.5.2.1-4). ✗ *(See Table 5)*

PIV Level Two: FAIL

- Must pass PIV level one compliance. ✗
- Native template generator must pass level one compliance. ✓
- Must match templates from native template generator with an $\text{FNMR}_{\text{FMR}}(0.0001) \leq 0.02$ using one finger (4.5.3-2) ✗

Notes

- This report will be updated as new matching algorithms and template generators pass the compliance test. These updates will not change the PASS/FAIL decision above.
- NIST reserves the right to decertify a matcher if it later discovers the matcher violates PIV specifications in some previously undetected way.

Contents

List of Figures

List of Tables

1 Introduction

This report card presents measurements of performance and interoperability for a single fingerprint matching algorithm submitted to NIST as part of the ongoing MINEX Evaluation. It reports whether the matcher passes the technical requirements for PIV-compliance described in the NIST Special Publication 800-76-2: Biometric Specifications for Personal Identity Verification.

2 Methodology

Testing is performed at a NIST facility. Each participant's submission is validated by NIST (http://www.nist.gov/itl/iad/ig/ominex.cfm) before undergoing full testing to ensure it operates correctly. If the matcher passes the validation procedure, it is then used to compare standard fingerprint templates. Performance is assessed against templates created by a template generation algorithm submitted by the participant as well as templates created by other compliant template generators.

2.1 Dataset

Testing is performed over a single dataset of sequestered fingerprint images. The images were collected by U.S. Visit at ports of entry into the United States. They consist of Live-scan plain impressions of left and right index fingers. WSQ [1] compression was applied to all images at a ratio of 15:1. The most recent capture of each subject was treated as the authentication sample, and the next most recent as the enrolled sample.

The dataset was divided into 123 962 mated and 124 994 non-mated subject pairings. Since both left and right index fingerprints are available for each subject, this provides 247 924 mated and 249 988 nonmated single-finger comparisons (after database consolidation). This also means that when left and right index fingers are fused at the score level [2, 6], the sets condense to 123 962 mated and 124 994 nonmated comparison scores.

2.2 Accuracy Metrics

Core matching accuracy is presented in the form of Detection Error Tradeoff (DET) plots [5], which show the trade-off between the False Match Rate (FMR) and the False Non-Match Rate (FNMR) as a decision threshold is adjusted. Formally, let m_i $(i = 1 \dots M)$ be the ith mated comparison score, and n_j $(j = 1 \dots N)$ the jth non-mated comparison score. Then the statistics are

$$\text{FNMR}(\tau) = \frac{1}{M}\sum_{i=1}^{M} \mathbb{1}\{m_i < \tau\}, \tag{1}$$

$$\text{FMR}(\tau) = \frac{1}{N}\sum_{j=1}^{N} \mathbb{1}\{n_j \geq \tau\}. \tag{2}$$

where $\mathbb{1}\{A\}$ is the indicator [3] of event A. Equations 1 and 2 define the curve parametrically with the decision threshold, τ, as the free parameter. In some figures and tables, FNMR is presented as a function of FMR. This relationship is determined by

$$\text{FNMR}_{\text{FMR}}(\alpha) = \min_{\tau} \{ \text{FNMR}(\tau) \mid \text{FMR}(\tau) \leq \alpha \}, \tag{3}$$

which reads as the smallest FNMR that can be achieved while maintaining an FMR less than or equal to α, the targeted FMR. This method of relating the two error statistics ensures FNMR is well-defined for all $0 \leq \alpha \leq 1$. When the matching algorithm produces only a few unique comparison scores, the maximum threshold, τ_0, that elicits an $\text{FMR}(\tau_0) \leq \alpha$ may, in fact, be quite a bit lower than α. Thus, Equation 3 imposes a natural penalty on matching algorithms that produce overly discretized scores.

Some figures show *pooled* DET accuracy, which is a measure of the accuracy of the matcher against all compliant template generators. Accuracy is measured by concatenating all comparison scores involving the matcher together and computing FMR and FNMR using Equations 2 and 1. This roughly simulates performance for a biometric system that employs one matcher and templates created by several template generators.

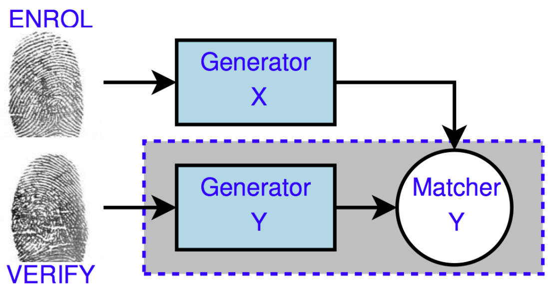

Figure 1: MINEX Interoperability Test Setup

2.3 Interoperability

Interoperability is tested in a manner similar to *Scenario 1* from the MINEX Evaluation Report [4] (see Figure 1). An enrolment template is prepared using submission X. Submission Y is used to prepare the authentication template and perform the match. The authentication template is always prepared by the same submission used to compare the templates. However, enrolment templates need not originate from the same submission. When they do, we refer to it as ”native” mode.

3 Results

This section details the performance of matcher B when it compares verification templates created by its own template generator to enrolment templates created by all MINEX compliant template generators. Sections 3.1 and 3.2 present accuracy results for single finger and two finger matching respectively. Sections 3.3 and 3.4 present potentially useful statistics not directly related to the performance of the matcher.

3.1 Single Finger

Singe finger comparison results show the combined results for left and right index comparisons. For reference, *NIST Special Publication 800-76-2* requires that the matcher and template generator achieve a native accuracy of $\text{FNMR}_{\text{FMR}}(0.0001) \leq 0.02$.

