Ongoing MINEX Report Card

Template Generator F

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Ongoing MINEX tested for compliance of NIST Special Publication 800-76-1, which was withdrawn July 2013.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: Innovatrics
Date Submitted: 2/1/2005
Date Validated: 3/15/2005
Date Completed: 3/21/2006

Library	Size (bytes)	MD5 Checksum
minexDLL.dll	335872	86a332f8069bb3acde1c5688ba7a16c2

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: FAIL

- All certified matchers must be able to match templates from this template generator with an $\text{FNMR}_{\text{FMR}}(0.01) \leq 0.01$ using two fingers (4.5.2.2-3). ✓
- Minutia density plots derived from generated templates do not exhibit a periodic, grid-like, or geometric structure without reasonable justification. ✗ *(See Section 3.4)*

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 template generator if it later discovers the template generator violates PIV specifications in some previously undetected way.

Contents

List of Figures

List of Tables

1 Introduction

Testing is performed at a NIST facility. Each participant's submission is validated by NIST 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 generator submitted by the participant as well as templates created by other compliant template generators.

2 Methodology

Testing is performed at a NIST facility. Each participant's submission is validated by NIST before undergoing full testing to ensure it operates correctly. If the template generator passes the validation procedure, performance is assessed by using MINEX compliant matching algorithms to compare templates created by the template generator. These matchers were submitted to the ongoing MINEX program by various participants.

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, 7], 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 [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

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

$$\text{FNMR}(\tau) = \frac{1}{M} \sum_{i=1}^{M} \mathbb{1}\{m_i < \tau\}. \tag{2}$$

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 $0 \leq \alpha \leq 1$. It also imposes a natural penalty on matching algorithms that produce heavily discretized scores.

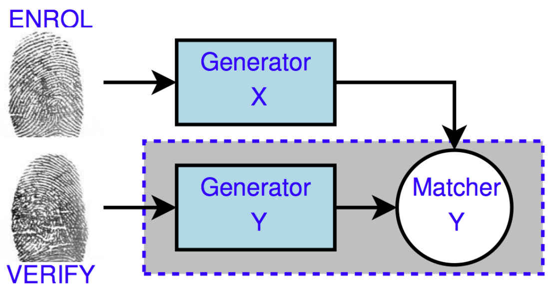


Figure 1: MINEX Interoperability Test Setup

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 as ”native” mode.

3 Results

This section details the performance of template generator F. Sections 3.1 and 3.2 present accuracy results for single finger and two finger matching respectively. Section 3.3 presents information on the number of minutia the template generator finds in the samples.

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 template generator achieve an accuracy of $\text{FNMR}_{\text{FMR}}(0.01) \leq 0.01$ against all compliant matchers.

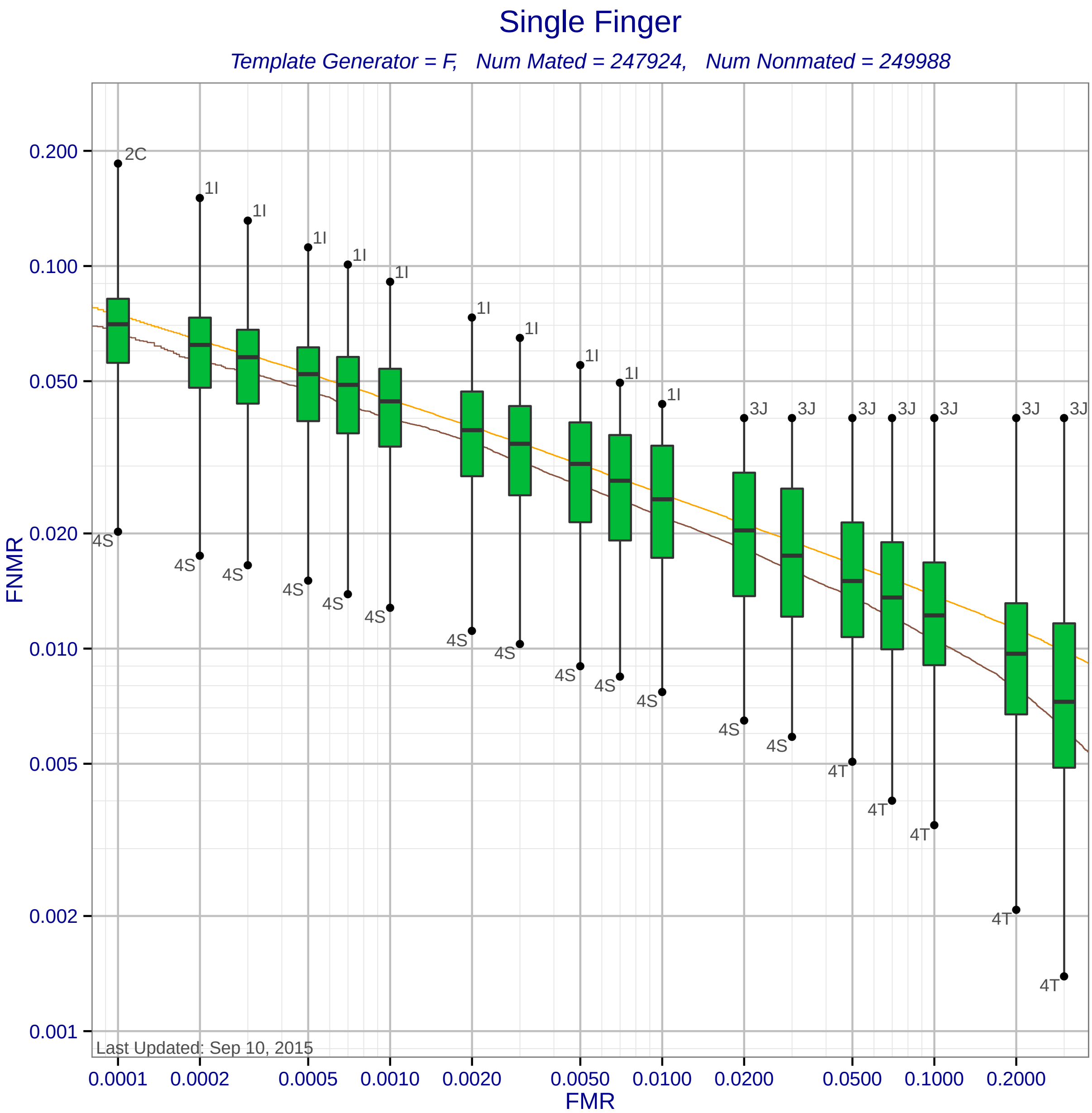


Figure 2: *Single finger DET statistics for template generator F. Each box shows the distribution of FNMRs at a fixed FMR across different matchers. The whisker ends show the minimum and maximum FNMRs. The brown curve shows the DET curve when the matcher and template generators were submitted by the same participant. The orange DET curve shows pooled performance when all matchers compare templates created by F.*

