Hisign+0007

Beijing Hisign Technology Co. Ltd.

Slap Fingerprint Segmentation Evaluation III

Last Updated: 15 September 2025

Contents

1 Participation Information

1.1 Names and Dates

- **Organization Name:** Beijing Hisign Technology Co. Ltd.
- **SlapSeg III Identifier:** `Hisign+0007`
- **SlapSeg III API Version:** 1.2.0
- **Provided Marketing Name:** "Hisign SlapsegSDK (version 2.0.0)"
- **Application Date:** 16 July 2025
- **First Submission Date:** 16 July 2025 (as version `0004`)
- **Validation Date:** 09 September 2025
- **Completion Date:** 15 September 2025

1.2 Libraries

Filename	MD5 Checksum	Size
libopenvino_intel_cpu_plugin.so	`1d6b86919725aeab0348c3c4911644b8`	52 MB
libopenvino_onnx_frontend.so.2460	`9c4ee78e97b68ccee185449ce0a0d44c`	5 MB
libslapsegiii_Hisign_0007.so	`2772797a7b6767d6b6f0bf8368033a0a`	5 MB
libtbb.so.12	`87fb511c95e11b8ddc1e01ff2904bb99`	310 kB
libopenvino.so.2460	`92962e20b7a2e2b2424baf1e9a5ac95e`	15 MB
HSSlap.dat	`bd5cf5c76a8b1c4186cc92e6d1227bc5`	11 MB

2 Tenprint Cards ("TwoInch" Data)

2.1 Segmentation Timing

All algorithms are run over a small fixed corpus of TwoInch images to estimate the total runtime of the evaluation. To be evaluated under SlapSeg III, algorithms **must** segment the timing corpus, on average, in under 1 500 milliseconds. This maximum reference time is documented in the SlapSeg III test plan, and is subject to change. Times are measured by running a single process on an isolated compute node equipped with an Intel Gold 6254 CPU (submissions received prior to February 2022 were timed with a Intel Xeon E5-4650 CPU).*=

Box plots of segmentation times are separated by slap orientation and capture technology in Figure 1. Tabular representations are enumerated in Table 1. Results are reported in milliseconds.

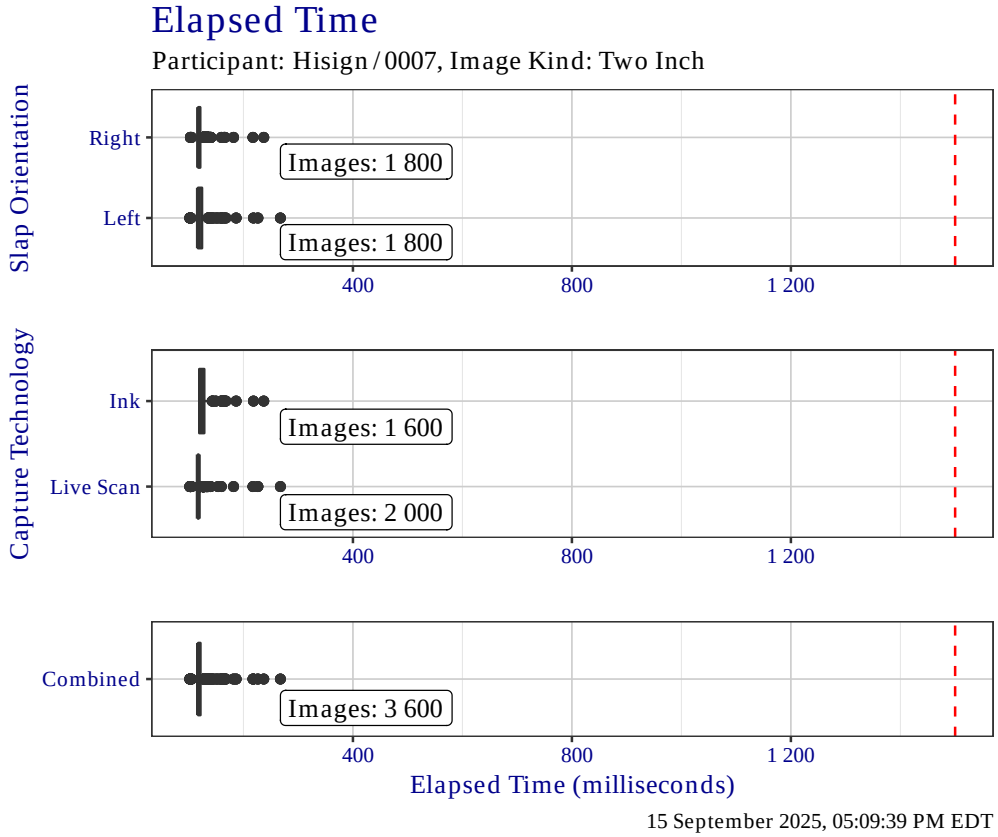

Figure 1: Box plots of elapsed time in milliseconds when segmenting the TwoInch timing test corpus, separated by slap orientation and capture technology.

Table 1: Elapsed time in milliseconds when segmenting the TwoInch timing test corpus, separated by slap orientation and capture technology.

	Right	Left	Live Scan	Ink	Combined
Minimum	103	102	102	117	102
25%	118	117	117	119	117
Median	118	118	117	122	118
75%	121	124	118	128	121
Maximum	237	268	268	237	268

2.2 Segmentation Centers and Dimensions

2.2.1 Segmentation Centers

The plots in this section show the distribution of segmentation position centers (x, y) for TwoInch data. At the top of each figure is a combined plot for all finger positions of a given slap orientation. These figures are isolated in plots faceted at the bottom of the figure.

Plots of segmentation centers for the right hand TwoInch data are shown in Figure 2 and plots of segmentation centers for the left hand are shown in Figure 3. Blank lines that may appear in the plots are **not** rendering artifacts. Rather, they are indicative of image downsampling. Centers have been normalized to 500 pixels per inch.

Points in each plot are plotted with a semi-transparent opacity. This results in points of particular color appearing "darker" to indicate a higher frequency of the observed value, while "lighter" points indicate a lower observed frequency.

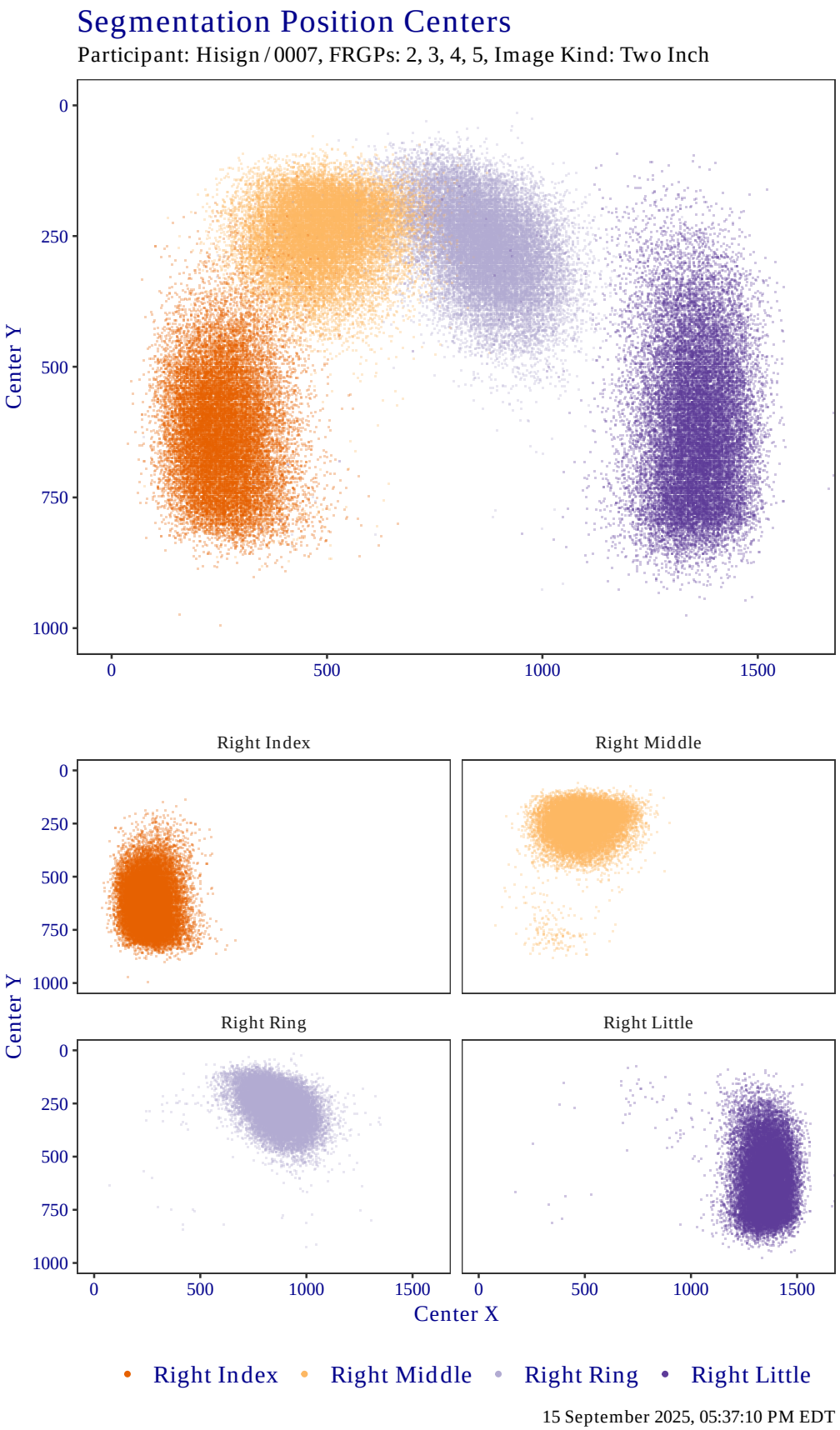

Figure 2: Segmentation centers for right hand TwoInch data.

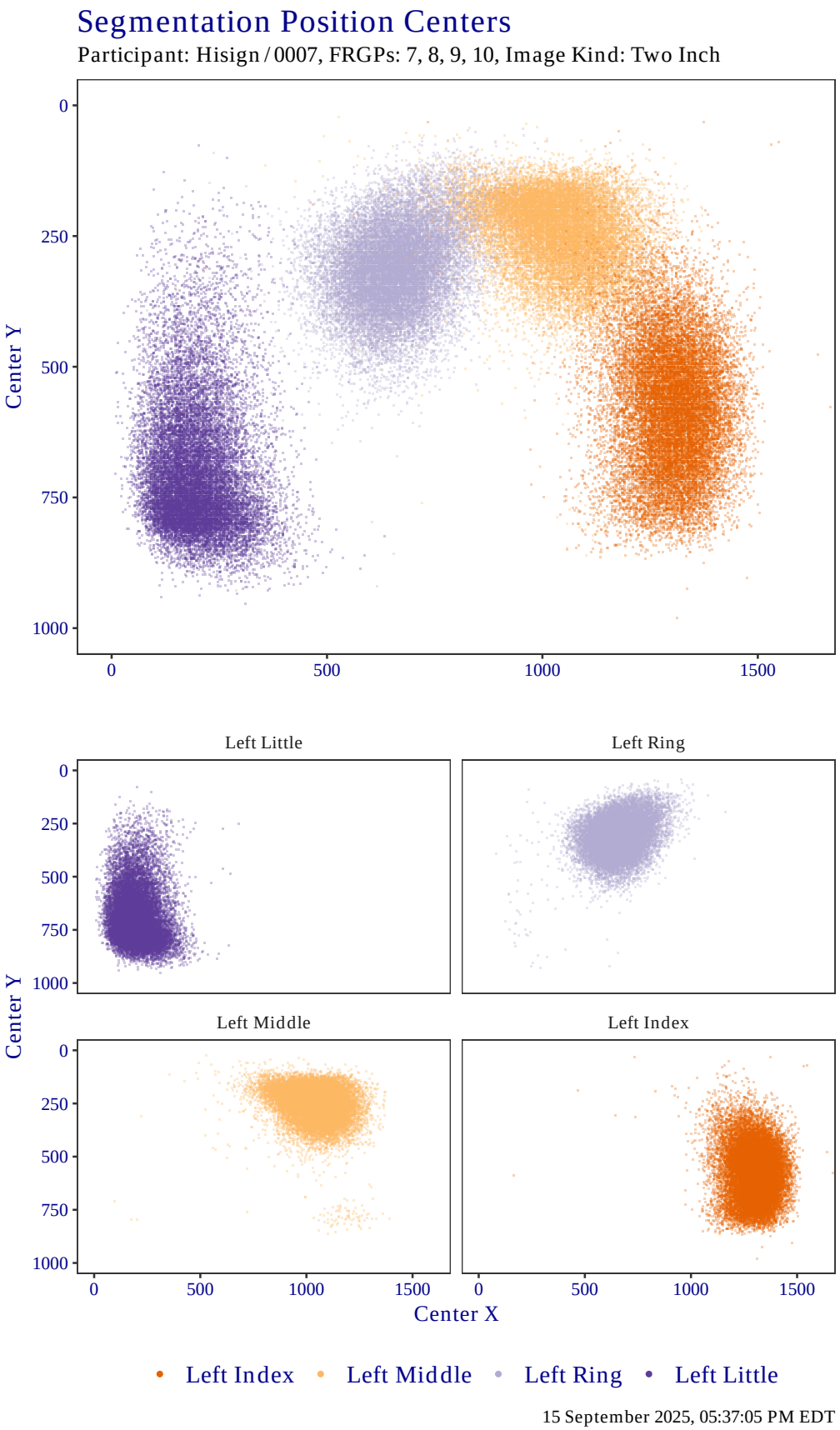

Figure 3: Segmentation centers for left hand TwoInch data.

2.2.2 Segmentation Dimensions

The plots in this section show the distribution of segmentation position widths and heights for TwoInch data. At the top of each figure is a combined plot for all finger positions of a given slap orientation. These figures are isolated in plots faceted at the bottom of the figure.

Plots of segmentation position dimensions for the right hand TwoInch data are shown in Figure 4 and the left hand in Figure 5. Blank lines that may appear in the plots are **not** rendering artifacts. Rather, they are indicative of image downsampling. Dimensions have been normalized to 500 pixels per inch.

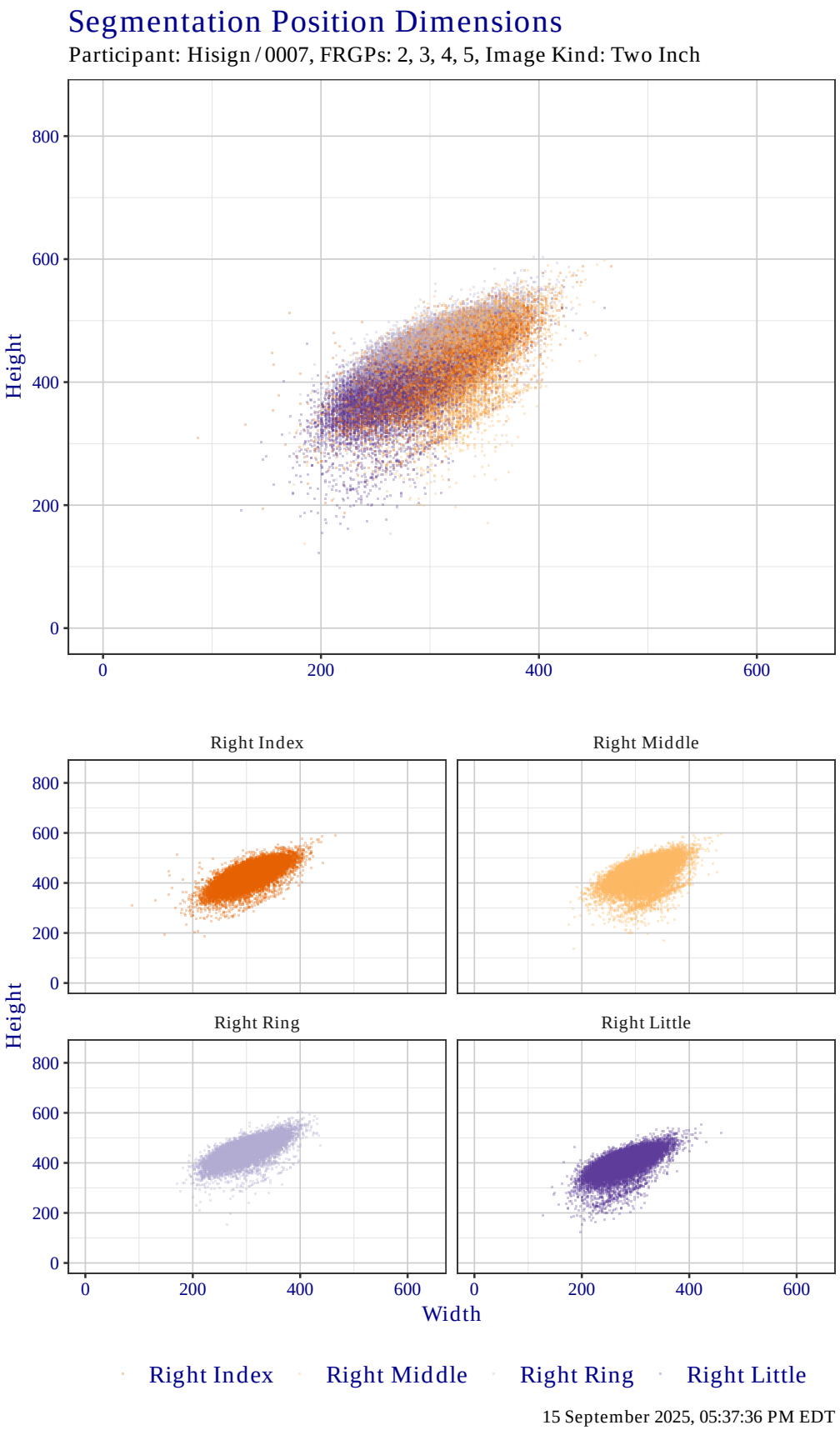

Figure 4: Segmentation position dimensions for right hand TwoInch data.

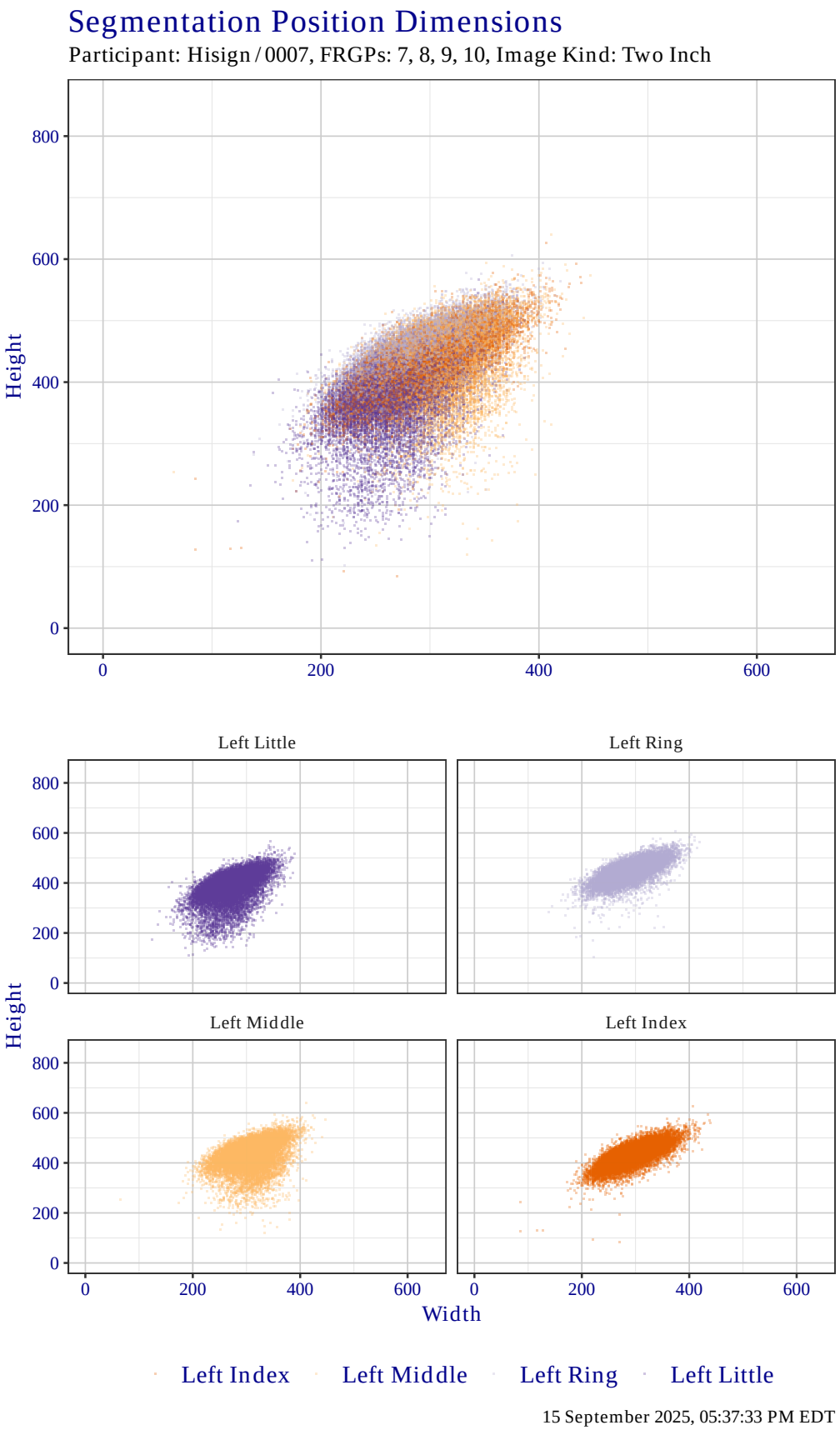

Figure 5: Segmentation position dimensions for left hand TwoInch data.

2.3 Detailed Segmentation Statistics

This section shows detailed results of segmentation of TwoInch data. Values in each table are the percentage that the variable in the left-most column was correctly segmented.

Each table has three columns of percentages. The *Standard Scoring* column shows the percentage of correctly-segmented positions based on the scoring metrics defined in the SlapSeg III scoring document. The *Ignoring Bottom Y* column shows how the percentage would change if the threshold for the *bottom Y* coordinate of the segmentation position was ignored. Similarly, the *Ignoring Bottom X and Y* columns shows how the percentage would change if only the top, left, and right sides of the segmentation position were considered. These two supplemental columns are included because it has traditionally been difficult to determine the exact location of the distal interphalangeal joint.

Table 2 shows how successful Hisign+0007 segmented fingers for each subject in the test corpus. Table 3 shows success for specific finger positions over the entire test corpus. Similarly, Table 4 shows success for segmenting the same finger position from both hands.

The remainder of the tables show success per subject when considering combinations of subsets of the fingers on each slap image. Table 5 shows success for combinations of all fingers, Table 6 for just the index and middle fingers, and Table 7 for all except the little finger.

