

ThalesCogent+0006

Thales Group

Evaluation of Latent Friction Ridge Technology (ELFT)

Technical performance report of automated latent fingerprint feature extraction and search software.

Last Updated: 28 March 2023

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Not Human Subjects Research

The National Institute of Standards and Technology's Research Protections Office reviewed the protocol for this project and determined it is "not human subjects research" as defined in 15 CFR 27, the Common Rule for the Protection of Human Subjects.

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1 Participation Information

1.1 Names

Information in this section is provided by the participant.

- **Participant Name:** Thales Group
- **ELFT Identifier:** ThalesCogent+0006
- **Exemplar Feature Extractor:**
 - **Marketing Name:** ThalesCogent Exemplar Extractor
- **Latent Feature Extractor:**
 - **Marketing Name:** ThalesCogent Latent Extractor
- **Search:**
 - **Marketing Name:** ThalesCogent Matcher

1.2 Dates

- **Participation Agreement Date:** 17 January 2023
- **First Submission Date:** 17 January 2023 (as version 0006)
- **Final Submission Date:** 17 January 2023 (as version 0006)
- **Validation Date:** 17 January 2023
- **Completion Date:** 31 January 2023
- **Report Last Updated Date:** 28 March 2023

1.3 Supplied Libraries and Configurations

Testing was completed using *Ubuntu 20.04.3 LTS*. Files provided by Thales Group are listed in Table 1.

Table 1: Information regarding library and configuration files provided as part of ThalesCogent+0006.

Filename	MD5 Checksum	Size (MB)
coml.1.d	121d525c083eb976a288a3dc4462fd21	139.3
libelft_ThalesCogent_0006.so	4bc217cddfd2394fe2a83f9705b510f6	11.1
libtensorflow_cc.so	11814cdaeb6aaef669631e4b7b7221e1	127.4
libtensorflow_framework.so	0959566c47de707e86dbccf2152fc066	18.1
mode05_1.json	b4d3b55ee560431fb4d431e7f7cf2e49	0.0
mode05_2.json	8b53b03297ca248ce7558bb01d8eb747	0.0
mode05_3.json	83568abeea4efc81b64feee48e38c1b2	0.0
mode05_4.json	1a1af419d0667d578f609eaa301f174c	0.0
mode05_5.json	034f37ee3548598f7585f61a7d33871d	0.0
mode05_6.json	5e1bb6fdda43e0c026b75535a442f2c4	0.0
mode05_7.json	a81433e5293fae455f53a2ef94dd844e	0.0
mode19_1.json	782b5d901aacf8b3ecde356353ed7524	0.0
mode19_2.json	87e68fc27bc4295a2e4b73c4ebf26264	0.0
mode19_3.json	4cb97b8dd3244ddec2bb047c00a4207e	0.0
mode19_4.json	f600994c72e8be833052e2d0c8eda748	0.0
mode19_5.json	fd62c13b88bf5dac3ee60fe24a12d0c9	0.0
mode19_6.json	8141bf44b4b3d250bd592d3538c88a1c	0.0
mode19_7.json	75b2c8b4a2bf7df0f603d675b2ae7190	0.0
platformConfigSchema.json	973e2358299e46e208302b2f279052e8	0.0
template_scale.d	856746724d3b51caf86dc9672dd38289	7.6
vfp_avl_data_v06.d	b126dad5e0c80b1e4a1e9e97dcc26f92	10.1

2 Timing Sample

A fixed sample of images was randomly and proportionally selected from the ELFT datasets. The sample is used to assess whether an implementation adheres to the computational speed requirements from the ELFT Test Plan. These values are chosen in such a way that allows the implementation flexibility while allowing NIST to complete the evaluation in a reasonable amount of time. If an implementation exceeds the maximum allowable duration, the participant will be asked to reduce the processing time of their software prior to NIST completing the evaluation. As such, *all* published ELFT submissions conform to the published speed requirements.

2.1 Processor Details

All measurements in this section were performed on a machine equipped with Intel Xeon Gold 6254 Central Processing Units (CPUs). Each CPU features a 3.10 GHz base frequency and 24.75 MB of cache. Timing tests are all **single threaded**—implementations are not permitted to use more than one thread during any function measured here. As such, these values can be used to understand expected scaled performance. NIST testing code embraces the single-threaded nature of implementations to fork processes during other non-timed portions of this evaluation, allowing participants to write thread-unsafe code while still using NIST resources to their maximum efficiency. This CPU supports executing several families of processor intrinsic functions, including AVX-512¹.

2.2 Composition

Table 2 shows the quantity of each type of fingerprint image comprising the timing sample dataset.

Table 2: Number of images of each generalized finger position comprising the timing sample dataset.

Image Type	Quantity
Latent	250
Four Finger	476
Full Palm	40
Partial Palm	47
Single Finger	2 784

2.3 Feature Extraction

Features were extracted from all images depicted in Table 2 and stored in templates. If a sample contained EFS data, it was included during this test.

2.3.1 Template Size

Table 3 and Figure 1 show the distribution of file sizes of templates. Failures of any kind reported during template generation result in NIST code writing 0 byte files. These files are excluded from the template size analysis in this section.

¹The complete set of advertised CPU flags is fpu, vme, de, pse, tsc, msr, pae, mce, cx8, apic, sep, mtrr, pge, mca, cmov, pat, pse36, clflush, dts, acpi, mmx, fxsr, sse, sse2, ss, ht, tm, pbe, syscall, nx, pdpe1gb, rdtscp, lm, constant_tsc, art, arch_perfmon, pebs, bts, rep_good, nopl, xtopology, nonstop_tsc, cpuid, aperfmperf, pni, pclmulqdq, dtes64, monitor, ds_cpl, vmx, smx, est, tm2, ssse3, sdbg, fma, cx16, xtp, pdcm, pcid, dca, sse4_1, sse4_2, x2apic, movbe, popcnt, tsc_deadline_timer, aes, xsave, avx, f16c, rdrand, lahf_lm, abm, 3dnowprefetch, cpuid_fault, epb, cat_l3, cdp_l3, invpcid_single, intel_ppin, ssbd, mba, ibrs, ibpb, stibp, ibrs_enhanced, tpr_shadow, vnmi, flexpriority, ept, vpid, ept_ad, fsgsbase, tsc_adjust, bmi1, avx2, smep, bmi2, erms, invpcid, cqm, mpx, rdt_a, avx512f, avx512dq, rdseed, adx, smap, clflushopt, clwb, intel_pt, avx512cd, avx512bw, avx512vl, xsaveopt, xsaves, xgetbv1, xsaves, cqm_llc, cqm_occup_llc, cqm_mbm_total, cqm_mbm_local, dtherm, ida, arat, pln, pts, pku, ospke, avx512_vnni, md_clear, flush_l1d, arch_capabilities

Table 3: Template file size summary statistics as seen on the Timing Sample dataset, in kB.