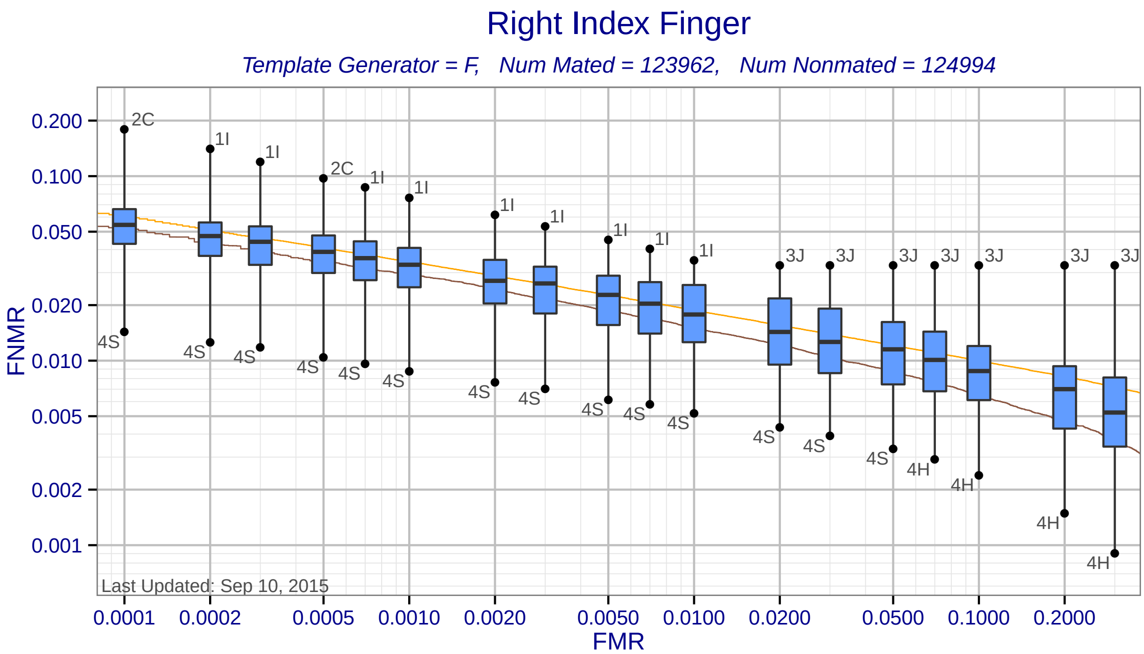


Figure 3: *Right Index Finger DET statistics for template generator F. Each box shows the distribution of FNMRs at a fixed FMR across different matchers. The whisker ends show the minimum and maximum FNMRs. The brown curve shows the DET curve when the matcher and template generators were submitted by the same participant. The orange DET curve shows pooled performance when all matchers use templates created by F.*

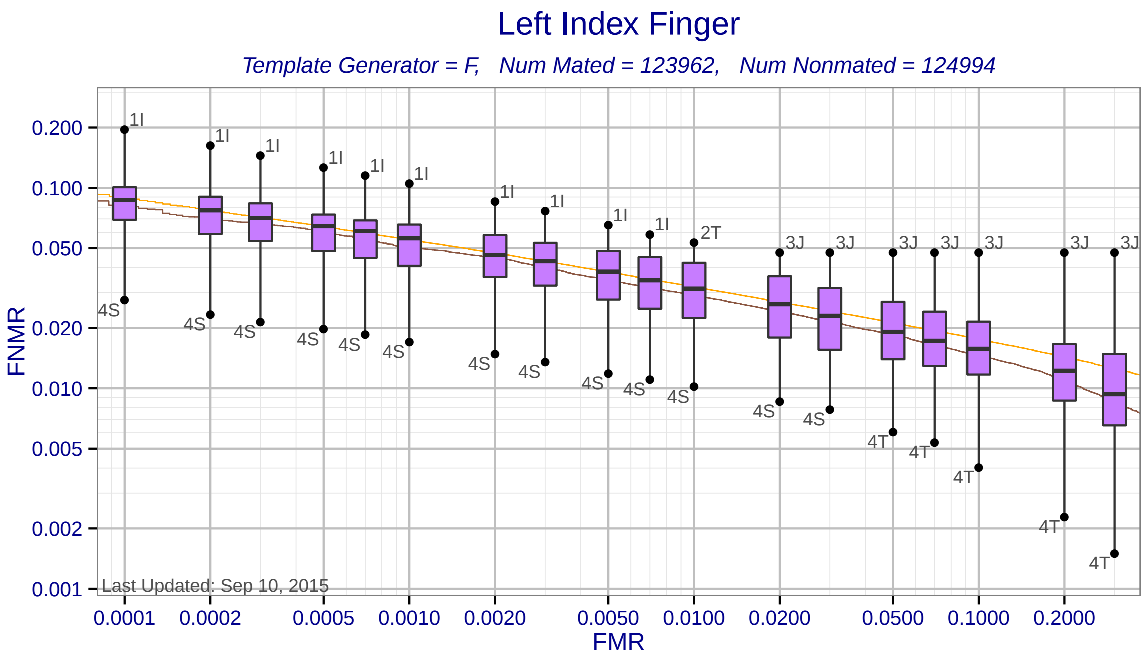


Figure 4: *Left Index Finger DET statistics for template generator F. Each box shows the distribution of FNMRs at a fixed FMR across different template generators. The brown curve shows the DET curve when the matcher and template generators were submitted by the same participant. The orange DET curve shows pooled performance when all matchers use templates created by F.*