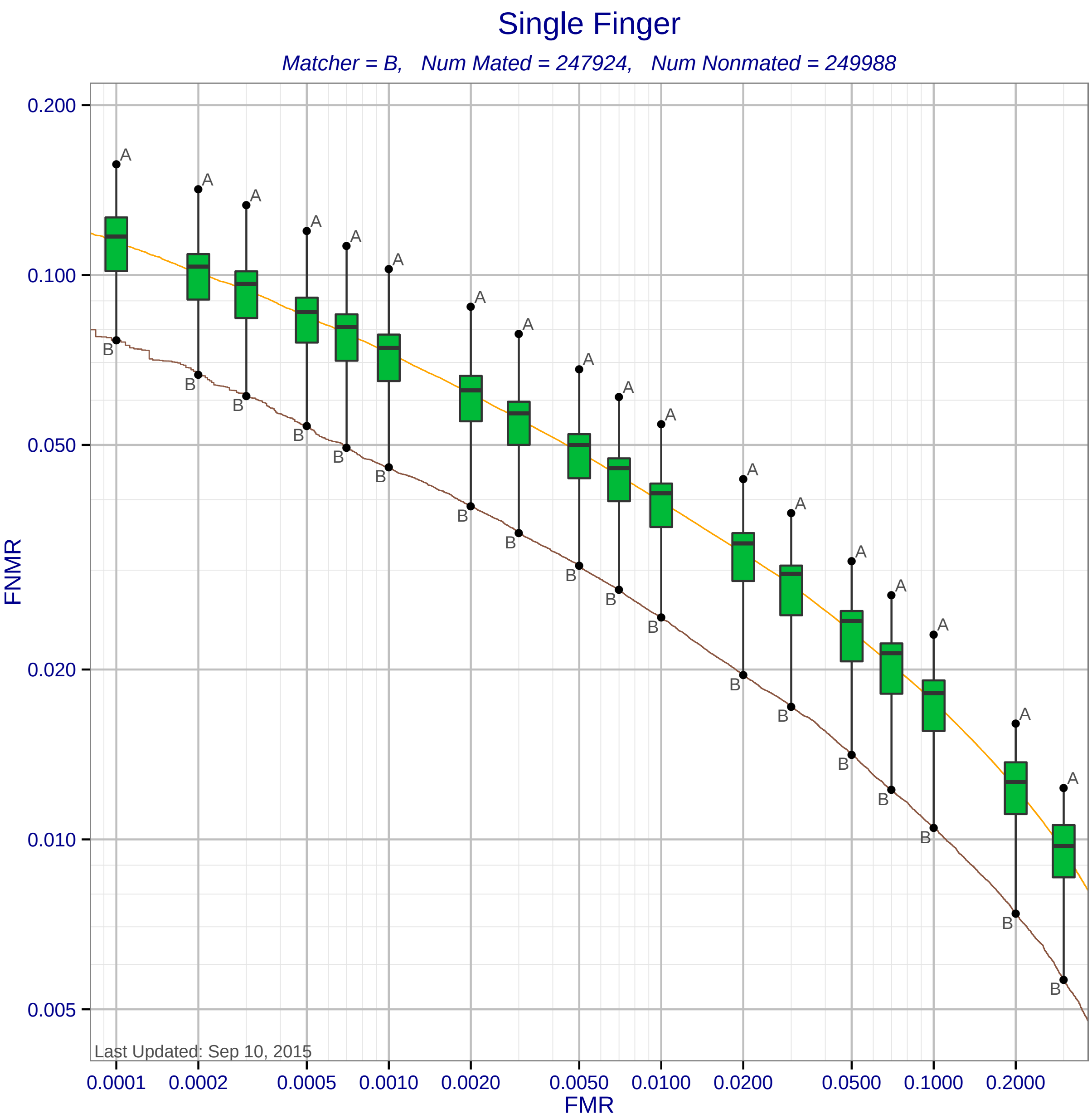

Figure 2: *Single finger DET statistics for matcher B. Each box shows the distribution of FNMRs at a fixed FMR across all MINEX compliant template generators. The ends of the whiskers show the minimum and maximum FNMRs. The orange DET curve shows pooled performance against all template generators.*

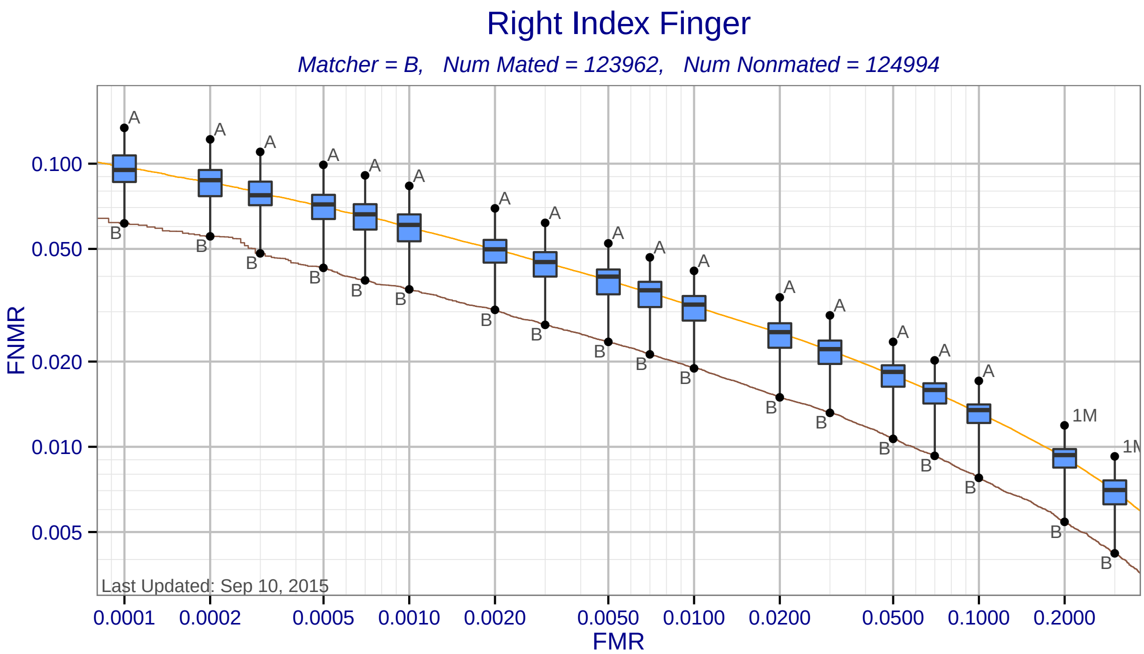

Figure 3: *Right index finger DET statistics for matcher B. Each box shows the distribution of FNMR at a fixed FMR across all MINEX compliant template generators. The ends of the whiskers show the minimum and maximum FNMRs. The orange DET curve shows pooled performance against all template generators.*

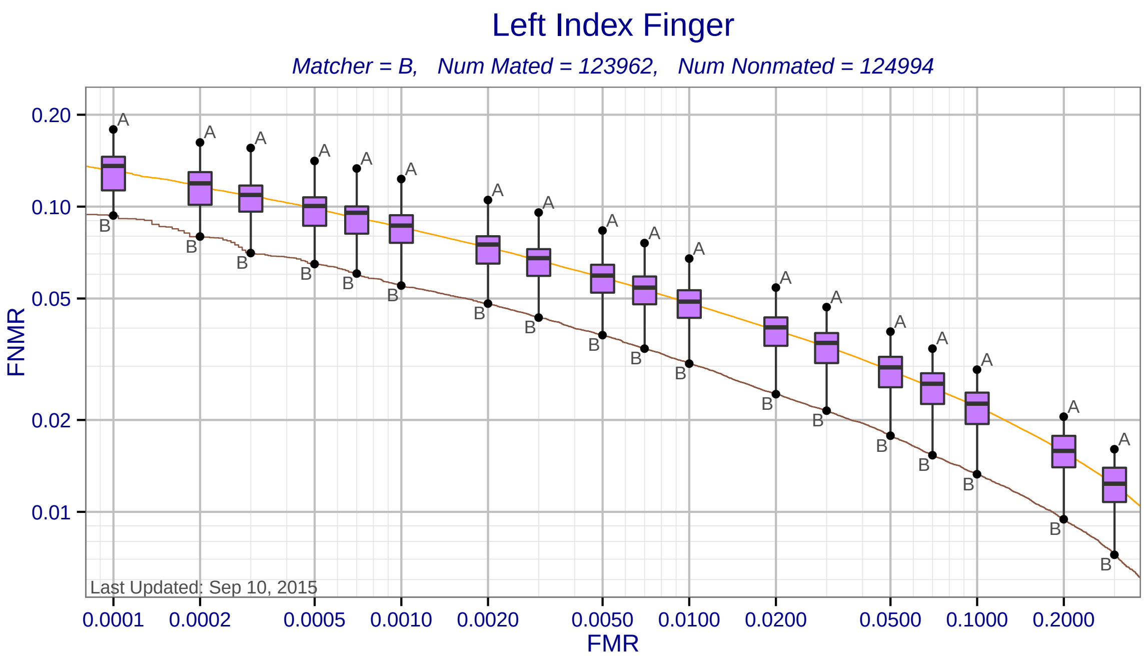

Figure 4: *Left index finger DET statistics for matcher B. Each box shows the distribution of FNMRs at a fixed FMR across all MINEX compliant template generators. The ends of whiskers show the minimum and maximum FNMRs. The orange DET curve shows pooled performance against all template generators.*

