Neurotechnology+0014

Neurotechnology

Slap Fingerprint Segmentation Evaluation III

Last Updated: 25 November 2024

Contents

1 Participation Information

1.1 Names and Dates

- **Organization Name:** Neurotechnology
- **SlapSeg III Identifier:** Neurotechnology+0014
- **SlapSeg III API Version:** 1.2.0
- **Provided Marketing Name:** "MegaMatcher"
- **Application Date:** 22 November 2024
- **First Submission Date:** 22 November 2024 (as version 0014)
- **Validation Date:** 24 November 2024
- **Completion Date:** 25 November 2024

1.2 Libraries

Filename	MD5 Checksum	Size
libslapsegiii_Neurotechnology_0014.so	6cdf2a902070c2db7cc20c7f1d736973	12 MB
libmkl_tiny.so	78499860662633254ebdff4168be8b60	25 MB
slapseg3.ndf	635783bf9c91919087d505ee15e0377b	158 MB
libopenvino_intel_cpu_plugin.so	0ed272ab4f994e930a6378a9ba3960a5	51 MB
libopenvino.so	2f8ca64bc055643456112fcabc549f1e	19 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.
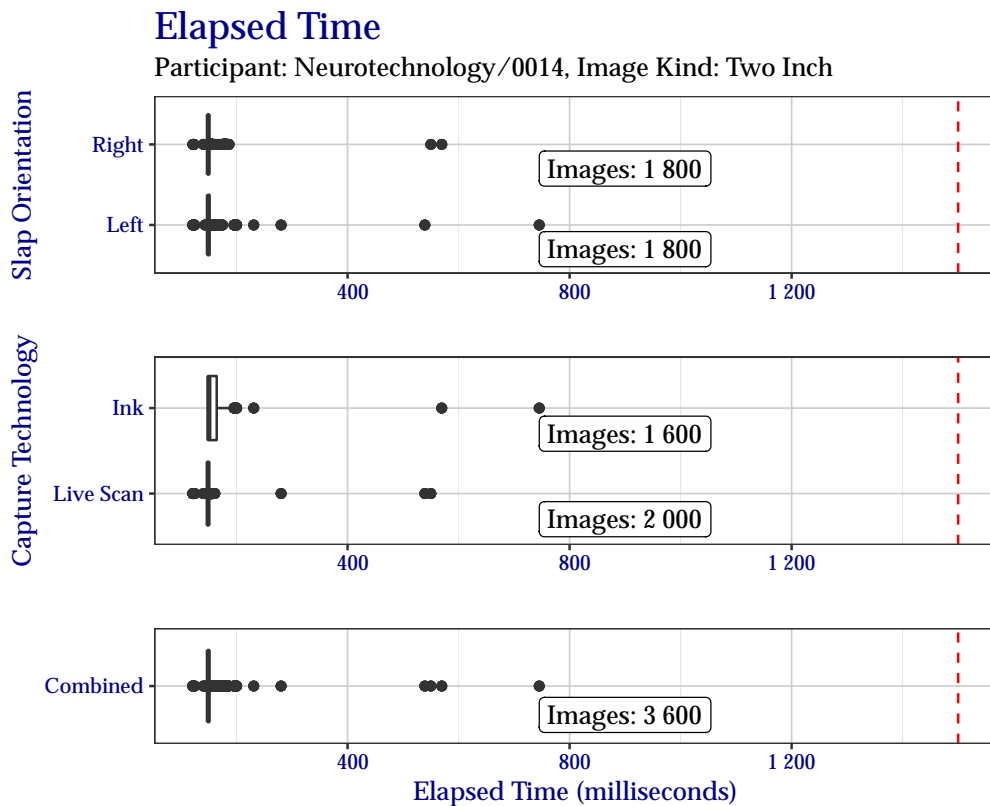
Figure 1: Box plots of elapsed time in milliseconds when segmenting the TwoInch timing test corpus, separated by slap orientation and capture technology.

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	121	121	121	146	121
25%	148	148	148	149	148
Median	149	149	149	150	149
75%	150	151	149	164	150
Maximum	570	745	550	745	745

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.

Segmentation Position Centers
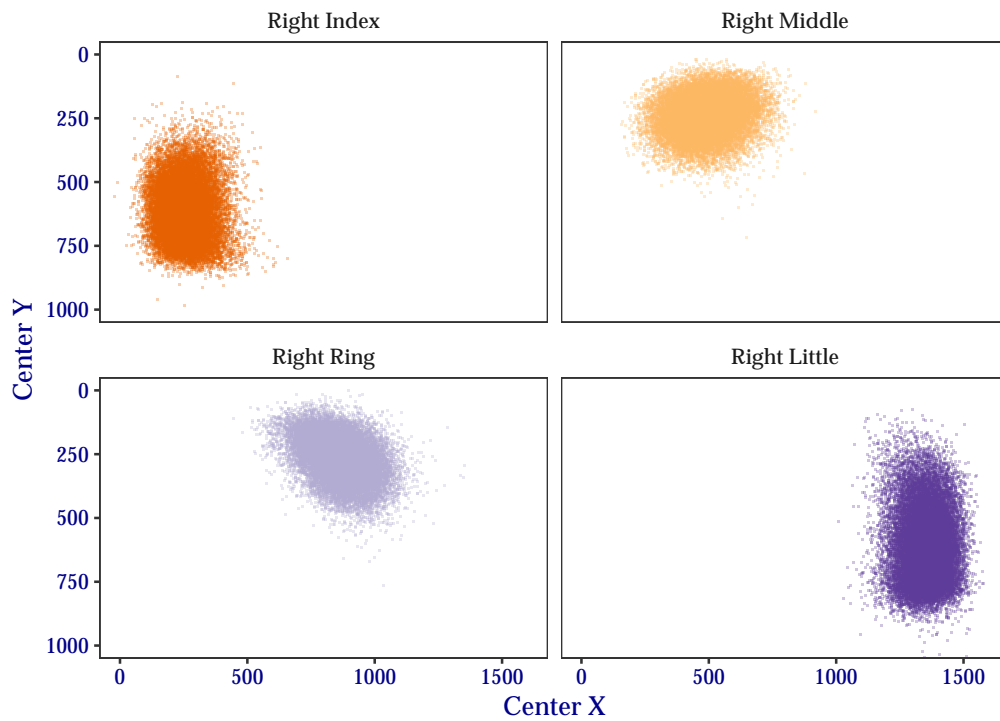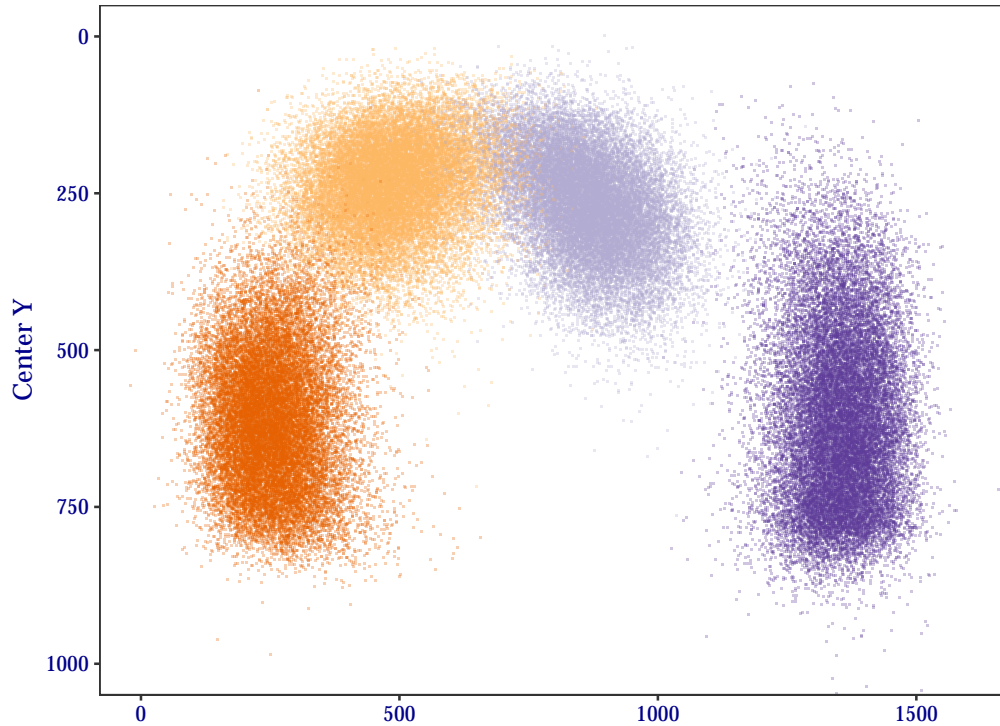
Participant: Neurotechnology/0014, FRGPs: 2, 3, 4, 5, Image Kind: Two Inch

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Figure 2: Segmentation centers for right hand TwoInch data.

Segmentation Position Centers

Participant: Neurotechnology/0014, FRGPs: 7, 8, 9, 10, Image Kind: Two Inch
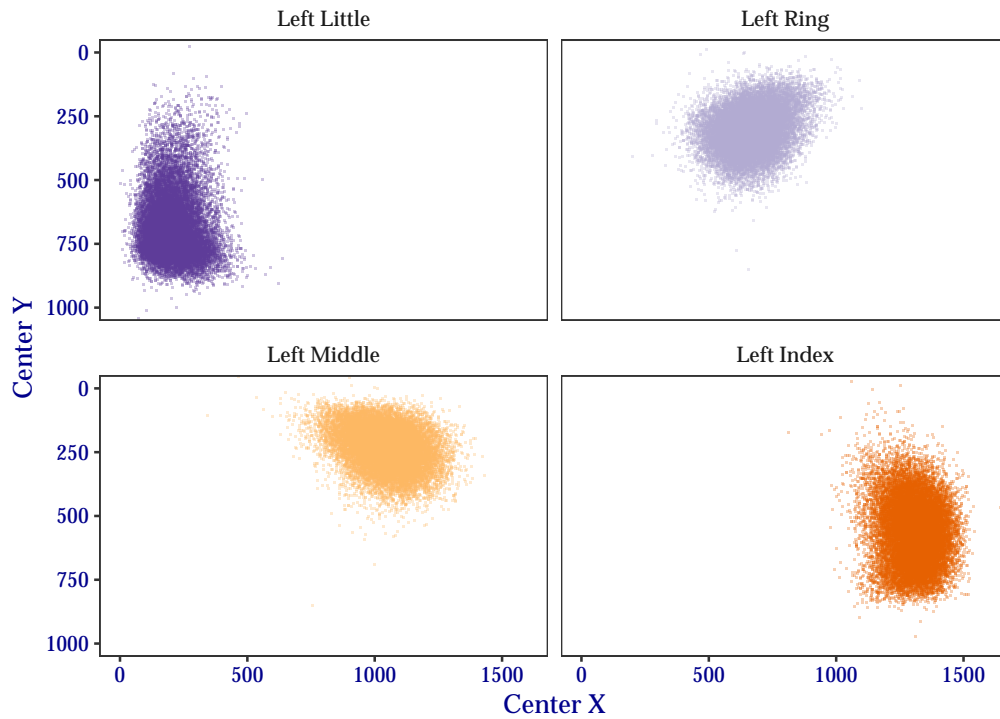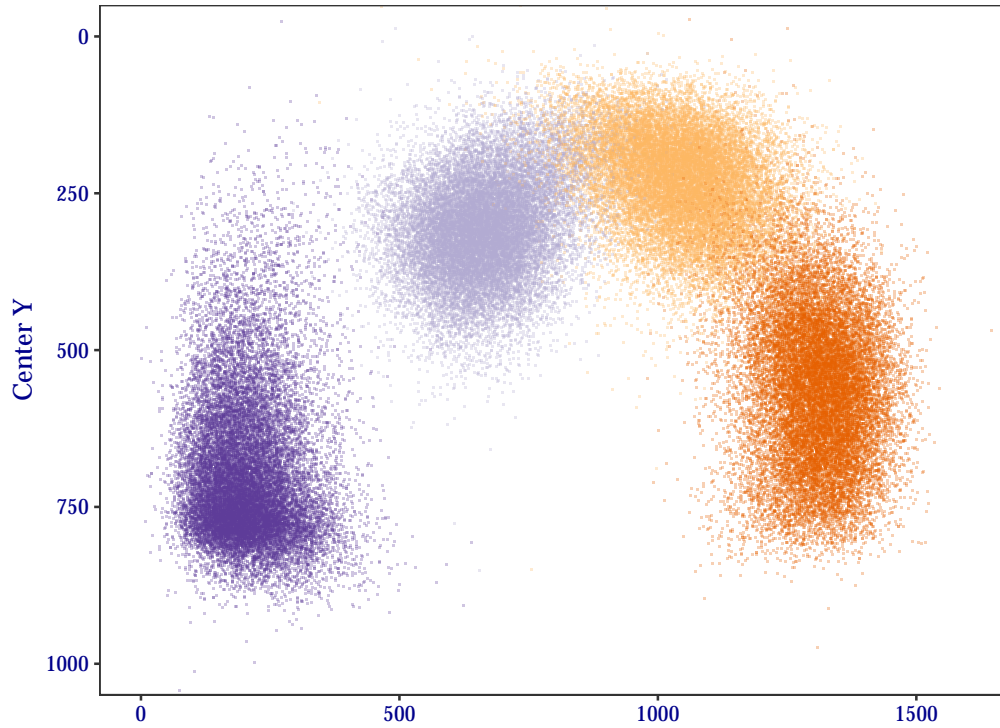
Figure 3: Segmentation centers for left hand TwoInch data.

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.