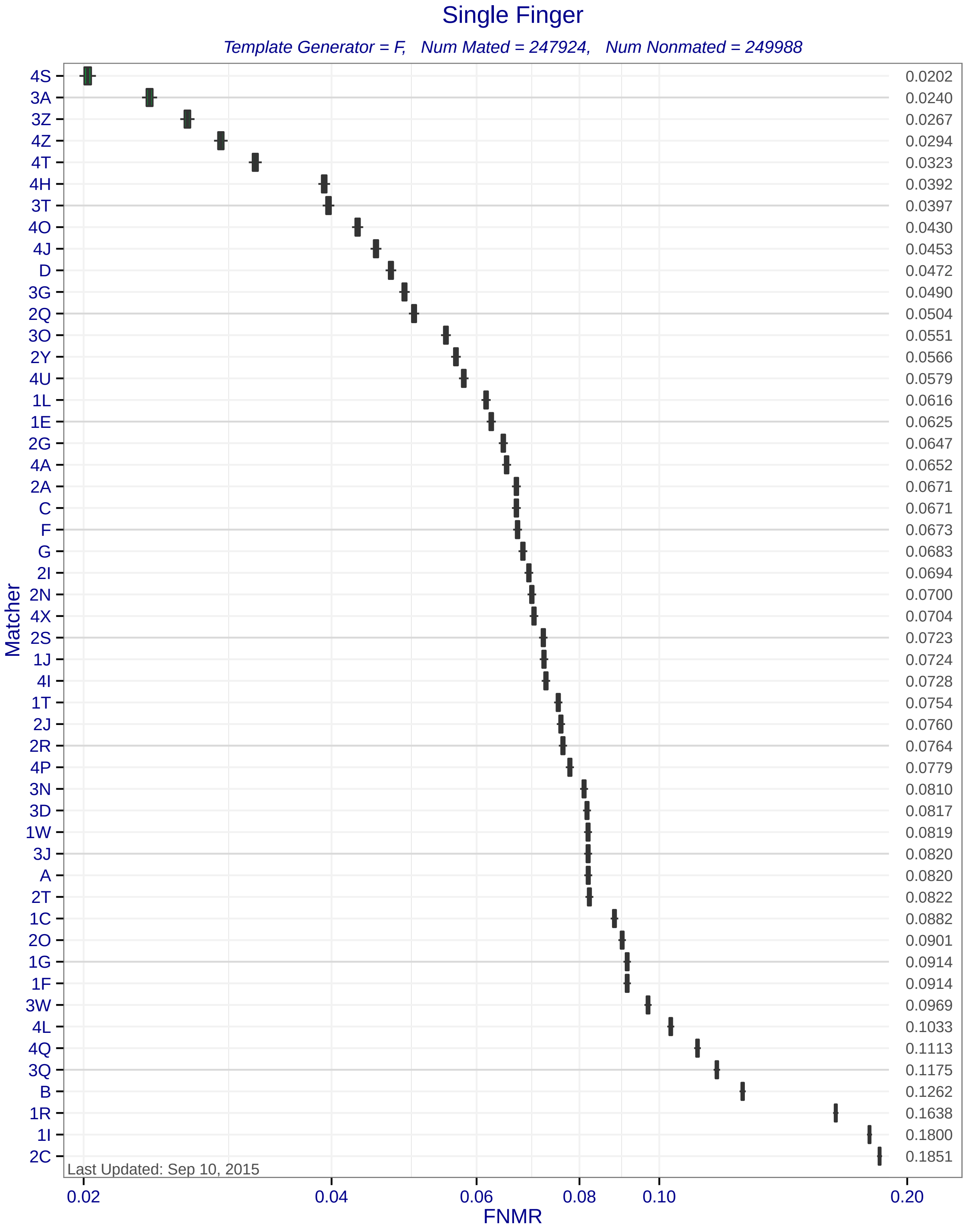


Figure 5: *Single Finger FNMRs at FMR=0.0001 when MINEX compliant matchers compare templates created by template generator F. Each box represents uncertainty about the true FNMR. The box edges mark the 50% confidence intervals while the whiskers mark the 90% confindence intervals. The numbers on the right show the actual computed FNMRs.*

3.2 Two Finger

This section presents accuracy when different MINEX compliant matchers compare templates created by template generator F. Two finger fusion is achieved by averaging the scores for left and right index fingers for each person.

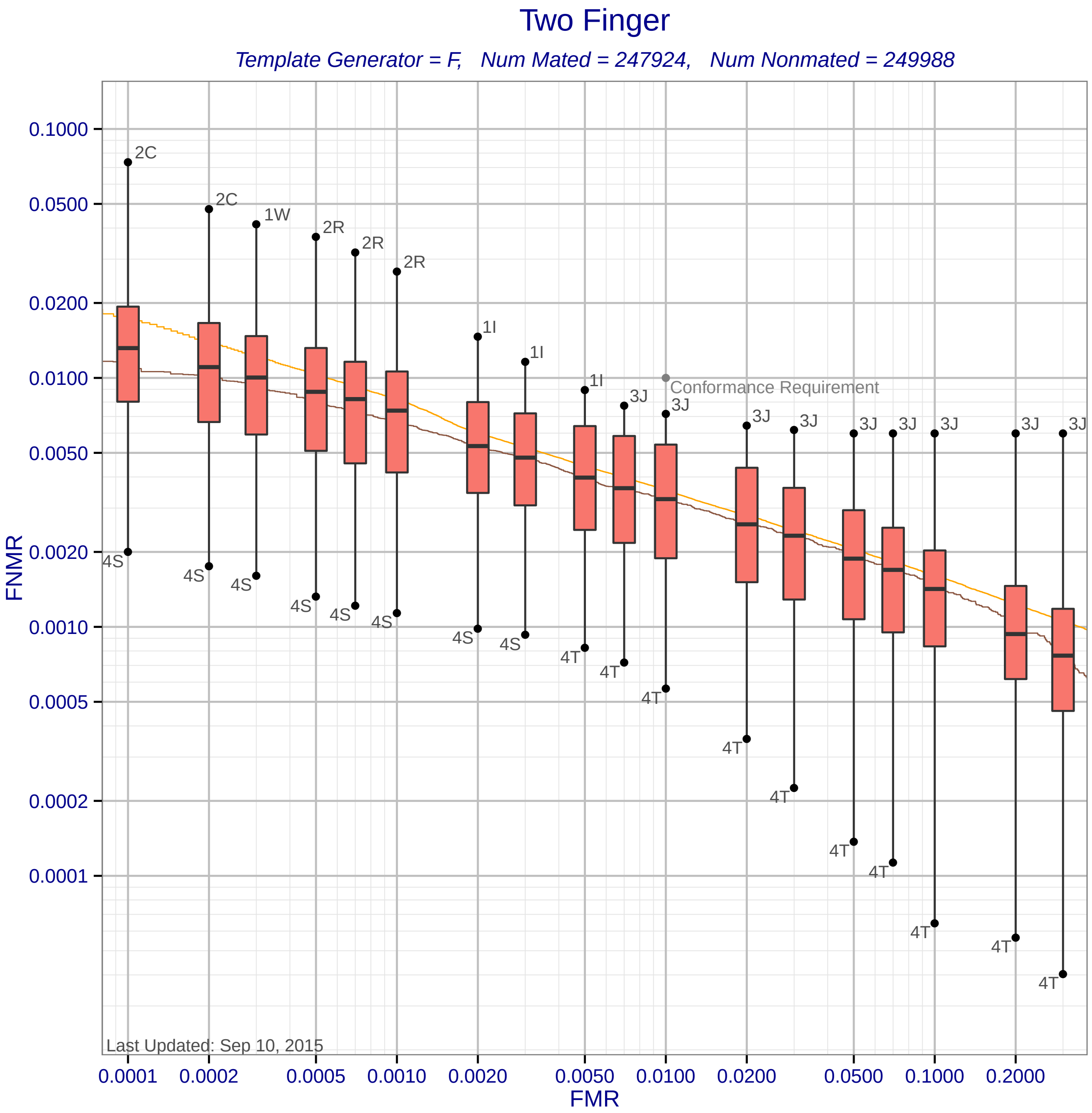


Figure 6: *Two Finger DET statistics for template generator F. Each box shows the distribution of FNMRs at a fixed FMR across different matchers. The whisker ends show the minimum and maximum FNMRs. The brown curve shows the DET curve when the matcher and template generators were submitted by the same participant. The orange DET curve shows pooled performance when all matchers use templates created by F. Score-level fusion is achieved by averaging the scores for left and right index fingers.*