Table 2: For each subject, the percentage that at least *Number of Fingers* fingers were correctly segmented, regardless of hand, for a maximum of eight correctly-segmented fingers. In *Standard Scoring*, scoring rules are followed exactly. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Number of Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
1	99.7	99.7	99.7
2	99.6	99.6	99.6
3	99.3	99.4	99.5
4	98.6	98.8	99.0
5	95.2	95.3	95.4
6	94.4	94.8	95.0
7	91.3	92.8	93.2
8	80.7	86.2	87.0

Table 3: For all subjects, percentage that a particular friction ridge generalized position was correctly segmented. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Finger	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Index	96.4	97.6	97.8
Middle	96.1	97.3	97.4
Ring	95.3	97.3	97.4
Little	97.8	98.6	98.9
Left			
Index	97.9	98.3	98.4
Middle	97.2	98.1	98.2
Ring	95.8	97.3	97.5
Little	97.6	98.0	98.4

Table 4: Percentage that a particular type of fingerprint was correctly segmented on *Either* or *Both* hands. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Index			
Either	99.2	99.3	99.3
Both	91.1	92.5	92.7
Middle			
Either	99.1	99.3	99.4
Both	90.4	92.1	92.3
Ring			
Either	98.8	99.3	99.4
Both	89.0	91.9	92.2
Little			
Either	99.2	99.3	99.4
Both	91.9	93.0	93.6

Table 5: Percentage of segmentation success by hand for combinations of all eight fingers of a TwoInch slap. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	99.6	99.6	99.6
At Least Two	99.2	99.4	99.4
At Least Three	97.5	98.3	98.4
All Four	89.3	93.6	94.0
Left			
Any	99.7	99.7	99.7
At Least Two	99.4	99.4	99.5
At Least Three	98.0	98.4	98.6
All Four	91.6	94.2	94.7

Table 6: Percentage of segmentation success by hand when only considering combinations of index and middle fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Either Index or Middle	98.7	98.9	98.9
Both Index and Middle	93.8	96.1	96.4
Left			
Either Index or Middle	99.1	99.2	99.2
Both Index and Middle	96.1	97.2	97.4

Table 7: Percentage of segmentation success by hand when only considering combinations of index, middle, and ring fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	99.4	99.5	99.5
At Least Two	97.9	98.5	98.6
All Three	90.5	94.2	94.6
Left			
Any	99.6	99.6	99.7
At Least Two	98.4	98.7	98.8
All Three	93.0	95.3	95.7

2.4 Handling Troublesome Images

2.4.1 Capture Failures

Segmentation algorithms may refuse to process an image. This may happen for a technical reason (e.g., the algorithm cannot parse the image data), or for a practical reason (e.g., the hand in the image is placed incorrectly). These failure scenarios are the result of capturing improper image data. In these types of scenarios, it is important to examine the cause of the failure. With many live scan capture setups, segmentation is performed immediately after capture. If an algorithm can detect that it won't be able to segment an image due to a technical or practical issue, it can alert the operator to perform a recapture before the subject leaves.

The SlapSeg III API encourages algorithms to identify these failure reasons by specifying pre-defined *deficiencies* in the image. Algorithms should attempt segmentation even if an image deficiency is encountered if at all possible. Note that SlapSeg III *guarantees* well-formed image data, so failures to parse are **not** an indicator of the data provided.

Hisign+0007 did **not** report any capture failures.

2.4.1.1 Recovery

When encountering a segmentation failure, SlapSeg III algorithms are encouraged to provide a *best-effort* segmentation when possible. In some cases, that best-effort may be correct, which reduces the amount of images that need to be manually adjudicated by an operator.

Hisign+0007 did not attempt any recovery segmentations.

2.4.2 Segmentation Failures

Even if an algorithm accepts an image for processing, it can still fail to process one or more fingers from the image, regardless of if the algorithm requested a recapture and provided best-effort segmentation.

The SlapSeg III API allows algorithms to communicate reasons for failure to process these fingers. In some cases, the distal phalanx in question might not be present in the image due to amputation or being placed outside the platen's capture area. It is imperative that the segmentation algorithm correctly report this as failing to segment the correct friction ridge generalized position without disrupting the sequence of valid positions present in the image. This can help prompt an operator to recapture or record additional information about the subject.

In SlapSeg III, a number of images are missing fingers or otherwise have fingers that will not be able to be segmented. Reasons for segmentation failures reported by Hisign+0007 are enumerated in Table 8.

Table 8: Count of self-reported segmentation failure reasoning.

Failure Reason	Fingers
Vendor Defined	356
Finger Not Found	0
Finger Found, but Can't Segment	0

2.4.3 Identifying Missing Fingers

A small portion of the test corpus in SlapSeg III are missing fingers. Table 9 shows how successful Hisign+0007 was in correctly determining if a finger was missing. The *Missed* row shows when a segmentation position was returned for a missing finger. All possible failure reasons are enumerated, but are not considered *Correctly Identified* because the algorithm specified failure for a reason other than the finger not being found.

Table 9: Performance of Hisign+0007 at detecting fingers missing from an image.

Result	Percentage
Missed	37.5
Correctly Identified	0.0
Other Failure: Finger Found, but Can't Segment	0.0
Other Failure: Vendor Defined	62.5
Other Failure: Segmentation Not Attempted	0.0

2.4.4 Sequence Error

Sequence error occurs when a fingerprint is segmented from an image but assigned an incorrect finger position (e.g., segmenting a right middle finger but labeling it a right index finger). Table 10 shows cases in which a segmentation position was returned that matched a ground truth segmentation position for a different finger in the same image.

Table 10: Percentage of images in the dataset where one or more segmentation positions correctly matched an incorrect finger position within the same image, indicating sequence error.

Hand	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Left	0.71	0.71	0.71
Right	0.88	0.89	0.92
Combined	0.80	0.81	0.82

3 Identification Flats ("ThreeInch" Data)

3.1 Segmentation Timing

All algorithms are run over a small fixed corpus of ThreeInch images to estimate the total runtime of the evaluation. To be evaluated under SlapSeg III, algorithms **must** segment the timing corpus, on average, in under 1 500 milliseconds. This maximum reference time is documented in the SlapSeg III test plan, and is subject to change. Times are measured by running a single process on an isolated compute node equipped with an Intel Gold 6254 CPU (submissions received prior to February 2022 were timed with a Intel Xeon E5-4650 CPU).

Box plots of segmentation times are separated by hand in Figure 6, with tabular representations are enumerated in Table 11. Results are reported in milliseconds

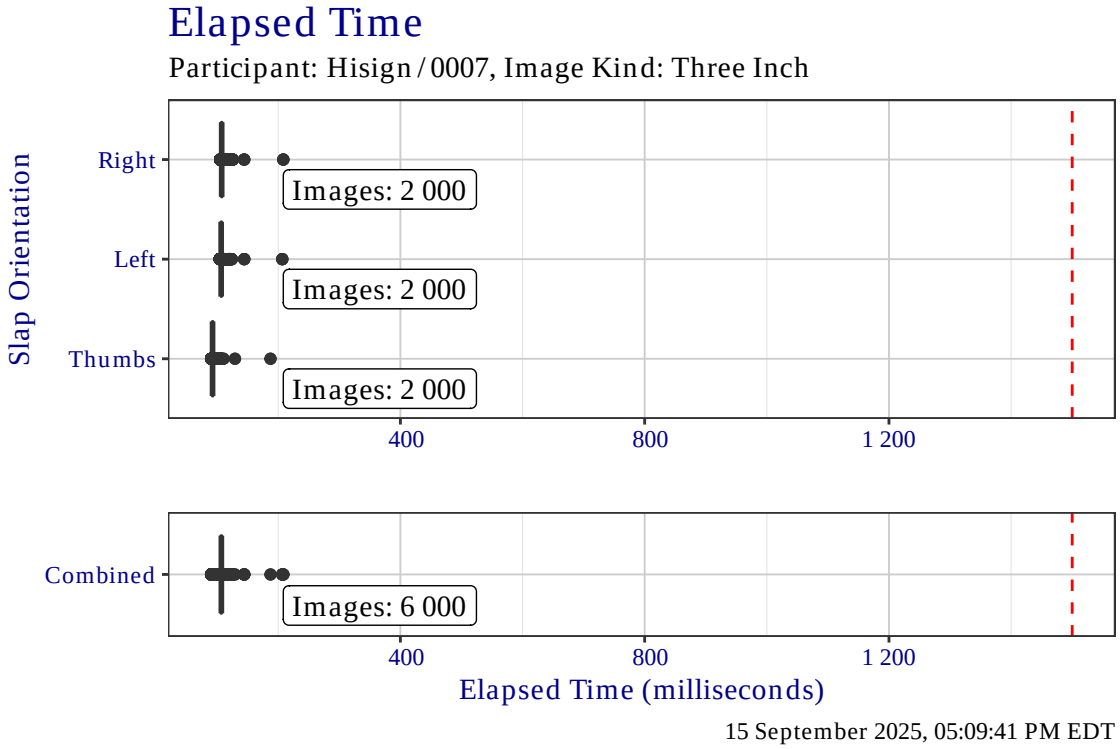

Figure 6: Box plots of elapsed time in milliseconds when segmenting the ThreeInch timing test corpus, separated by slap orientation.

Table 11: Elapsed time in milliseconds when segmenting the ThreeInch timing test corpus, separated by slap orientation.

	Right	Left	Thumbs	Combined
Minimum	105	104	90	90
25%	107	106	92	106
Median	107	107	92	107
75%	108	107	93	108
Maximum	208	207	187	208

3.2 Segmentation Centers and Dimensions

3.2.1 Segmentation Centers

The plots in this section show the distribution of segmentation position centers (x, y) for ThreeInch data. At the top of each figure is a combined plot for all finger positions of a given hand orientation. These figures are isolated in plots faceted at the bottom of the figure.

Plots of segmentation centers for the right hand ThreeInch data are shown in Figure 7, for the left hand in Figure 8, and for thumbs in Figure 9. Blank lines that may appear in the plots are **not** rendering artifacts. Rather, they are indicative of image downsampling. Centers have been normalized to 500 pixels per inch.

Points in each plot are plotted with a semi-transparent opacity. This results in points of particular color appearing "darker" to indicate a higher frequency of the observed value, while "lighter" points indicate a lower observed frequency.

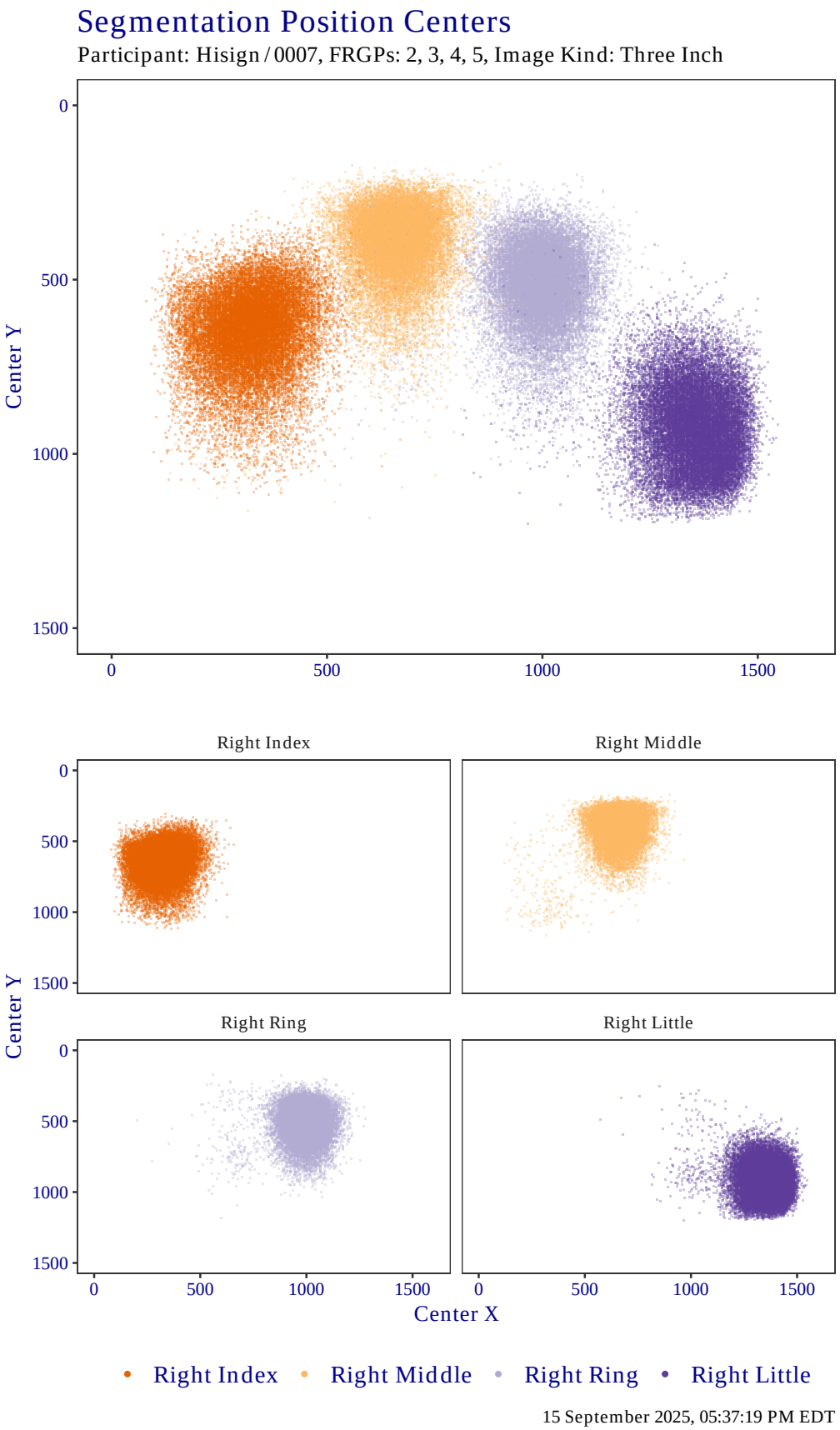

Figure 7: Segmentation centers for right hand ThreeInch data.

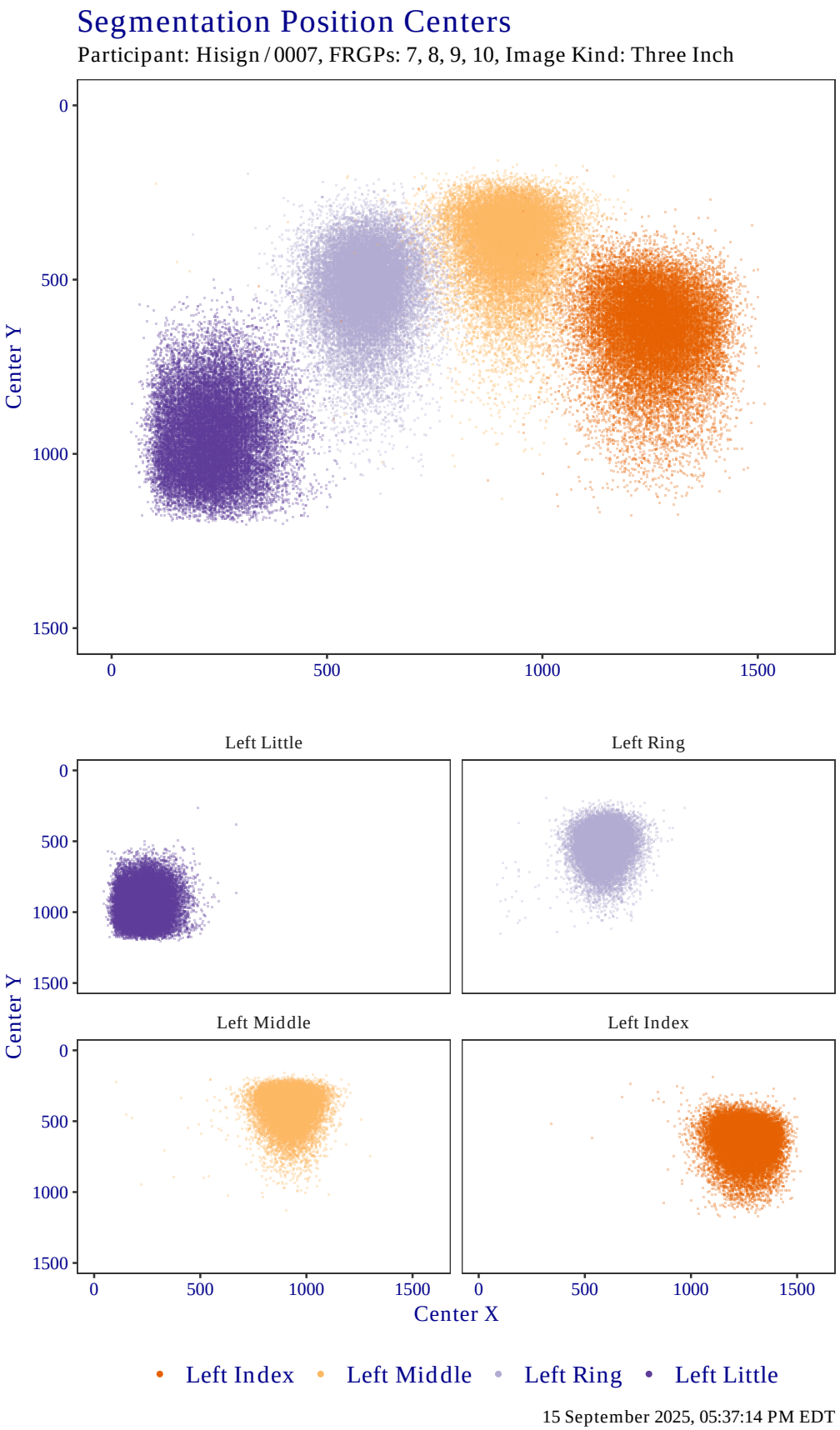

Figure 8: Segmentation centers for left hand ThreeInch data.

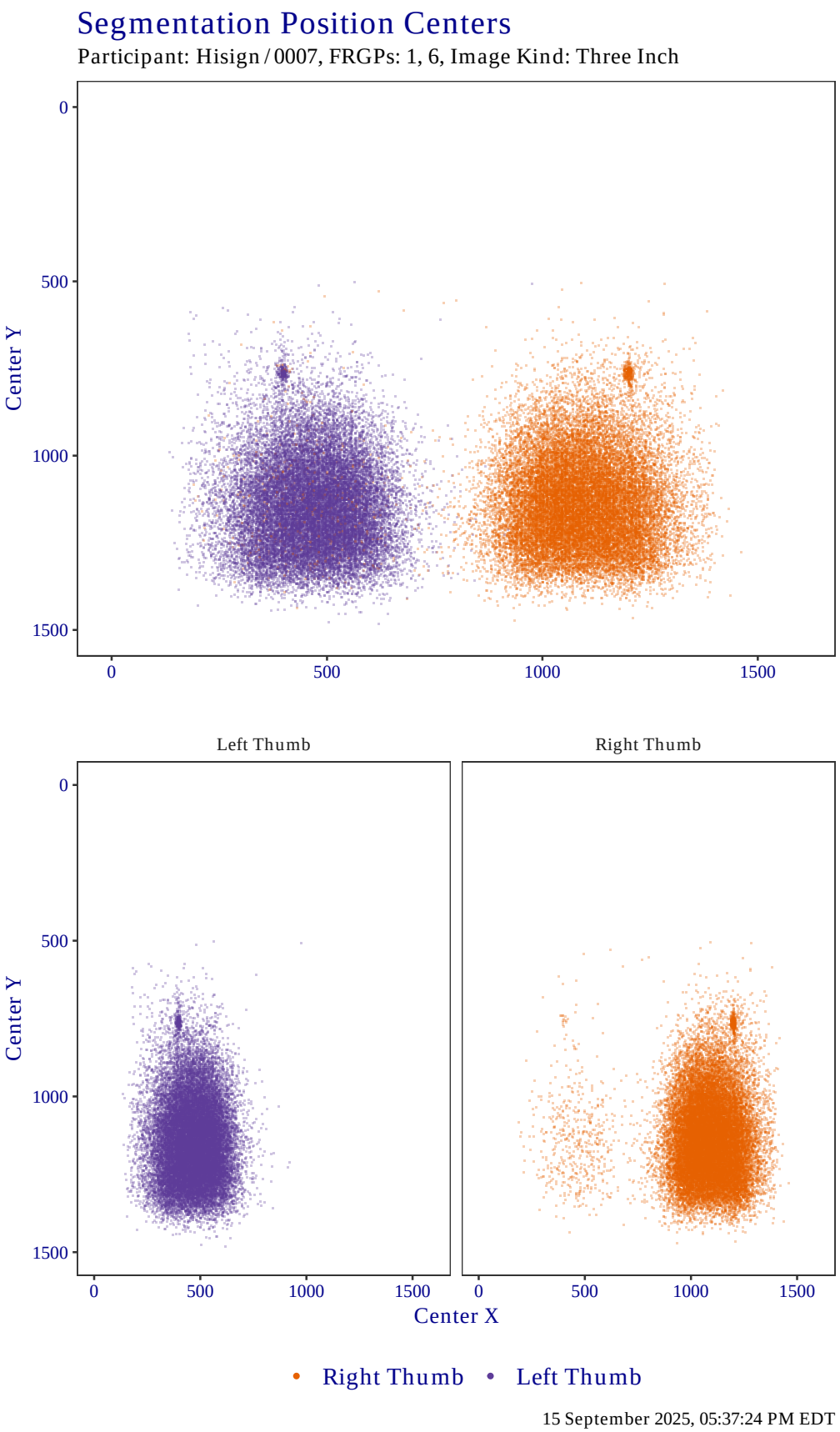

Figure 9: Segmentation centers for thumb ThreeInch data.

3.2.2 Segmentation Dimensions

The plots in this section show the distribution of segmentation position widths and heights for ThreeInch data. At the top of each figure is a combined plot for all finger positions of a given hand orientation. These figures are isolated in plots faceted at the bottom of the figure.

Plots of segmentation position dimensions for the right hand ThreeInch data are shown in Figure 11, for the left hand in Figure 10, and for thumbs in Figure 12. Blank lines that may appear in the plots are **not** rendering artifacts. Rather, they are indicative of image downsampling. Dimensions have been normalized to 500 pixels per inch.