Segmentation Position Dimensions
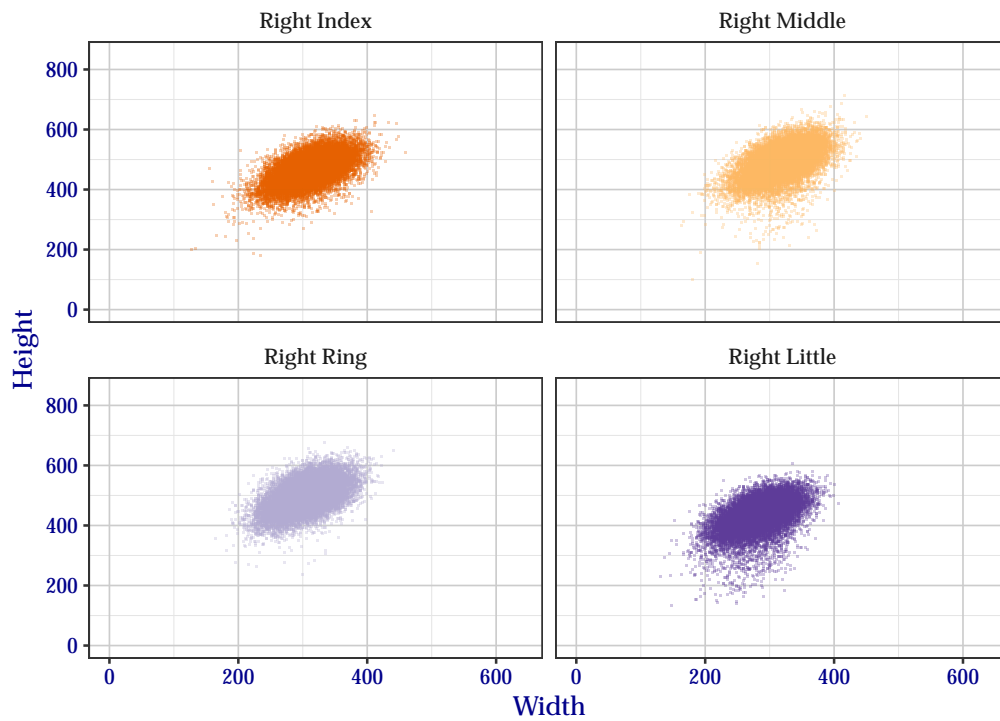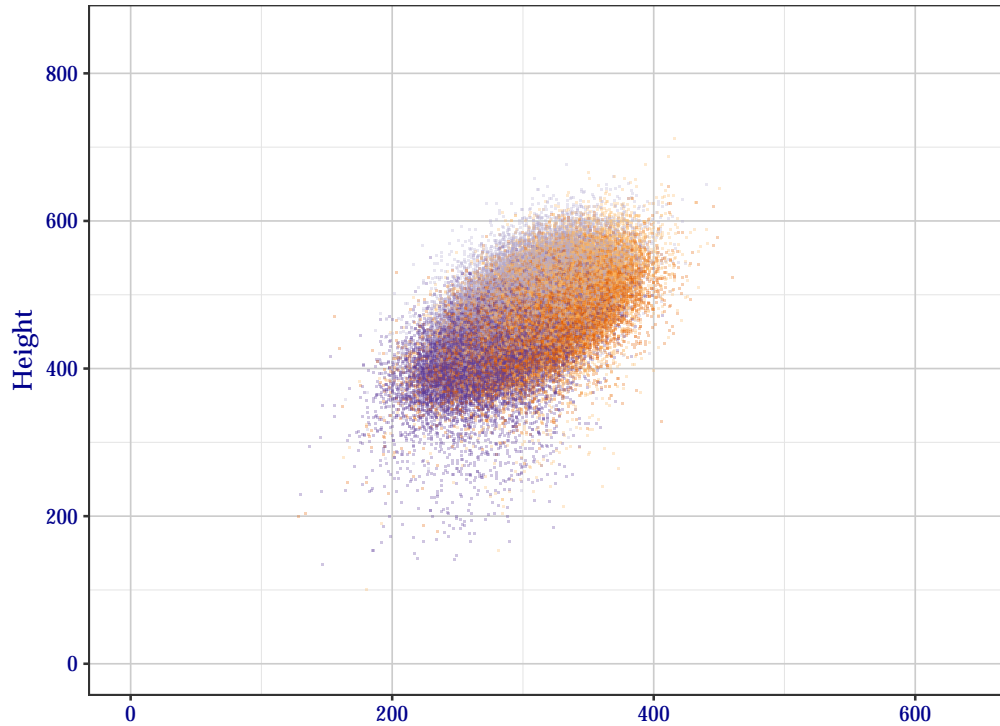
Participant: Neurotechnology/0014, FRGPs: 2, 3, 4, 5, Image Kind: Two Inch

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

Segmentation Position Dimensions

Participant: Neurotechnology/0014, FRGPs: 7, 8, 9, 10, Image Kind: Two Inch
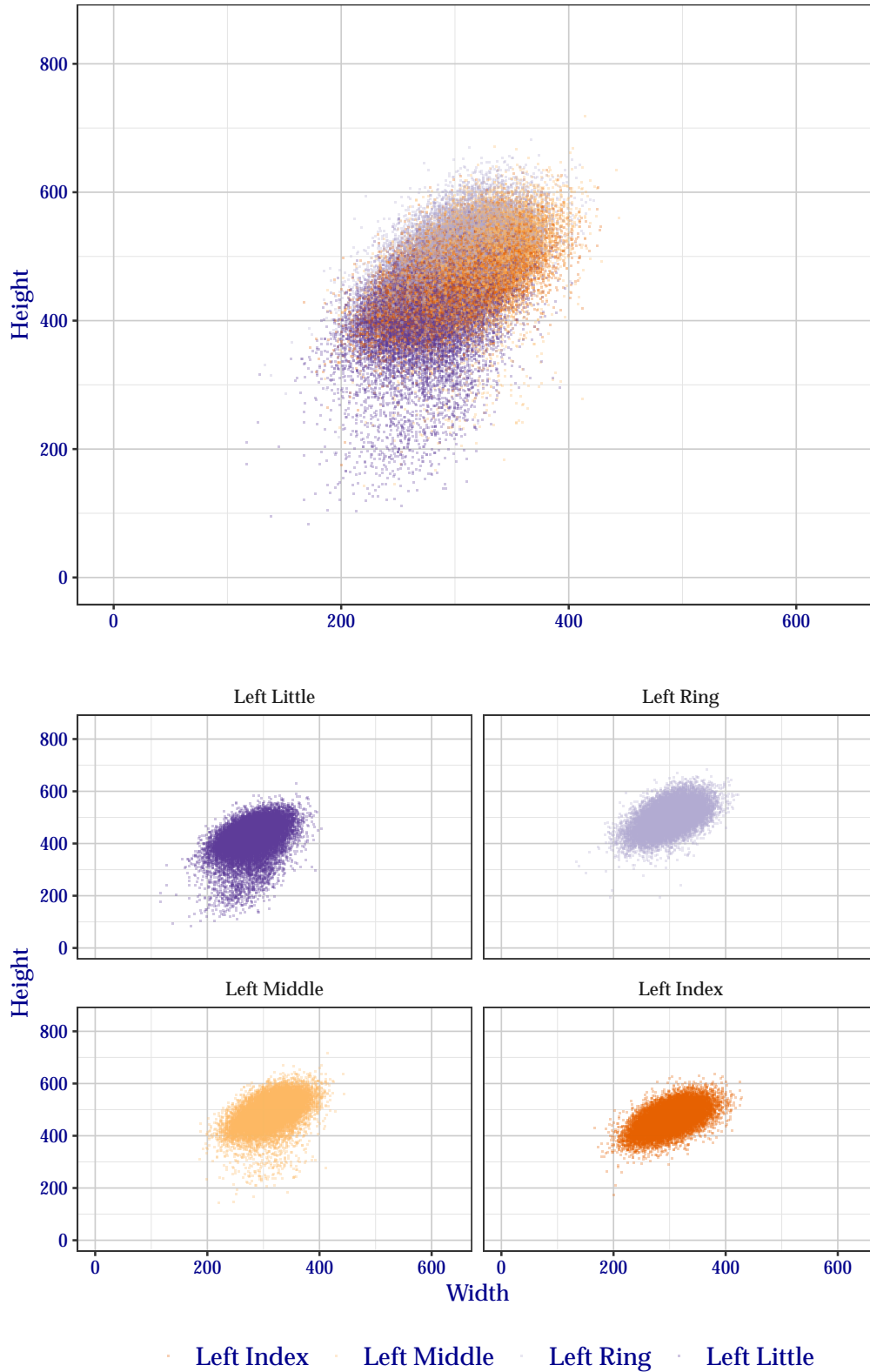
25 November 2024, 07:38:08 AM EST

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 Neurotechnology+0014 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	99.9	99.9	100.0
2	99.8	99.9	99.9
3	99.5	99.6	99.7
4	98.7	98.9	99.0
5	95.5	95.5	95.6
6	94.3	94.5	94.7
7	89.8	90.4	90.7
8	71.8	74.4	74.8

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	98.4	99.4	99.6
Middle	90.1	90.5	90.7
Ring	96.6	97.0	97.2
Little	98.0	98.6	98.8
Left			
Index	98.6	99.1	99.2
Middle	87.9	88.3	88.4
Ring	97.4	97.9	98.0
Little	97.5	97.8	98.0

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	99.6	99.6	99.7
Both	93.4	94.7	94.9
Middle			
Either	96.8	96.9	97.0
Both	78.4	79.0	79.1
Ring			
Either	99.5	99.5	99.6
Both	90.7	91.5	91.7
Little			
Either	99.4	99.6	99.6
Both	91.7	92.4	92.8

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	99.9	99.9	99.9
At Least Two	99.7	99.7	99.8
At Least Three	98.0	98.3	98.5
All Four	85.6	87.6	88.0
Left			
Any	99.8	99.8	99.8
At Least Two	99.4	99.5	99.6
At Least Three	98.1	98.3	98.4
All Four	84.1	85.4	85.7

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	99.7	99.8	99.9
Both Index and Middle	88.8	90.2	90.4
Left			
Either Index or Middle	99.5	99.6	99.6
Both Index and Middle	87.0	87.8	87.9

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	99.8	99.8	99.9
At Least Two	98.4	98.6	98.8
All Three	86.9	88.4	88.8
Left			
Any	99.7	99.7	99.8
At Least Two	98.6	98.8	98.9
All Three	85.7	86.7	86.9

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.

Reasons for capture-type failures reported by `Neurotechnology+0014` are enumerated in Table 8. Note that for TwoInch data, images are expected to be rotated, so a capture failure of *Rotation Detected* is unacceptable.

Table 8: Count of self-reported capture-type failure reasoning.

Failure Reason	Images
Request Recapture (No Attempt)	4

In situations where the algorithm feels that the presented image should be recaptured (Table 8), one or more image deficiencies must be identified. These deficiencies are enumerated in Table 9. At this point, NIST does not have a groundtruth of image deficiencies, but plans to update this table with the accuracy of deficiency observations in the future.

Table 9: Count of image deficiencies reported when requesting a recapture.

Deficiency	Count
Hand Geometry	4

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.

`Neurotechnology+0014` 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 `Neurotechnology+0014` are enumerated in Table 10.

Table 10: Count of self-reported segmentation failure reasoning.

Failure Reason	Fingers
Finger Not Found	35
Finger Found, but Can't Segment	0
Vendor Defined	0

2.4.3   Identifying Missing Fingers

A small portion of the test corpus in SlapSeg III are missing fingers. Table 11 shows how successful `Neurotechnology+0014` 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 11: Performance of `Neurotechnology+0014` at detecting fingers missing from an image.

Result	Percentage
Missed	18.7
Correctly Identified	37.5
Other Failure: Finger Found, but Can't Segment	0.0
Other Failure: Vendor Defined	0.0
Other Failure: Segmentation Not Attempted	43.8

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 12 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 12: 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	0.02	0.02	0.02
Right	0.01	0.01	0.01
Combined	0.02	0.02	0.02

2.5   Determining Orientation

An *optional* portion of the SlapSeg III API asked participants to determine the hand orientation of an image. Participants were provided the kind (e.g., Tenprint card) and capture technology (e.g., ink), and needed to determine whether the image was of the left or right hand.

Overall Two Inch accuracy: 99.9%

Table 13: Percentage of accuracy when determining hand orientation of a two inch image. The first column indicates the true hand orientation. Subsequent columns indicate the percentage of the time in which the indicated hand orientation was hypothesized.

	Left	Right	Skip
Left	**99.9**	0.1	0
Right	0.1	**99.9**	0

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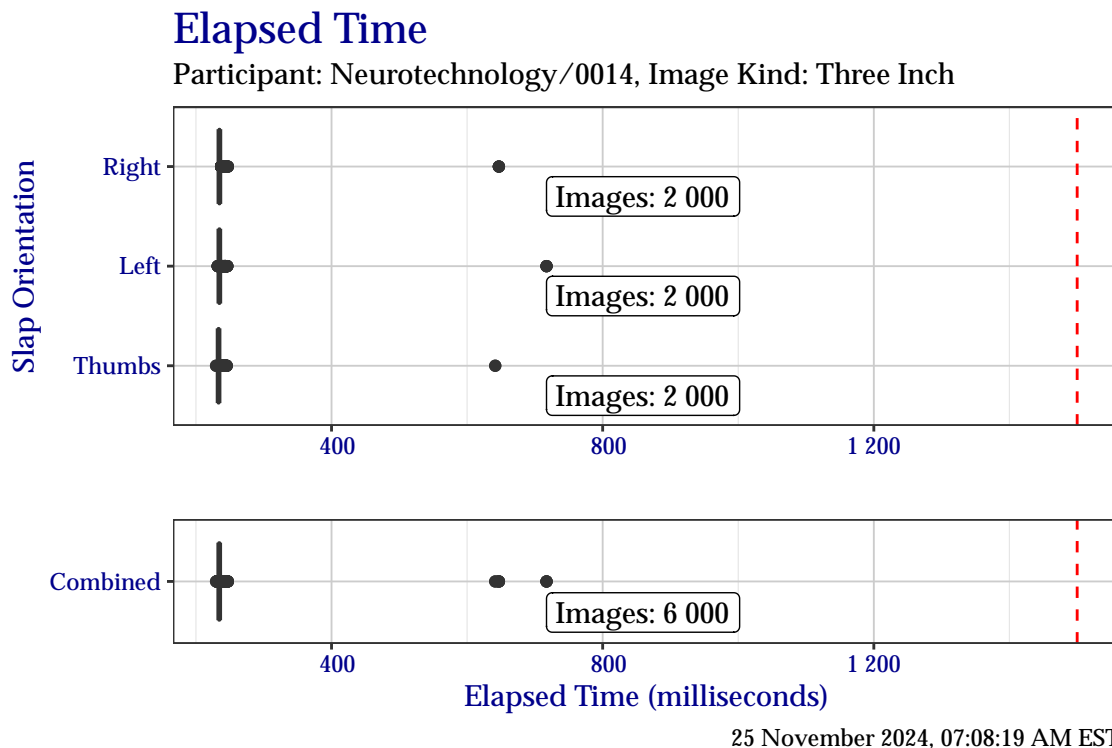
Figure 6: Box plots of elapsed time in milliseconds when segmenting the ThreeInch timing test corpus, separated by slap orientation.

Table 14: Elapsed time in milliseconds when segmenting the ThreeInch timing test corpus, separated by slap orientation.

	Right	Left	Thumbs	Combined
Minimum	232	232	230	230
25%	234	234	233	234
Median	235	235	233	234
75%	235	235	234	235
Maximum	647	717	642	717

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.

