

NISTIR 7821

PFTII report

**Plain and Rolled Fingerprint Matching
with Proprietary Templates**

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PFTII report: Plain and Rolled Fingerprint Matching with Proprietary Templates

Abstract

This report is an extension of the “Two Finger Matching with Vendor SDK¹ Matches” [1] which evaluated the accuracy of matching two plain impression fingerprints (right index and left index) with proprietary fingerprint templates. This study is based on National Institute of Standards and Technology’s (NIST) ongoing proprietary fingerprint template (PFTII) program (<http://www.nist.gov/itl/iad/ig/pftii.cfm>) which evaluates matching two plain index fingers of two datasets and six fingers (both thumbs, index fingers, and middle fingers) of one dataset. The fingerprint matches are performed between different types of print impressions: plain vs. plain images (p2p), plain vs. rolled images (p2r), and rolled vs. rolled images (r2r). The proprietary template size, the timings for template extractions, and comparisons are examined and summarized.

1. Introduction

Prior to PFTII, the proprietary fingerprint template (PFT) evaluations were performed to measure the accuracy of two-finger matching verification systems [1] for two plain impression fingerprints. In another study [2], the performance from matching images of plain impression fingerprints, (referred in this report as “plain”), and rolled impression fingerprints, (referred in this report as “rolled”), of thumbs, index, middle, ring and little fingers were shown for the participant’s SDK matchers. In [3], studies on fingerprint matching accuracy have been researched on plain to rolled fingerprint matching using the NIST Algorithmic Test Bed (ATB)² on various datasets. However in [2, 3], the dataset size for the plain to rolled comparison were significantly smaller.

The PFTII evaluation expands the size of both gallery and probe sets from PFT. Two of the fingerprints datasets from the PFT evaluation are carried forward from the ongoing PFT evaluation, but added samples. A new data set which comprises ten print rolled images is included in the evaluation for PFTII. Details of the datasets are described in section 2.

With the increased size of the PFTII dataset, and three comparisons (p2p, p2r, r2r) for six fingers, the volume of image records has tripled. A new data storage management, “RecordStore”, has been introduced and implemented in the PFTII evaluation process. Detail of the “RecordStore” will be described later in the evaluation strategy section.

Detection Error Trade-off (DET) curves, Equal error rate (EER), False Match Rate (FMR), and False non-Match Rate (FNMR) are shown in the report. There are several new measurements being reported for PFTII:

¹ SDK stands for Software Development Kit. Software libraries developed to a standardized application programming interface (API) are supplied to NIST for evaluation.

² ATB is a prototype evaluation system provided by the Federal Bureau of Investigation (FBI) to NIST to support benchmark studies of the Integrated Automated Fingerprint Identification System (IAFIS).

- Fail To Enroll (FTE)
When the matcher fails to extract the template, a null template is created, and an FTE is counted. The null template will continue to be processed for the comparison which measures the true DET.
- Proprietary template size
The API has been modified to include the output of the size of proprietary template.
- Matcher's template enrollment time and comparison time
Both the enrollment and comparison time contain only CPU time (in micro seconds), deliberately omitting the I/O time.
- Confidence Interval for FMR and FNMR
95% confidence intervals of FNMR at FMR= 0.0001, and FMR at FNMR= {0.002, 0.005} are computed by the binomial estimation with $\hat{p} - \delta \leq \hat{p} \leq \hat{p} + \delta$ where \hat{p} is the computed FNMR and FMR,

$$\delta = \Phi^{-1}(1 - \alpha/2) * (\hat{p}(1 - \hat{p})/N)^{1/2}$$

N = the sample size, Φ^{-1} is the inverse of cumulative Normal distribution, and $\alpha = 0.05$. This is based on previous research in PFT results, which showed that there is no significant difference between binomial and bootstrap estimations [4] in this application.

2. Dataset

Two of the two-finger datasets, DHS2 and POEBVA, are carried forward from the original PFT evaluation, but with additional 60K pairs respectively. A new ten print dataset is created from a combination of two different data sources, Arizona Department of Public Safety (AZDPS) and LA County Sheriff Department (LA) to form dataset AZLA. A random 120K subjects with mates were selected from the joint set of subjects with more than one ten print record, and 120K non-mate subjects from the joint set of having only one ten print record were selected. The distribution of the sample set AZLA is about 60% from AZ and 40% from LA of subjects with mates, and 12% from AZ and 88% from LA for the non-mates. Note that there are more subjects with multiple ten print records in AZ ($\approx 100K$ of 376K), while more subject with only one ten print record from LA (≈ 1.5 M of 1.6M) as indicated from dataset descriptions in section 2.1.

The mate data used in dataset AZLA are pre-evaluated and consolidated using the NIST ATB system and the examiner confirmation. The original 60K mates from DHS2 and POEBVA were consolidated from the PFT evaluations, but the new 60K additional mates will be consolidated as needed as the PFTII evaluation progresses.

1K samples from datasets; AZ, LA, DHS2, and POEBVA were selected having a specific fixed image size on which the template size and timings are measured:

- AZ: Probe – 800x800 pixels, Gallery – 800x800 pixels
- LA: Probe – 400x776 pixels, Gallery – 422x1000 pixels
- DHS2: Probe – 368x368 pixels, Gallery – 368x368 pixels
- POEBVA: Probe – 368x368 pixels, Gallery – 500x500 pixels

Description of datasets DHS2 and POEBVA can be found in [2], while AZDPS, and LA are listed as following:

AZDPS data (AZ)	
Description Data from the Arizona Department of Public Safety.	
Number of Subjects ≈270K with one record ≈105K with 2 or more records	records per Subject One or more records per subject. Each record contains one 10-print card.
Impression Type Live-scan Rolled and Plain	Finger Positions Captured 10 fingerprints taken from rolled impressions and 10 fingerprints taken from 2 plain thumbs and segmentation of 2 plain slap-4 images on the same 10-print card
Capture Device(s) NA	Other Available Images None
Availability Government use only	
Data Preparation Segmentations of 2 plain slap-4 impressions were done by NIST <i>nfseg</i> ³ program. Only the successful automatic segmentation results were used. If one of the four segmented impressions failed the NIST Fingerprint Quality (NFIQ) program, then the other three segmented impressions were excluded as well. Only a few impressions were excluded for this reason. Data used in the evaluation were consolidated for subjects with mutiple records.	

³ *nfseg*, a fingerprint segmentation algorithm, is in the NIST Biometric Image Software (NBIS) distribution which can be found in <http://www.nist.gov/itl/iad/ig/nbis.cfm>.

LA Country Sheriff Department (LA)	
Description Data from the Los Angeles County Sheriff Department	
Number of Subjects ≈1.5 Million with one record ≈74K with 2 or more records	records per Subject One or more records per subject. Each record contains one 10-print card.
Impression Type Live-scan and Ink Rolled and Plain	Finger Positions Captured 10 fingerprints taken from rolled impressions and 10 fingerprints taken from 2 plain thumbs and segmentation of 2 plain slap-4 images on the same 10-print card
Capture Device(s) ⁴ DBI 1133S CGT EP 1680 CSI CLS1	Other Available Images Palm print Face Scar Mark and Tattoo
Availability Government use only	
Data Preparation Segmentations of 2 plain slap-4 impressions were done by NIST <i>nfseg</i> program. Only the successful automatic segmentation results were used. If one of the four segmented impressions failed the NFIQ program, then the other three segmented impressions were excluded as well. Only a few impressions were excluded for this reason. Data used in the evaluation were consolidated for subjects with multiple records.	

⁴ Specific hardware and software products identified in this report do not imply recommendation or endorsement by NIST.

2.1 PFTII dataset Image Quality

All the fingerprint impressions in DHS2 and POEBVA are live scan. For AZLA, the impression types are mixed live scan and rescan from ten print cards; this mix is 93% from live scan and 7% from ink, as determined by meta-data provided with dataset.

The performance of the fingerprint recognition technique and the template extraction algorithm relies on the quality of the fingerprint images. The overall quality summarization for the sample datasets of PFTII are calculated by the following recommended equations from [4]⁵:

FMR	Equations for NFIQ summarization
0.0001	$105.41 - 5.41p_1 - 9.15p_2 - 23.82p_3 - 55.81p_4 - 105.41p_5$
0.001	$102.75 - 2.75p_1 - 5.37p_2 - 14.38p_3 - 42.25p_4 - 102.75p_5$
0.01	$101.91 - 1.91p_1 - 3.97p_2 - 10.24p_3 - 34.03p_4 - 101.91p_5$

where p_i is the proportion of the fingerprints with NFIQ of value $i = 1 \dots 5$, for PFTII datasets fingerprints. The resulting quality summary index is shown on Figure 1 for plain finger 02, 07 (right and left index fingers):

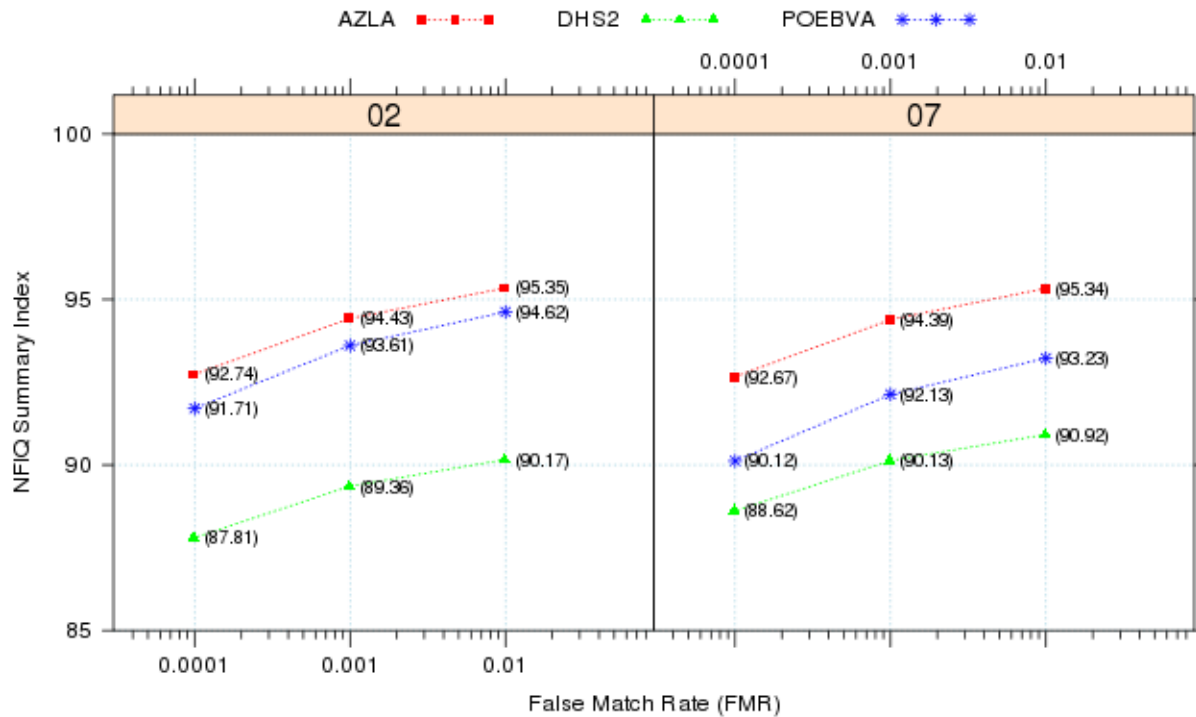


Figure 1: Dataset NIFQ Summaries

Figure 1 shows overall the quality indices of finger 02 and 07 for all three datasets: AZLA, POEBVA, and DHS2. The index is in the range of [0,100] where 0 represents the lowest quality,

⁵ This Biometric quality summarization is based on the weighted normalized NFIQ frequency for verification system.

100 as the best quality, so the higher the summary index value, the better quality of the dataset. This is opposite the NFIQ index (the lower the better). Within each dataset, the quality differs. For ALZA, Finger 02 is slightly better than Finger 07. For DHS2, 07 is slightly better than 02. However in POEBVA, finger 02 is much better than 07. In the summary section, we will analyze if there is any correlation of these quality indices with the matching performance of the algorithms.

3. Evaluation Strategy

PFTII continues to evaluate one-to-one fingerprint matching accuracy by the following configuration:

- \mathcal{G} : Gallery set of size 120,000 subjects
- \mathcal{P}_M : Probe mate set of size 120,000 subjects
- \mathcal{P}_{NM} : Probe non-mate of size 120,000 subjects

with the following constraints:

- \mathcal{P}_M contains exactly the same subject IDs as \mathcal{G} , but with images that have been acquired at a different time.
- Consolidation of Subject IDs

There are no common IDs between \mathcal{G} and \mathcal{P}_{NM} , from which it necessarily follows that there are no common IDs between \mathcal{P}_M and \mathcal{P}_{NM} . Fingerprint matching always involved the same finger position only (e.g., right index to right index) for both the probes and the gallery.

The order of the matching of the pairs are computed randomly.

3.1 RecordStore

In PFTII, the total fingerprint images have more than tripled over that of PFT from 1.5 million to 5.8 million, while the number of comparisons jumped from 1.4 million to 5.2 million. This creates an extra load on the storage system with a much larger number of files to be processed.

Traditionally, the PFT evaluation would generate individual file output for each proprietary enrollment template from each participant, in addition to consuming large numbers of files as input. In many file systems, managing a huge number of files is not efficient and leads to difficulties for processing. The file system overhead ultimately hampers the runtime of the evaluation.

Therefore an alternative file I/O strategy was applied for PFTII. This strategy called, RecordStore, was designed by NIST to provide an abstraction for performing record-oriented input and output to an underlying storage system.

A RecordStore is an implementation of a data management strategy that is controlled by a common code interface to support basic methods such as read() and write(). One simple data management strategy is to store each record into a separate file, reproducing what has typically

been done in the evaluation. Another strategy could be to store records in a remote relational database.

For PFTII, a Berkeley DB⁴ implementation of the RecordStore has been used, which provides significant speed improvements when reading and writing templates compared to individual files on disk. RecordStores maintain this flexibility in that they can be easily merged together into a larger RecordStore, a benefit which enables PFTII execution to be distributed across a cluster of blade computers while taking advantage of greatly improved I/O throughput. This dramatically reduces the time of the entire evaluation process, making the large number of measurements feasible.

However the implementation of RecordStore does not affect the timing of enrollment nor the timing of the comparison since only the processing time is collected and measured.

3.2 Hardware

The 1K sample evaluations are performed on a specific computer with 4XAMD⁴ Quad 2.3 GHz/8MB cache processors, 192 GB of RAM, and a 64 bit operating system. The rest of the PFTII evaluations are ran from a list of available hardware as specified in the PFTII Evaluation Plan (http://www.nist.gov/itl/iad/ig/upload/PFTII_Evaluation_Plan.pdf).

4. Results

To simplify the notations in the report, finger positions are labeled according to the following:

Finger position label	01	02	03	06	07	08	01+06	02+07	03+08
Description	Right Thumb	Right Index	Right Middle	Left Thumb	Left Index	Left Middle	Right and Left Thumb	Right and Left Index	Right and Left Middle

Table 1: Finger Position Description

Finger position 01, 02, and 03 are from the right hand, 06, 07, and 08 from the left hand, while 01+06, 02+07, and 03+08 represent the simple sum scores fusion from their respective finger positions.

To date, there have been three participants in PFTII listed as the following. The evaluation is ongoing and open to the entire fingerprint matching community (including vendors and academics).

Participant code	Organization Name
3A	Avalon Biometrics S.L.
3B	ID Solutions, Inc.
3C	Patrima Technology Company

Table 2: PFTII Participant List as September 2011

This report explicitly analyzes each matcher’s algorithm, and illustrates: first the matcher’s template size, enrollment timing, and comparison timing statistics; second, the performance by DET and error statistics for each individual matcher according to the different comparison types (p2p,p2r,r2r). Each matcher’s results are categorized by the following two groups:

I. 1K Sample Template Size and Timing statistics:

Figure v*-1, Table v-1	Box chart and detail table for maximum, 75%, median, 25%, and minimum of template size.
Figure v-2, Table v-2	Box chart and detail table for maximum, 75 %, median, 25 %, and minimum time of enrollment and comparison in second.

II. Performance by DET curves and Error statistics:

Figure v-3	DET curves**: p2p comparison for datasets AZLA, DHS2, POEBVA, and all three combinations for finger 02, 07, 02+07.
Figure v-4	DET curves: p2p, p2r, and r2r for AZLA only, with fingers (01, 02 ,03, 06, 07, 08, 01+06, 02+07, 03+08)
Figure v-5, Table v-3	EERs and FTEs
Figure v-6, Table v-4	FMRs @ FNMR= {.002, 0.005} and 95% Confidence Intervals
Figure v-7, Table v-4	FNMRs @ FMR = .0001 and 95% Confidence Intervals

Note: * v is substituted by 3A, 3B, and 3C.

** One set of curves which connects the FNMRs from a fixed matcher thresholds (scores are not normalized) which are corresponding to FMR= {0.0001, 0.005, 0.001, 0.05, 0.01}. For convenience, thresholds were selected from results of the POEBVA dataset and then applied to the DET curves for the other datasets.

The many figures and tables for each matcher are shown in Appendix A.

4.1 Template Size

Unlike the MINEX⁶ template format which has a size limit of 800 bytes with a standard fixed format, a proprietary template has no size limit with the matcher defined format.

The template size summary is displayed in Figure 2. There is a large variation in the resulting template size; the largest one from 3A is four times the smallest one from 3C within each dataset. Even the smallest 3C sizes are larger than the maximum size of MINEX.

⁶ MINEX is the NIST ongoing Minutiae Interoperability Exchange Test which uses International Committee for Information Technology Standards (INCITS) 378 specification.

Detail of the five statistics distributions are shown in Figure and Table 3A-1, 3B-1, 3C -1 of Appendix A. We found that it's very consistent over matchers and datasets; the larger the image, the larger the proprietary template size.

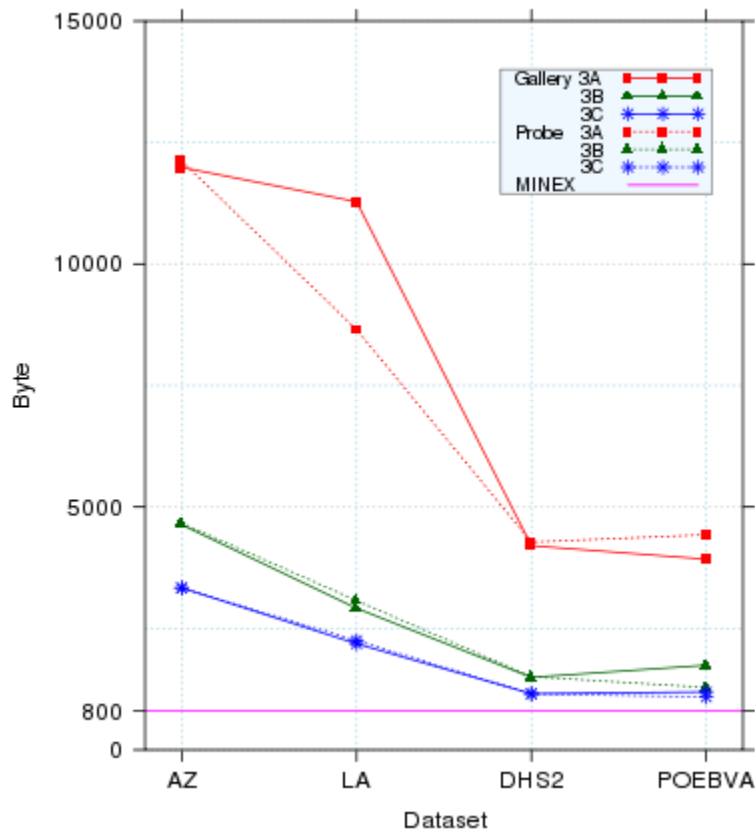


Figure 2: 1K Sample Template Size

4.2 1K Sample Enrollment and Comparison Timing

As specified in the PFTII application evaluation plan (section 3.2), we recommend the average enrollment time not exceeding 3 second and comparison time not exceeding one tenth of a second. In Figure 3, the evaluation timing summary from the median of both timings, it is shown that all the matchers meet the recommendations in both enrollment and comparison. Figures 3A-2, 3B-2, and 3C-2 in Appendix A show the detailed timing statistics from each matcher by dataset. We make the following observations:

- The larger the template size is, the longer the time to enroll and to compare.
- The maximum enrollment time is ≈ 6 seconds, while the minimum is ≈ 0 seconds.
- With regard to possible relationship between the enrollment and comparison times, we observe (Figure 3), that one matcher has the longest median enrollment time (twice the shortest time) but has the shortest median comparison time (one tenth the longest time). The timings from the other two matchers are in similar ranges.

