MINEX III Report Card

Matcher startek+0010

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

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Participant Details

Company: Startek Engineering Inc.
Provided CBEFF PID: `002b 0001`

Date Application Received: 02/28/2019
Date First Submitted: 03/04/2019 (as generator version `0010`)
Date Validated: 03/04/2019
Date Completed: 03/04/2019

Library	Size (bytes)	MD5 Checksum
libminexiii_startek_0010.so	986896	`35afec93ef5a7e4d2411f8c927f25613`

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.

It also includes **MINEX III compliance** results per the criteria detailed in sections 4 through 8 of the Minutiae Interoperability Exchange (MINEX) III Test Plan and Application Programming Interface.

PIV Level One: PASS
- 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). ✓
- Average template comparison time must be no more than 10 milliseconds (6.4). ✓

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) ✗

MINEX III: FAIL
- Must pass MINEX III validation. ✓
- Must pass PIV level two matcher compliance. ✗
- Matcher must produce at least 512 distinct comparison scores over the entire dataset when comparing templates from different subjects. (1189906) ✓

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 MINEX III or PIV specifications in some previously undetected way.
- This submission is not compliant, and is therefore *not* a member of the pooled DET curves published throughout all MINEX III report cards.

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 III Evaluation. It reports whether the matcher passes the technical requirements for MINEX III as described in Section 8 of the MINEX III Test Plan and Application Programming Interface. Full details on the ongoing MINEX III program can be found on the MINEX III homepage. Questions should be directed to minex@nist.gov.

2 Methodology

Testing is performed at a NIST facility. Each participant's submission is validated by NIST (https://www.nist.gov/itl/iad/image-group/participation-minex-iii) 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 MINEX III 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 $533\,767$ mated and $1\,067\,530$ non-mated subject pairings. Since both left and right index fingerprints are available for each subject, this provides $1\,061\,657$ mated and $2\,127\,712$ non-mated single-finger comparisons (after database consolidation). When left and right index fingers are fused at the score level [3, 7], the sets condense to $530\,394$ mated and $1\,062\,814$ non-mated comparison scores.

2.2 Accuracy Metrics

Core matching accuracy is presented in the form of Detection Error Tradeoff (DET) plots [6], 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 ($i = 1 \ldots M$) be the ith mated comparison score, and n_j ($j = 1 \ldots N$) 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 [4] 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.

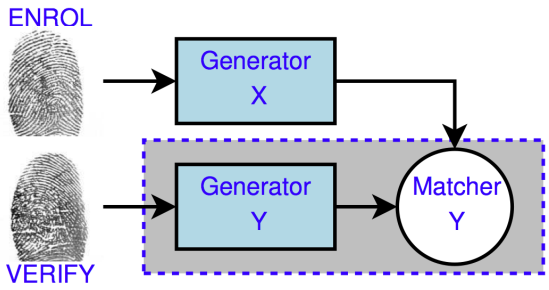

Figure 1: MINEX III Interoperability Test Setup

2.3 Interoperability

Interoperability is tested in a manner similar to *Scenario 1* from the MINEX Evaluation Report [5] (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.

2.4 Uncertainty Estimation

Some figures in this report include boxplots that convey the uncertainty associated with a statistic. The boxplots are intended to show the expected variation in the observed value if one assumes repeated iid sampling from the same population. They are not intended to reflect how the statistic might change over different test data or even different sampling strategies over the same data.

Estimates of uncertainty are computed using the Wilson Score method [8] which overcomes certain problems associated with applying the Central Limit Theorem to a discretized estimator. We make several simplifying assumptions when applying the method to biometric identification. Most notably, separate searches against the same enrollment database are treated as independent samples, yet we know positive correlations exist due to Doddingtons Zoo [2]. We also report estimates of the variability of FNIR at a fixed FPIR when in fact it is the decision threshold that is fixed. Uncertainty with respect to what decision threshold corresponds to the targeted FPIR results in increased uncertainty about the true value of FNIR. However, our estimates of FPIR are fairly tight due to the large number of non-mated searches performed, so they are not expected to have a large impact on the estimates.

3 Results

This section details the performance of matcher startek+0010 when it compares verification templates created by its own template generator to enrolment templates created by all MINEX III compliant template generators. Sections 3.1 and 3.2 present accuracy results for single finger and two finger matching respectively. Sections 3.4 and 3.5 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 $\text{FNMR}_{\text{FMR}}(0.0001) \leq 0.02$.

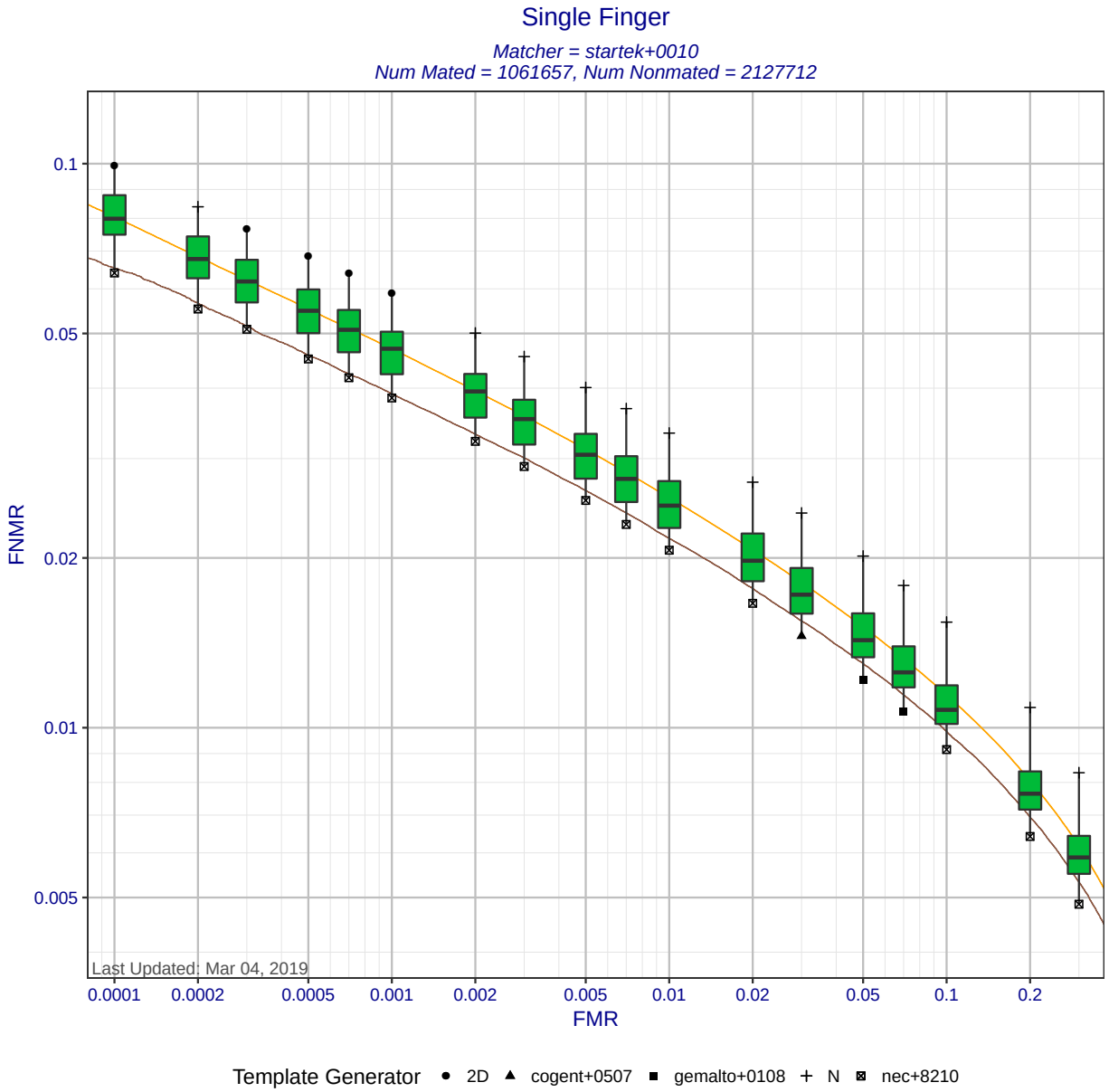

Figure 2: *Single finger DET statistics for matcher startek+0010. Each box shows the distribution of FNMRs at a fixed FMR across all MINEX III compliant template generators. The ends of the whiskers show the minimum and maximum FNMRs. The orange DET curve shows pooled performance against all template generators.*