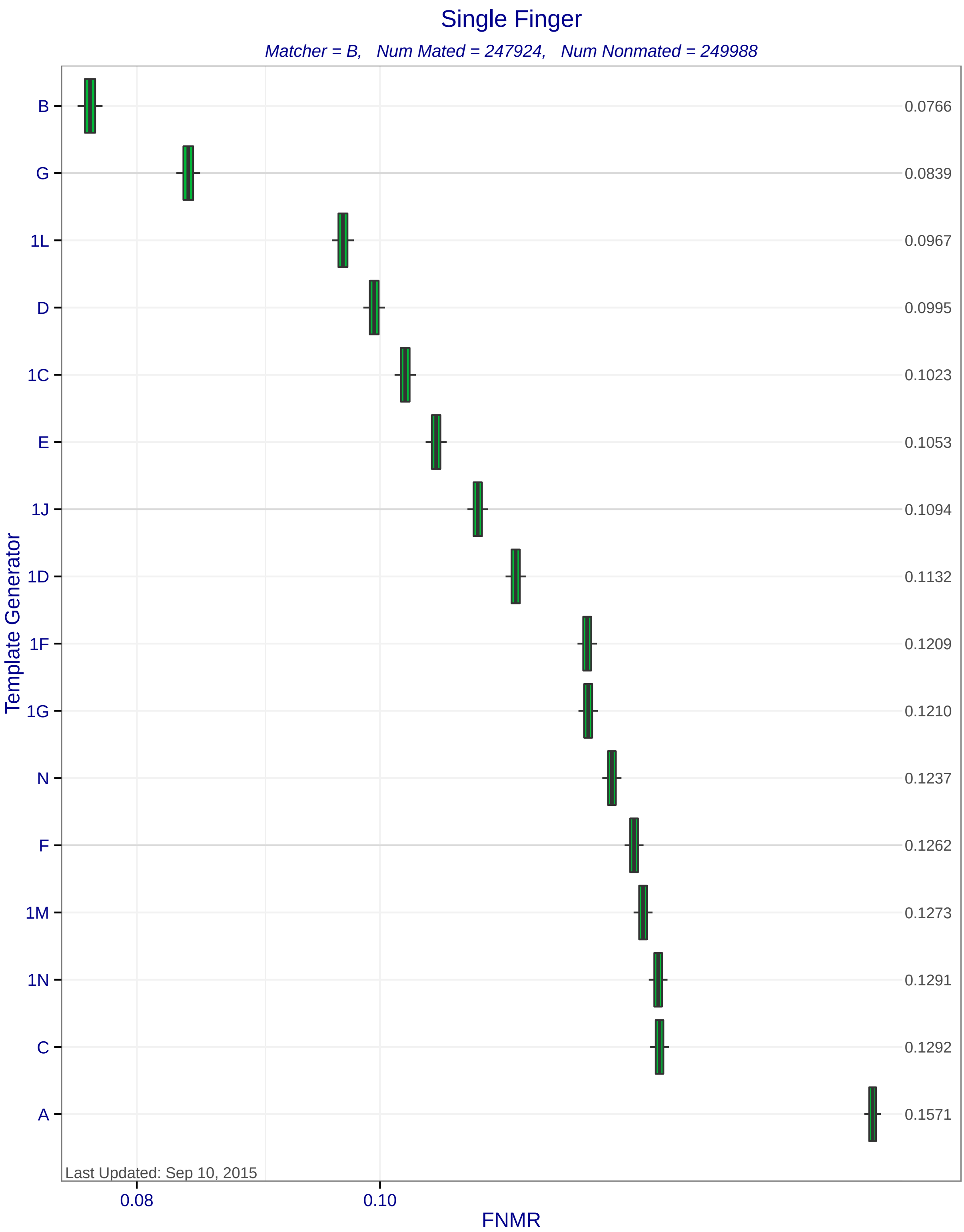

Figure 5: *Single finger FNMRs at FMR = 0.0001 when matcher B compares templates created by different template generators. The ends of the whiskers show the minimum and maximum FNMRs. Each box represents uncertainty about the true FNMR. The box edges mark the 50% confidence intervals while the whiskers mark the 90% confindence intervals. The numbers on the right show the actual computed FNMRs.*

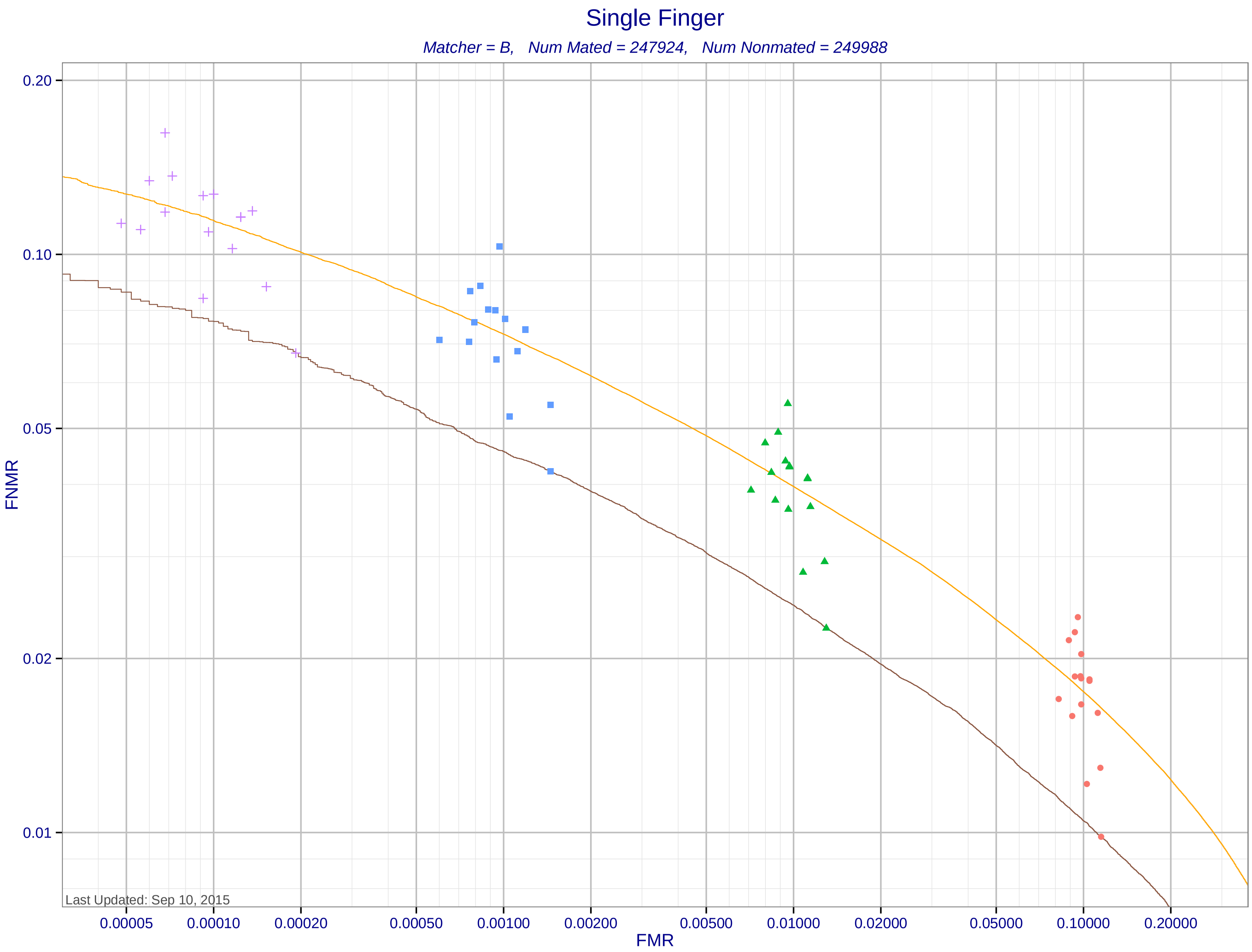

Figure 6: *Single finger DET accuracy for matcher B. Each cluster of points represents the variation in FMR and FNMR across MINEX compliant template generators at a fixed decision threshold. Each point corresponds to an (FMR, FNMR) pair for a specific template generator at a particular decision threshold. Four clusters are produced corresponding to four decision thresholds which produce pooled FMRs of* 10^{-1}, 10^{-2}, 10^{-3}, *and* 10^{-4}. *The orange DET curve shows pooled performance against all template generators.*

3.2 Two Finger

This section presents accuracy when matcher B compares templates created by all MINEX compliant template generators. Two-finger fusion is achieved by averaging the scores for left and right index fingers for each person. *NIST Special Publication 800-76-2* requires the matcher to achieve an accuracy of $\text{FNMR}_{\text{FMR}}(0.01) \leq 0.01$ for all MINEX compliant template generators.