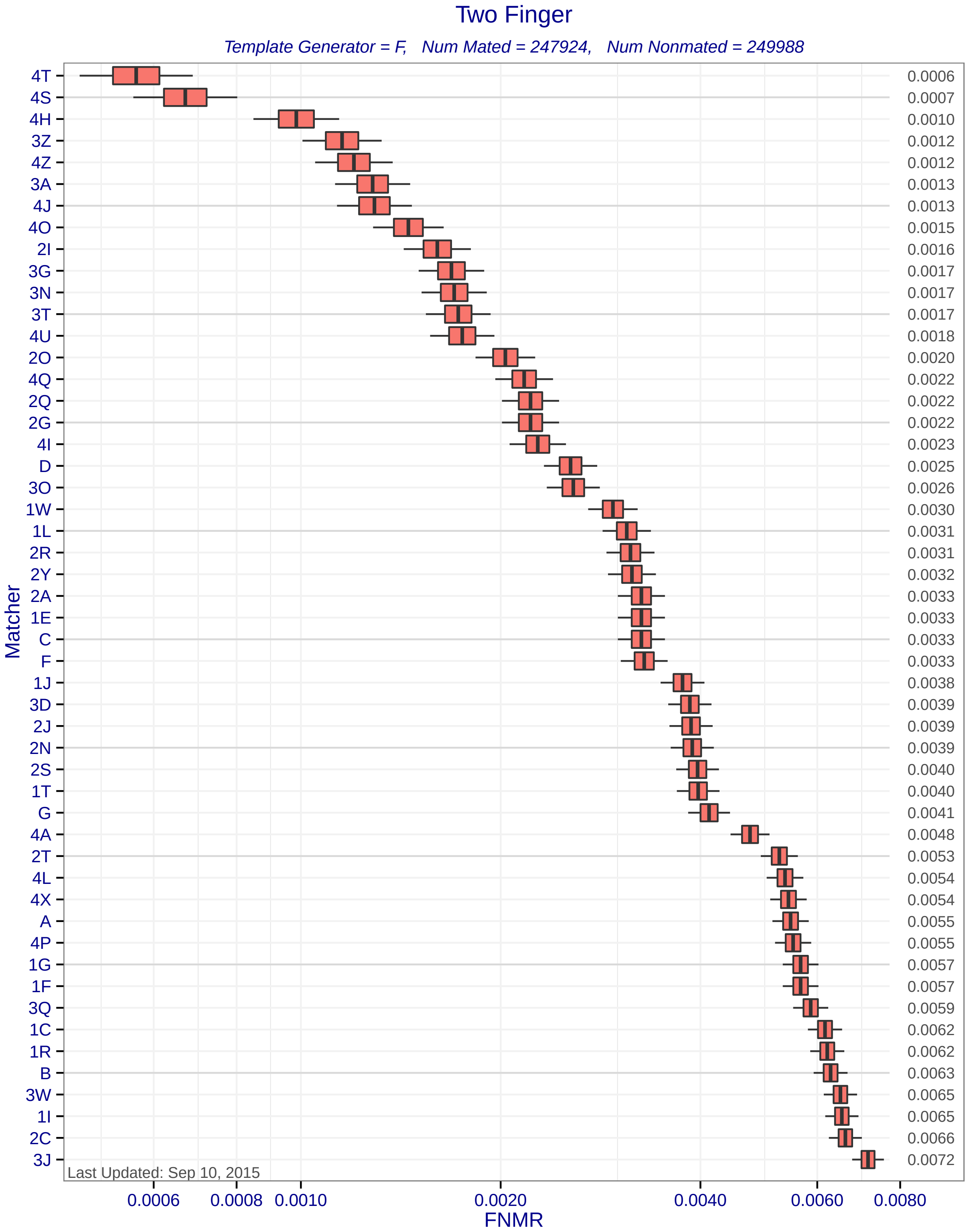


Figure 7: *Two Finger FNMR at FMR=0.01 when different matchers compare templates created by template generator F. Each box represents uncertainty about the true FNMR. The box edges mark the 50% confidence intervals while the whiskers mark the 90% confindence intervals. The numbers on the right show the actual computed FNMRs. Score-level fusion is achieved by averaging the scores for left and right index fingers.*

3.3 Minutia Counts

This section presents information relating to the number of minutia the template generator finds in fingerprint images. The relative number of minutia found in common fingerprint images has been shown to influence matching outcomes [8, 5].

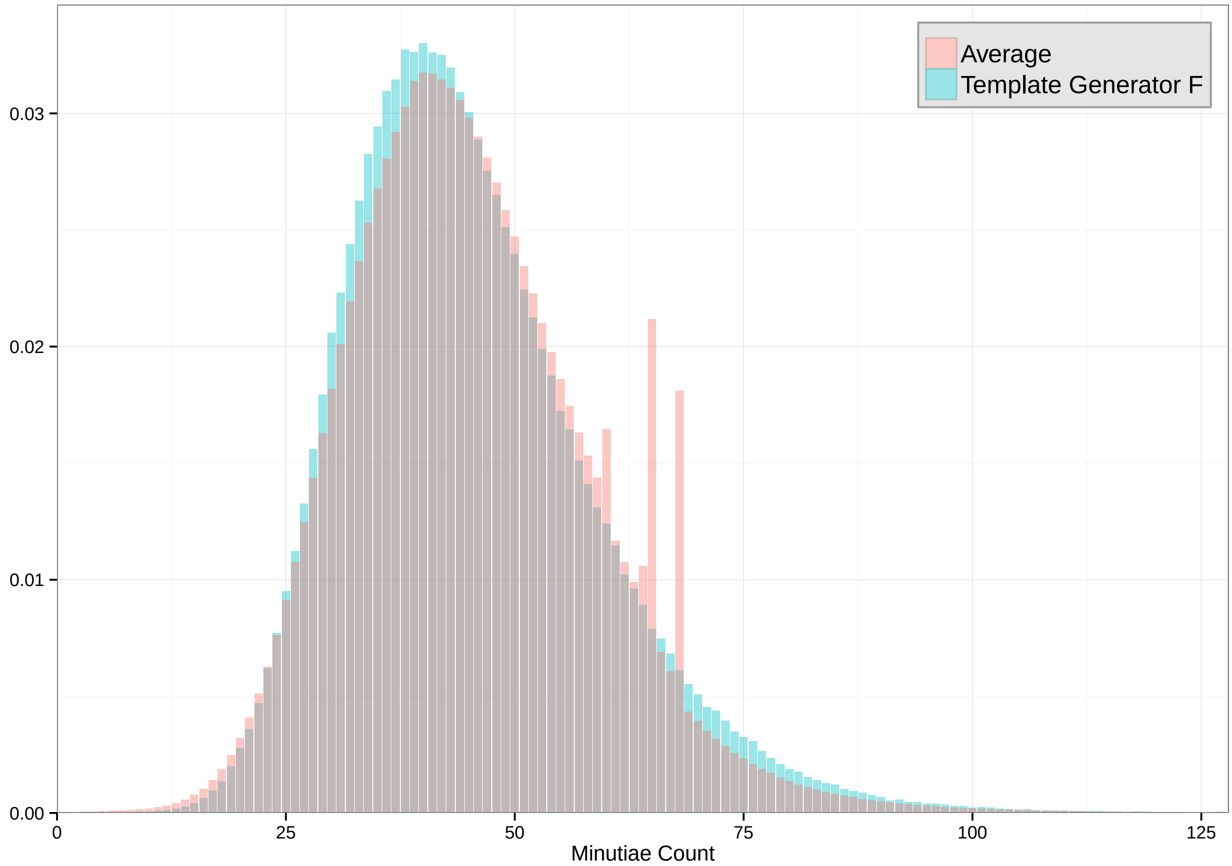
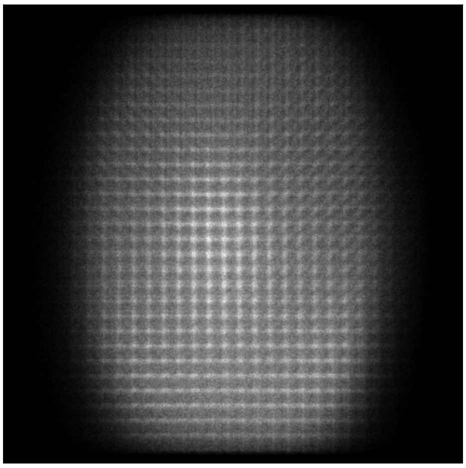