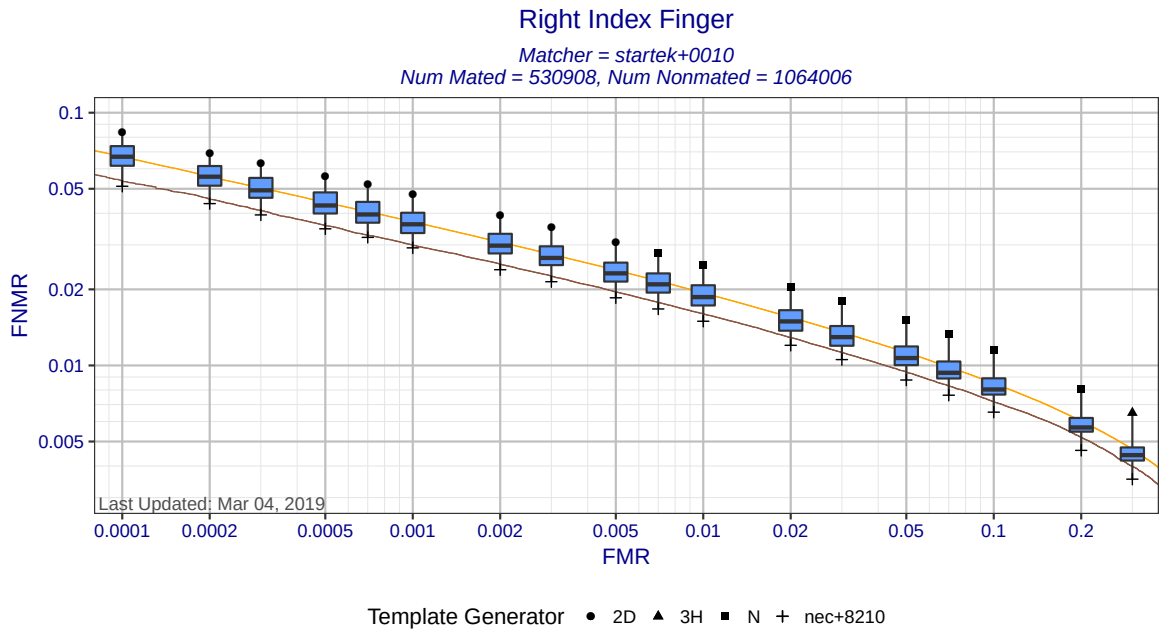

Figure 3: *Right index finger DET statistics for matcher startek+0010. Each box shows the distribution of FNMR at a fixed FMR across all MINEX III compliant template generators. The ends of the whiskers show the minimum and maximum FNMRs. The orange DET curve shows pooled performance against all template generators.*

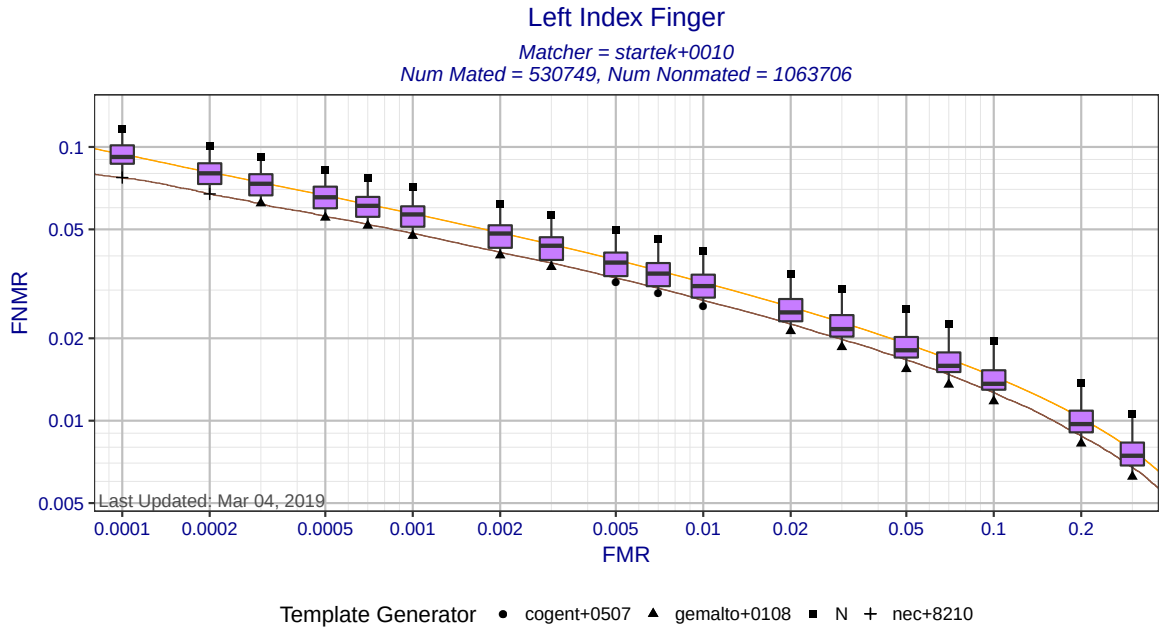

Figure 4: *Left index finger DET statistics for matcher startek+0010. Each box shows the distribution of FNMRs at a fixed FMR across all MINEX III compliant template generators. The ends of whiskers show the minimum and maximum FNMRs. The orange DET curve shows pooled performance against all template generators.*

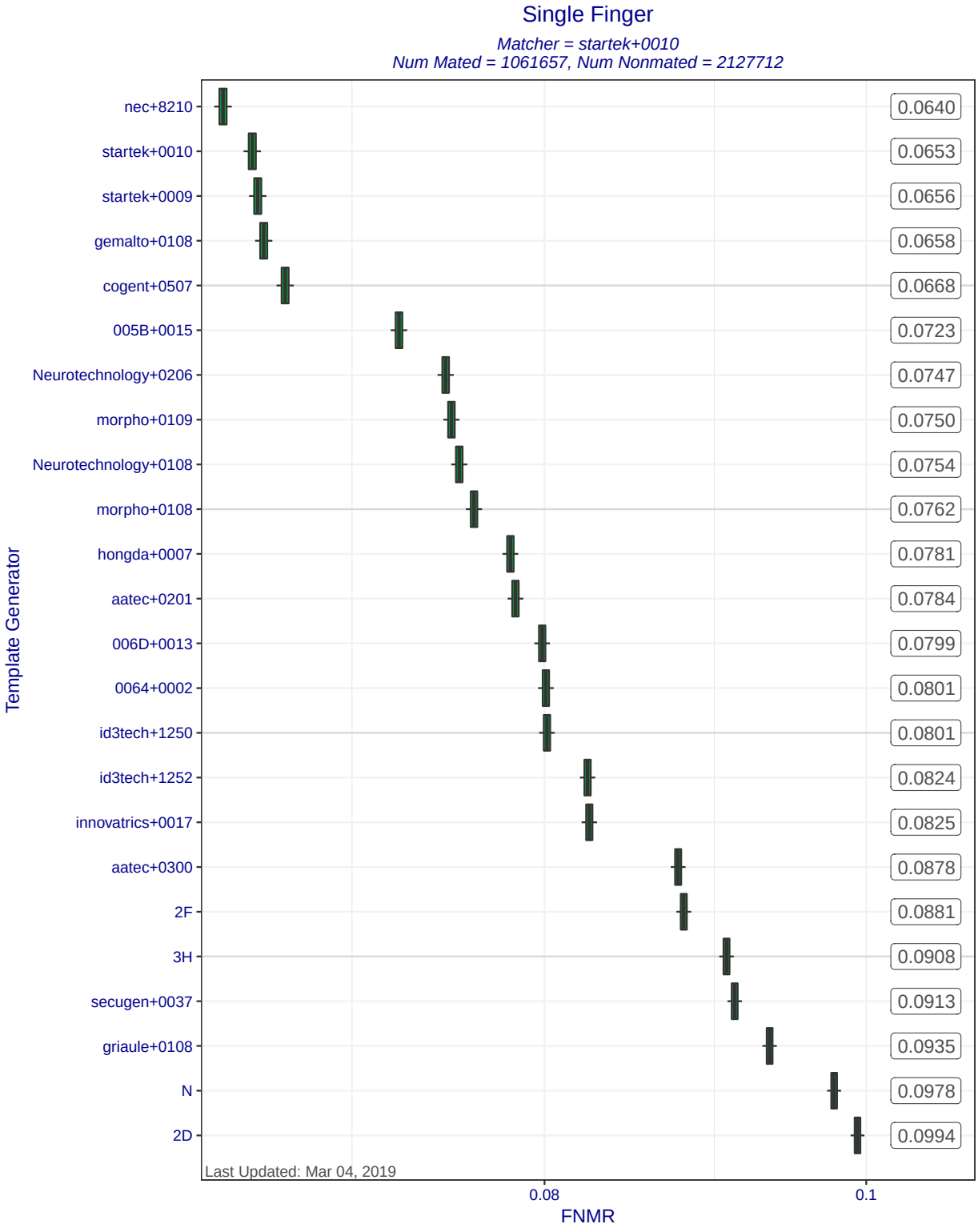

Figure 5: *Single finger FNMRs at FMR = 0.0001 when matcher startek+0010 compares templates created by different template generators. The ends of the whiskers show the minimum and maximum FNMRs. Each box represents uncertainty about the true FNMR. The box edges mark the 50% confidence intervals while the whiskers mark the 90% confidence intervals. The numbers on the right show the actual computed FNMRs.*