Image Type	Minimum	25%	Median	Mean	75%	Maximum	Failures	Attempts
Latent	0.8	4.2	12.7	11.9	17.5	36.3	0	250
Single Finger	2.5	8.3	10.1	10.1	11.9	19.2	2	2784
Four Finger	10.3	14.7	16.2	16.2	17.6	24.7	0	476
Partial Palm	0.3	10.8	16.6	14.1	18.1	26.4	0	47
Full Palm	21.4	24.8	26.0	26.0	27.4	29.9	0	40

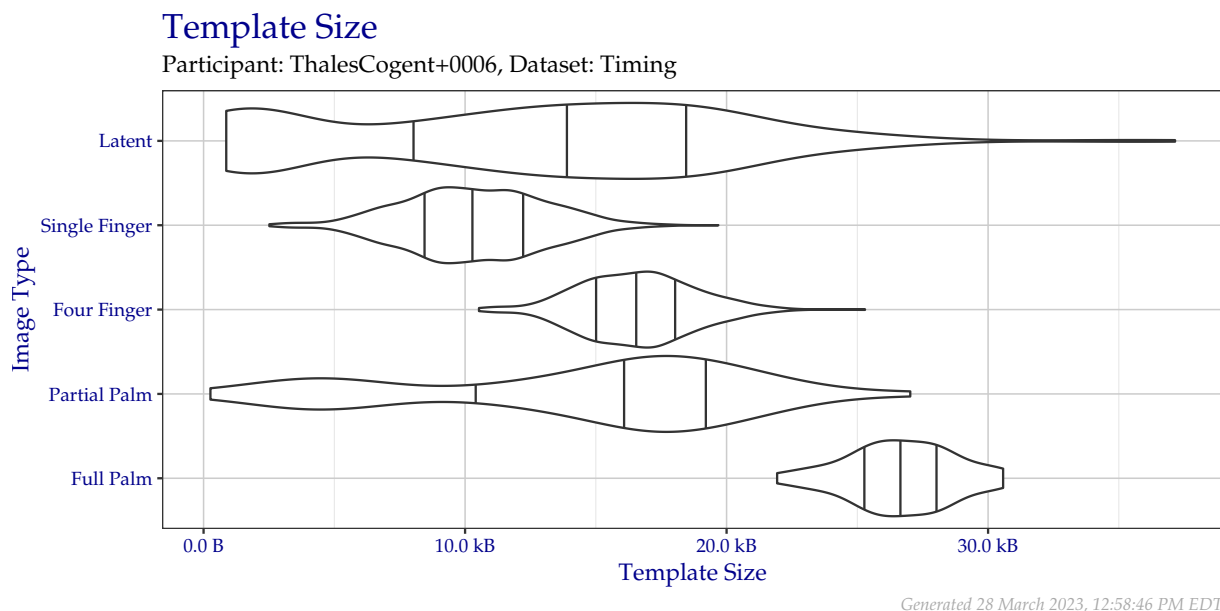


Figure 1: Violin plot of template file sizes as seen on the Timing Sample dataset. Vertical lines from left to right indicate the 25%, 50%, and 75% quantiles respectively.

2.3.2 Template Creation Duration

Table 4 and Figure 2 show the distribution of template creation durations in seconds. Failures of any kind reported during template generation result in NIST code writing 0 byte files, but only after the template creation method returns. These times are included in the template creation duration analysis in this section.

Table 4: Duration of template creation in seconds for images from the Timing Sample dataset.

Image Type	Minimum	25%	Median	Mean	75%	Maximum	Failures	Attempts
Latent	3.0	7.1	9.5	15.3	13.8	225.5	0	250
Single Finger	0.0	0.2	0.2	0.3	0.3	0.5	2	2784
Four Finger	0.3	0.4	0.5	0.5	0.5	0.8	0	476
Partial Palm	0.6	1.8	2.1	2.2	2.6	4.0	0	47
Full Palm	2.9	3.9	4.2	4.2	4.5	5.2	0	40

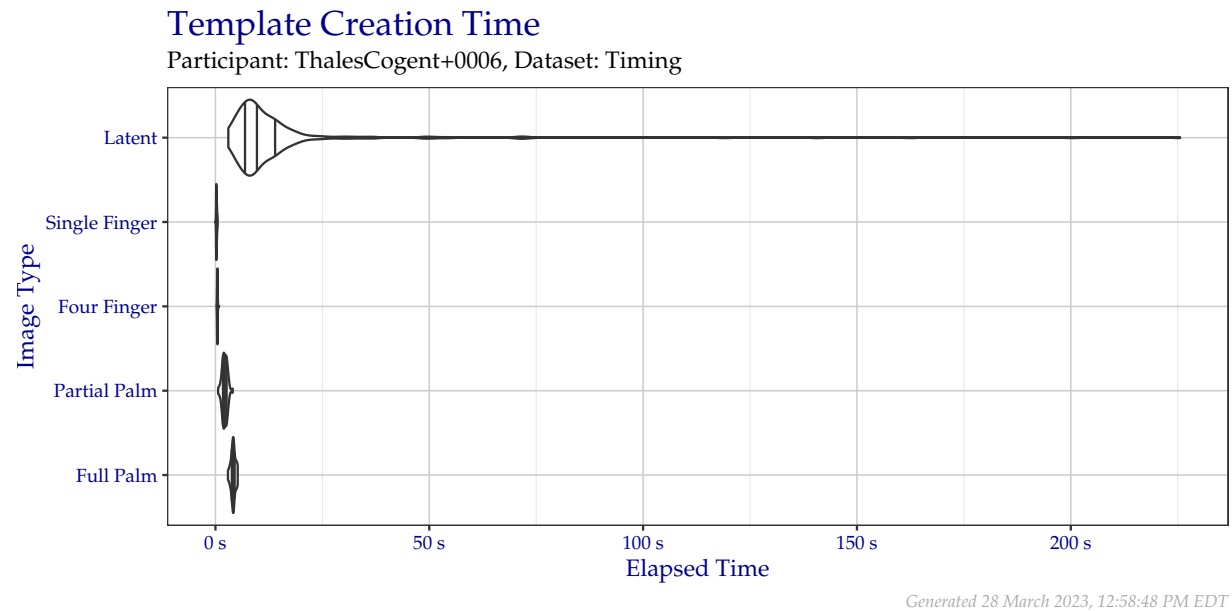


Figure 2: Violin plot of the duration of template creation in seconds for images from the Timing Sample dataset. Vertical lines from left to right indicate the 25%, 50%, and 75% quantiles respectively.

2.3.3 Template Creation Memory Consumption

Figure 3 shows the amount of RAM consumed by the single testing process as a function of time during the template creation procedure, including RAM consumed by the NIST testing apparatus.

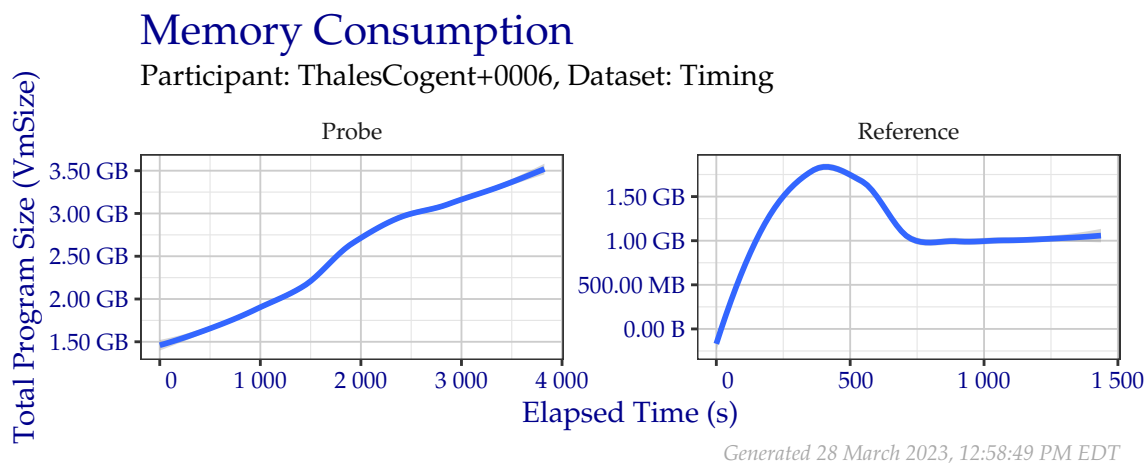


Figure 3: Amount of RAM used while creating templates in the Timing Sample dataset.

2.4 Enrollment Database

Reference templates are combined into a participant-defined database structure for optimal searching. Each database consisted of $\approx 1\,600\,000$ distractor subjects. Each subject had at least one, but typically twenty, distal phalanges distributed over rolled and flat impression captures to enroll. $\approx 150\,000$ had one or more palm captures.

