ThalesCogent+0013

Thales Group

Evaluation of Latent Friction Ridge Technology (ELFT)

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

Last Updated: 12 September 2024

Contents

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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+0013`
- **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:** 12 August 2024
- **First Submission Date:** 12 August 2024 (as version `0012`)
- **Final Submission Date:** 03 September 2024 (as version `0013`)
- **Validation Date:** 03 September 2024
- **Completion Date:** 12 September 2024
- **Report Last Updated Date:** 12 September 2024

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+0013.

Filename	MD5 Checksum	Size (MB)
coml.1.d	8e32c7409bb514a5a2b9bb5009ede47f	139.3
libelft_ThalesCogent_0013.so	e8ca6e2df90b69db11a36697dcd7f6c7	49.3
libonnxruntime.so.1.17.1	241129e1a53bd17de06bf1e642588630	15.5
libtensorflow_cc.so.1	1fa14066b33dbb8d51a2a54338ded56a	272.6
libtensorflow_framework.so.1	fa7b3720a4199ef2cf6a0df670480b74	39.0
mode05_1.json	7f517a8d582018d81fbd1efe32b272c9	0.0
mode05_2.json	40840641b84dd26ec6bfcc07be52fc0c	0.0
mode05_3.json	da2b6057bc52b215402bf35a11a9b614	0.0
mode05_4.json	acbaabc6e8cd6123828b764cd46e53be	0.0
mode05_5.json	6948c536c1431bc274ba98a0fad5d7ac	0.0
mode05_6.json	9f3acd9b71670fdff67f266df79bdccb	0.0
mode05_7.json	4f4fdd967ab373f0cd3bd8413d7167b6	0.0
mode19_1.json	a46f6da6b23137d3b715b0d31589299f	0.0
mode19_2.json	0f050bfa44aed51b13a8999b8815e0f9	0.0
mode19_3.json	5010cdc5ab99558320cf5d7cacc0ec11	0.0
mode19_4.json	9dd754cc1db71784d0c2be9a580d53ec	0.0
mode19_5.json	fd62c13b88bf5dac3ee60fe24a12d0c9	0.0
mode19_6.json	8141bf44b4b3d250bd592d3538c88a1c	0.0
mode19_7.json	75b2c8b4a2bf7df0f603d675b2ae7190	0.0
ortdnnlib_data1.dat	21ebc1c2f20a29312d71ca7ae5dcf251	66.7
ortdnnlib_data2.dat	9c2642ffb34096cbbccd0e9d005bb0b3	0.6
ortdnnlib_data3.dat	10656a2dbd8b66e20290191f29c51977	339.5
ortdnnlib_data4.dat	d95e56293145589c64ea54551199fb17	146.8
ortdnnlib_data5.dat	7bf103487aa40d0dec6d27a8f7c9db45	92.2
platformConfigSchema.json	e6f76c3414f29b127268e0782de798dd	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 CPU core 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-512[1].

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	243
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 not 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.

[1]The 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`, `xtpr`, `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`, `xsavec`, `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	3.5	6.6	8.5	16.3	11.1	323.7	0	243
Single Finger	3.6	14.0	16.1	16.1	18.3	26.4	0	2 784
Four Finger	21.7	36.0	39.1	39.1	42.2	55.4	0	476
Partial Palm	0.8	100.6	135.0	129.7	164.6	215.8	0	47
Full Palm	162.7	183.7	195.6	194.3	203.6	224.6	0	40

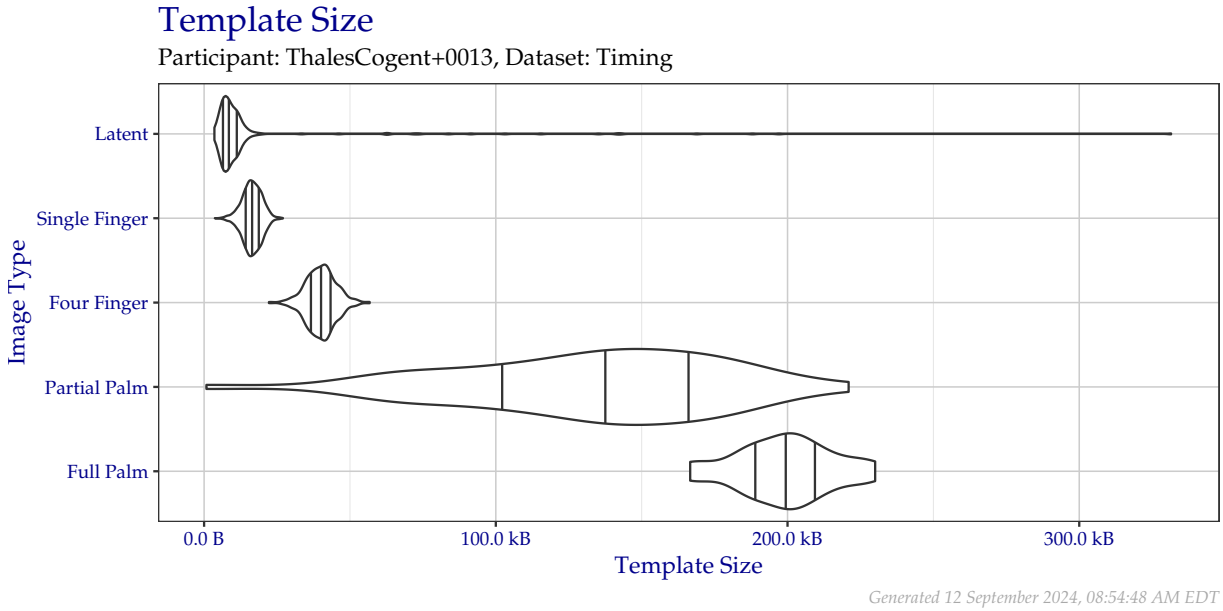

Figure 1: Violin plot of template file sizes as seen on the Timing Sample dataset. Vertical lines from left to right indicate the 25%, 50%, and 75% quantiles respectively.

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	1.5	3.0	4.0	6.1	5.4	87.0	0	243
Single Finger	0.5	3.7	4.4	4.3	5.0	7.3	0	2 784
Four Finger	4.8	8.9	9.9	9.9	10.9	15.1	0	476
Partial Palm	1.6	6.4	10.0	8.9	11.6	16.8	0	47
Full Palm	12.2	15.2	16.1	16.3	17.7	19.2	0	40

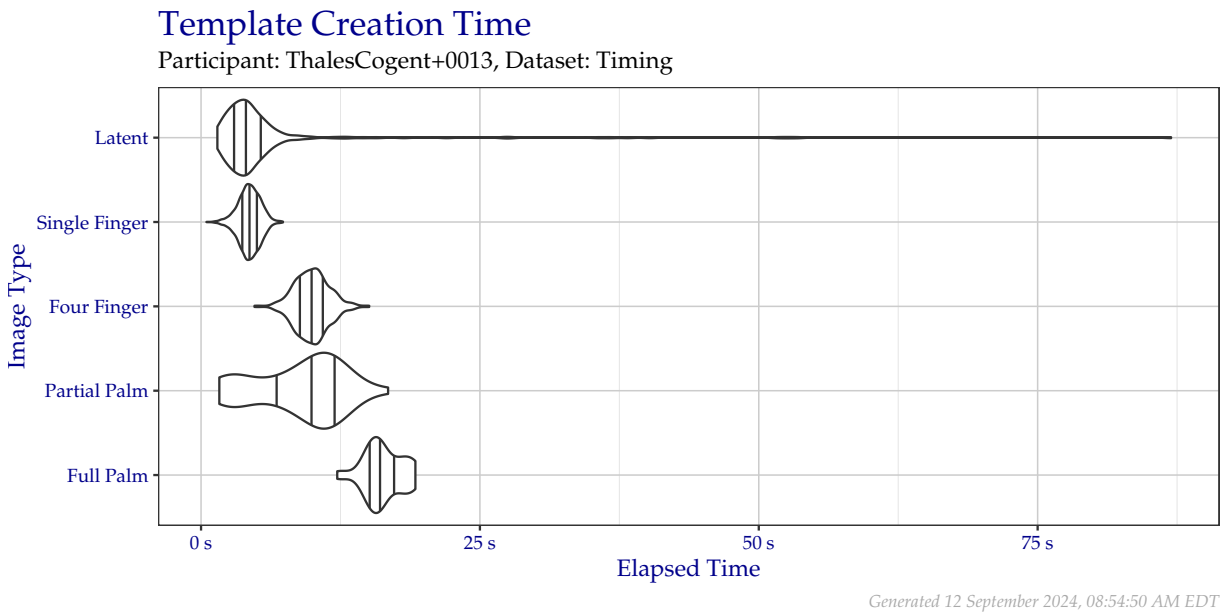

Figure 2: Violin plot of the duration of template creation in seconds for images from the Timing Sample dataset. Vertical lines from left to right indicate the 25%, 50%, and 75% quantiles respectively.

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.