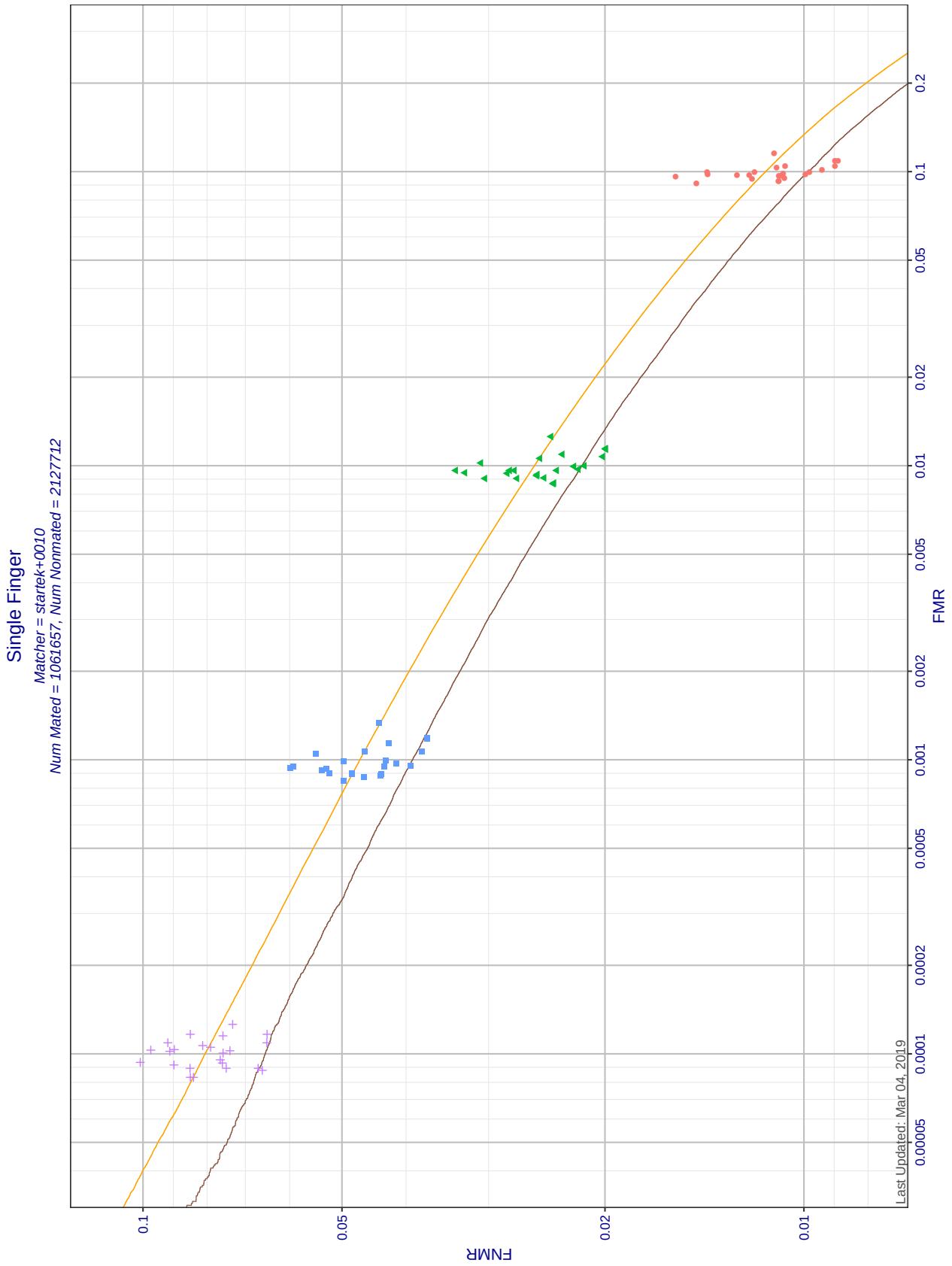

Figure 6: *Single finger DET accuracy for matcher startek+0010. Each cluster of points represents the variation in FMR and FNMR across MINEX III compliant template generators at a fixed decision threshold. Each point corresponds to an (FMR, FNMR) pair for a specific template generator at a particular 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 startek+0010 compares templates created by all MINEX III 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 III compliant template generators.

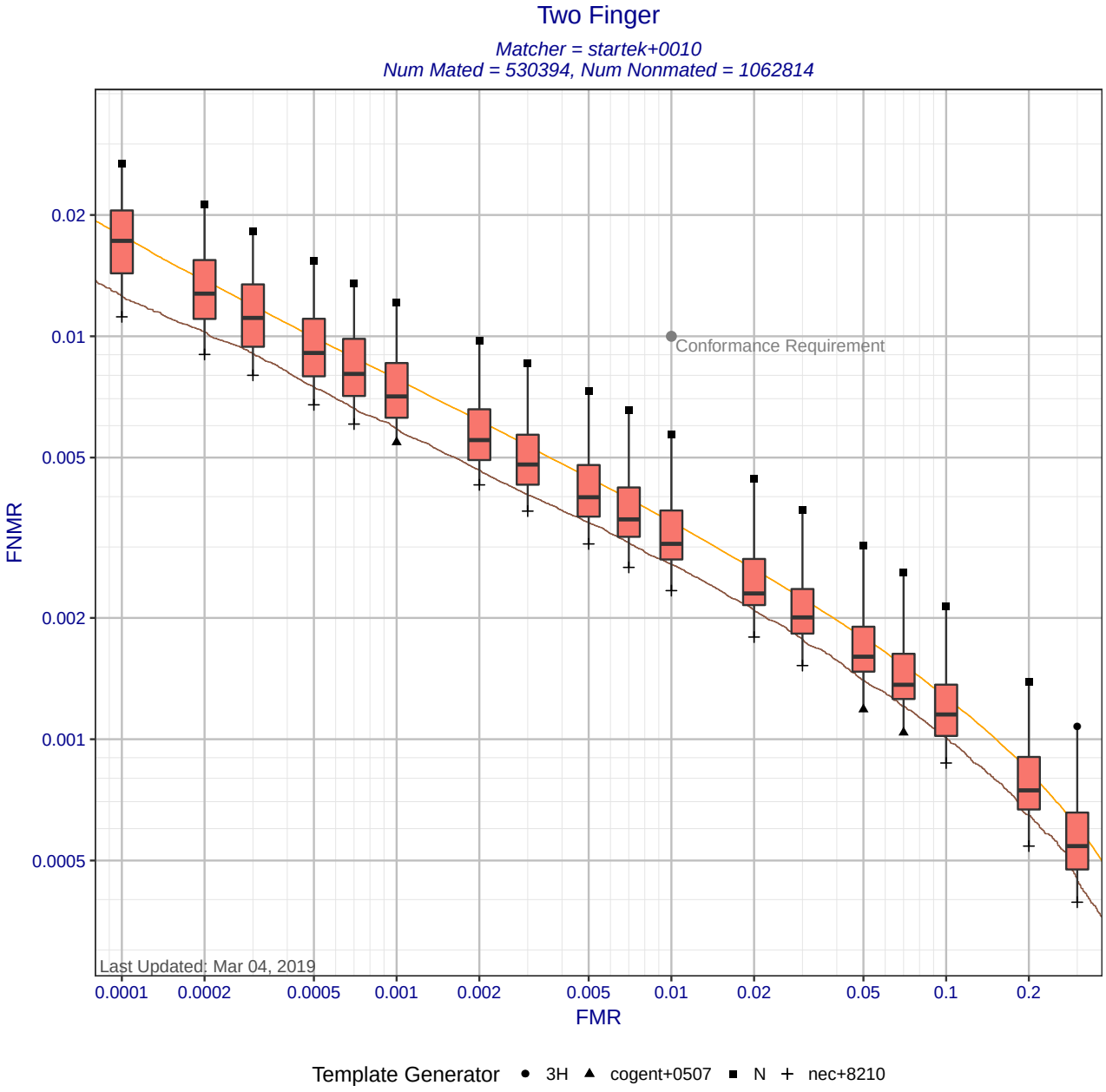

Figure 7: *Two finger DET statistics for matcher startek+0010. Each box shows the distribution of FNMRs at a fixed FMR across all MINEX III compliant template generators. The whisker ends show the minimum and maximum FNMRs. The orange DET curve shows pooled performance against all template generators. Score-level fusion is achieved by averaging the scores for left and right index fingers.*