Segmentation Position Centers
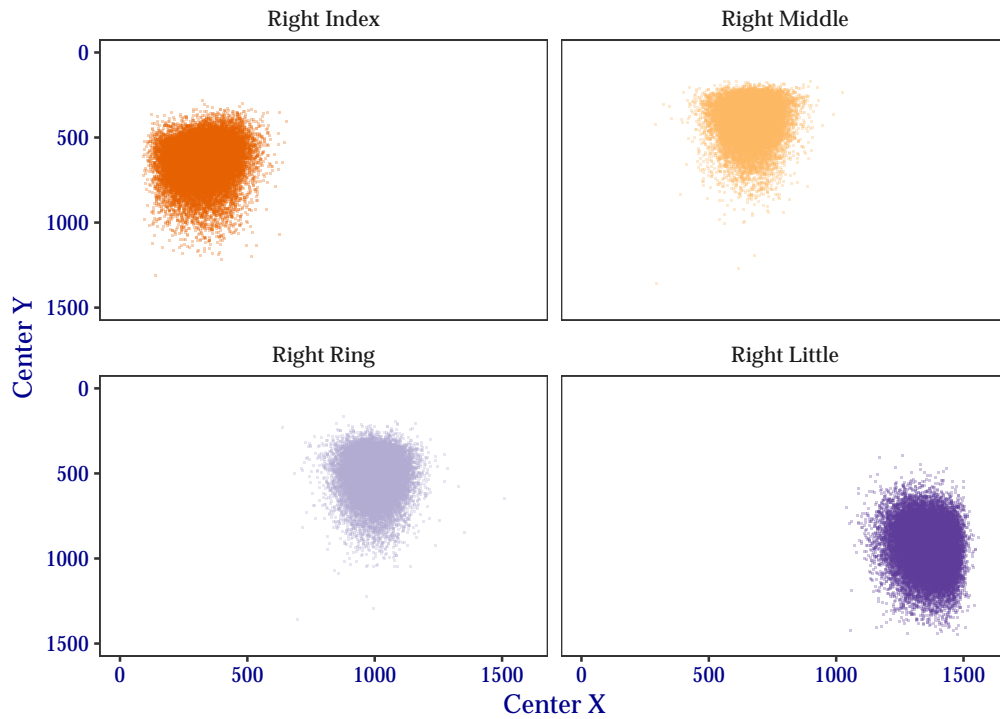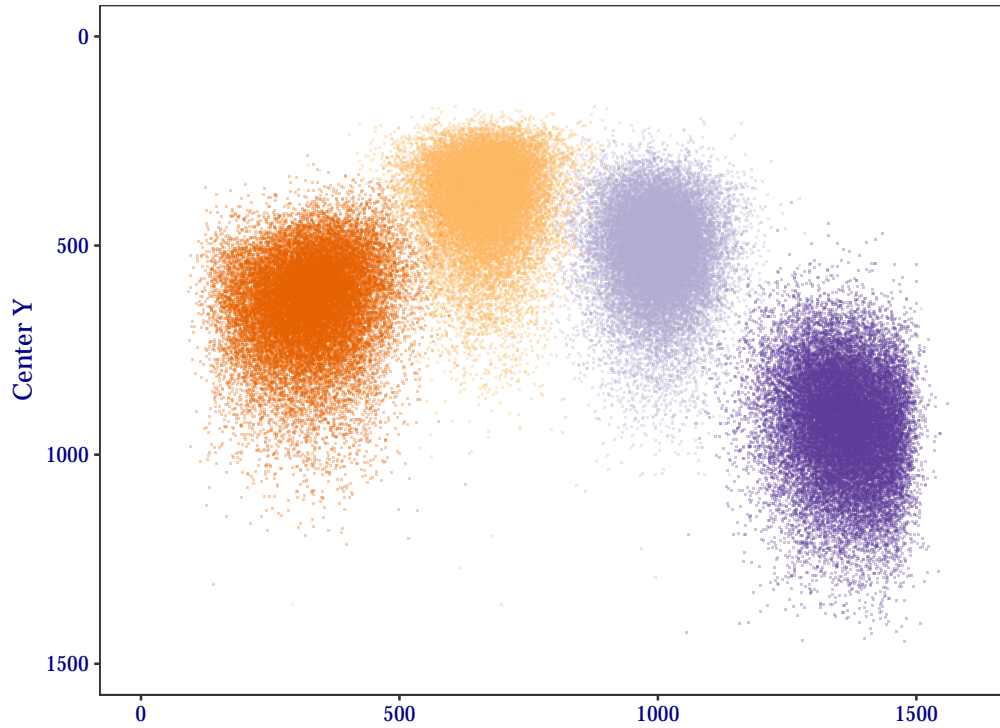
Participant: Neurotechnology/0014, FRGPs: 2, 3, 4, 5, Image Kind: Three Inch

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Figure 7: Segmentation centers for right hand ThreeInch data.

Segmentation Position Centers

Participant: Neurotechnology/0014, FRGPs: 7, 8, 9, 10, Image Kind: Three Inch
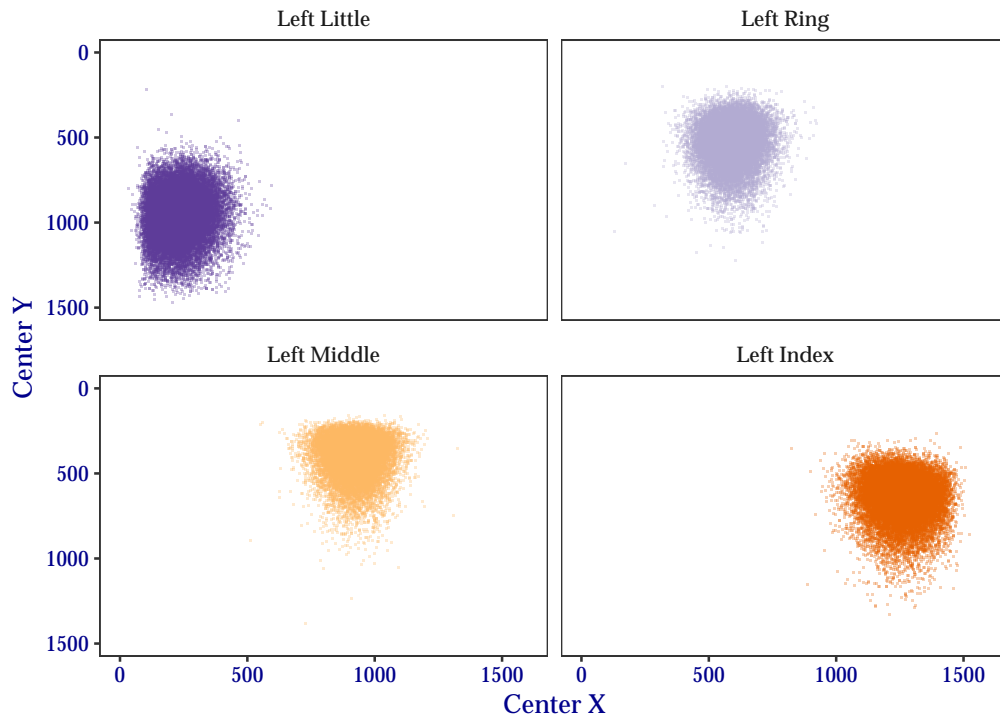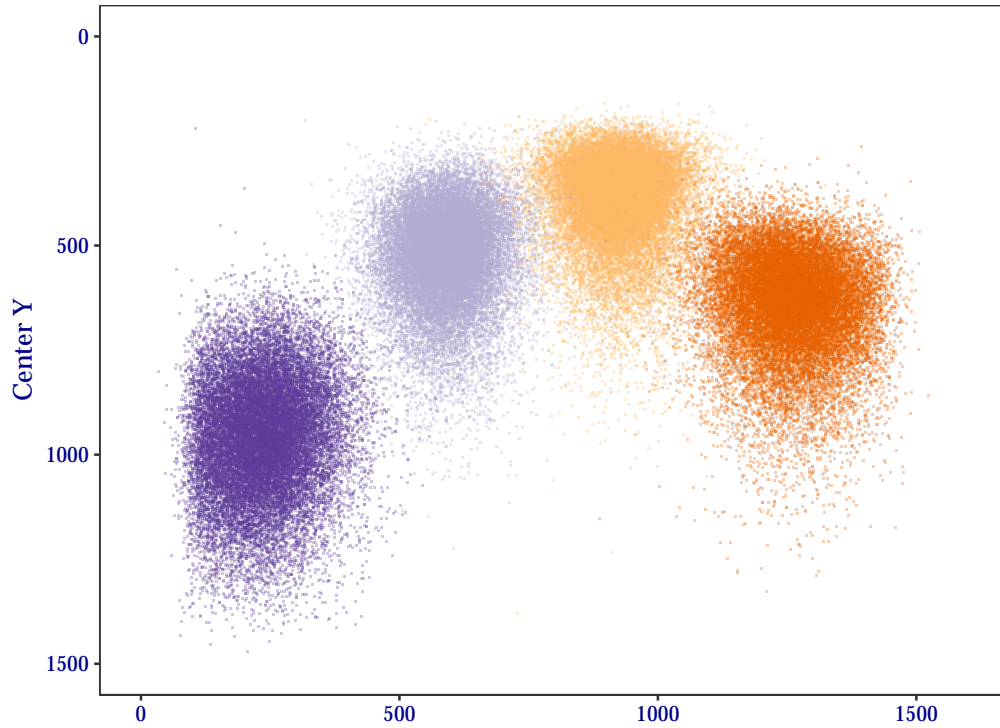
25 November 2024, 07:37:51 AM EST

Figure 8: Segmentation centers for left hand ThreeInch data.

Segmentation Position Centers

Participant: Neurotechnology/0014, FRGPs: 1, 6, Image Kind: Three Inch

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.

Segmentation Position Dimensions

Participant: Neurotechnology/0014, FRGPs: 7, 8, 9, 10, Image Kind: Three Inch
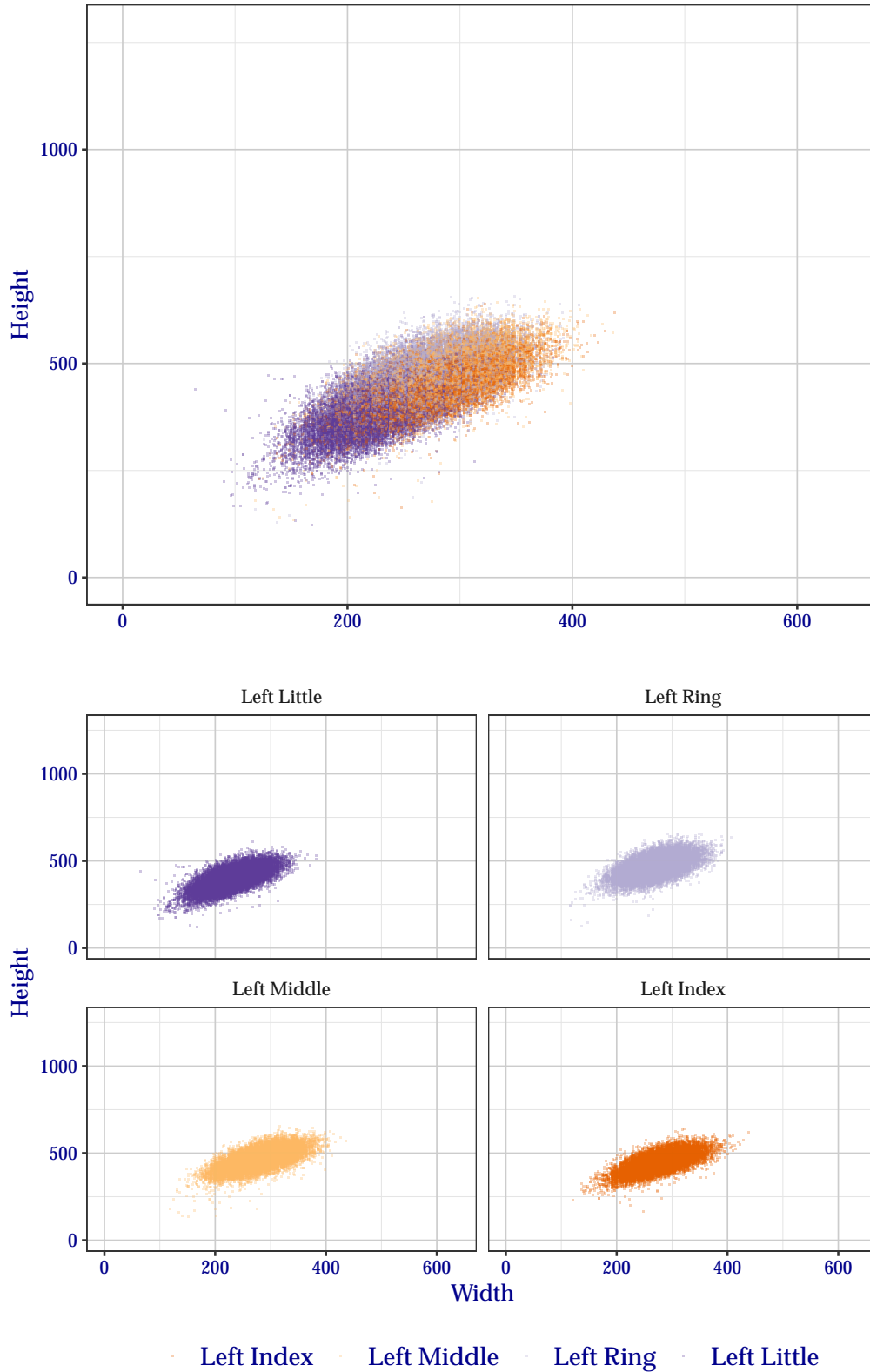
25 November 2024, 07:38:15 AM EST

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

Segmentation Position Dimensions
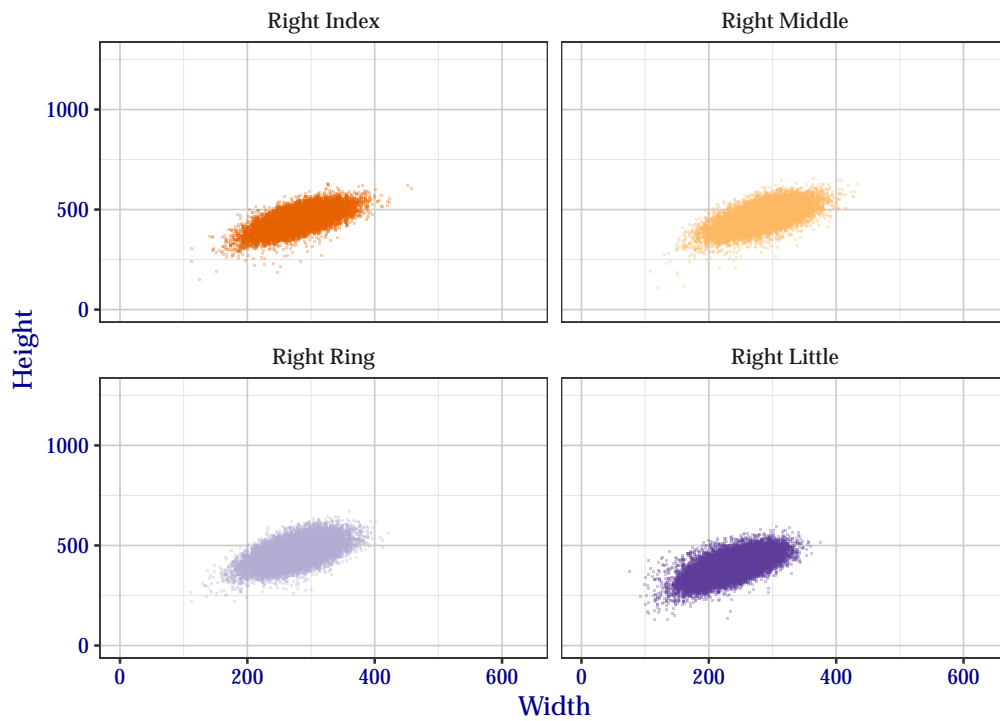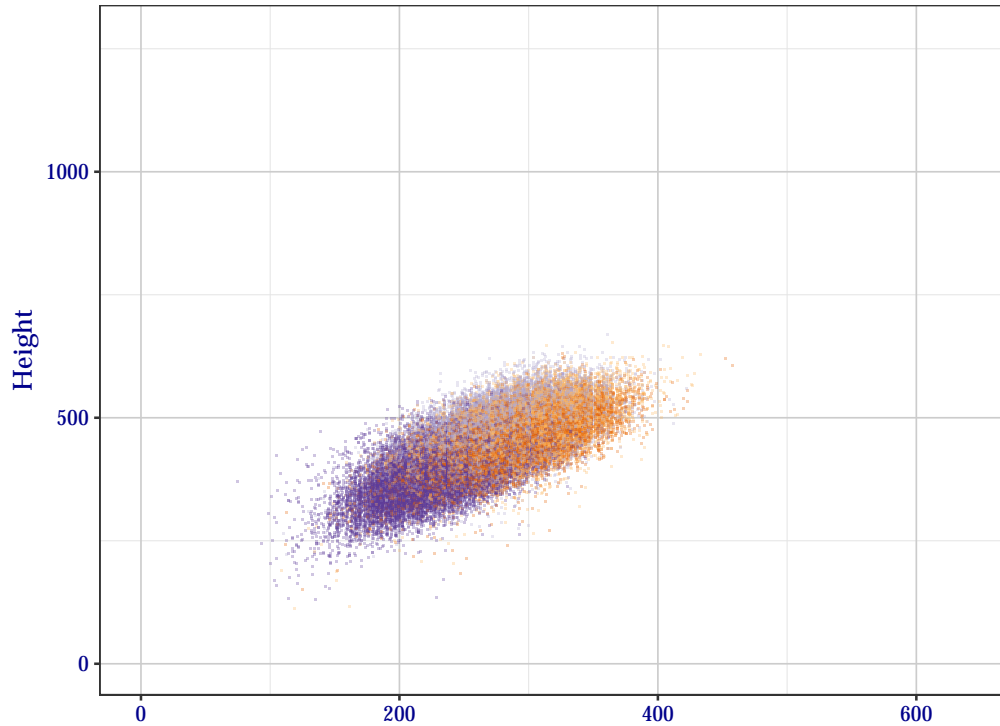
Participant: Neurotechnology/0014, FRGPs: 2, 3, 4, 5, Image Kind: Three Inch