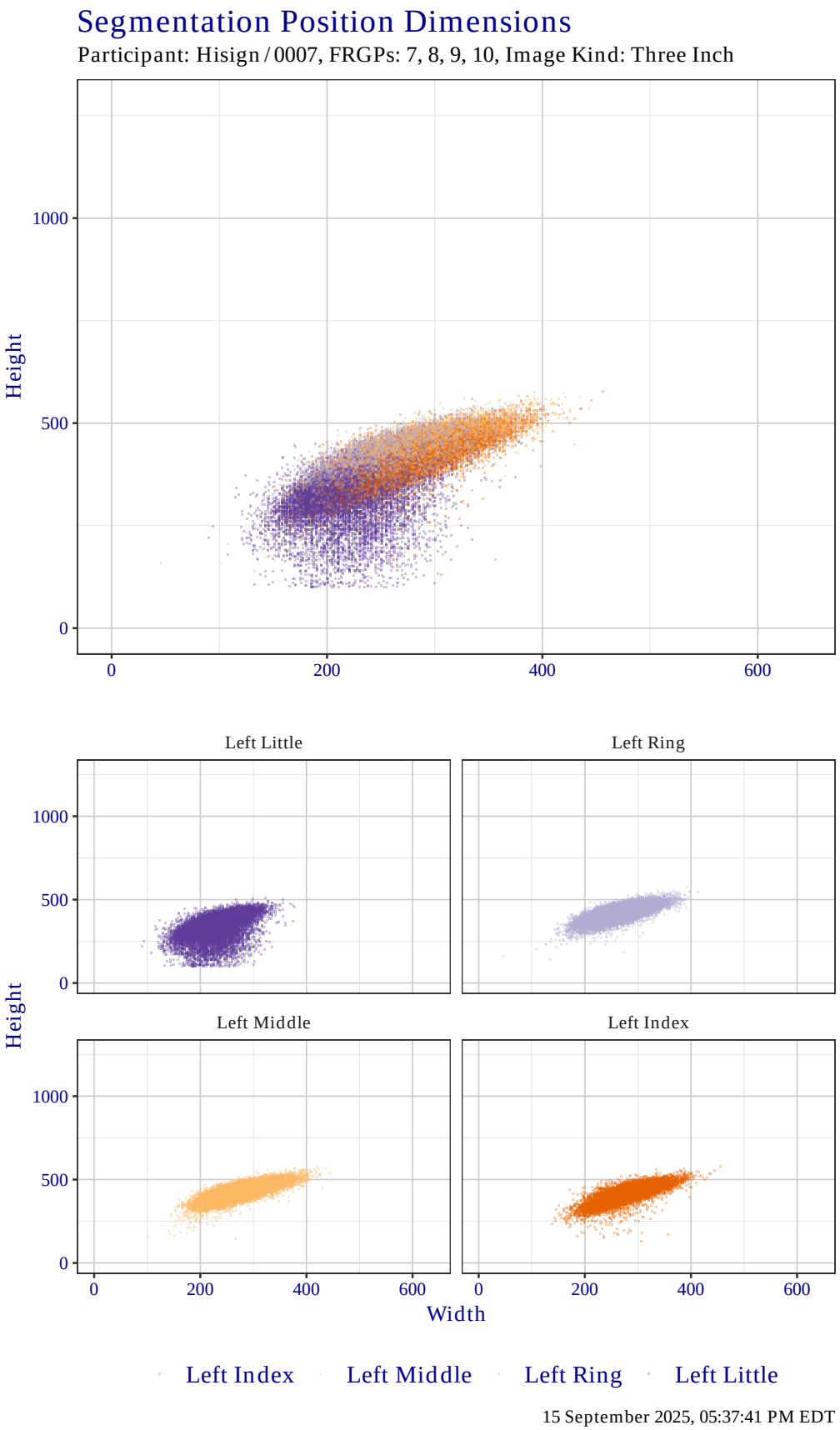

Figure 10: Segmentation position dimensions for left hand ThreeInch data.

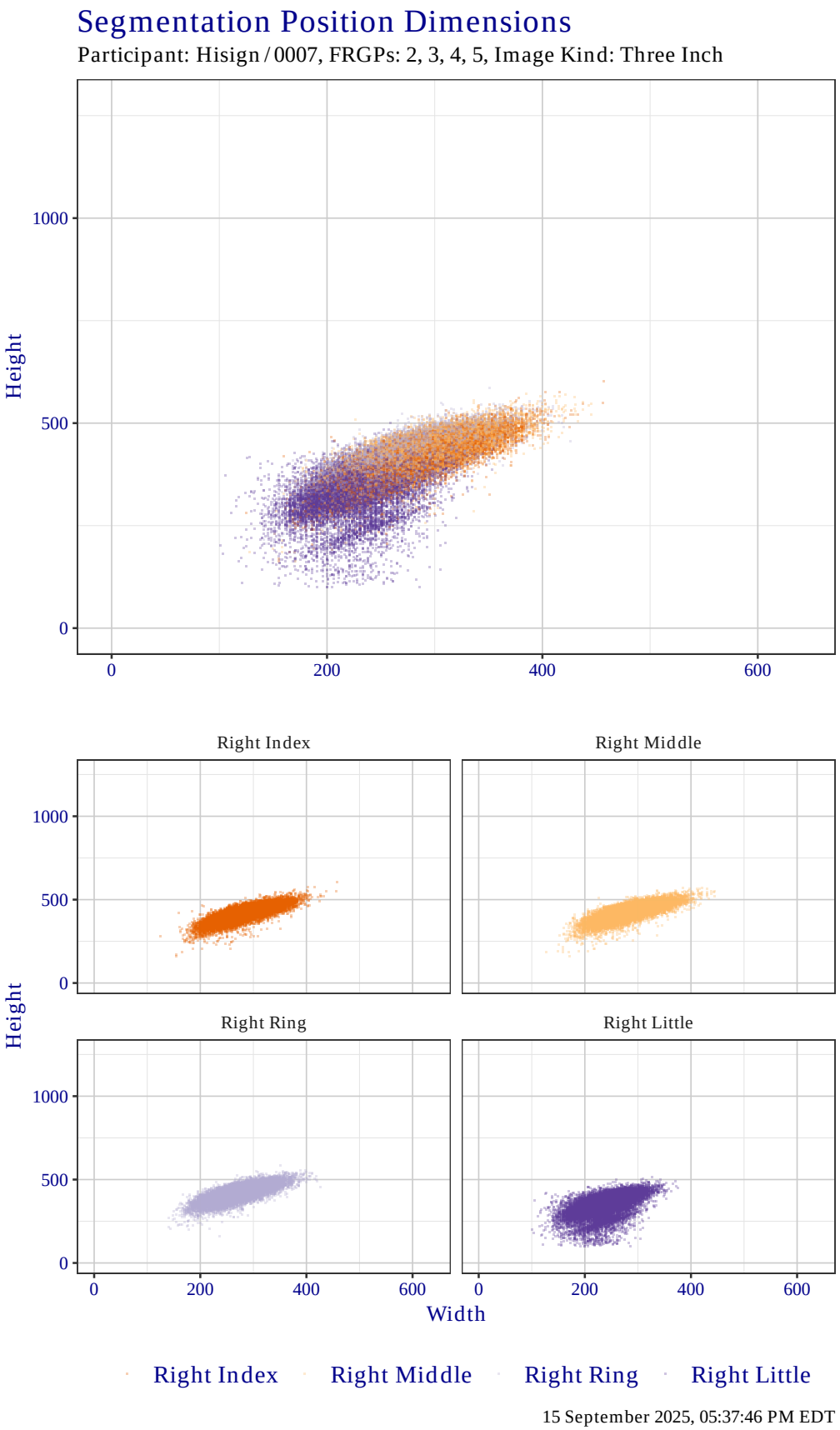

Figure 11: Segmentation position dimensions for right hand ThreeInch data.

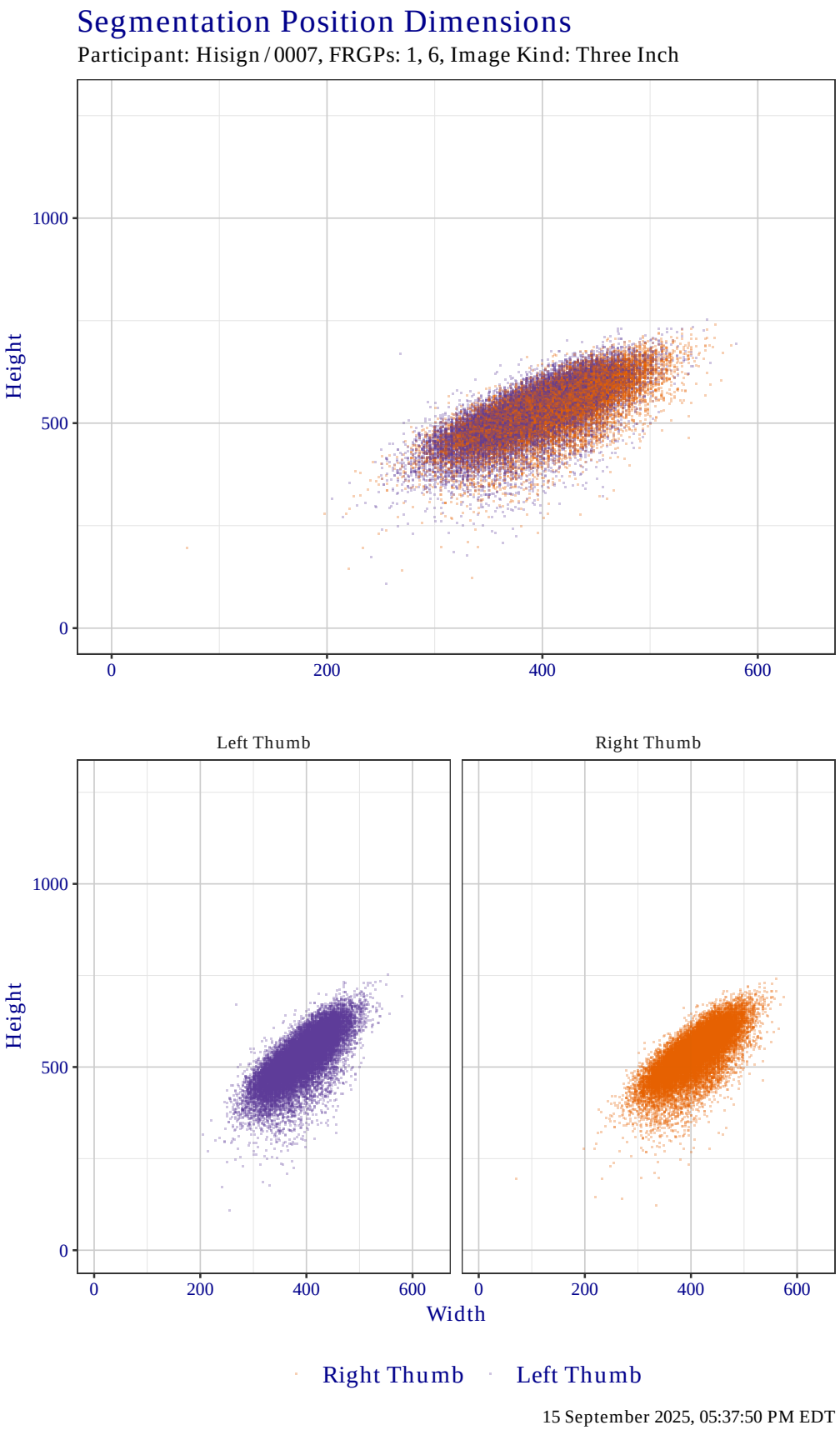

Figure 12: Segmentation position dimensions for thumb ThreeInch data.

3.3 Detailed Segmentation Statistics

This section shows detailed results of segmentation of ThreeInch data. Values in each table are the percentage that the variable in the left-most column was correctly segmented.

Each table has three columns of percentages. The *Standard Scoring* column shows the percentage of correctly-segmented positions based on the scoring metrics defined in the SlapSeg III scoring document. The *Ignoring Bottom Y* column shows how the percentage would change if the threshold for the *bottom Y* coordinate of the segmentation position was ignored. Similarly, the *Ignoring Bottom X and Y* columns shows how the percentage would change if only the top, left, and right sides of the segmentation position were considered. These two supplemental columns are included because it has traditionally been difficult to determine the exact location of the distal interphalangeal joint.

Table 12 shows how successful Hisign+0007 segmented fingers for each subject in the test corpus. Table 13 shows success for specific finger positions over the entire test corpus. Similarly, Table 14 shows success for segmenting the same finger position from both hands.

The remainder of the tables show success per subject when considering combinations of subsets of the fingers on each slap image. Table 15 shows success for combinations of all fingers, Table 16 for just the index and middle fingers, and Table 17 for all except the little finger.

Table 12: For each subject, the percentage that at least *Number of Fingers* fingers were correctly segmented, regardless of hand, for a maximum of eight correctly-segmented fingers. In *Standard Scoring*, scoring rules are followed exactly. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Number of Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
1	99.7	99.7	99.7
2	99.4	99.5	99.5
3	98.4	98.4	98.4
4	97.7	97.7	98.1
5	95.7	95.7	95.9
6	95.1	95.2	95.5
7	94.0	94.0	94.9
8	90.8	91.0	93.7
9	78.4	78.7	87.4
10	54.5	55.2	71.9

Table 13: For all subjects, percentage that a particular friction ridge generalized position was correctly segmented. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Finger	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Thumb	93.3	93.9	94.1
Index	98.2	98.2	98.6
Middle	97.5	97.5	98.5
Ring	92.7	92.7	94.9
Little	83.9	83.9	93.0
Left			
Thumb	92.0	92.6	92.9
Index	97.5	97.5	98.4
Middle	97.7	97.7	98.9
Ring	95.8	95.8	98.0
Little	80.0	80.0	93.2

Table 14: Percentage that a particular type of fingerprint was correctly segmented on *Either* or *Both* hands. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Thumb			
Either	96.2	96.3	96.4
Both	89.2	90.3	90.7
Index			
Either	99.6	99.6	99.8
Both	93.5	93.5	94.5
Middle			
Either	99.6	99.6	99.8
Both	93.0	93.0	94.9
Ring			
Either	98.9	98.9	99.6
Both	87.0	87.0	90.8
Little			
Either	91.8	91.8	98.2
Both	69.9	69.9	85.6

Table 15: Percentage of segmentation success by hand for combinations of all ten fingers of a ThreeInch slap. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	99.5	99.5	99.5
At Least Two	97.7	97.7	97.8
At Least Three	97.1	97.1	97.4
At Least Four	93.1	93.2	95.3
All Five	69.5	70.0	80.2
Left			
Any	99.6	99.6	99.6
At Least Two	98.3	98.3	98.4
At Least Three	97.6	97.6	98.1
At Least Four	93.0	93.1	96.2
All Five	65.8	66.3	80.2

Table 16: Percentage of segmentation success by hand when only considering combinations of index and middle fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are gnored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Either	99.1	99.1	99.1
Both	96.6	96.6	98.0
Left			
Either	99.6	99.6	99.8
Both	95.6	95.6	97.5

Table 17: Percentage of segmentation success by hand when only considering combinations of index, middle, and ring fingers. In *Ignoring Bottom Y*, the bottom left and right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and right coordinates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	99.1	99.1	99.2
At Least Two	98.3	98.3	98.8
All Three	90.9	90.9	94.0
Left			
Any	99.8	99.8	99.9
At Least Two	99.0	99.0	99.5
All Three	92.2	92.2	95.9

3.4 Handling Troublesome Images

3.4.1 Capture Failures

Segmentation algorithms may refuse to process an image. This may happen for a technical reason (e.g., the algorithm cannot parse the image data), or for a practical reason (e.g., the hand in the image is placed incorrectly). These failure scenarios are the result of capturing improper image data. In these types of scenarios, it is important to examine the cause of the failure. With many live scan capture setups, segmentation is performed immediately after capture. If an algorithm can detect that it won't be able to segment an image due to a technical or practical issue, it can alert the operator to perform a recapture before the subject leaves.

The SlapSeg III API encourages algorithms to identify these failure reasons by specifying pre-defined *deficiencies* in the image. Algorithms should attempt segmentation even if an image deficiency is encountered if at all possible. Note that SlapSeg III *guarantees* well-formed image data, so failures to parse are **not** an indicator of the data provided.

Hisign+0007 did **not** report any capture failures.

3.4.1.1 Recovery

When encountering a segmentation failure, SlapSeg III algorithms are encouraged to provide a *best-effort* segmentation when possible. In some cases, that best-effort may be correct, which reduces the amount of images that need to be manually adjudicated by an operator.

Hisign+0007 did not attempt any recovery segmentations.

3.4.2 Segmentation Failures

Even if an algorithm accepts an image for processing, it can still fail to process one or more fingers from the image, regardless of if the algorithm requested a recapture and provided best-effort segmentation.

The SlapSeg III API allows algorithms to communicate reasons for failure to process these fingers. In some cases, the distal phalanx in question might not be present in the image due to amputation or being placed outside the platen's capture area. It is imperative that the segmentation algorithm correctly report this as failing to segment the correct friction ridge generalized position without disrupting the sequence of valid positions present in the image. This can help prompt an operator to recapture or record additional information about the subject.

In SlapSeg III, a number of images are missing fingers or otherwise have fingers that will not be able to be segmented. Reasons for segmentation failures reported by Hisign+0007 are enumerated in Table 18.

Table 18: Count of self-reported segmentation failure reasoning.

Failure Reason	Fingers
Vendor Defined	1 730
Finger Not Found	0
Finger Found, but Can't Segment	0

3.4.3 Identifying Missing Fingers

A small portion of the test corpus in SlapSeg III are missing fingers. Table 19 shows how successful Hisign+0007 was in correctly determining if a finger was missing. The *Missed* row shows when a segmentation position was returned for a missing finger. All possible failure reasons are enumerated, but are not considered *Correctly Identified* because the algorithm specified failure for a reason other than the finger not being found.

Table 19: Performance of Hisign+0007 at detecting fingers missing from an image.

Result	Percentage
Missed	43.8
Correctly Identified	0.0
Other Failure: Finger Found, but Can't Segment	0.0
Other Failure: Vendor Defined	56.2
Other Failure: Segmentation Not Attempted	0.0

3.4.4 Sequence Error

Sequence error occurs when a fingerprint is segmented from an image but assigned an incorrect finger position (e.g., segmenting a right middle finger but labeling it a right index finger). Table 20 shows cases in which a segmentation position was returned that matched a ground truth segmentation position for a different finger in the same image.

Table 20: Percentage of images in the dataset where one or more segmentation positions correctly matched an incorrect finger position within the same image, indicating sequence error.

Hand	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Left	0.16	0.16	0.16
Right	0.83	0.83	0.84
Thumbs	1.83	1.91	1.92
Combined	0.93	0.96	0.97

4 Upper Palm ("FiveInch" Data)

4.1 Segmentation Timing

All algorithms are run over a small fixed corpus of FiveInch images to estimate the total runtime of the evaluation. To be evaluated under SlapSeg III, algorithms **must** segment the timing corpus, on average, in under 1 500 milliseconds. This maximum reference time is documented in the SlapSeg III test plan, and is subject to change. Times are measured by running a single process on an isolated compute node equipped with an Intel Gold 6254 CPU (submissions received prior to February 2022 were timed with a Intel Xeon E5-4650 CPU).

Box plots of segmentation times are separated by slap orientation in Figure 13. Tabular representations are enumerated in Table 21. Results are reported in milliseconds.

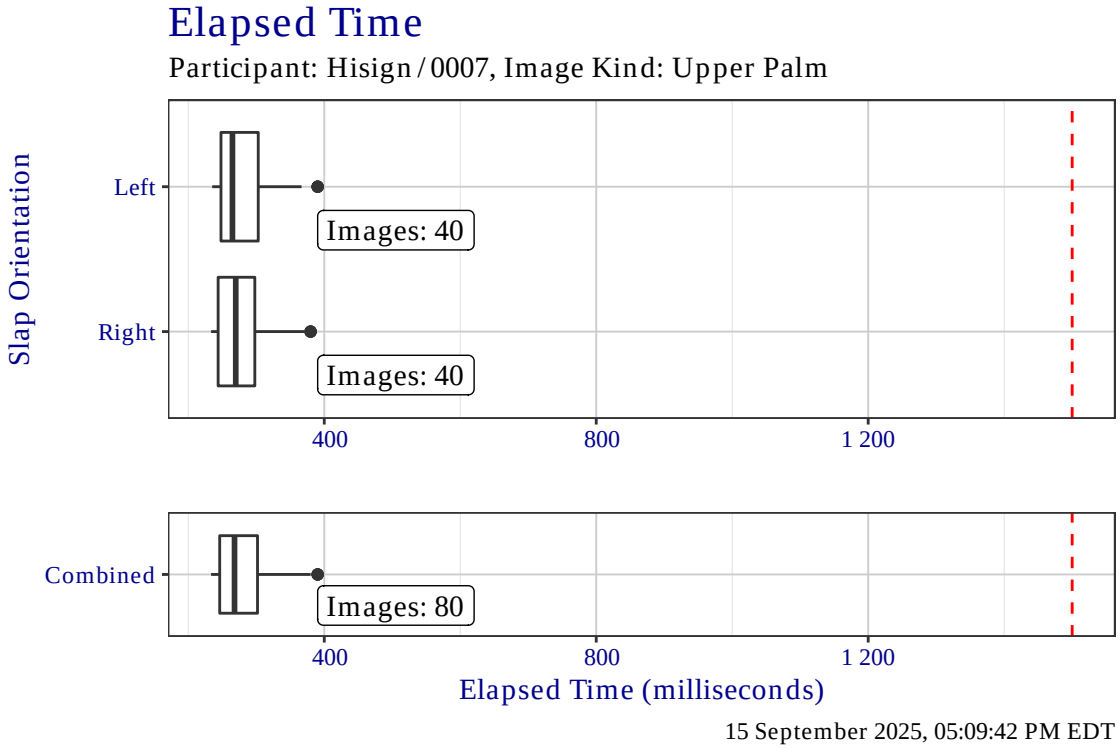

Figure 13: Box plots of elapsed time in milliseconds when segmenting the FiveInch timing test corpus, separated by slap orientation.

Table 21: Elapsed time in milliseconds when segmenting the FiveInch timing test corpus, separated by slap orientation.

	Right	Left	Combined
Minimum	234	235	234
25%	244	248	246
Median	270	265	268
75%	298	303	302
Maximum	380	390	390

4.2 Segmentation Centers and Dimensions

4.2.1 Segmentation Centers

The plots in this section show the distribution of segmentation position centers (x, y) for FiveInch data. At the top of each figure is a combined plot for all finger positions of a given slap orientation. These figures are isolated in plots faceted at the bottom of the figure.

Plots of segmentation centers for the right hand FiveInch data are shown in Figure 14 and plots of segmentation centers for the left hand are shown in Figure 15. Blank lines that may appear in the plots are **not** rendering artifacts. Rather, they are indicative of image downsampling. Centers have been normalized to 500 pixels per inch.

Points in each plot are plotted with a semi-transparent opacity. This results in points of particular color appearing "darker" to indicate a higher frequency of the observed value, while "lighter" points indicate a lower observed frequency.

Figure 14: Segmentation centers for right hand FiveInch data.