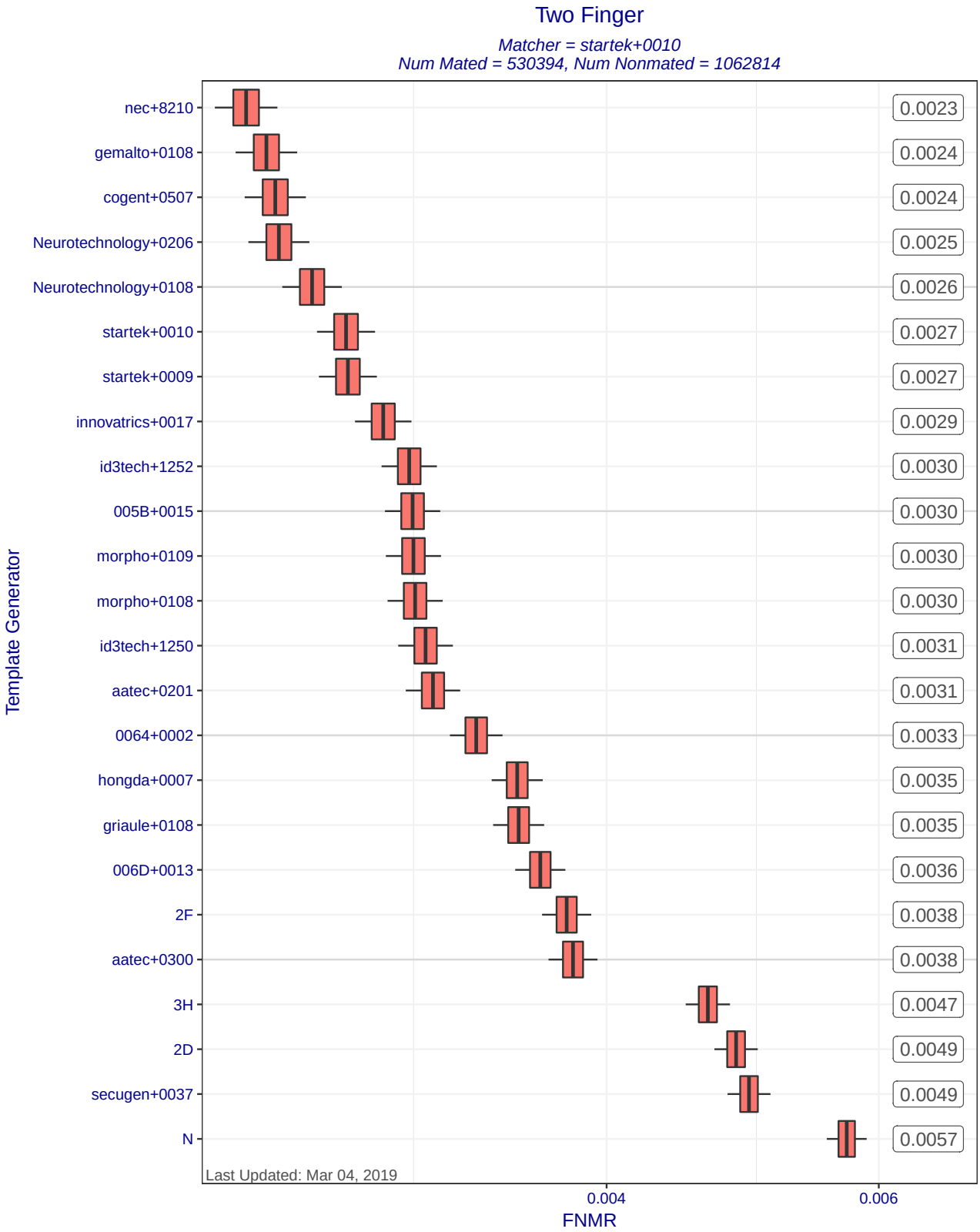

Figure 8: *Two finger FNMR at FMR=0.01 when matcher startek+0010 compares templates created by different template generators. Each box represents uncertainty about the true FNMR. The box edges mark the 50% confidence intervals while the whiskers mark the 90% confidence intervals. The numbers on the right show the actual computed FNMRs. Score-level fusion is achieved by averaging the scores for left and right index fingers.*

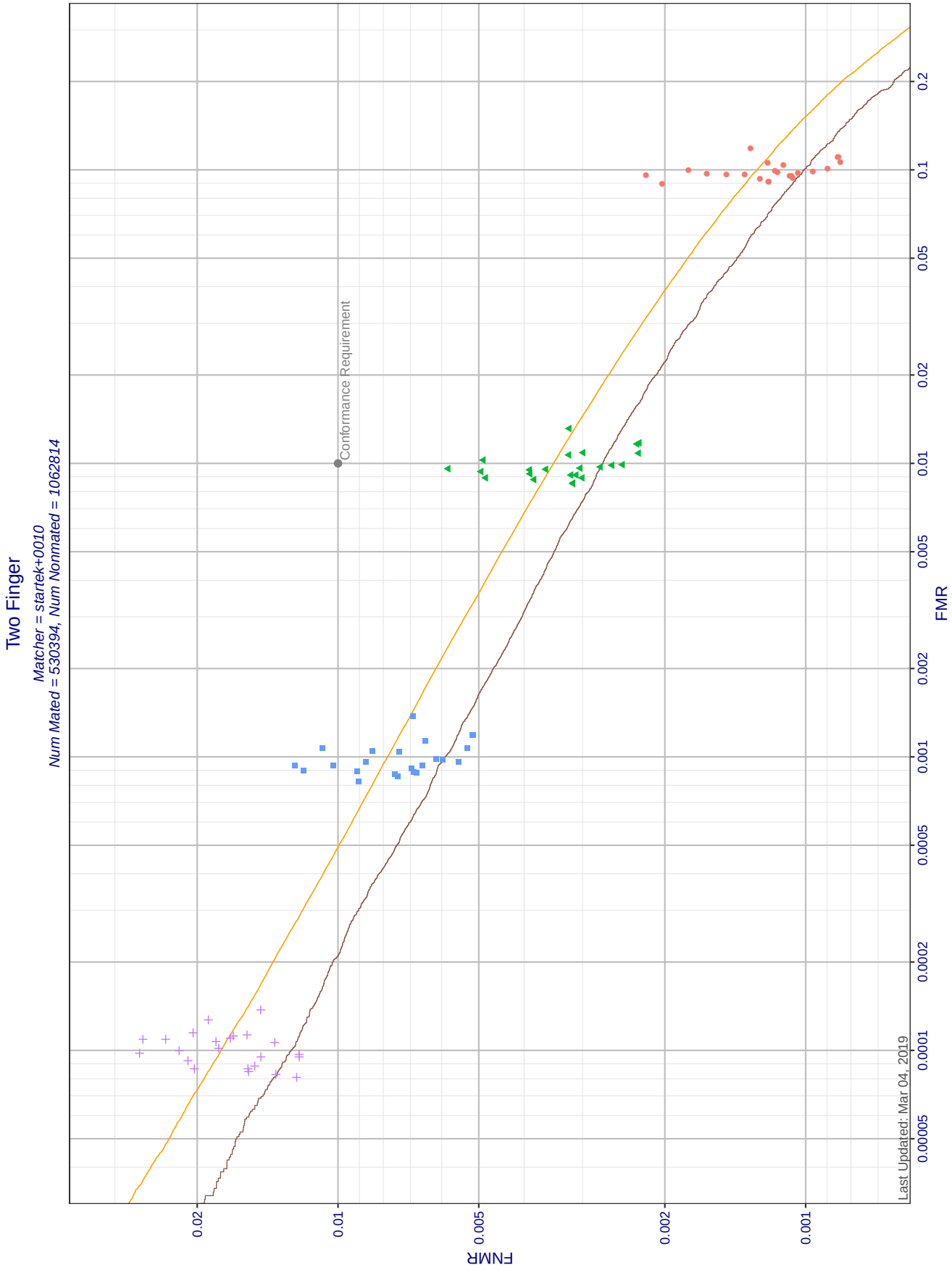

Figure 9: *Two finger DET accuracy for matcher startek+0010. Each cluster of points represents the variation in FMR and FNMR across MINEX III compliant template generators at a fixed decision threshold. Each point corresponds to an (FMR, FNMR) pair for a specific template generator at a particular decision 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 Match Times

To achieve PIV compliance, the matcher must average no more than 10 milliseconds (0.01 seconds) per comparison. Speeds are timed on a machine with an Intel Xeon E5-2680 CPU.