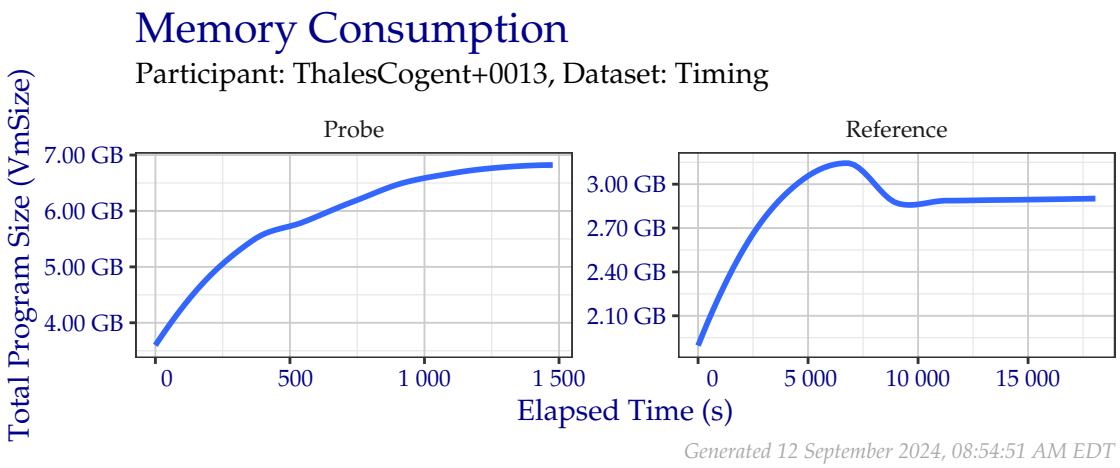

Figure 3: Amount of RAM used while creating templates in the Timing Sample dataset.

2.4 Enrollment Database

Reference templates are combined into a participant-defined database structure for optimal searching. Each database consisted of ≈ 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. ≈ 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	635.1 GB
Raw Templates on Disk	480.0 GB

2.5 Search

Out of the latent templates generated in Table 2, a fixed random sample of 24 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 24 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.

Note: In October 2023, NIST discovered a probe image in the search dataset contained invalid resolution information. This probe has been removed from the test, reducing the number of searches to 24. Evaluations run prior to this change will show total elapsed time measures including the now-omitted search.

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	631	876	1 030	1 089	1 288	2 204	0	24
True	629	891	1 033	1 102	1 275	2 618	0	24

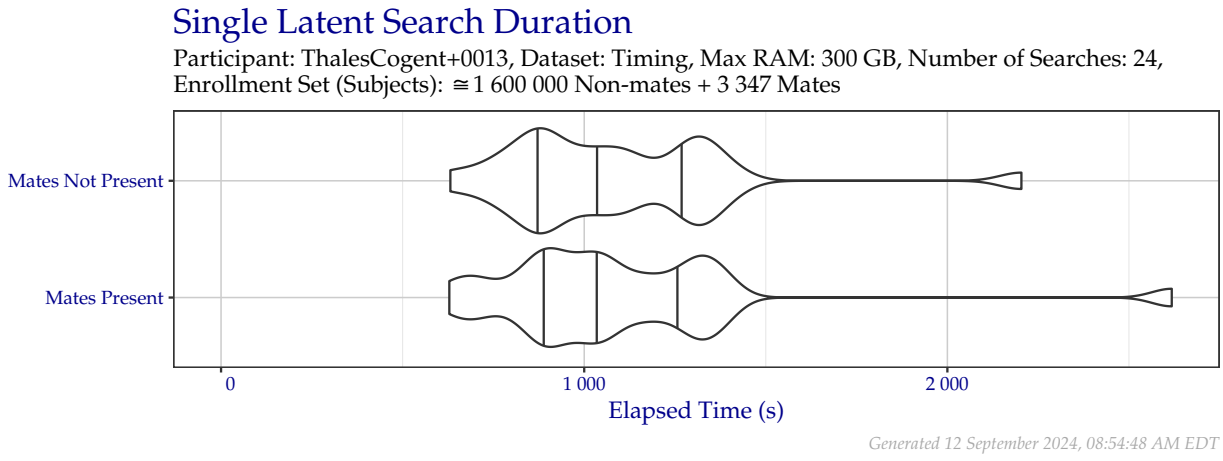

Figure 4: Violin plot of search time durations of the search probe set from the Timing Sample dataset. Vertical lines from left to right indicate the 25%, 50%, and 75% quantiles respectively.

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.

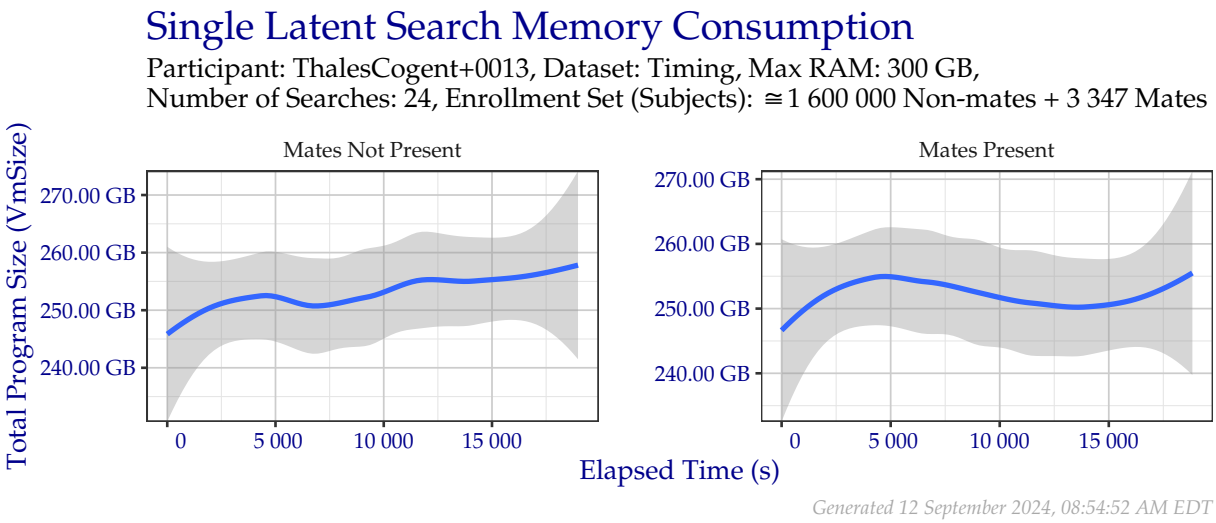

Figure 5: Amount of RAM used while searching templates in the Timing Sample dataset.

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 and quantity of EFS data present varies for each sample in each dataset and may have been entirely omitted. 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 − miss rate, or 1 − 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 rank = 1 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 and quantity of EFS data present varies for each sample in each dataset and may have been entirely omitted. 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	≈ 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	EFS	0	48
Probe	Image	0	49
Probe	Image + EFS	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.

Probe Content	Failures	Attempts
EFS	0	48
Image	0	49
Image + EFS	0	49

5.2 CMC

5.2.1 Plots

5.2.1.1 All Probes

The CMC plots in Figure 6 show the FNIR of ThalesCogent+0013 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.

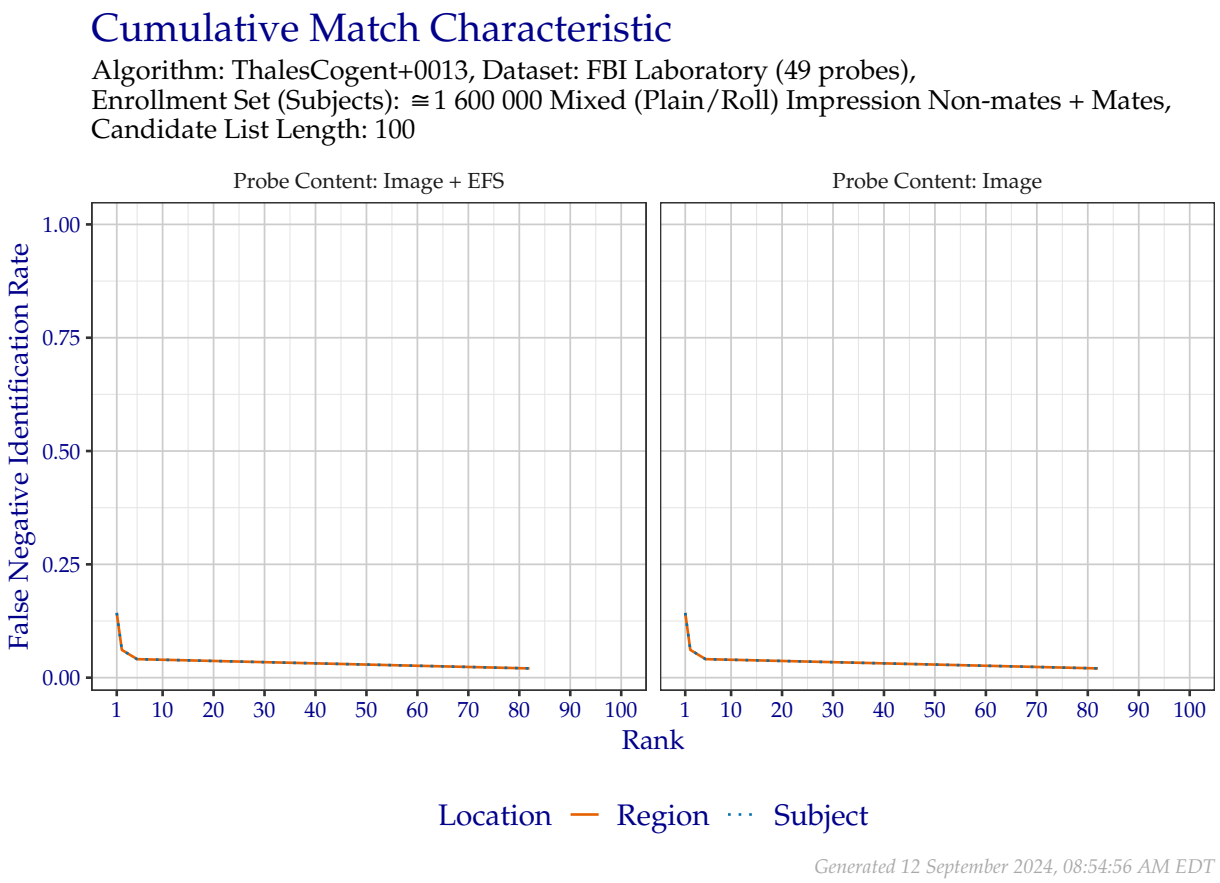

Figure 6: CMC when searching FBI Laboratory probes, faceted by whether probe EFS data was provided.