While the participant-defined enrollment database should contain information about all references, the file size may be significantly different than the space consumed by concatenation of all individual reference templates. Additionally, the participant-defined database structure may be a structure unique or especially optimized for this evaluation and not necessarily similar to a structure deployed operationally. The sum of file sizes for both types of reference storage are shown in Table 5.

Table 5: Sum of file storage needed to hold all distractor reference templates in the Timing Sample.

Storage Type	Size
Participant-Defined Enrollment Database	439.8 GB
Raw Templates on Disk	252.4 GB

2.5 Search

Out of the latent templates generated in Table 2, a fixed random sample of 25 of the resulting latent templates were searched against the enrollment database described in Subsection 2.4. The results presented in Subsection 2.5 are based on the measurements made on or during those 25 searches.

2.5.1 Search Duration

Table 6 and Figure 4 show the amount of time elapsed during searches of the fixed search probe set when searching against the enrollment database described in Subsection 2.4. While unsuccessful searches expend operator time, they are not included in this metric, because search failures typically occur instantaneously (e.g., a template indicates that a probe was of too poor quality to search), which can artificially lower the average search time.

ELFT defines maximum average search durations for participants based on the number of subjects in the enrollment database. Due to the potential for extended runtimes, NIST may choose to allow some discretion in the enforcement of maximum search durations during times of high demand for compute resources. For example, if a maximum average search duration was 4 hours, but after completing all searches, the average search duration was 4.5 hours, it may be prudent to continue the evaluation, since a resubmission may require regeneration of millions of templates and several thousand repeated searches.

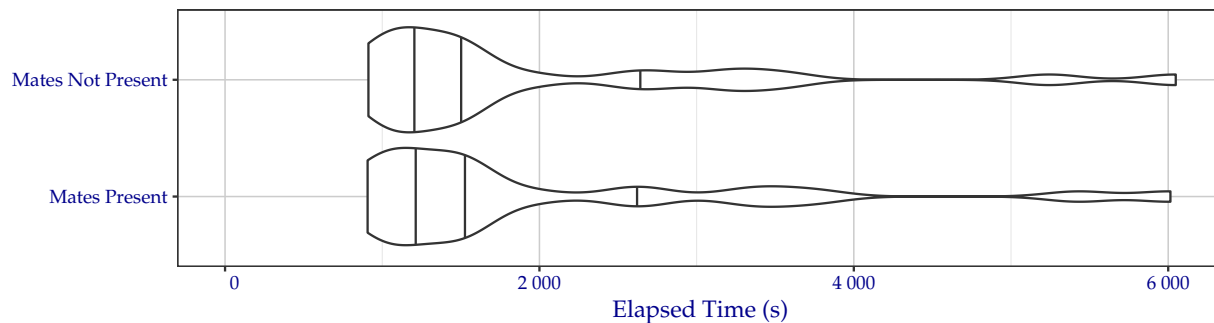
Note: In March 2023, NIST lowered the number of searches from 100 to 25, with all 25 probes depicting a distal phalanx. It also doubled the average quantity of impressions per subject by combining previously separate plain and rolled impressions for each subject. ELFT does not mandate the strategy in which multiple impressions of the same reference finger are stored or searched in the enrollment database, but it does impose search time maximums on a per-subject basis, *not* per-impression. This means that in Table 6 and Figure 4, there may be average search durations *significantly* higher than the evaluation permitted maximum for implementations submitted prior to March 2023.

Table 6: Search time durations of the search probe set from the Timing Sample dataset, in seconds. This data is visualized in Figure 4.

Mated?	Min	25%	Median	Mean	75%	Maximum	Failures	Searches
False	912	1 157	1 436	1 994	2 556	6 048	0	25
True	907	1 116	1 491	2 019	2 561	6 014	0	25

Single Latent Search Duration

Participant: ThalesCogent+0006, Dataset: Timing, Max RAM: 300 GB, Number of Searches: 25,
Enrollment Set (Subjects): $\approx 1\,600\,000$ Non-mates + $3\,347$ Mates



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Figure 4: Violin plot of search time durations of the search probe set from the Timing Sample dataset. Vertical lines from left to right indicate the 25%, 50%, and 75% quantiles respectively.

2.5.2 Search Memory Consumption

Figure 5 shows the amount of RAM consumed by the single testing process as a function of time during the search procedure, including RAM consumed by the NIST testing apparatus. Implementations were permitted to use up to 300 GB of RAM (of a total available 384 GB) to load their enrollment database, the rest of which was stored on a local solid-state storage device. Note the different scales on each panel—implementations that do not change the contents of RAM may not show variation.

Single Latent Search Memory Consumption

Participant: ThalesCogent+0006, Dataset: Timing, Max RAM: 300 GB,
Number of Searches: 25, Enrollment Set (Subjects): $\approx 1\,600\,000$ Non-mates + 3 347 Mates

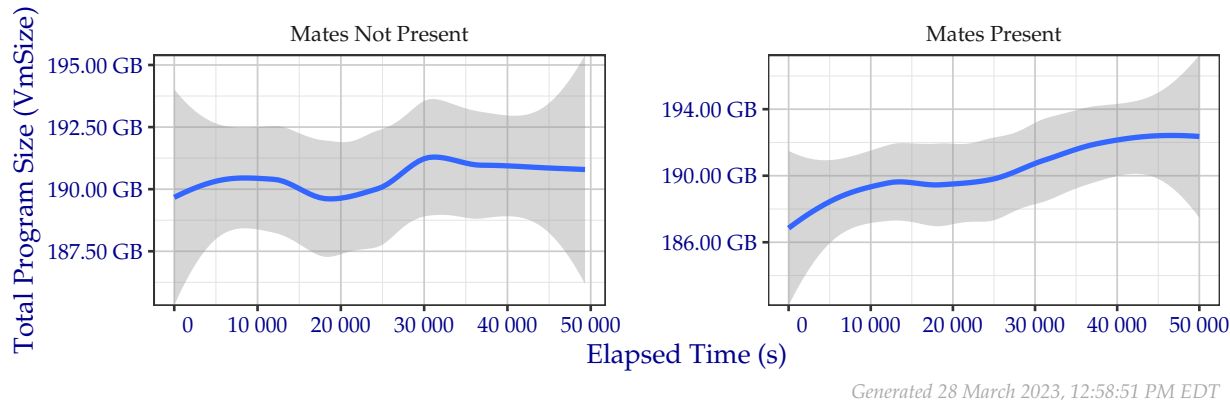


Figure 5: Amount of RAM used while searching templates in the Timing Sample dataset.

3 Metrics

3.1 Location

When a metric depicts search accuracy in this document, it is reported in terms of Location: Region and Subject.

- **Region:** The correct region of the correct subject was returned.
 - For search probes sourced from a distal phalanx (i.e., a “latent fingerprint”), the correct finger position 1–10 shall be returned.
 - For search probes sourced from a palm or a non-distal phalanx, the most localized region shall be returned. Some palm regions may be interchangeable based on the exemplars provided (e.g., a palm probe’s source could reasonably be seen in a lower palm, hypothenar, and writer’s palm exemplar). Credit is given for **Region** in this case.
- **Subject:** Any position from the correct subject is returned. This is designed to reward the situation where an implementation cannot ascertain the most localized region from the set of exemplars enrolled and may indicate segmentation error.

3.2 Cumulative Match Characteristic (CMC)

The Cumulative Match Characteristic (CMC) plots in this document show the false negative identification rate (FNIR) without respect for similarity score when searching probes against a enrollment database where a single mated identity for each search probe was present.