- There is a big variation of the comparison time.
- A few of the maximum comparison times of the matchers are more than an order of magnitude greater than their own median time (Figure 3C-2 in Appendix A). This may be caused by the initialization from the matchers.

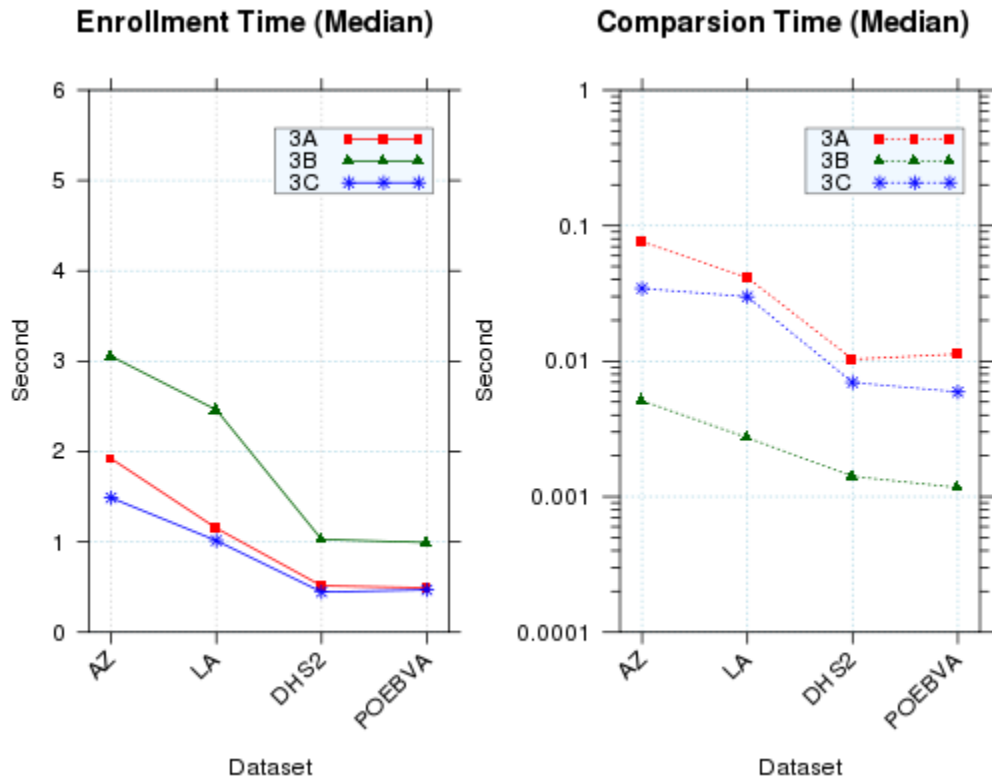


Figure 3: 1K Sample Timing Summary

4.3 Performance of P2P for Right Index, Left Index and two index fingers combined.

DET characteristic curves from Figures 3A-3, 3B-3, and 3C-3 in Appendix A are one of the major performance measurements for the PFTII evaluation. The figures display the FNMRs in the range of $(0.0001 \leq FMR < 0.1)$ of each matcher individually with respect to the different datasets: AZLA, DHS2, POEBVA and all three sets combined. Also in the figures, a list of FNMRs which are rendered through specific thresholds are obtained from the POEBVA dataset with $FMR = \{0.0001, 0.0005, 0.001, 0.005\}$. This demonstrates the FNMRs from different datasets with the same thresholds. Note that the thresholds displayed are not normalized from the matcher scores.

Figure 4 is the summary of Figures 3A-3, 3B-3, and 3C-3 from Appendix A, by matcher. Figure 5 shows the summary of DETs by dataset.

3A = Avalon Biometrics S.L.	3B = ID Solutions, Inc.	3C = Patrima Technology Company
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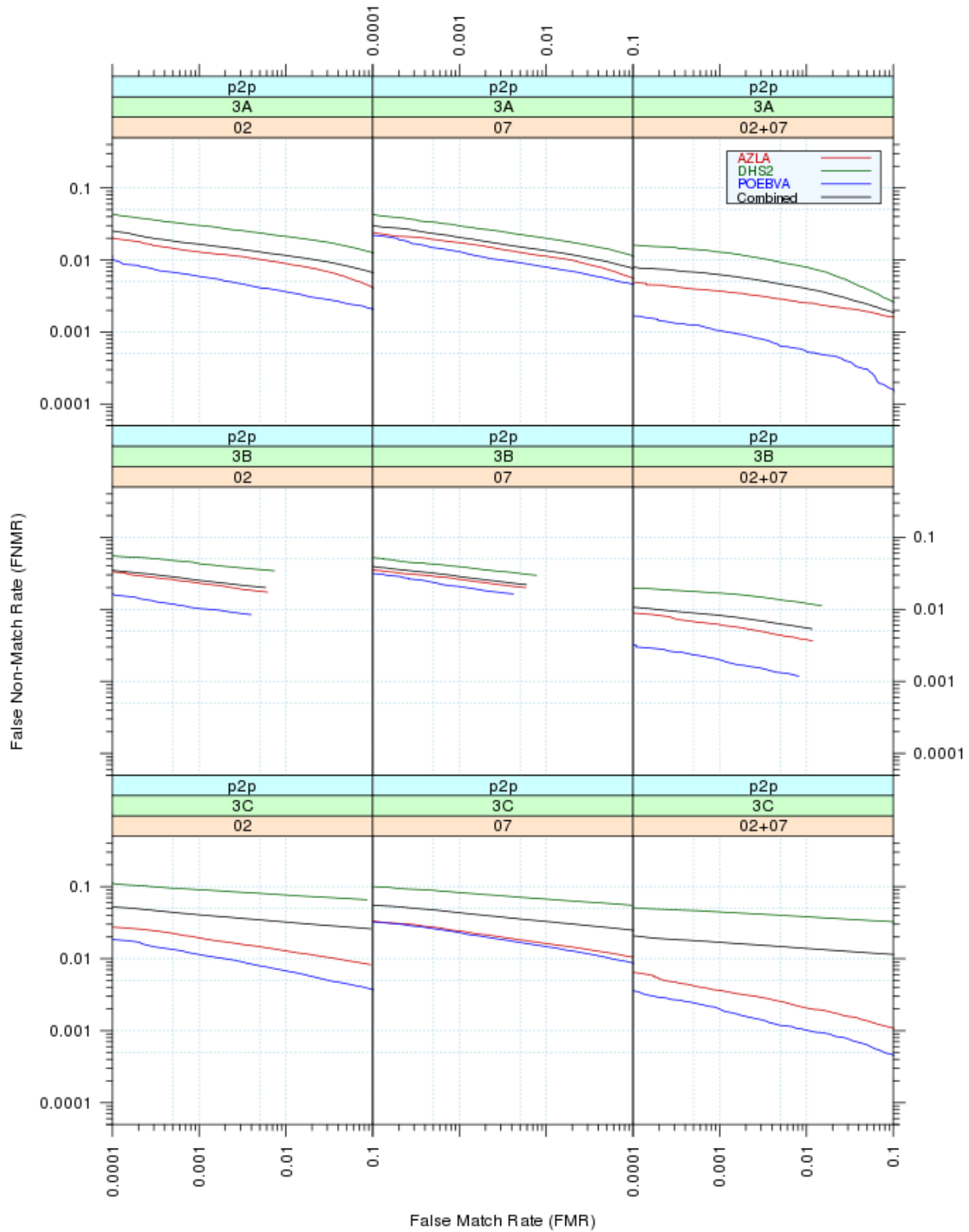


Figure 4: FNMR vs. FMR from matcher 3A, 3B, 3C for Plain vs. Plain Comparison by Right index, Left index, and two index fingers fusion.

3A = Avalon Biometrics S.L.	3B = ID Solutions, Inc.	3C = Patrima Technology Company
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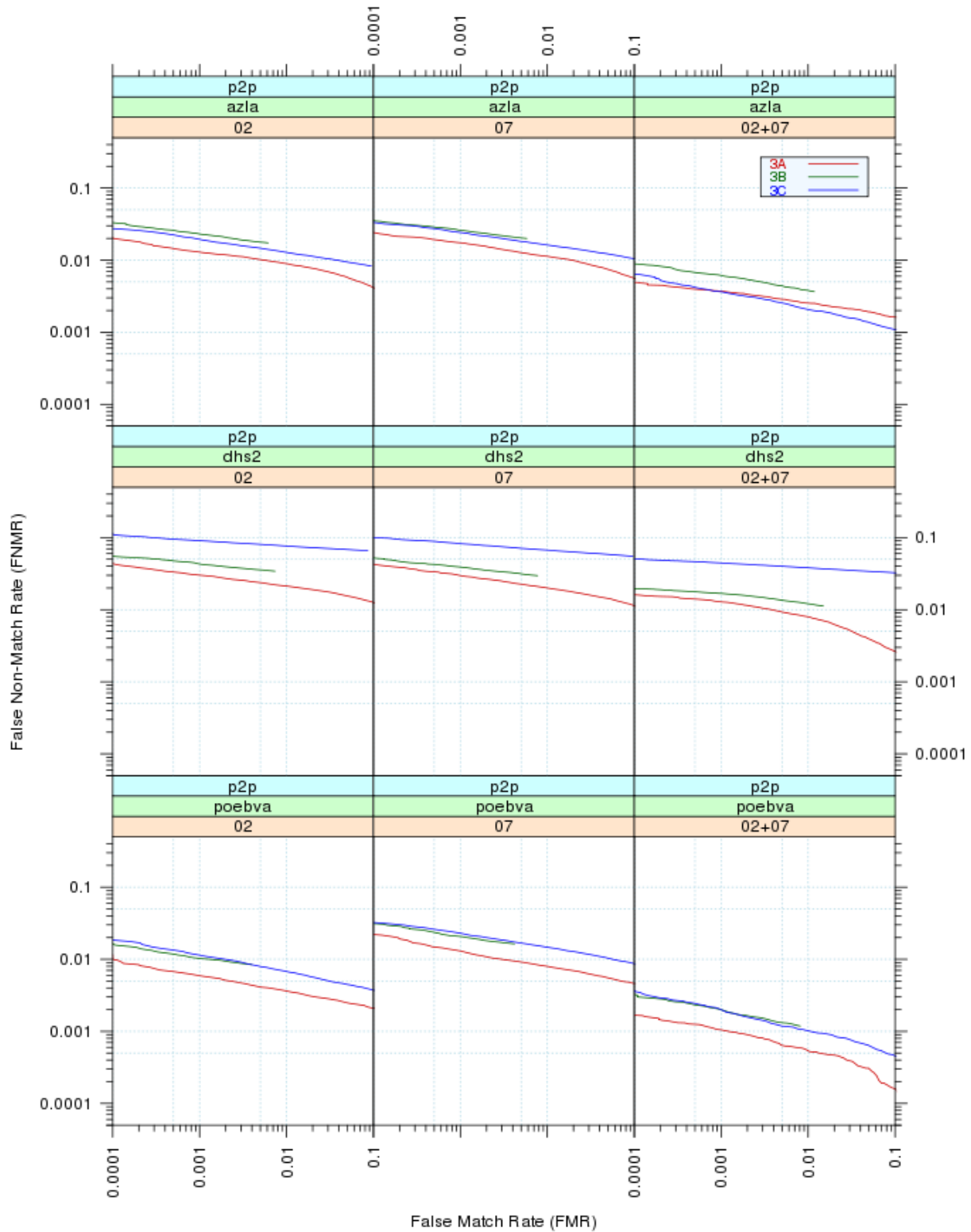


Figure 5: FNMR vs. FMR from AZLA, DHS2, POEBVA, for Plain vs. Plain Comparison by Right index, Left index, and two index fingers fusion.

3A = Avalon Biometrics S.L.	3B = ID Solutions, Inc.	3C = Patrima Technology Company
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Together with Table 3 of the FNMRs at $FMR = \{0.0001, 0.001\}$, and the observations, we find the following:

Plain vs. Plain		FNMR					
		FMR = 0.0001			FMR = 0.001		
Matcher	Finger	AZLA	DHS2	POEBVA	AZLA	DHS2	POEBVA
3A	02	0.0199	0.0430	0.0099	0.0130	0.0301	0.0059
3B	02	0.0331	0.0554	0.0162	0.0234	0.0434	0.0102
3C	02	0.0273	0.1098	0.0185	0.0194	0.0904	0.0115
3A	07	0.0239	0.0418	0.0217	0.0174	0.0296	0.0130
3B	07	0.0350	0.0522	0.0318	0.0261	0.0393	0.0207
3C	07	0.0333	0.0993	0.0321	0.0242	0.0824	0.0228
3A	02+07	0.0049	0.0160	0.0017	0.0037	0.0128	0.0011
3B	02+07	0.0089	0.0196	0.0032	0.0063	0.0169	0.0020
3C	02+07	0.0064	0.0507	0.0036	0.0036	0.0445	0.0020

Table 3: FNMR values for Plain to Plain print comparison with right (02), left (07) index and the sum fusion (02+07) from three datasets. Cells are shaded green with the lowest FNMR for each finger position among matchers.

- Regardless the matcher, dataset POEBVA continues to show the best results with the lowest FNMRs of the three sets, while DHS2 is the worst of the three sets; AZLA and all three datasets combined are second and third in the ranks. (Figure 4).
- However, according to the image quality summary index (Figure 1), AZLA is shown with better quality than POEBVA. One reason may be the plain index fingerprints were segmented from the slap image of the ten print card (which were rescanned from paper) for AZLA, while POEBVA plain index images were captured from live scan. DHS2 is the least accurate dataset which is consistent with the worst quality summary index.
- Right index finger (02) is more accurate than left index finger (07) except 3C, where there is no significant difference between them.
- There are no significant difference between 3B and 3C for datasets POEBVA and AZLA (Figure 5), whereas there is a larger gap between 3B and 3C from DHS2 where 3B is close to 3A.

4.4 Performance of Comparisons: Plain vs. Plain, Plain vs. Rolled, and Rolled vs. Rolled prints for Dataset AZLA.

This is the second performance measurement for PFTII evaluation in Figure {3A, 3B, 3C}-4 in Appendix A. In this section we study the performance differences among those three comparison types. In each of the individual matcher's DET figures, all three comparison types: p2p, p2r, and r2r, are displayed by six finger positions and three sum-fused results of the left and right positions. Regarding those figures, we make the following observations:

3A = Avalon Biometrics S.L.	3B = ID Solutions, Inc.	3C = Patrima Technology Company
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- Again the simple two finger sum-fused are more accurate than single finger, regardless the finger positions (01, 02, 03, 06, 07, 08) and the comparison types.
- Right thumb (01), right index finger (02), and right middle finger (03) perform slightly better than those same positions from the left (06, 07, 08) for matcher 3A, while there are no significant difference from matcher 3B and 3C.
- For matcher 3A and 3B, r2r has higher accuracy than p2p or p2r for index fingers (02, 07) and middle fingers (03, 08) as indicated in [3]. However, there is no significant differences for the p2p and p2r for the thumb positions (01, 06).
- For matcher 3C, all the p2p, p2r, and r2r are very similar, where r2r is slightly better with all the fingers except the thumbs (01, 06) where p2p is better than p2r and r2r.

Besides the matcher individual figures in Appendix A, one summary table and three figures are included below.

- Table 4 shows the FNMR values for three comparison types, grouped by matcher and finger position.
- Figure 6, 7, and 8 display the FMR vs. FNMR for each comparison type.

The figures demonstrate the difference between the comparison types, or the similar results within the same type of comparison among the algorithms.

In order to be comparable to the previous PFT evaluations, an additional testing set is setup with a gallery subset of size 60K, a probe mate subset of size 60K, and the same probe non-mate set of size 120K for the three datasets: AZLA, POEBVA, and DHS2 for fingers 02, 07 and 02+07. In this way, the DET and ROC curves are based on 60K genuine scores and 120K imposter scores. These figures and tables are also included in Appendix B.

4.5 FTE and EER

Table 5 displays FTE counts for each algorithm. Theoretically, FTEs should contribute to higher error rate for FNMRs, nevertheless the rate is so small ($0 \leq FTE \leq 0.0021$) that it has shown little impact on the results from our observations. Noted that FTE = 0 for matcher 3B across all enrollments.

For 30% of matcher 3B's comparisons, EER could not be produced because the minimum of FNMR is greater than the maximum of FMR.

3A = Avalon Biometrics S.L.	3B = ID Solutions, Inc.	3C = Patrima Technology Company
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Comparison Type	Matcher	FMR = 0.0001			FMR = 0.001		
		01	02	03	01	02	03
Plain vs. Plain		01	02	03	01	02	03
	3A	0.0095	0.0199	0.0228	0.0062	0.0130	0.0172
	3B	0.0098	0.0331	0.0299	0.0064	0.0234	0.0193
	3C	0.0177	0.0273	0.0286	0.0132	0.0194	0.0219
		06	07	08	06	07	08
	3A	0.0101	0.0239	0.0260	0.0072	0.0174	0.0196
	3B	0.0071	0.0350	0.0285	0.0054	0.0261	0.0209
	3C	0.0214	0.0333	0.0373	0.0153	0.0242	0.0280
		01+06	02+07	03+08	01+06	02+07	03+08
	3A	0.0021	0.0049	0.0070	0.0016	0.0037	0.0055
	3B	0.0019	0.0089	0.0091	0.0014	0.0063	0.0065
	3C	0.0041	0.0064	0.0093	0.0027	0.0036	0.0063
Plain vs. Rolled		01	02	03	01	02	03
	3A	0.0123	0.0194	0.0242	0.0080	0.0140	0.0175
	3B	0.0095	0.0300	0.0229	0.0076	0.0197	0.0166
	3C	0.0278	0.0402	0.0434	0.0202	0.0287	0.0316
		06	07	08	06	07	08
	3A	0.0153	0.0252	0.0255	0.0098	0.0173	0.0193
	3B	0.0086	0.0293	0.0234	0.0065	0.0217	0.0179
	3C	0.0362	0.0424	0.0508	0.0259	0.0329	0.0379
		01+06	02+07	03+08	01+06	02+07	03+08
	3A	0.0027	0.0056	0.0072	0.0024	0.0037	0.0051
	3B	0.0023	0.0085	0.0074	0.0018	0.0057	0.0055
	3C	0.0080	0.0110	0.0151	0.0053	0.0065	0.0092
Rolled vs. Rolled		01	02	03	01	02	03
	3A	0.0091	0.0070	0.0084	0.0076	0.0047	0.0060
	3B	0.0057	0.0066	0.0054	0.0046	0.0051	0.0046
	3C	0.0301	0.0266	0.0260	0.0222	0.0197	0.0190
		06	07	08	06	07	08
	3A	0.0123	0.0083	0.0109	0.0077	0.0052	0.0071
	3B	0.0046	0.0072	0.0062	0.0039	0.0057	0.0052
	3C	0.0383	0.0317	0.0299	0.0267	0.0208	0.0217
		01+06	02+07	03+08	01+06	02+07	03+08
	3A	0.0023	0.0014	0.0018	0.0023	0.0014	0.0018
	3B	0.0013	0.0017	0.0015	0.0009	0.0012	0.0013
	3C	0.0104	0.0079	0.0088	0.0072	0.0055	0.0063

Table 4: FNMR values for Dataset AZLA at FMR = {0.0001, 0.001} with all finger positions and all three comparison types.