5.2.1.2 Probes with EFS Data

Not all of the probes in the FBI Laboratory dataset contain EFS data. The plot in Figure 7 shows the CMC over *only* the probes that contained EFS data. This plot also differs from Figure 6 with the inclusion of a line for probes where no image was provided when creating the probe template, meaning the only information available was EFS data. Only the *region* success location is shown.

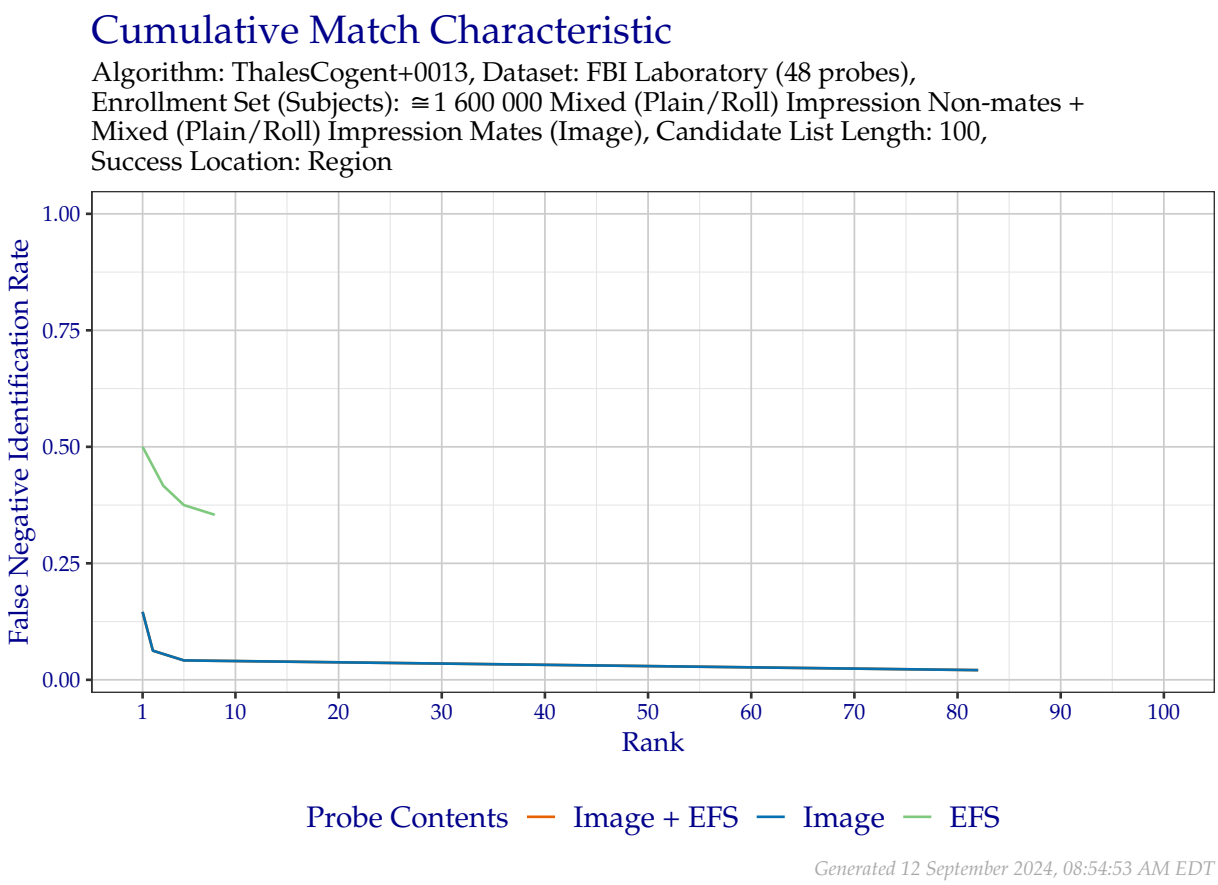

Figure 7: CMC of region location when searching only the FBI Laboratory probes that contained EFS data.

5.2.2 FNIR at Select Rank

5.2.2.1 All Probes

The values in Table 10 correspond to Figure 6.

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

Probe Content	Rank 1	Rank ≤ 2	Rank ≤ 5	Rank ≤ 10	Rank ≤ 50	Rank ≤ 100
Image	0.1429	0.0612	0.0408	0.0408	0.0408	0.0204
Image + EFS	0.1429	0.0612	0.0408	0.0408	0.0408	0.0204

5.2.2.2 Probes with EFS Data

The values in Table 11 correspond to Figure 7.

Table 11: Region FNIR values from CMC plotted in Figure 7.

Probe Content	Rank 1	Rank ≤ 2	Rank ≤ 5	Rank ≤ 10	Rank ≤ 50	Rank ≤ 100
EFS	0.5000	0.4583	0.3750	0.3542	0.3542	0.3542
Image	0.1458	0.0625	0.0417	0.0417	0.0417	0.0208
Image + EFS	0.1458	0.0625	0.0417	0.0417	0.0417	0.0208

5.3 DET

5.3.1 Plots

5.3.1.1 All Probes

The DET plots in Figure 8 show the false positive and false negative identification rate tradeoffs of ThalesCogent+0013 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 12. Annotated values indicate similarity scores from the Region line, which are tabulated in Table 14.

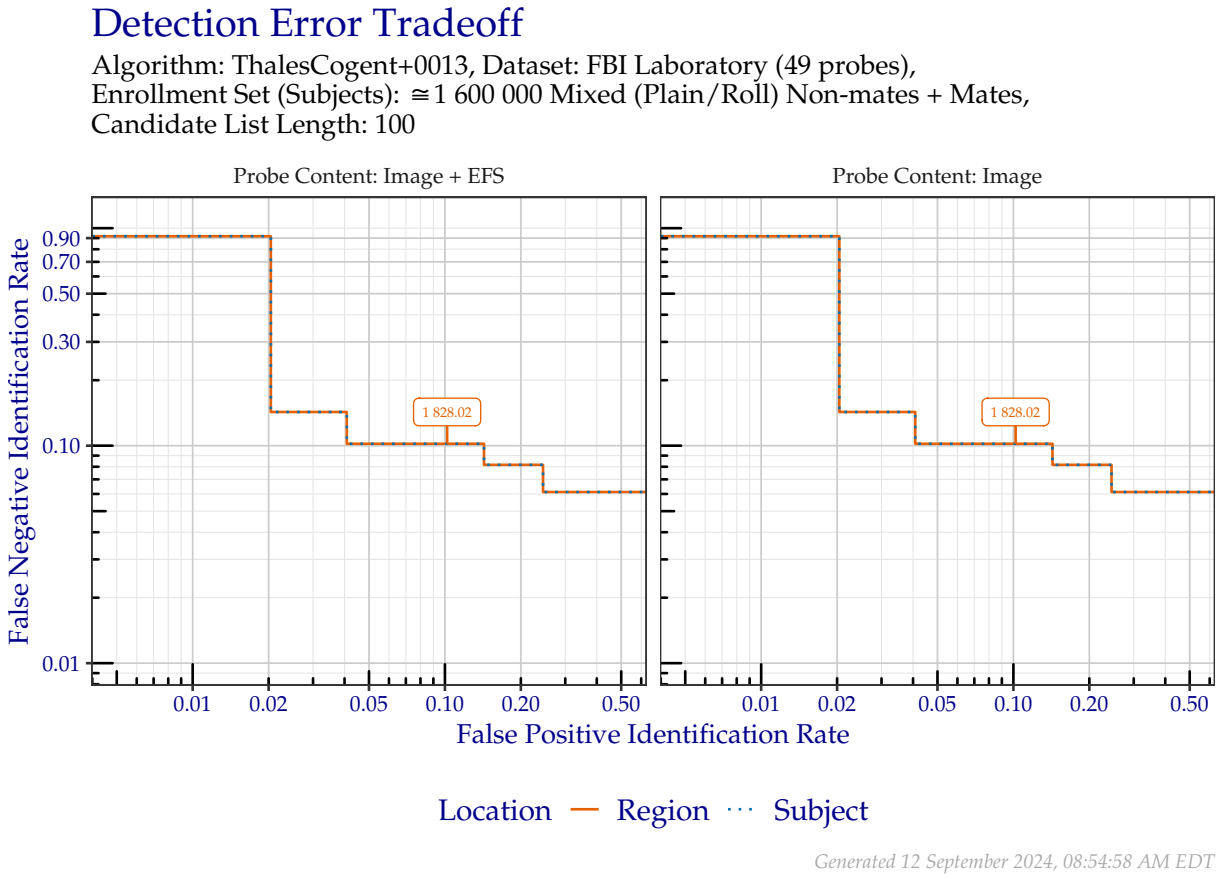

Figure 8: DET when searching FBI Laboratory probes, faceted by whether probe EFS data was provided. Annotated values indicate similarity scores from the Region line.

5.3.1.2 Probes with EFS Data

Not all of the probes in the FBI Laboratory dataset contain EFS data. The plot in Figure 9 shows the DET over *only* the probes that contained EFS data. This plot also differs from Figure 8 with the inclusion of a line for probes where no image was provided when creating the probe template, meaning the only information available was EFS data. Only the *region* success location is shown.