- $\approx 1\,600\,000$ non-mated subjects were enrolled.
 - All subjects had at least one, but typically twenty, images containing distal phalanges. This typically included ten individually rolled impressions and “Identification Flat” captures featuring more than one distal phalanx per image that must be segmented by the implementation.
 - $\approx 150\,000$ had one or more palm captures to enroll.
- The requested size of the candidate list was always 100 subjects.
- All possible Extended Feature Set (EFS) data was provided when “Image + EFS” is listed for probes. The type of EFS data present varies for each sample in each dataset. Initial experiments show nominal (if any) change when EFS data was provided alongside exemplars.
- Probe impression type was always “Unknown Finger” or “Unknown Palm,” as appropriate. Future studies may show results using the impression type “Unknown Friction Ridge” for both types of probes.
- The metric *hit rate* is equivalent to $1 - \text{miss rate}$, or $1 - \text{FNIR}$. For example, an FNIR of 0.1 indicates a hit rate of 0.9 (i.e., 90%).

3.3 Detection Error Tradeoff (DET)

The Detection Error Tradeoff (DET) plots in this document show the tradeoff between false positive and false negative identification rates when searching probes against a enrollment database where a single mated identity for each search probe was present.

- $\approx 1\,600\,000$ non-mated subjects were enrolled.
 - All subjects had at least one, but typically twenty, images containing distal phalanges. This typically included ten individually rolled impressions and “Identification Flat” captures featuring more than one distal phalanx per image that must be segmented by the implementation.
 - $\approx 150\,000$ had one or more palm captures to enroll.
 - Non-mated similarity scores come from all ranks when searching probes against an enrollment dataset without any mated subjects enrolled.
- The requested size of the candidate list was always 100 subjects.
 - Mated similarity scores come from the correct location appearing at *any* rank.
- All possible EFS data was provided when “Image + EFS” is listed for probes. The type of EFS data present varies for each sample in each dataset. Initial experiments show nominal (if any) change when EFS data was provided alongside exemplars.

- Probe impression type was always “Unknown Finger” or “Unknown Palm,” as appropriate. Future studies may show results using the impression type “Unknown Friction Ridge” for both types of probes.

4 Non-mated Distractor Subjects

When searching probes in each of the subsequent sections, the non-mated distractor subjects that comprised the majority of each enrollment database remained the same. The results of Section 4 are based off of these distractor subjects.

4.1 Failures

Table 7 shows the number of failures to create reference templates for non-mated distractor subjects.

Table 7: Number of failures to create reference templates.

Distal Phalanx Impression Type	Failures	\approx Attempts
Mixed (Plain/Roll)	0	1 600 000

5 FBI Laboratory

The results of Section 5 are based on searches of the sequestered dataset *FBI Laboratory*. This dataset consists of 49 operational latent distal phalanx probes. Examiners at the FBI annotated several of the probe images with EFS features, possibly with algorithm assistance. These examiners then confirmed the ground truth mate. All probes searched were a single sample depicting a region from a distal phalanx. EFS data provided with the probe image *may* include:

- Pattern classification
- Minutia locations (unconfirmed source)

5.1 Failures

Table 8 shows the number of failures to create templates. Table 9 shows the number of failures to produce a candidate list.

Table 8: Number of failures to create templates.

Image Type	Content	Failures	Attempts
Exemplar	Image	0	38
Probe	Image + EFS	0	49
Probe	Image	0	49

Table 9: Number of failures to produce a candidate list. This number includes any failures to create a probe template from Table 8.

Distractor Imp.	Probe Content	Failures	Attempts
Mixed (Plain/Roll)	Image	0	49
Mixed (Plain/Roll)	Image + EFS	0	49

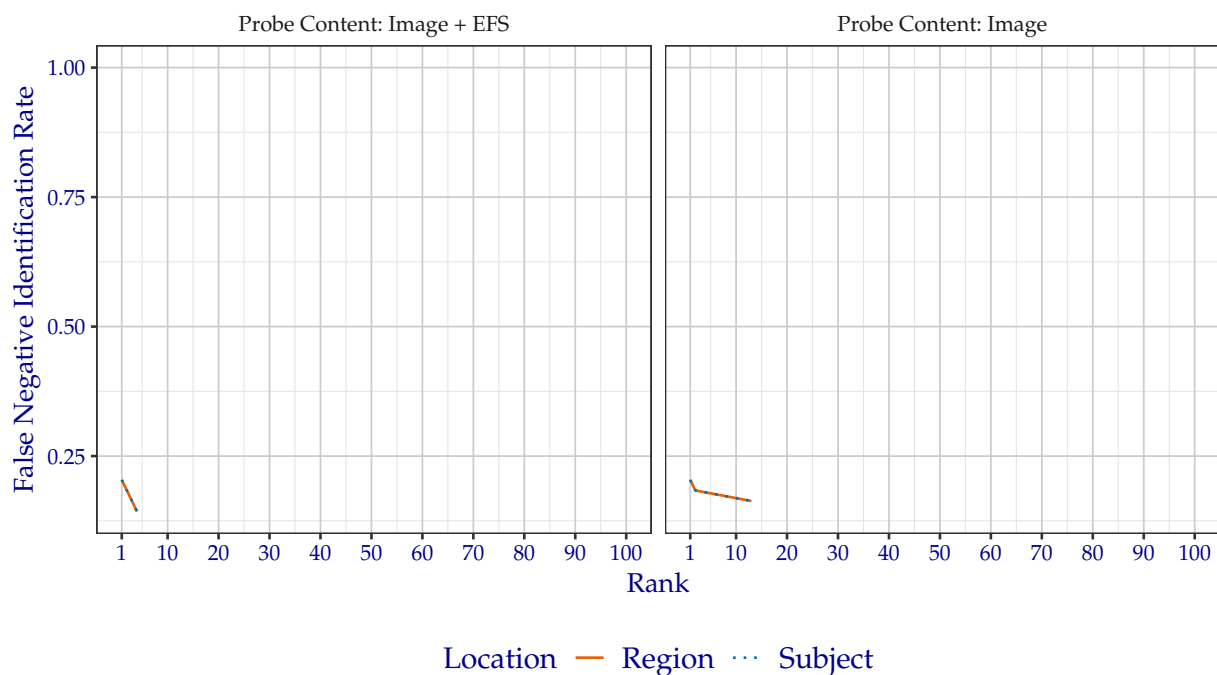
5.2 CMC

5.2.1 Plots

The CMC plots in Figure 6 show the FNIR of ThalesCogent+0006 when searching FBI Laboratory against enrollment database where a single mated identity for each search probe was present. The plots are faceted by whether probe EFS data was provided. Tabular versions of FNIR at select ranks can be viewed in Table 10.

Cumulative Match Characteristic

Algorithm: ThalesCogent+0006, Dataset: FBI Laboratory (49 probes),
Enrollment Set (Subjects): $\approx 1\,600\,000$ Mixed (Plain/Roll) Impression Non-mates + Mates,
Candidate List Length: 100



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Figure 6: CMC when searching FBI Laboratory probes, faceted by whether probe EFS data was provided.

5.2.2 FNIR at Select Rank

The values in Table 10 correspond to Figure 6.

Table 10: Region FNIR values from CMC plotted in Figure 6.