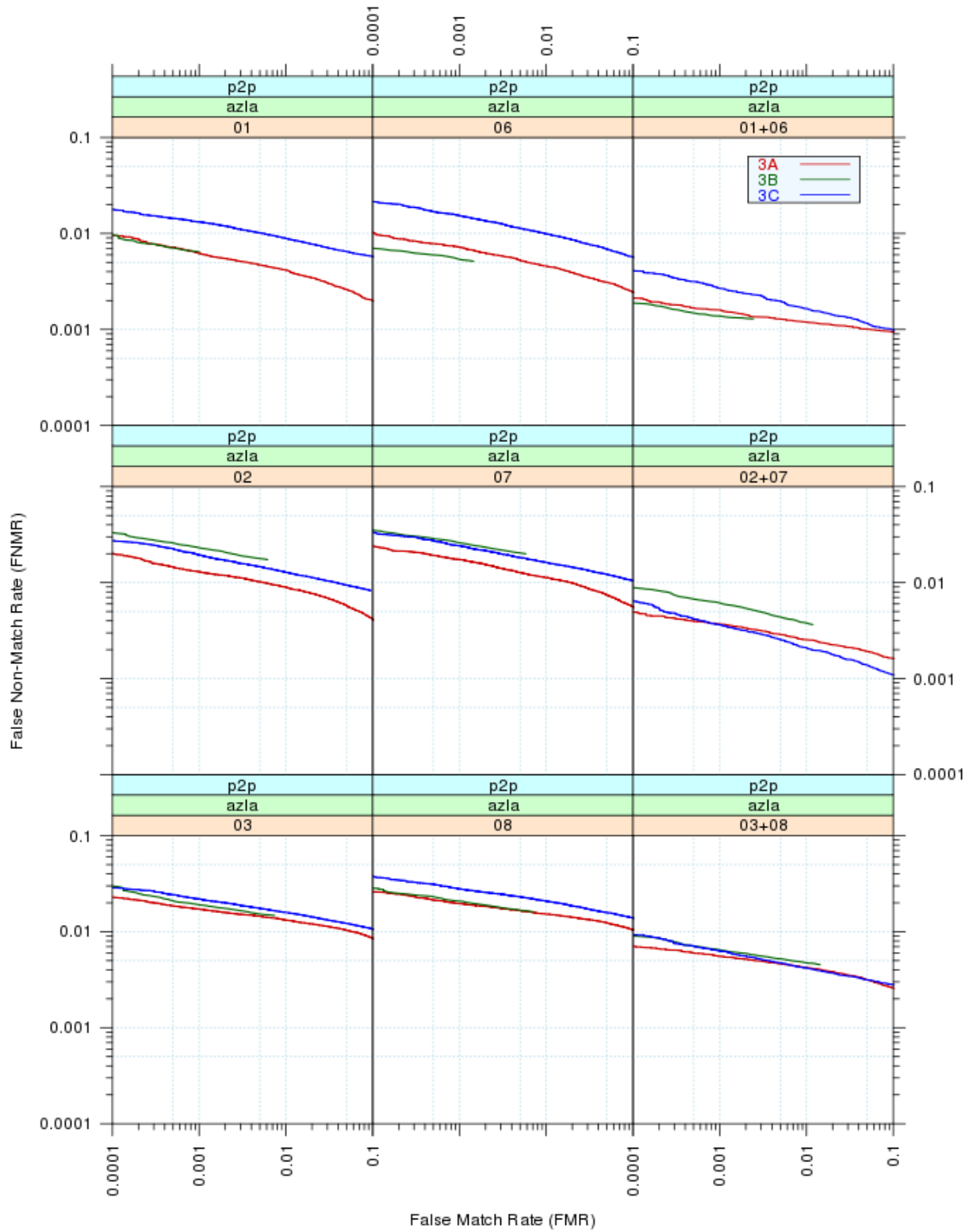


Figure 6: FNMR vs. FMR from AZLA for Plain vs. Plain with all finger positions and their respective sum fusions.

3A = Avalon Biometrics S.L.	3B = ID Solutions, Inc.	3C = Patrima Technology Company
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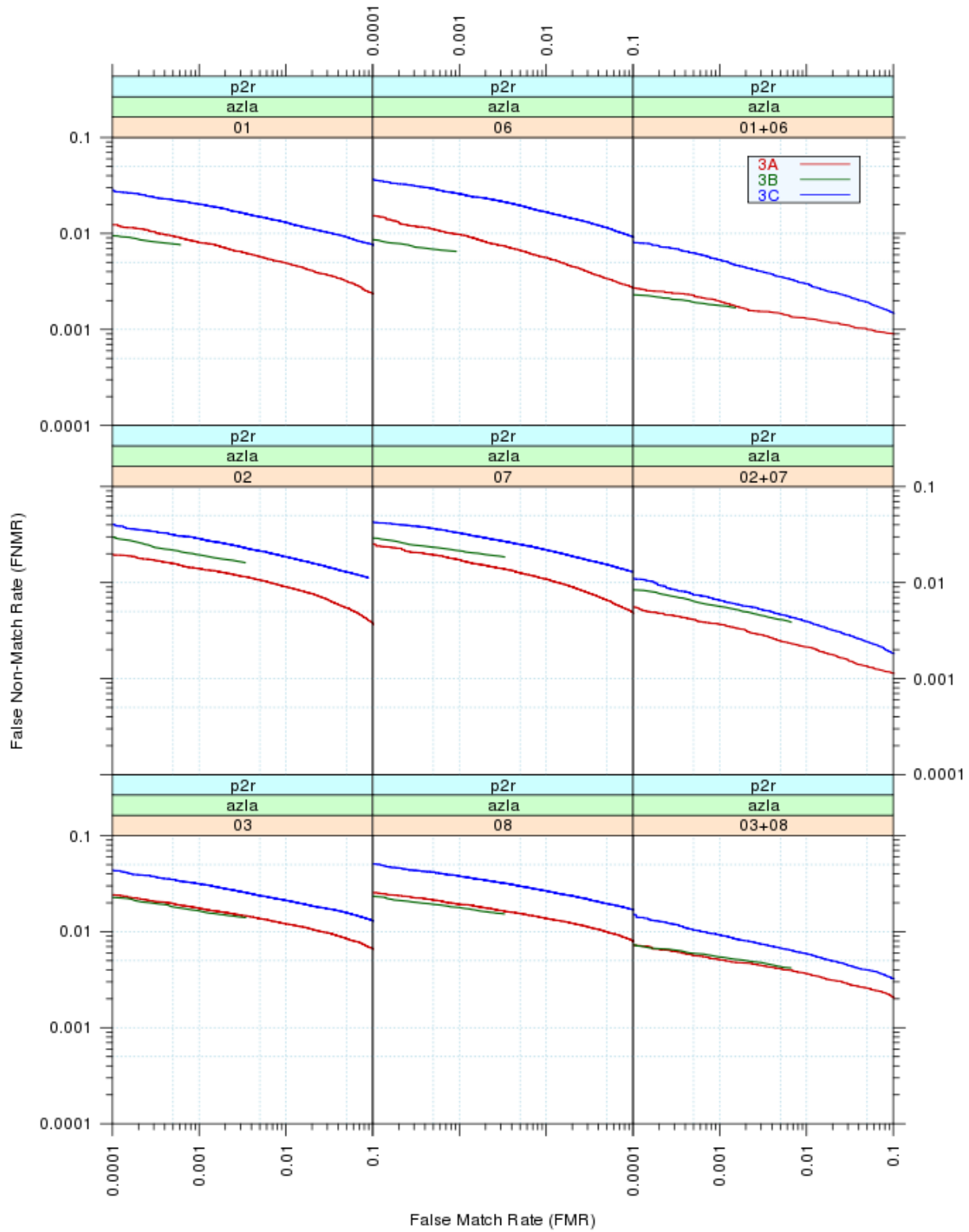


Figure 7: FNMR vs. FMR from AZLA for Plain vs. rolled with all finger positions and their respective sum fusions.

3A = Avalon Biometrics S.L.	3B = ID Solutions, Inc.	3C = Patrima Technology Company
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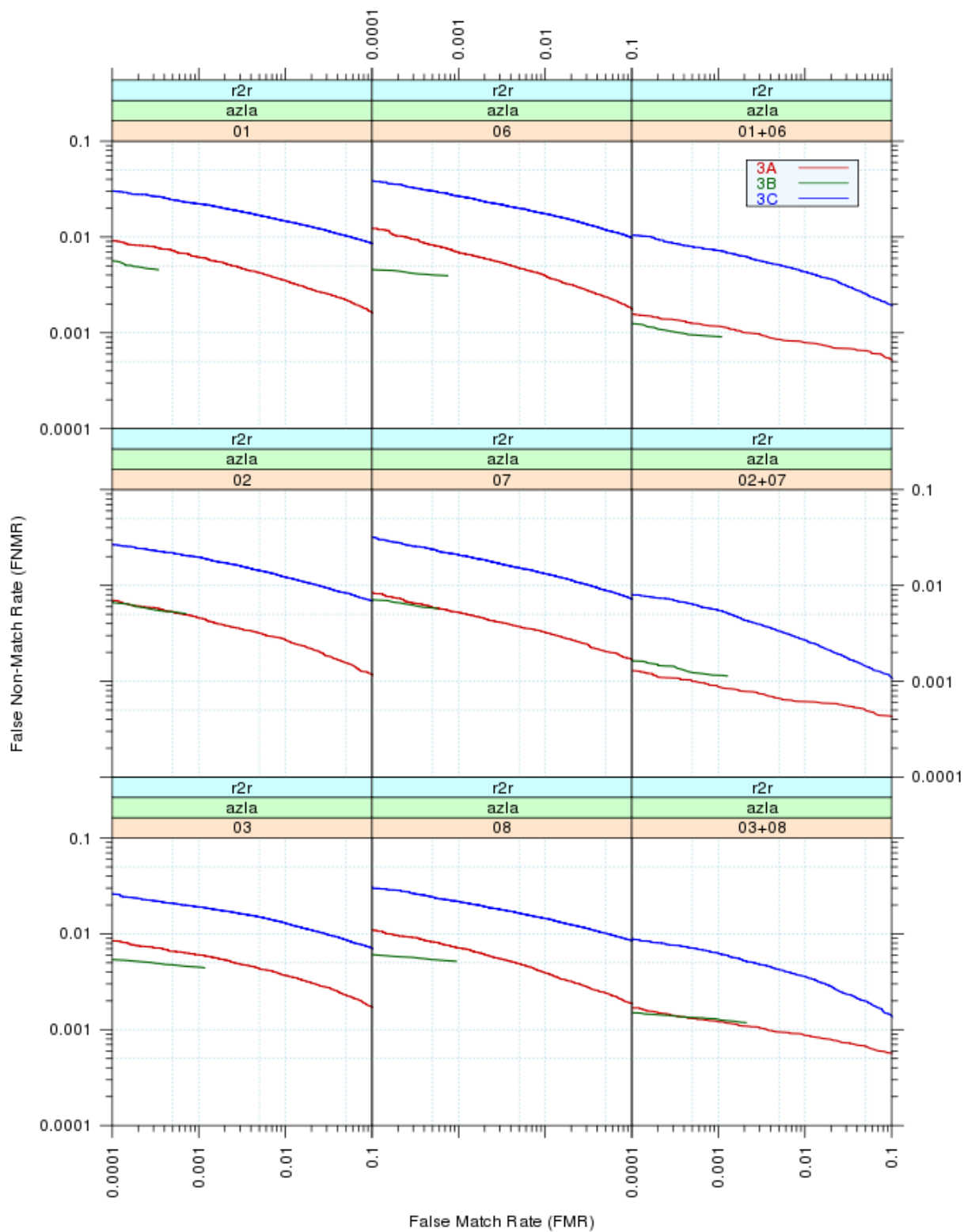


Figure 8: FNMR vs. FMR from AZLA for Plain vs. Plain with all finger positions and their respective sum fusions.

3A = Avalon Biometrics S.L.	3B = ID Solutions, Inc.	3C = Patrima Technology Company
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Comparison Type	Dataset	Finger Position	FTE Count				
			3A	3B	3C		
p2p	AZLA	02	69	5	0		
		07	81	2	0		
		02+07	150	7	0		
	DHS2	02	45	762	0		
		07	31	524	0		
		02+07	76	1286	0		
	POEBVA	02	1	0	0		
		07	0	0	0		
		02+07	1	0	0		
p2p	AZLA	01	37	40	0		
		02	69	5	0		
		03	25	0	0		
		06	24	26	0		
		07	81	2	0		
		08	17	4	0		
		01+06	61	66	0		
		02+07	150	7	0		
		03+08	42	4	0		
		p2r	AZLA	01	26	35	0
				02	28	9	0
03	14			5	0		
06	17			16	0		
07	33			7	0		
08	17			9	0		
01+06	43			51	0		
02+07	61			16	0		
03+08	31			14	0		
r2r	AZLA			01	16	26	0
				02	9	13	0
		03	6	11	0		
		06	9	11	0		
		07	6	7	0		
		08	13	14	0		
		01+06	25	37	0		
		02+07	15	20	0		
		03+08	19	25	0		

Table 5: FTE Counts for all matchers, and the total number for a single finger is 360,000, and the total two fingers sum fusion is 720,000.

5. Summary

From the results on three SDK matchers, each algorithm demonstrates different performance by the three comparison types. We have found there are some uncertainties and some similarities as follows:

- The simple two fingers sum-fused score results is better than one single finger.
- All the algorithms performed the best with dataset POEBVA.
- The majority of rolled vs. rolled results are better than plain .vs. plain or plain vs. rolled, except 3C (Figure 3C-4 in Appendix A).
- Thumb comparison is not always better than index finger or middle finger. E.g., thumb comparison for 3A is worse with rolled vs. rolled (Figure 3A-4 in Appendix A).

PFTII is an on-going NIST evaluation program. Future SDK matcher results will be published to the PFTII web site at http://www.nist.gov/itl/iad/ig/pftii_results.cfm. A future report is planned to evaluate previous PFT and MINEX results to study the improvement in fingerprint matching performance over time.

6. References

- [1] Craig I. Watson, Charles Wilson, Mike Indovina, Brian Cochran: "Two Finger matching with Vendor SDK Matchers"; NISTIR 7249, July 2005.
- [2] C. I. Watson, C. L. Wilson, K. Marshall, R. Snelick, " Studies of One-to-One Fingerprint matchers with Vendor SDK matchers"; NISTIR 7221, April 2005.
- [3] Stephen S. Wood and Charles L. Wilson; "Studies of Plain-to-Rolled Fingerprint Matching Using the NIST Algorithmic Test Bed (ATB)"; NISTIR 7112; April, 2004.
- [4] Elham Tabassi, Patrick Grother, "Quality Summarization Recommendations on Biometric Quality Summarization across the Application Domain"; NISTIR 7422, May, 2007.
- [5] Su Lan Cheng, Ross Micheals, Z.Q. John Lu;" Comparison of Confidence Intervals for Large Operational Biometric Data by Parametric and Non-parametric Methods"; NISTIR 7740, November, 2010.

7. Appendix - A

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A-3	Figure 3A-2 & Table 3A-2	1K Sample Enrollment and Comparison Timing Statistics
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A-5	Figure 3A-4	DET for all Finger Positions; (01, 02 ,03, 06, 07, 08, 01+06, 02+07, 03+08) from AZLA
A-6	Figure 3A-5	EERs and FTEs
A-7	Figure 3A-6	FMRs @ FNMR = (.002, 0.005) and 95% Confidence Intervals
A-8	Figure 3A-7	FNMRs @ FMR = .0001 and 95% Confidence Intervals
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I. Matcher 3A

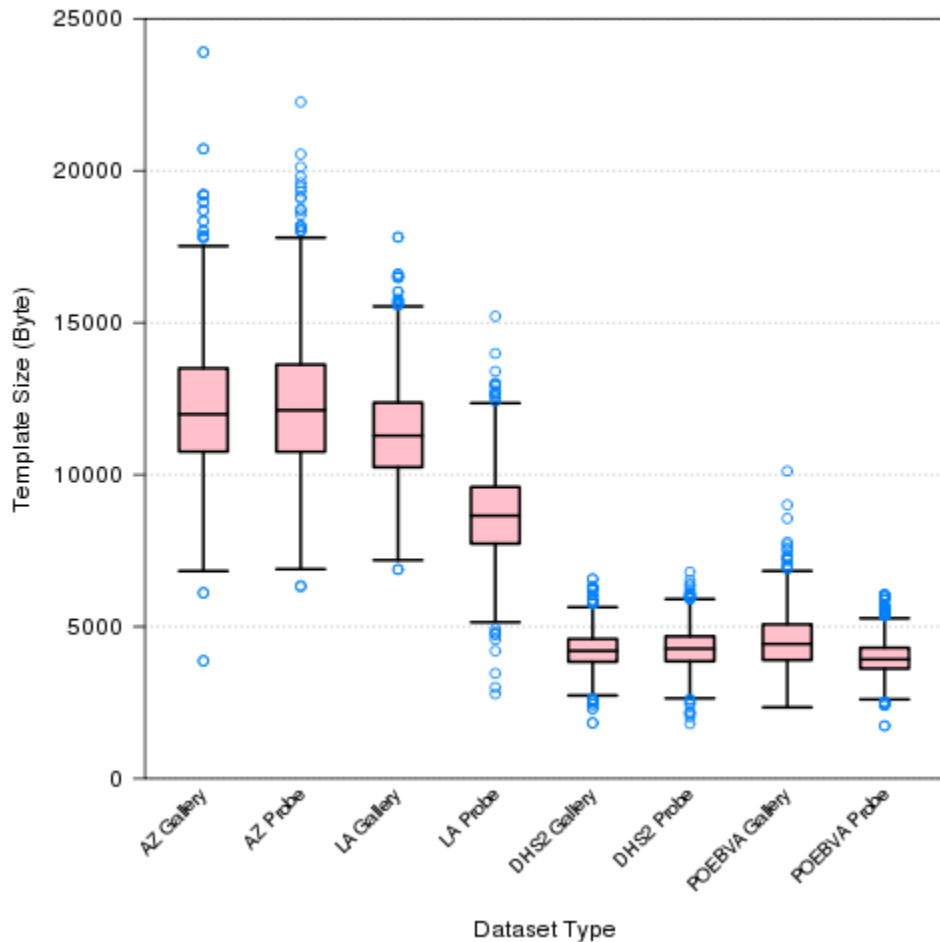


Figure 3A-1: 1K Sample Template Size Distribution

Dataset	AZ	AZ	LA	LA	DHS2	DHS2	POEBVA	POEBVA
Type	Gallery	Probe	Gallery	Probe	Gallery	Probe	Gallery	Probe
WidthxHeight (pixels)	800x800	800x800	412x1000	400x776	368x368	368x368	500x500	368x368
Maximum	23901	22262	17814	15211	6566	6796	10120	6050
75%	13501	13622	12371	9595	4594	4683	5076	4307
Median	11988	12121	11283	8651	4201	4275	4429	3924
25%	10758	10752	10246	7730	3842	3862	3901	3619
Minimum	3875	6308	6883	2788	1834	1808	2346	1738