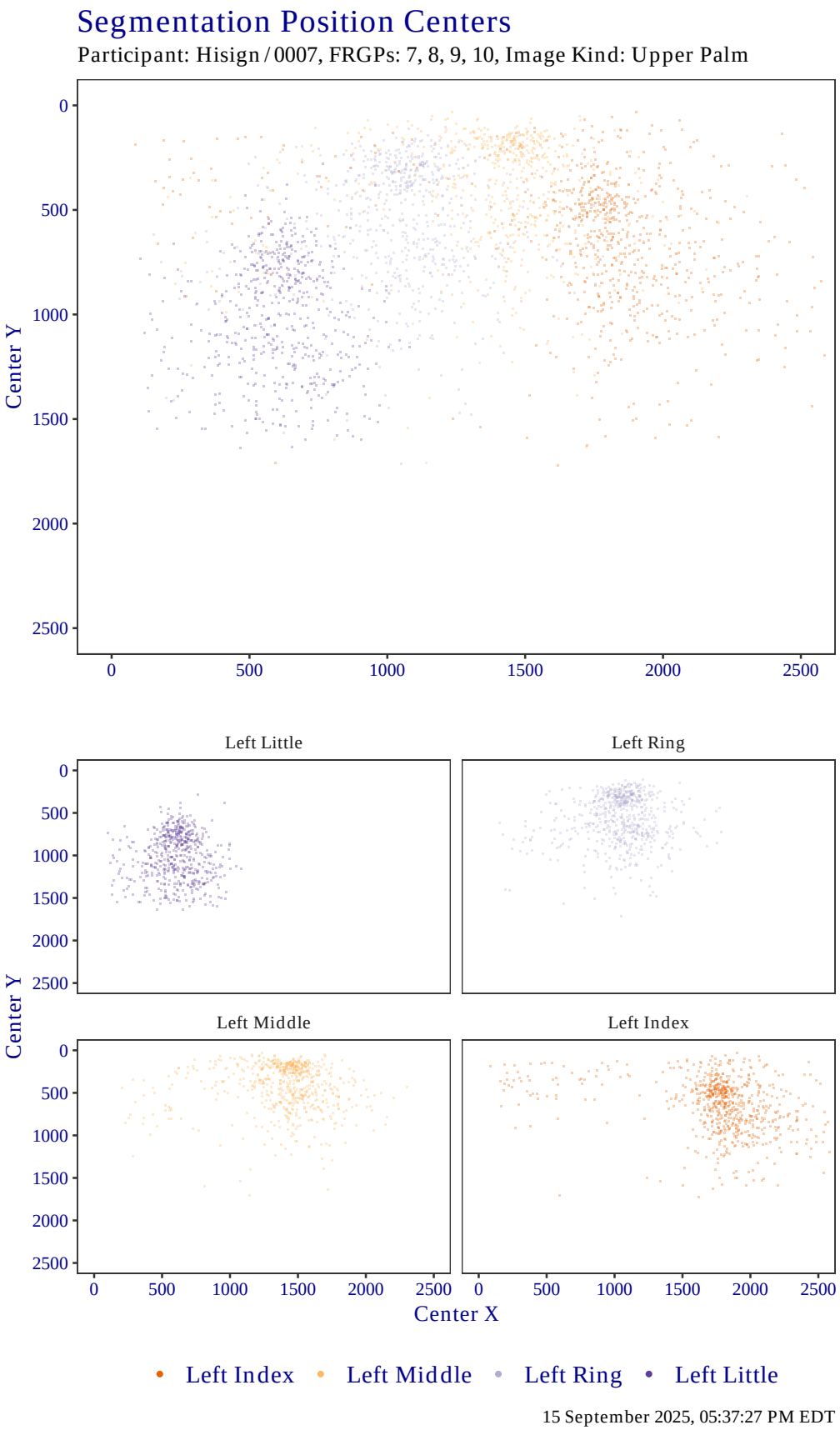

Figure 15: Segmentation centers for left hand FiveInch data.

4.2.2 Segmentation Dimensions

The plots in this section show the distribution of segmentation position widths and heights for FiveInch data. At the top of each figure is a combined plot for all finger positions of a given slap orientation. These figures are isolated in plots faceted at the bottom of the figure.

Plots of segmentation position dimensions for the right hand FiveInch data are shown in Figure 16 and the left hand in Figure 17. Blank lines that may appear in the plots are **not** rendering artifacts. Rather, they are indicative of image downsampling. Dimensions have been normalized to 500 pixels per inch.

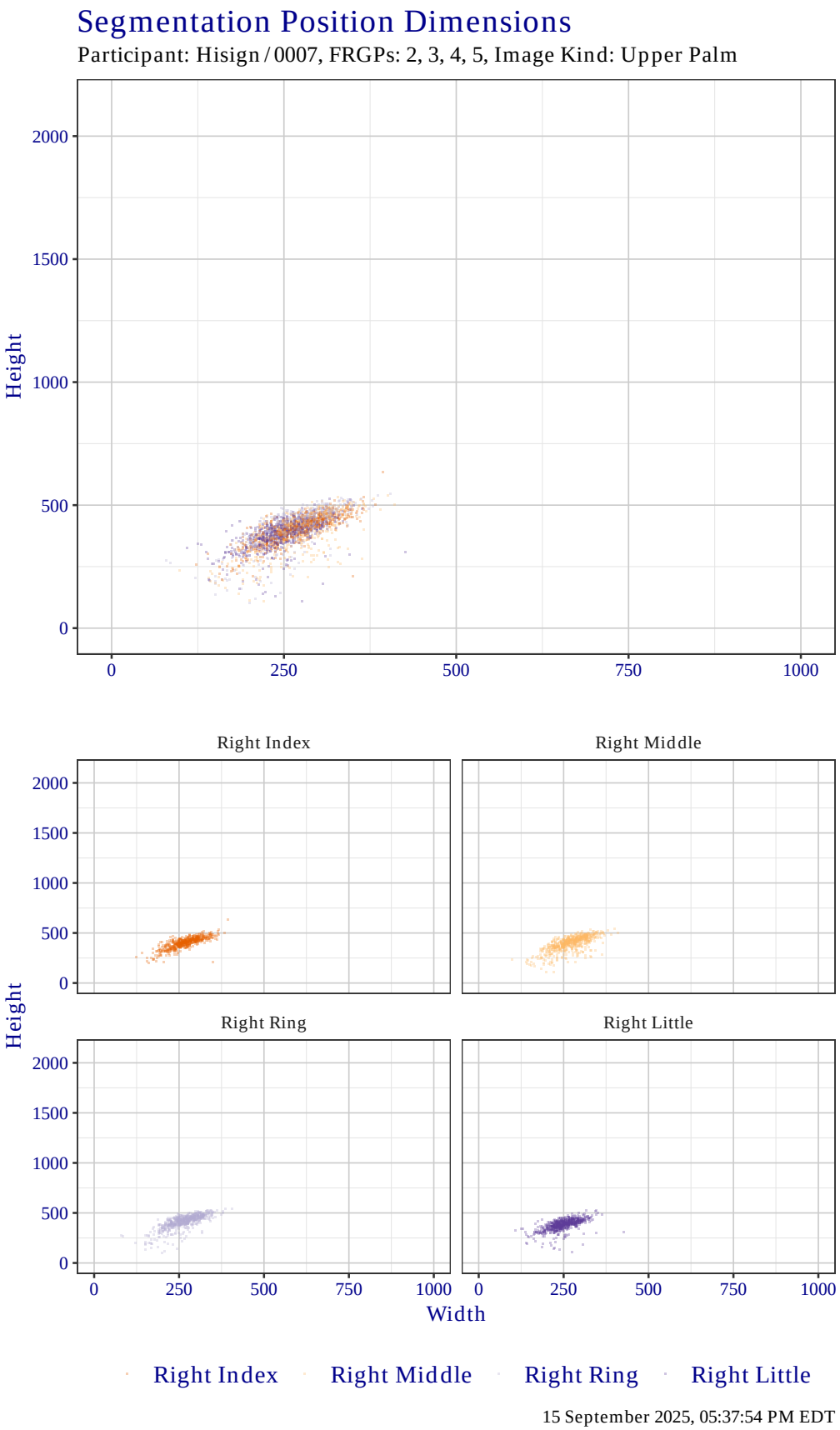

Figure 16: Segmentation position dimensions for right hand FiveInch data.

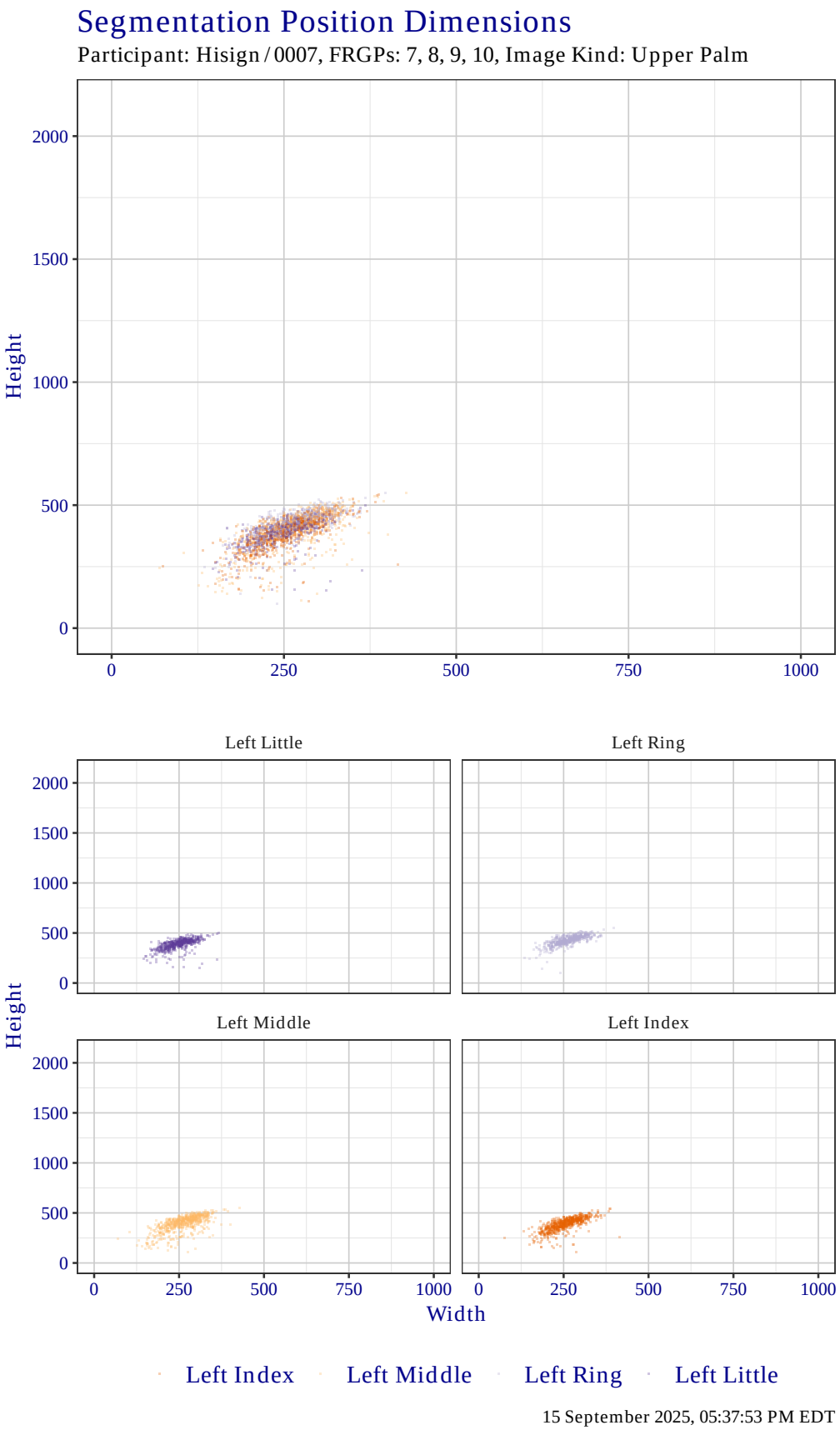

Figure 17: Segmentation position dimensions for left hand FiveInch data.

4.3 Detailed Segmentation Statistics

This section shows detailed results of segmentation of FiveInch data. Values in each table are the percentage that the variable in the left-most column was correctly segmented.

Each table has three columns of percentages. The *Standard Scoring* column shows the percentage of correctly-segmented positions based on the scoring metrics defined in the SlapSeg III scoring document. The *Ignoring Bottom Y* column shows how the percentage would change if the threshold for the *bottom Y* coordinate of the segmentation position was ignored. Similarly, the *Ignoring Bottom X and Y* columns shows how the percentage would change if only the top, left, and right sides of the segmentation position were considered. These two supplemental columns are included because it has traditionally been difficult to determine the exact location of the distal interphalangeal joint.

Table 22 shows how successful Hisign+0007 segmented fingers for each subject in the test corpus. Table 23 shows success for specific finger positions over the entire test corpus. Similarly, Table 24 shows success for segmenting the same finger position from both hands.

The remainder of the tables show success per subject when considering combinations of subsets of the fingers on each slap image. Table 25 shows success for combinations of all fingers, Table 26 for just the index and middle fingers, and Table 27 for all except the little finger.

Table 22: For each subject, the percentage that at least *Number of Fingers* fingers were correctly segmented, regardless of hand, for a maximum of eight correctly-segmented fingers. In *Standard Scoring*, scoring rules are followed exactly. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Number of Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
1	91.4	91.4	91.6
2	85.8	86.0	86.0
3	81.9	82.5	82.6
4	78.5	80.2	80.2
5	72.3	73.0	73.0
6	66.9	67.2	67.3
7	62.1	64.2	64.3
8	48.9	53.6	54.8

Table 23: For all subjects, percentage that a particular friction ridge generalized position was correctly segmented. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Finger	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Index	72.7	72.9	73.0
Middle	72.5	72.6	72.9
Ring	76.5	77.5	77.5
Little	81.2	83.6	83.8
Left			
Index	79.0	80.5	80.5
Middle	73.6	73.9	74.0
Ring	73.1	74.7	74.7
Little	63.9	67.2	68.3

Table 24: Percentage that a particular type of fingerprint was correctly segmented on *Either* or *Both* hands. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Index			
Either	84.3	85.1	85.2
Both	66.3	67.1	67.1
Middle			
Either	80.9	80.9	81.0
Both	64.0	64.4	64.7
Ring			
Either	83.1	83.7	83.7
Both	65.2	67.3	67.3
Little			
Either	86.3	89.2	89.3
Both	57.7	60.5	61.5

Table 25: Percentage of segmentation success by hand for combinations of all eight fingers of a FiveInch slap. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	86.7	86.7	86.8
At Least Two	77.5	77.9	78.1
At Least Three	73.4	73.7	73.8
All Four	65.3	68.4	68.5
Left			
Any	82.2	82.5	82.5
At Least Two	75.3	75.5	75.5
At Least Three	73.2	74.0	74.0
All Four	58.9	64.3	65.5

Table 26: Percentage of segmentation success by hand when only considering combinations of index and middle fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Either Index or Middle	74.2	74.3	74.5
Both Index and Middle	71.0	71.1	71.4
Left			
Either Index or Middle	82.0	82.1	82.1
Both Index and Middle	70.7	72.3	72.4

Table 27: Percentage of segmentation success by hand when only considering combinations of index, middle, and ring fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	77.9	78.2	78.2
At Least Two	73.9	74.1	74.3
All Three	69.8	70.7	70.9
Left			
Any	82.0	82.4	82.4
At Least Two	75.2	75.3	75.3
All Three	68.6	71.4	71.5

4.4 Handling Troublesome Images

4.4.1 Capture Failures

Segmentation algorithms may refuse to process an image. This may happen for a technical reason (e.g., the algorithm cannot parse the image data), or for a practical reason (e.g., the hand in the image is placed incorrectly). These failure scenarios are the result of capturing improper image data. In these types of scenarios, it is important to examine the cause of the failure. With many live scan capture setups, segmentation is performed immediately after capture. If an algorithm can detect that it won't be able to segment an image due to a technical or practical issue, it can alert the operator to perform a recapture before the subject leaves.

The SlapSeg III API encourages algorithms to identify these failure reasons by specifying pre-defined *deficiencies* in the image. Algorithms should attempt segmentation even if an image deficiency is encountered if at all possible. Note that SlapSeg III *guarantees* well-formed image data, so failures to parse are **not** an indicator of the data provided.

Hisign+0007 did **not** report any capture failures.

4.4.1.1 Recovery

When encountering a segmentation failure, SlapSeg III algorithms are encouraged to provide a *best-effort* segmentation when possible. In some cases, that best-effort may be correct, which reduces the amount of images that need to be manually adjudicated by an operator.

Hisign+0007 did not attempt any recovery segmentations.

4.4.2 Segmentation Failures

Even if an algorithm accepts an image for processing, it can still fail to process one or more fingers from the image, regardless of if the algorithm requested a recapture and provided best-effort segmentation.

The SlapSeg III API allows algorithms to communicate reasons for failure to process these fingers. In some cases, the distal phalanx in question might not be present in the image due to amputation or being placed outside the platen's capture area. It is imperative that the segmentation algorithm correctly report this as failing to segment the correct friction ridge generalized position without disrupting the sequence of valid positions present in the image. This can help prompt an operator to recapture or record additional information about the subject.

In SlapSeg III, a number of images are missing fingers or otherwise have fingers that will not be able to be segmented. Reasons for segmentation failures reported by Hisign+0007 are enumerated in Table 28.

Table 28: Count of self-reported segmentation failure reasoning.

Failure Reason	Fingers
Vendor Defined	1 039
Finger Not Found	0
Finger Found, but Can't Segment	0

4.4.3 Identifying Missing Fingers

A small portion of the test corpus in SlapSeg III are missing fingers. Table 29 shows how successful Hisign+0007 was in correctly determining if a finger was missing. The *Missed* row shows when a segmentation position was returned for a missing finger. All possible failure reasons are enumerated, but are not considered *Correctly Identified* because the algorithm specified failure for a reason other than the finger not being found.

Table 29: Performance of Hisign+0007 at detecting fingers missing from an image.

Result	Percentage
Missed	21.7
Correctly Identified	0.0
Other Failure: Finger Found, but Can't Segment	0.0
Other Failure: Vendor Defined	78.3
Other Failure: Segmentation Not Attempted	0.0

4.4.4 Sequence Error

Sequence error occurs when a fingerprint is segmented from an image but assigned an incorrect finger position (e.g., segmenting a right middle finger but labeling it a right index finger). Table 30 shows cases in which a segmentation position was returned that matched a ground truth segmentation position for a different finger in the same image.

Table 30: Percentage of images in the dataset where one or more segmentation positions correctly matched an incorrect finger position within the same image, indicating sequence error.

Hand	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Left	15.78	16.18	16.45
Right	11.44	11.57	11.57
Combined	13.61	13.88	14.01

5 Full Palm ("EightInch" Data)

5.1 Segmentation Timing

All algorithms are run over a small fixed corpus of EightInch images to estimate the total runtime of the evaluation. To be evaluated under SlapSeg III, algorithms **must** segment the timing corpus, on average, in under 1 500 milliseconds. This maximum reference time is documented in the SlapSeg III test plan, and is subject to change. Times are measured by running a single process on an isolated compute node equipped with an Intel Gold 6254 CPU (submissions received prior to February 2022 were timed with a Intel Xeon E5-4650 CPU).

Box plots of segmentation times are separated by slap orientation in Figure 18. Tabular representations are enumerated in Table 31. Results are reported in milliseconds.

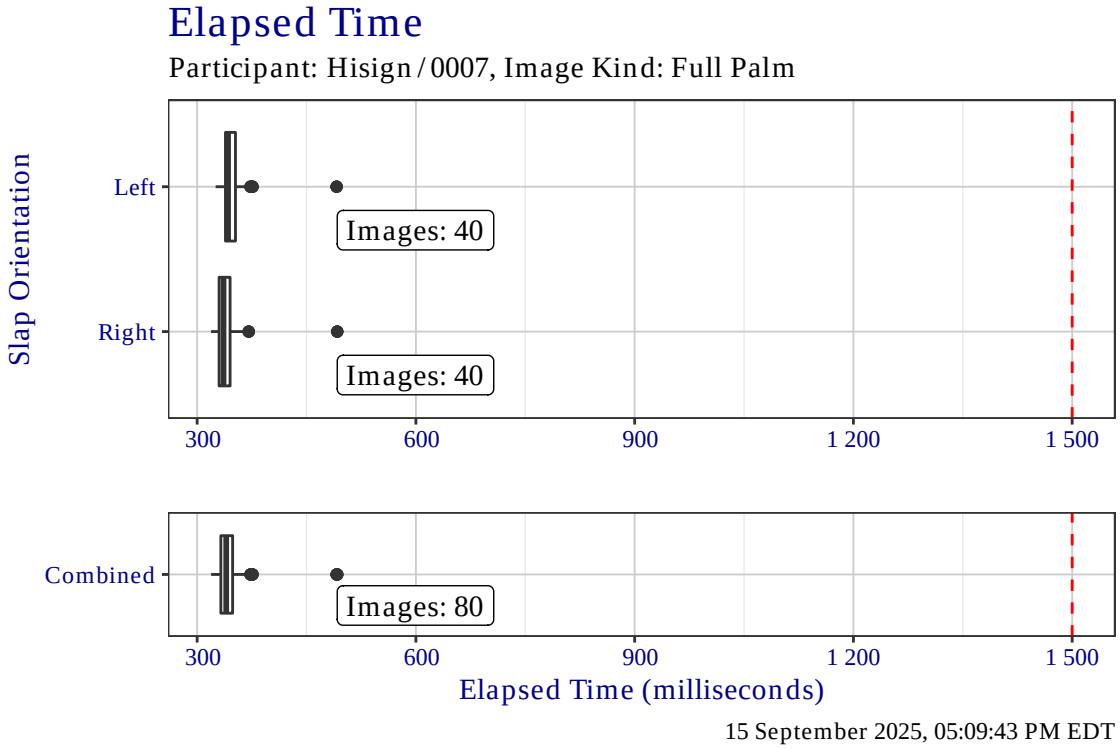

Figure 18: Box plots of elapsed time in milliseconds when segmenting the EightInch timing test corpus, separated by slap orientation.

Table 31: Elapsed time in milliseconds when segmenting the EightInch timing test corpus, separated by slap orientation and capture technology.

	Right	Left	Combined
Minimum	319	325	319
25%	330	339	333
Median	336	342	340
75%	345	353	349
Maximum	492	491	492

5.2 Segmentation Centers and Dimensions

5.2.1 Segmentation Centers

The plots in this section show the distribution of segmentation position centers (x, y) for EightInch data. At the top of each figure is a combined plot for all finger positions of a given slap orientation. These figures are isolated in plots faceted at the bottom of the figure.

Plots of segmentation centers for the right hand EightInch data are shown in Figure 19 and plots of segmentation centers for the left hand are shown in Figure 20. Blank lines that may appear in the plots are **not** rendering artifacts. Rather, they are indicative of image downsampling. Centers have been normalized to 500 pixels per inch.

Points in each plot are plotted with a semi-transparent opacity. This results in points of particular color appearing "darker" to indicate a higher frequency of the observed value, while "lighter" points indicate a lower observed frequency.

Figure 19: Segmentation centers for right hand EightInch data.