Distractor Imp.	Probe Content	Rank 1	Rank ≤ 50	Rank ≤ 100
Mixed (Plain/Roll)	Image	0.2041	0.1633	0.1633
Mixed (Plain/Roll)	Image + EFS	0.2041	0.1429	0.1429

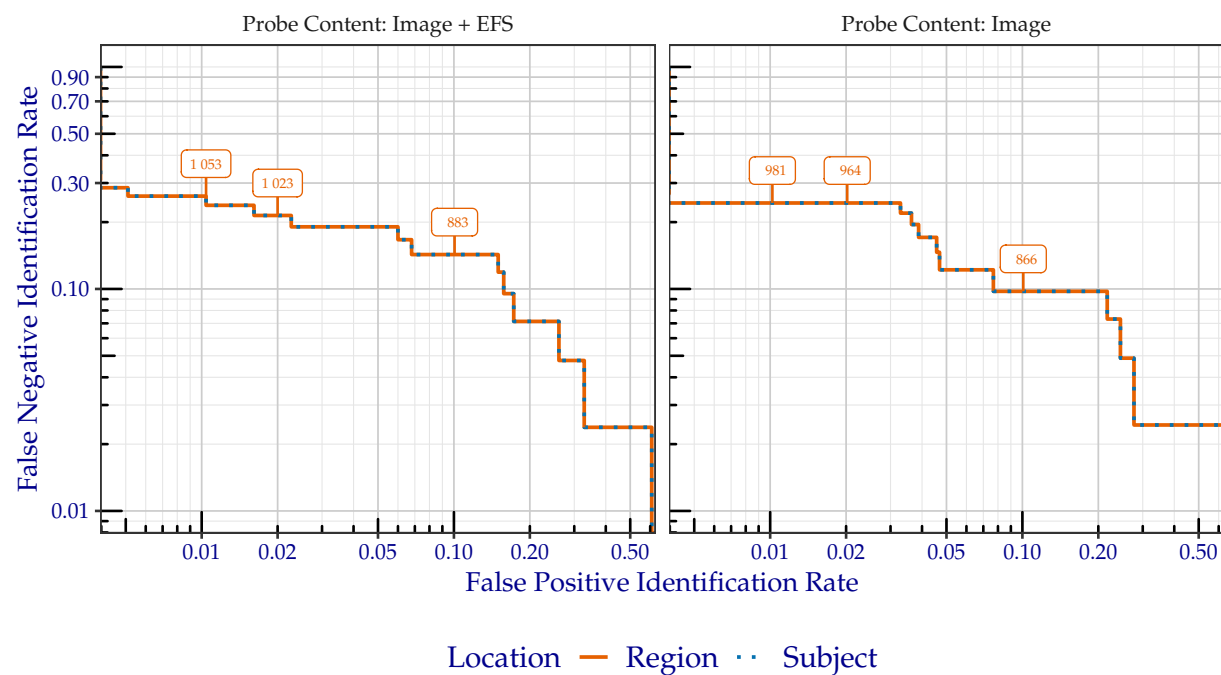
5.3 DET

5.3.1 Plots

The DET plots in Figure 7 show the false positive and false negative identification rate tradeoffs of ThalesCogent+0006 when searching FBI Laboratory against enrollment database where a single mated identity for each search probe was present. The plots are faceted by whether probe EFS data was provided. Tabular versions of FNIR at select FPIR can be viewed in Table 11. Annotated values indicate similarity scores, which are tabulated in Table 12.

Detection Error Tradeoff

Algorithm: ThalesCogent+0006, Dataset: FBI Laboratory (49 probes),
Enrollment Set (Subjects): $\approx 1\,600\,000$ Mixed (Plain/Roll) Non-mates + Mates,
Candidate List Length: 100



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Figure 7: DET when searching FBI Laboratory probes, faceted by whether probe EFS data was provided. Annotated values indicate similarity scores.

5.3.2 FNIR at Select FPIR

The values in Table 11 correspond to Figure 7.

Table 11: Region FNIR values corresponding to FPIR plotted in Figure 7.

Distractor Imp.	Probe Content	FPIR = 0.01	FPIR = 0.02	FPIR = 0.1
Mixed (Plain/Roll)	Image	0.2439	0.2439	0.0976
Mixed (Plain/Roll)	Image + EFS	0.2619	0.2143	0.1429

5.3.3 Similarity Score Thresholds at Select FPIR

The values in Table 12 correspond to similarity score thresholds observed at the select FPIR values from Table 11.

Table 12: Similarity score thresholds corresponding to select FPIR values from Table 11.

Distractor Imp.	Probe Content	FPIR = 0.01	FPIR = 0.02	FPIR = 0.1
Mixed (Plain/Roll)	Image	981	964	866
Mixed (Plain/Roll)	Image + EFS	1 053	1 023	883

6 FBI-Provided Solved Dataset #1

The results of Section 6 are based on searches of the sequestered dataset *FBI-Provided Solved Dataset #1*. This dataset consists of 516 operational probes collected from a particular type of crime. Examiners at the FBI annotated several of the probe images with EFS features, possibly with algorithm assistance. These examiners then confirmed the ground truth mate. All probes searched were a single sample depicting a region from a distal phalanx. EFS data provided with the probe image *may* include:

- Pattern classification
- Core locations (unconfirmed source)
- Delta locations (unconfirmed source)
- Minutia locations (unconfirmed source)

6.1 Failures

Table 13 shows the number of failures to create templates. Table 14 shows the number of failures to produce a candidate list.

Table 13: Number of failures to create templates.

Image Type	Content	Failures	Attempts
Exemplar	Image	0	173
Probe	Image + EFS	0	516
Probe	Image	0	516

Table 14: Number of failures to produce a candidate list. This number includes any failures to create a probe template from Table 13.

Distractor Imp.	Probe Content	Failures	Attempts
Mixed (Plain/Roll)	Image	0	516
Mixed (Plain/Roll)	Image + EFS	0	516

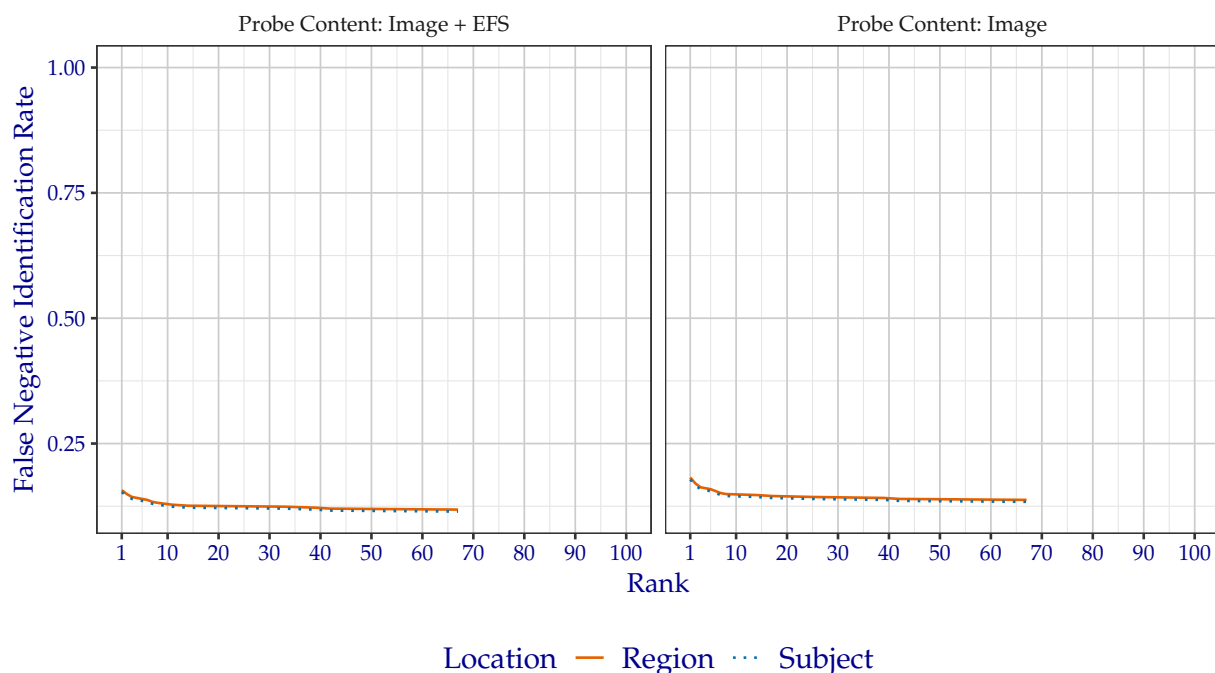
6.2 CMC

6.2.1 Plots

The CMC plots in Figure 8 show the FNIR of ThalesCogent+0006 when searching FBI-Provided Solved Dataset 1 against enrollment database where a single mated identity for each search probe was present. The plots are faceted by the mated impression type and whether probe EFS data was provided. Tabular versions of FNIR at select ranks can be viewed in Table 15.