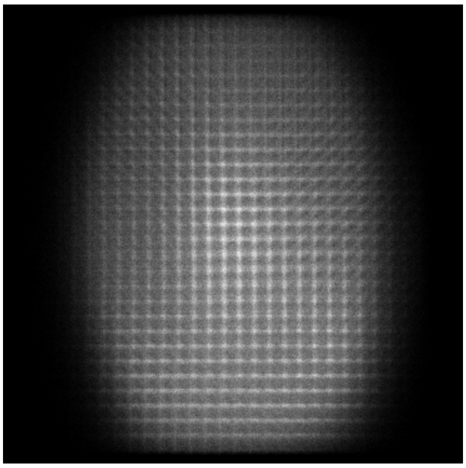
Figure 8: *Probability distribution of the number of minutia the template generator found in the samples. The* average *probability distribution shows the combined distribution of minutia counts across all compliant template generators.*

3.4 Minutia Density Plots

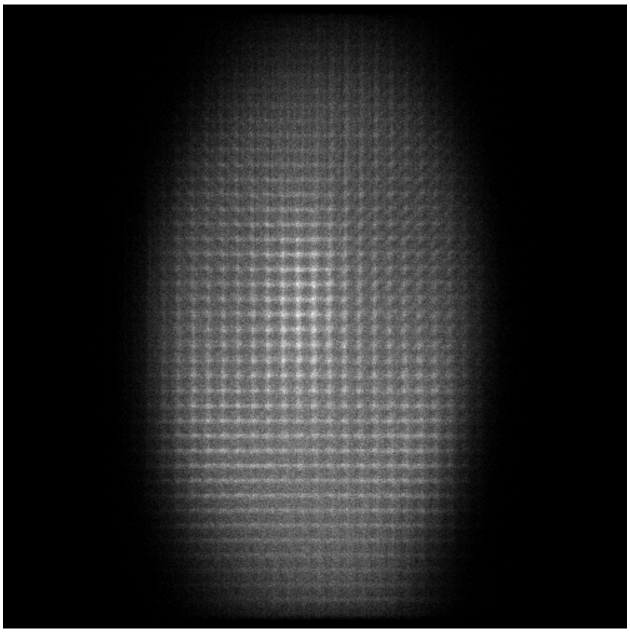
Minutia density plots show where the template generator tends to find minutia in fingerprint images. They are 2D histograms where the degree of illumination at an (x, y) coordinate indicates how frequently the software located a minutiae point at that location. The purpose of showing minutia density plots is to determine whether the template generator exhibits regional preference when locating minutia.

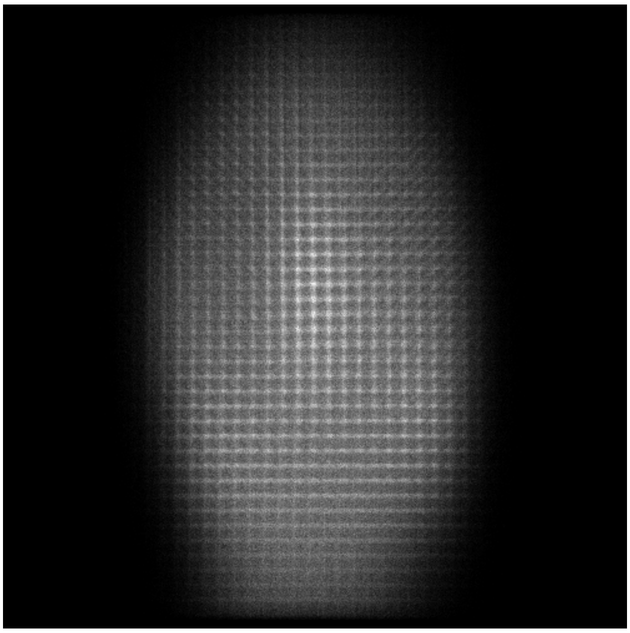
NIST has determined that this template generator produces minutia exhibiting a periodic structure. This is an indication that the template generator is departing from the minutia placement requirements of INCITS 378, clause 5. The expected pattern is a locally uniform distribution, and the appearance of local structure indicates systematic non-conformance with the standard. Given such behavior negatively affects interoperability[8], developers are asked to determine the cause of such behavior – for example, as an artifact of a tilebased image processing algorithms applied to the input fingerprint image and to resubmit corrected algorithms.





(a) Minutia density plot for 251 874 368x368 right indexes. (b) Minutia density plot for 251 874 368x368 left indexes.





(c) Minutia density plot for 123 120 500x500 right indexes. (d) Minutia density plot for 123 120 500x500 left indexes.

Figure 9: 2D Minutia density plots.

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 the report do not present actual accuracy numbers.

Table 1: *Single finger FNMRs at various FMRs when F and MINEX compliant matchers compare templates created by template generator F.*