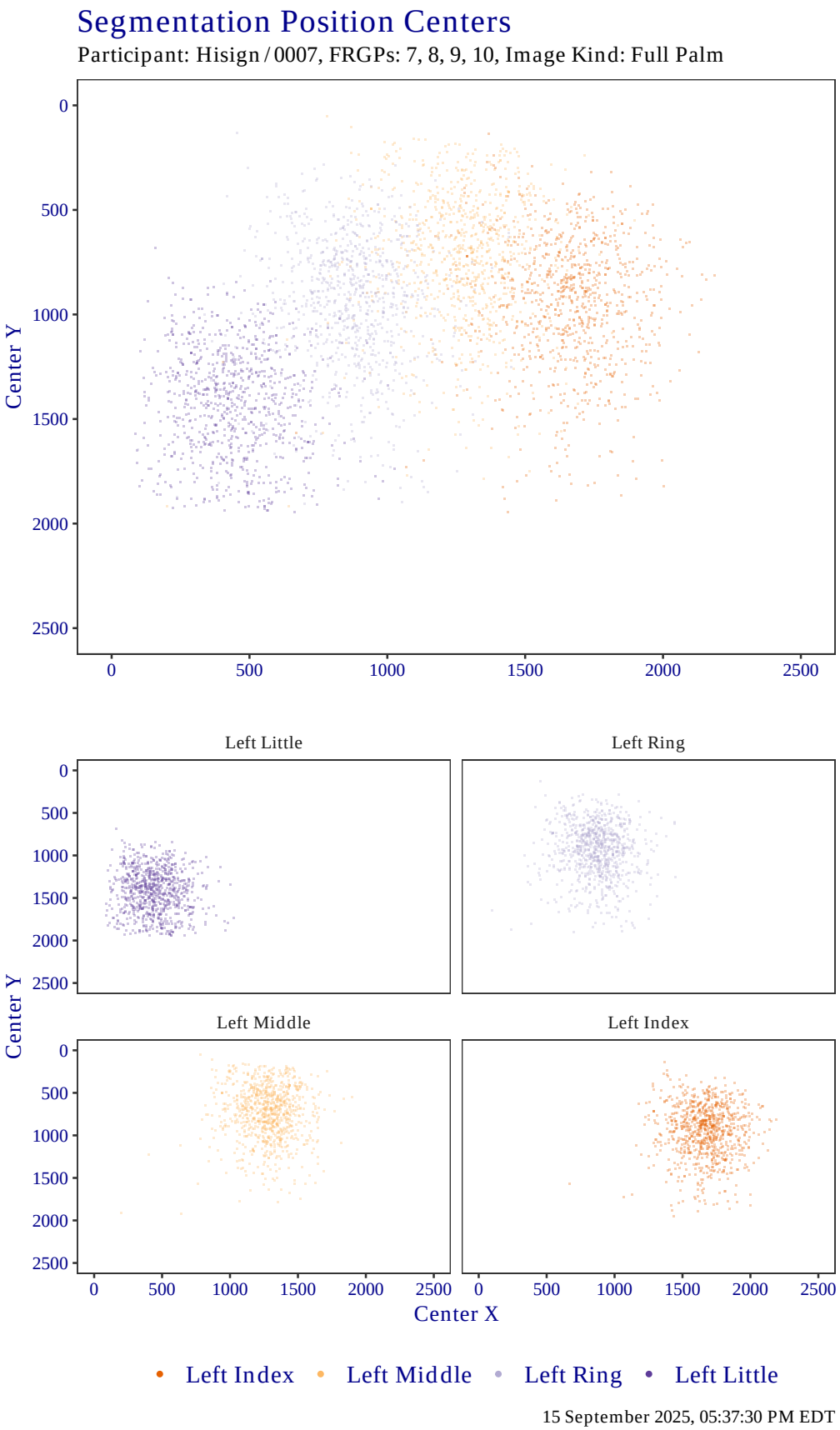

Figure 20: Segmentation centers for left hand EightInch data.

5.2.2 Segmentation Dimensions

The plots in this section show the distribution of segmentation position widths and heights for EightInch data. At the top of each figure is a combined plot for all finger positions of a given slap orientation. These figures are isolated in plots faceted at the bottom of the figure.

Plots of segmentation position dimensions for the right hand EightInch data are shown in Figure 21 and the left hand in Figure 22. Blank lines that may appear in the plots are **not** rendering artifacts. Rather, they are indicative of image downsampling. Dimensions have been normalized to 500 pixels per inch.

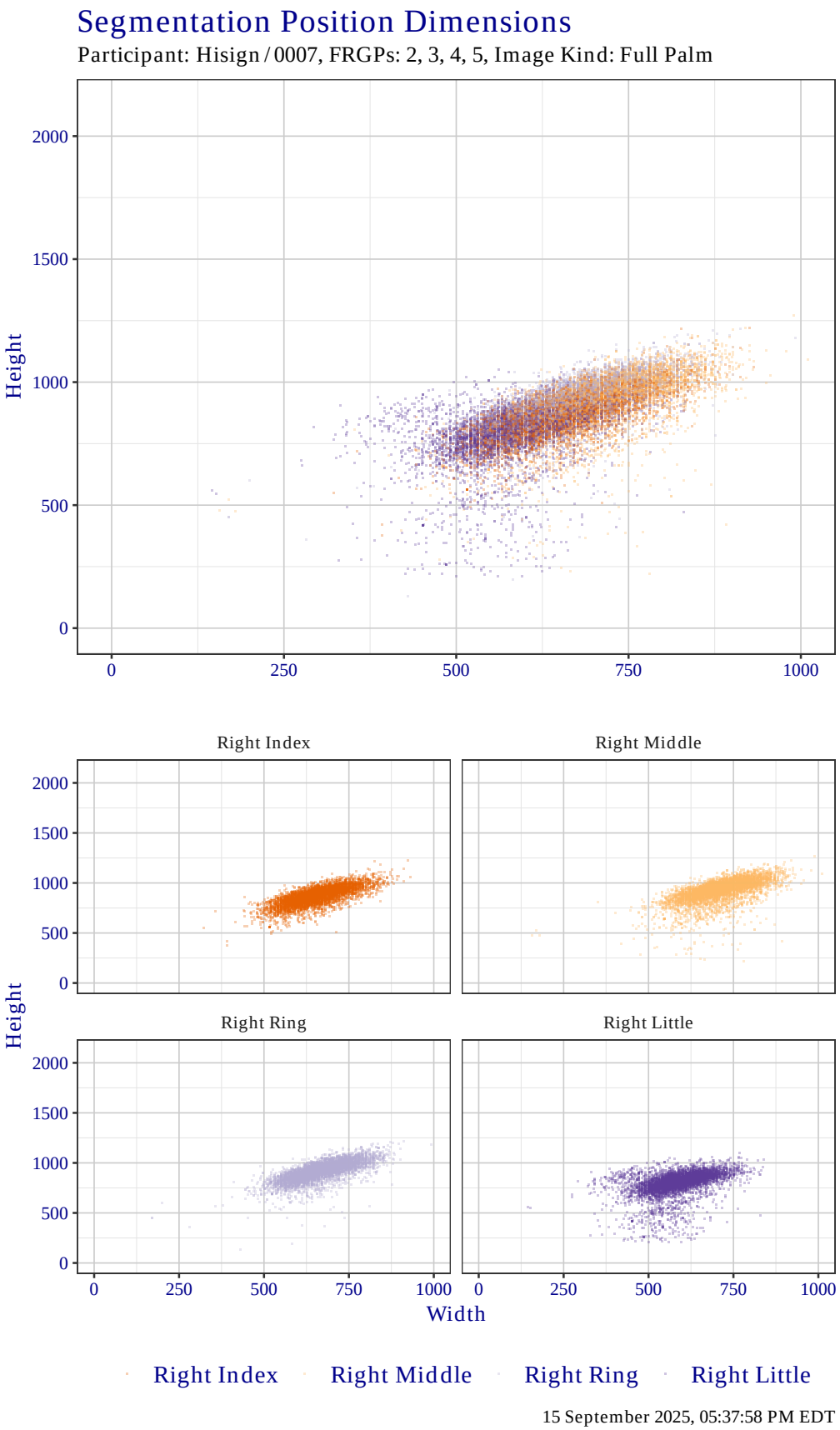

Figure 21: Segmentation position dimensions for right hand EightInch data.

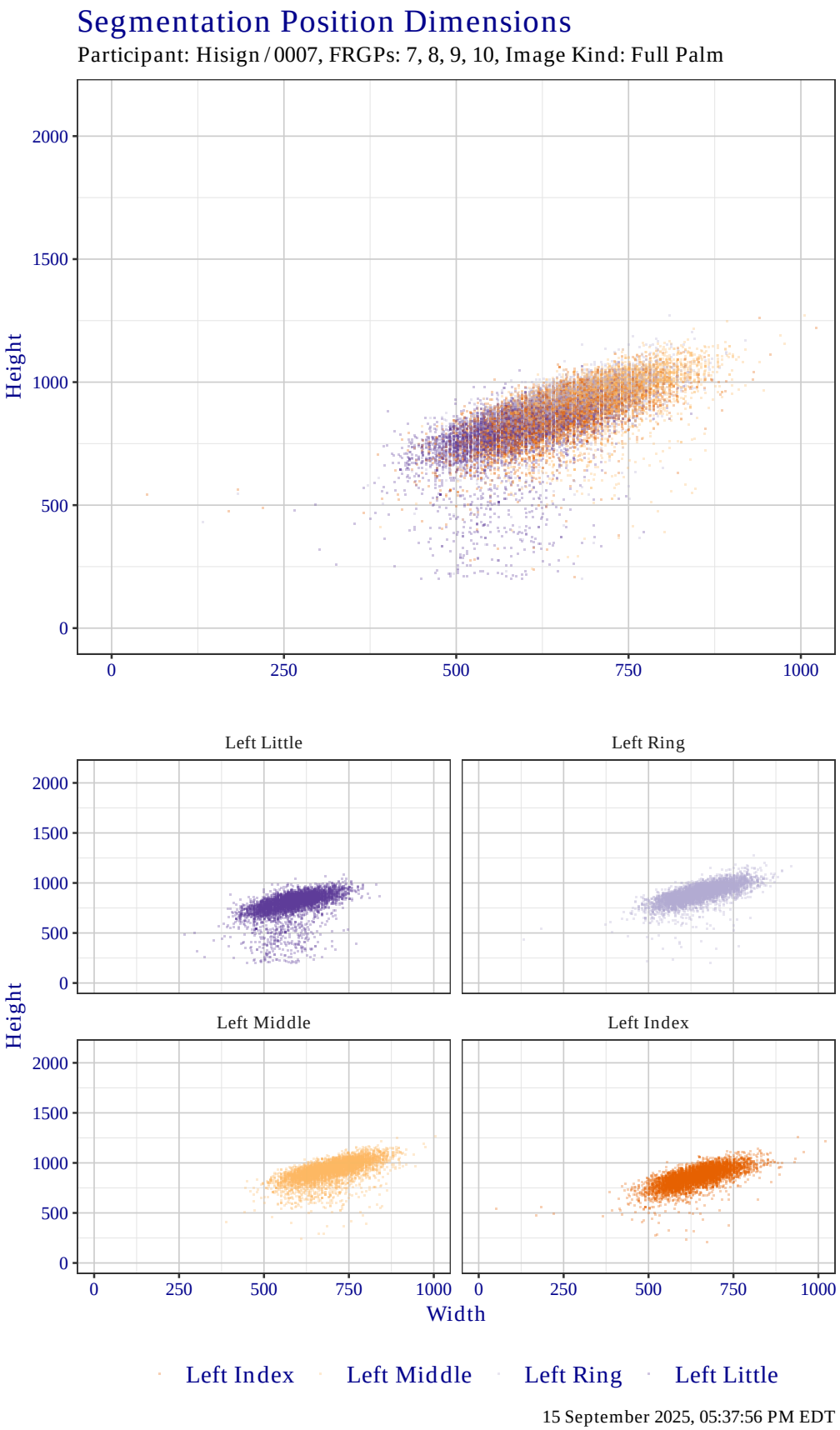

Figure 22: Segmentation position dimensions for left hand EightInch data.

5.3 Detailed Segmentation Statistics

NOTE: *The following segmentation statistics are based on a limited subset (approximately 15%) of the anticipated Full Palm dataset. This analysis will be updated as soon as NIST can obtain the remainder of the dataset.*

This section shows detailed results of segmentation of EightInch data. Values in each table are the percentage that the variable in the left-most column was correctly segmented.

Each table has three columns of percentages. The *Standard Scoring* column shows the percentage of correctly-segmented positions based on the scoring metrics defined in the SlapSeg III scoring document. The *Ignoring Bottom Y* column shows how the percentage would change if the threshold for the *bottom Y* coordinate of the segmentation position was ignored. Similarly, the *Ignoring Bottom X and Y* columns shows how the percentage would change if only the top, left, and right sides of the segmentation position were considered. These two supplemental columns are included because it has traditionally been difficult to determine the exact location of the distal interphalangeal joint.

Table 32 shows how successful Hisign+0007 segmented fingers for each subject in the test corpus. Table 33 shows success for specific finger positions over the entire test corpus. Similarly, Table 34 shows success for segmenting the same finger position from both hands.

The remainder of the tables show success per subject when considering combinations of subsets of the fingers on each slap image. Table 35 shows success for combinations of all fingers, Table 36 for just the index and middle fingers, and Table 37 for all except the little finger.

Table 32: For each subject, the percentage that at least *Number of Fingers* fingers were correctly segmented, regardless of hand, for a maximum of eight correctly-segmented fingers. In *Standard Scoring*, scoring rules are followed exactly. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Number of Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
1	99.7	99.7	99.7
2	99.4	99.7	99.7
3	99.0	99.7	99.7
4	96.9	97.6	97.6
5	96.0	96.0	96.0
6	95.1	95.5	95.5
7	90.5	94.5	94.6
8	76.9	85.3	86.4

Table 33: For all subjects, percentage that a particular friction ridge generalized position was correctly segmented. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Finger	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Index	95.3	95.4	95.4
Middle	95.6	95.6	95.7
Ring	95.3	95.5	95.5
Little	85.6	91.0	91.7
Left			
Index	98.5	98.9	99.0
Middle	98.7	98.9	98.9
Ring	96.9	98.4	98.7
Little	87.4	94.1	94.1

Table 34: Percentage that a particular type of fingerprint was correctly segmented on *Either* or *Both* hands. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Index			
Either	99.4	99.7	99.7
Both	94.4	94.6	94.7
Middle			
Either	99.4	99.4	99.4
Both	94.9	95.1	95.2
Ring			
Either	99.0	99.7	99.7
Both	93.2	94.3	94.6
Little			
Either	93.3	97.5	97.6
Both	79.7	87.7	88.3

Table 35: Percentage of segmentation success by hand for combinations of all eight fingers of a EightInch slap. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	96.4	96.4	96.4
At Least Two	96.1	96.1	96.1
At Least Three	95.4	95.5	95.5
All Four	83.9	89.5	90.3
Left			
Any	99.2	99.2	99.2
At Least Two	98.7	99.1	99.1
At Least Three	97.7	99.0	99.0
All Four	85.9	93.0	93.4

Table 36: Percentage of segmentation success by hand when only considering combinations of index and middle fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Either Index or Middle	96.0	96.0	96.0
Both Index and Middle	94.9	95.1	95.2
Left			
Either Index or Middle	99.2	99.2	99.2
Both Index and Middle	98.0	98.5	98.6

Table 37: Percentage of segmentation success by hand when only considering combinations of index, middle, and ring fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	96.1	96.1	96.1
At Least Two	96.0	96.0	96.0
All Three	94.1	94.5	94.6
Left			
Any	99.2	99.2	99.2
At Least Two	98.7	99.1	99.1
All Three	96.2	97.8	98.3

5.4 Handling Troublesome Images

5.4.1 Capture Failures

Segmentation algorithms may refuse to process an image. This may happen for a technical reason (e.g., the algorithm cannot parse the image data), or for a practical reason (e.g., the hand in the image is placed incorrectly). These failure scenarios are the result of capturing improper image data. In these types of scenarios, it is important to examine the cause of the failure. With many live scan capture setups, segmentation is performed immediately after capture. If an algorithm can detect that it won't be able to segment an image due to a technical or practical issue, it can alert the operator to perform a recapture before the subject leaves.

The SlapSeg III API encourages algorithms to identify these failure reasons by specifying pre-defined *deficiencies* in the image. Algorithms should attempt segmentation even if an image deficiency is encountered if at all possible. Note that SlapSeg III *guarantees* well-formed image data, so failures to parse are **not** an indicator of the data provided.

Hisign+0007 did **not** report any capture failures.

5.4.1.1 Recovery

When encountering a segmentation failure, SlapSeg III algorithms are encouraged to provide a *best-effort* segmentation when possible. In some cases, that best-effort may be correct, which reduces the amount of images that need to be manually adjudicated by an operator.

Hisign+0007 did not attempt any recovery segmentations.

5.4.2 Segmentation Failures

Even if an algorithm accepts an image for processing, it can still fail to process one or more fingers from the image, regardless of if the algorithm requested a recapture and provided best-effort segmentation.

The SlapSeg III API allows algorithms to communicate reasons for failure to process these fingers. In some cases, the distal phalanx in question might not be present in the image due to amputation or being placed outside the platen's capture area. It is imperative that the segmentation algorithm correctly report this as failing to segment the correct friction ridge generalized position without disrupting the sequence of valid positions present in the image. This can help prompt an operator to recapture or record additional information about the subject.

In SlapSeg III, a number of images are missing fingers or otherwise have fingers that will not be able to be segmented. Reasons for segmentation failures reported by Hisign+0007 are enumerated in Table 38.

Table 38: Count of self-reported segmentation failure reasoning.

Failure Reason	Fingers
Vendor Defined	523
Finger Not Found	0
Finger Found, but Can't Segment	0

5.4.3 Identifying Missing Fingers

A small portion of the test corpus in SlapSeg III are missing fingers. Table 39 shows how successful Hisign+0007 was in correctly determining if a finger was missing. The *Missed* row shows when a segmentation position was returned for a missing finger. All possible failure reasons are enumerated, but are not considered *Correctly Identified* because the algorithm specified failure for a reason other than the finger not being found.

Table 39: Performance of Hisign+0007 at detecting fingers missing from an image.

Result	Percentage
Missed	0.0
Correctly Identified	100.0
Other Failure: Finger Found, but Can't Segment	0.0
Other Failure: Vendor Defined	0.0
Other Failure: Segmentation Not Attempted	0.0

5.4.4 Sequence Error

Sequence error occurs when a fingerprint is segmented from an image but assigned an incorrect finger position (e.g., segmenting a right middle finger but labeling it a right index finger). Table 40 shows cases in which a segmentation position was returned that matched a ground truth segmentation position for a different finger in the same image.

Table 40: Percentage of images in the dataset where one or more segmentation positions correctly matched an incorrect finger position within the same image, indicating sequence error.

Hand	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Left	0.57	0.80	0.80
Right	2.99	3.33	3.33
Combined	1.78	2.07	2.07

A Tenprint Cards ("TwoInch" Data)

A.1 Bootstrap Confidence for Segmentation Statistics

This section shows the same detailed results of segmentation of TwoInch data from Section 2.3, but with an added bootstrap confidence interval. For each observation, a bootstrap routine with 1 000 replicates was run, and a 95 % confidence interval extracted. The lower and upper confidence from that confidence interval are printed in each column within square brackets.

In Table 41, results are shown of how successful `Hisign+0007` segmented fingers for each subject in the test corpus. Table 42 shows success for specific finger positions over the entire test corpus. Similarly, Table 43 shows success for segmenting the same finger position from both hands.

The remainder of the tables show success per subject when considering combinations of subsets of the fingers in each slap image. Table 44 shows success for combinations of all fingers, Table 46 for the all except the little finger, and Table 45 for just the index and middle fingers.

Table 41: For each subject, the percentage that at least *Number of Fingers* fingers were correctly segmented, regardless of hand, for a maximum of eight correctly-segmented fingers. In *Standard Scoring*, scoring rules are followed exactly. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Number of Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
1	99.7 [99.6, 99.8]	99.7 [99.6, 99.8]	99.7 [99.6, 99.8]
2	99.6 [99.4, 99.7]	99.6 [99.5, 99.7]	99.6 [99.5, 99.7]
3	99.3 [99.2, 99.4]	99.4 [99.3, 99.5]	99.5 [99.3, 99.6]
4	98.6 [98.4, 98.8]	98.8 [98.6, 99.0]	99.0 [98.8, 99.1]
5	95.2 [94.8, 95.6]	95.3 [94.9, 95.7]	95.4 [95.0, 95.7]
6	94.4 [94.0, 94.8]	94.8 [94.4, 95.2]	95.0 [94.6, 95.3]
7	91.3 [90.8, 91.8]	92.8 [92.3, 93.2]	93.2 [92.8, 93.6]
8	80.7 [80.1, 81.4]	86.2 [85.6, 86.7]	87.0 [86.4, 87.6]

Table 42: For all subjects, Percentage that a particular friction ridge generalized position was correctly segmented. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Finger	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Index	96.4 [96.2, 96.6]	97.6 [97.4, 97.8]	97.8 [97.6, 98.0]
Middle	96.1 [95.8, 96.3]	97.3 [97.1, 97.5]	97.4 [97.2, 97.6]
Ring	95.3 [95.0, 95.6]	97.3 [97.1, 97.5]	97.4 [97.2, 97.6]
Little	97.8 [97.6, 98.0]	98.6 [98.4, 98.8]	98.9 [98.7, 99.0]
Left			
Index	97.9 [97.7, 98.1]	98.3 [98.1, 98.5]	98.4 [98.3, 98.6]
Middle	97.2 [97.0, 97.5]	98.1 [97.9, 98.3]	98.2 [98.0, 98.4]
Ring	95.8 [95.5, 96.1]	97.3 [97.1, 97.5]	97.5 [97.3, 97.8]
Little	97.6 [97.4, 97.8]	98.0 [97.8, 98.2]	98.4 [98.2, 98.5]

Table 43: Percentage that a particular type of fingerprint was correctly segmented on *Either* or *Both* hands. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Index			
Either	99.2 [99.1, 99.4]	99.3 [99.1, 99.4]	99.3 [99.2, 99.5]
Both	91.1 [90.6, 91.6]	92.5 [92.0, 92.9]	92.7 [92.3, 93.2]
Middle			
Either	99.1 [99.0, 99.3]	99.3 [99.2, 99.5]	99.4 [99.3, 99.5]
Both	90.4 [89.9, 90.9]	92.1 [91.6, 92.6]	92.3 [91.8, 92.7]
Ring			
Either	98.8 [98.6, 99.0]	99.3 [99.1, 99.4]	99.4 [99.3, 99.5]
Both	89.0 [88.5, 89.6]	91.9 [91.4, 92.4]	92.2 [91.8, 92.7]
Little			
Either	99.2 [99.1, 99.4]	99.3 [99.1, 99.4]	99.4 [99.2, 99.5]
Both	91.9 [91.5, 92.4]	93.0 [92.5, 93.4]	93.6 [93.1, 94.0]

Table 44: Percentage of segmentation success by hand for combinations of all eight fingers of a TwoInch slap. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	99.6 [99.6, 99.7]	99.6 [99.6, 99.7]	99.6 [99.6, 99.7]
At Least Two	99.2 [99.2, 99.4]	99.4 [99.3, 99.5]	99.4 [99.4, 99.5]
At Least Three	97.5 [97.6, 97.9]	98.3 [98.2, 98.5]	98.4 [98.4, 98.6]
All Four	89.3 [90.1, 90.7]	93.6 [93.6, 94.1]	94.0 [94.1, 94.6]
Left			
Any	99.7 [99.6, 99.7]	99.7 [99.6, 99.7]	99.7 [99.6, 99.7]
At Least Two	99.4 [99.2, 99.4]	99.4 [99.3, 99.5]	99.5 [99.4, 99.5]
At Least Three	98.0 [97.6, 97.9]	98.4 [98.2, 98.5]	98.6 [98.4, 98.6]
All Four	91.6 [90.1, 90.7]	94.2 [93.6, 94.1]	94.7 [94.1, 94.6]