Table 3A-1: Template Size (Byte)

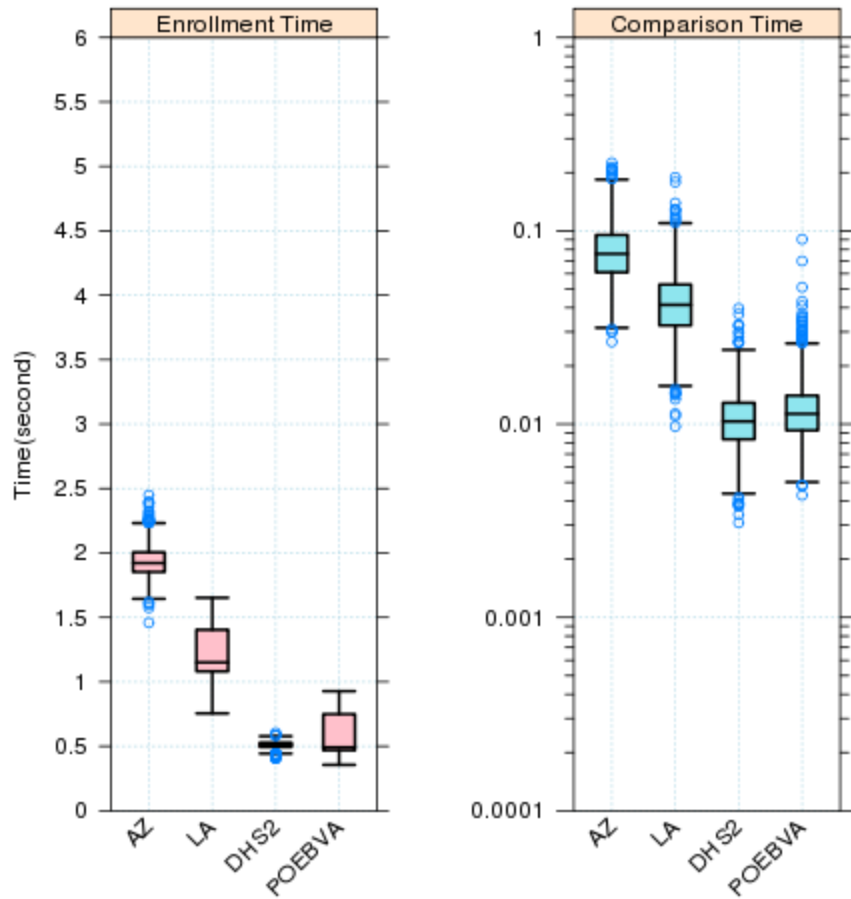


Figure 3A-2: 1K Sample Enrollment and Comparison Time

Enrollment Time (second)

Dataset	AZ	LA	DHS2	POEBVA
Maximum	2.4488	1.6522	0.6042	0.9276
75%	2.0047	1.4039	0.5283	0.7493
Median	1.9216	1.1506	0.5124	0.4918
25%	1.8523	1.0811	0.4942	0.4694
Minimum	1.4591	0.7552	0.4046	0.3557

Comparison Time (second)

Dataset	AZ	LA	DHS2	POEBVA
Maximum	0.2245	0.1888	0.0397	0.0904
75%	0.0952	0.0527	0.0129	0.0140
Median	0.0759	0.0414	0.0103	0.0113
25%	0.0609	0.0324	0.0083	0.0093
Minimum	0.0267	0.0097	0.0031	0.0043

Table 3A-2: Enrollment and Comparison Time (second)

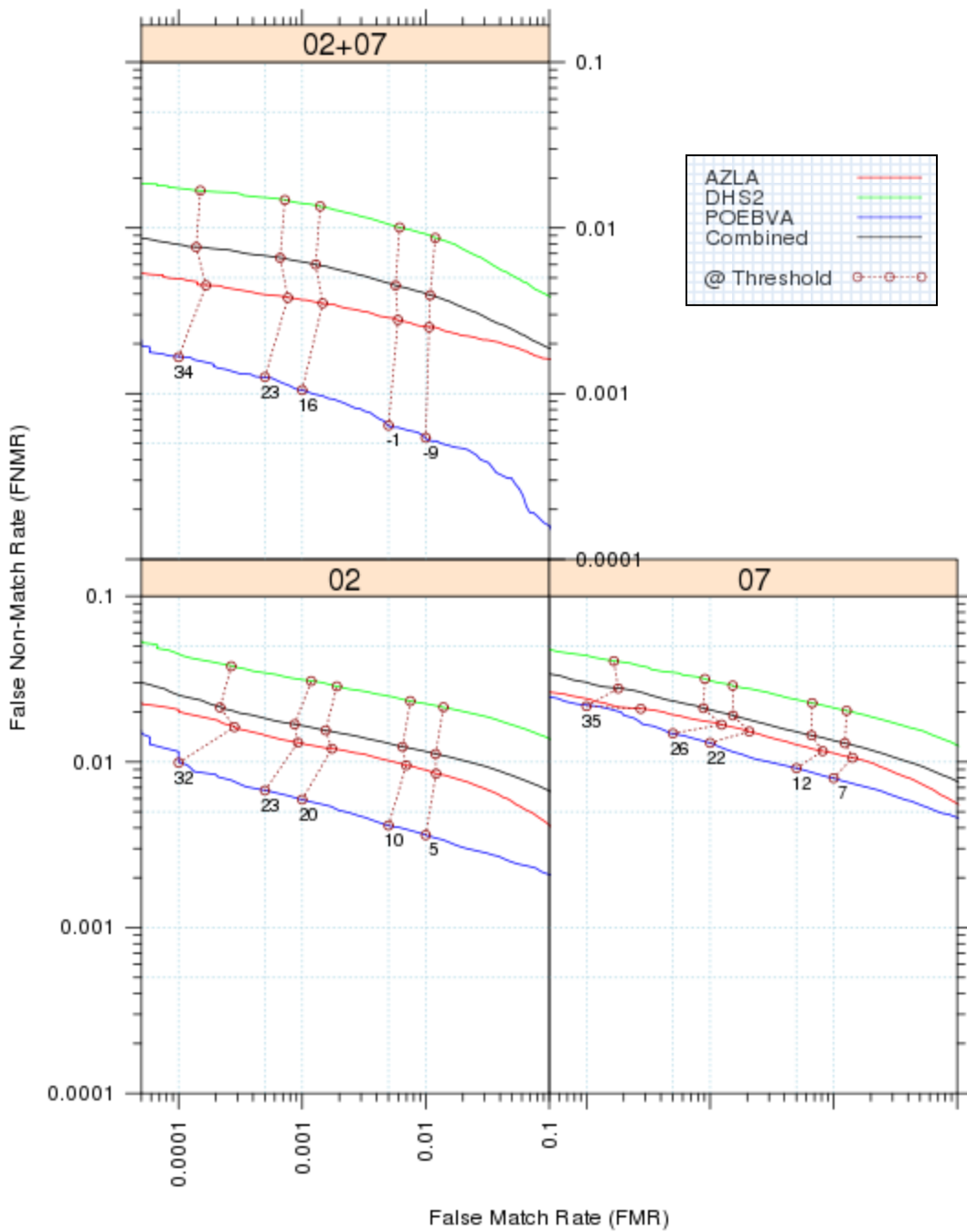


Figure 3A-3: DET for ALL Datasets (P2P)

3A = Avalon Biometrics S.L.	3B = ID Solutions, Inc.	3C = Patrima Technology Company
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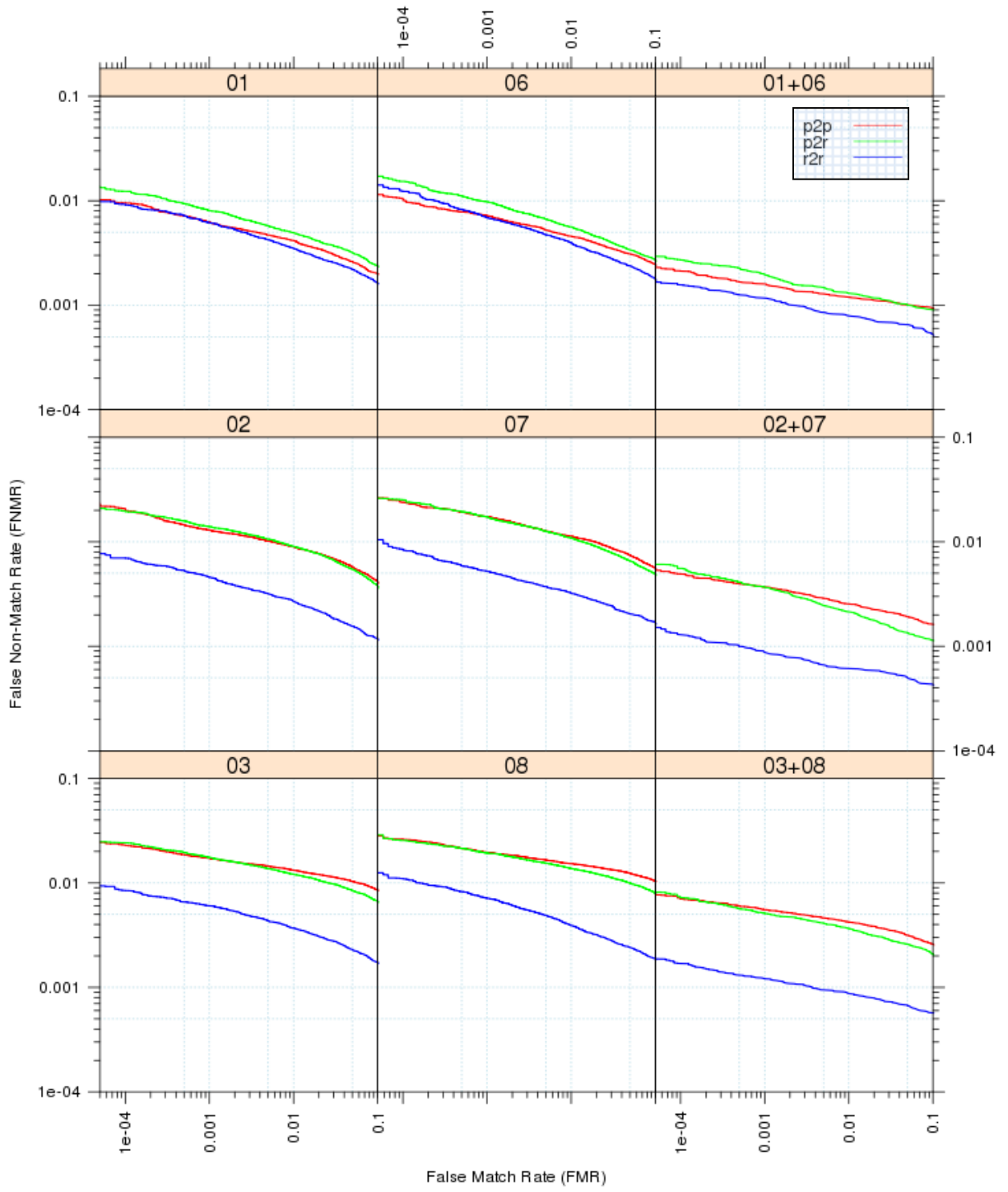


Figure 3A-4: DET for dataset AZLA

3A = Avalon Biometrics S.L.	3B = ID Solutions, Inc.	3C = Patrima Technology Company
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Note: p2p - plain vs. plain; p2r - plain vs. rolled; r2r – rolled vs. rolled.

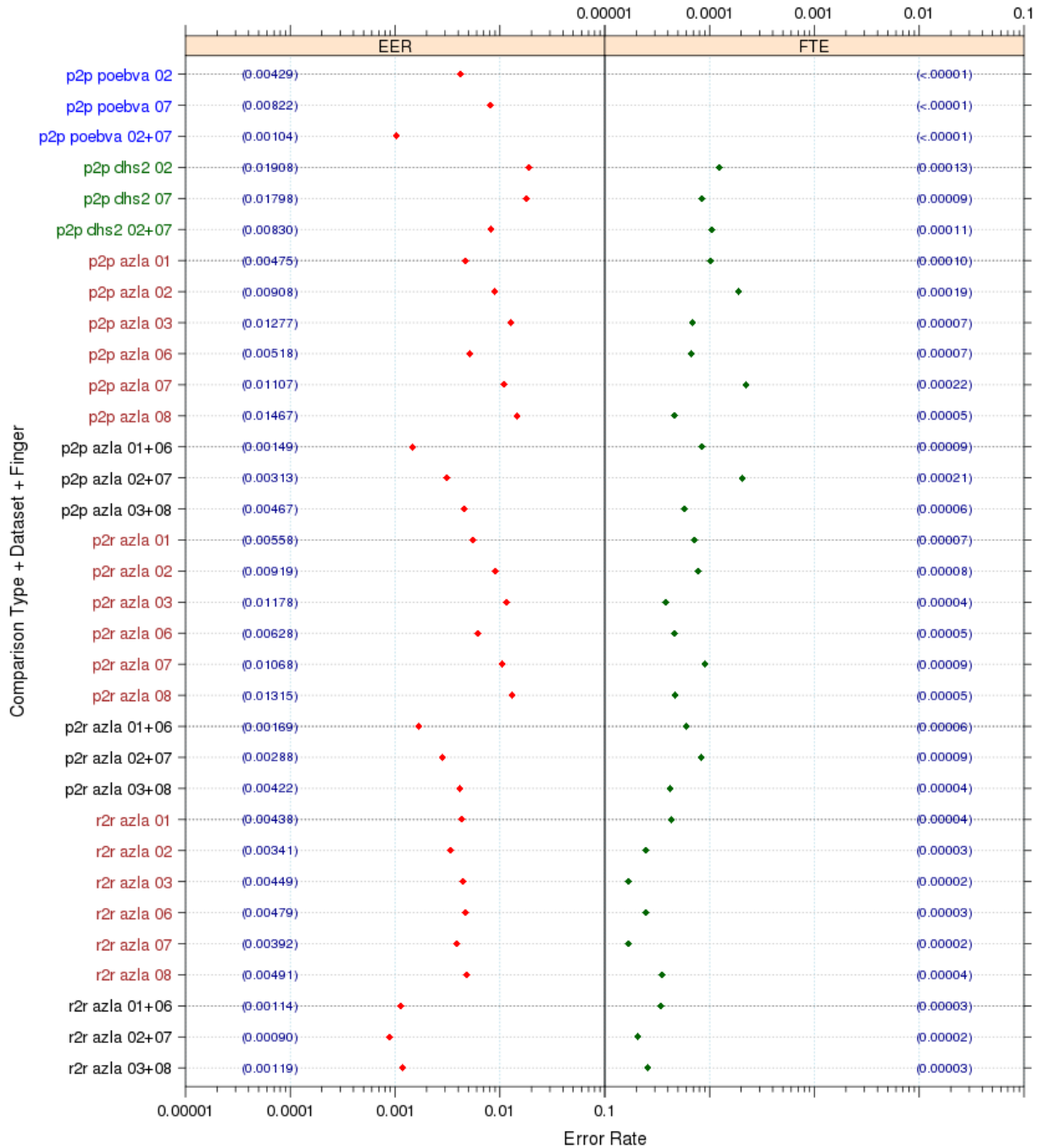


Figure 3A-5 EER and FTE

3A = Avalon Biometrics S.L. 3B = ID Solutions, Inc. 3C = Patrima Technology Company