Matcher	FNMR @ FMR=0.01	FNMR @ FMR=0.001	FNMR @ FMR=0.0001
A	0.0357 ± 0.0006	0.0549 ± 0.0008	0.0820 ± 0.0009
B	0.0424 ± 0.0007	0.0787 ± 0.0009	0.126 ± 0.001
C	0.0220 ± 0.0005	0.0402 ± 0.0006	0.0671 ± 0.0008
D	0.0206 ± 0.0005	0.0322 ± 0.0006	0.0472 ± 0.0007
F	0.0221 ± 0.0005	0.0401 ± 0.0006	0.0673 ± 0.0008
G	0.0343 ± 0.0006	0.0451 ± 0.0007	0.0683 ± 0.0008
1C	0.0336 ± 0.0006	0.0572 ± 0.0008	0.0882 ± 0.0009
1E	0.0270 ± 0.0005	0.0428 ± 0.0007	0.0625 ± 0.0008
1F	0.0356 ± 0.0006	0.0599 ± 0.0008	0.0914 ± 0.0010
1G	0.0356 ± 0.0006	0.0599 ± 0.0008	0.0914 ± 0.0010
1I	0.0436 ± 0.0007	0.0909 ± 0.0009	0.180 ± 0.001
1J	0.0246 ± 0.0005	0.0459 ± 0.0007	0.0724 ± 0.0009
1L	0.0231 ± 0.0005	0.0393 ± 0.0006	0.0616 ± 0.0008
1R	0.0407 ± 0.0007	0.0855 ± 0.0009	0.164 ± 0.001
1T	0.0279 ± 0.0005	0.0483 ± 0.0007	0.0754 ± 0.0009
1W	0.0252 ± 0.0005	0.0478 ± 0.0007	0.0819 ± 0.0009
2A	0.0220 ± 0.0005	0.0402 ± 0.0006	0.0671 ± 0.0008
2C	0.0417 ± 0.0007	0.0882 ± 0.0009	0.185 ± 0.001
2G	0.0196 ± 0.0005	0.0388 ± 0.0006	0.0647 ± 0.0008
2I	0.0166 ± 0.0004	0.0350 ± 0.0006	0.0694 ± 0.0008
2J	0.0260 ± 0.0005	0.0492 ± 0.0007	0.0760 ± 0.0009
2N	0.0284 ± 0.0005	0.0469 ± 0.0007	0.0700 ± 0.0008
2O	0.0168 ± 0.0004	0.0357 ± 0.0006	0.0901 ± 0.0009
2Q	0.0177 ± 0.0004	0.0298 ± 0.0006	0.0504 ± 0.0007
2R	0.0267 ± 0.0005	0.0463 ± 0.0007	0.0764 ± 0.0009
2S	0.0281 ± 0.0005	0.0472 ± 0.0007	0.0723 ± 0.0009
2T	0.0422 ± 0.0007	0.0595 ± 0.0008	0.0822 ± 0.0009
2Y	0.0208 ± 0.0005	0.0345 ± 0.0006	0.0566 ± 0.0008
3A	0.0118 ± 0.0004	0.0171 ± 0.0004	0.0240 ± 0.0005
3D	0.0315 ± 0.0006	0.0529 ± 0.0007	0.0817 ± 0.0009
3G	0.0159 ± 0.0004	0.0289 ± 0.0006	0.0490 ± 0.0007
3J	0.0420 ± 0.0007	0.0567 ± 0.0008	0.0820 ± 0.0009
3N	0.0183 ± 0.0004	0.0441 ± 0.0007	0.0810 ± 0.0009
3O	0.0206 ± 0.0005	0.0344 ± 0.0006	0.0551 ± 0.0008
3Q	0.0408 ± 0.0007	0.0766 ± 0.0009	0.117 ± 0.001
3T	0.0149 ± 0.0004	0.0251 ± 0.0005	0.0397 ± 0.0006
3W	0.0342 ± 0.0006	0.0613 ± 0.0008	0.0969 ± 0.0010
3Z	0.0110 ± 0.0003	0.0179 ± 0.0004	0.0267 ± 0.0005
4A	0.0307 ± 0.0006	0.0443 ± 0.0007	0.0652 ± 0.0008
4H	0.0110 ± 0.0003	0.0215 ± 0.0005	0.0392 ± 0.0006

Table 1: *(continued)*

Matcher	FNMR @ FMR=0.01	FNMR @ FMR=0.001	FNMR @ FMR=0.0001
4I	0.0206 ± 0.0005	0.0417 ± 0.0007	0.0728 ± 0.0009
4J	0.0131 ± 0.0004	0.0258 ± 0.0005	0.0453 ± 0.0007
4L	0.0326 ± 0.0006	0.0558 ± 0.0008	0.103 ± 0.001
4O	0.0138 ± 0.0004	0.0266 ± 0.0005	0.0430 ± 0.0007
4P	0.0306 ± 0.0006	0.0499 ± 0.0007	0.0779 ± 0.0009
4Q	0.0213 ± 0.0005	0.0446 ± 0.0007	0.111 ± 0.001
4S	0.0077 ± 0.0003	0.0128 ± 0.0004	0.0202 ± 0.0005
4T	0.0096 ± 0.0003	0.0193 ± 0.0005	0.0323 ± 0.0006
4U	0.0169 ± 0.0004	0.0331 ± 0.0006	0.0579 ± 0.0008
4X	0.0349 ± 0.0006	0.0486 ± 0.0007	0.0704 ± 0.0008
4Z	0.0106 ± 0.0003	0.0185 ± 0.0004	0.0294 ± 0.0006

Table 2: *Right index finger FNMRs at various FMRs when F and MINEX compliant matchers compare templates created by template generator F.*

Matcher	FNMR @ FMR=0.01	FNMR @ FMR=0.001	FNMR @ FMR=0.0001
A	0.0259 ± 0.0007	0.0408 ± 0.0009	0.065 ± 0.001
B	0.0340 ± 0.0008	0.066 ± 0.001	0.106 ± 0.001
C	0.0150 ± 0.0006	0.0293 ± 0.0008	0.048 ± 0.001
D	0.0149 ± 0.0006	0.0241 ± 0.0007	0.0363 ± 0.0009
F	0.0151 ± 0.0006	0.0295 ± 0.0008	0.052 ± 0.001
G	0.0262 ± 0.0007	0.0322 ± 0.0008	0.051 ± 0.001
1C	0.0266 ± 0.0008	0.0447 ± 0.0010	0.065 ± 0.001
1E	0.0204 ± 0.0007	0.0331 ± 0.0008	0.0467 ± 0.0010
1F	0.0264 ± 0.0007	0.0480 ± 0.0010	0.077 ± 0.001
1G	0.0264 ± 0.0007	0.0480 ± 0.0010	0.077 ± 0.001
1I	0.0350 ± 0.0009	0.077 ± 0.001	0.168 ± 0.002
1J	0.0178 ± 0.0006	0.0355 ± 0.0009	0.059 ± 0.001
1L	0.0175 ± 0.0006	0.0308 ± 0.0008	0.051 ± 0.001
1R	0.0335 ± 0.0008	0.076 ± 0.001	0.146 ± 0.002
1T	0.0212 ± 0.0007	0.0366 ± 0.0009	0.058 ± 0.001
1W	0.0185 ± 0.0006	0.0353 ± 0.0009	0.061 ± 0.001
2A	0.0150 ± 0.0006	0.0293 ± 0.0008	0.048 ± 0.001
2C	0.0331 ± 0.0008	0.076 ± 0.001	0.180 ± 0.002
2G	0.0133 ± 0.0005	0.0264 ± 0.0007	0.054 ± 0.001
2I	0.0117 ± 0.0005	0.0255 ± 0.0007	0.052 ± 0.001
2J	0.0181 ± 0.0006	0.0354 ± 0.0009	0.061 ± 0.001
2N	0.0205 ± 0.0007	0.0349 ± 0.0009	0.055 ± 0.001
2O	0.0113 ± 0.0005	0.0260 ± 0.0007	0.098 ± 0.001
2Q	0.0127 ± 0.0005	0.0223 ± 0.0007	0.0367 ± 0.0009
2R	0.0195 ± 0.0006	0.0355 ± 0.0009	0.061 ± 0.001
2S	0.0195 ± 0.0006	0.0339 ± 0.0008	0.052 ± 0.001
2T	0.0312 ± 0.0008	0.0453 ± 0.0010	0.064 ± 0.001
2Y	0.0145 ± 0.0006	0.0248 ± 0.0007	0.0419 ± 0.0009
3A	0.0087 ± 0.0004	0.0125 ± 0.0005	0.0178 ± 0.0006
3D	0.0238 ± 0.0007	0.0418 ± 0.0009	0.060 ± 0.001
3G	0.0111 ± 0.0005	0.0208 ± 0.0007	0.0372 ± 0.0009
3J	0.0342 ± 0.0008	0.0473 ± 0.0010	0.071 ± 0.001
3N	0.0127 ± 0.0005	0.0315 ± 0.0008	0.067 ± 0.001
3O	0.0154 ± 0.0006	0.0268 ± 0.0008	0.0446 ± 0.0010
3Q	0.0303 ± 0.0008	0.062 ± 0.001	0.101 ± 0.001
3T	0.0104 ± 0.0005	0.0182 ± 0.0006	0.0289 ± 0.0008
3W	0.0255 ± 0.0007	0.0481 ± 0.0010	0.074 ± 0.001
3Z	0.0079 ± 0.0004	0.0133 ± 0.0005	0.0204 ± 0.0007
4A	0.0242 ± 0.0007	0.0358 ± 0.0009	0.054 ± 0.001
4H	0.0072 ± 0.0004	0.0153 ± 0.0006	0.0295 ± 0.0008