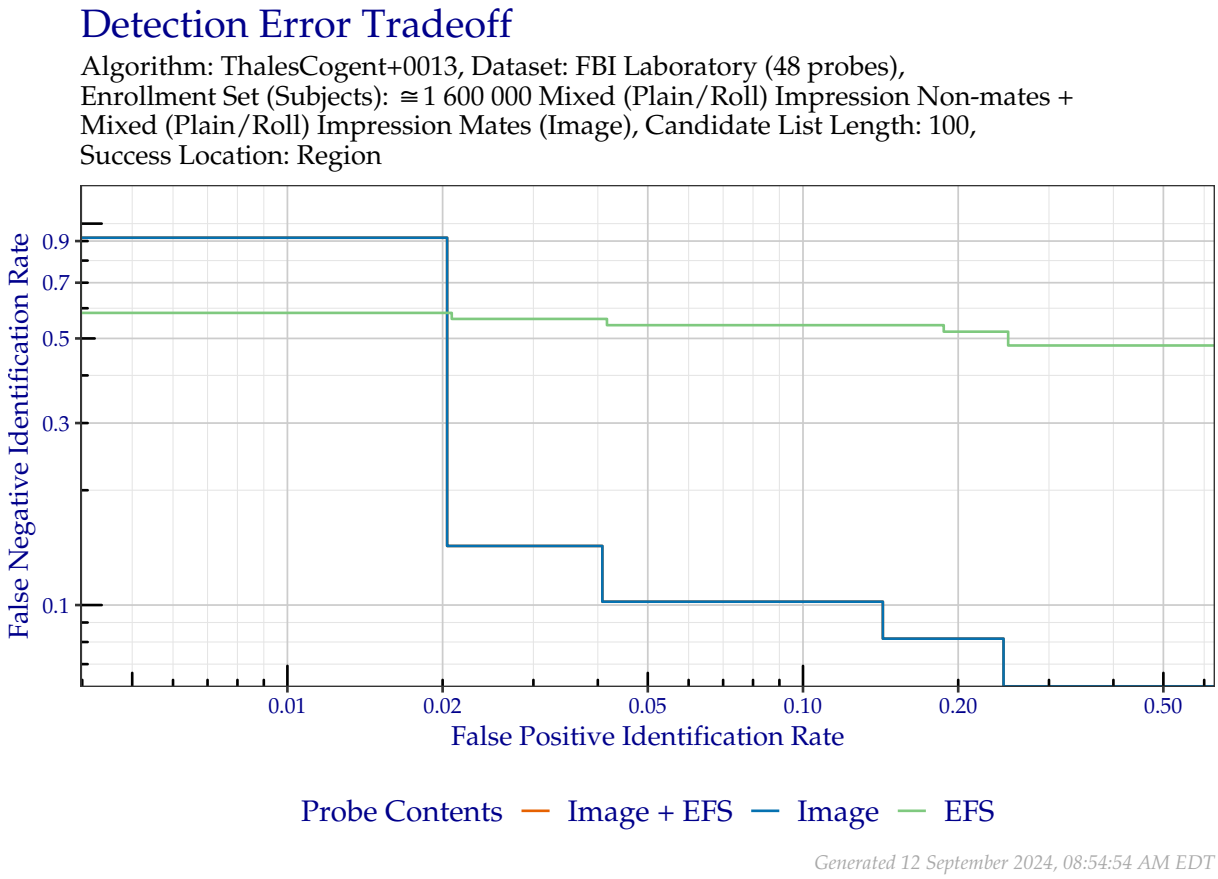

Figure 9: DET of region location when searching only the FBI Laboratory probes that contained EFS data.

5.3.2 FNIR at Select FPIR

5.3.2.1 All Probes

The values in Table 12 correspond to Figure 8.

Table 12: Region FNIR values corresponding to FPIR plotted in Figure 8.

Probe Content	FPIR = 0.1
Image	0.102
Image + EFS	0.102

5.3.2.2 Probes with EFS Data

The values in Table 13 correspond to Figure 9.

Table 13: Region FNIR values corresponding to FPIR plotted in Figure 9.

Probe Content	FPIR = 0.1
EFS	0.5417
Image	0.1020
Image + EFS	0.1020

5.3.3 Similarity Score Thresholds at Select FPIR

The values in Table 14 correspond to similarity score thresholds observed at the select FPIR values from Table 12.

Table 14: Similarity score thresholds corresponding to select FPIR values from Table 12.

Probe Content	FPIR = 0.1
Image	1 828.02
Image + EFS	1 828.02

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 15 shows the number of failures to create templates. Table 16 shows the number of failures to produce a candidate list.

Table 15: Number of failures to create templates.

Image Type	Content	Failures	Attempts
Exemplar	Image	0	173
Probe	EFS	0	285
Probe	Image	0	516
Probe	Image + EFS	0	516

Table 16: Number of failures to produce a candidate list. This number includes any failures to create a probe template from Table 15.

Probe Content	Failures	Attempts
EFS	0	285
Image	0	516
Image + EFS	0	516

6.2 CMC

6.2.1 Plots

6.2.1.1 All Probes

The CMC plots in Figure 10 show the FNIR of ThalesCogent+0013 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 17.

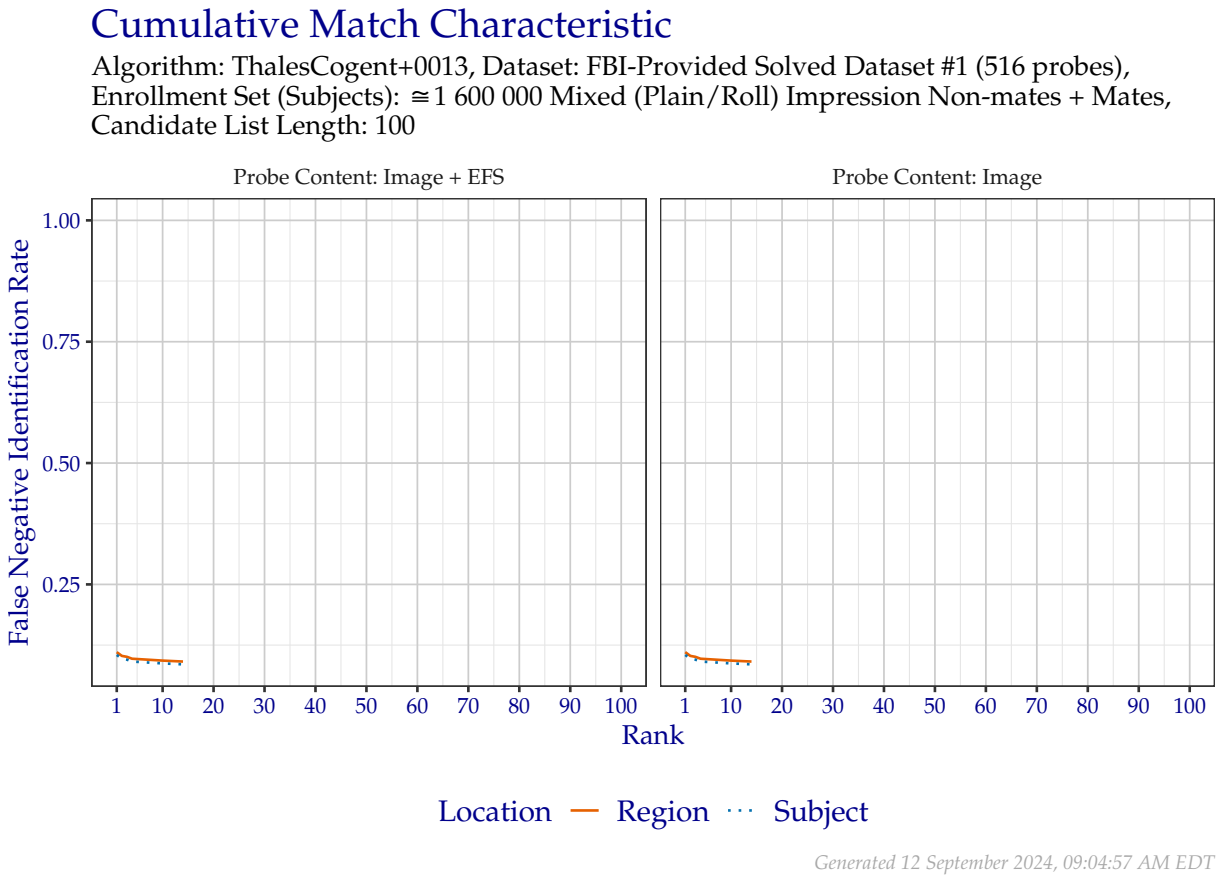

Figure 10: CMC when searching FBI-Provided Solved Dataset #1 probes, faceted by the mated impression type and whether probe EFS data was provided.

6.2.1.2 Probes with EFS Data

Not all of the probes in the FBI-Provided Solved Dataset #1 dataset contain EFS data. The plot in Figure 11 shows the CMC over *only* the probes that contained EFS data. This plot also differs from Figure 10 with the inclusion of a line for probes where no image was provided when creating the probe template, meaning the only information available was EFS data. Only the *region* success location is shown.