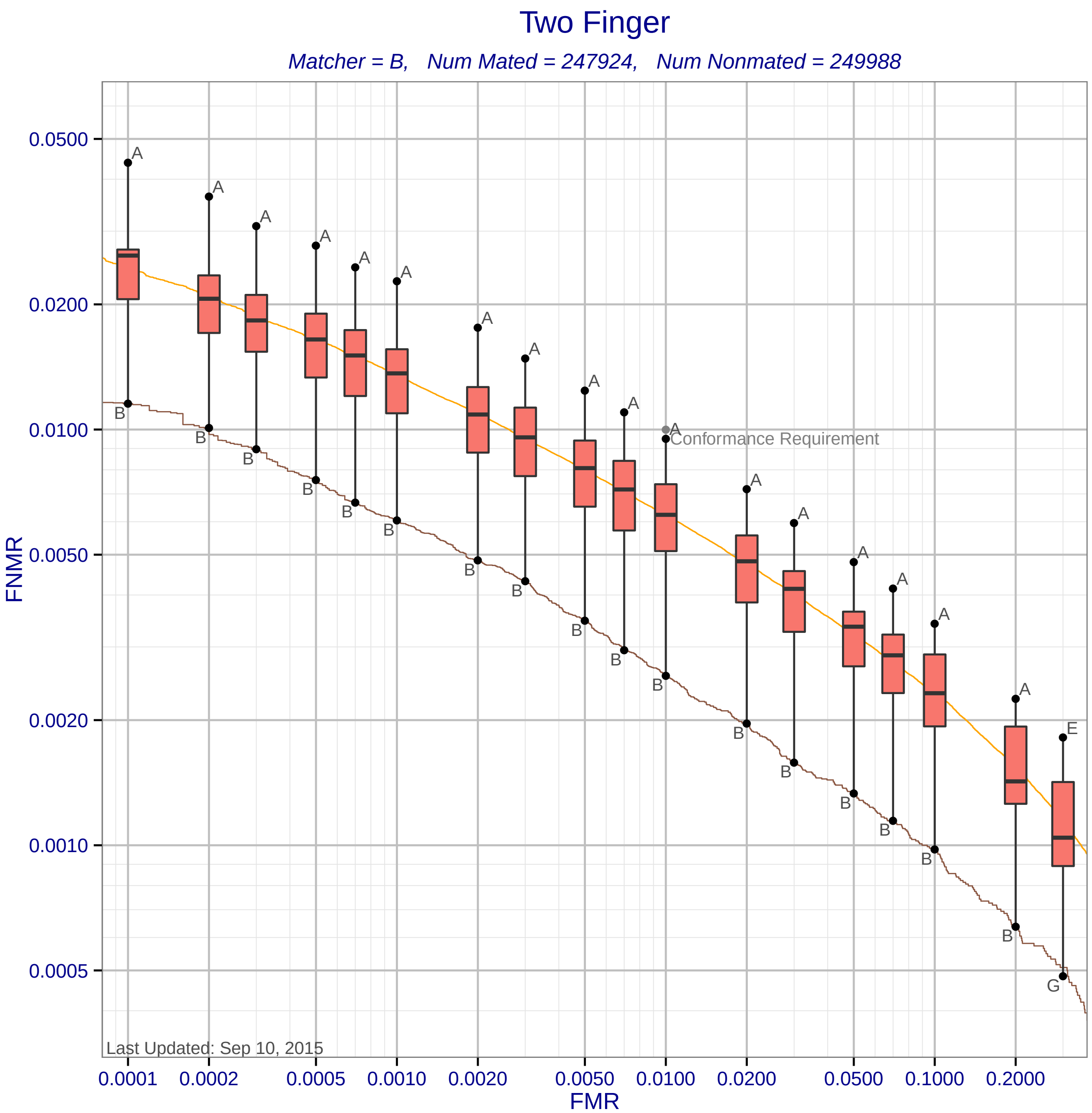

Figure 7: *Two finger DET statistics for matcher B. Each box shows the distribution of FNMRs at a fixed FMR across all MINEX compliant template generators. The whisker ends show the minimum and maximum FNMRs. The orange DET curve shows pooled performance against all template generators. Score-level fusion is achieved by averaging the scores for left and right index fingers.*

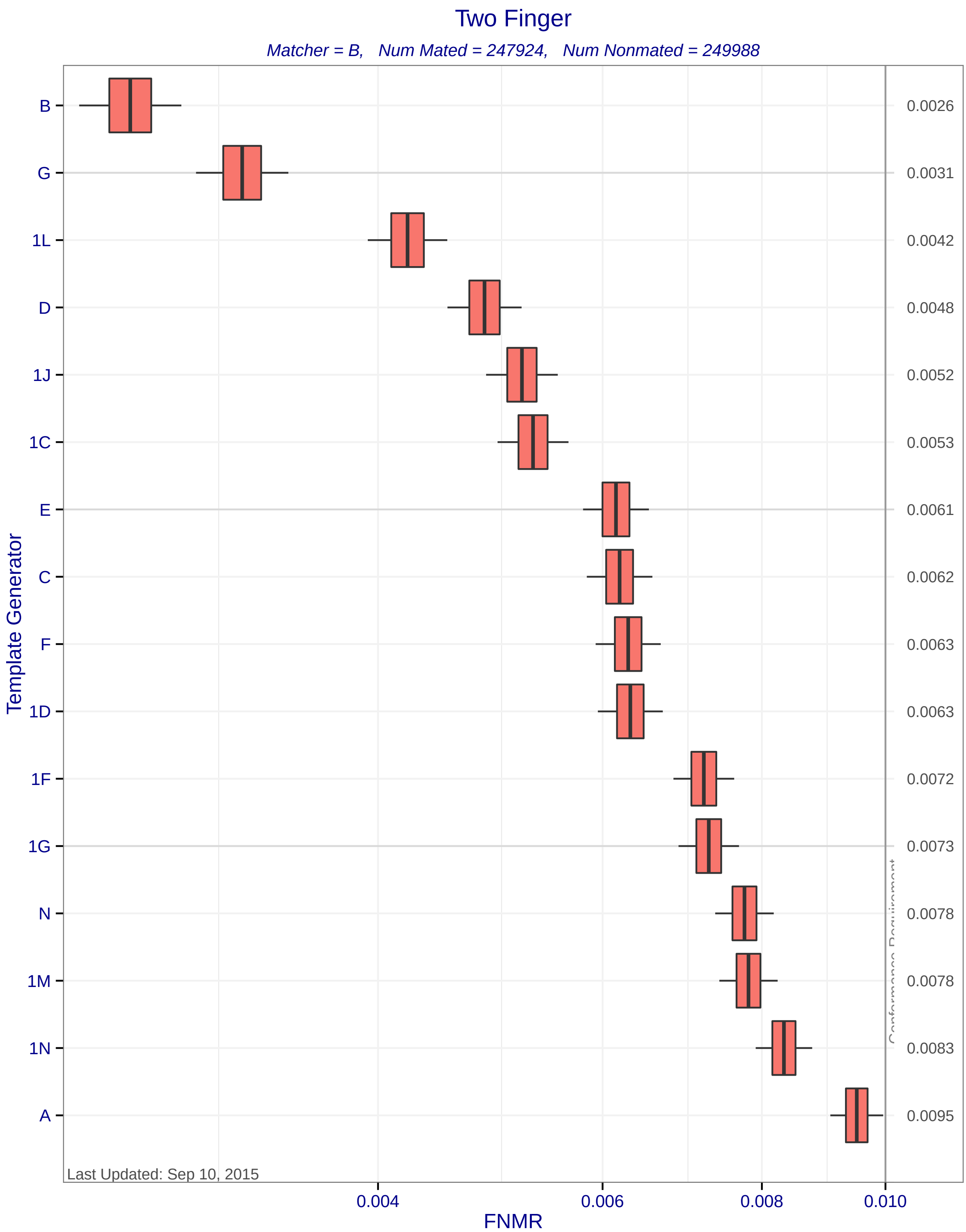

Figure 8: *Two finger FNMR at FMR=0.01 when matcher B compares templates created by different template generators. Each box represents uncertainty about the true FNMR. The box edges mark the 50% confidence intervals while the whiskers mark the 90% confindence intervals. The numbers on the right show the actual computed FNMRs. Score-level fusion is achieved by averaging the scores for left and right index fingers.*