Table 2: *(continued)*

Matcher	FNMR @ FMR=0.01	FNMR @ FMR=0.001	FNMR @ FMR=0.0001
4I	0.0149 ± 0.0006	0.0324 ± 0.0008	0.054 ± 0.001
4J	0.0084 ± 0.0004	0.0171 ± 0.0006	0.0310 ± 0.0008
4L	0.0234 ± 0.0007	0.0409 ± 0.0009	0.082 ± 0.001
4O	0.0091 ± 0.0004	0.0180 ± 0.0006	0.0330 ± 0.0008
4P	0.0213 ± 0.0007	0.0367 ± 0.0009	0.061 ± 0.001
4Q	0.0160 ± 0.0006	0.0340 ± 0.0008	0.092 ± 0.001
4S	0.0052 ± 0.0003	0.0088 ± 0.0004	0.0143 ± 0.0006
4T	0.0075 ± 0.0004	0.0145 ± 0.0006	0.0232 ± 0.0007
4U	0.0125 ± 0.0005	0.0252 ± 0.0007	0.0440 ± 0.0010
4X	0.0267 ± 0.0008	0.0380 ± 0.0009	0.057 ± 0.001
4Z	0.0069 ± 0.0004	0.0124 ± 0.0005	0.0202 ± 0.0007

Table 3: *Left index finger FNMRs at various FMRs when F and MINEX compliant matchers compare templates created by template generator F.*

Matcher	FNMR @ FMR=0.01	FNMR @ FMR=0.001	FNMR @ FMR=0.0001
A	0.0451 ± 0.0010	0.068 ± 0.001	0.101 ± 0.001
B	0.051 ± 0.001	0.091 ± 0.001	0.146 ± 0.002
C	0.0290 ± 0.0008	0.052 ± 0.001	0.085 ± 0.001
D	0.0262 ± 0.0007	0.0402 ± 0.0009	0.059 ± 0.001
F	0.0292 ± 0.0008	0.051 ± 0.001	0.081 ± 0.001
G	0.0424 ± 0.0009	0.058 ± 0.001	0.087 ± 0.001
1C	0.0410 ± 0.0009	0.070 ± 0.001	0.105 ± 0.001
1E	0.0337 ± 0.0008	0.053 ± 0.001	0.076 ± 0.001
1F	0.0448 ± 0.0010	0.072 ± 0.001	0.109 ± 0.001
1G	0.0448 ± 0.0010	0.072 ± 0.001	0.109 ± 0.001
1I	0.053 ± 0.001	0.105 ± 0.001	0.195 ± 0.002
1J	0.0314 ± 0.0008	0.056 ± 0.001	0.087 ± 0.001
1L	0.0288 ± 0.0008	0.0474 ± 0.0010	0.073 ± 0.001
1R	0.0480 ± 0.0010	0.095 ± 0.001	0.172 ± 0.002
1T	0.0347 ± 0.0009	0.061 ± 0.001	0.095 ± 0.001
1W	0.0322 ± 0.0008	0.059 ± 0.001	0.100 ± 0.001
2A	0.0290 ± 0.0008	0.052 ± 0.001	0.085 ± 0.001
2C	0.051 ± 0.001	0.100 ± 0.001	0.187 ± 0.002
2G	0.0262 ± 0.0007	0.051 ± 0.001	0.078 ± 0.001
2I	0.0219 ± 0.0007	0.0454 ± 0.0010	0.086 ± 0.001
2J	0.0341 ± 0.0008	0.063 ± 0.001	0.091 ± 0.001
2N	0.0363 ± 0.0009	0.059 ± 0.001	0.087 ± 0.001
2O	0.0223 ± 0.0007	0.0449 ± 0.0010	0.089 ± 0.001
2Q	0.0225 ± 0.0007	0.0371 ± 0.0009	0.067 ± 0.001
2R	0.0340 ± 0.0008	0.057 ± 0.001	0.090 ± 0.001
2S	0.0369 ± 0.0009	0.060 ± 0.001	0.091 ± 0.001
2T	0.053 ± 0.001	0.074 ± 0.001	0.100 ± 0.001
2Y	0.0271 ± 0.0008	0.0444 ± 0.0010	0.071 ± 0.001
3A	0.0148 ± 0.0006	0.0217 ± 0.0007	0.0307 ± 0.0008
3D	0.0394 ± 0.0009	0.065 ± 0.001	0.102 ± 0.001
3G	0.0210 ± 0.0007	0.0372 ± 0.0009	0.065 ± 0.001
3J	0.050 ± 0.001	0.066 ± 0.001	0.095 ± 0.001
3N	0.0243 ± 0.0007	0.058 ± 0.001	0.094 ± 0.001
3O	0.0251 ± 0.0007	0.0408 ± 0.0009	0.060 ± 0.001
3Q	0.050 ± 0.001	0.092 ± 0.001	0.137 ± 0.002
3T	0.0195 ± 0.0006	0.0328 ± 0.0008	0.050 ± 0.001
3W	0.0432 ± 0.0009	0.076 ± 0.001	0.119 ± 0.002
3Z	0.0140 ± 0.0005	0.0224 ± 0.0007	0.0339 ± 0.0008
4A	0.0373 ± 0.0009	0.053 ± 0.001	0.078 ± 0.001
4H	0.0149 ± 0.0006	0.0279 ± 0.0008	0.050 ± 0.001