25 November 2024, 07:38:19 AM EST

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

Segmentation Position Dimensions
Participant: Neurotechnology/0014, FRGPs: 1, 6, Image Kind: Three Inch
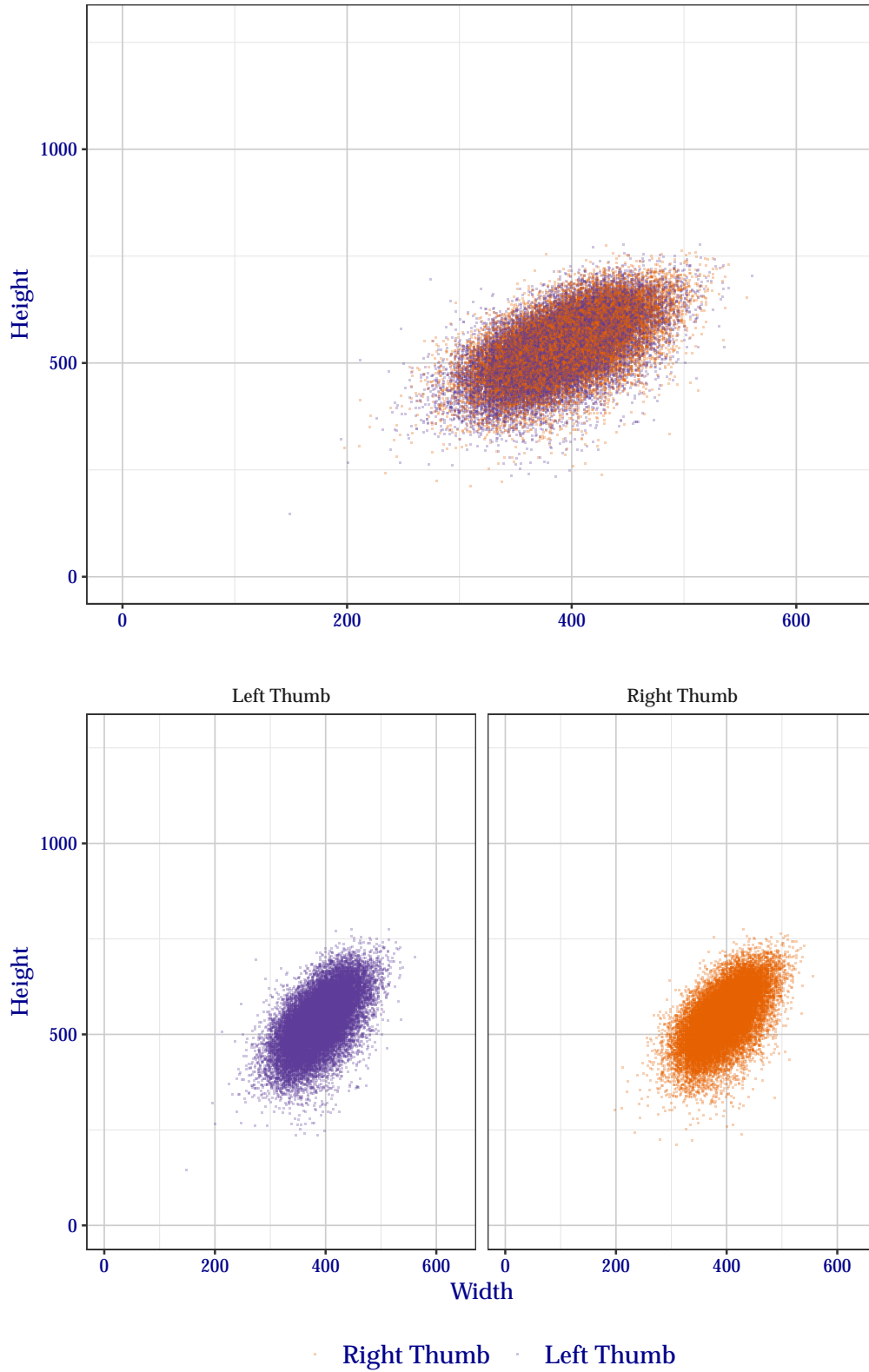
25 November 2024, 07:38:23 AM EST
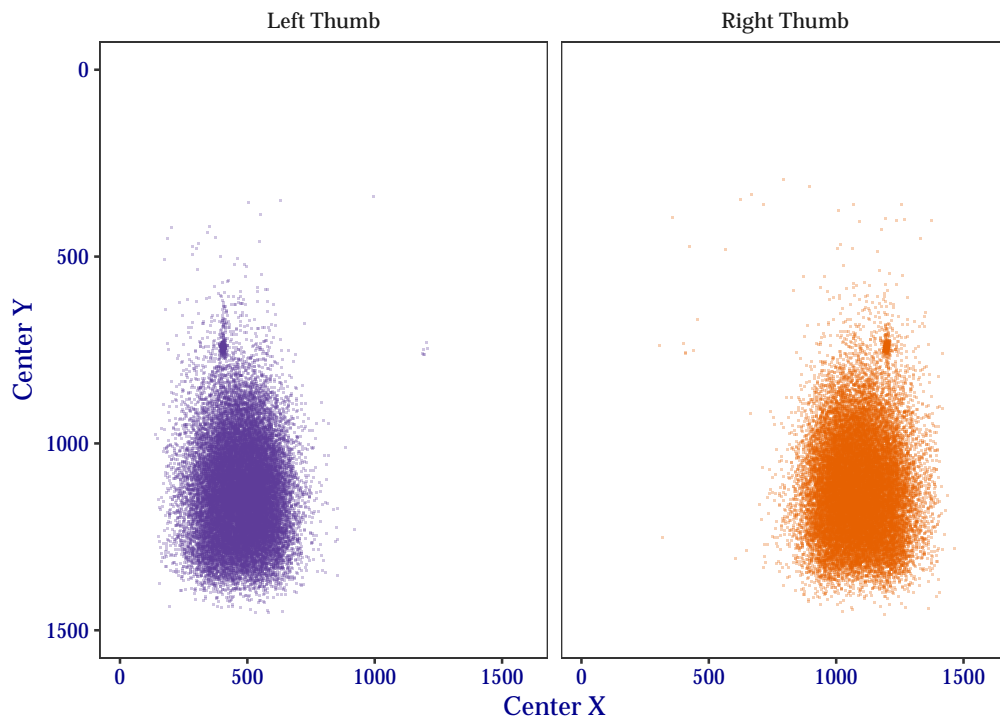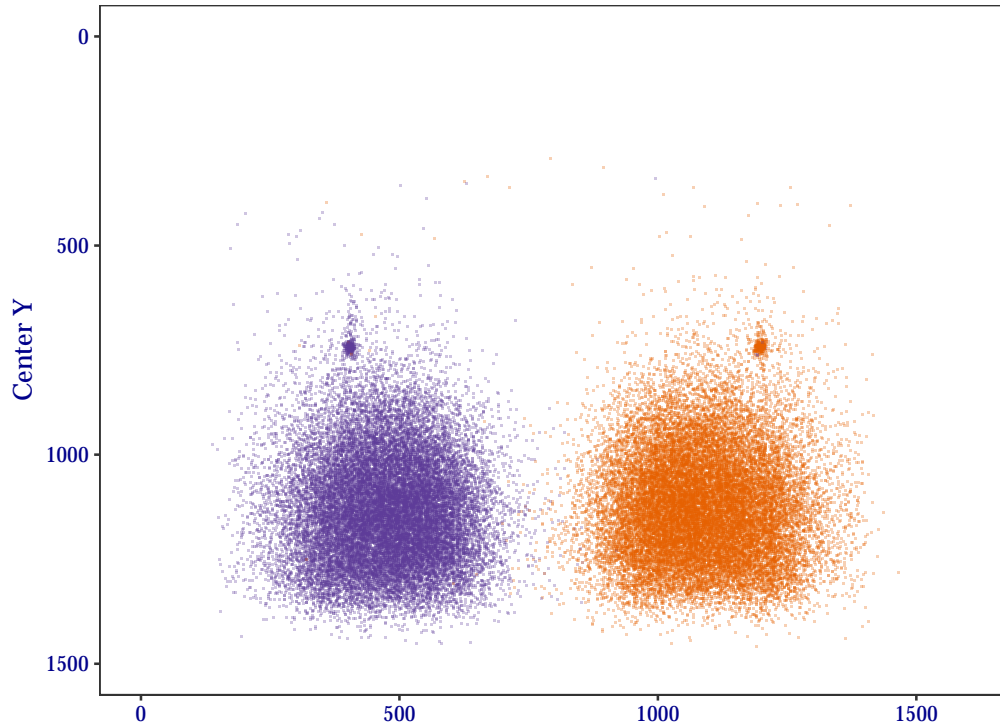
Figure 12: Segmentation position dimensions for thumb ThreeInch data.

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 15 shows how successful Neurotechnology+0014 segmented fingers for each subject in the test corpus. Table 16 shows success for specific finger positions over the entire test corpus. Similarly, Table 17 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 18 shows success for combinations of all fingers, Table 19 for just the index and middle fingers, and Table 20 for all except the little finger.

Table 15: 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	99.8	99.8	99.8
2	99.5	99.5	99.5
3	98.5	98.5	98.5
4	98.3	98.3	98.3
5	95.9	95.9	95.9
6	95.9	95.9	95.9
7	95.7	95.7	95.8
8	95.0	95.0	95.2
9	90.4	90.6	91.1
10	73.5	73.9	75.5

Table 16: 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	92.4	92.6	93.0
Index	99.4	99.4	99.4
Middle	99.1	99.1	99.4
Ring	97.2	97.3	97.6
Little	96.1	96.1	96.2
Left			
Thumb	91.3	91.5	91.9
Index	98.8	98.8	98.9
Middle	98.9	98.9	99.3
Ring	98.6	98.8	99.1
Little	96.8	96.8	96.8

Table 17: 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	97.6	97.7	97.8
Both	86.2	86.4	87.2
Index			
Either	99.9	99.9	99.9
Both	95.6	95.6	95.8
Middle			
Either	99.9	99.9	99.9
Both	95.4	95.4	96.1
Ring			
Either	99.7	99.8	99.8
Both	93.4	93.7	94.2
Little			
Either	99.4	99.4	99.4
Both	91.0	91.0	91.1

Table 18: 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	99.6	99.6	99.7
At Least Two	98.5	98.5	98.5
At Least Three	98.3	98.3	98.3
At Least Four	96.6	96.7	96.9
All Five	82.2	82.5	83.3
Left			
Any	99.7	99.7	99.7
At Least Two	98.5	98.5	98.5
At Least Three	98.3	98.3	98.4
At Least Four	97.0	97.0	97.2
All Five	82.0	82.3	83.3

Table 19: 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	99.9	99.9	99.9
Both	98.5	98.5	98.9
Left			
Either	99.9	99.9	99.9
Both	97.8	97.9	98.3

Table 20: 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	100.0	100.0	100.0
At Least Two	99.7	99.7	99.7
All Three	96.0	96.1	96.7
Left			
Any	100.0	100.0	100.0
At Least Two	99.7	99.7	99.8
All Three	96.7	96.9	97.5

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.

Reasons for capture-type failures reported by Neurotechnology+0014 are enumerated in Table 21.

Table 21: Count of self-reported capture-type failure reasoning.

Failure Reason	Images
Request Recapture (No Attempt)	9

In situations where the algorithm feels that the presented image should be recaptured (Table 21), one or more image deficiencies must be identified. These deficiencies are enumerated in Table 22. At this point, NIST does not have a groundtruth of image deficiencies, but plans to update this table with the accuracy of deficiency observations in the future.

Table 22: Count of image deficiencies reported when requesting a recapture.

Deficiency	Count
Hand Geometry	9

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.

Neurotechnology+0014 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 Neurotechnology+0014 are enumerated in Table 23.

Table 23: Count of self-reported segmentation failure reasoning.

Failure Reason	Fingers
Finger Not Found	197
Finger Found, but Can't Segment	0
Vendor Defined	0

3.4.3   Identifying Missing Fingers

A small portion of the test corpus in SlapSeg III are missing fingers. Table 24 shows how successful Neurotechnology+0014 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 24: Performance of Neurotechnology+0014 at detecting fingers missing from an image.

Result	Percentage
Missed	19.7
Correctly Identified	74.5
Other Failure: Finger Found, but Can't Segment	0.0
Other Failure: Vendor Defined	0.0
Other Failure: Segmentation Not Attempted	5.8

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 25 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 25: 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	0.03	0.03	0.03
Right	0.02	0.02	0.02
Thumbs	0.05	0.05	0.05
Combined	0.03	0.03	0.03

3.5 Determining Orientation

An *optional* portion of the SlapSeg III API asked participants to determine the hand orientation of an image. Participants were provided the kind (e.g., Identification Flat) and needed to determine whether the image was of the left hand, right hand, or thumbs.

Overall Three Inch accuracy: 99.8%

Table 26: Percentage of accuracy when determining hand orientation of a three inch image. The first column indicates the true hand orientation. Subsequent columns indicate the percentage of the time in which the indicated hand orientation was hypothesized.

	Left	Right	Skip	Thumbs
Left	**99.8**	0.2	0	0
Right	0.3	**99.7**	0	0
Thumbs	0	0.1	0	**99.9**

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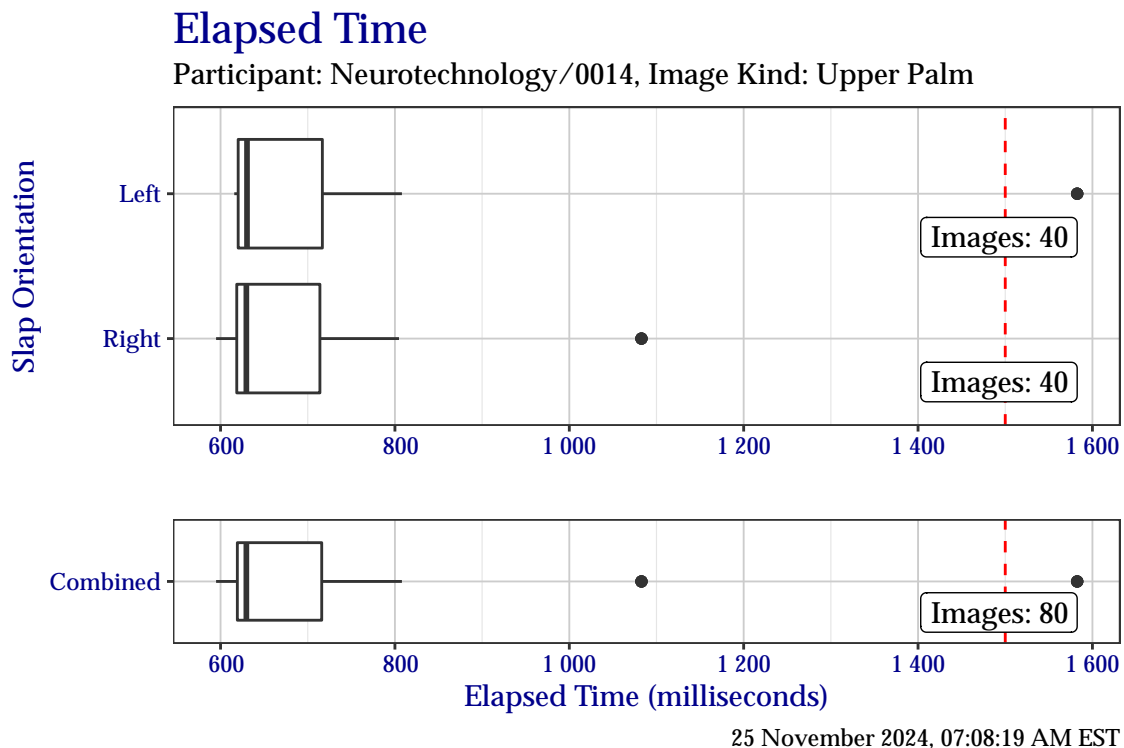
Figure 13: Box plots of elapsed time in milliseconds when segmenting the FiveInch timing test corpus, separated by slap orientation.