Cumulative Match Characteristic

Algorithm: ThalesCogent+0006, Dataset: FBI-Provided Solved Dataset #1 (516 probes),
Enrollment Set (Subjects): $\approx 1\,600\,000$ Mixed (Plain/Roll) Impression Non-mates + Mates,
Candidate List Length: 100



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Figure 8: CMC when searching FBI-Provided Solved Dataset 1 probes, faceted by the mated impression type and whether probe EFS data was provided.

6.2.2 FNIR at Select Rank

The values in Table 15 correspond to Figure 8.

Table 15: Region FNIR values from CMC plotted in Figure 8.

Distractor Imp.	Probe Content	Rank 1	Rank ≤ 50	Rank ≤ 100
Mixed (Plain/Roll)	Image	0.1822	0.1395	0.1376
Mixed (Plain/Roll)	Image + EFS	0.1570	0.1202	0.1182

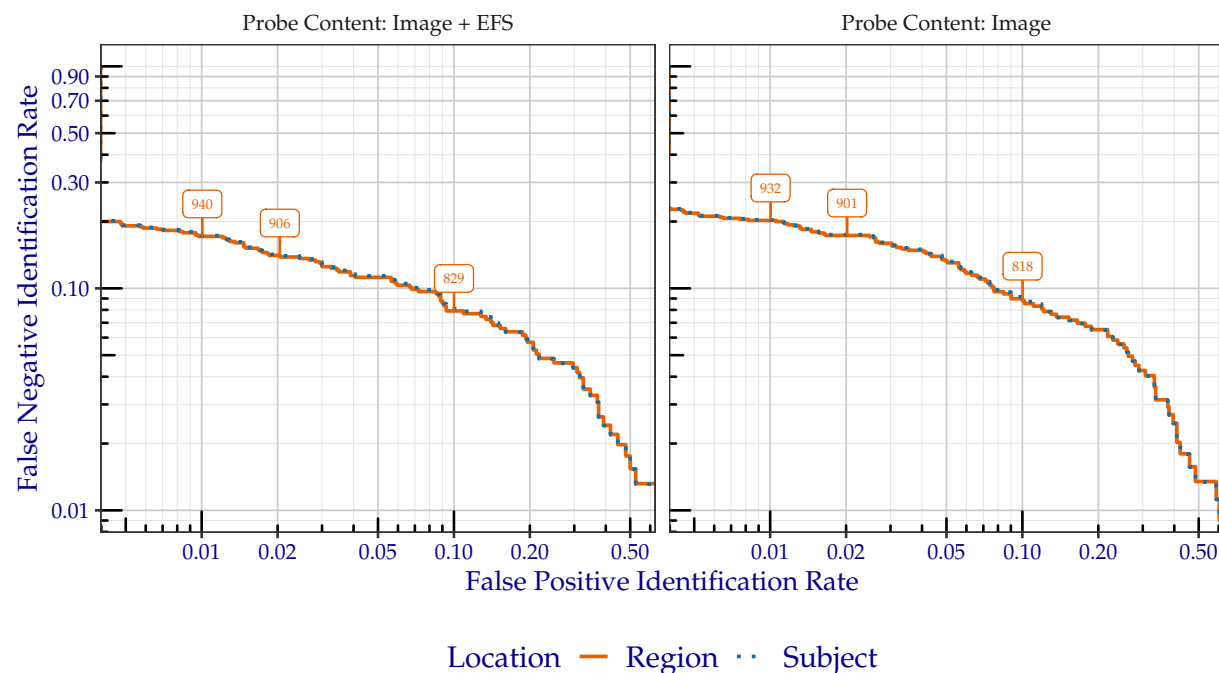
6.3 DET

6.3.1 Plots

The DET plots in Figure 9 show the false positive and false negative identification rate tradeoffs of ThalesCogent+0006 when searching FBI-Provided Solved Dataset 1 against enrollment database where a single mated identity for each search probe was present. The plots are faceted by the mated impression type and whether probe EFS data was provided. Tabular versions of FNIR at select FPIR can be viewed in Table 16. Annotated values indicate similarity scores, which are tabulated in Table 17.

Detection Error Tradeoff

Algorithm: ThalesCogent+0006, Dataset: FBI-Provided Solved Dataset #1 (516 probes),
Enrollment Set (Subjects): $\approx 1\,600\,000$ Mixed (Plain/Roll) Non-mates + Mates,
Candidate List Length: 100



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Figure 9: DET when searching FBI-Provided Solved Dataset 1 probes, faceted by the mated impression type and whether probe EFS data was provided. Annotated values indicate similarity scores.

6.3.2 FNIR at Select FPIR

The values in Table 16 correspond to Figure 9.

Table 16: Region FNIR values corresponding to FPIR plotted in Figure 9.

Distractor Imp.	Probe Content	FPIR = 0.01	FPIR = 0.02	FPIR = 0.1
Mixed (Plain/Roll)	Image	0.2022	0.1730	0.0899
Mixed (Plain/Roll)	Image + EFS	0.1714	0.1407	0.0791

6.3.3 Similarity Score Thresholds at Select FPIR

The values in Table 17 correspond to similarity score thresholds observed at the select FPIR values from Table 16.

Table 17: Similarity score thresholds corresponding to select FPIR values from Table 16.

Distractor Imp.	Probe Content	FPIR = 0.01	FPIR = 0.02	FPIR = 0.1
Mixed (Plain/Roll)	Image	932	901	818
Mixed (Plain/Roll)	Image + EFS	940	906	829

7 Michigan State Police

The results of Section 7 are based on searches of the sequestered dataset *Michigan State Police*. This dataset consist of of 2 174 operational latent probes. No EFS data was provided for probes or mated exemplars.

All probes searched were a single friction ridge sample from somewhere on the hand. Because the ELFT API indicates to implementations whether an image comes from the distal or palm region, analysis is separated between the two.

Note: While NIST biometric technology evaluations typically use sequestered law enforcement data, a literature search indicates that this collection of data may have been supplied to other research organizations that are not subject to the same strict sequestration policies as NIST.

7.1 Failures

Table 18 shows the number of failures to create templates. Table 19 shows the number of failures to produce a candidate list.

Table 18: Number of failures to create templates.

Image Type	Content	Distal Failures	Palm Failures	Attempts
Exemplar	Image	0	0	1 365
Probe	Image	0	3	2 174

Table 19: Number of failures to produce a candidate list. This number includes any failures to create a probe template from Table 18.