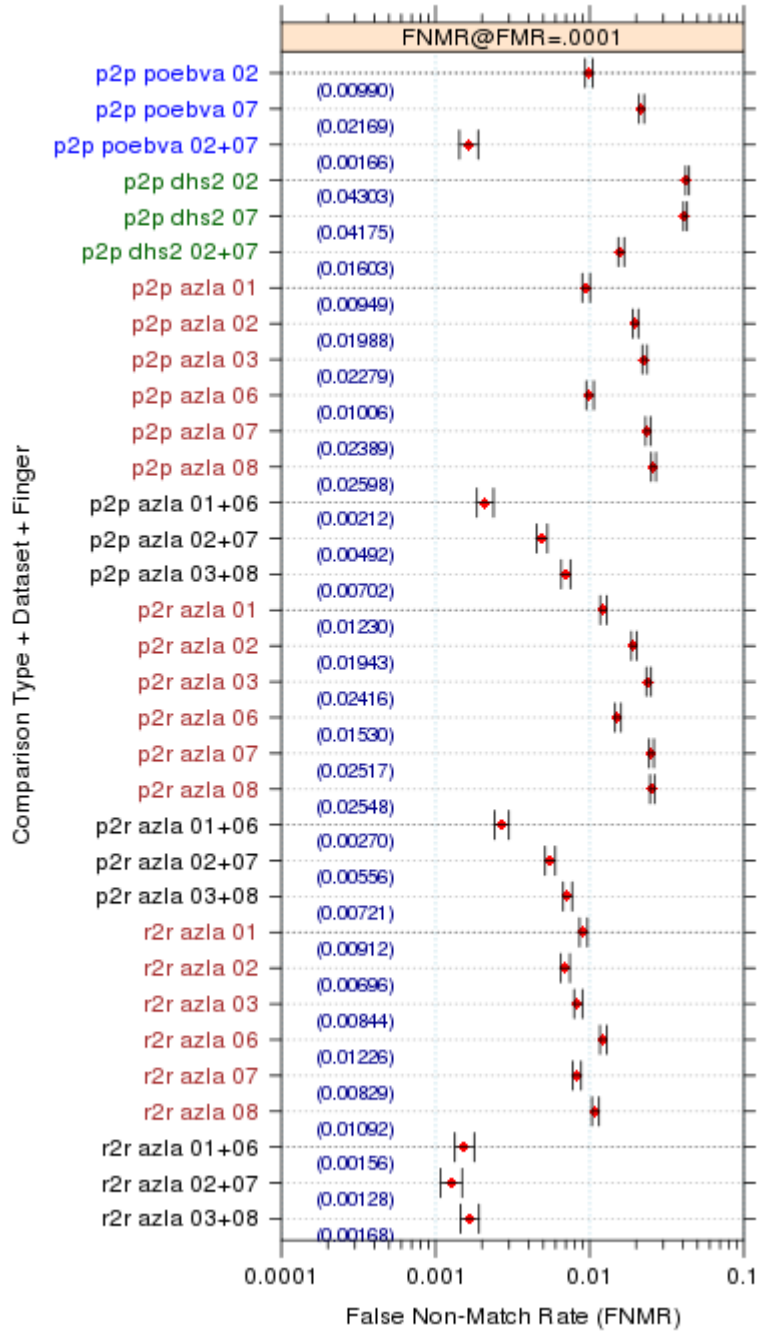


Figure 3A-6: FNMRs @ FMR = .0001 and 95% Confidence Intervals

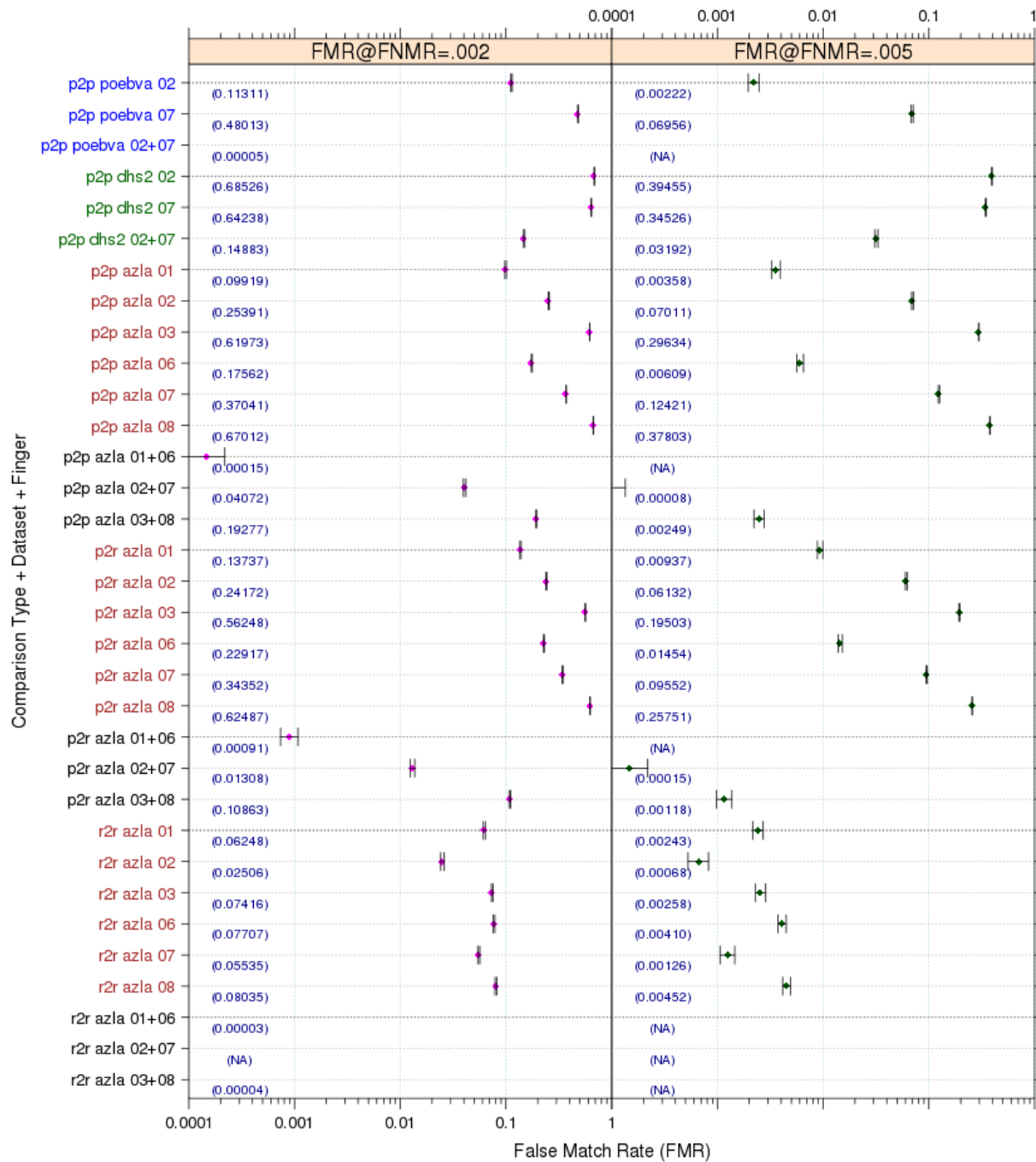


Figure 3A-7: FMRs@FNMR = { .002, 0.005 } and 95% Confidence Intervals

Note: NA – The number couldn't be reliably measured with the current sample size of 120,000.

3A = Avalon Biometrics S.L.	3B = ID Solutions, Inc.	3C = Patrima Technology Company
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Comparison Type	Dataset	Finger position	EER	FTE Rate	FTE count
p2p	poebva	02	0.004292	0.000003	1
p2p	poebva	07	0.008225	0.000000	0
p2p	poebva	02+07	0.001042	0.000001	1
p2p	dhs2	02	0.020142	0.000125	45
p2p	dhs2	07	0.018942	0.000086	31
p2p	dhs2	02+07	0.009308	0.000106	76
p2p	azla	01	0.004750	0.000103	37
p2p	azla	02	0.009083	0.000192	69
p2p	azla	03	0.012767	0.000069	25
p2p	azla	06	0.005183	0.000067	24
p2p	azla	07	0.011075	0.000225	81
p2p	azla	08	0.014667	0.000047	17
p2p	azla	01+06	0.001492	0.000085	61
p2p	azla	02+07	0.003125	0.000208	150
p2p	azla	03+08	0.004667	0.000058	42
p2r	azla	01	0.005583	0.000072	26
p2r	azla	02	0.009192	0.000078	28
p2r	azla	03	0.011783	0.000039	14
p2r	azla	06	0.006275	0.000047	17
p2r	azla	07	0.010683	0.000092	33
p2r	azla	08	0.013150	0.000047	17
p2r	azla	01+06	0.001692	0.000060	43
p2r	azla	02+07	0.002883	0.000085	61
p2r	azla	03+08	0.004217	0.000043	31
r2r	azla	01	0.004383	0.000044	16
r2r	azla	02	0.003408	0.000025	9
r2r	azla	03	0.004492	0.000017	6
r2r	azla	06	0.004792	0.000025	9
r2r	azla	07	0.003925	0.000017	6
r2r	azla	08	0.004908	0.000036	13
r2r	azla	01+06	0.001142	0.000035	25
r2r	azla	02+07	0.000900	0.000021	15
r2r	azla	03+08	0.001192	0.000026	19

Table 3A-3: EER and FTE table

3A = Avalon Biometrics S.L.	3B = ID Solutions, Inc.	3C = Patrima Technology Company
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Matching Type	Dataset	Finger position	FNMR1@ FMR= 0.0001	95% Confidence Interval of FNMR	FMR1 @ FNMR= 0.002	95% Confidence Interval of FMR1	FMR2@ FNMR= 0.005	95% Confidence Interval of FMR2
p2p	poebva	02	0.00990	± 0.00056	0.11311	± 0.001792	0.00223	± 0.00026
p2p	poebva	07	0.02169	± 0.00082	0.48013	± 0.002827	0.06956	± 0.00143
p2p	poebva	02+07	0.00166	± 0.00023	0.00005	± 0.000040	NA	NA
p2p	dhs2	02	0.04423	± 0.00116	0.91418	± 0.001585	0.48573	± 0.00282
p2p	dhs2	07	0.04291	± 0.00114	0.86804	± 0.001915	0.44215	± 0.00281
p2p	dhs2	02+07	0.01724	± 0.00073	0.63236	± 0.002728	0.05437	± 0.00128
p2p	azla	01	0.00949	± 0.00055	0.09919	± 0.001691	0.00358	± 0.00033
p2p	azla	02	0.01988	± 0.00079	0.25391	± 0.002463	0.07011	± 0.00144
p2p	azla	03	0.02279	± 0.00084	0.61973	± 0.002747	0.29634	± 0.00258
p2p	azla	06	0.01006	± 0.00057	0.17562	± 0.002153	0.00609	± 0.00044
p2p	azla	07	0.02389	± 0.00086	0.37041	± 0.002732	0.12421	± 0.00186
p2p	azla	08	0.02598	± 0.00090	0.67012	± 0.002660	0.37803	± 0.00274
p2p	azla	01+06	0.00212	± 0.00026	0.00015	± 0.000069	NA	NA
p2p	azla	02+07	0.00492	± 0.00039	0.04072	± 0.001118	0.00008	± 0.00005
p2p	azla	03+08	0.00702	± 0.00047	0.19277	± 0.002232	0.00249	± 0.00028
p2r	azla	01	0.01230	± 0.00062	0.13738	± 0.001948	0.00938	± 0.00054
p2r	azla	02	0.01943	± 0.00078	0.24173	± 0.002422	0.06132	± 0.00135
p2r	azla	03	0.02416	± 0.00086	0.56248	± 0.002807	0.19503	± 0.00224
p2r	azla	06	0.01530	± 0.00069	0.22917	± 0.002378	0.01454	± 0.00067
p2r	azla	07	0.02517	± 0.00088	0.34352	± 0.002687	0.09553	± 0.00166
p2r	azla	08	0.02548	± 0.00089	0.62488	± 0.002739	0.25751	± 0.00247
p2r	azla	01+06	0.00270	± 0.00029	0.00091	± 0.00017	NA	NA
p2r	azla	02+07	0.00556	± 0.00042	0.01308	± 0.000643	0.00015	± 0.00006
p2r	azla	03+08	0.00721	± 0.00047	0.10863	± 0.001761	0.00118	± 0.00019
r2r	azla	01	0.00913	± 0.00053	0.06248	± 0.001369	0.00243	± 0.00027
r2r	azla	02	0.00696	± 0.00047	0.02506	± 0.000884	0.00068	± 0.00014
r2r	azla	03	0.00844	± 0.00051	0.07416	± 0.001483	0.00258	± 0.00028
r2r	azla	06	0.01226	± 0.00062	0.07707	± 0.001509	0.00410	± 0.00036
r2r	azla	07	0.00829	± 0.00051	0.05535	± 0.001294	0.00126	± 0.00020
r2r	azla	08	0.01092	± 0.00058	0.08035	± 0.001538	0.00452	± 0.00037
r2r	azla	01+06	0.00156	± 0.00022	0.00003	± 0.000028	NA	NA
r2r	azla	02+07	0.00128	± 0.00020	NA	NA	NA	NA
r2r	azla	03+08	0.00168	± 0.00023	0.00004	± 0.000037	NA	NA

Table 3A-4: FNMR@FMR=0.0001, FMRs@FNMR = {0.002, 0.005} and 95% Confidence Intervals

Note: NA – The number couldn't be reliably measured with the current sample size of 120,000.

II. Matcher 3B

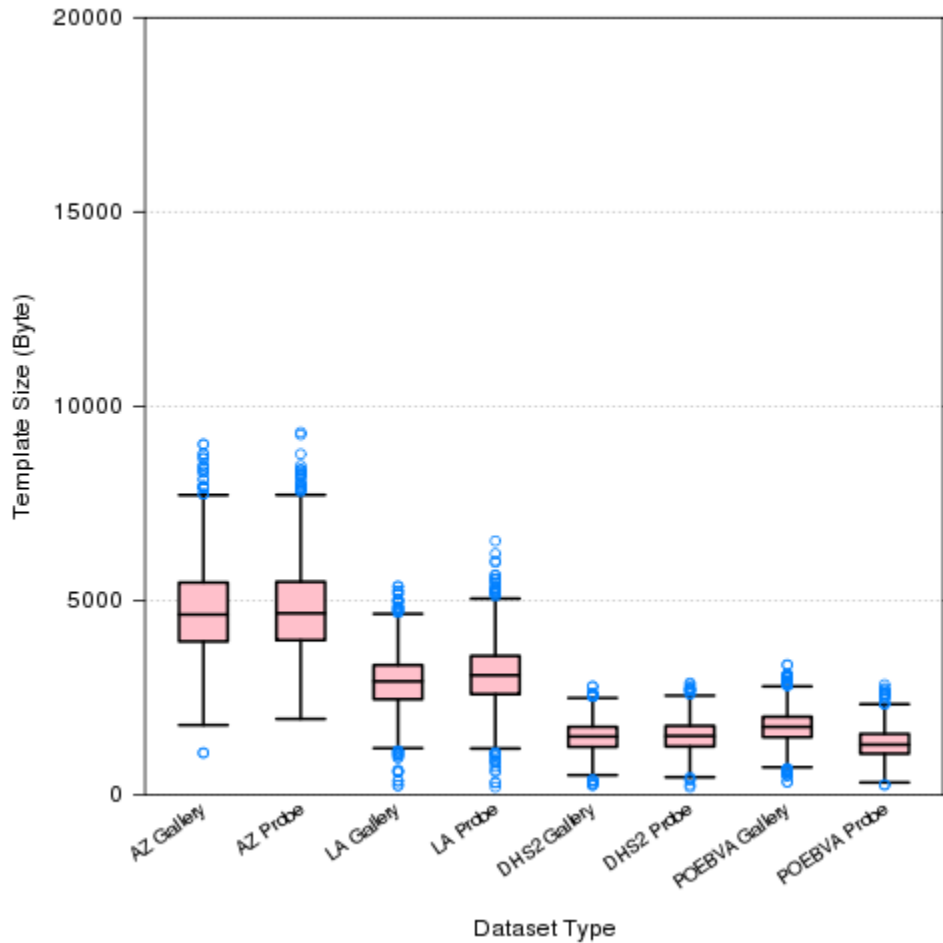


Figure 3B-1: 1K Sample Template Size Distribution

Dataset	AZ	AZ	LA	LA	DHS2	DHS2	POEBVA	POEBVA
Type	Gallery	Probe	Gallery	Probe	Gallery	Probe	Gallery	Probe
Width x Height (pixels)	800x800	800x800	412x1000	400x776	368x368	368x368	500x500	368x368
Maximum	9018	9324	5360	6529	2782	2872	3339	2830
75%	5458	5477	3333	3569	1743	1769	2003	1562
Median	4633	4666	2914	3072	1492	1507	1742	1284
25%	3941	3973	2452	2584	1225	1237	1475	1052
Minimum	1072	1946	233	191	240	191	326	241

Table 3B-1: Template Size (Byte)

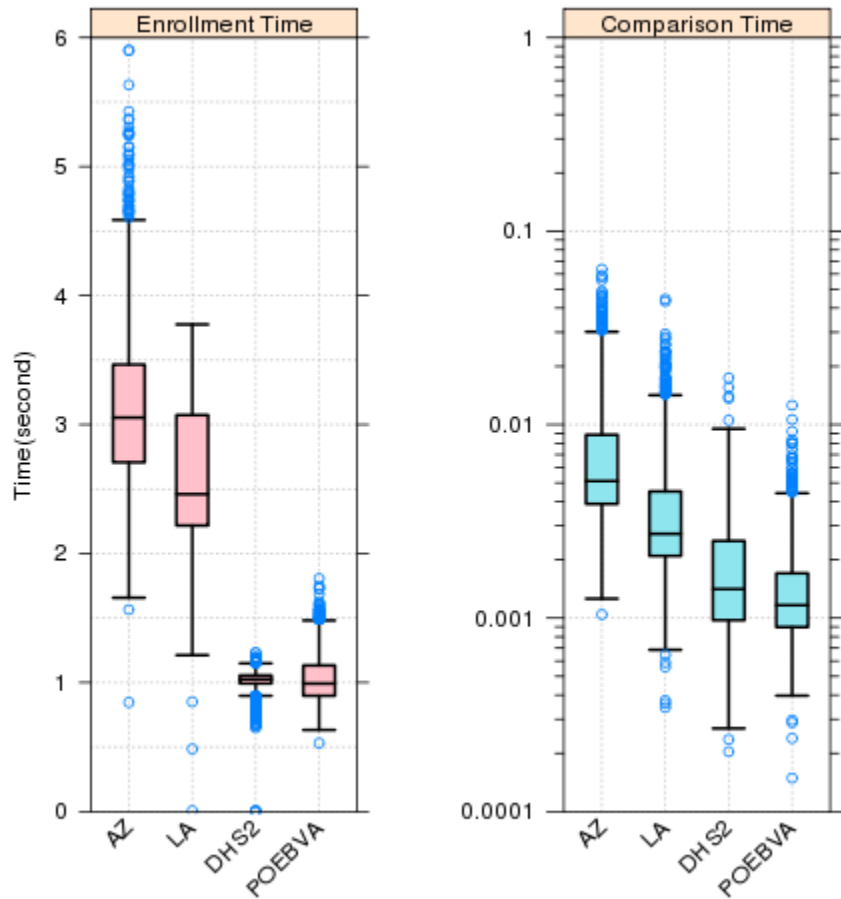


Figure 3B-2: 1K Sample Enrollment and Comparison Time

Enrollment Time (second)

Dataset	AZ	LA	DHS2	POEBVA
Maximum	5.9013	3.7762	1.2305	1.8059
75%	3.4654	3.0734	1.0557	1.1325
Median	3.0539	2.4603	1.0260	0.9923
25%	2.7068	2.2169	0.9924	0.8975
Minimum	0.8461	0.0056	0.0027	0.5310

Comparison Time (second)

Dataset	AZ	LA	DHS2	POEBVA
Maximum	0.06350	0.04454	0.0174	0.0126
75%	0.00885	0.00451	0.0025	0.0017
Median	0.00511	0.00273	0.0014	0.0012
25%	0.00389	0.00209	0.0010	0.0009
Minimum	0.00104	0.00035	0.0002	0.0001

Table 3B-2: Enrollment and Comparison Time (second)

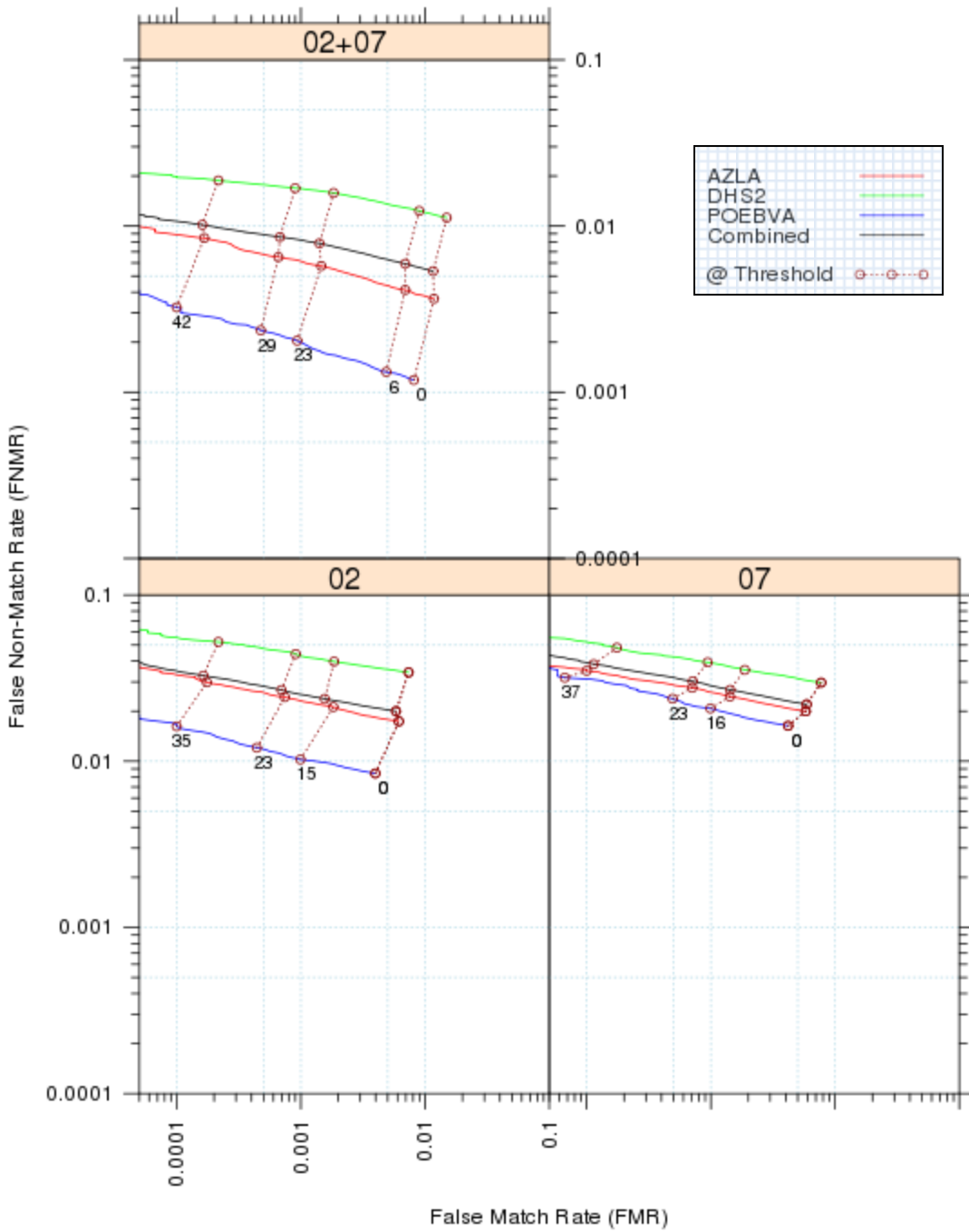


Figure 3B-3: DET for ALL Datasets (P2P)