Table 27: Elapsed time in milliseconds when segmenting the FiveInch timing test corpus, separated by slap orientation.

	Right	Left	Combined
Minimum	595	616	595
25%	619	620	619
Median	630	630	630
75%	714	717	716
Maximum	1 083	1 583	1 583

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.

Segmentation Position Centers
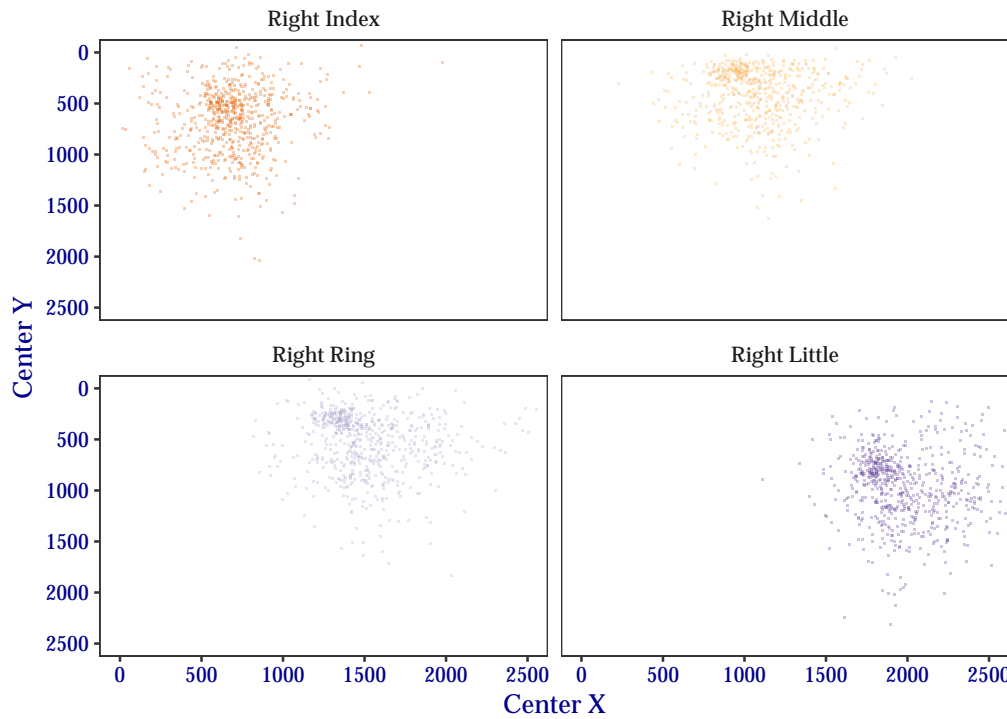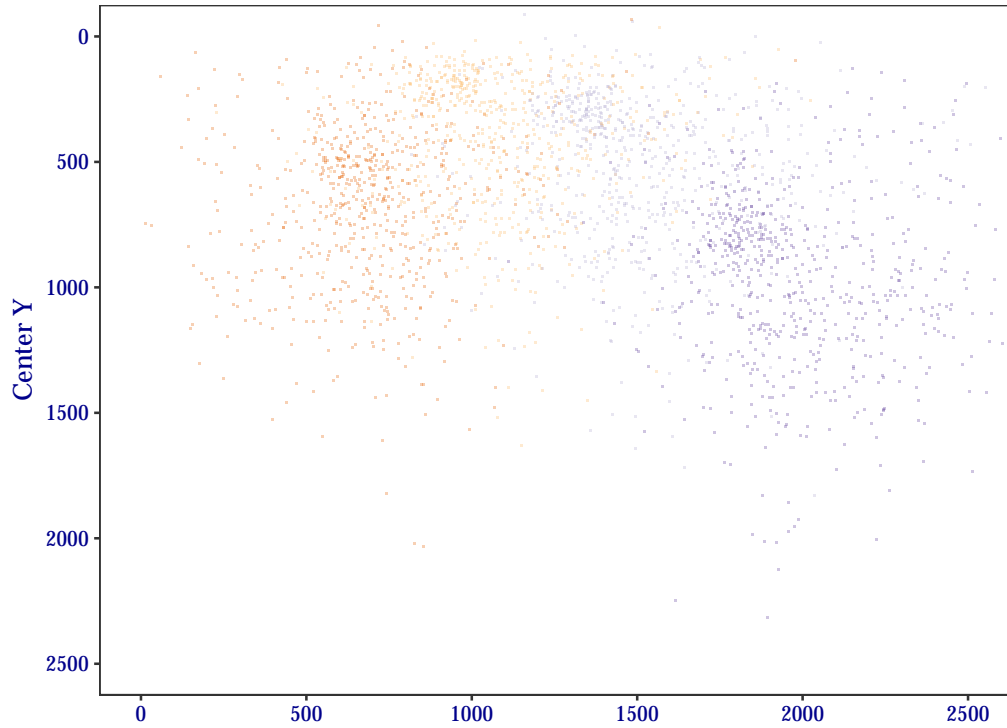
Participant: Neurotechnology/0014, FRGPs: 2, 3, 4, 5, Image Kind: Upper Palm

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Figure 14: Segmentation centers for right hand FiveInch data.

Segmentation Position Centers

Participant: Neurotechnology/0014, FRGPs: 7, 8, 9, 10, Image Kind: Upper Palm
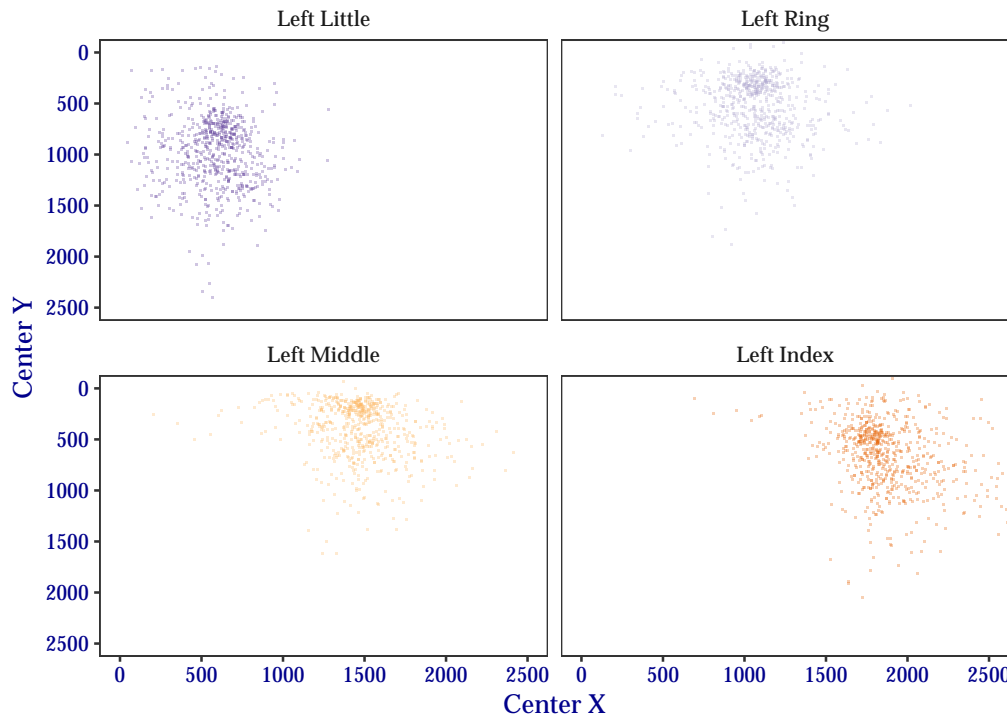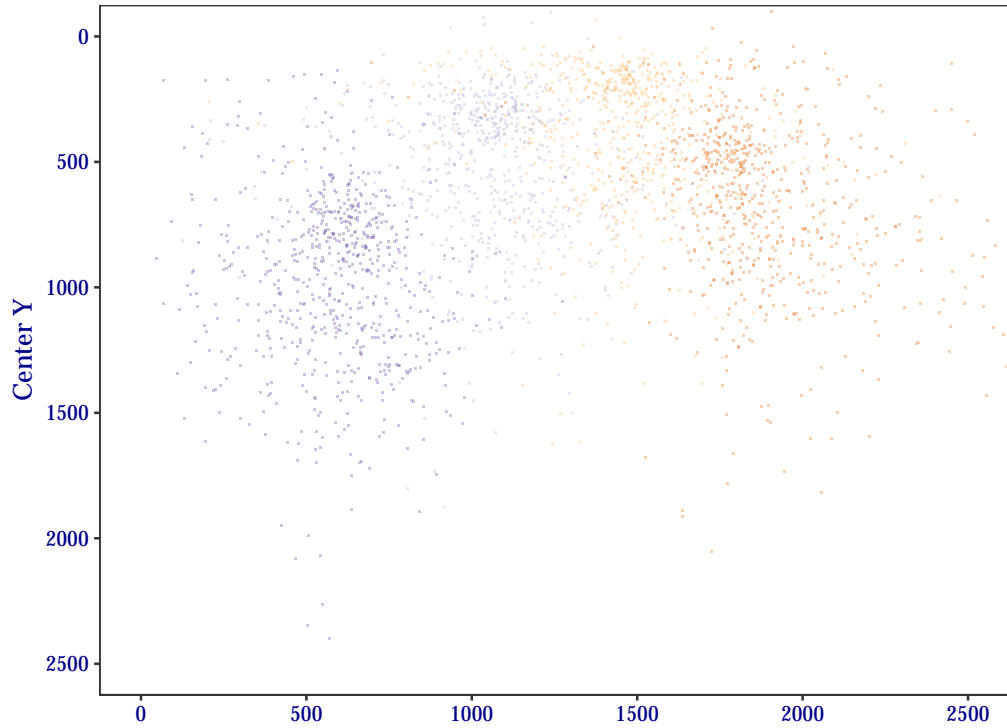
25 November 2024, 07:38:03 AM EST

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.

Segmentation Position Dimensions
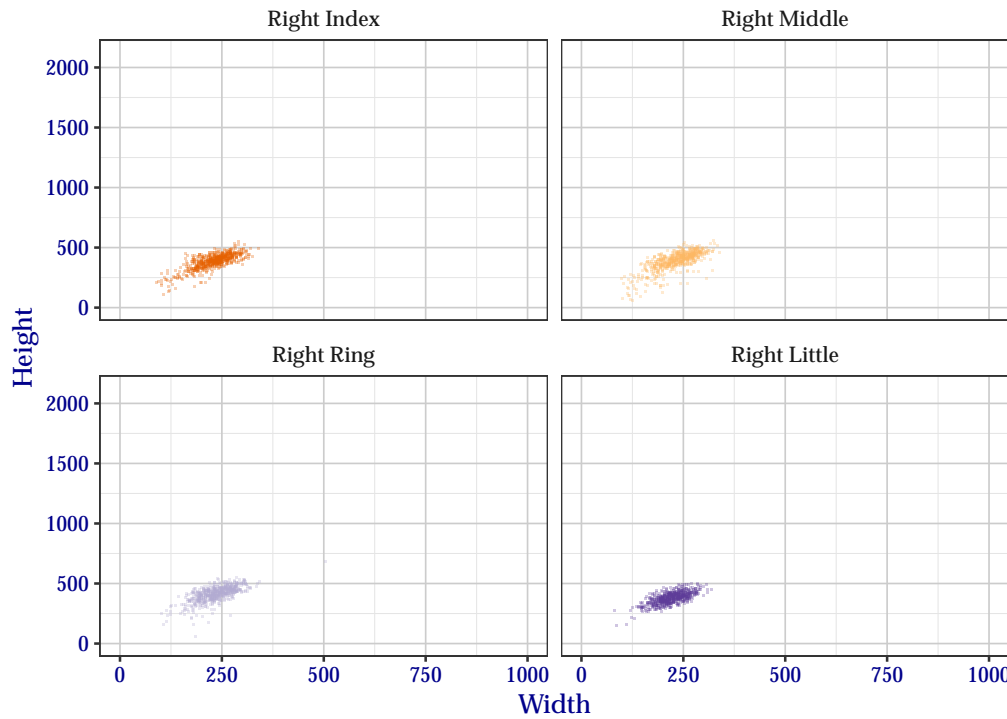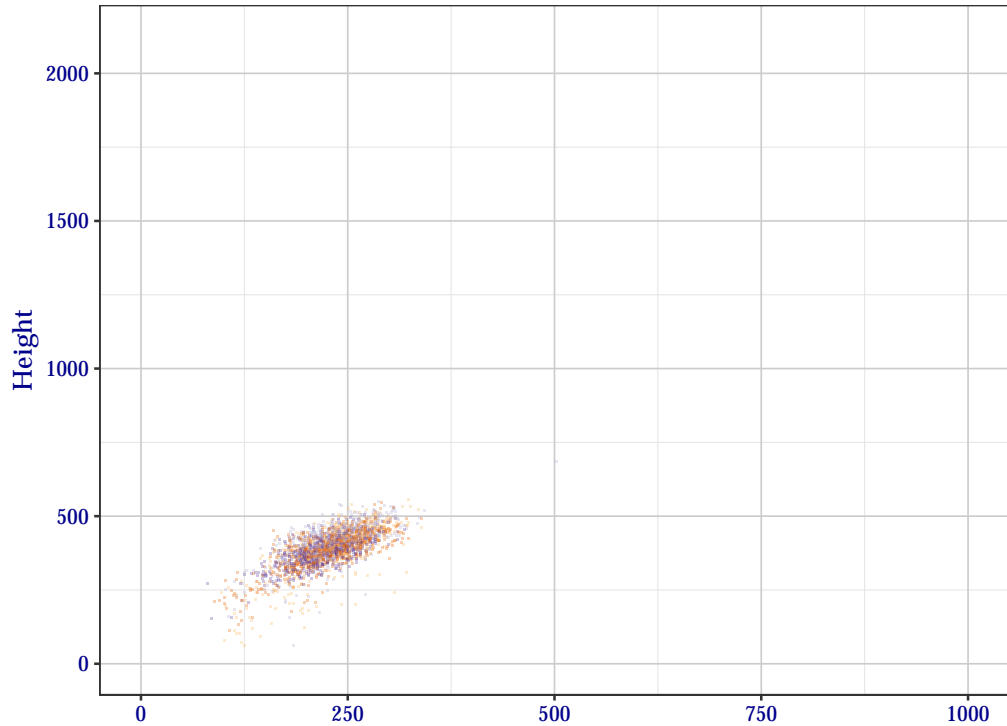
Participant: Neurotechnology/0014, FRGPs: 2, 3, 4, 5, Image Kind: Upper Palm