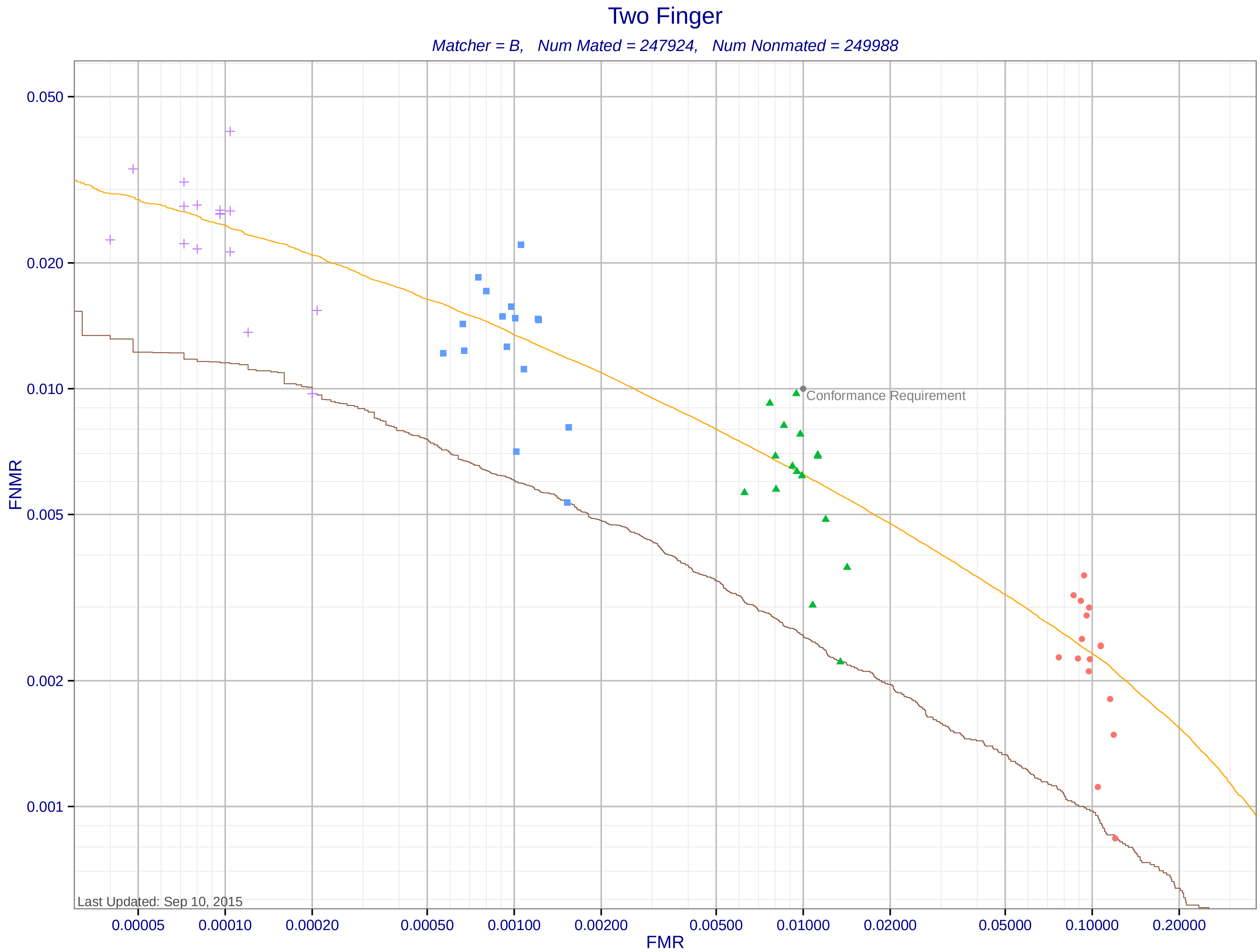

Figure 9: *Two finger DET accuracy for matcher B. Each cluster of points represents the variation in FMR and FNMR across MINEX compliant template generators at a fixed decision threshold. Each point corresponds to an (FMR, FNMR) pair for a specific template generator at a particular decision threshold. Four clusters are produced corresponding to four decision thresholds which produce pooled FMRs of 10^{-1}, 10^{-2}, 10^{-3}, and 10^{-4}. The orange DET curve shows pooled performance against all template generators. Score-level fusion is achieved by averaging the scores for left and right index fingers.*

3.3 Threshold Statistics

Results in this section are computed by concatenating comparison scores for matcher B across all MINEX compliant template generators.

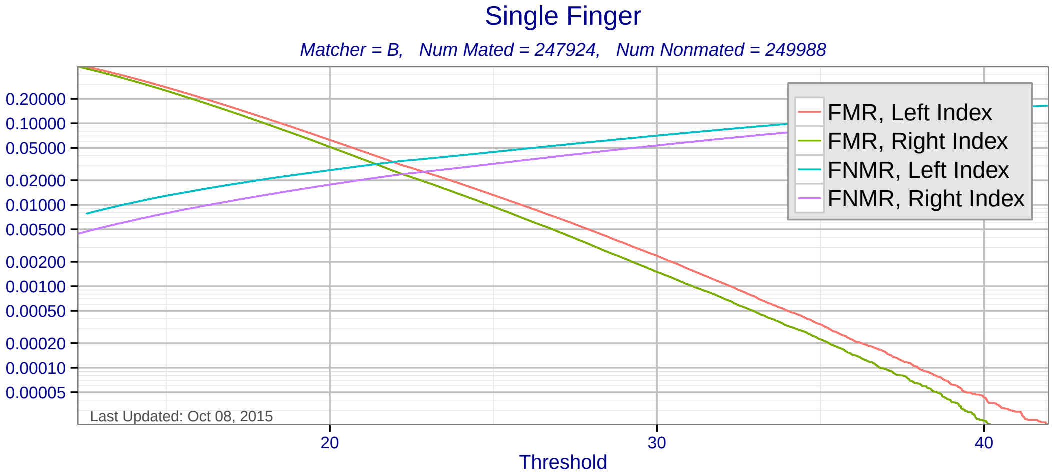

Figure 10: *Single finger FMR and FNMR as a function of score threshold for matcher B using templates created by all MINEX compliant template generators. Separate curves are presented for left and right index fingers.*

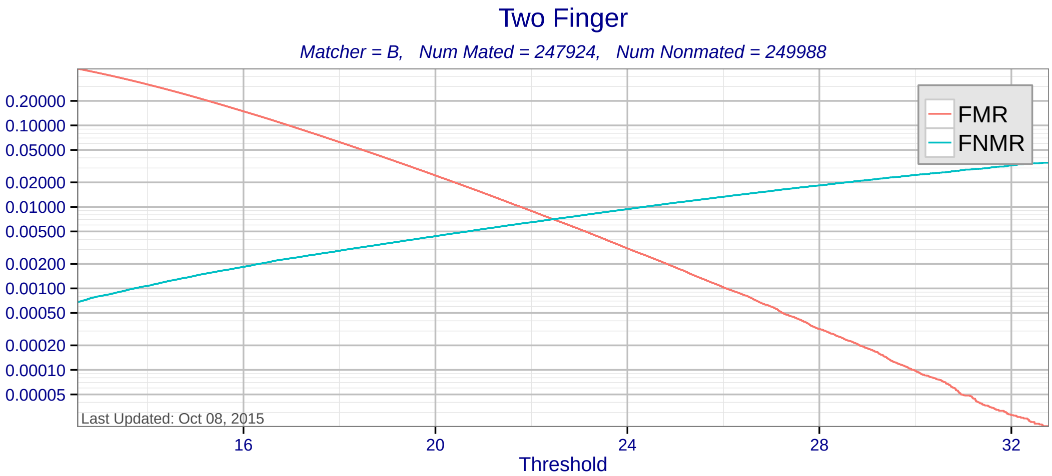

Figure 11: *Two finger FMR and FNMR as a function of score threshold for matcher B using templates created by all MINEX compliant template generators. Score-level fusion is achieved by averaging scores for the left and right index fingers.*

	FMR=0.1	FMR=0.01	FMR=0.001	FMR=0.0001
Right index finger	18.037	24.877	31.109	36.826
Left index finger	18.538	25.881	32.271	37.982
Single finger	18.288	25.400	31.767	37.489
Two finger	16.964	21.794	26.069	29.972

Table 1: *Threshold calibration table. The cells show the thresholds corresponding to the FMR indicated by the column header.*

3.4 Q-Q Plot

The Q-Q plot compares two probability distributions. It plots the quantile of one distribution as a function of the other. If the curve follows the $y = x$ line, then the distributions are identical. If the FMR curve is above the $y = x$ line, then the left index finger tends to produce lower non-mated scores than the left index finger. If the FNMR curve is above the $y = x$ line, then the left index finger tends to produce lower mated scores than the left index finger. A jagged and/or truncated cur ve is indicative of discretized scores.