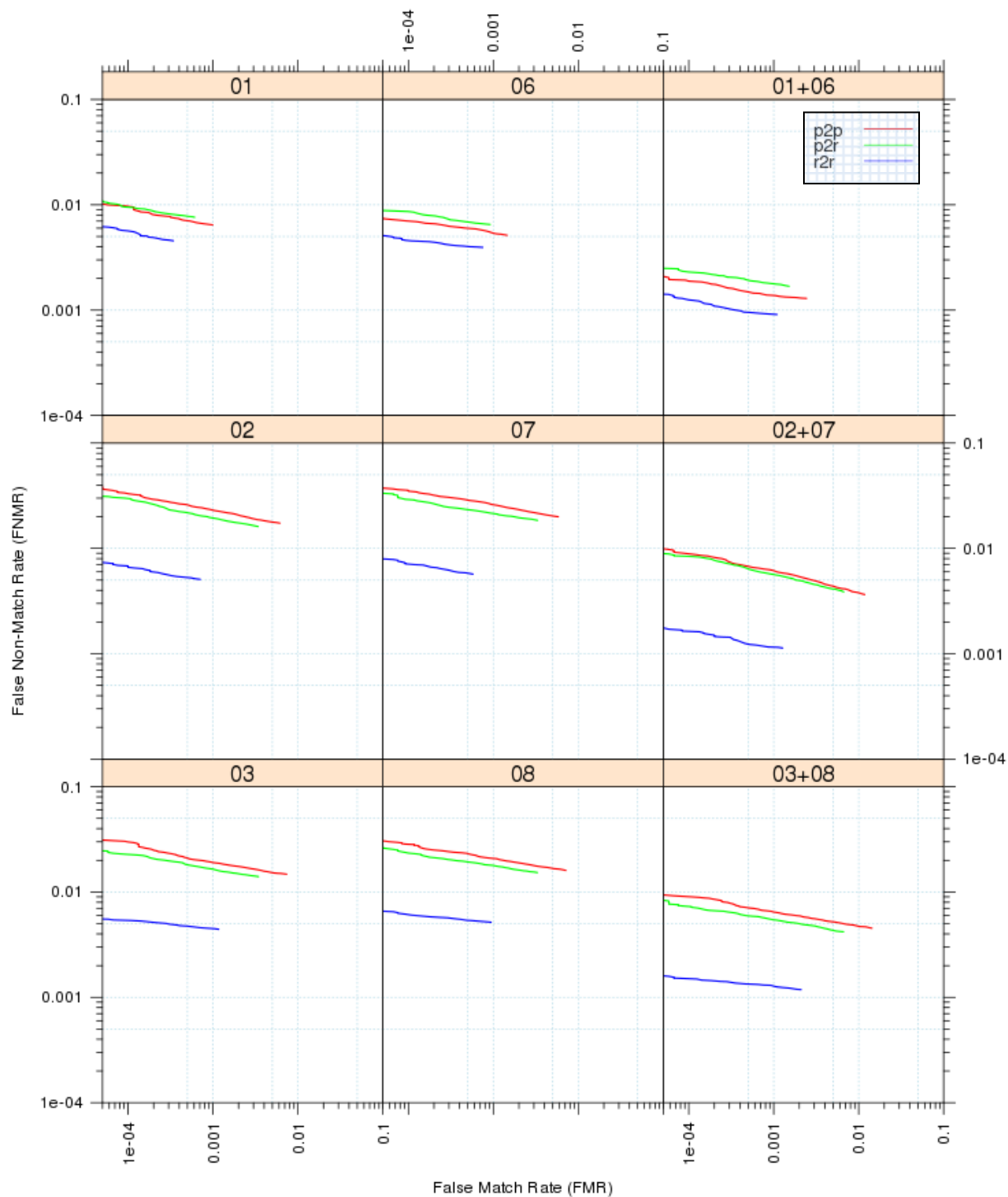


Figure 3B-4: DET for dataset AZLA

Note: p2p - plain vs. plain; p2r - plain vs. rolled; r2r – rolled vs. rolled.

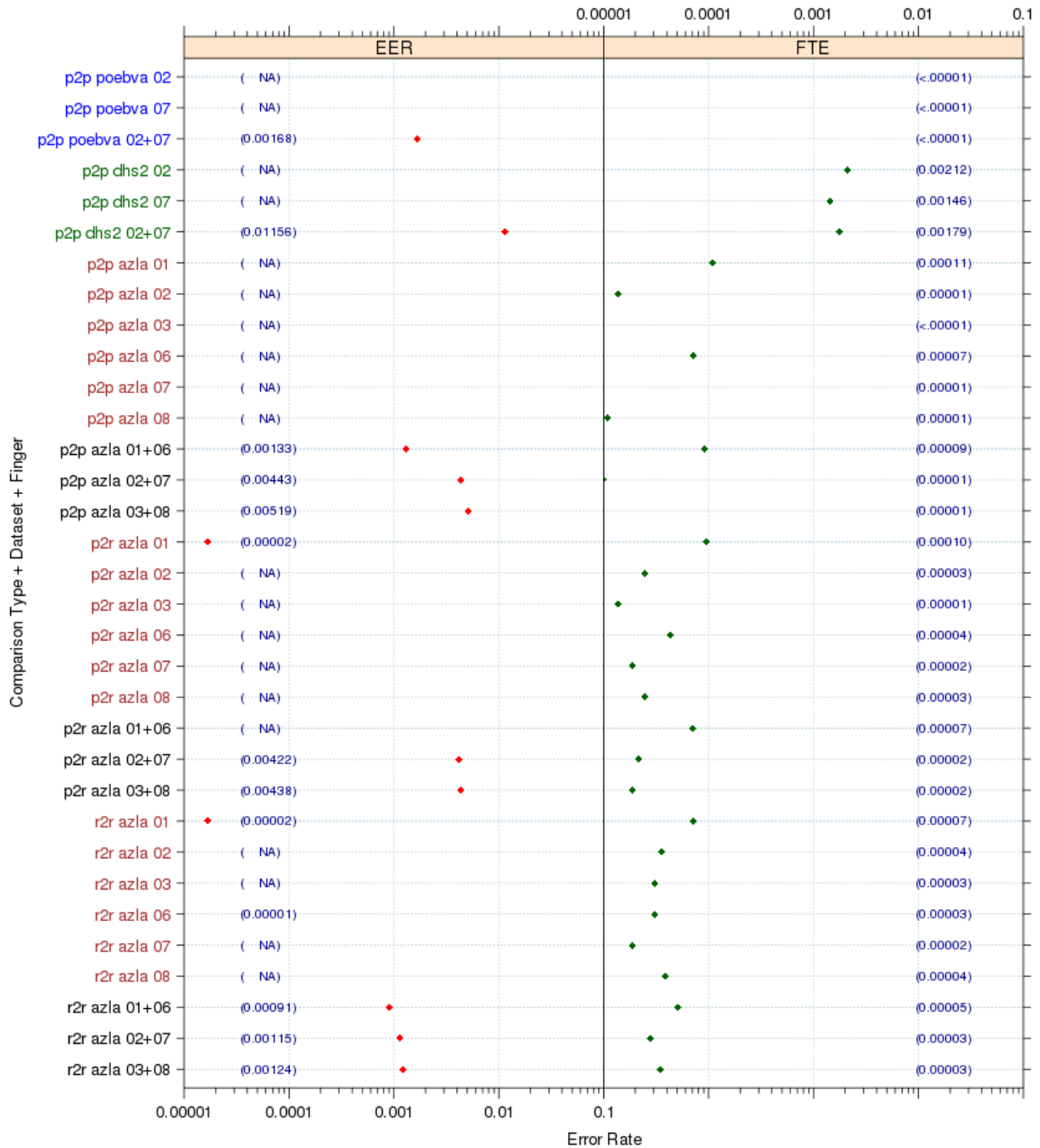


Figure 3B-5: EER and FTE

Note: NA - Could not obtain EER due to the minimum of FNMR is greater than the maximum of FMR (Figure 3B - 4).

3A = Avalon Biometrics S.L.	3B = ID Solutions, Inc.	3C = Patrima Technology Company
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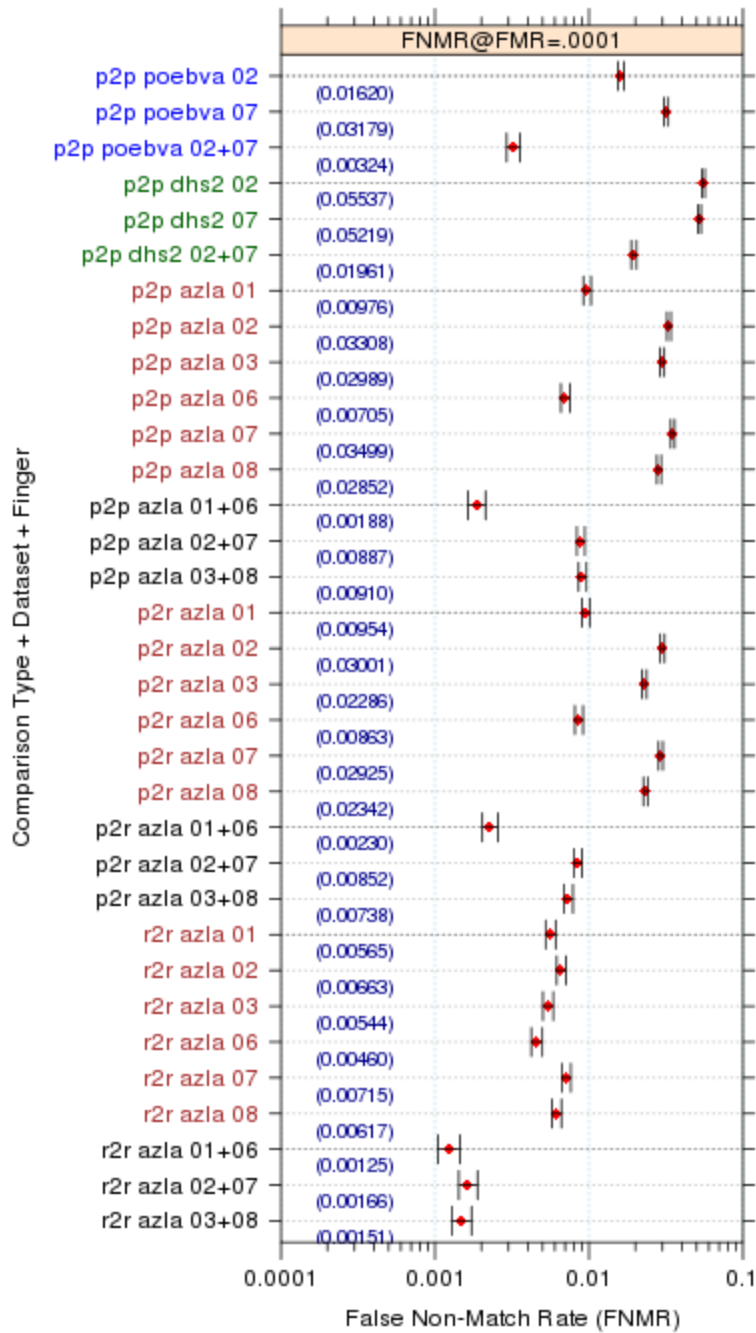


Figure 3B-6: FNMRs @ FMR = .0001 and 95% Confidence Intervals

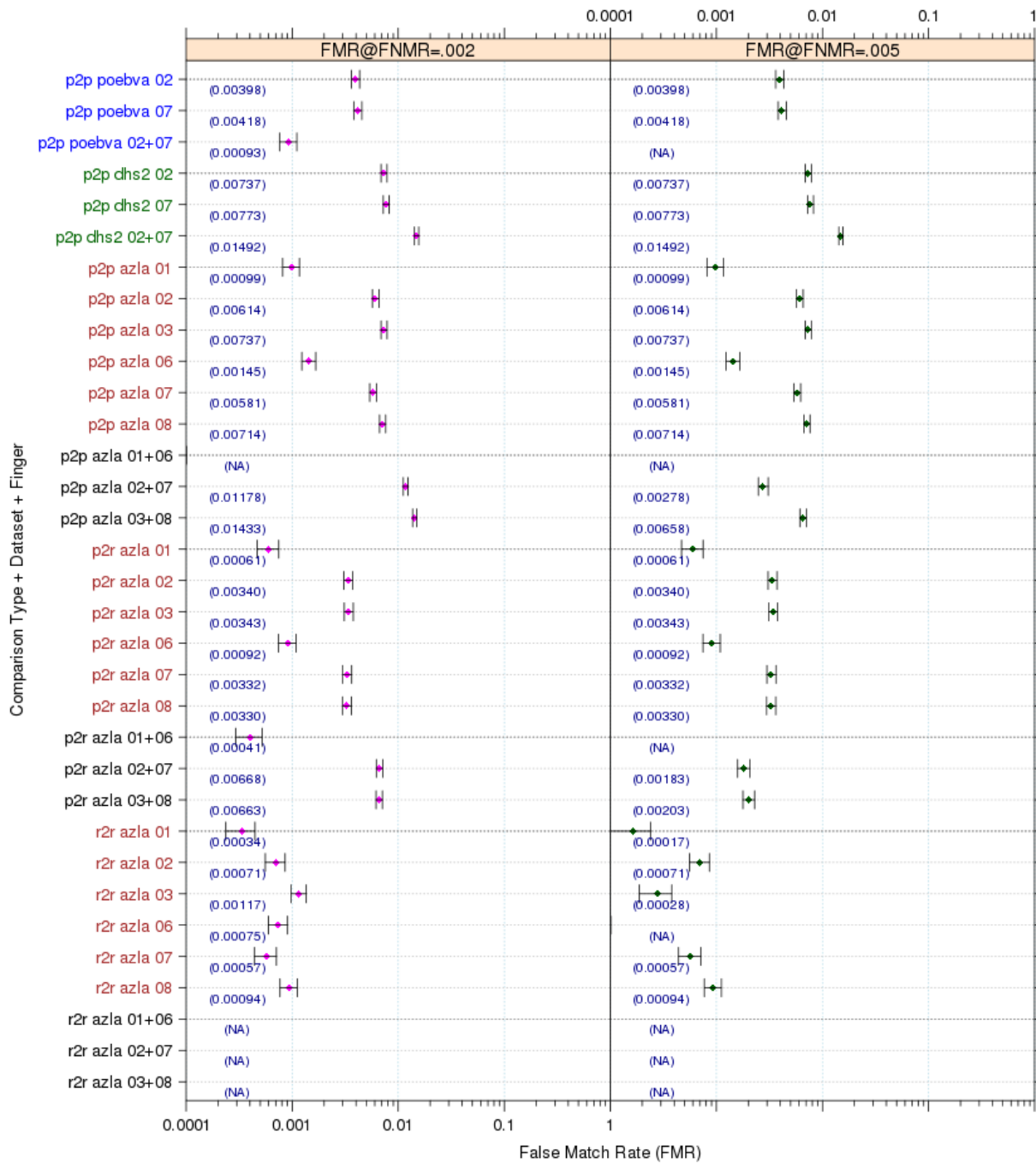


Figure 3B-7: FMRs @ FNMR = {0.002, 0.005} and 95% Confidence Intervals

Note: NA – The number couldn't be reliably measured with the current sample size of 120,000.

Comparison Type	Dataset	Finger Position	EER	FTE Rate	FTE count
p2p	poebva	02	0.004292	0.000003	1
p2p	poebva	07	0.008225	0.000000	0
p2p	poebva	02+07	0.001042	0.000001	1
p2p	dhs2	02	NA	0.00212	762**
p2p	dhs2	07	NA	0.00146	524**
p2p	dhs2	02+07	0.0116	0.00179	1286**
p2p	azla	01	NA*	0.00011	40
p2p	azla	02	NA	0.00001	5
p2p	azla	03	NA	0.00000	0
p2p	azla	06	NA	0.00007	26
p2p	azla	07	NA	0.00001	2
p2p	azla	08	NA	0.00001	4
p2p	azla	01+06	0.0013	0.00009	66
p2p	azla	02+07	0.0044	0.00001	7
p2p	azla	03+08	0.0052	0.00001	4
p2r	azla	01	NA	0.00010	35
p2r	azla	02	NA	0.00003	9
p2r	azla	03	NA	0.00001	5
p2r	azla	06	NA	0.00004	16
p2r	azla	07	NA	0.00002	7
p2r	azla	08	NA	0.00003	9
p2r	azla	01+06	NA	0.00007	51
p2r	azla	02+07	0.0042	0.00002	16
p2r	azla	03+08	0.0044	0.00002	14
r2r	azla	01	NA	0.00007	26
r2r	azla	02	NA	0.00004	13
r2r	azla	03	NA	0.00003	11
r2r	azla	06	NA	0.00003	11
r2r	azla	07	NA	0.00002	7
r2r	azla	08	NA	0.00004	14
r2r	azla	01+06	0.0009	0.00005	37
r2r	azla	02+07	0.0012	0.00003	20
r2r	azla	03+08	0.0012	0.00004	25

Table 3B-3: EER and FTE table

Note: * NA Could not obtain EER due to the minimal FNMR is greater than the maximal of FMR (Fig 4).