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

Segmentation Position Dimensions

Participant: Neurotechnology/0014, FRGPs: 7, 8, 9, 10, Image Kind: Upper Palm
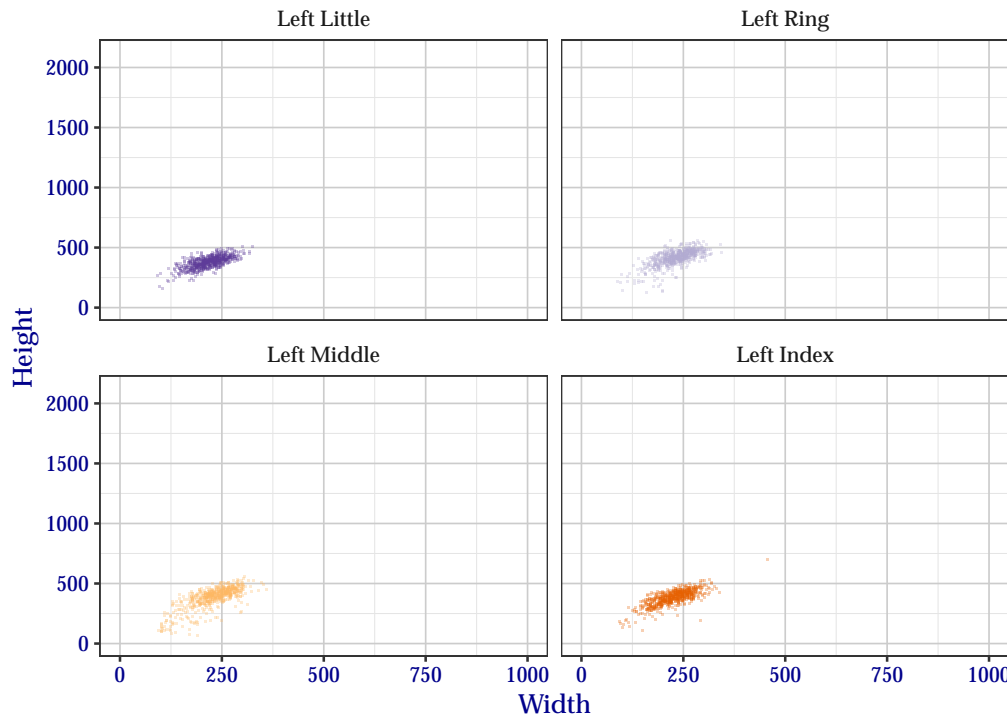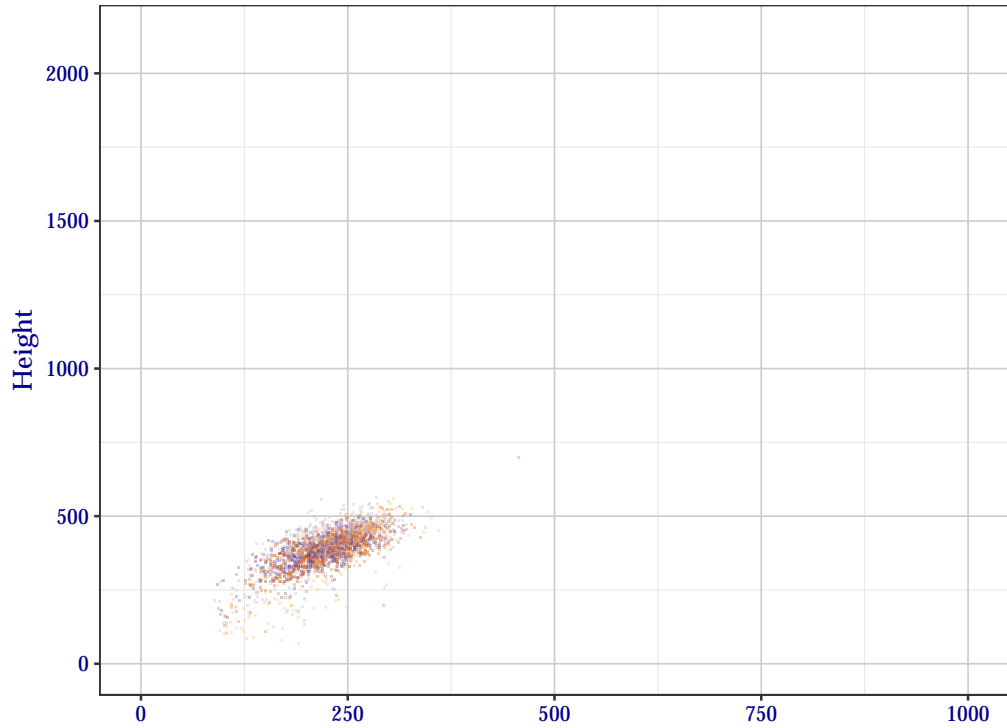
25 November 2024, 07:38:26 AM EST

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 28 shows how successful `Neurotechnology+0014` segmented fingers for each subject in the test corpus. Table 29 shows success for specific finger positions over the entire test corpus. Similarly, Table 30 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 31 shows success for combinations of all fingers, Table 32 for just the index and middle fingers, and Table 33 for all except the little finger.

Table 28: 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	99.9	99.9	99.9
2	99.9	99.9	99.9
3	99.2	99.2	99.2
4	98.7	98.7	99.1
5	95.0	95.1	95.8
6	89.9	90.3	91.0
7	80.2	80.4	81.8
8	58.0	58.6	62.5

Table 29: 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	93.1	93.1	94.5
Middle	91.2	91.4	92.8
Ring	91.5	91.8	92.2
Little	90.4	90.4	91.2
Left			
Index	92.4	92.7	93.2
Middle	90.2	90.2	90.3
Ring	91.0	91.5	92.2
Little	86.6	86.7	88.5

Table 30: 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	97.8	97.8	98.2
Both	86.3	86.6	88.1
Middle			
Either	97.9	97.9	98.0
Both	82.1	82.2	83.7
Ring			
Either	98.0	98.2	98.3
Both	83.0	83.7	84.6
Little			
Either	98.4	98.4	98.8
Both	77.2	77.3	79.4

Table 31: 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	99.6	99.6	99.7
At Least Two	97.7	97.7	97.9
At Least Three	91.4	91.5	92.0
All Four	77.5	77.8	81.1
Left			
Any	99.5	99.6	99.7
At Least Two	97.7	97.9	98.0
At Least Three	91.0	91.0	91.6
All Four	72.0	72.7	74.8

Table 32: 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	98.1	98.1	98.3
Both Index and Middle	86.2	86.3	89.1
Left			
Either Index or Middle	98.4	98.4	98.5
Both Index and Middle	84.2	84.5	85.0

Table 33: 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	99.1	99.1	99.2
At Least Two	95.2	95.2	95.5
All Three	81.5	81.9	84.8
Left			
Any	99.1	99.2	99.3
At Least Two	95.2	95.2	95.5
All Three	79.3	80.0	80.9

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.

Reasons for capture-type failures reported by Neurotechnology+0014 are enumerated in Table 34.

Table 34: Count of self-reported capture-type failure reasoning.

Failure Reason	Images
Request Recapture (No Attempt)	115

In situations where the algorithm feels that the presented image should be recaptured (Table 34), one or more image deficiencies must be identified. These deficiencies are enumerated in Table 35. At this point, NIST does not have a groundtruth of image deficiencies, but plans to update this table with the accuracy of deficiency observations in the future.

Table 35: Count of image deficiencies reported when requesting a recapture.

Deficiency	Count
Hand Geometry	115

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.

Neurotechnology+0014 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 Neurotechnology+0014 are enumerated in Table 36.

Table 36: Count of self-reported segmentation failure reasoning.

Failure Reason	Fingers
Finger Not Found	440
Finger Found, but Can't Segment	0
Vendor Defined	0

4.4.3 Identifying Missing Fingers

A small portion of the test corpus in SlapSeg III are missing fingers. Table 37 shows how successful Neurotechnology+0014 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 37: Performance of Neurotechnology+0014 at detecting fingers missing from an image.

Result	Percentage
Missed	15.5
Correctly Identified	37.1
Other Failure: Finger Found, but Can't Segment	0.0
Other Failure: Vendor Defined	0.0
Other Failure: Segmentation Not Attempted	47.4

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 38 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 38: 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	4.77	4.77	4.91
Right	3.99	3.99	4.26
Combined	4.38	4.38	4.58

4.5   Determining Orientation

An *optional* portion of the SlapSeg III API asked participants to determine the hand orientation of an image. Participants were provided the kind (e.g., upper palm) and needed to determine whether the image was of the left or right hand.

Overall Upper Palm accuracy: 87.5%

Table 39: Percentage of accuracy when determining hand orientation of an upper palm image. The first column indicates the true hand orientation. Subsequent columns indicate the percentage of the time in which the indicated hand orientation was hypothesized.

	Left	Right	Skip
Left	**85**	7.8	7.2
Right	1.6	**90.1**	8.3

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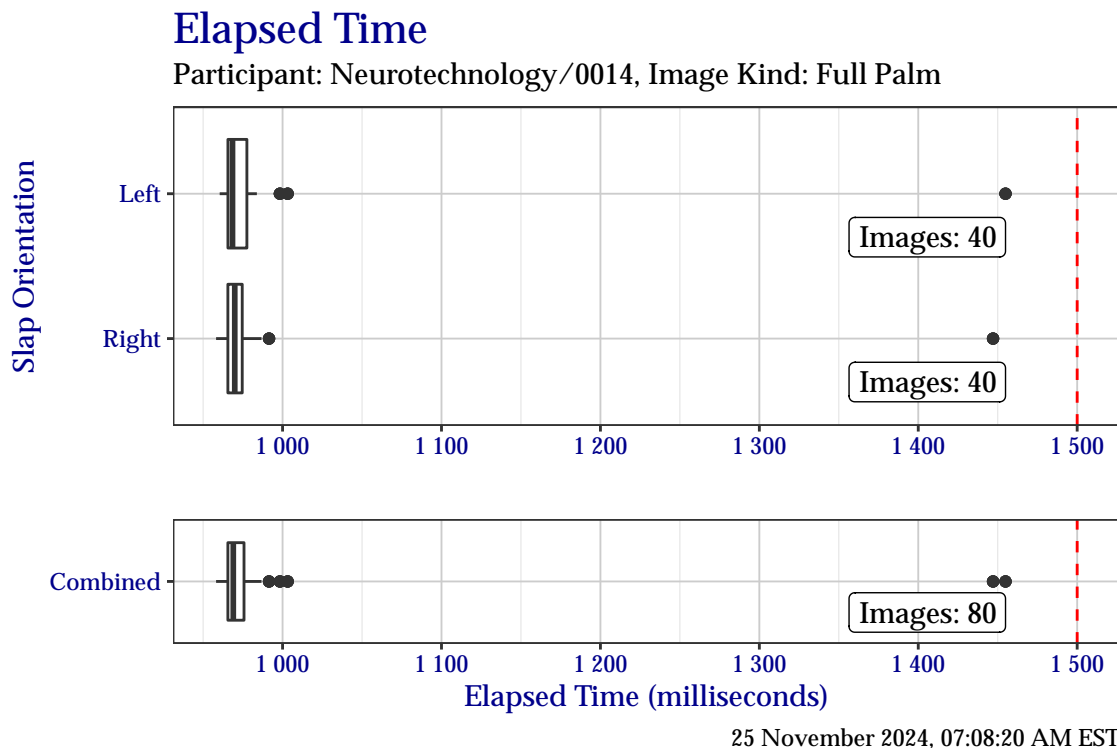
Figure 18: Box plots of elapsed time in milliseconds when segmenting the EightInch timing test corpus, separated by slap orientation.

Table 40: Elapsed time in milliseconds when segmenting the EightInch timing test corpus, separated by slap orientation and capture technology.

	Right	Left	Combined
Minimum	958	960	958
25%	966	966	966
Median	970	969	969
75%	975	978	976
Maximum	1 447	1 455	1 455

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.

Segmentation Position Centers
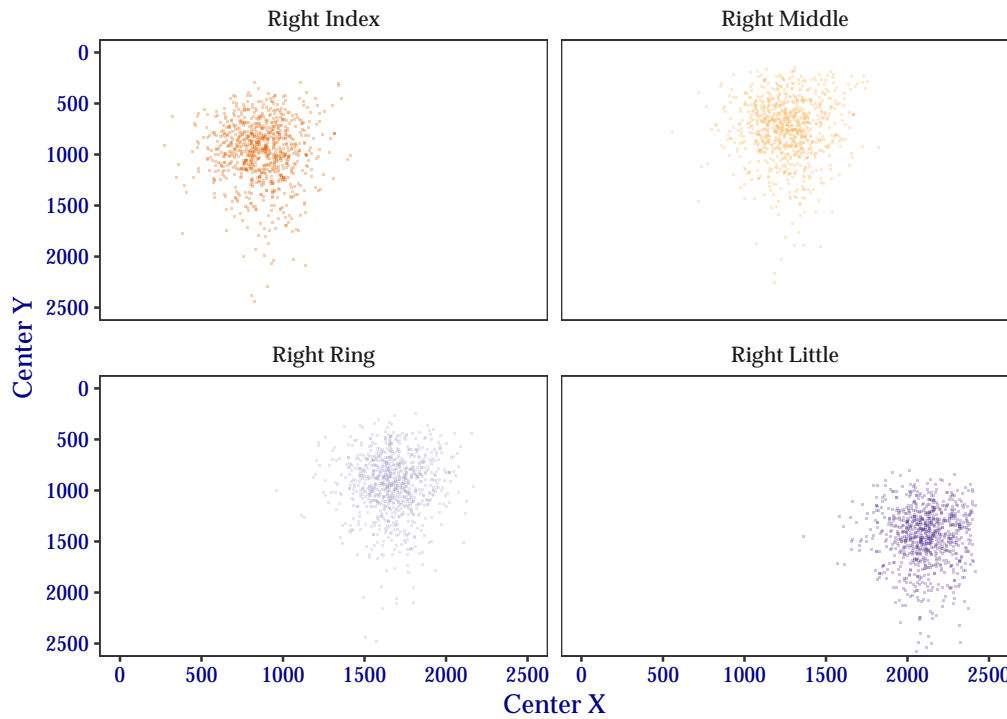
Participant: Neurotechnology/0014, FRGPs: 2, 3, 4, 5, Image Kind: Full Palm

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Figure 19: Segmentation centers for right hand EightInch data.