Table 3: *(continued)*

Matcher	FNMR @ FMR=0.01	FNMR @ FMR=0.001	FNMR @ FMR=0.0001
4I	0.0268 ± 0.0008	0.052 ± 0.001	0.094 ± 0.001
4J	0.0182 ± 0.0006	0.0343 ± 0.0009	0.060 ± 0.001
4L	0.0422 ± 0.0009	0.071 ± 0.001	0.118 ± 0.002
4O	0.0188 ± 0.0006	0.0351 ± 0.0009	0.056 ± 0.001
4P	0.0392 ± 0.0009	0.063 ± 0.001	0.094 ± 0.001
4Q	0.0265 ± 0.0008	0.057 ± 0.001	0.134 ± 0.002
4S	0.0102 ± 0.0005	0.0170 ± 0.0006	0.0275 ± 0.0008
4T	0.0127 ± 0.0005	0.0246 ± 0.0007	0.0450 ± 0.0010
4U	0.0215 ± 0.0007	0.0410 ± 0.0009	0.078 ± 0.001
4X	0.0431 ± 0.0009	0.059 ± 0.001	0.086 ± 0.001
4Z	0.0147 ± 0.0006	0.0253 ± 0.0007	0.0399 ± 0.0009

Table 4: *Two finger FNMRs at various FMRs when F and MINEX compliant matchers compare templates created by template generator F.*

Matcher	FNMR @ FMR=0.01	FNMR @ FMR=0.001	FNMR @ FMR=0.0001
A	0.0055 ± 0.0002	0.0104 ± 0.0003	0.0354 ± 0.0006
B	0.0063 ± 0.0003	0.0144 ± 0.0004	0.0266 ± 0.0005
C	0.0033 ± 0.0002	0.0066 ± 0.0003	0.0113 ± 0.0003
D	0.0025 ± 0.0002	0.0042 ± 0.0002	0.0060 ± 0.0003
F	0.0033 ± 0.0002	0.0067 ± 0.0003	0.0114 ± 0.0003
G	0.0041 ± 0.0002	0.0081 ± 0.0003	0.0141 ± 0.0004
1C	0.0062 ± 0.0003	0.0116 ± 0.0004	0.0201 ± 0.0005
1E	0.0033 ± 0.0002	0.0056 ± 0.0002	0.0090 ± 0.0003
1F	0.0057 ± 0.0002	0.0109 ± 0.0003	0.0187 ± 0.0004
1G	0.0057 ± 0.0002	0.0109 ± 0.0003	0.0187 ± 0.0004
1I	0.0065 ± 0.0003	0.0210 ± 0.0005	0.0610 ± 0.0008
1J	0.0038 ± 0.0002	0.0088 ± 0.0003	0.0167 ± 0.0004
1L	0.0031 ± 0.0002	0.0058 ± 0.0002	0.0100 ± 0.0003
1R	0.0062 ± 0.0003	0.0182 ± 0.0004	0.0555 ± 0.0008
1T	0.0040 ± 0.0002	0.0083 ± 0.0003	0.0135 ± 0.0004
1W	0.0030 ± 0.0002	0.0208 ± 0.0005	0.0511 ± 0.0007
2A	0.0033 ± 0.0002	0.0066 ± 0.0003	0.0113 ± 0.0003
2C	0.0066 ± 0.0003	0.0198 ± 0.0005	0.0736 ± 0.0009
2G	0.0022 ± 0.0002	0.0056 ± 0.0002	0.0110 ± 0.0003
2I	0.0016 ± 0.0001	0.0041 ± 0.0002	0.0100 ± 0.0003
2J	0.0039 ± 0.0002	0.0090 ± 0.0003	0.0169 ± 0.0004
2N	0.0039 ± 0.0002	0.0074 ± 0.0003	0.0127 ± 0.0004
2O	0.0020 ± 0.0001	0.0042 ± 0.0002	0.0112 ± 0.0003
2Q	0.0022 ± 0.0002	0.0042 ± 0.0002	0.0074 ± 0.0003
2R	0.0031 ± 0.0002	0.0268 ± 0.0005	0.0532 ± 0.0007
2S	0.0040 ± 0.0002	0.0078 ± 0.0003	0.0132 ± 0.0004
2T	0.0053 ± 0.0002	0.0095 ± 0.0003	0.0136 ± 0.0004
2Y	0.0032 ± 0.0002	0.0058 ± 0.0003	0.0104 ± 0.0003
3A	0.0013 ± 0.0001	0.0019 ± 0.0001	0.0028 ± 0.0002
3D	0.0039 ± 0.0002	0.0075 ± 0.0003	0.0132 ± 0.0004
3G	0.0017 ± 0.0001	0.0035 ± 0.0002	0.0065 ± 0.0003
3J	0.0072 ± 0.0003	0.0116 ± 0.0004	0.0188 ± 0.0004
3N	0.0017 ± 0.0001	0.0059 ± 0.0003	0.0178 ± 0.0004
3O	0.0026 ± 0.0002	0.0049 ± 0.0002	0.0084 ± 0.0003
3Q	0.0059 ± 0.0003	0.0144 ± 0.0004	0.0267 ± 0.0005
3T	0.0017 ± 0.0001	0.0029 ± 0.0002	0.0050 ± 0.0002
3W	0.0065 ± 0.0003	0.0125 ± 0.0004	0.0207 ± 0.0005
3Z	0.0012 ± 0.0001	0.0021 ± 0.0001	0.0031 ± 0.0002
4A	0.0048 ± 0.0002	0.0085 ± 0.0003	0.0146 ± 0.0004
4H	0.0010 ± 0.0001	0.0021 ± 0.0002	0.0045 ± 0.0002

Table 4: *(continued)*

Matcher	FNMR @ FMR=0.01	FNMR @ FMR=0.001	FNMR @ FMR=0.0001
4I	0.0023 ± 0.0002	0.0055 ± 0.0002	0.0108 ± 0.0003
4J	0.0013 ± 0.0001	0.0029 ± 0.0002	0.0052 ± 0.0002
4L	0.0054 ± 0.0002	0.0111 ± 0.0003	0.0204 ± 0.0005
4O	0.0015 ± 0.0001	0.0033 ± 0.0002	0.0060 ± 0.0003
4P	0.0055 ± 0.0002	0.0102 ± 0.0003	0.0199 ± 0.0005
4Q	0.0022 ± 0.0002	0.0074 ± 0.0003	0.0219 ± 0.0005
4S	0.00067 ± 0.00009	0.0011 ± 0.0001	0.0020 ± 0.0001
4T	0.00056 ± 0.00008	0.0015 ± 0.0001	0.0028 ± 0.0002
4U	0.0018 ± 0.0001	0.0039 ± 0.0002	0.0077 ± 0.0003
4X	0.0054 ± 0.0002	0.0091 ± 0.0003	0.0152 ± 0.0004
4Z	0.0012 ± 0.0001	0.0023 ± 0.0002	0.0036 ± 0.0002

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] Olaf Henniger and Dirk Scheuermann. Minutiae template conformance and interoperability issues. In Arslan Brömme, Christoph Busch, and Detlef Hühnlein, editors, *BIOSIG*, volume 108 of *LNI*, pages 25–32. GI, 2007. 10

[6] 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

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

[8] Elham Tabassi, Patrick Grother, Wayne Salamon, and Craig Watson. Minutiae interoperability. In Arslan Brömme, Christoph Busch, and Detlef Hühnlein, editors, *BIOSIG*, volume 155 of *LNI*, pages 13–30. GI, 2009. 10, 11