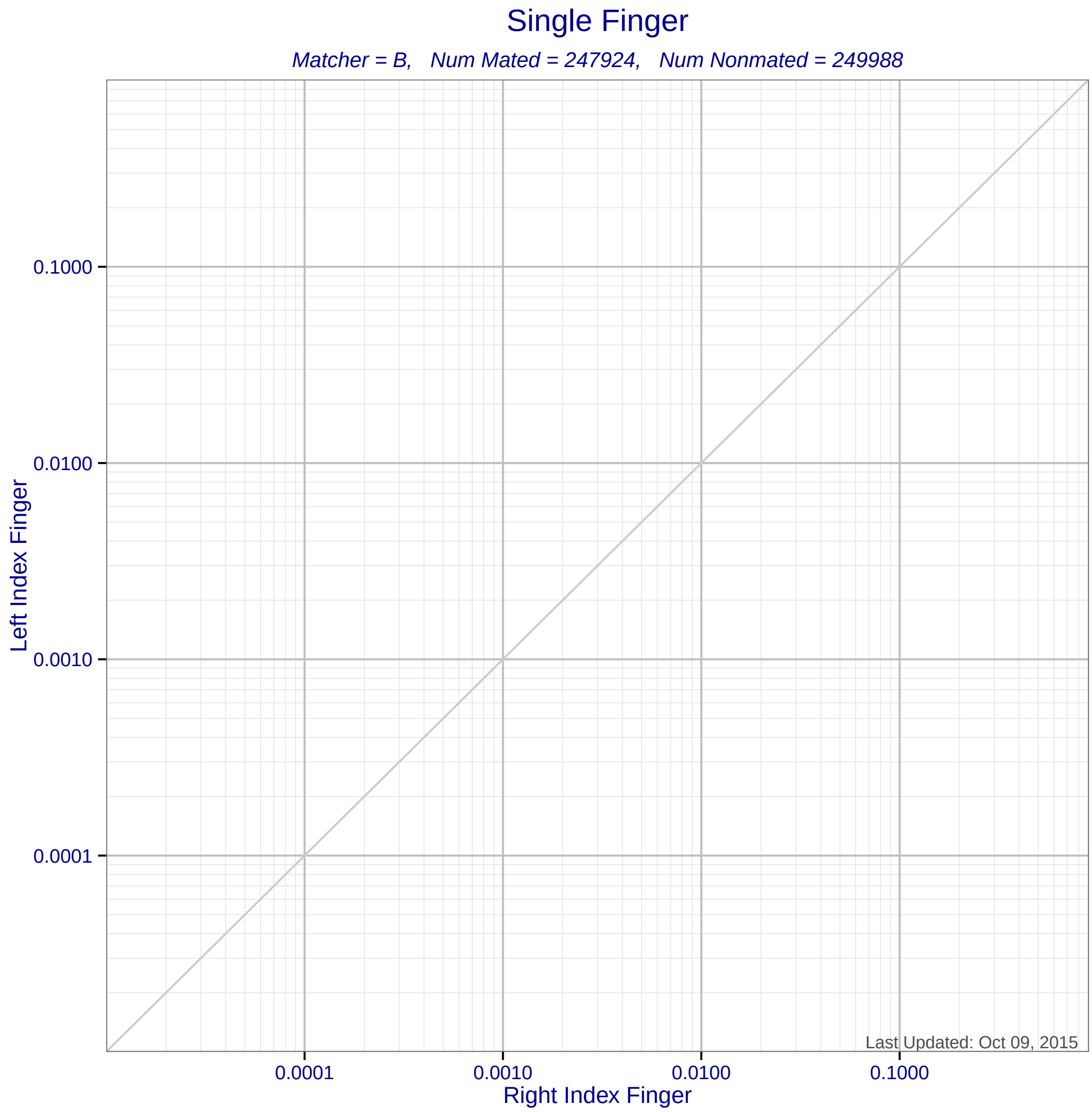

Figure 12: *Q-Q plot comparing score distributions for left and right index fingers.*

3.5 Minutiae Count Statistics

This section shows how the number of minutia found in the samples affects recognition accuracy. To be robust to spoofing and other active attacks, the algorithm should not allow FMR to rise sharply as the number of available minutia decreases. Nor should it allow FMR to rise sharply as the number of detected minutia increases.

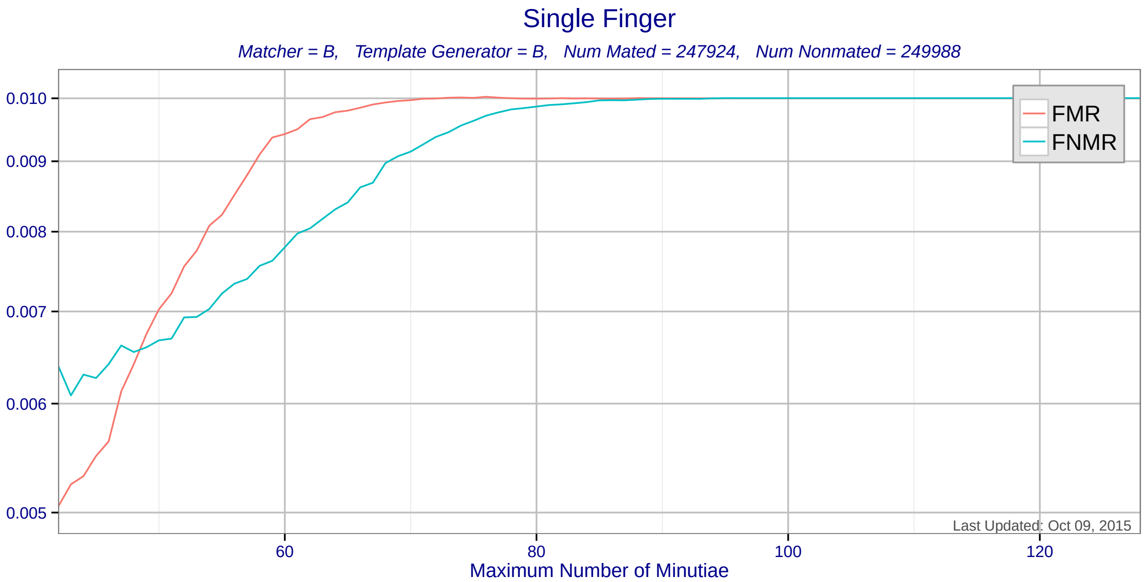

Figure 13: *FNMR and FMR as a function of the number of minutia found by the template generator. The vertical axis defines a filter criterion such that FNMR and FMR are computed over only those comparisons where at least one of the compared templates has* no more *than the specified number of minutia. The threshold is fixed separately for FNMR and FMR to elicit an error rate of approximately 0.01 over unfiltered comparisons.*