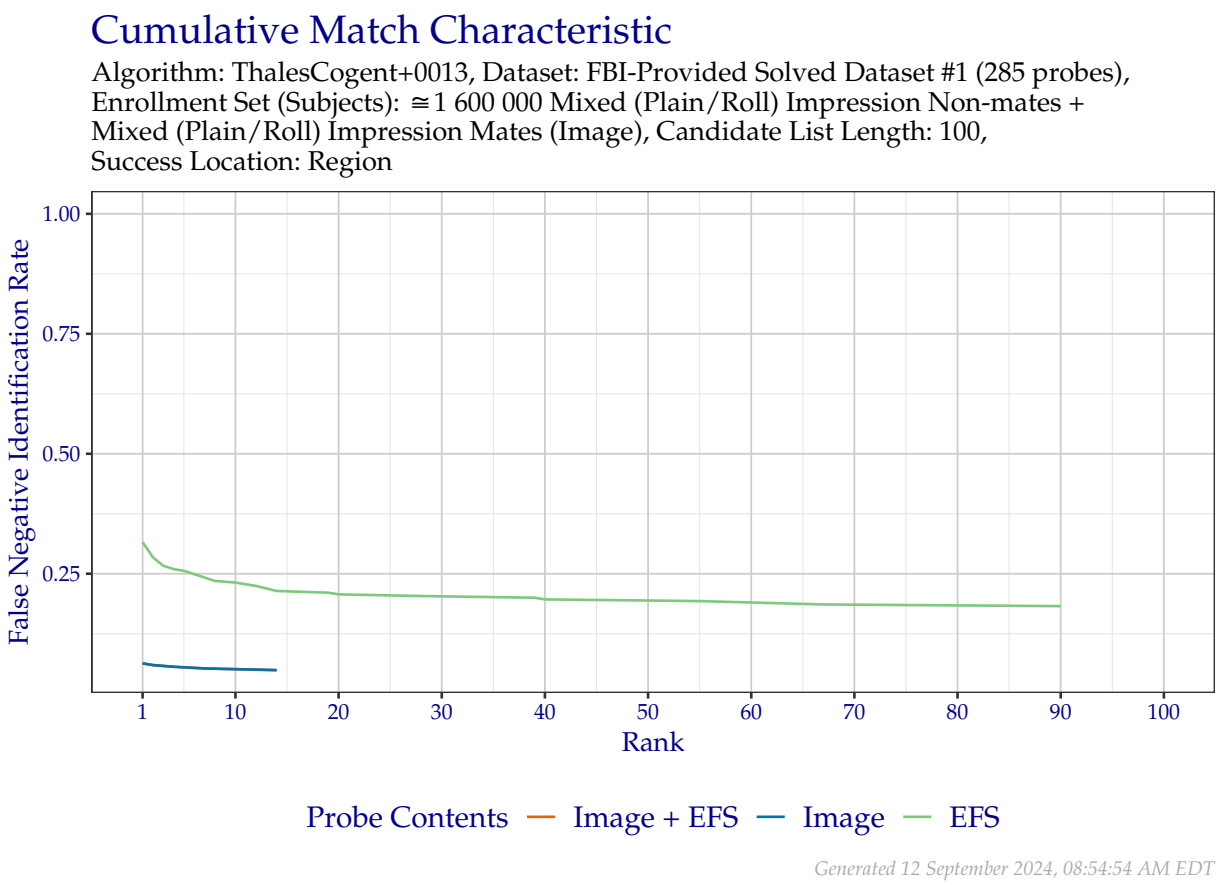

Figure 11: CMC of region location when searching only the FBI-Provided Solved Dataset #1 probes that contained EFS data.

6.2.2 FNIR at Select Rank

6.2.2.1 All Probes

The values in Table 17 correspond to Figure 10.

Table 17: Region FNIR values from CMC plotted in Figure 10.

Probe Content	Rank 1	Rank ≤ 2	Rank ≤ 5	Rank ≤ 10	Rank ≤ 50	Rank ≤ 100
Image	0.1105	0.1027	0.0969	0.093	0.0911	0.0911
Image + EFS	0.1105	0.1027	0.0969	0.093	0.0911	0.0911

6.2.2.2 Probes with EFS Data

The values in Table 18 correspond to Figure 11.

Table 18: Region FNIR values from CMC plotted in Figure 11.

Probe Content	Rank 1	Rank ≤ 2	Rank ≤ 5	Rank ≤ 10	Rank ≤ 50	Rank ≤ 100
EFS	0.3158	0.2842	0.2561	0.2316	0.1965	0.1825
Image	0.0632	0.0596	0.0561	0.0526	0.0491	0.0491
Image + EFS	0.0632	0.0596	0.0561	0.0526	0.0491	0.0491

6.3 DET

6.3.1 Plots

6.3.1.1 All Probes

The DET plots in Figure 12 show the false positive and false negative identification rate tradeoffs of `ThalesCogent+0013` 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 19. Annotated values indicate similarity scores from the Region line, which are tabulated in Table 21.

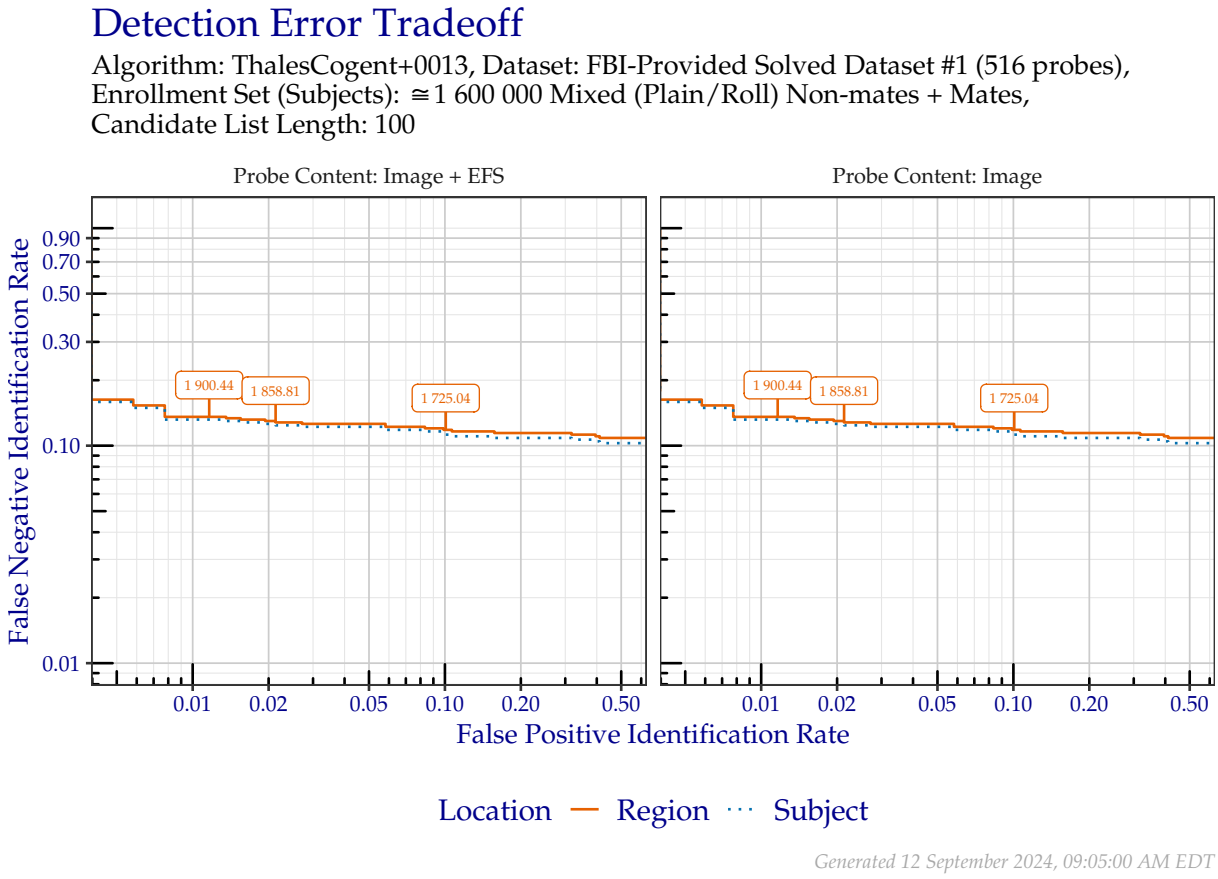

Figure 12: DET when searching FBI-Provided Solved Dataset #1 probes, faceted by the mated impression type and whether probe EFS data was provided. Annotated values indicate similarity scores from the Region line.

6.3.1.2 Probes with EFS Data

Not all of the probes in the FBI-Provided Solved Dataset #1 dataset contain EFS data. The plot in Figure 13 shows the DET over *only* the probes that contained EFS data. This plot also differs from Figure 12 with the inclusion of a line for probes where no image was provided when creating the probe template, meaning the only information available was EFS data. Only the *region* success location is shown.