Distractor Imp.	Probe Content	Distal Failures	Palm Failures	Attempts
Mixed (Plain/Roll)	Image	0	3	2 174

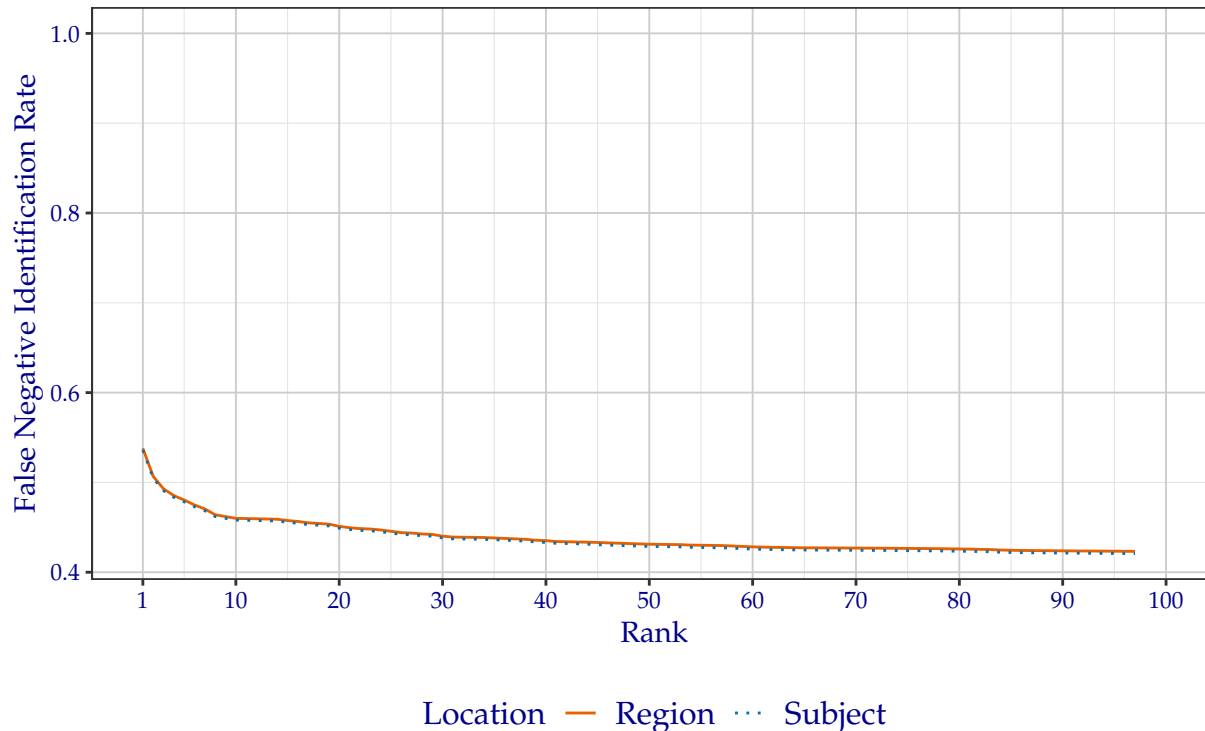
7.2 Distal Region CMC

7.2.1 Plots

The CMC in Figure 10 shows results from *only* the distal phalanx probes from Michigan State Police.

Cumulative Match Characteristic

Algorithm: ThalesCogent+0006, Dataset: Michigan State Police (2 013 probes),
Enrollment Set (Subjects): $\approx 1\,600\,000$ Mixed (Plain/Roll) Impression Non-mates +
Mixed (Plain/Roll) Impression Mates (Image), Candidate List Length: 100



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Figure 10: CMC when searching Michigan State Police distal phalanx probes.

7.2.2 FNIR at Select Rank

The values in Table 20 correspond to Figure 10.

Table 20: Region FNIR values from CMC plotted in Figure 10.

Distractor Imp.	Probe Content	Rank 1	Rank ≤ 50	Rank ≤ 100
Mixed (Plain/Roll)	Image	0.538	0.4312	0.4232

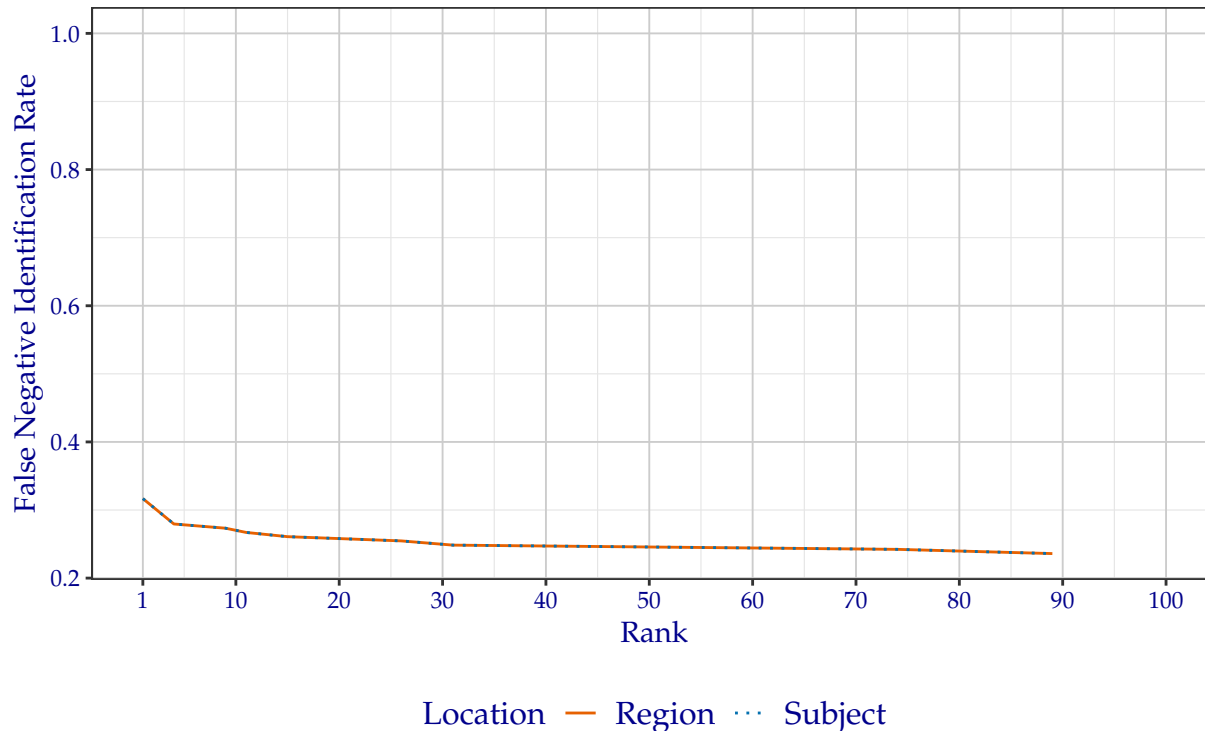
7.3 Palm Region CMC

7.3.1 Plots

The CMC in Figure 11 shows results from *only* the palm probes from Michigan State Police.

Cumulative Match Characteristic

Algorithm: ThalesCogent+0006, Dataset: Michigan State Police (161 probes),
Enrollment Set (Subjects): $\approx 150\,000$ Non-mates + Mates (Image),
Candidate List Length: 100



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Figure 11: CMC when searching Michigan State Police palm probes.

7.3.2 FNIR at Select Rank

The values in Table 21 correspond to Figure 11.