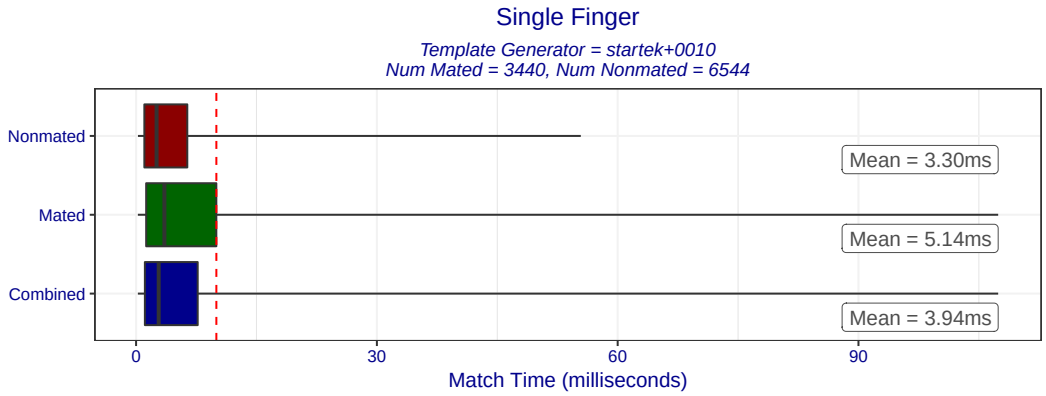

Figure 10: *Boxplot of match times for single finger comparisons. The box edges mark the 10th and 90th percentiles while the whiskers mark the maximum and minimum comparison times.*

3.4 Threshold Statistics

Results in this section are computed by concatenating comparison scores for matcher startek+0010 across all MINEX III compliant template generators.

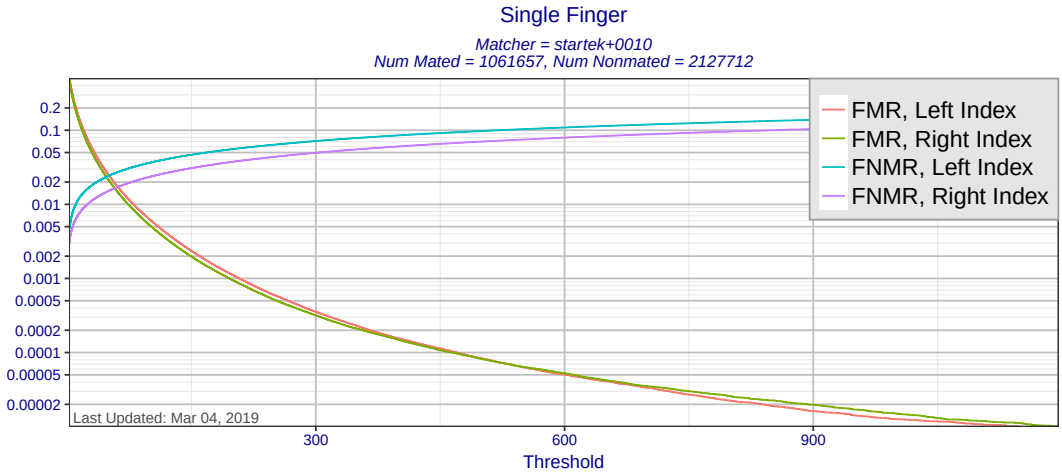

Figure 11: *Single finger FMR and FNMR as a function of score threshold for matcher startek+0010 using templates created by all MINEX III compliant template generators. Separate curves are presented for left and right index fingers.*

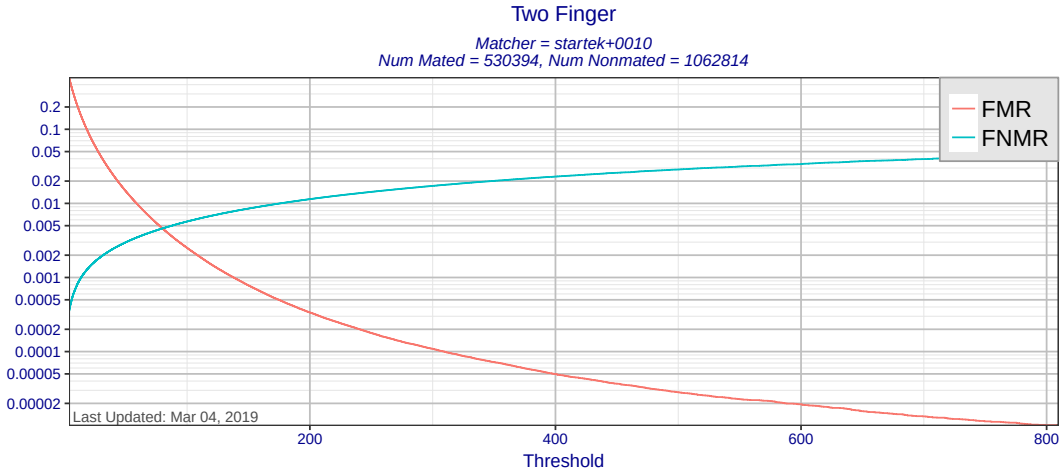

Figure 12: *Two finger FMR and FNMR as a function of score threshold for matcher startek+0010 using templates created by all MINEX III compliant template generators. Score-level fusion is achieved by averaging scores for the left and right index fingers.*

	FMR=0.1	FMR=0.01	FMR=0.001	FMR=0.0001
Right index finger	18.093	73.777	195.54	464.06
Left index finger	20.088	80.095	207.64	470.20
Single finger	19.097	77.014	201.96	467.67
Two finger	18.332	58.886	137.95	309.39

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

3.5 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 right 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 right index finger. A jagged and/or truncated curve is indicative of discretized scores.