Table 45: Percentage of segmentation success by hand when only considering combinations of index and middle fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Either Index or Middle	98.7 [98.8, 99.0]	98.9 [98.9, 99.1]	98.9 [98.9, 99.1]
Both Index and Middle	93.8 [94.6, 95.0]	96.1 [96.4, 96.8]	96.4 [96.7, 97.0]
Left			
Either Index or Middle	99.1 [98.8, 99.0]	99.2 [98.9, 99.1]	99.2 [98.9, 99.1]
Both Index and Middle	96.1 [94.6, 95.0]	97.2 [96.4, 96.8]	97.4 [96.7, 97.0]

Table 46: Percentage of segmentation success by hand when only considering combinations of index, middle, and ring fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	99.4 [99.4, 99.6]	99.5 [99.5, 99.6]	99.5 [99.5, 99.7]
At Least Two	97.9 [98.0, 98.2]	98.5 [98.5, 98.7]	98.6 [98.6, 98.8]
All Three	90.5 [91.4, 91.9]	94.2 [94.5, 94.9]	94.6 [94.9, 95.3]
Left			
Any	99.6 [99.4, 99.6]	99.6 [99.5, 99.6]	99.7 [99.5, 99.7]
At Least Two	98.4 [98.0, 98.2]	98.7 [98.5, 98.7]	98.8 [98.6, 98.8]
All Three	93.0 [91.4, 91.9]	95.3 [94.5, 94.9]	95.7 [94.9, 95.3]

A.2 Jaccard Index

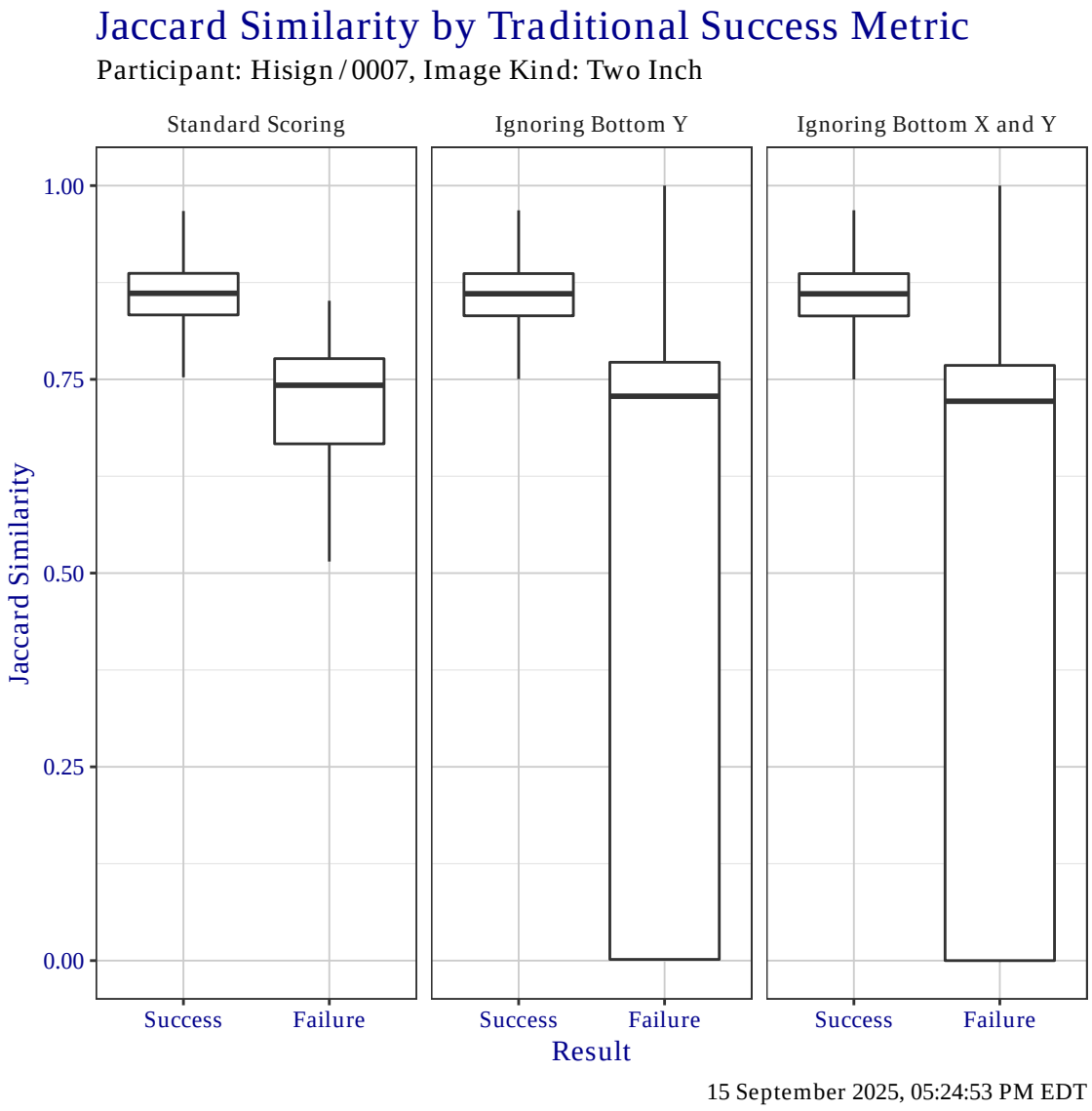

Figure 23: Boxplot of Jaccard similarity indices as compared to the traditional success metrics. Outliers have been removed for clarity.

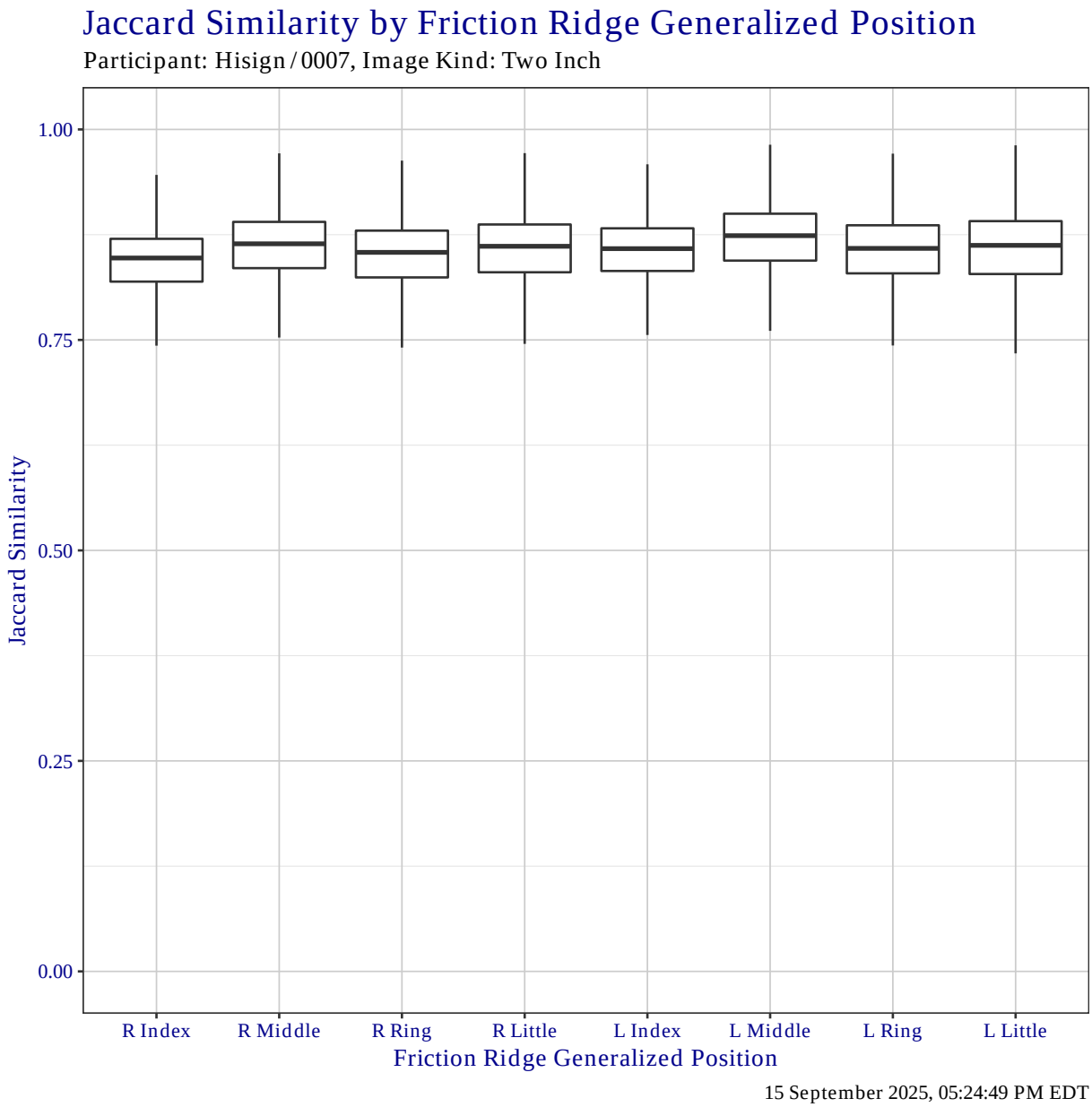

Figure 24: Boxplot of Jaccard similarity indices for each friction ridge generalized position. Outliers have been removed for clarity.

Table 47: For each subject, the percentage that at least *Number of Fingers* fingers were segmented with a Jaccard index in the indicated range.

Number of Fingers	≥0.5	≥0.6	≥0.7	≥0.8	≥0.9	≥0.95	≥0.98
1	99.8	99.8	99.8	99.6	62.8	4.3	0.1
2	99.7	99.7	99.7	99.1	33.2	0.3	0.0
3	99.7	99.6	99.5	98.0	15.0	0.0	0.0
4	99.5	99.4	99.0	96.1	5.7	0.0	0.0
5	95.5	95.5	95.5	92.3	1.6	0	0
6	95.3	95.3	95.3	87.1	0.3	0	0
7	94.4	94.4	94.1	75.5	0.1	0	0
8	94.0	93.8	90.5	49.3	0.0	0	0

Table 48: For all subjects, percentage that a particular friction ridge generalized position was segmented with a Jaccard index in the indicated range.

Finger	0-0.5	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1.0
Right						
Index	1.1	0.0	0.7	13.1	80.5	4.6
Middle	1.0	0.0	0.3	7.7	73.6	17.4
Ring	0.4	0.0	0.4	11.5	76.4	11.3
Little	0.3	0.1	0.6	9.7	74.6	14.7
Left						
Index	0.6	0.1	0.4	8.3	78.7	11.9
Middle	0.7	0.0	0.3	6.1	67.9	25.0
Ring	0.5	0.0	0.5	10.0	74.1	14.9
Little	0.8	0.1	0.8	11.1	69.1	18.1

Table 49: Percentage of segmentation obtaining a Jaccard index in the indicated ranges, by hand, for combinations of all eight fingers of a TwoInch slap.

Fingers	≥0.5	≥0.6	≥0.7	≥0.8	≥0.9	≥0.95	≥0.98
Right							
Any	99.7	99.7	99.7	99.1	35.7	1.3	0.0
At Least Two	99.6	99.6	99.6	97.1	10.1	0.0	0.0
At Least Three	99.0	99.0	98.9	90.2	2.0	0.0	0.0
All Four	98.9	98.7	96.9	66.6	0.2	0.0	0.0
Left							
Any	99.8	99.8	99.8	99.4	45.6	3.1	0.1
At Least Two	99.7	99.7	99.6	97.6	18.0	0.2	0.0
At Least Three	99.2	99.2	99.0	91.9	5.4	0.0	0.0
All Four	98.8	98.6	96.8	70.8	0.9	0.0	0.0

Table 50: Percentage of segmentation obtaining a Jaccard index in the indicated ranges, by hand, for combinations of index and middle fingers of a TwoInch slap.

Fingers	≥0.5	≥0.6	≥0.7	≥0.8	≥0.9	≥0.95	≥0.98
Right							
Either Index or Middle	99.0	99.0	99.0	96.8	20.7	0.7	0.0
Both Index and Middle	98.9	98.8	97.9	79.3	1.3	0.0	0.0
Left							
Either Index or Middle	99.4	99.4	99.4	97.6	31.7	1.7	0.0
Both Index and Middle	99.2	99.2	98.5	85.8	5.1	0.0	0.0

Table 51: Percentage of segmentation obtaining a Jaccard index in the indicated ranges, by hand, for combinations of index, middle, and ring fingers of a TwoInch slap.

Fingers	≥0.5	≥0.6	≥0.7	≥0.8	≥0.9	≥0.95	≥0.98
Right							
Any	99.7	99.7	99.7	98.5	27.5	1.1	0.0
At Least Two	99.0	99.0	98.9	93.1	5.3	0.0	0.0
All Three	98.9	98.8	97.5	72.1	0.5	0.0	0.0
Left							
Any	99.8	99.8	99.8	98.9	38.4	2.2	0.1
At Least Two	99.3	99.3	99.2	95.0	11.3	0.1	0.0
All Three	99.1	99.0	97.9	78.6	2.0	0.0	0.0

B Identification Flats ("ThreeInch" Data)

B.1 Bootstrap Confidence for Segmentation Statistics

This section shows the same detailed results of segmentation of ThreeInch data from Section 3.3, but with an added bootstrap confidence interval. For each observation, a bootstrap routine with 1 000 replicates was run, and a 95 % confidence interval extracted. The lower and upper confidence from that confidence interval are printed in each column within square brackets.

In Table 52, results are shown of how successful `Hisign+0007` segmented fingers for each subject in the test corpus. Table 53 shows success for specific finger positions over the entire test corpus. Similarly, Table 54 shows success for segmenting the same finger position from both hands.

The remainder of the tables show success per subject when considering combinations of subsets of the fingers in each slap image. Table 55 shows success for combinations of all fingers, Table 57 for the all except the little finger, and Table 56 for just the index and middle fingers.

Table 52: For each subject, the percentage that at least *Number of Fingers* fingers were correctly segmented, regardless of hand, for a maximum of eight correctly-segmented fingers. In *Standard Scoring*, scoring rules are followed exactly. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Number of Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
1	99.7 [99.6, 99.8]	99.7 [99.6, 99.8]	99.7 [99.6, 99.8]
2	99.4 [99.3, 99.5]	99.5 [99.4, 99.5]	99.5 [99.4, 99.6]
3	98.4 [98.2, 98.5]	98.4 [98.2, 98.5]	98.4 [98.3, 98.6]
4	97.7 [97.5, 97.8]	97.7 [97.5, 97.9]	98.1 [97.9, 98.2]
5	95.7 [95.4, 95.9]	95.7 [95.4, 95.9]	95.9 [95.6, 96.1]
6	95.1 [94.9, 95.4]	95.2 [94.9, 95.4]	95.5 [95.3, 95.8]
7	94.0 [93.7, 94.3]	94.0 [93.7, 94.3]	94.9 [94.6, 95.1]
8	90.8 [90.5, 91.2]	91.0 [90.6, 91.3]	93.7 [93.4, 94.0]
9	78.4 [77.9, 78.9]	78.7 [78.2, 79.3]	87.4 [87.0, 87.9]
10	54.5 [53.9, 55.1]	55.2 [54.6, 55.8]	71.9 [71.3, 72.4]

Table 53: For all subjects, Percentage that a particular friction ridge generalized position was correctly segmented. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Finger	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Thumb	93.3 [93.0, 93.7]	93.9 [93.6, 94.2]	94.1 [93.8, 94.4]
Index	98.2 [98.0, 98.3]	98.2 [98.0, 98.3]	98.6 [98.4, 98.7]
Middle	97.5 [97.3, 97.7]	97.5 [97.3, 97.7]	98.5 [98.3, 98.6]
Ring	92.7 [92.4, 93.0]	92.7 [92.4, 93.0]	94.9 [94.6, 95.2]
Little	83.9 [83.4, 84.3]	83.9 [83.4, 84.3]	93.0 [92.6, 93.3]
Left			
Thumb	92.0 [91.6, 92.3]	92.6 [92.2, 92.9]	92.9 [92.6, 93.2]
Index	97.5 [97.3, 97.7]	97.5 [97.3, 97.7]	98.4 [98.2, 98.5]
Middle	97.7 [97.5, 97.9]	97.7 [97.5, 97.9]	98.9 [98.7, 99.0]
Ring	95.8 [95.5, 96.0]	95.8 [95.5, 96.0]	98.0 [97.8, 98.2]
Little	80.0 [79.5, 80.5]	80.0 [79.5, 80.5]	93.2 [92.9, 93.5]

Table 54: Percentage that a particular type of fingerprint was correctly segmented on *Either* or *Both* hands. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Thumb			
Either	96.2 [96.0, 96.4]	96.3 [96.1, 96.6]	96.4 [96.2, 96.6]
Both	89.2 [88.8, 89.6]	90.3 [89.9, 90.6]	90.7 [90.3, 91.0]
Index			
Either	99.6 [99.5, 99.7]	99.6 [99.5, 99.7]	99.8 [99.7, 99.9]
Both	93.5 [93.2, 93.8]	93.5 [93.2, 93.9]	94.5 [94.3, 94.8]
Middle			
Either	99.6 [99.5, 99.7]	99.6 [99.5, 99.6]	99.8 [99.7, 99.8]
Both	93.0 [92.7, 93.3]	93.0 [92.7, 93.4]	94.9 [94.7, 95.2]
Ring			
Either	98.9 [98.8, 99.1]	98.9 [98.8, 99.1]	99.6 [99.5, 99.7]
Both	87.0 [86.5, 87.4]	87.0 [86.6, 87.4]	90.8 [90.4, 91.1]
Little			
Either	91.8 [91.5, 92.2]	91.8 [91.5, 92.1]	98.2 [98.0, 98.4]
Both	69.9 [69.3, 70.4]	69.9 [69.3, 70.4]	85.6 [85.2, 86.0]

Table 55: Percentage of segmentation success by hand for combinations of all ten fingers of a ThreeInch slap. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	99.5 [99.5, 99.6]	99.5 [99.5, 99.6]	99.5 [99.5, 99.6]
At Least Two	97.7 [97.9, 98.2]	97.7 [97.9, 98.2]	97.8 [98.0, 98.2]
At Least Three	97.1 [97.2, 97.5]	97.1 [97.2, 97.5]	97.4 [97.6, 97.9]
At Least Four	93.1 [92.8, 93.3]	93.2 [92.9, 93.4]	95.3 [95.6, 95.9]
All Five	69.5 [67.3, 68.1]	70.0 [67.8, 68.6]	80.2 [79.9, 80.6]
Left			
Any	99.6 [99.5, 99.6]	99.6 [99.5, 99.6]	99.6 [99.5, 99.6]
At Least Two	98.3 [97.9, 98.2]	98.3 [97.9, 98.2]	98.4 [98.0, 98.2]
At Least Three	97.6 [97.2, 97.5]	97.6 [97.2, 97.5]	98.1 [97.6, 97.9]
At Least Four	93.0 [92.8, 93.3]	93.1 [92.9, 93.4]	96.2 [95.6, 95.9]
All Five	65.8 [67.3, 68.1]	66.3 [67.8, 68.6]	80.2 [79.9, 80.6]

Table 56: Percentage of segmentation success by hand when only considering combinations of index and middle fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Either Index or Middle	99.1 [99.3, 99.4]	99.1 [99.3, 99.4]	99.1 [99.4, 99.5]
Both Index and Middle	96.6 [95.9, 96.3]	96.6 [95.9, 96.3]	98.0 [97.6, 97.8]
Left			
Either Index or Middle	99.6 [99.3, 99.4]	99.6 [99.3, 99.4]	99.8 [99.4, 99.5]
Both Index and Middle	95.6 [95.9, 96.3]	95.6 [95.9, 96.3]	97.5 [97.6, 97.8]

Table 57: Percentage of segmentation success by hand when only considering combinations of index, middle, and ring fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	99.1 [99.4, 99.5]	99.1 [99.4, 99.5]	99.2 [99.5, 99.6]
At Least Two	98.3 [98.6, 98.8]	98.3 [98.6, 98.8]	98.8 [99.1, 99.2]
All Three	90.9 [91.3, 91.8]	90.9 [91.3, 91.8]	94.0 [94.7, 95.1]
Left			
Any	99.8 [99.4, 99.5]	99.8 [99.4, 99.5]	99.9 [99.5, 99.6]
At Least Two	99.0 [98.6, 98.8]	99.0 [98.6, 98.8]	99.5 [99.1, 99.2]
All Three	92.2 [91.3, 91.8]	92.2 [91.3, 91.8]	95.9 [94.7, 95.1]

B.2 Jaccard Index

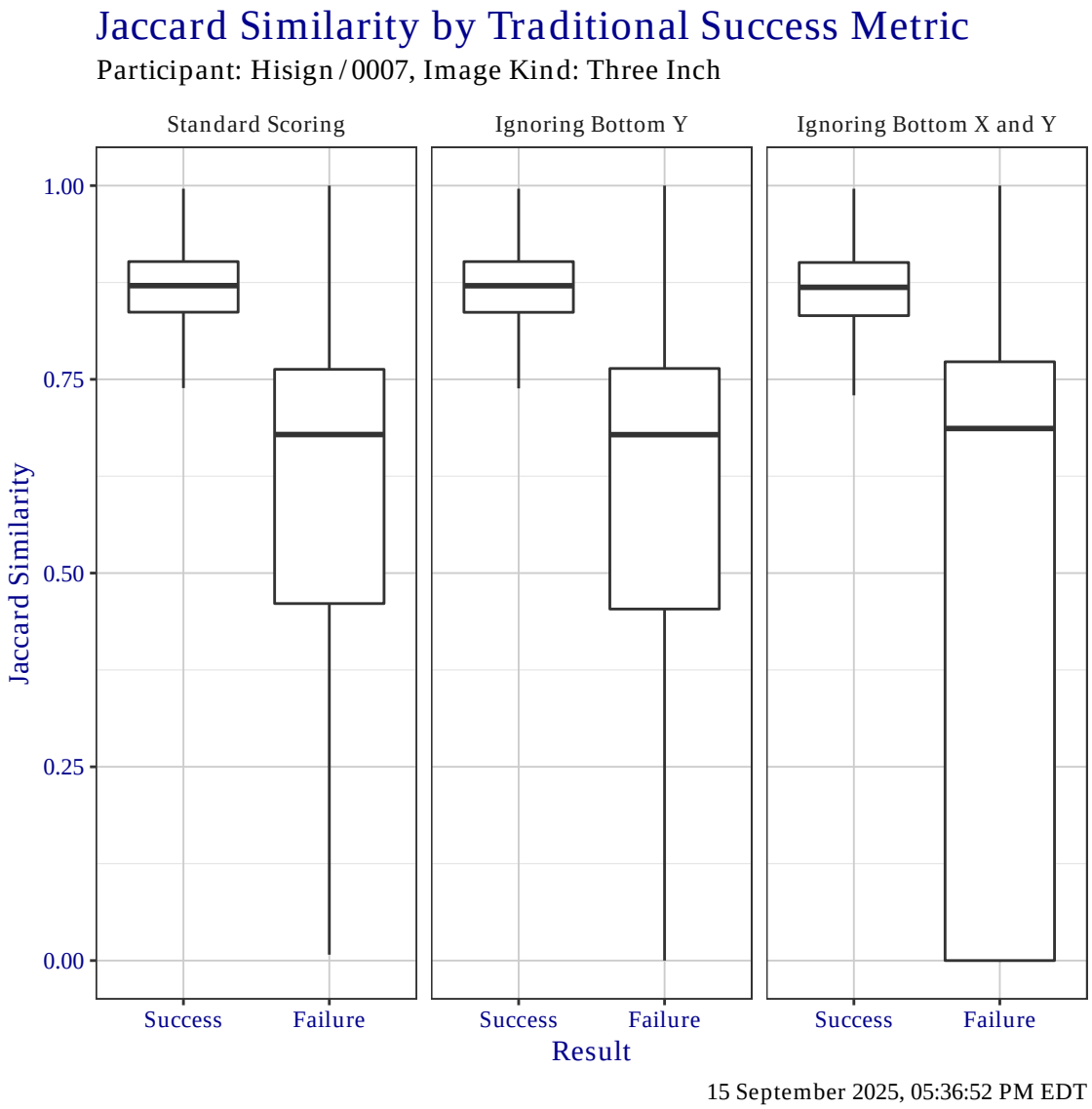

Figure 25: Boxplot of Jaccard similarity indices as compared to the traditional success metrics. Outliers have been removed for clarity.