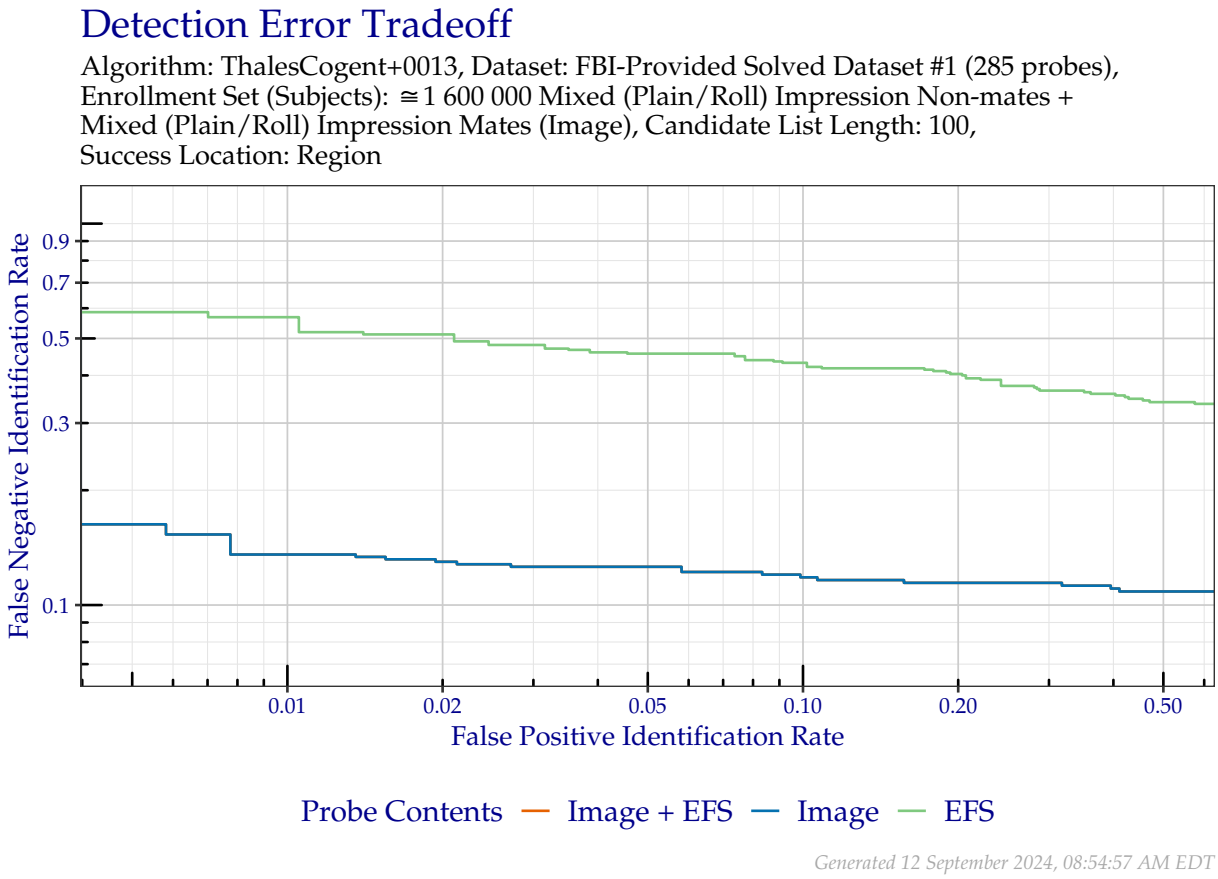

Figure 13: DET of region location when searching only the FBI-Provided Solved Dataset #1 probes that contained EFS data.

6.3.2 FNIR at Select FPIR

6.3.2.1 All Probes

The values in Table 19 correspond to Figure 12.

Table 19: Region FNIR values corresponding to FPIR plotted in Figure 12.

Probe Content	FPIR = 0.01	FPIR = 0.02	FPIR = 0.1
Image	0.1357	0.1279	0.1182
Image + EFS	0.1357	0.1279	0.1182

6.3.2.2 Probes with EFS Data

The values in Table 20 correspond to Figure 13.

Table 20: Region FNIR values corresponding to FPIR plotted in Figure 13.

Probe Content	FPIR = 0.01	FPIR = 0.02	FPIR = 0.1
EFS	0.5193	0.4912	0.4211
Image	0.1357	0.1279	0.1182
Image + EFS	0.1357	0.1279	0.1182

6.3.3 Similarity Score Thresholds at Select FPIR

The values in Table 21 correspond to similarity score thresholds observed at the select FPIR values from Table 19.

Table 21: Similarity score thresholds corresponding to select FPIR values from Table 19.

Probe Content	FPIR = 0.01	FPIR = 0.02	FPIR = 0.1
Image	1 900.44	1 858.81	1 725.04
Image + EFS	1 900.44	1 858.81	1 725.04

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 22 shows the number of failures to create templates. Table 23 shows the number of failures to produce a candidate list.

Table 22: 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 23: Number of failures to produce a candidate list. This number includes any failures to create a probe template from Table 22.

Probe Content	Distal Failures	Palm Failures	Attempts
Image	0	3	2 174

7.2 Distal Region CMC

7.2.1 Plots

The CMC in Figure 14 shows results from *only* the distal phalanx probes from Michigan State Police.

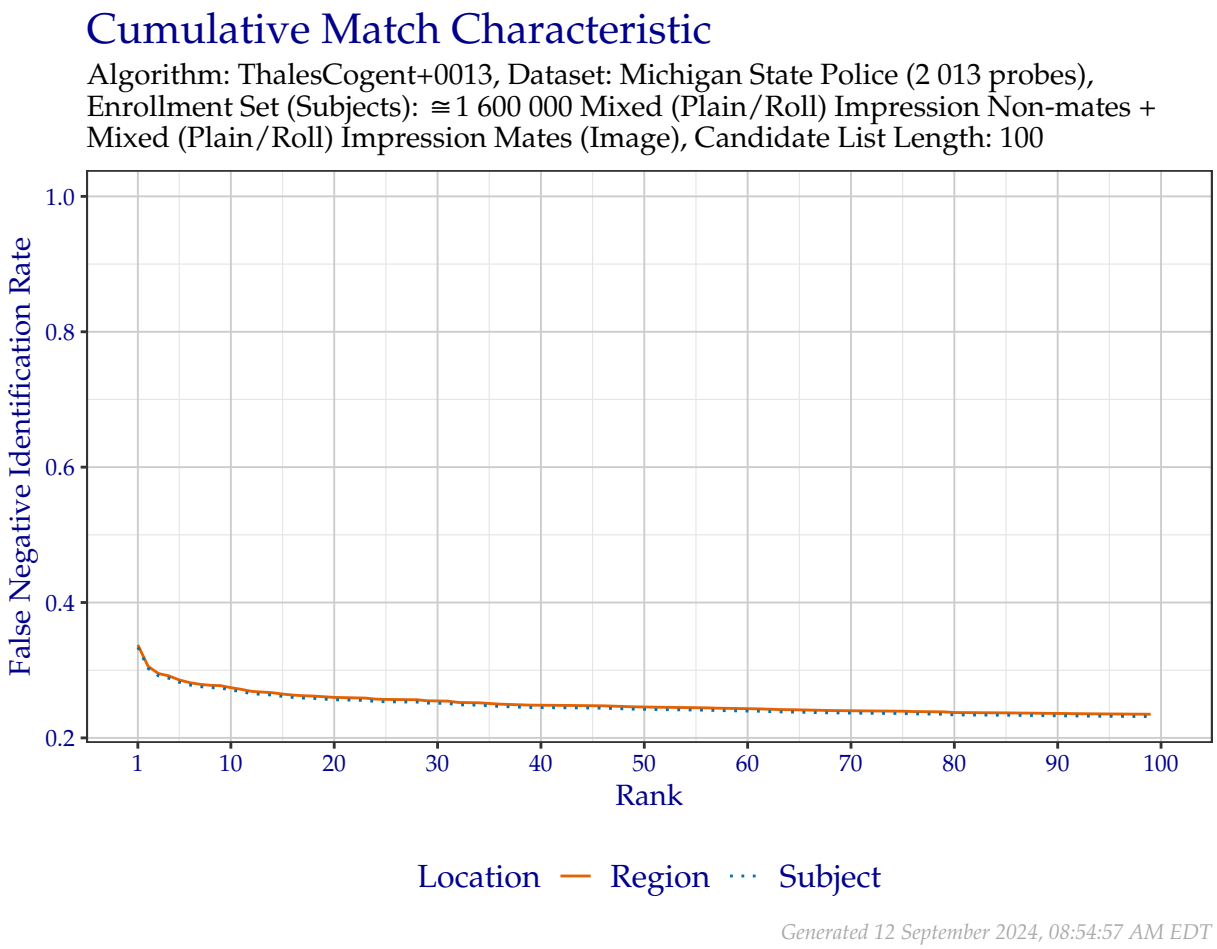

Figure 14: CMC when searching Michigan State Police distal phalanx probes.

7.2.2 FNIR at Select Rank

The values in Table 24 correspond to Figure 14.

Table 24: Region FNIR values from CMC plotted in Figure 14.

Probe Content	Rank 1	Rank ≤ 2	Rank ≤ 5	Rank ≤ 10	Rank ≤ 50	Rank ≤ 100
Image	0.3373	0.3055	0.2856	0.2742	0.2459	0.235

7.3 Palm Region CMC

7.3.1 Plots

The CMC in Figure 15 shows results from *only* the palm probes from Michigan State Police.