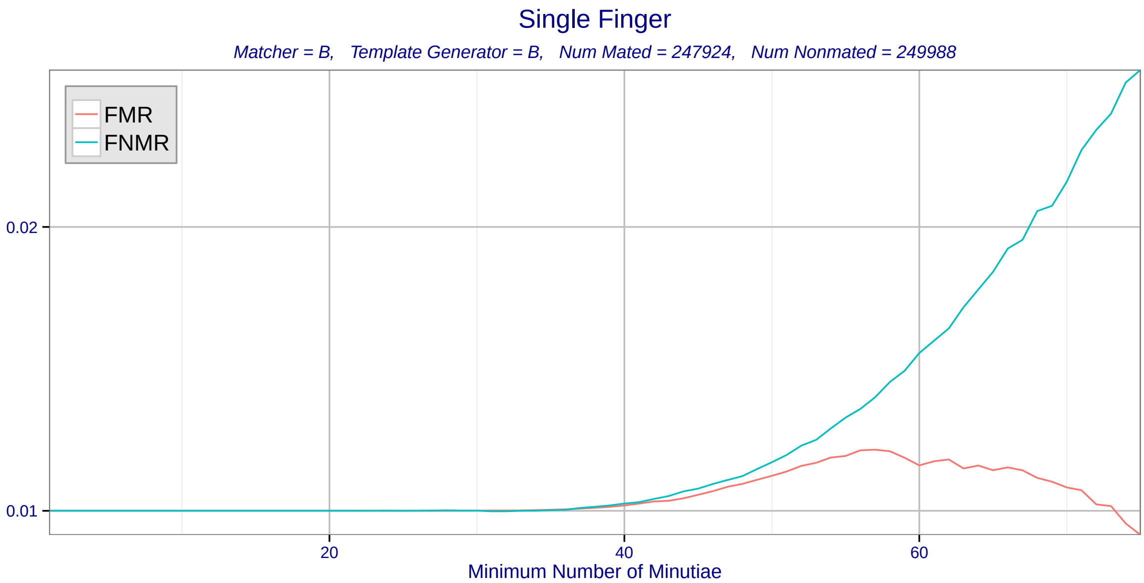

Figure 14: *FNMR and FMR as a function of the number of minutia found by the template generator. The vertical axis defines a filter criterion such that FNMR and FMR are computed over only those comparisons where at least one of the compared templates has* at least *the indicated number of minutia. The threshold is fixed separately for FNMR and FMR to elicit an error rate of approximately 0.01 over unfiltered comparisons.*

4 Performance Tables

The following tables present accuracy number, including estimates of uncertainty in the form of 90% confidence bounds. These tables are provided because most of the figures in the main body of this report do not present numerical results.

Table 2: *Single finger FNMRs at various FMRs when matcher B compares templates created by its template generator and PIV-compliant template generators.*

Enroller	FNMR @ FMR=0.01	FNMR @ FMR=0.001	FNMR @ FMR=0.0001
A	0.0544 ± 0.0007	0.103 ± 0.001	0.157 ± 0.001
B	0.0247 ± 0.0005	0.0456 ± 0.0007	0.0766 ± 0.0009
C	0.0426 ± 0.0007	0.0783 ± 0.0009	0.129 ± 0.001
D	0.0356 ± 0.0006	0.0638 ± 0.0008	0.0995 ± 0.0010
E	0.0358 ± 0.0006	0.0652 ± 0.0008	0.105 ± 0.001
F	0.0424 ± 0.0007	0.0787 ± 0.0009	0.126 ± 0.001
G	0.0289 ± 0.0006	0.0532 ± 0.0007	0.0839 ± 0.0009
N	0.0431 ± 0.0007	0.0777 ± 0.0009	0.124 ± 0.001
1C	0.0359 ± 0.0006	0.0666 ± 0.0008	0.102 ± 0.001
1D	0.0399 ± 0.0006	0.0716 ± 0.0009	0.113 ± 0.001
1F	0.0422 ± 0.0007	0.0770 ± 0.0009	0.121 ± 0.001
1G	0.0424 ± 0.0007	0.0771 ± 0.0009	0.121 ± 0.001
1J	0.0381 ± 0.0006	0.0699 ± 0.0008	0.109 ± 0.001
1L	0.0318 ± 0.0006	0.0602 ± 0.0008	0.0967 ± 0.0010
1M	0.0475 ± 0.0007	0.0838 ± 0.0009	0.127 ± 0.001
1N	0.0442 ± 0.0007	0.0822 ± 0.0009	0.129 ± 0.001
1T	–	–	–
1Y	–	–	–
2A	–	–	–
2C	–	–	–
2D	–	–	–
2F	–	–	–
2G	–	–	–
2I	–	–	–
2J	–	–	–
2K	–	–	–
2L	–	–	–
2M	–	–	–
2N	–	–	–
2O	–	–	–
2P	–	–	–
2Q	–	–	–
2R	–	–	–
2S	–	–	–
2T	–	–	–
2W	–	–	–
2Y	–	–	–
3A	–	–	–
3B	–	–	–
3D	–	–	–

Table 2: *(continued)*

Enroller	FNMR @ FMR=0.01	FNMR @ FMR=0.001	FNMR @ FMR=0.0001
3F	–	–	–
3G	–	–	–
3H	–	–	–
3M	–	–	–
3N	–	–	–
3O	–	–	–
3Q	–	–	–
3S	–	–	–
3T	–	–	–
3V	–	–	–
3W	–	–	–
3Z	–	–	–
4C	–	–	–
4F	–	–	–
4K	–	–	–
4L	–	–	–
4M	–	–	–
4N	–	–	–
4O	–	–	–
4Q	–	–	–
4S	–	–	–
4T	–	–	–
4U	–	–	–
4W	–	–	–
4X	–	–	–
4Z	–	–	–

Table 3: *Right index finger FNMRs at various FMRs when matcher B compares templates created by its template generator and PIV-compliant template generators.*

Enroller	FNMR @ FMR=0.01	FNMR @ FMR=0.001	FNMR @ FMR=0.0001
A	0.0418 ± 0.0009	0.083 ± 0.001	0.134 ± 0.002
B	0.0189 ± 0.0006	0.0360 ± 0.0009	0.062 ± 0.001
C	0.0343 ± 0.0008	0.067 ± 0.001	0.105 ± 0.001
D	0.0271 ± 0.0008	0.052 ± 0.001	0.082 ± 0.001
E	0.0282 ± 0.0008	0.054 ± 0.001	0.091 ± 0.001
F	0.0340 ± 0.0008	0.066 ± 0.001	0.106 ± 0.001
G	0.0225 ± 0.0007	0.0425 ± 0.0009	0.073 ± 0.001
N	0.0328 ± 0.0008	0.061 ± 0.001	0.106 ± 0.001
1C	0.0303 ± 0.0008	0.058 ± 0.001	0.088 ± 0.001
1D	0.0334 ± 0.0008	0.062 ± 0.001	0.109 ± 0.001
1F	0.0317 ± 0.0008	0.061 ± 0.001	0.095 ± 0.001
1G	0.0318 ± 0.0008	0.061 ± 0.001	0.095 ± 0.001
1J	0.0294 ± 0.0008	0.057 ± 0.001	0.088 ± 0.001
1L	0.0242 ± 0.0007	0.0476 ± 0.0010	0.082 ± 0.001
1M	0.0392 ± 0.0009	0.073 ± 0.001	0.114 ± 0.001
1N	0.0363 ± 0.0009	0.070 ± 0.001	0.112 ± 0.001
1T	–	–	–
1Y	–	–	–
2A	–	–	–
2C	–	–	–
2D	–	–	–
2F	–	–	–
2G	–	–	–
2I	–	–	–
2J	–	–	–
2K	–	–	–
2L	–	–	–
2M	–	–	–
2N	–	–	–
2O	–	–	–
2P	–	–	–
2Q	–	–	–
2R	–	–	–
2S	–	–	–
2T	–	–	–
2W	–	–	–
2Y	–	–	–
3A	–	–	–
3B	–	–	–
3D	–	–	–