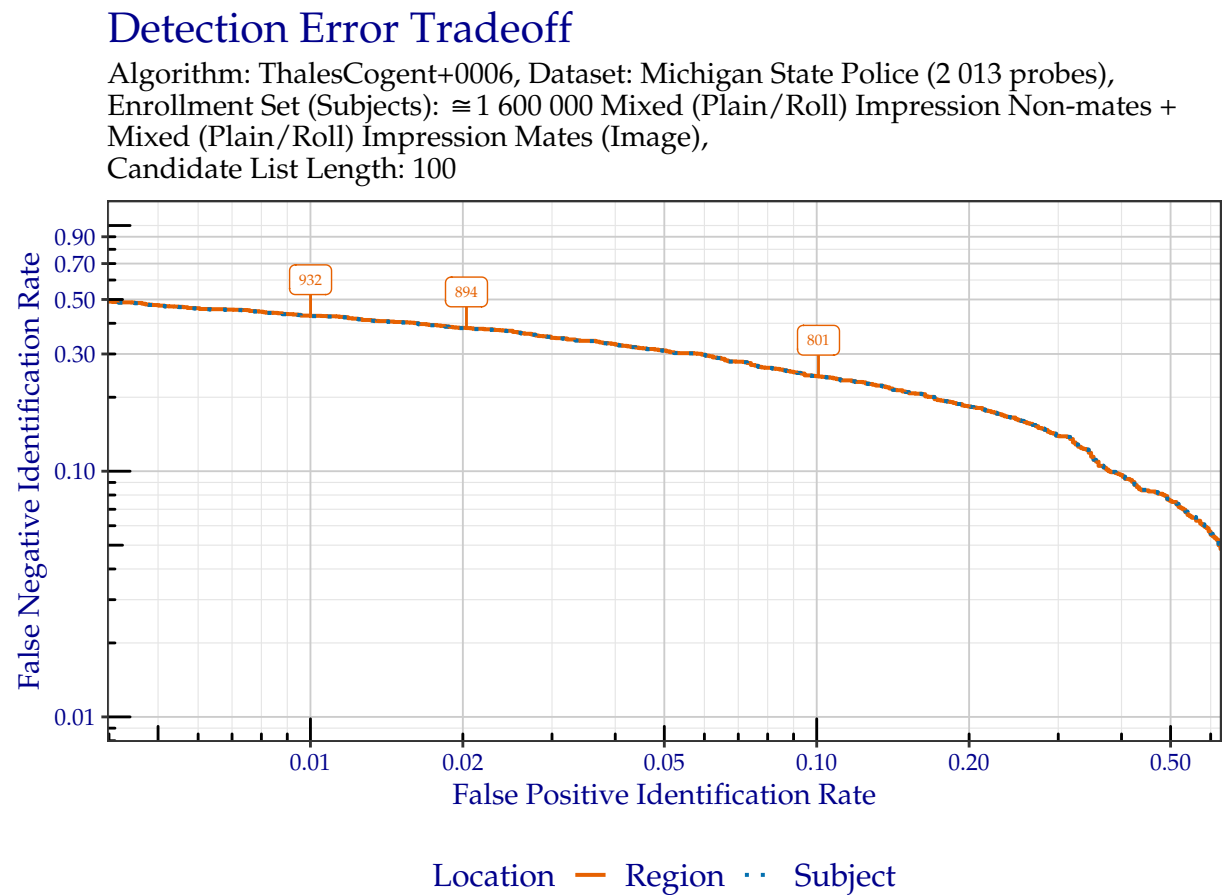
Table 21: Region FNIR values from CMC plotted in Figure 11.

Distractor Imp.	Probe Content	Rank 1	Rank ≤ 50	Rank ≤ 100
Mixed (Plain/Roll)	Image	0.3168	0.2484	0.236

7.4 Distal Region DET

7.4.1 Plots

The DET in Figure 12 shows results from *only* the distal phalanx probes from Michigan State Police. Annotated values indicate similarity scores, which are tabulated in Table 23.



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Figure 12: DET when searching Michigan State Police distal phalanx probes. Annotated values indicate similarity scores.

7.4.2 FNIR at Select FPIR

The values in Table 22 correspond to Figure 12.

Table 22: Region FNIR values corresponding to FPIR plotted in Figure 12.

Distractor Imp.	Probe Content	FPIR = 0.01	FPIR = 0.02	FPIR = 0.1
Mixed (Plain/Roll)	Image	0.4298	0.3833	0.2438

7.4.3 Similarity Score Thresholds at Select FPIR

The values in Table 23 correspond to similarity score thresholds observed at the select FPIR values from Table 22.

Table 23: Similarity score thresholds corresponding to select FPIR values from Table 22.

Distractor Imp.	Probe Content	FPIR = 0.01	FPIR = 0.02	FPIR = 0.1
Mixed (Plain/Roll)	Image	932	894	801

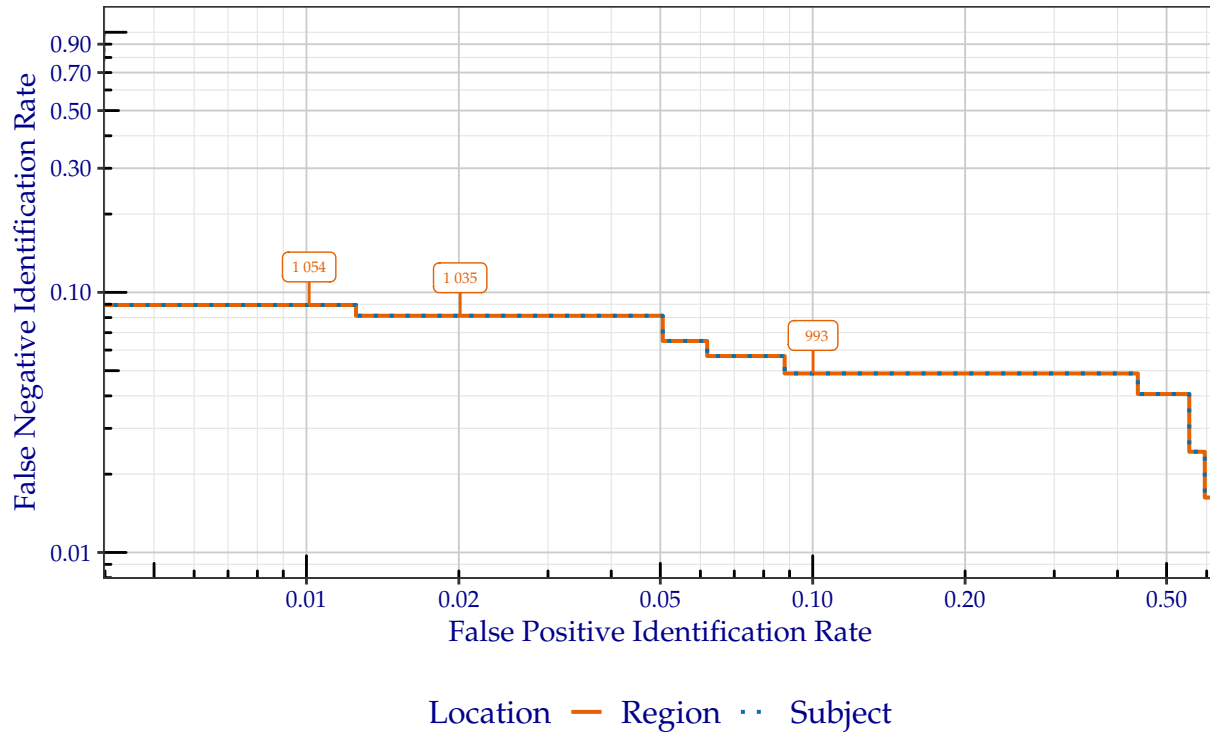
7.5 Palm Region DET

7.5.1 Plots

The DET in Figure 13 shows results from *only* the palm probes from Michigan State Police. Annotated values indicate similarity scores, which are tabulated in Table 25.

Detection Error Tradeoff

Algorithm: ThalesCogent+0006, Dataset: Michigan State Police (161 probes),
Enrollment Set (Subjects): $\approx 150\,000$ Non-mates + Mates (Image),
Candidate List Length: 100



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Figure 13: DET when searching Michigan State Police palm probes. Annotated values indicate similarity scores.

7.5.2 FNIR at Select FPIR

The values in Table 24 correspond to Figure 13.

Table 24: Region FNIR values corresponding to FPIR plotted in Figure 13.

Distractor Imp.	Probe Content	FPIR = 0.01	FPIR = 0.02	FPIR = 0.1
Mixed (Plain/Roll)	Image	0.0894	0.0813	0.0488

7.5.3 Similarity Score Thresholds at Select FPIR

The values in Table 25 correspond to similarity score thresholds observed at the select FPIR values from Table 24.

Table 25: Similarity score thresholds corresponding to select FPIR values from Table 24.

Distractor Imp.	Probe Content	FPIR = 0.01	FPIR = 0.02	FPIR = 0.1
Mixed (Plain/Roll)	Image	1 054	1 035	993