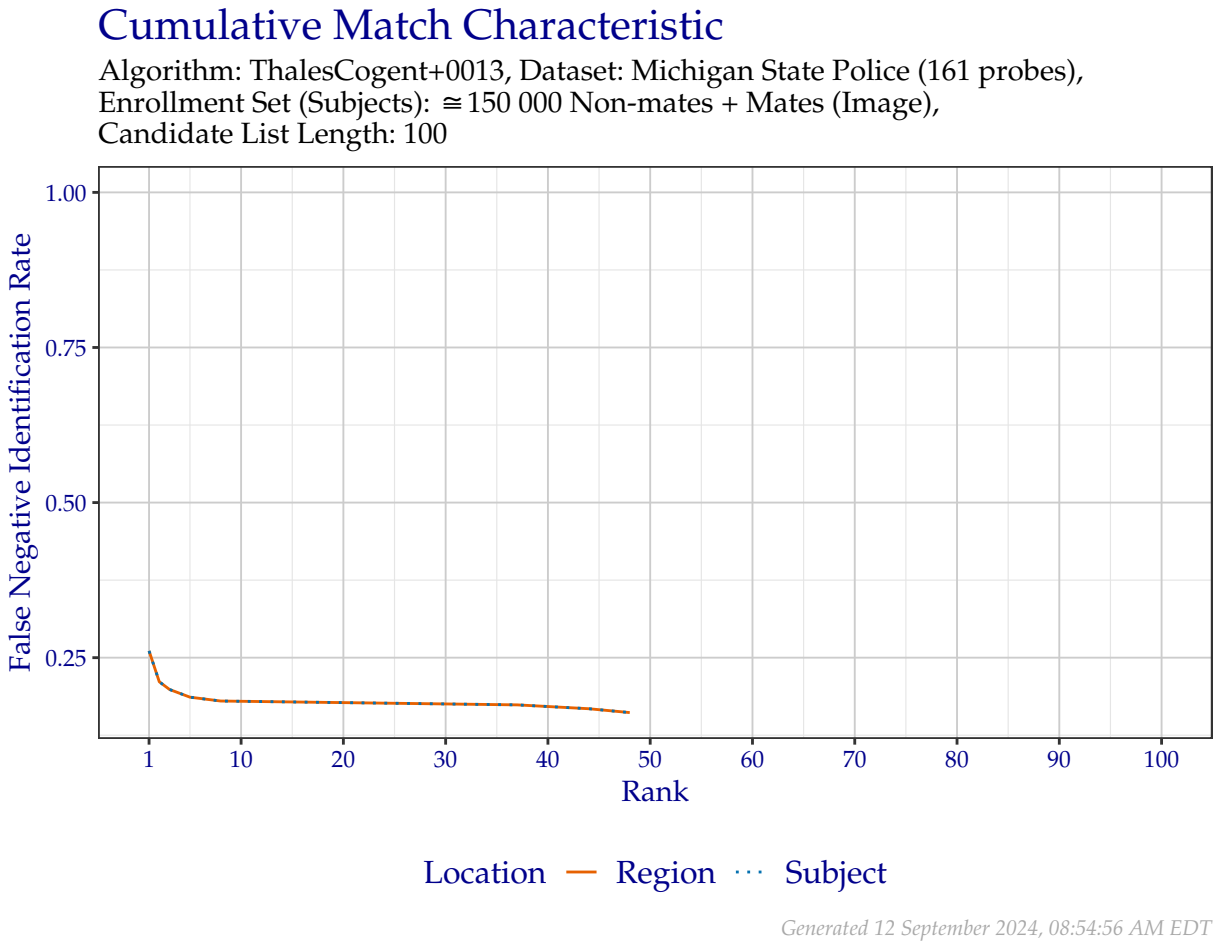

Figure 15: CMC when searching Michigan State Police palm probes.

7.3.2 FNIR at Select Rank

The values in Table 25 correspond to Figure 15.

Table 25: Region FNIR values from CMC plotted in Figure 15.

Probe Content	Rank 1	Rank ≤ 2	Rank ≤ 5	Rank ≤ 10	Rank ≤ 50	Rank ≤ 100
Image	0.2609	0.2112	0.1863	0.1801	0.1615	0.1615

7.4 Distal Region DET

7.4.1 Plots

The DET in Figure 16 shows results from *only* the distal phalanx probes from Michigan State Police. Annotated values indicate similarity scores from the Region line, which are tabulated in Table 27.

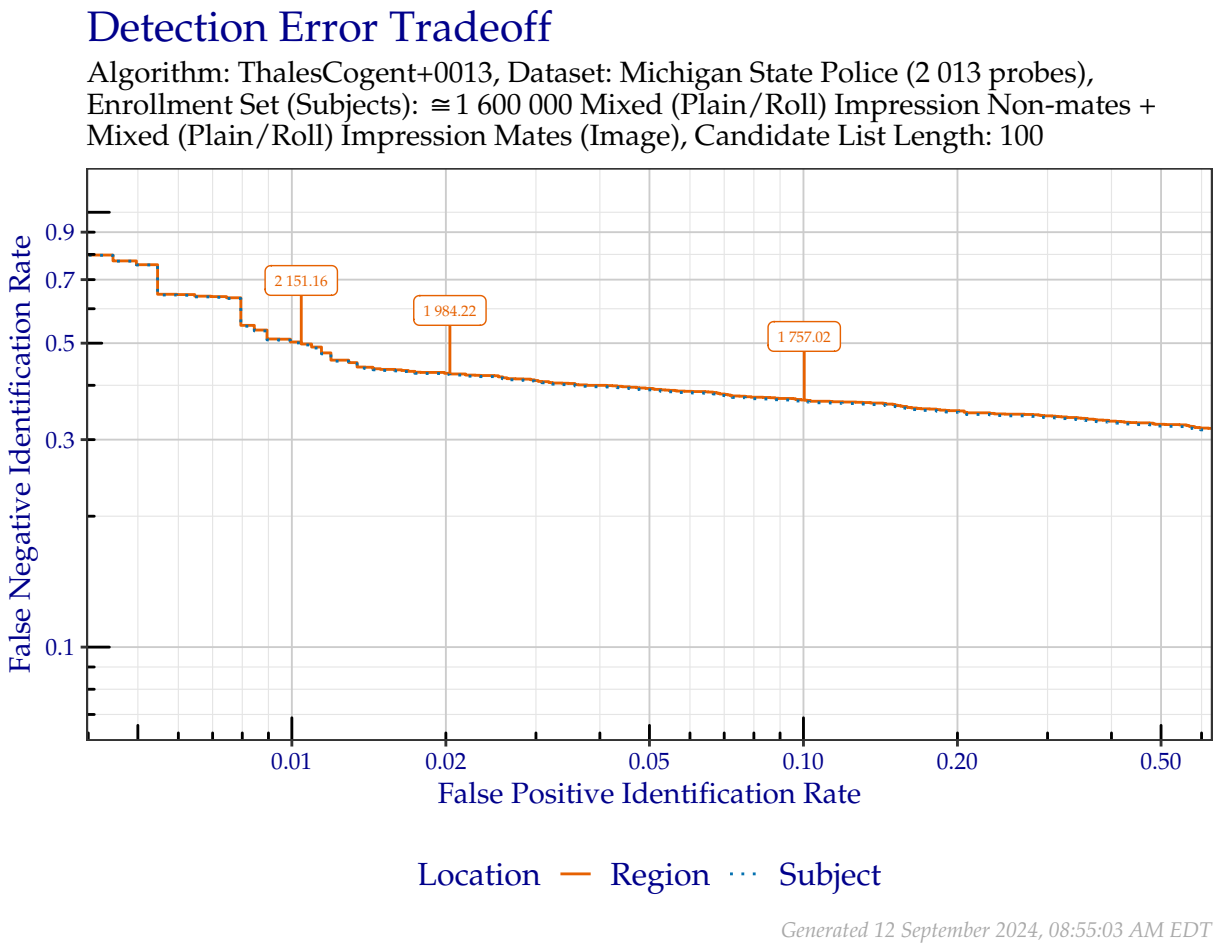

Figure 16: DET when searching Michigan State Police distal phalanx probes. Annotated values indicate similarity scores from the Region line.

7.4.2 FNIR at Select FPIR

The values in Table 26 correspond to Figure 16.

Table 26: Region FNIR values corresponding to FPIR plotted in Figure 16.

Probe Content	FPIR = 0.01	FPIR = 0.02	FPIR = 0.1
Image	0.4978	0.4247	0.3701

7.4.3 Similarity Score Thresholds at Select FPIR

The values in Table 27 correspond to similarity score thresholds observed at the select FPIR values from Table 26.

Table 27: Similarity score thresholds corresponding to select FPIR values from Table 26.

Probe Content	FPIR = 0.01	FPIR = 0.02	FPIR = 0.1
Image	2 151.16	1 984.22	1 757.02

7.5 Palm Region DET

7.5.1 Plots

The DET in Figure 17 shows results from *only* the palm probes from Michigan State Police. Annotated values indicate similarity scores from the Region line, which are tabulated in Table 29.

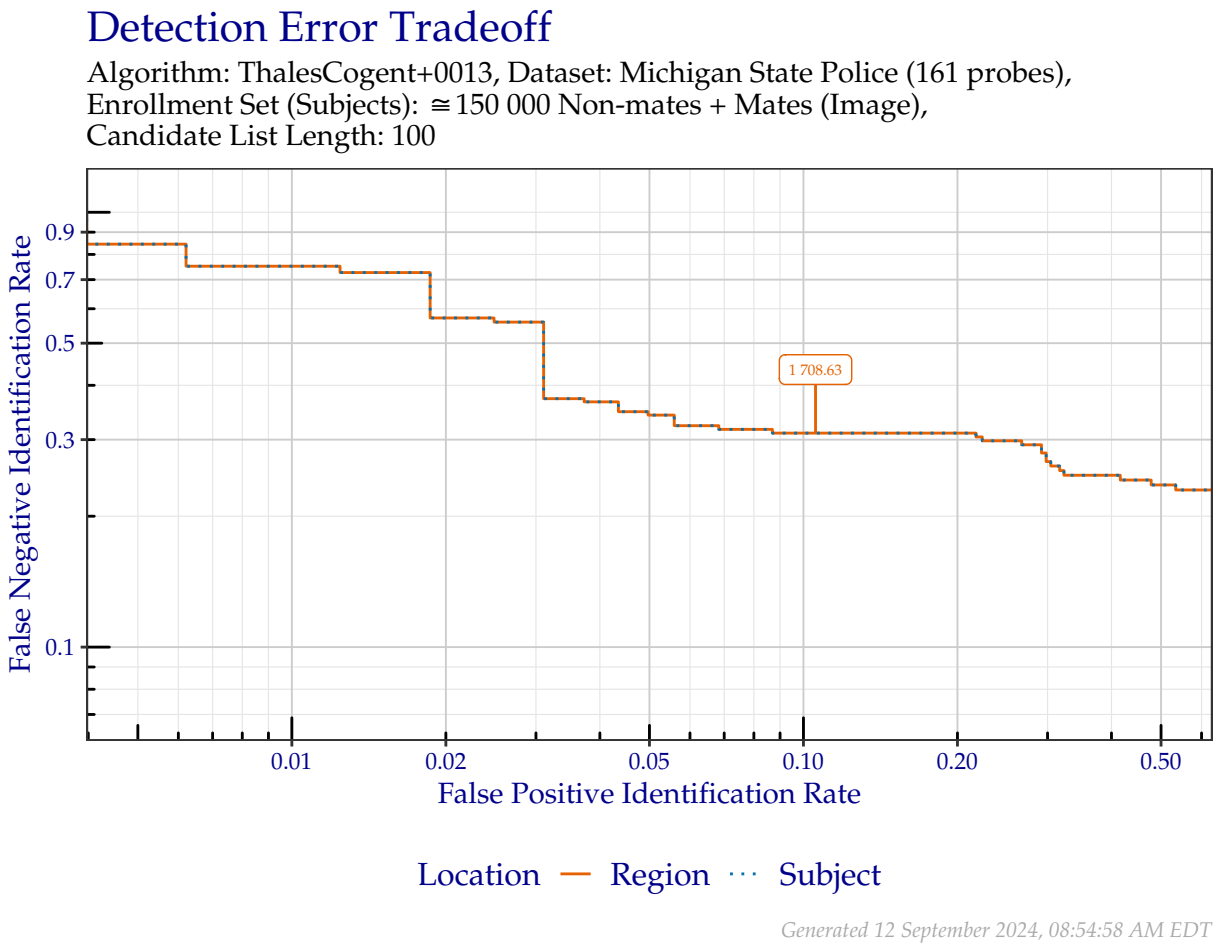

Figure 17: DET when searching Michigan State Police palm probes. Annotated values indicate similarity scores from the Region line.