** Could not enroll when the images were very low contrast.

Matching Type	Dataset	Finger position	FNMR@ FMR= 0.0001	95% Confidence Interval of FNMR	FMR1 @ FNMR= 0.002	95% Confidence Interval of FMR1	FMR2 @ FNMR= 0.005	95% Confidence Interval of FMR2
p2p	poebva	02	0.016200	±0.00071	0.0040	±0.00036	0.0040	±0.00036
p2p	poebva	07	0.031792	±0.00099	0.0042	±0.00037	0.0042	±0.00037
p2p	poebva	02+07	0.003242	±0.00032	0.00001	±0.00002	0.00001	±0.00002
p2p	dhs2	02	0.055367	±0.00129	0.0074	±0.00048	0.0074	±0.00048
p2p	dhs2	07	0.052192	±0.00126	0.0077	±0.00050	0.0077	±0.00050
p2p	dhs2	02+07	0.019608	±0.00078	0.0149	±0.00069	0.0149	±0.00069
p2p	azla	01	0.009758	±0.00056	0.0010	±0.00018	0.0010	±0.00018
p2p	azla	02	0.033075	±0.00101	0.0061	±0.00044	0.0061	±0.00044
p2p	azla	03	0.029892	±0.00096	0.0074	±0.00048	0.0074	±0.00048
p2p	azla	06	0.007050	±0.00047	0.0015	±0.00022	0.0015	±0.00022
p2p	azla	07	0.034992	±0.00104	0.0058	±0.00043	0.0058	±0.00043
p2p	azla	08	0.028517	±0.00094	0.0071	±0.00048	0.0071	±0.00048
p2p	azla	01+06	0.001883	±0.00025	NA	NA	NA	NA
p2p	azla	02+07	0.008875	±0.00053	0.0028	±0.00030	0.0028	±0.00030
p2p	azla	03+08	0.009100	±0.00054	0.0066	±0.00046	0.0066	±0.00046
p2r	azla	01	0.009542	±0.00055	0.0006	±0.00014	0.0006	±0.00014
p2r	azla	02	0.030008	±0.00097	0.0034	±0.00033	0.0034	±0.00033
p2r	azla	03	0.022858	±0.00085	0.0034	±0.00033	0.0034	±0.00033
p2r	azla	06	0.008625	±0.00052	0.0009	±0.00017	0.0009	±0.00017
p2r	azla	07	0.029250	±0.00095	0.0033	±0.00033	0.0033	±0.00033
p2r	azla	08	0.023417	±0.00086	0.0033	±0.00032	0.0033	±0.00032
p2r	azla	01+06	0.002300	±0.00027	NA	NA	NA	NA
p2r	azla	02+07	0.008517	±0.00052	0.0018	±0.00024	0.0018	±0.00024
p2r	azla	03+08	0.007383	±0.00048	0.0020	±0.00026	0.0020	±0.00026
r2r	azla	01	0.005650	±0.00042	0.0002	±0.00007	0.0002	±0.00007
r2r	azla	02	0.006633	±0.00046	0.0007	±0.00015	0.0007	±0.00015
r2r	azla	03	0.005442	±0.00042	0.0003	±0.00010	0.0003	±0.00010
r2r	azla	06	0.0046	±0.00038	0.0001	±0.00004	0.0001	±0.00004
r2r	azla	07	0.007150	±0.00048	0.0006	±0.00014	0.0006	±0.00014
r2r	azla	08	0.006175	±0.00044	0.0009	±0.00017	0.0009	±0.00017
r2r	azla	01+06	0.001250	±0.00020	NA	NA	NA	NA
r2r	azla	02+07	0.001658	±0.00023	NA	NA	NA	NA
r2r	azla	03+08	0.001508	±0.00022	NA	NA	NA	NA

Table 3B-4: FNMR @ FMR=0.0001, FMRs@ FNMR = {0.002, 0.005} and 95% Confidence Intervals

Note: NA – The number couldn't be reliably measured with the current sample size of 120,000.

III Matcher 3C

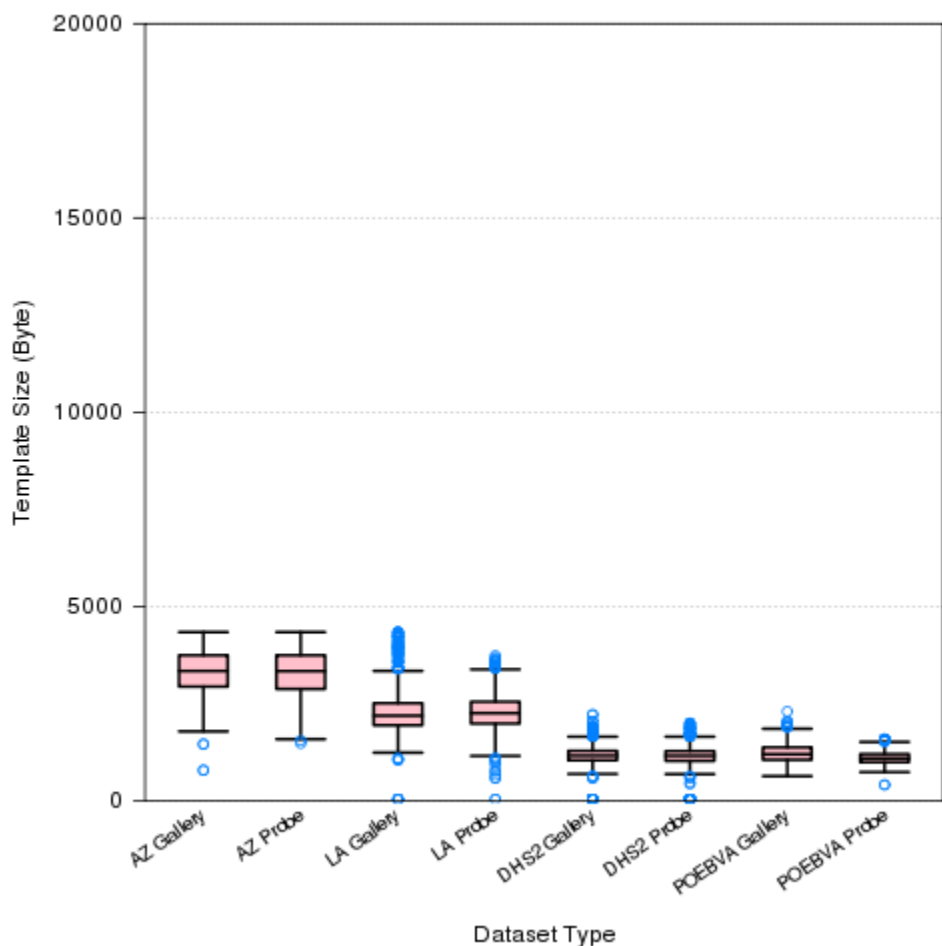


Figure 3C-1: 1K Sample Template Size Distribution

Dataset	AZ	AZ	LA	LA	DHS2	DHS2	POEBVA	POEBVA
Type	Gallery	Probe	Gallery	Probe	Gallery	Probe	Gallery	Probe
WidthxHeight (pixels)	800x800	800x800	412x1000	400x776	368x368	368x368	500x500	368x368
Maximum	4336	4336	4336	3728	2212	1996	2292	1584
75%	3740	3740	2506	2544	1280	1272	1368	1196
Median	3334	3330	2184	2250	1156	1152	1192	1088
25%	2932	2872	1938	1980	1036	1020	1048	988
Minimum	780	1472	32	32	32	32	628	404

Table 3C-1: Template Size (Byte)

3A = Avalon Biometrics S.L.

3B = ID Solutions, Inc.

3C = Patrima Technology Company

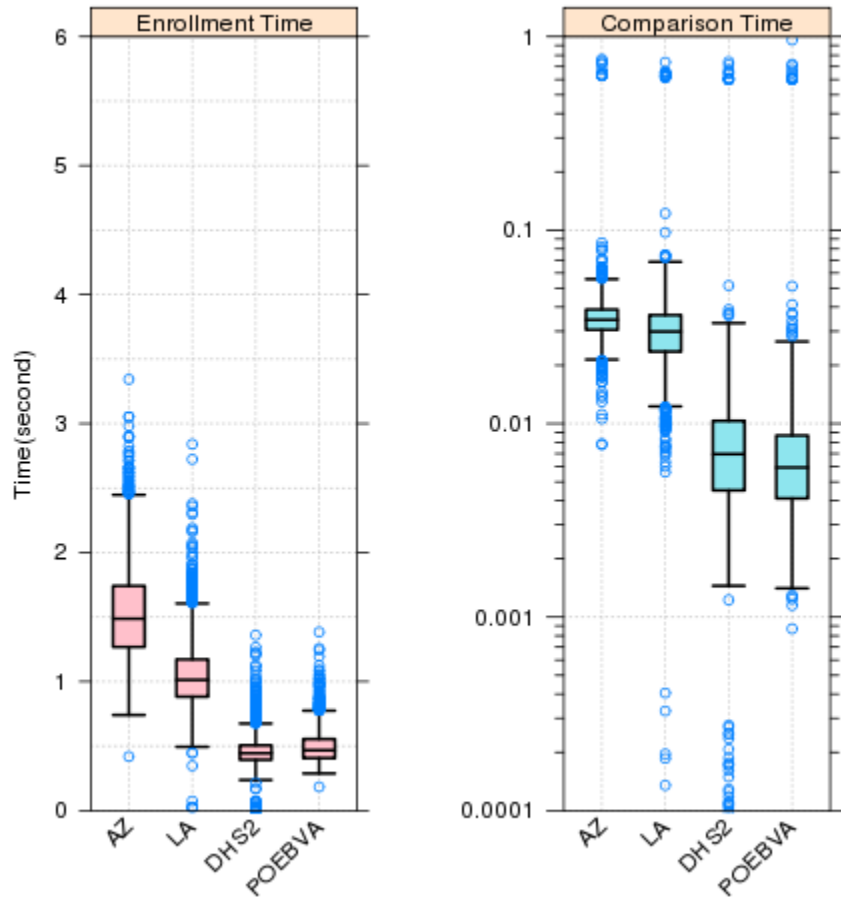


Figure 3C-2: 1K Sample Enrollment and Comparison Time

Enrollment Time (second)

Dataset	AZ	LA	DHS2	POEBVA
Maximum	3.3429	2.8403	1.3596	1.3840
75%	1.7416	1.1718	0.5060	0.5542
Median	1.4869	1.0129	0.4444	0.4673
25%	1.2677	0.8824	0.3930	0.4064
Minimum	0.4188	0.0195	0.0076	0.1833

Comparison Time (second)

Dataset	AZ	LA	DHS2	POEBVA
Maximum	0.7627	0.7373	0.7415	0.9595
75%	0.0388	0.0364	0.0103	0.0087
Median	0.0344	0.0299	0.0070	0.0059
25%	0.0305	0.0235	0.0045	0.0041
Minimum	0.0078	0.0000	0.0000	0.0009

Table 3C-2: Enrollment and Comparison Time (second)

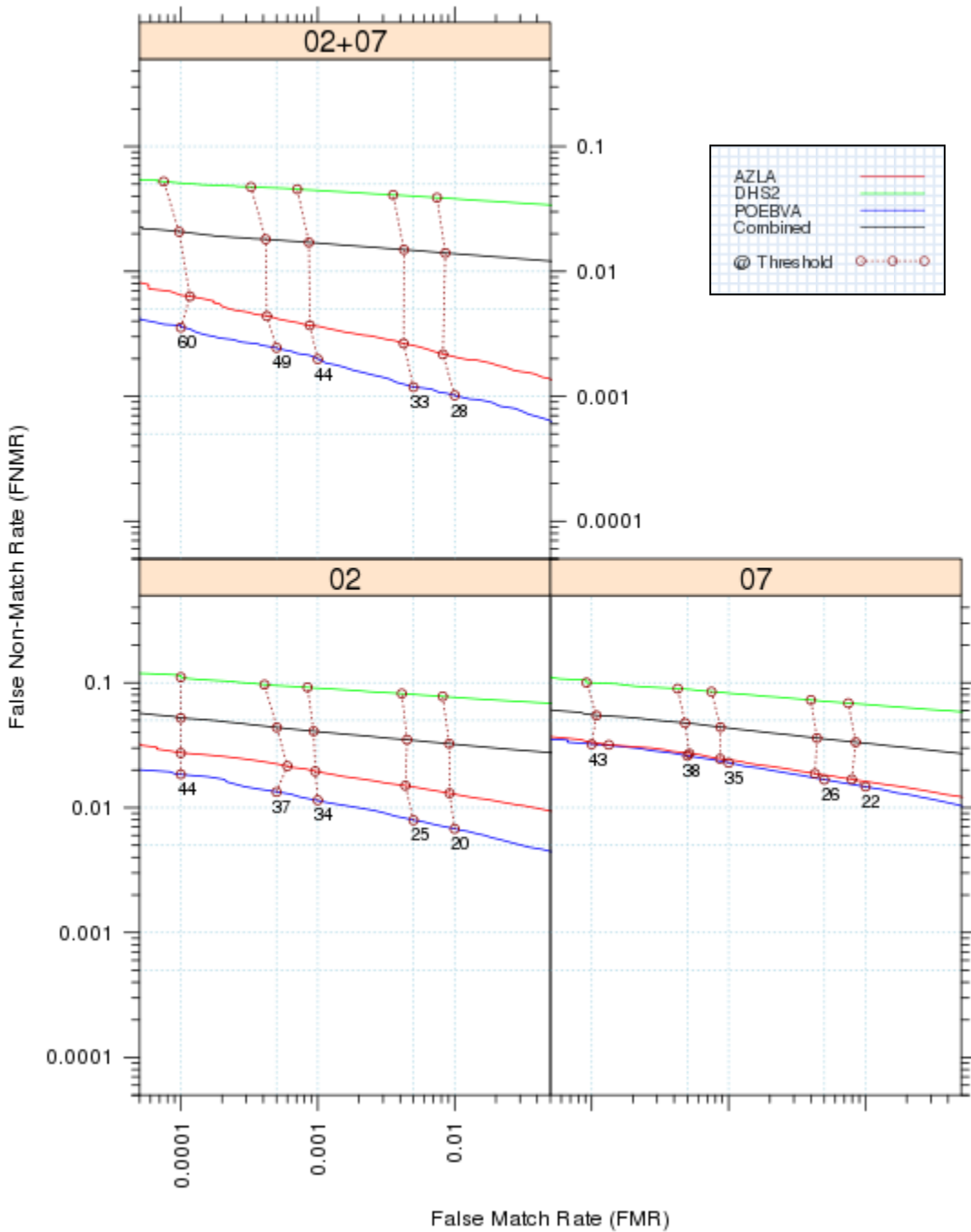


Figure 3C-3: DET for ALL Datasets (P2P)

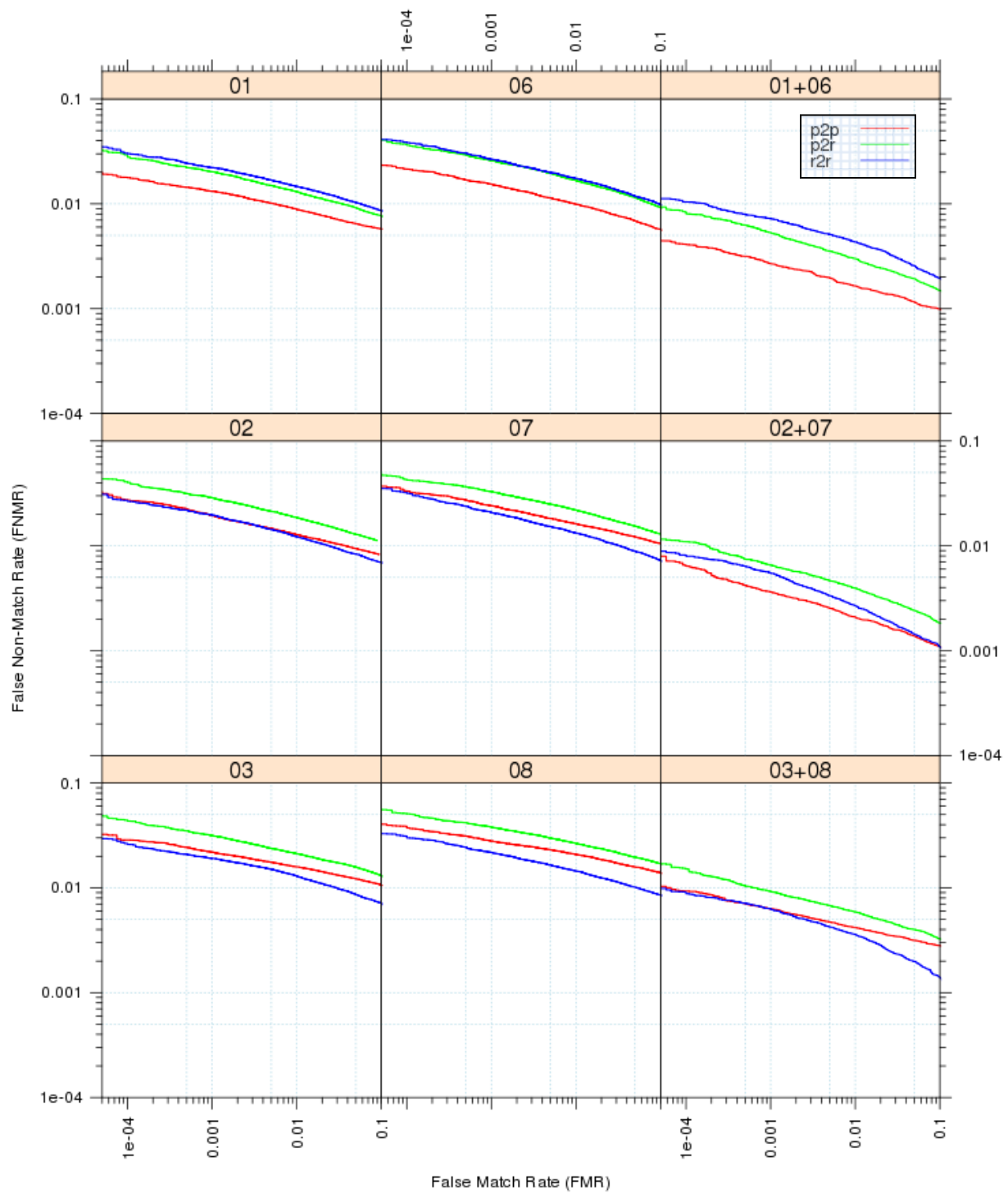


Figure 3C-4: DET for dataset AZLA

Note: p2p - plain vs. plain; p2r - plain vs. rolled; r2r – rolled vs. rolled.