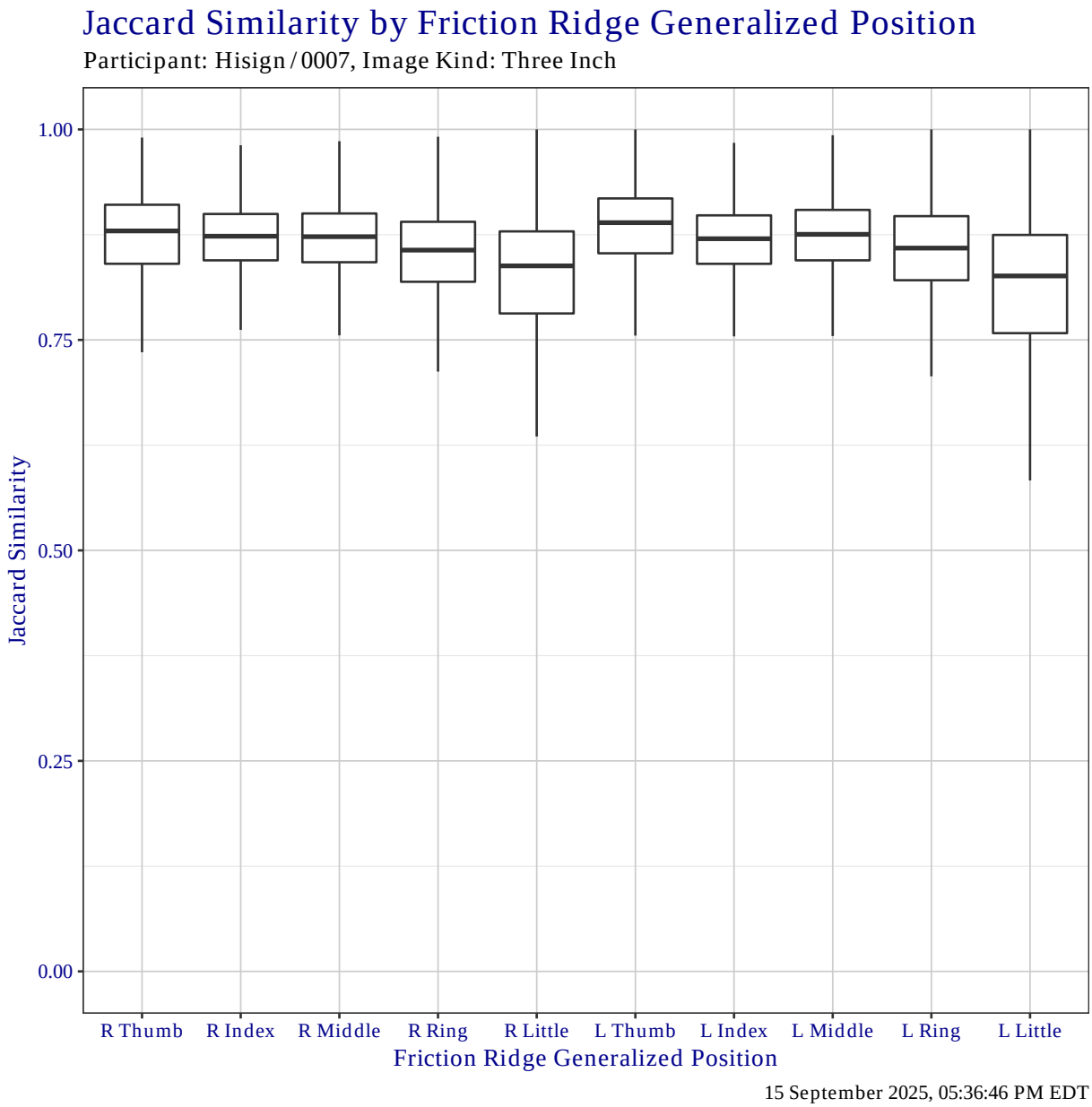

Figure 26: Boxplot of Jaccard similarity indices for each friction ridge generalized position. Outliers have been removed for clarity.

Table 58: For each subject, the percentage that at least *Number of Fingers* fingers were segmented with a Jaccard index in the indicated range.

Number of Fingers	≥0.5	≥0.6	≥0.7	≥0.8	≥0.9	≥0.95	≥0.98
1	99.7	99.7	99.7	99.6	86.4	20.9	1.0
2	99.6	99.6	99.6	99.2	65.3	3.6	0.0
3	98.5	98.5	98.4	98.0	42.4	0.5	0.0
4	98.2	98.1	97.9	96.8	24.6	0.1	0.0
5	95.9	95.9	95.8	94.1	12.5	0.0	0.0
6	95.6	95.5	95.4	91.7	5.5	0.0	0
7	95.2	95.2	95.0	86.4	2.1	0	0
8	95.1	94.9	94.1	76.0	0.6	0	0
9	91.5	90.0	86.4	55.8	0.1	0	0
10	84.7	79.8	69.5	29.0	0.0	0	0

Table 59: For all subjects, percentage that a particular friction ridge generalized position was segmented with a Jaccard index in the indicated range.

Finger	0-0.5	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1.0
Right						
Thumb	2.8	0.1	0.7	7.9	55.1	33.4
Index	0.9	0.1	0.3	5.5	68.5	24.7
Middle	0.9	0.0	0.3	6.3	67.3	25.2
Ring	0.8	0.1	1.1	14.5	64.9	18.6
Little	3.8	2.6	5.0	19.9	54.4	14.3
Left						
Thumb	3.8	0.1	0.5	4.9	50.1	40.6
Index	0.2	0.1	0.4	7.2	68.7	23.4
Middle	0.2	0.0	0.4	6.6	64.4	28.4
Ring	0.2	0.1	0.7	14.2	61.5	23.3
Little	6.1	3.7	6.4	21.9	47.2	14.7

Table 60: Percentage of segmentation obtaining a Jaccard index in the indicated ranges, by hand, for combinations of all ten fingers of a ThreeInch slap.

Fingers	≥0.5	≥0.6	≥0.7	≥0.8	≥0.9	≥0.95	≥0.98
Right							
Any	99.7	99.7	99.6	99.2	65.9	9.5	0.4
At Least Two	97.8	97.8	97.8	96.6	31.0	0.9	0.0
At Least Three	97.8	97.8	97.6	93.1	12.5	0.1	0.0
At Least Four	97.5	97.3	96.4	81.3	3.8	0.0	0.0
All Five	89.0	86.4	80.2	48.3	0.6	0.0	0.0
Left							
Any	99.7	99.7	99.7	99.4	70.1	13.2	0.7
At Least Two	98.4	98.4	98.4	96.7	35.3	1.5	0.0
At Least Three	98.4	98.4	98.2	92.5	15.8	0.1	0.0
At Least Four	97.9	97.6	96.4	80.1	5.4	0.0	0.0
All Five	86.0	82.3	75.3	45.5	0.9	0.0	0.0

Table 61: Percentage of segmentation obtaining a Jaccard index in the indicated ranges, by hand, for combinations of index and middle fingers of a ThreeInch slap.

Fingers	≥0.5	≥0.6	≥0.7	≥0.8	≥0.9	≥0.95	≥0.98
Right							
Either Index or Middle	99.2	99.2	99.1	97.3	39.2	3.9	0.2
Both Index and Middle	99.1	99.0	98.4	88.4	10.7	0.2	0.0
Left							
Either Index or Middle	99.9	99.9	99.9	97.8	40.5	4.6	0.2
Both Index and Middle	99.7	99.6	98.8	87.1	11.2	0.2	0.0

Table 62: Percentage of segmentation obtaining a Jaccard index in the indicated ranges, by hand, for combinations of index, middle, and ring fingers of a ThreeInch slap.

Fingers	≥0.5	≥0.6	≥0.7	≥0.8	≥0.9	≥0.95	≥0.98
Right							
Any	99.2	99.2	99.2	97.9	45.8	5.4	0.3
At Least Two	99.2	99.1	99.0	93.9	18.1	0.5	0.0
All Three	99.1	99.0	97.4	77.4	4.6	0.1	0.0
Left							
Any	99.9	99.9	99.9	98.5	48.2	7.1	0.3
At Least Two	99.9	99.9	99.7	93.7	21.0	0.7	0.0
All Three	99.7	99.5	98.0	77.5	5.9	0.0	0

C Upper Palm ("FiveInch" Data)

C.1 Bootstrap Confidence for Segmentation Statistics

This section shows the same detailed results of segmentation of FiveInch data from Section 4.3, but with an added bootstrap confidence interval. For each observation, a bootstrap routine with 1 000 replicates was run, and a 95 % confidence interval extracted. The lower and upper confidence from that confidence interval are printed in each column within square brackets.

In Table 63, results are shown of how successful Hisign+0007 segmented fingers for each subject in the test corpus. Table 64 shows success for specific finger positions over the entire test corpus. Similarly, Table 65 shows success for segmenting the same finger position from both hands.

The remainder of the tables show success per subject when considering combinations of subsets of the fingers in each slap image. Table 66 shows success for combinations of all fingers, Table 68 for the all except the little finger, and Table 67 for just the index and middle fingers.

Table 63: For each subject, the percentage that at least *Number of Fingers* fingers were correctly segmented, regardless of hand, for a maximum of eight correctly-segmented fingers. In *Standard Scoring*, scoring rules are followed exactly. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Number of Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
1	91.4 [89.3, 93.4]	91.4 [89.5, 93.4]	91.6 [89.6, 93.4]
2	85.8 [83.3, 88.1]	86.0 [83.5, 88.4]	86.0 [83.5, 88.5]
3	81.9 [79.1, 84.7]	82.5 [79.6, 85.1]	82.6 [79.8, 85.2]
4	78.5 [75.6, 81.4]	80.2 [77.6, 83.0]	80.2 [77.1, 83.1]
5	72.3 [69.2, 75.6]	73.0 [70.0, 76.1]	73.0 [69.7, 76.4]
6	66.9 [63.6, 69.8]	67.2 [63.8, 70.4]	67.3 [64.0, 70.8]
7	62.1 [58.8, 65.7]	64.2 [60.7, 67.3]	64.3 [60.7, 67.6]
8	48.9 [45.3, 52.4]	53.6 [50.1, 57.3]	54.8 [51.4, 58.4]

Table 64: For all subjects, Percentage that a particular friction ridge generalized position was correctly segmented. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Finger	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Index	72.7 [69.5, 75.9]	72.9 [69.5, 76.1]	73.0 [69.8, 76.1]
Middle	72.5 [69.1, 75.7]	72.6 [69.7, 75.8]	72.9 [69.8, 76.1]
Ring	76.5 [73.5, 79.5]	77.5 [74.2, 80.6]	77.5 [74.7, 80.6]
Little	81.2 [78.5, 83.8]	83.6 [81.0, 86.4]	83.8 [81.2, 86.4]
Left			
Index	79.0 [76.3, 82.1]	80.5 [77.7, 83.3]	80.5 [77.6, 83.6]
Middle	73.6 [70.2, 76.7]	73.9 [70.7, 76.9]	74.0 [70.8, 77.2]
Ring	73.1 [70.0, 76.0]	74.7 [71.5, 77.6]	74.7 [71.4, 77.9]
Little	63.9 [60.5, 67.1]	67.2 [63.8, 70.4]	68.3 [65.0, 71.5]

Table 65: Percentage that a particular type of fingerprint was correctly segmented on *Either* or *Both* hands. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Index			
Either	84.3 [81.7, 86.8]	85.1 [82.5, 87.5]	85.2 [82.9, 87.9]
Both	66.3 [62.7, 69.7]	67.1 [63.6, 70.2]	67.1 [63.5, 70.5]
Middle			
Either	80.9 [78.0, 83.8]	80.9 [78.1, 83.5]	81.0 [78.0, 83.8]
Both	64.0 [60.6, 67.5]	64.4 [61.1, 67.9]	64.7 [61.1, 68.0]
Ring			
Either	83.1 [80.4, 85.9]	83.7 [80.9, 86.6]	83.7 [81.0, 86.3]
Both	65.2 [61.8, 68.6]	67.3 [64.0, 70.9]	67.3 [63.9, 70.5]
Little			
Either	86.3 [83.8, 88.9]	89.2 [86.8, 91.4]	89.3 [87.1, 91.6]
Both	57.7 [54.2, 61.0]	60.5 [56.9, 64.0]	61.5 [58.0, 65.0]

Table 66: Percentage of segmentation success by hand for combinations of all eight fingers of a FiveInch slap. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	86.7 [82.6, 86.4]	86.7 [82.7, 86.4]	86.8 [83.0, 86.6]
At Least Two	77.5 [74.2, 78.7]	77.9 [74.6, 79.0]	78.1 [74.6, 78.9]
At Least Three	73.4 [71.0, 75.4]	73.7 [71.5, 76.2]	73.8 [71.7, 76.0]
All Four	65.3 [59.6, 64.5]	68.4 [63.9, 68.7]	68.5 [64.6, 69.3]
Left			
Any	82.2 [82.6, 86.4]	82.5 [82.7, 86.4]	82.5 [83.0, 86.6]
At Least Two	75.3 [74.2, 78.7]	75.5 [74.6, 79.0]	75.5 [74.6, 78.9]
At Least Three	73.2 [71.0, 75.4]	74.0 [71.5, 76.2]	74.0 [71.7, 76.0]
All Four	58.9 [59.6, 64.5]	64.3 [63.9, 68.7]	65.5 [64.6, 69.3]

Table 67: Percentage of segmentation success by hand when only considering combinations of index and middle fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Either Index or Middle	74.2 [75.9, 80.3]	74.3 [76.2, 80.3]	74.5 [76.4, 80.5]
Both Index and Middle	71.0 [68.5, 73.1]	71.1 [69.3, 74.0]	71.4 [69.6, 74.2]
Left			
Either Index or Middle	82.0 [75.9, 80.3]	82.1 [76.2, 80.3]	82.1 [76.4, 80.5]
Both Index and Middle	70.7 [68.5, 73.1]	72.3 [69.3, 74.0]	72.4 [69.6, 74.2]

Table 68: Percentage of segmentation success by hand when only considering combinations of index, middle, and ring fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	77.9 [77.9, 82.0]	78.2 [78.2, 82.2]	78.2 [78.3, 82.3]
At Least Two	73.9 [72.4, 76.8]	74.1 [72.4, 76.8]	74.3 [72.6, 77.1]
All Three	69.8 [66.7, 71.2]	70.7 [68.7, 73.2]	70.9 [68.7, 73.4]
Left			
Any	82.0 [77.9, 82.0]	82.4 [78.2, 82.2]	82.4 [78.3, 82.3]
At Least Two	75.2 [72.4, 76.8]	75.3 [72.4, 76.8]	75.3 [72.6, 77.1]
All Three	68.6 [66.7, 71.2]	71.4 [68.7, 73.2]	71.5 [68.7, 73.4]

C.2 Jaccard Index

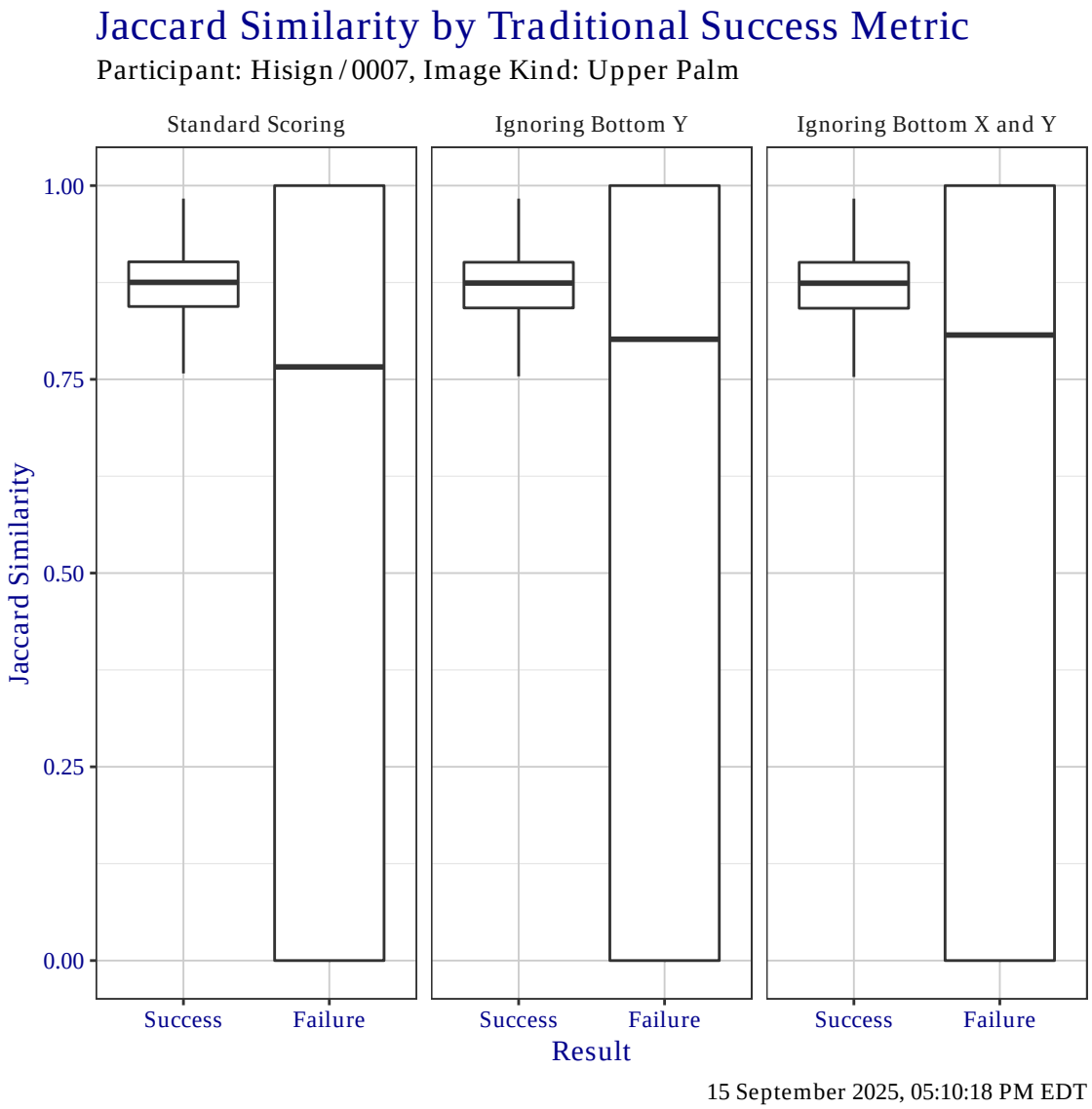

Figure 27: Boxplot of Jaccard similarity indices as compared to the traditional success metrics. Outliers have been removed for clarity.

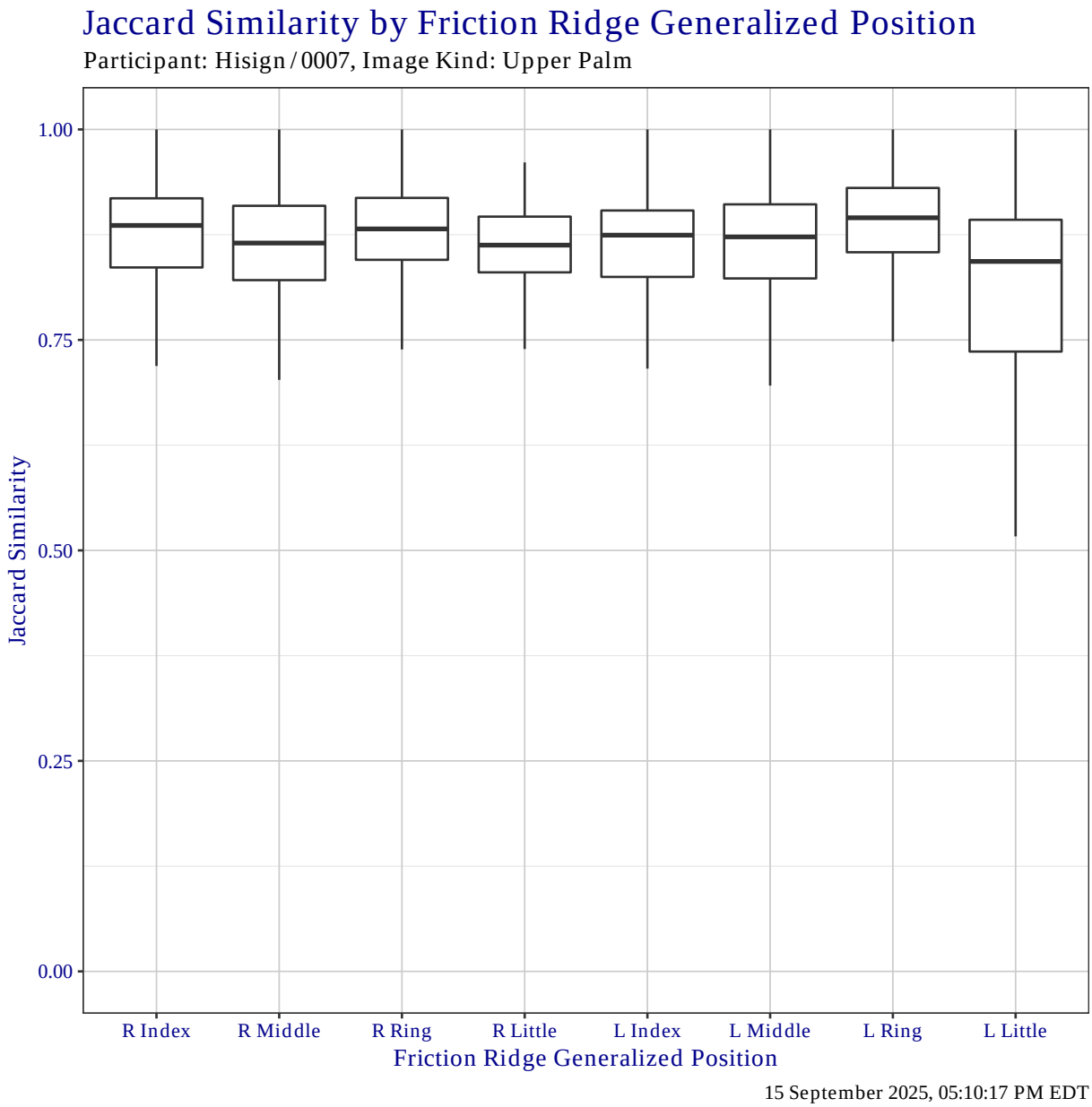

Figure 28: Boxplot of Jaccard similarity indices for each friction ridge generalized position. Outliers have been removed for clarity.