7.5.2 FNIR at Select FPIR

The values in Table 28 correspond to Figure 17.

Table 28: Region FNIR values corresponding to FPIR plotted in Figure 17.

Probe Content	FPIR = 0.1
Image	0.3106

7.5.3 Similarity Score Thresholds at Select FPIR

The values in Table 29 correspond to similarity score thresholds observed at the select FPIR values from Table 28.

Table 29: Similarity score thresholds corresponding to select FPIR values from Table 28.

Probe Content	FPIR = 0.1
Image	1 708.63

8 DoD-Provided Dataset #1

The results of Section 8 are based on searches of the sequestered dataset *DoD-Provided Dataset #1*. This dataset consists of 5 259 probes collected operationally by the United States Department of Defense. All probes searched were a single sample depicting a region from a distal phalanx. No EFS data was provided. Only Subject-level ground truth information was provided.

8.1 Failures

Table 30 shows the number of failures to create templates. Table 31 shows the number of failures to produce a candidate list.

Table 30: Number of failures to create templates.

Image Type	Content	Failures	Attempts
Exemplar	Image	0	5 289
Probe	Image	0	5 259

Table 31: Number of failures to produce a candidate list. This number includes any failures to create a probe template from Table 30.

Probe Content	Failures	Attempts
Image	0	5 259

8.2 CMC

8.2.1 Plots

The CMC plots in Figure 18 show the FNIR of ThalesCogent+0013 when searching DoD-Provided Dataset #1 against enrollment database where a single mated identity for each search probe was present. Tabular versions of FNIR at select ranks can be viewed in Table 32.

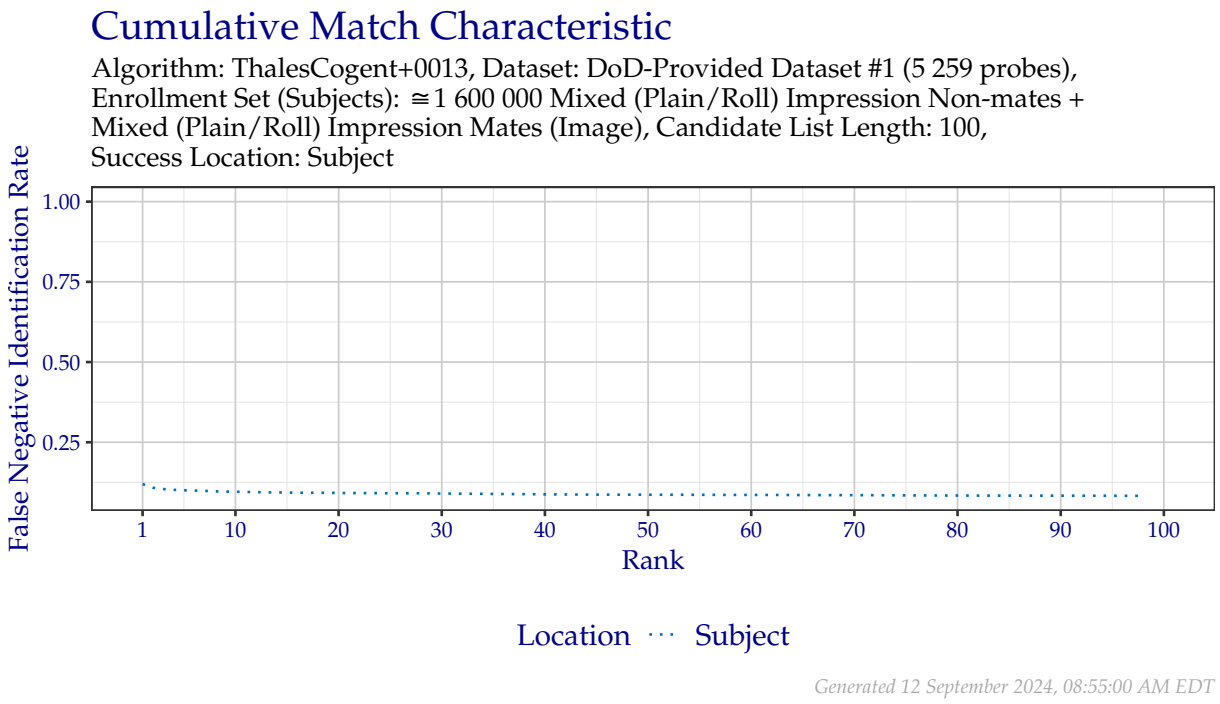

Figure 18: CMC when searching DoD-Provided Dataset #1 probes, faceted by whether probe EFS data was provided.

8.2.2 FNIR at Select Rank

The values in Table 32 correspond to Figure 18.

Table 32: Region FNIR values from CMC plotted in Figure 18.

Probe Content	Rank 1	Rank ≤ 2	Rank ≤ 5	Rank ≤ 10	Rank ≤ 50	Rank ≤ 100
Image	0.1196	0.1082	0.1004	0.0956	0.0865	0.0829

8.3 DET

8.3.1 Plots

The DET plots in Figure 19 show the false positive and false negative identification rate tradeoffs of ThalesCogent+0013 when searching DoD-Provided Dataset #1 against enrollment database where a single mated identity for each search probe was present. Tabular versions of FNIR at select FPIR can be viewed in Table 33. Annotated values indicate similarity scores from the Subject line, which are tabulated in Table 34.

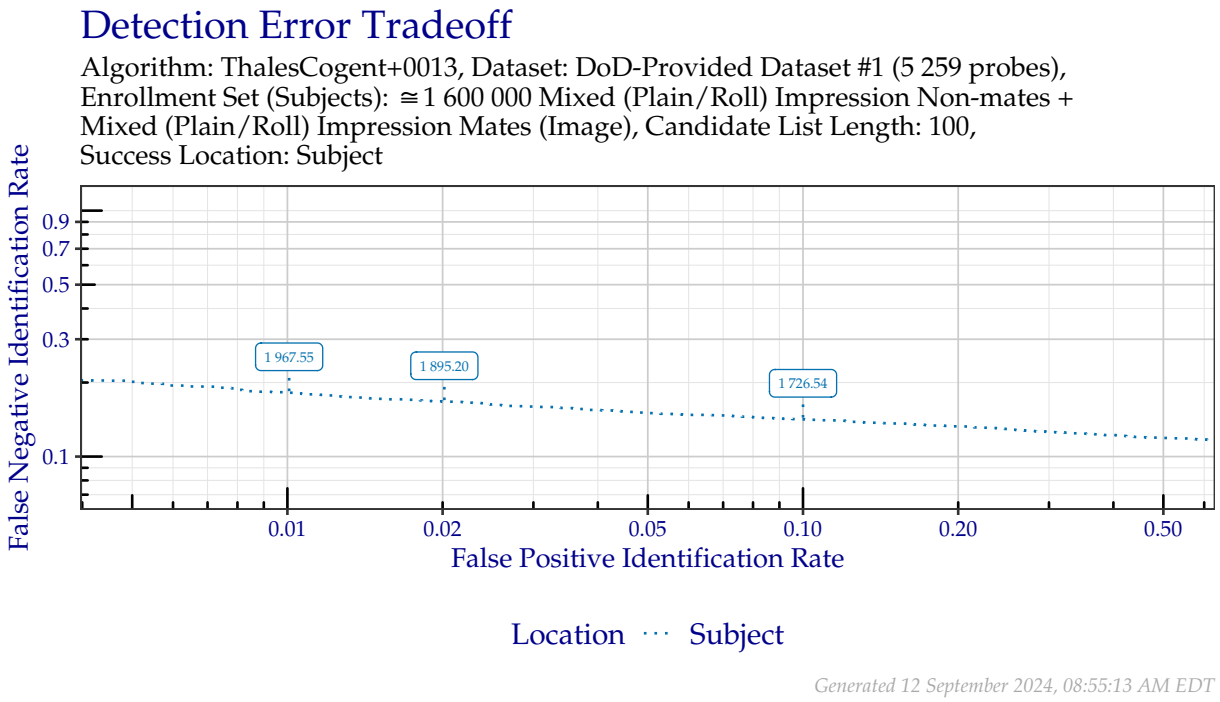

Figure 19: DET when searching DoD-Provided Dataset #1 probes. Annotated values indicate similarity scores from the Subject line.

8.3.2 FNIR at Select FPIR

The values in Table 33 correspond to Figure 19.

Table 33: Subject FNIR values corresponding to FPIR plotted in Figure 19.

Probe Content	FPIR = 0.01	FPIR = 0.02	FPIR = 0.1
Image	0.1818	0.1671	0.1419

8.3.3 Similarity Score Thresholds at Select FPIR

The values in Table 34 correspond to similarity score thresholds observed at the select FPIR values from Table 33.

Table 34: Similarity score thresholds corresponding to select FPIR values from Table 33.

Probe Content	FPIR = 0.01	FPIR = 0.02	FPIR = 0.1
Image	1 967.55	1 895.2	1 726.54