Table 3: *(continued)*

Enroller	FNMR @ FMR=0.01	FNMR @ FMR=0.001	FNMR @ FMR=0.0001
3F	–	–	–
3G	–	–	–
3H	–	–	–
3M	–	–	–
3N	–	–	–
3O	–	–	–
3Q	–	–	–
3S	–	–	–
3T	–	–	–
3V	–	–	–
3W	–	–	–
3Z	–	–	–
4C	–	–	–
4F	–	–	–
4K	–	–	–
4L	–	–	–
4M	–	–	–
4N	–	–	–
4O	–	–	–
4Q	–	–	–
4S	–	–	–
4T	–	–	–
4U	–	–	–
4W	–	–	–
4X	–	–	–
4Z	–	–	–

Table 4: *Left index finger FNMRs at various FMRs when matcher B compares templates created by its template generator and PIV-compliant template generators.*

Enroller	FNMR @ FMR=0.01	FNMR @ FMR=0.001	FNMR @ FMR=0.0001
A	0.068 ± 0.001	0.123 ± 0.002	0.179 ± 0.002
B	0.0306 ± 0.0008	0.055 ± 0.001	0.093 ± 0.001
C	0.051 ± 0.001	0.090 ± 0.001	0.145 ± 0.002
D	0.0439 ± 0.0010	0.077 ± 0.001	0.113 ± 0.001
E	0.0438 ± 0.0010	0.077 ± 0.001	0.118 ± 0.002
F	0.051 ± 0.001	0.091 ± 0.001	0.146 ± 0.002
G	0.0356 ± 0.0009	0.064 ± 0.001	0.097 ± 0.001
N	0.054 ± 0.001	0.094 ± 0.001	0.142 ± 0.002
1C	0.0416 ± 0.0009	0.074 ± 0.001	0.112 ± 0.001
1D	0.0464 ± 0.0010	0.082 ± 0.001	0.119 ± 0.002
1F	0.053 ± 0.001	0.094 ± 0.001	0.146 ± 0.002
1G	0.053 ± 0.001	0.094 ± 0.001	0.146 ± 0.002
1J	0.0469 ± 0.0010	0.083 ± 0.001	0.130 ± 0.002
1L	0.0393 ± 0.0009	0.072 ± 0.001	0.109 ± 0.001
1M	0.056 ± 0.001	0.095 ± 0.001	0.148 ± 0.002
1N	0.053 ± 0.001	0.094 ± 0.001	0.145 ± 0.002
1T	–	–	–
1Y	–	–	–
2A	–	–	–
2C	–	–	–
2D	–	–	–
2F	–	–	–
2G	–	–	–
2I	–	–	–
2J	–	–	–
2K	–	–	–
2L	–	–	–
2M	–	–	–
2N	–	–	–
2O	–	–	–
2P	–	–	–
2Q	–	–	–
2R	–	–	–
2S	–	–	–
2T	–	–	–
2W	–	–	–
2Y	–	–	–
3A	–	–	–
3B	–	–	–
3D	–	–	–

Table 4: *(continued)*

Enroller	FNMR @ FMR=0.01	FNMR @ FMR=0.001	FNMR @ FMR=0.0001
3F	–	–	–
3G	–	–	–
3H	–	–	–
3M	–	–	–
3N	–	–	–
3O	–	–	–
3Q	–	–	–
3S	–	–	–
3T	–	–	–
3V	–	–	–
3W	–	–	–
3Z	–	–	–
4C	–	–	–
4F	–	–	–
4K	–	–	–
4L	–	–	–
4M	–	–	–
4N	–	–	–
4O	–	–	–
4Q	–	–	–
4S	–	–	–
4T	–	–	–
4U	–	–	–
4W	–	–	–
4X	–	–	–
4Z	–	–	–

Table 5: *Two finger FNMRs at various FMRs when matcher B compares templates created by its template generator and PIV-compliant template generators.*

Enroller	FNMR @ FMR=0.01	FNMR @ FMR=0.001	FNMR @ FMR=0.0001
A	0.0095 ± 0.0003	0.0227 ± 0.0005	0.0438 ± 0.0007
B	0.0026 ± 0.0002	0.0060 ± 0.0003	0.0115 ± 0.0004
C	0.0062 ± 0.0003	0.0149 ± 0.0004	0.0266 ± 0.0005
D	0.0048 ± 0.0002	0.0106 ± 0.0003	0.0202 ± 0.0005
E	0.0061 ± 0.0003	0.0124 ± 0.0004	0.0207 ± 0.0005
F	0.0063 ± 0.0003	0.0144 ± 0.0004	0.0266 ± 0.0005
G	0.0031 ± 0.0002	0.0071 ± 0.0003	0.0146 ± 0.0004
N	0.0078 ± 0.0003	0.0156 ± 0.0004	0.0267 ± 0.0005
1C	0.0053 ± 0.0002	0.0111 ± 0.0003	0.0209 ± 0.0005
1D	0.0063 ± 0.0003	0.0129 ± 0.0004	0.0282 ± 0.0005
1F	0.0072 ± 0.0003	0.0156 ± 0.0004	0.0262 ± 0.0005
1G	0.0073 ± 0.0003	0.0156 ± 0.0004	0.0262 ± 0.0005
1J	0.0052 ± 0.0002	0.0115 ± 0.0004	0.0217 ± 0.0005
1L	0.0042 ± 0.0002	0.0096 ± 0.0003	0.0187 ± 0.0004
1M	0.0078 ± 0.0003	0.0160 ± 0.0004	0.0309 ± 0.0006
1N	0.0083 ± 0.0003	0.0173 ± 0.0004	0.0307 ± 0.0006
1T	–	–	–
1Y	–	–	–
2A	–	–	–
2C	–	–	–
2D	–	–	–
2F	–	–	–
2G	–	–	–
2I	–	–	–
2J	–	–	–
2K	–	–	–
2L	–	–	–
2M	–	–	–
2N	–	–	–
2O	–	–	–
2P	–	–	–
2Q	–	–	–
2R	–	–	–
2S	–	–	–
2T	–	–	–
2W	–	–	–
2Y	–	–	–
3A	–	–	–
3B	–	–	–
3D	–	–	–

Table 5: *(continued)*

Enroller	FNMR @ FMR=0.01	FNMR @ FMR=0.001	FNMR @ FMR=0.0001
3F	–	–	–
3G	–	–	–
3H	–	–	–
3M	–	–	–
3N	–	–	–
3O	–	–	–
3Q	–	–	–
3S	–	–	–
3T	–	–	–
3V	–	–	–
3W	–	–	–
3Z	–	–	–
4C	–	–	–
4F	–	–	–
4K	–	–	–
4L	–	–	–
4M	–	–	–
4N	–	–	–
4O	–	–	–
4Q	–	–	–
4S	–	–	–
4T	–	–	–
4U	–	–	–
4W	–	–	–
4X	–	–	–
4Z	–	–	–

5 References

[1] Jonathan N. Bradley, Christopher M. Brislawn, and Thomas Hopper. FBI wavelet/scalar quantization standard for gray-scale fingerprint image compression. In *SPIE, Visual Information Processing II*, 1961. 3

[2] Patrick Grother Elham Tabassi, George W. Quinn. When to fuse two biometrics. In *IEEE Computer Society on Computer Vision and Pattern Recognition, Workshop on Multi-Biometrics*, 2006. 3

[3] Robert Fontana, Giovanni Pistone, and Maria Rogantin. Cliassification of two-level factorial fractions. *Journal of Statistical Planning and Inference*, 87:149–172, 2000. 3

[4] P. Grother, M. McCabe, C. Watson, M. Indovina, W. Salamon, P. Flanagan, E. Tabassi, E. Newton, and C. Wilson. Performance and Interoperability of the INCITS 378 Fingerprint Template. Technical report, NIST, 2006. 4

[5] A. Martin, G. Doddington, T. Kamm, M. Ordowski, and M. Przybocki. The DET curve in assessment of detection task performance. In *Proc. Eurospeech*, pages 1895–1898, 1997. 3

[6] George W. Quinn. Evaluation of latent fingerprint technologies: Fusion. In *NIST Latent Fingerprint Testing Workshop Recognition, Workshop*, 2009. 3