Segmentation Position Centers

Participant: Neurotechnology/0014, FRGPs: 7, 8, 9, 10, Image Kind: Full Palm
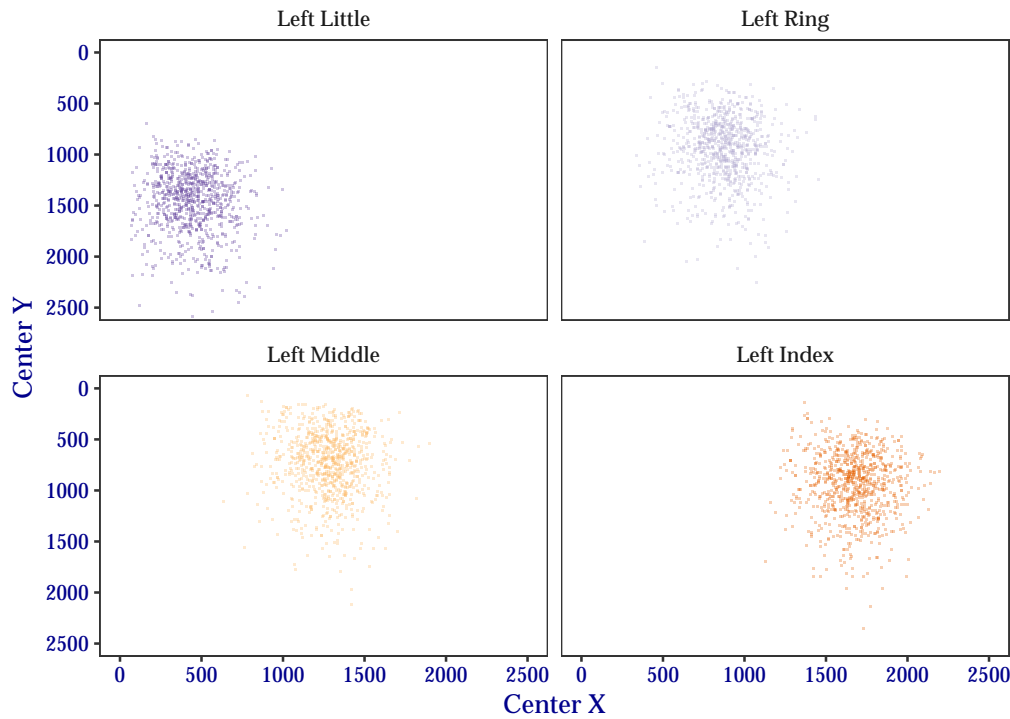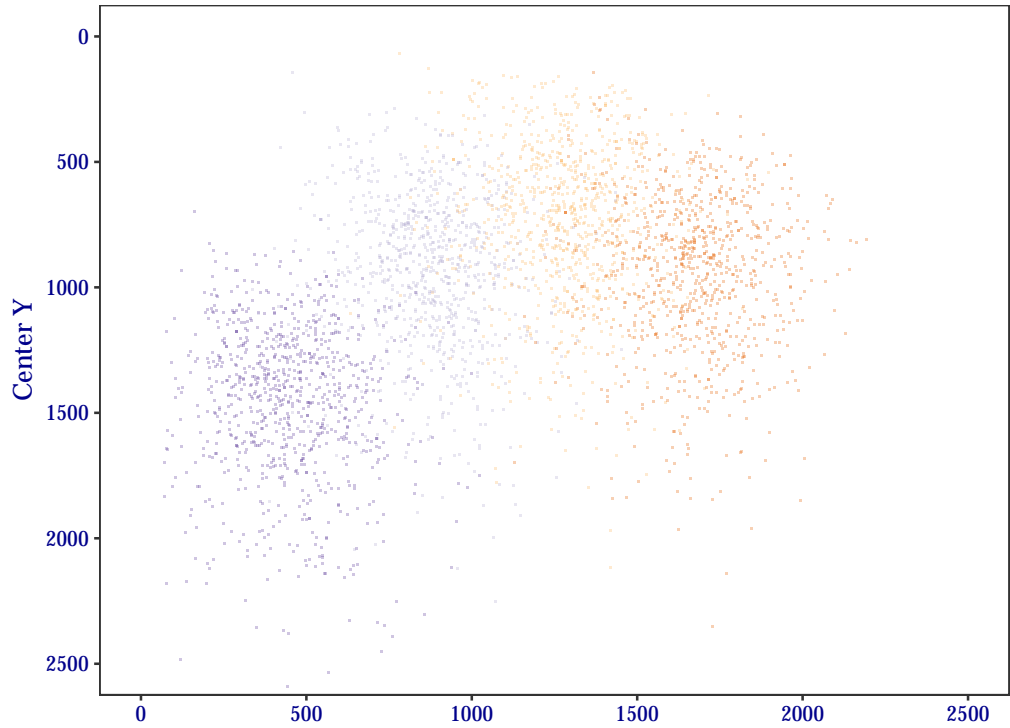
Figure 20: Segmentation centers for left hand EightInch data.

25 November 2024, 07:38:05 AM EST

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.

Segmentation Position Dimensions

Participant: Neurotechnology/0014, FRGPs: 2, 3, 4, 5, Image Kind: Full Palm
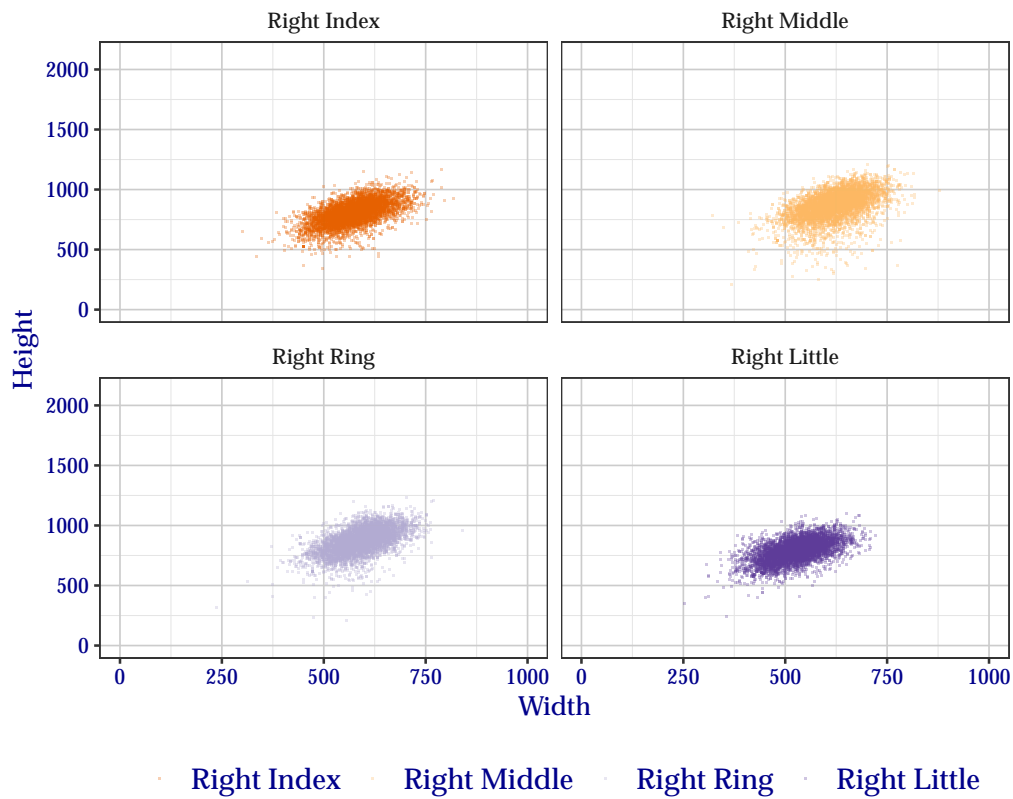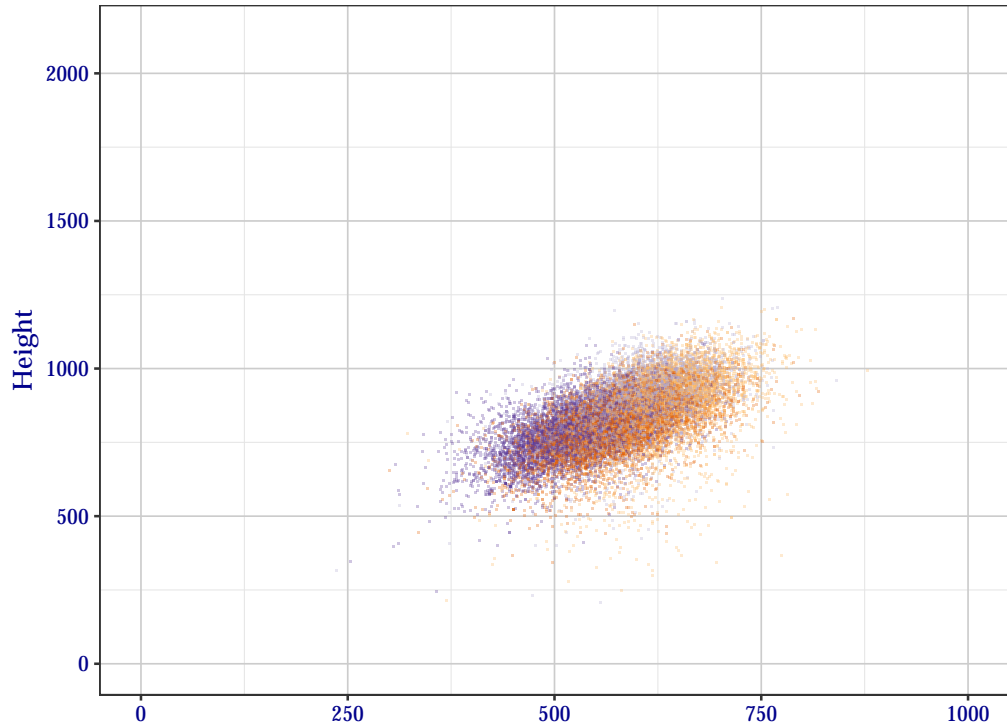
Figure 21: Segmentation position dimensions for right hand EightInch data.

Segmentation Position Dimensions

Participant: Neurotechnology/0014, FRGPs: 7, 8, 9, 10, Image Kind: Full Palm
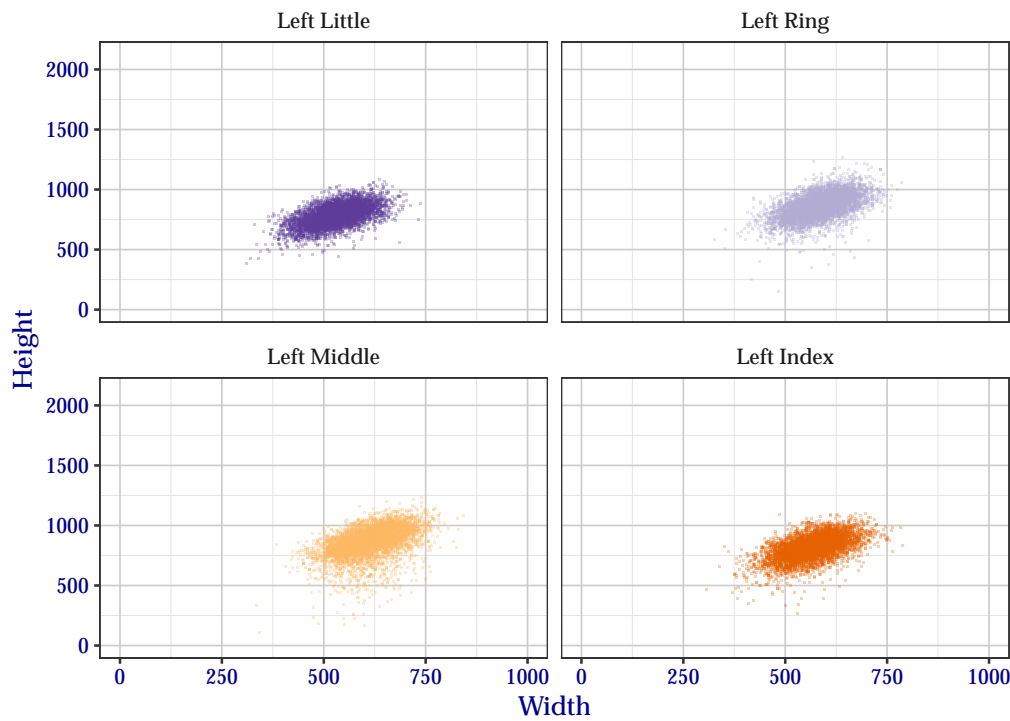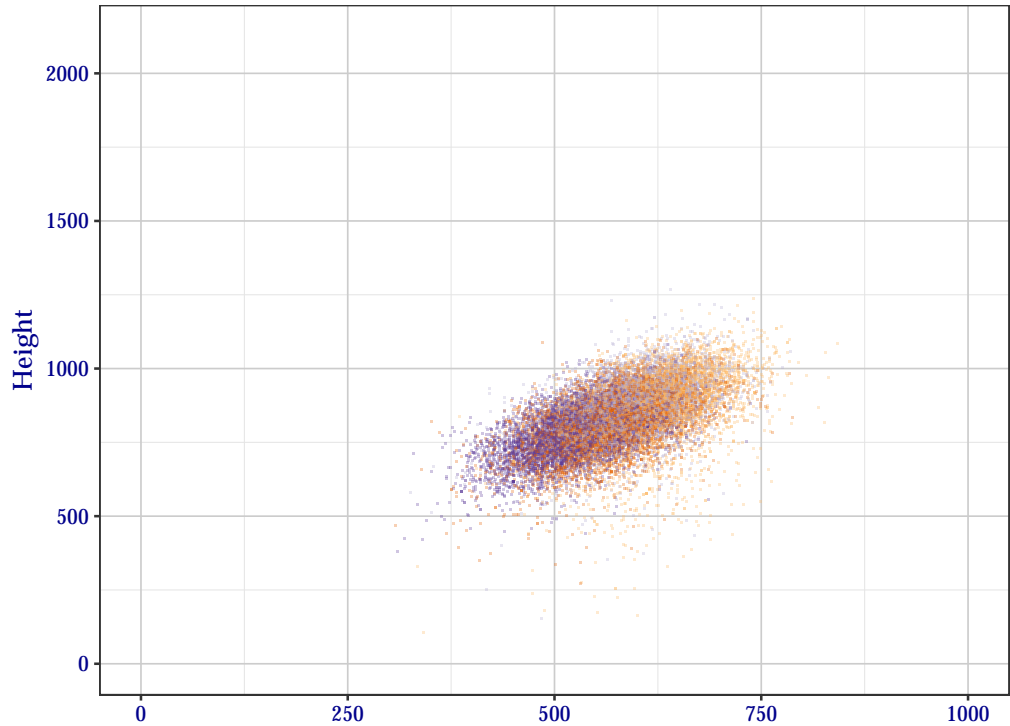
25 November 2024, 07:38:28 AM EST

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 41 shows how successful `Neurotechnology+0014` 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 on each slap image. Table 44 shows success for combinations of all fingers, Table 45 for just the index and middle fingers, and Table 46 for all except the little finger.

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.

Number of Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
1	100.0	100.0	100.0
2	100.0	100.0	100.0
3	100.0	100.0	100.0
4	99.9	99.9	100.0
5	99.9	99.9	100.0
6	99.9	99.9	99.9
7	98.9	98.9	99.2
8	92.9	93.2	94.3

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.

Finger	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Index	98.4	98.5	98.6
Middle	99.2	99.2	99.3
Ring	99.1	99.1	99.5
Little	98.9	98.9	99.1
Left			
Index	99.0	99.0	99.0
Middle	99.3	99.4	99.5
Ring	99.0	99.1	99.5
Little	98.6	98.6	98.7

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.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Index			
Either	100.0	100.0	100.0
Both	97.4	97.5	97.6
Middle			
Either	100.0	100.0	100.0
Both	98.5	98.6	98.9
Ring			
Either	100.0	100.0	100.0
Both	98.0	98.2	99.1
Little			
Either	99.9	99.9	100.0
Both	97.6	97.6	97.8

Table 44: 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	100.0	100.0	100.0
At Least Two	100.0	100.0	100.0
At Least Three	99.8	99.8	99.9
All Four	95.7	95.9	96.7
Left			
Any	99.9	99.9	100.0
At Least Two	99.9	99.9	100.0
At Least Three	99.4	99.4	99.5
All Four	96.7	96.9	97.2

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.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Either Index or Middle	100.0	100.0	100.0
Both Index and Middle	97.6	97.7	97.9
Left			
Either Index or Middle	99.8	99.8	99.8
Both Index and Middle	98.5	98.6	98.7

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.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	100.0	100.0	100.0
At Least Two	99.9	99.9	100.0
All Three	96.8	96.9	97.5
Left			
Any	99.9	99.9	100.0
At Least Two	99.8	99.8	99.8
All Three	97.6	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.