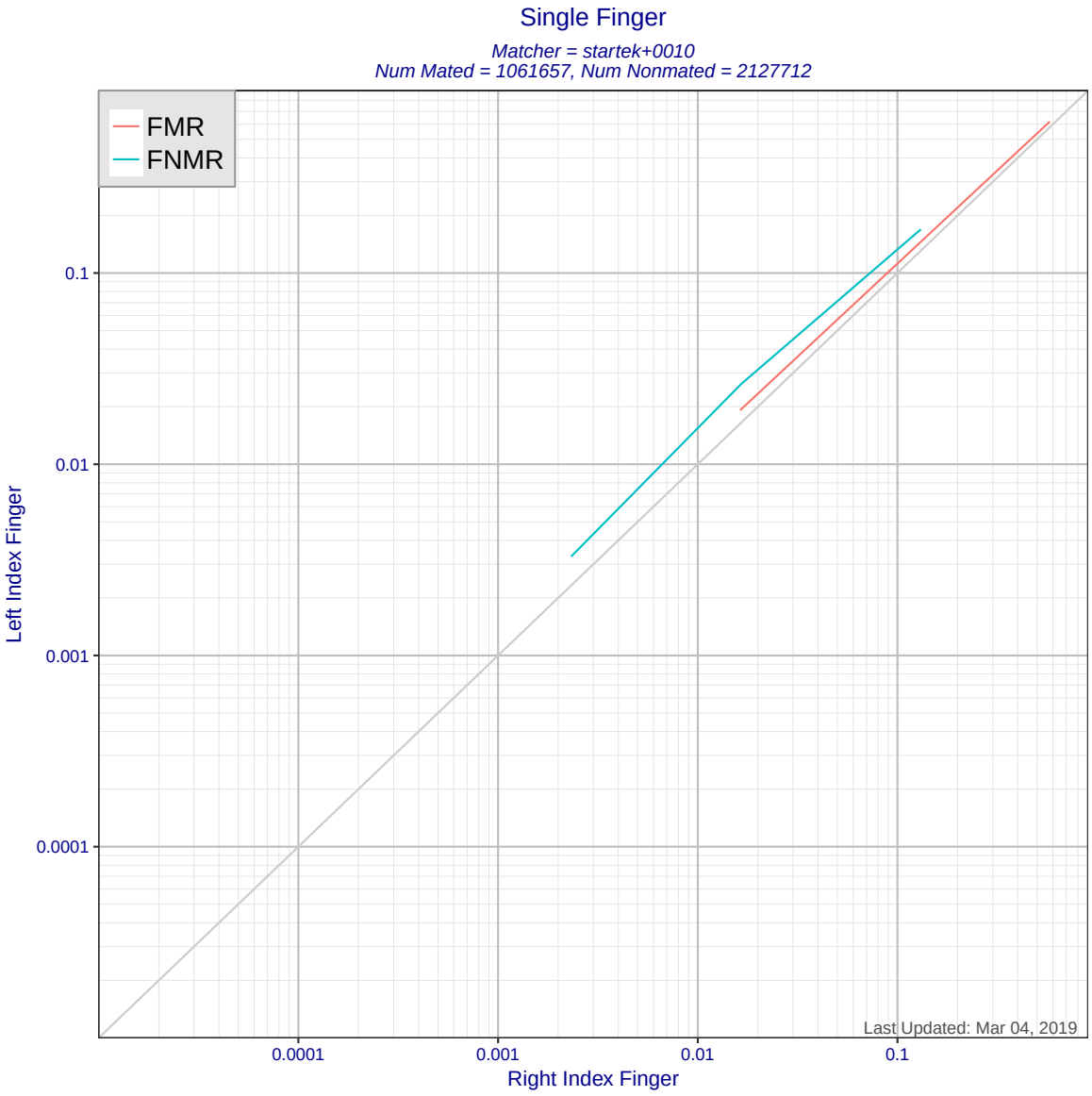

Figure 13: *Q-Q plot comparing score distributions for left and right index fingers.*

3.6 Effect of Minutia Count on Accuracy

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.

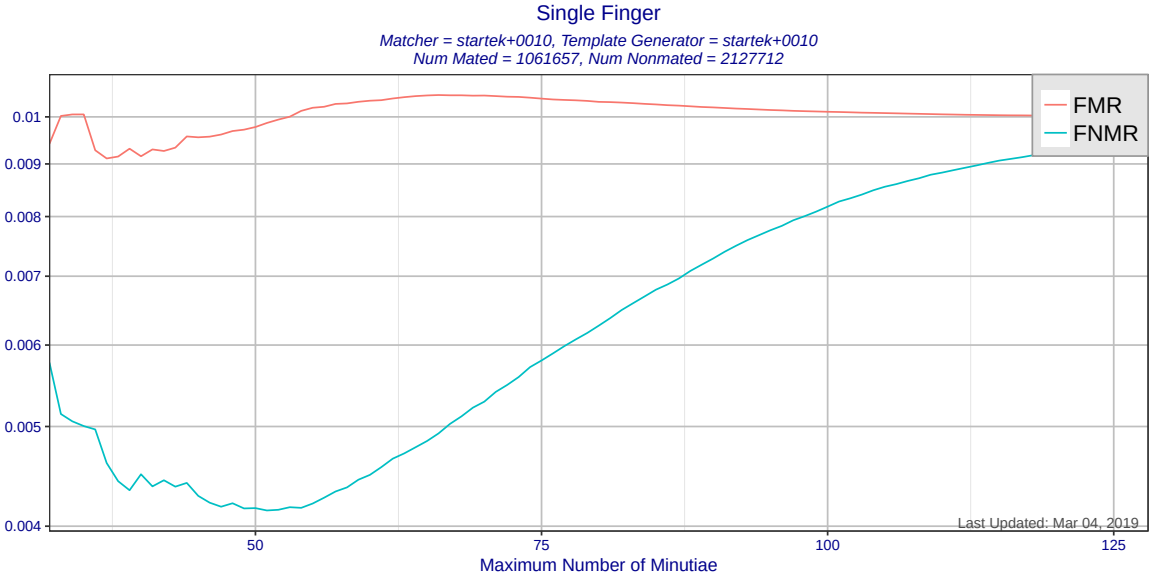

Figure 14: *FNMR and FMR as a function of the number of minutia found by the template generator. The vertical axis defines a filter criterion such that FNMR and FMR are computed over only those comparisons where at least one of the compared templates has* no more *than the specified number of minutia. The threshold is fixed separately for FNMR and FMR to elicit an error rate of approximately 0.01 over unfiltered comparisons.*

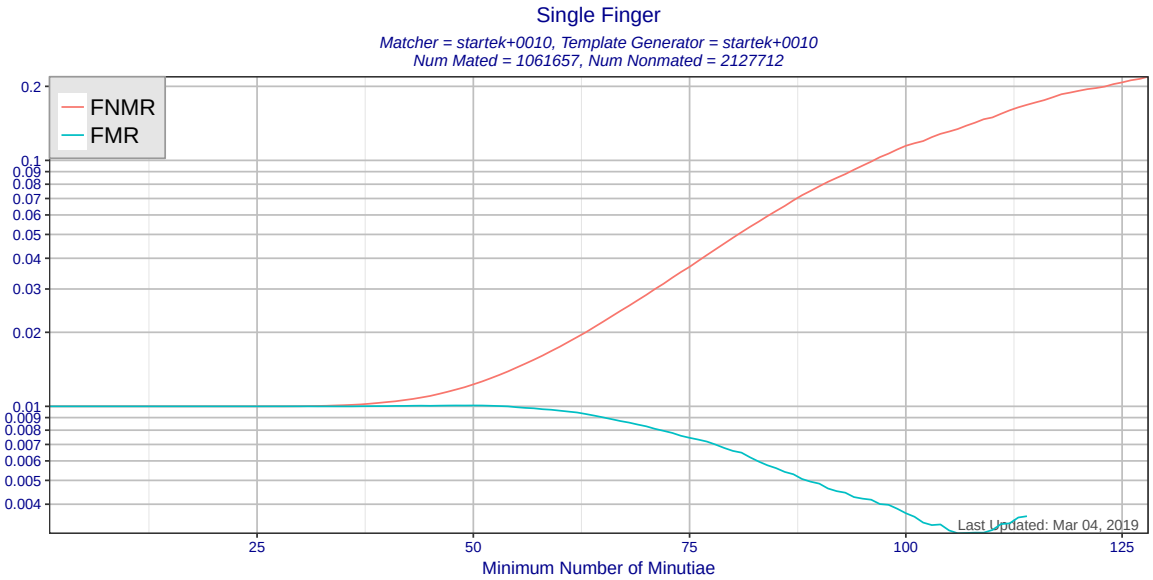

Figure 15: *FNMR and FMR as a function of the number of minutia found by the template generator. The vertical axis defines a filter criterion such that FNMR and FMR are computed over only those comparisons where at least one of the compared templates has* at least *the indicated number of minutia. The threshold is fixed separately for FNMR and FMR to elicit an error rate of approximately 0.01 over unfiltered comparisons.*

3.7 Comparison to Ongoing MINEX

MINEX III uses a larger set of comparisons than the older ongoing MINEX evaluation. Although this is generally good because it provides more accurate estimates of performance in MINEX III, it makes it more difficult to directly compare the results in this report to the archived ones from ongoing MINEX. The tables below report DET accuracy at fixed FMRs computed over the same set of comparisons that were used in ongoing MINEX. Ongoing MINEX reported FNMR at FMR $= 0.01$ for two-finger.