Table 69: For each subject, the percentage that at least *Number of Fingers* fingers were segmented with a Jaccard index in the indicated range.

Number of Fingers	≥0.5	≥0.6	≥0.7	≥0.8	≥0.9	≥0.95	≥0.98
1	99.2	99.2	98.9	98.9	83.5	27.9	22.0
2	98.9	98.9	98.7	97.9	62.7	18.6	18.1
3	97.9	97.8	97.4	95.9	41.8	15.2	15.0
4	94.7	94.5	93.5	91.0	26.1	12.8	12.6
5	88.1	88.0	87.5	83.9	15.9	9.6	9.6
6	82.5	82.3	81.6	75.1	9.9	7.8	7.8
7	74.3	73.8	72.7	60.1	5.9	5.8	5.8
8	69.2	67.6	63.0	42.0	5.0	4.9	4.9

Table 70: For all subjects, percentage that a particular friction ridge generalized position was segmented with a Jaccard index in the indicated range.

Finger	0-0.5	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1.0
Right						
Index	13.0	0.1	0.5	3.2	45.0	38.2
Middle	10.0	0	0.6	6.8	53.2	29.4
Ring	9.0	0.3	0.4	3.4	51.1	35.8
Little	5.8	0.5	1.5	7.6	61.7	22.9
Left						
Index	10.6	0.3	1.7	7.0	52.8	27.6
Middle	11.7	0.3	1.0	7.4	47.9	31.7
Ring	9.0	0	0.9	3.4	40.9	45.8
Little	20.3	1.3	2.1	9.8	44.9	21.6

Table 71: Percentage of segmentation obtaining a Jaccard index in the indicated ranges, by hand, for combinations of all ten fingers of a FiveInch slap.

Fingers	≥0.5	≥0.6	≥0.7	≥0.8	≥0.9	≥0.95	≥0.98
Right							
Any	96.8	96.8	96.5	96.4	66.2	20.6	17.7
At Least Two	94.7	94.7	94.5	92.4	34.4	14.0	13.8
At Least Three	87.9	87.8	87.4	83.2	17.0	12.1	12.1
All Four	82.7	81.9	79.7	65.0	8.5	7.8	7.8
Left							
Any	96.6	96.6	96.2	95.2	67.9	21.0	17.2
At Least Two	91.2	91.2	90.8	89.4	37.0	13.4	13.4
At Least Three	82.8	82.5	82.0	75.6	14.5	7.8	7.8
All Four	77.9	76.3	71.8	52.8	7.3	6.6	6.6

Table 72: Percentage of segmentation obtaining a Jaccard index in the indicated ranges, by hand, for combinations of index and middle fingers of a FiveInch slap.

Fingers	≥0.5	≥0.6	≥0.7	≥0.8	≥0.9	≥0.95	≥0.98
Right							
Either Index or Middle	91.4	91.4	91.2	89.9	49.3	18.4	17.3
Both Index and Middle	85.6	85.5	84.4	75.8	18.2	12.8	12.8
Left							
Either Index or Middle	95.6	95.6	95.4	92.4	45.9	14.9	13.9
Both Index and Middle	82.1	81.6	79.0	67.5	13.4	7.4	7.4

Table 73: Percentage of segmentation obtaining a Jaccard index in the indicated ranges, by hand, for combinations of index, middle, and ring fingers of a FiveInch slap.

Fingers	≥0.5	≥0.6	≥0.7	≥0.8	≥0.9	≥0.95	≥0.98
Right							
Any	94.9	94.9	94.8	94.1	60.6	20.1	17.7
At Least Two	88.4	88.4	88.2	85.4	28.3	14.0	13.8
All Three	84.6	84.2	83.0	73.0	14.4	11.7	11.7
Left							
Any	96.4	96.4	96.0	94.8	63.7	19.4	16.6
At Least Two	91.0	91.0	90.6	86.9	31.3	13.3	13.3
All Three	81.3	80.8	77.9	64.9	10.1	7.4	7.4

D Full Palm ("EightInch" Data)

D.1 Bootstrap Confidence for Segmentation Statistics

NOTE: *The following segmentation statistics are based on a limited subset (approximately 15%) of the anticipated Full Palm dataset. This analysis will be updated as soon as NIST can obtain the remainder of the dataset.*

This section shows the same detailed results of segmentation of EightInch data from Section 5.3, but with an added bootstrap confidence interval. For each observation, a bootstrap routine with 1 000 replicates was run, and a 95 % confidence interval extracted. The lower and upper confidence from that confidence interval are printed in each column within square brackets.

In Table 74, results are shown of how successful `Hisign+0007` segmented fingers for each subject in the test corpus. Table 75 shows success for specific finger positions over the entire test corpus. Similarly, Table 76 shows success for segmenting the same finger position from both hands.

The remainder of the tables show success per subject when considering combinations of subsets of the fingers in each slap image. Table 77 shows success for combinations of all fingers, Table 79 for the all except the little finger, and Table 78 for just the index and middle fingers.

Table 74: For each subject, the percentage that at least *Number of Fingers* fingers were correctly segmented, regardless of hand, for a maximum of eight correctly-segmented fingers. In *Standard Scoring*, scoring rules are followed exactly. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Number of Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
1	99.7 [99.2, 100.0]	99.7 [99.2, 100.0]	99.7 [99.3, 100.0]
2	99.4 [98.9, 99.9]	99.7 [99.2, 100.0]	99.7 [99.2, 100.0]
3	99.0 [98.3, 99.5]	99.7 [99.2, 100.0]	99.7 [99.2, 100.0]
4	96.9 [95.7, 97.9]	97.6 [96.6, 98.6]	97.6 [96.4, 98.5]
5	96.0 [94.6, 97.2]	96.0 [94.7, 97.2]	96.0 [94.6, 97.1]
6	95.1 [93.4, 96.4]	95.5 [94.1, 96.8]	95.5 [94.1, 96.9]
7	90.5 [88.5, 92.3]	94.5 [92.9, 96.0]	94.6 [93.0, 96.1]
8	76.9 [74.1, 79.5]	85.3 [82.9, 87.6]	86.4 [84.1, 88.7]

Table 75: For all subjects, Percentage that a particular friction ridge generalized position was correctly segmented. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Finger	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Index	95.3 [93.8, 96.6]	95.4 [93.9, 96.8]	95.4 [94.1, 96.8]
Middle	95.6 [94.3, 97.0]	95.6 [94.3, 96.9]	95.7 [94.4, 97.0]
Ring	95.3 [93.7, 96.6]	95.5 [94.1, 96.9]	95.5 [94.0, 96.8]
Little	85.6 [83.2, 87.8]	91.0 [89.0, 93.0]	91.7 [89.9, 93.4]
Left			
Index	98.5 [97.7, 99.3]	98.9 [98.0, 99.5]	99.0 [98.3, 99.7]
Middle	98.7 [97.9, 99.4]	98.9 [98.0, 99.5]	98.9 [98.2, 99.5]
Ring	96.9 [95.6, 97.9]	98.4 [97.5, 99.2]	98.7 [97.9, 99.4]
Little	87.4 [85.2, 89.5]	94.1 [92.6, 95.6]	94.1 [92.5, 95.6]

Table 76: Percentage that a particular type of fingerprint was correctly segmented on *Either* or *Both* hands. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Index			
Either	99.4 [98.9, 99.9]	99.7 [99.2, 100.0]	99.7 [99.2, 100.0]
Both	94.4 [92.8, 95.9]	94.6 [93.1, 96.1]	94.7 [93.1, 96.2]
Middle			
Either	99.4 [98.9, 99.9]	99.4 [98.9, 99.9]	99.4 [98.9, 99.9]
Both	94.9 [93.4, 96.4]	95.1 [93.7, 96.6]	95.2 [93.7, 96.6]
Ring			
Either	99.0 [98.3, 99.5]	99.7 [99.2, 100.0]	99.7 [99.3, 100.0]
Both	93.2 [91.5, 94.8]	94.3 [92.6, 95.7]	94.6 [93.0, 96.1]
Little			
Either	93.3 [91.6, 94.9]	97.5 [96.3, 98.5]	97.6 [96.6, 98.5]
Both	79.7 [77.0, 82.4]	87.7 [85.5, 89.9]	88.3 [86.1, 90.3]

Table 77: Percentage of segmentation success by hand for combinations of all eight fingers of a EightInch slap. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	96.4 [97.1, 98.5]	96.4 [97.1, 98.4]	96.4 [97.2, 98.5]
At Least Two	96.1 [96.6, 98.2]	96.1 [96.8, 98.3]	96.1 [96.8, 98.3]
At Least Three	95.4 [95.7, 97.4]	95.5 [96.4, 98.0]	95.5 [96.4, 98.0]
All Four	83.9 [83.1, 86.6]	89.5 [89.9, 92.5]	90.3 [90.6, 93.2]
Left			
Any	99.2 [97.1, 98.5]	99.2 [97.1, 98.4]	99.2 [97.2, 98.5]
At Least Two	98.7 [96.6, 98.2]	99.1 [96.8, 98.3]	99.1 [96.8, 98.3]
At Least Three	97.7 [95.7, 97.4]	99.0 [96.4, 98.0]	99.0 [96.4, 98.0]
All Four	85.9 [83.1, 86.6]	93.0 [89.9, 92.5]	93.4 [90.6, 93.2]

Table 78: Percentage of segmentation success by hand when only considering combinations of index and middle fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Either Index or Middle	96.0 [96.9, 98.3]	96.0 [96.8, 98.3]	96.0 [96.8, 98.3]
Both Index and Middle	94.9 [95.7, 97.3]	95.1 [95.9, 97.6]	95.2 [96.0, 97.7]
Left			
Either Index or Middle	99.2 [96.9, 98.3]	99.2 [96.8, 98.3]	99.2 [96.8, 98.3]
Both Index and Middle	98.0 [95.7, 97.3]	98.5 [95.9, 97.6]	98.6 [96.0, 97.7]

Table 79: Percentage of segmentation success by hand when only considering combinations of index, middle, and ring fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	96.1 [96.8, 98.3]	96.1 [96.9, 98.3]	96.1 [96.9, 98.3]
At Least Two	96.0 [96.6, 98.1]	96.0 [96.8, 98.2]	96.0 [96.8, 98.2]
All Three	94.1 [94.1, 96.1]	94.5 [95.2, 97.0]	94.6 [95.5, 97.2]
Left			
Any	99.2 [96.8, 98.3]	99.2 [96.9, 98.3]	99.2 [96.9, 98.3]
At Least Two	98.7 [96.6, 98.1]	99.1 [96.8, 98.2]	99.1 [96.8, 98.2]
All Three	96.2 [94.1, 96.1]	97.8 [95.2, 97.0]	98.3 [95.5, 97.2]

D.2 Jaccard Index

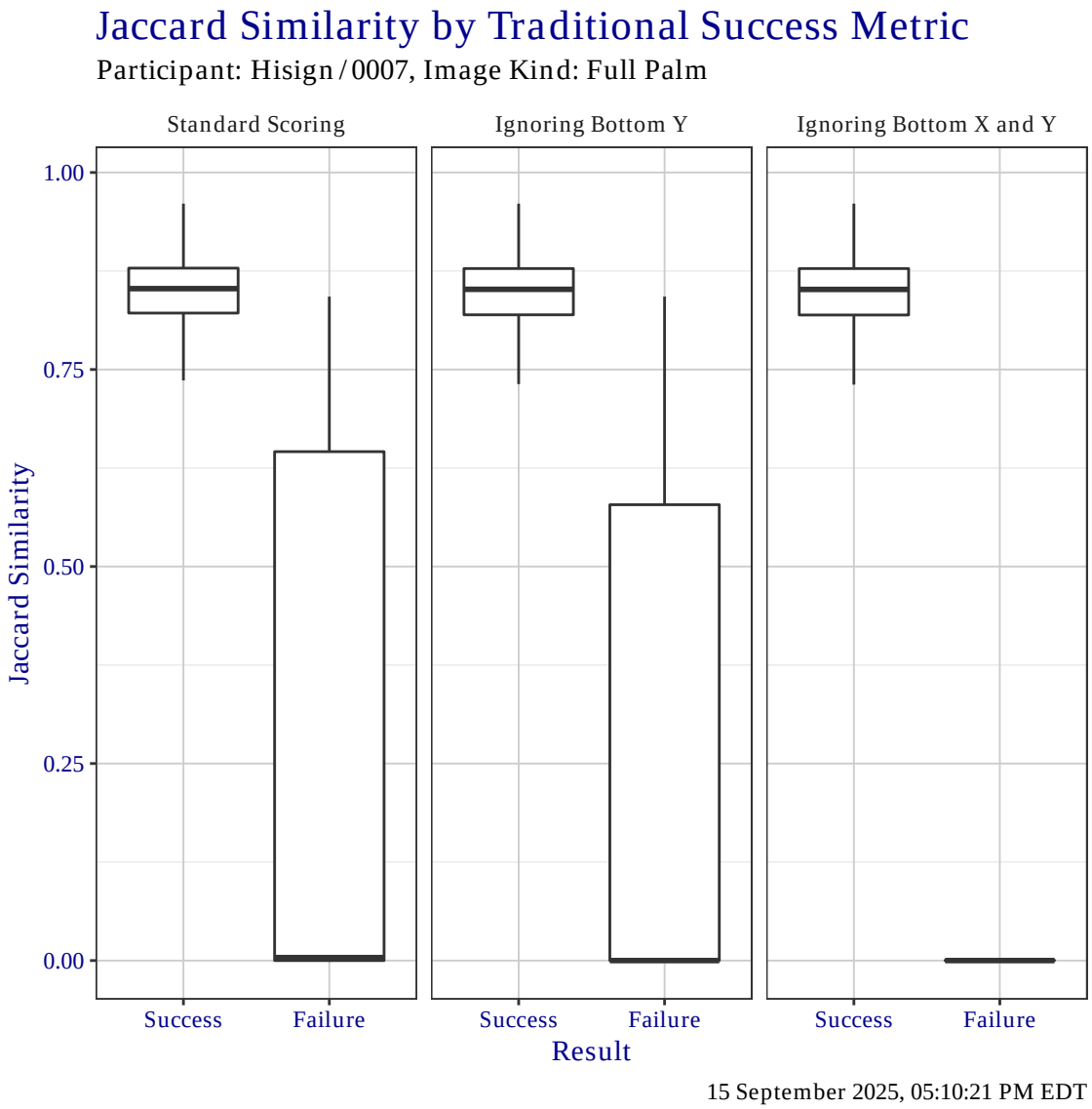

Figure 29: Boxplot of Jaccard similarity indices as compared to the traditional success metrics. Outliers have been removed for clarity.

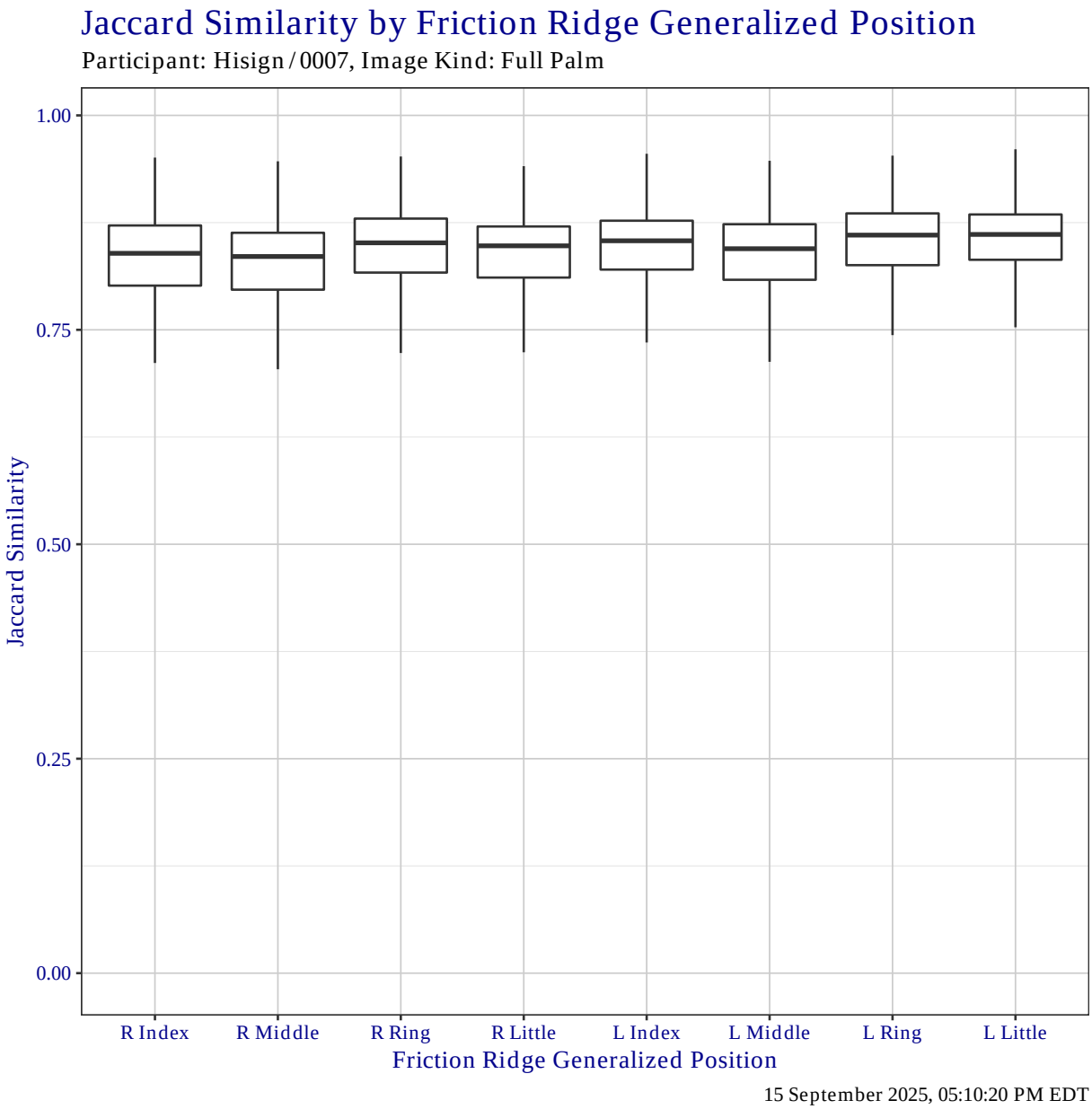

Figure 30: Boxplot of Jaccard similarity indices for each friction ridge generalized position. Outliers have been removed for clarity.

Table 80: For each subject, the percentage that at least *Number of Fingers* fingers were segmented with a Jaccard index in the indicated range.

Number of Fingers	≥0.5	≥0.6	≥0.7	≥0.8	≥0.9	≥0.95	≥0.98
1	99.7	99.7	99.7	99.5	41.6	0.8	0.1
2	99.7	99.7	99.5	98.3	17.4	0	0
3	99.5	99.4	99.4	96.1	7.1	0	0
4	97.6	97.5	97.2	91.5	2.9	0	0
5	96.1	96.0	95.9	86.0	1.4	0	0
6	95.5	95.4	95.1	76.8	0.5	0	0
7	94.0	92.8	91.0	60.6	0	0	0
8	88.7	86.9	80.1	38.7	0	0	0

Table 81: For all subjects, percentage that a particular friction ridge generalized position was segmented with a Jaccard index in the indicated range.

Finger	0-0.5	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1.0
Right						
Index	4.3	0.1	0.8	18.5	68.0	8.3
Middle	4.0	0.1	0.9	21.4	68.6	5.0
Ring	4.0	0	0.6	13.9	70.9	10.6
Little	5.4	2.2	3.1	10.5	72.5	6.3
Left						
Index	0.9	0.3	0.1	12.5	77.8	8.4
Middle	0.9	0	1.2	18.0	72.9	7.0
Ring	1.4	0	0.6	11.1	73.6	13.3
Little	8.3	0.9	2.1	4.5	72.3	11.9

Table 82: Percentage of segmentation obtaining a Jaccard index in the indicated ranges, by hand, for combinations of all ten fingers of a EightInch slap.

Fingers	≥0.5	≥0.6	≥0.7	≥0.8	≥0.9	≥0.95	≥0.98
Right							
Any	96.6	96.4	96.4	94.1	21.7	0.3	0.1
At Least Two	96.1	96.1	95.9	87.9	6.4	0.0	0.0
At Least Three	96.0	96.0	95.3	77.0	1.7	0.0	0.0
All Four	93.7	91.4	86.9	51.1	0.2	0.0	0.0
Left							
Any	99.2	99.2	99.2	98.7	29.4	0.5	0.0
At Least Two	99.1	99.0	98.9	94.7	8.7	0.0	0.0
At Least Three	98.7	98.6	98.5	83.7	2.1	0.0	0.0
All Four	91.5	90.6	86.9	60.1	0.5	0.0	0.0

Table 83: Percentage of segmentation obtaining a Jaccard index in the indicated ranges, by hand, for combinations of index and middle fingers of a EightInch slap.

Fingers	≥0.5	≥0.6	≥0.7	≥0.8	≥0.9	≥0.95
Right						
Either Index or Middle	96.0	96.0	95.7	85.6	11.4	0.1
Both Index and Middle	95.7	95.5	94.0	64.3	1.8	0
Left						
Either Index or Middle	99.2	99.2	99.2	92.9	13.7	0.1
Both Index and Middle	99.0	98.7	97.5	73.2	1.7	0

Table 84: Percentage of segmentation obtaining a Jaccard index in the indicated ranges, by hand, for combinations of index, middle, and ring fingers of a EightInch slap.

Fingers	≥0.5	≥0.6	≥0.7	≥0.8	≥0.9	≥0.95	≥0.98
Right							
Any	96.1	96.1	96.1	90.3	17.8	0.3	0.1
At Least Two	96.0	96.0	95.5	80.7	5.1	0	0
All Three	95.6	95.4	93.6	60.3	0.9	0	0
Left							
Any	99.2	99.2	99.2	96.4	23.1	0.3	0
At Least Two	99.1	99.0	98.9	87.8	4.7	0	0
All Three	98.5	98.4	96.7	68.7	0.9	0	0