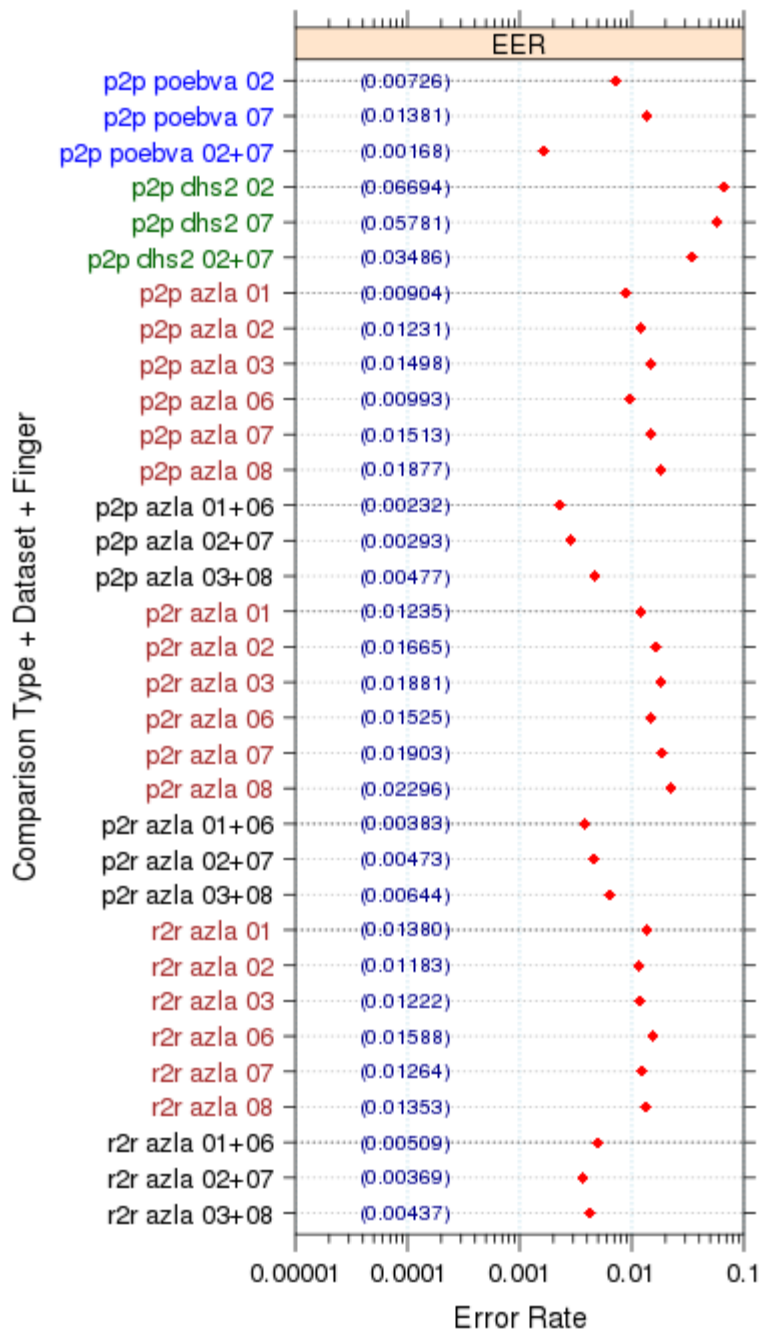


Figure 3C-5: EER and FTE

Note: EER table is not presented in Figure 5 due to all the EER = 0.

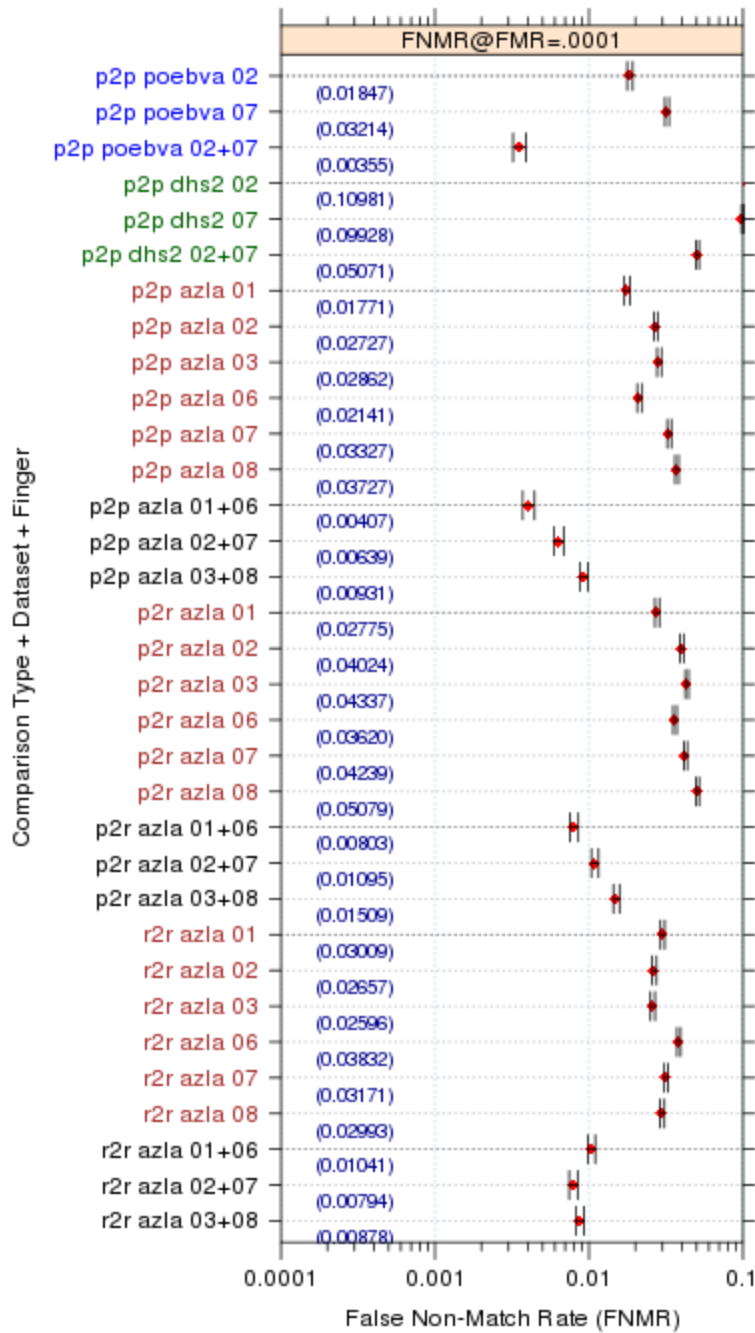


Figure 3C-3: FNMRs @ FMR = .0001 and 95% Confidence Intervals

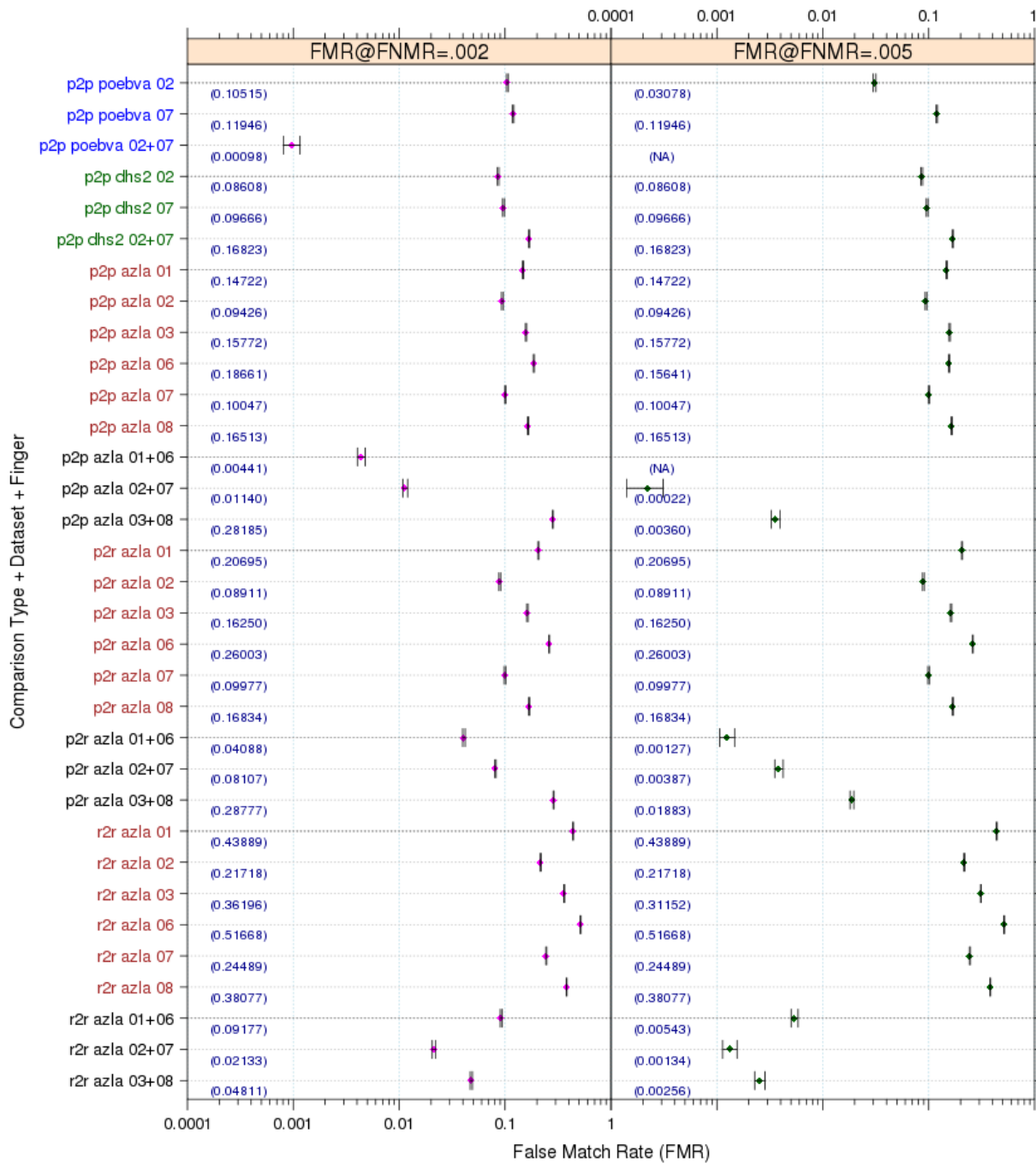


Figure 3C-7: FMRs @ FNMR = (.002, 0.005) and 95% Confidence Intervals

Note: NA – The number couldn't be reliably measured with the current sample size of 120,000.

Comparison Type	Dataset	Finger Position	EER	FTE Rate	FTE count
p2p	poebva	02	0.0073	0	0
p2p	poebva	07	0.0138	0	0
p2p	poebva	02+07	0.0017	0	0
p2p	dhs2	02	0.0669	0	0
p2p	dhs2	07	0.0578	0	0
p2p	dhs2	02+07	0.0349	0	0
p2p	azla	01	0.0090	0	0
p2p	azla	02	0.0123	0	0
p2p	azla	03	0.0150	0	0
p2p	azla	06	0.0099	0	0
p2p	azla	07	0.0151	0	0
p2p	azla	08	0.0188	0	0
p2p	azla	01+06	0.0023	0	0
p2p	azla	02+07	0.0029	0	0
p2p	azla	03+08	0.0048	0	0
p2r	azla	01	0.0124	0	0
p2r	azla	02	0.0167	0	0
p2r	azla	03	0.0188	0	0
p2r	azla	06	0.0153	0	0
p2r	azla	07	0.0190	0	0
p2r	azla	08	0.0230	0	0
p2r	azla	01+06	0.0038	0	0
p2r	azla	02+07	0.0047	0	0
p2r	azla	03+08	0.0064	0	0
r2r	azla	01	0.0138	0	0
r2r	azla	02	0.0118	0	0
r2r	azla	03	0.0122	0	0
r2r	azla	06	0.0159	0	0
r2r	azla	07	0.0126	0	0
r2r	azla	08	0.0135	0	0
r2r	azla	01+06	0.0051	0	0
r2r	azla	02+07	0.0037	0	0
r2r	azla	03+08	0.0044	0	0

Table 3C-3: EER, FTE and FTE Count

Note: All the FET count are 0s, Hence FTE = 0

Matching Type	Dataset	Finger position	FNMR@ FMR= 0.0001	95% Confidence Interval of FNMR	FMR1 @ FNMR= 0.002	95% Confidence Interval of FMR1	FMR2 @ FNMR= 0.005	95% Confidence Interval of FMR2
p2p	poebva	02	0.0185	±0.00076	0.1052	±0.00174	0.0308	±0.00098
p2p	poebva	07	0.0321	±0.00100	0.1195	±0.00184	0.1195	±0.00184
p2p	poebva	02+07	0.0036	±0.00034	0.0010	±0.00018	NA	NA
p2p	dhs2	02	0.1098	±0.00177	0.0861	±0.00159	0.0861	±0.00159
p2p	dhs2	07	0.0993	±0.00169	0.0967	±0.00167	0.0967	±0.00167
p2p	dhs2	02+07	0.0507	±0.00124	0.1682	±0.00212	0.1682	±0.00212
p2p	azla	01	0.0177	±0.00075	0.1472	±0.00201	0.1472	±0.00201
p2p	azla	02	0.0273	±0.00092	0.0943	±0.00165	0.0943	±0.00165
p2p	azla	03	0.0286	±0.00094	0.1577	±0.00206	0.1577	±0.00206
p2p	azla	06	0.0214	±0.00082	0.1866	±0.00220	0.1564	±0.00206
p2p	azla	07	0.0333	±0.00102	0.1005	±0.00170	0.1005	±0.00170
p2p	azla	08	0.0373	±0.00107	0.1651	±0.00210	0.1651	±0.00210
p2p	azla	01+06	0.0041	±0.00036	0.0044	±0.00038	NA	NA
p2p	azla	02+07	0.0064	±0.00045	0.0114	±0.00060	0.0002	±0.00009
p2p	azla	03+08	0.0093	±0.00054	0.2819	±0.00255	0.0036	±0.00034
p2r	azla	01	0.0278	±0.00093	0.2070	±0.00229	0.2070	±0.00229
p2r	azla	02	0.0402	±0.00111	0.0891	±0.00161	0.0891	±0.00161
p2r	azla	03	0.0434	±0.00115	0.1625	±0.00209	0.1625	±0.00209
p2r	azla	06	0.0362	±0.00106	0.2600	±0.00248	0.2600	±0.00248
p2r	azla	07	0.0424	±0.00114	0.0998	±0.00170	0.0998	±0.00170
p2r	azla	08	0.0508	±0.00124	0.1683	±0.00212	0.1683	±0.00212
p2r	azla	01+06	0.0080	±0.00051	0.0409	±0.00112	0.0013	±0.00020
p2r	azla	02+07	0.0110	±0.00059	0.0811	±0.00154	0.0039	±0.00035
p2r	azla	03+08	0.0151	±0.00069	0.2878	±0.00256	0.0188	±0.00077
r2r	azla	01	0.0301	±0.00097	0.4389	±0.00281	0.4389	±0.00281
r2r	azla	02	0.0266	±0.00091	0.2172	±0.00233	0.2172	±0.00233
r2r	azla	03	0.0260	±0.00090	0.3620	±0.00272	0.3115	±0.00262
r2r	azla	06	0.0383	±0.00109	0.5167	±0.00283	0.5167	±0.00283
r2r	azla	07	0.0317	±0.00099	0.2449	±0.00243	0.2449	±0.00243
r2r	azla	08	0.0299	±0.00096	0.3808	±0.00275	0.3808	±0.00275
r2r	azla	01+06	0.0104	±0.00057	0.0918	±0.00163	0.0054	±0.00042
r2r	azla	02+07	0.0079	±0.00050	0.0213	±0.00082	0.0013	±0.00021
r2r	azla	03+08	0.0088	±0.00053	0.0481	±0.00121	0.0026	±0.00029

Table 3C-4: FMRs @ FNMR = {,002, 0.005} and 95% Confidence Intervals

Note: NA – The number couldn't be reliably measured with the current sample size of 120,000.

8. Appendix - B

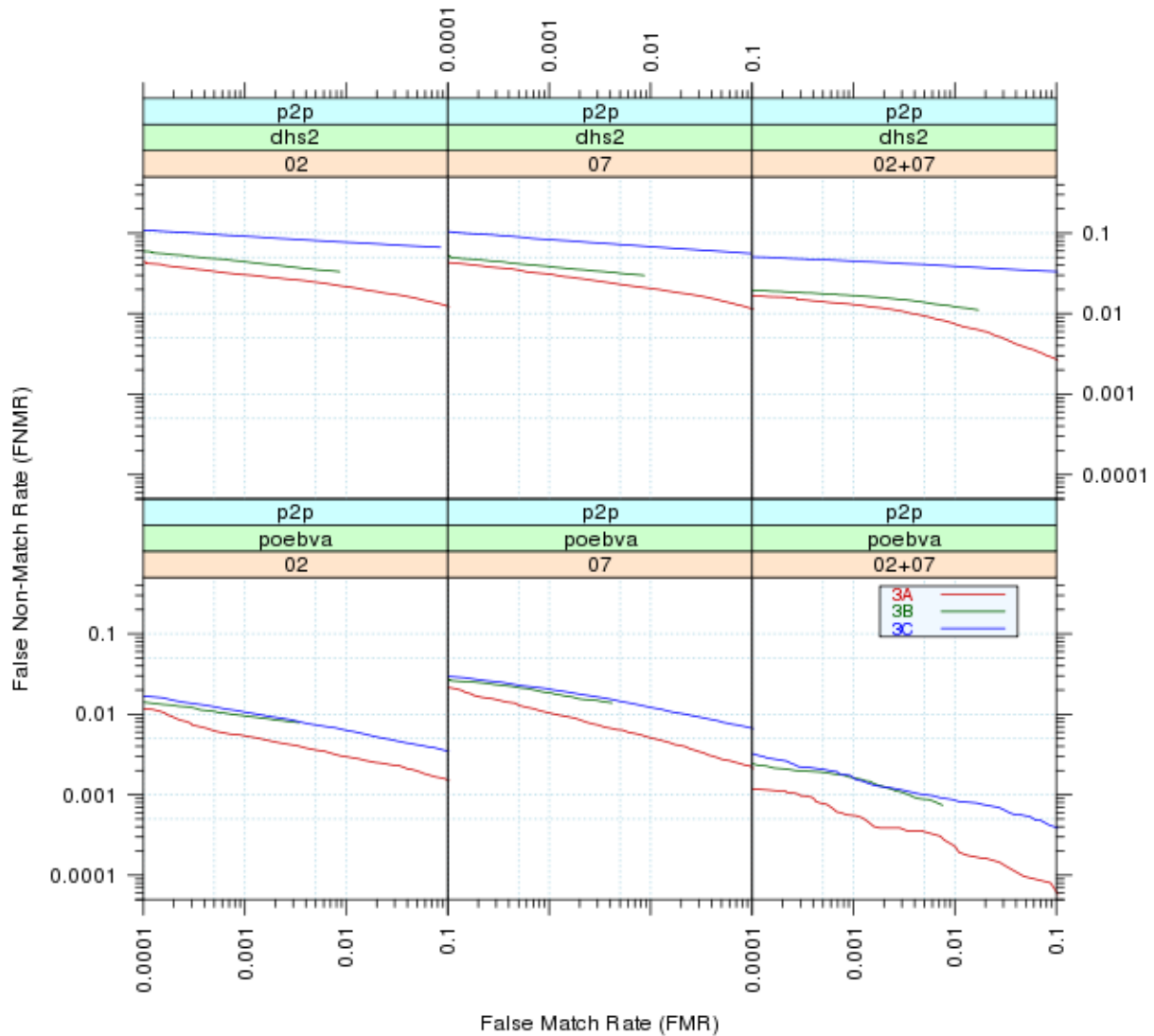


Figure 9: FNMR vs. FMR from DHS2 and POEBVA of PFT sample for Plain vs. Plain Comparison by Right index, Left index, and two index fingers fusion.

Plain vs. Plain		FNMR					
SDK	Dataset	FMR = 0.0001			FMR = 0.001		
		02	07	02+07	02	07	02+07
3A	dhs2	0.0434	0.0430	0.0166	0.0304	0.0310	0.0130
3B	dhs2	0.0600	0.0516	0.0195	0.0445	0.0388	0.0168
3C	dhs2	0.1089	0.1041	0.0508	0.0914	0.0833	0.0448
3A	poebva	0.0117	0.0215	0.0012	0.0054	0.0104	0.0006
3B	poebva	0.0140	0.0267	0.0025	0.0096	0.0185	0.0017
3C	poebva	0.0167	0.0293	0.0032	0.0107	0.0204	0.0016

Table 1: FNMR at FMR = {0.0001, 0.001}

3A = Avalon Biometrics S.L.

3B = ID Solutions, Inc.

3C = Patrima Technology Company