Table 2: *Single finger FNMRs at various FMRs when matcher startek+0010 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
005B+0015	0.0239 ± 0.0005	0.0454 ± 0.0007	0.0850 ± 0.0009
0064+0002	0.0274 ± 0.0005	0.0526 ± 0.0007	0.0930 ± 0.0010
006D+0013	0.0287 ± 0.0006	0.0536 ± 0.0007	0.0860 ± 0.0009
2D	0.0354 ± 0.0006	0.0665 ± 0.0008	0.110 ± 0.001
2F	0.0296 ± 0.0006	0.0568 ± 0.0008	0.1007 ± 0.0010
3H	0.0303 ± 0.0006	0.0571 ± 0.0008	0.0956 ± 0.0010
aatec+0201	0.0246 ± 0.0005	0.0475 ± 0.0007	0.0813 ± 0.0009
aatec+0300	0.0287 ± 0.0006	0.0543 ± 0.0007	0.0942 ± 0.0010
cogent+0507	0.0213 ± 0.0005	0.0415 ± 0.0007	0.0774 ± 0.0009
gemalto+0108	0.0213 ± 0.0005	0.0420 ± 0.0007	0.0787 ± 0.0009
griaule+0108	0.0292 ± 0.0006	0.0569 ± 0.0008	0.102 ± 0.001
hongda+0007	0.0269 ± 0.0005	0.0522 ± 0.0007	0.0891 ± 0.0009
id3tech+1250	0.0254 ± 0.0005	0.0494 ± 0.0007	0.0893 ± 0.0009
id3tech+1252	0.0255 ± 0.0005	0.0490 ± 0.0007	0.0885 ± 0.0009
innovatrics+0017	0.0249 ± 0.0005	0.0486 ± 0.0007	0.0859 ± 0.0009
morpho+0108	0.0233 ± 0.0005	0.0451 ± 0.0007	0.0804 ± 0.0009
morpho+0109	0.0234 ± 0.0005	0.0453 ± 0.0007	0.0813 ± 0.0009
N	0.0370 ± 0.0006	0.0682 ± 0.0008	0.117 ± 0.001
nec+8210	0.0212 ± 0.0005	0.0416 ± 0.0007	0.0740 ± 0.0009
Neurotechnology+0108	0.0228 ± 0.0005	0.0439 ± 0.0007	0.0901 ± 0.0009
Neurotechnology+0206	0.0215 ± 0.0005	0.0424 ± 0.0007	0.0745 ± 0.0009
secugen+0037	0.0334 ± 0.0006	0.0602 ± 0.0008	0.110 ± 0.001
startek+0009	0.0226 ± 0.0005	0.0421 ± 0.0007	0.0743 ± 0.0009
startek+0010	0.0225 ± 0.0005	0.0421 ± 0.0007	0.0765 ± 0.0009

Table 3: *Two finger FNMRs at various FMRs when matcher startek+0010 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
005B+0015	0.0027 ± 0.0002	0.0061 ± 0.0004	0.0178 ± 0.0006
0064+0002	0.0033 ± 0.0003	0.0077 ± 0.0004	0.0222 ± 0.0007
006D+0013	0.0035 ± 0.0003	0.0087 ± 0.0004	0.0181 ± 0.0006
2D	0.0050 ± 0.0003	0.0123 ± 0.0005	0.0323 ± 0.0008
2F	0.0038 ± 0.0003	0.0088 ± 0.0004	0.0222 ± 0.0007
3H	0.0042 ± 0.0003	0.0099 ± 0.0005	0.0211 ± 0.0007
aatec+0201	0.0030 ± 0.0003	0.0069 ± 0.0004	0.0178 ± 0.0006
aatec+0300	0.0037 ± 0.0003	0.0084 ± 0.0004	0.0202 ± 0.0007
cogent+0507	0.0021 ± 0.0002	0.0055 ± 0.0003	0.0134 ± 0.0005
gemalto+0108	0.0022 ± 0.0002	0.0056 ± 0.0003	0.0138 ± 0.0005
griaule+0108	0.0036 ± 0.0003	0.0090 ± 0.0004	0.0255 ± 0.0007
hongda+0007	0.0035 ± 0.0003	0.0082 ± 0.0004	0.0168 ± 0.0006
id3tech+1250	0.0029 ± 0.0003	0.0068 ± 0.0004	0.0203 ± 0.0007
id3tech+1252	0.0028 ± 0.0002	0.0069 ± 0.0004	0.0190 ± 0.0006

Table 3: *(continued)*

Enroller	FNMR @ FMR=0.01	FNMR @ FMR=0.001	FNMR @ FMR=0.0001
innovatrics+0017	0.0027 ± 0.0002	0.0063 ± 0.0004	0.0217 ± 0.0007
morpho+0108	0.0026 ± 0.0002	0.0067 ± 0.0004	0.0163 ± 0.0006
morpho+0109	0.0026 ± 0.0002	0.0064 ± 0.0004	0.0177 ± 0.0006
N	0.0061 ± 0.0004	0.0137 ± 0.0005	0.0327 ± 0.0008
nec+8210	0.0023 ± 0.0002	0.0056 ± 0.0003	0.0129 ± 0.0005
Neurotechnology+0108	0.0024 ± 0.0002	0.0061 ± 0.0004	0.0243 ± 0.0007
Neurotechnology+0206	0.0022 ± 0.0002	0.0057 ± 0.0004	0.0134 ± 0.0005
secugen+0037	0.0050 ± 0.0003	0.0117 ± 0.0005	0.0305 ± 0.0008
startek+0009	0.0027 ± 0.0002	0.0056 ± 0.0003	0.0130 ± 0.0005
startek+0010	0.0026 ± 0.0002	0.0057 ± 0.0004	0.0155 ± 0.0006

4 Performance Tables

The following tables present accuracy numbers, 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 4: *Single finger FNMRs at various FMRs when matcher startek+0010 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
005B+0015	0.0234 ± 0.0002	0.0426 ± 0.0003	0.0723 ± 0.0004
0064+0002	0.0255 ± 0.0003	0.0470 ± 0.0003	0.0801 ± 0.0004
006D+0013	0.0264 ± 0.0003	0.0480 ± 0.0003	0.0799 ± 0.0004
2D	0.0321 ± 0.0003	0.0590 ± 0.0004	0.0994 ± 0.0005
2F	0.0276 ± 0.0003	0.0511 ± 0.0004	0.0881 ± 0.0005
3H	0.0296 ± 0.0003	0.0526 ± 0.0004	0.0908 ± 0.0005
aatec+0201	0.0239 ± 0.0002	0.0437 ± 0.0003	0.0784 ± 0.0004
aatec+0300	0.0272 ± 0.0003	0.0496 ± 0.0003	0.0878 ± 0.0005
cogent+0507	0.0208 ± 0.0002	0.0388 ± 0.0003	0.0668 ± 0.0004
gemalto+0108	0.0208 ± 0.0002	0.0386 ± 0.0003	0.0658 ± 0.0004
griaule+0108	0.0276 ± 0.0003	0.0518 ± 0.0004	0.0935 ± 0.0005
hongda+0007	0.0258 ± 0.0003	0.0470 ± 0.0003	0.0781 ± 0.0004
id3tech+1250	0.0248 ± 0.0002	0.0473 ± 0.0003	0.0801 ± 0.0004
id3tech+1252	0.0248 ± 0.0002	0.0472 ± 0.0003	0.0824 ± 0.0004
innovatrics+0017	0.0240 ± 0.0002	0.0450 ± 0.0003	0.0825 ± 0.0004
morpho+0108	0.0231 ± 0.0002	0.0422 ± 0.0003	0.0762 ± 0.0004
morpho+0109	0.0230 ± 0.0002	0.0425 ± 0.0003	0.0750 ± 0.0004
N	0.0333 ± 0.0003	0.0586 ± 0.0004	0.0978 ± 0.0005
nec+8210	0.0206 ± 0.0002	0.0384 ± 0.0003	0.0640 ± 0.0004
Neurotechnology+0108	0.0222 ± 0.0002	0.0429 ± 0.0003	0.0754 ± 0.0004
Neurotechnology+0206	0.0215 ± 0.0002	0.0411 ± 0.0003	0.0747 ± 0.0004
secugen+0037	0.0310 ± 0.0003	0.0554 ± 0.0004	0.0913 ± 0.0005
startek+0009	0.0218 ± 0.0002	0.0390 ± 0.0003	0.0656 ± 0.0004
startek+0010	0.0217 ± 0.0002	0.0391 ± 0.0003	0.0653 ± 0.0004
Pooled	0.0256 ± 0.0003	0.0470 ± 0.0003	0.0806 ± 0.0004

Table 5: *Right index finger FNMRs at various FMRs when matcher startek+0010 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
005B+0015	0.0178 ± 0.0003	0.0335 ± 0.0004	0.0593 ± 0.0005
0064+0002	0.0196 ± 0.0003	0.0373 ± 0.0004	0.0670 ± 0.0006
006D+0013	0.0204 ± 0.0003	0.0387 ± 0.0004	0.0696 ± 0.0006
2D	0.0248 ± 0.0004	0.0476 ± 0.0005	0.0840 ± 0.0006
2F	0.0210 ± 0.0003	0.0405 ± 0.0004	0.0742 ± 0.0006
3H	0.0233 ± 0.0003	0.0425 ± 0.0005	0.0797 ± 0.0006
aatec+0201	0.0180 ± 0.0003	0.0344 ± 0.0004	0.0639 ± 0.0006
aatec+0300	0.0206 ± 0.0003	0.0399 ± 0.0004	0.0739 ± 0.0006
cogent+0507	0.0155 ± 0.0003	0.0300 ± 0.0004	0.0537 ± 0.0005
gemalto+0108	0.0156 ± 0.0003	0.0301 ± 0.0004	0.0540 ± 0.0005
griaule+0108	0.0210 ± 0.0003	0.0412 ± 0.0004	0.0810 ± 0.0006
hongda+0007	0.0188 ± 0.0003	0.0362 ± 0.0004	0.0616 ± 0.0005
id3tech+1250	0.0188 ± 0.0003	0.0374 ± 0.0004	0.0694 ± 0.0006
id3tech+1252	0.0186 ± 0.0003	0.0375 ± 0.0004	0.0706 ± 0.0006
innovatrics+0017	0.0179 ± 0.0003	0.0352 ± 0.0004	0.0677 ± 0.0006
morpho+0108	0.0173 ± 0.0003	0.0333 ± 0.0004	0.0635 ± 0.0005
morpho+0109	0.0174 ± 0.0003	0.0338 ± 0.0004	0.0642 ± 0.0006
N	0.0251 ± 0.0004	0.0456 ± 0.0005	0.0802 ± 0.0006
nec+8210	0.0150 ± 0.0003	0.0292 ± 0.0004	0.0512 ± 0.0005
Neurotechnology+0108	0.0172 ± 0.0003	0.0348 ± 0.0004	0.0649 ± 0.0006
Neurotechnology+0206	0.0163 ± 0.0003	0.0328 ± 0.0004	0.0618 ± 0.0005
secugen+0037	0.0235 ± 0.0003	0.0436 ± 0.0005	0.0736 ± 0.0006
startek+0009	0.0160 ± 0.0003	0.0296 ± 0.0004	0.0527 ± 0.0005
startek+0010	0.0160 ± 0.0003	0.0299 ± 0.0004	0.0537 ± 0.0005
Pooled	0.0194 ± 0.0003	0.0370 ± 0.0004	0.0668 ± 0.0006

Table 6: *Left index finger FNMRs at various FMRs when matcher startek+0010 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
005B+0015	0.0292 ± 0.0004	0.0518 ± 0.0005	0.0864 ± 0.0006
0064+0002	0.0317 ± 0.0004	0.0567 ± 0.0005	0.0933 ± 0.0007
006D+0013	0.0325 ± 0.0004	0.0574 ± 0.0005	0.0896 ± 0.0006
2D	0.0396 ± 0.0004	0.0706 ± 0.0006	0.1152 ± 0.0007
2F	0.0345 ± 0.0004	0.0620 ± 0.0005	0.1020 ± 0.0007
3H	0.0361 ± 0.0004	0.0628 ± 0.0005	0.1008 ± 0.0007
aatec+0201	0.0298 ± 0.0004	0.0531 ± 0.0005	0.0919 ± 0.0007
aatec+0300	0.0339 ± 0.0004	0.0594 ± 0.0005	0.1023 ± 0.0007
cogent+0507	0.0262 ± 0.0004	0.0478 ± 0.0005	0.0798 ± 0.0006
gemalto+0108	0.0263 ± 0.0004	0.0474 ± 0.0005	0.0778 ± 0.0006
griaule+0108	0.0344 ± 0.0004	0.0629 ± 0.0005	0.1066 ± 0.0007
hongda+0007	0.0330 ± 0.0004	0.0583 ± 0.0005	0.0950 ± 0.0007
id3tech+1250	0.0310 ± 0.0004	0.0572 ± 0.0005	0.0906 ± 0.0006
id3tech+1252	0.0310 ± 0.0004	0.0570 ± 0.0005	0.0942 ± 0.0007
innovatrics+0017	0.0303 ± 0.0004	0.0549 ± 0.0005	0.0971 ± 0.0007
morpho+0108	0.0289 ± 0.0004	0.0516 ± 0.0005	0.0883 ± 0.0006
morpho+0109	0.0287 ± 0.0004	0.0513 ± 0.0005	0.0855 ± 0.0006
N	0.0418 ± 0.0005	0.0717 ± 0.0006	0.1160 ± 0.0007
nec+8210	0.0265 ± 0.0004	0.0479 ± 0.0005	0.0773 ± 0.0006
Neurotechnology+0108	0.0274 ± 0.0004	0.0510 ± 0.0005	0.0873 ± 0.0006
Neurotechnology+0206	0.0268 ± 0.0004	0.0497 ± 0.0005	0.0876 ± 0.0006
secugen+0037	0.0389 ± 0.0004	0.0674 ± 0.0006	0.1086 ± 0.0007
startek+0009	0.0277 ± 0.0004	0.0487 ± 0.0005	0.0787 ± 0.0006
startek+0010	0.0275 ± 0.0004	0.0484 ± 0.0005	0.0768 ± 0.0006
Pooled	0.0320 ± 0.0004	0.0571 ± 0.0005	0.0942 ± 0.0007

Table 7: *Two finger FNMRs at various FMRs when matcher startek+0010 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
005B+0015	0.0030 ± 0.0001	0.0065 ± 0.0002	0.0143 ± 0.0003
0064+0002	0.0033 ± 0.0001	0.0075 ± 0.0002	0.0175 ± 0.0003
006D+0013	0.0036 ± 0.0001	0.0084 ± 0.0002	0.0191 ± 0.0003
2D	0.0049 ± 0.0002	0.0114 ± 0.0002	0.0265 ± 0.0004
2F	0.0038 ± 0.0001	0.0087 ± 0.0002	0.0205 ± 0.0003
3H	0.0047 ± 0.0002	0.0100 ± 0.0002	0.0219 ± 0.0003
aatec+0201	0.0031 ± 0.0001	0.0069 ± 0.0002	0.0170 ± 0.0003
aatec+0300	0.0038 ± 0.0001	0.0086 ± 0.0002	0.0205 ± 0.0003
cogent+0507	0.0024 ± 0.0001	0.0055 ± 0.0002	0.0120 ± 0.0002
gemalto+0108	0.0024 ± 0.0001	0.0055 ± 0.0002	0.0121 ± 0.0002
griaule+0108	0.0035 ± 0.0001	0.0086 ± 0.0002	0.0214 ± 0.0003
hongda+0007	0.0035 ± 0.0001	0.0077 ± 0.0002	0.0165 ± 0.0003
id3tech+1250	0.0031 ± 0.0001	0.0072 ± 0.0002	0.0188 ± 0.0003
id3tech+1252	0.0030 ± 0.0001	0.0071 ± 0.0002	0.0182 ± 0.0003
innovatrics+0017	0.0029 ± 0.0001	0.0067 ± 0.0002	0.0173 ± 0.0003
morpho+0108	0.0030 ± 0.0001	0.0065 ± 0.0002	0.0144 ± 0.0003
morpho+0109	0.0030 ± 0.0001	0.0066 ± 0.0002	0.0144 ± 0.0003
N	0.0057 ± 0.0002	0.0121 ± 0.0002	0.0269 ± 0.0004
nec+8210	0.0023 ± 0.0001	0.0055 ± 0.0002	0.0112 ± 0.0002
Neurotechnology+0108	0.0026 ± 0.0001	0.0061 ± 0.0002	0.0143 ± 0.0003
Neurotechnology+0206	0.0025 ± 0.0001	0.0055 ± 0.0002	0.0141 ± 0.0003
secugen+0037	0.0049 ± 0.0002	0.0111 ± 0.0002	0.0242 ± 0.0003
startek+0009	0.0027 ± 0.0001	0.0059 ± 0.0002	0.0127 ± 0.0003
startek+0010	0.0027 ± 0.0001	0.0059 ± 0.0002	0.0126 ± 0.0003
Pooled	0.0035 ± 0.0001	0.0078 ± 0.0002	0.0178 ± 0.0003

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