Reasons for capture-type failures reported by Neurotechnology+0014 are enumerated in Table 47.

Table 47: Count of self-reported capture-type failure reasoning.

Failure Reason	Images
Request Recapture (No Attempt)	1

In situations where the algorithm feels that the presented image should be recaptured (Table 47), one or more image deficiencies must be identified. These deficiencies are enumerated in Table 48. At this point, NIST does not have a groundtruth of image deficiencies, but plans to update this table with the accuracy of deficiency observations in the future.

Table 48: Count of image deficiencies reported when requesting a recapture.

Deficiency	Count
Hand Geometry	1

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.

Neurotechnology+0014 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 `Neurotechnology+0014` are enumerated in Table 49.

Table 49: Count of self-reported segmentation failure reasoning.

Failure Reason	Fingers
Finger Not Found	26
Finger Found, but Can't Segment	0
Vendor Defined	0

5.4.3 Identifying Missing Fingers

A small portion of the test corpus in SlapSeg III are missing fingers. Table 50 shows how successful `Neurotechnology+0014` 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 50: Performance of `Neurotechnology+0014` 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 51 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 51: 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	0.00	0.00	0.00
Right	0.00	0.00	0.00
Combined	0.00	0.00	0.00

5.5   Determining Orientation

An *optional* portion of the SlapSeg III API asked participants to determine the hand orientation of an image. Participants were provided the kind (e.g., full palm) and needed to determine whether the image was of the left or right hand.

Overall Full Palm accuracy: 99.9%

Table 52: Percentage of accuracy when determining hand orientation of an full palm image. The first column indicates the true hand orientation. Subsequent columns indicate the percentage of the time in which the indicated hand orientation was hypothesized.

	Left	Right	Skip
Left	**99.9**	0.1	0
Right	0.1	**99.9**	0

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 53, results are shown of how successful Neurotechnology+0014 segmented fingers for each subject in the test corpus. Table 54 shows success for specific finger positions over the entire test corpus. Similarly, Table 55 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 56 shows success for combinations of all fingers, Table 58 for the all except the little finger, and Table 57 for just the index and middle fingers.

Table 53: 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	99.9 [99.9, 100.0]	99.9 [99.9, 100.0]	100.0 [99.9, 100.0]
2	99.8 [99.8, 99.9]	99.9 [99.8, 99.9]	99.9 [99.9, 100.0]
3	99.5 [99.4, 99.7]	99.6 [99.5, 99.7]	99.7 [99.6, 99.8]
4	98.7 [98.5, 98.9]	98.9 [98.7, 99.1]	99.0 [98.9, 99.2]
5	95.5 [95.1, 95.8]	95.5 [95.1, 95.8]	95.6 [95.2, 95.9]
6	94.3 [93.9, 94.7]	94.5 [94.1, 94.9]	94.7 [94.3, 95.1]
7	89.8 [89.2, 90.3]	90.4 [89.9, 90.9]	90.7 [90.3, 91.2]
8	71.8 [71.0, 72.6]	74.4 [73.6, 75.1]	74.8 [74.0, 75.6]

Table 54: 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	98.4 [98.2, 98.6]	99.4 [99.3, 99.5]	99.6 [99.5, 99.7]
Middle	90.1 [89.8, 90.5]	90.5 [90.1, 90.9]	90.7 [90.3, 91.0]
Ring	96.6 [96.4, 96.9]	97.0 [96.7, 97.2]	97.2 [97.0, 97.4]
Little	98.0 [97.8, 98.2]	98.6 [98.5, 98.8]	98.8 [98.7, 99.0]
Left			
Index	98.6 [98.4, 98.7]	99.1 [99.0, 99.2]	99.2 [99.1, 99.3]
Middle	87.9 [87.5, 88.4]	88.3 [87.8, 88.7]	88.4 [87.9, 88.8]
Ring	97.4 [97.2, 97.7]	97.9 [97.7, 98.1]	98.0 [97.8, 98.2]
Little	97.5 [97.3, 97.7]	97.8 [97.6, 98.0]	98.0 [97.8, 98.2]

Table 55: 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	99.6 [99.5, 99.7]	99.6 [99.5, 99.7]	99.7 [99.6, 99.8]
Both	93.4 [93.0, 93.8]	94.7 [94.3, 95.1]	94.9 [94.5, 95.3]
Middle			
Either	96.8 [96.4, 97.1]	96.9 [96.6, 97.2]	97.0 [96.7, 97.3]
Both	78.4 [77.7, 79.0]	79.0 [78.2, 79.7]	79.1 [78.3, 79.8]
Ring			
Either	99.5 [99.3, 99.6]	99.5 [99.4, 99.6]	99.6 [99.5, 99.7]
Both	90.7 [90.2, 91.1]	91.5 [91.0, 92.0]	91.7 [91.2, 92.2]
Little			
Either	99.4 [99.2, 99.5]	99.6 [99.4, 99.7]	99.6 [99.5, 99.7]
Both	91.7 [91.2, 92.2]	92.4 [92.0, 92.9]	92.8 [92.4, 93.3]

Table 56: 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	99.9 [99.8, 99.9]	99.9 [99.8, 99.9]	99.9 [99.9, 99.9]
At Least Two	99.7 [99.5, 99.6]	99.7 [99.5, 99.7]	99.8 [99.6, 99.7]
At Least Three	98.0 [97.9, 98.2]	98.3 [98.2, 98.4]	98.5 [98.4, 98.6]
All Four	85.6 [84.6, 85.2]	87.6 [86.3, 86.9]	88.0 [86.6, 87.3]
Left			
Any	99.8 [99.8, 99.9]	99.8 [99.8, 99.9]	99.8 [99.9, 99.9]
At Least Two	99.4 [99.5, 99.6]	99.5 [99.5, 99.7]	99.6 [99.6, 99.7]
At Least Three	98.1 [97.9, 98.2]	98.3 [98.2, 98.4]	98.4 [98.4, 98.6]
All Four	84.1 [84.6, 85.2]	85.4 [86.3, 86.9]	85.7 [86.6, 87.3]

Table 57: 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	99.7 [99.5, 99.6]	99.8 [99.6, 99.7]	99.9 [99.7, 99.8]
Both Index and Middle	88.8 [87.7, 88.3]	90.2 [88.8, 89.4]	90.4 [89.0, 89.5]
Left			
Either Index or Middle	99.5 [99.5, 99.6]	99.6 [99.6, 99.7]	99.6 [99.7, 99.8]
Both Index and Middle	87.0 [87.7, 88.3]	87.8 [88.8, 89.4]	87.9 [89.0, 89.5]

Table 58: 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	99.8 [99.7, 99.8]	99.8 [99.7, 99.8]	99.9 [99.8, 99.9]
At Least Two	98.4 [98.4, 98.6]	98.6 [98.6, 98.8]	98.8 [98.7, 98.9]
All Three	86.9 [86.0, 86.6]	88.4 [87.3, 87.9]	88.8 [87.6, 88.2]
Left			
Any	99.7 [99.7, 99.8]	99.7 [99.7, 99.8]	99.8 [99.8, 99.9]
At Least Two	98.6 [98.4, 98.6]	98.8 [98.6, 98.8]	98.9 [98.7, 98.9]
All Three	85.7 [86.0, 86.6]	86.7 [87.3, 87.9]	86.9 [87.6, 88.2]

A.2 Jaccard Index

Jaccard Similarity by Traditional Success Metric
Participant: Neurotechnology/0014, Image Kind: Two Inch
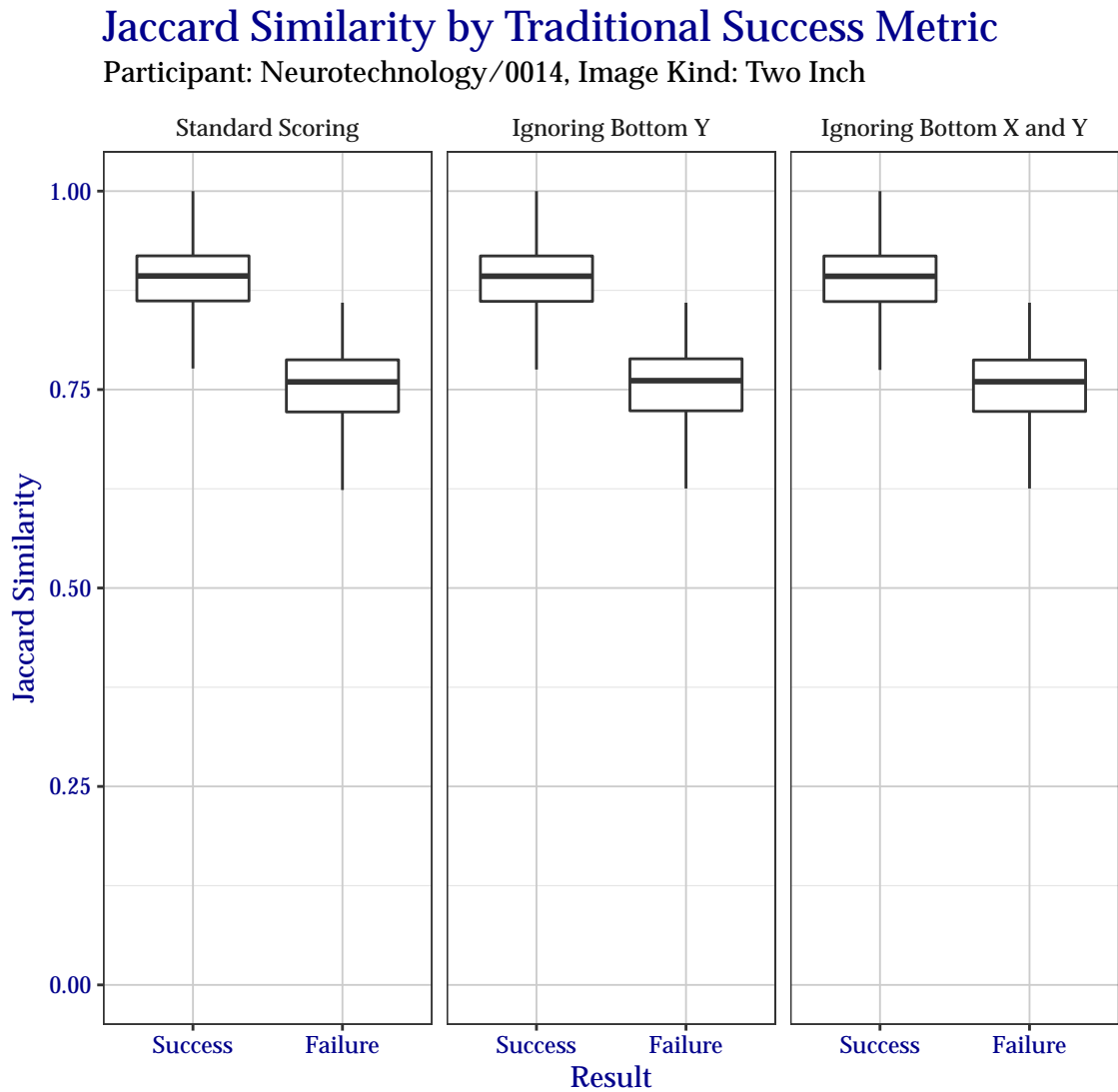
25 November 2024, 07:23:05 AM EST

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

Jaccard Similarity by Friction Ridge Generalized Position
Participant: Neurotechnology/0014, Image Kind: Two Inch

25 November 2024, 07:23:01 AM EST
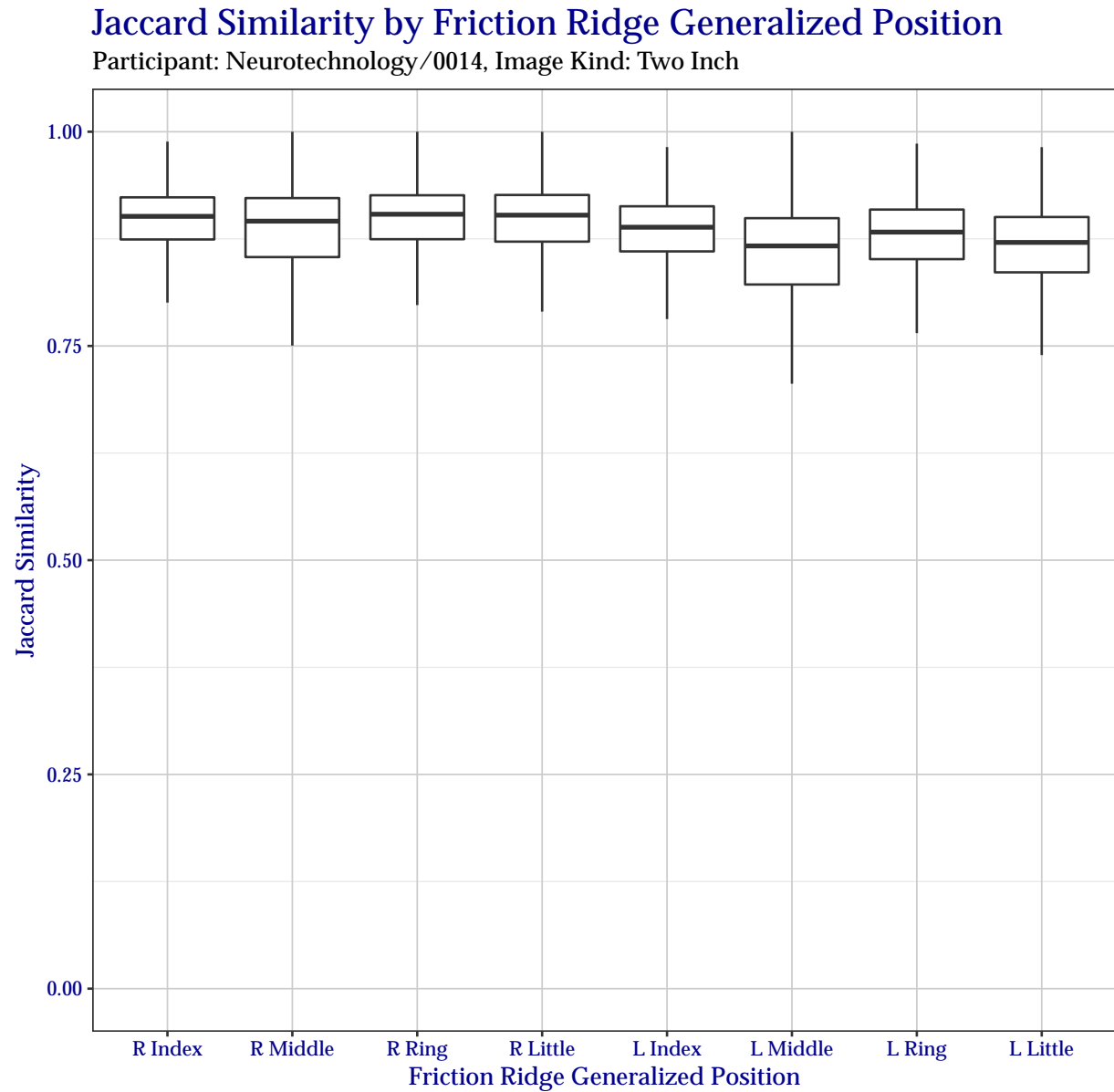
Figure 24: Boxplot of Jaccard similarity indices for each friction ridge generalized position. Outliers have been removed for clarity.

Table 59: 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	100.0	100.0	100.0	99.9	89.8	22.5	0.6
2	100.0	100.0	99.9	99.8	78.2	6.3	0.1
3	99.9	99.9	99.8	99.3	61.9	1.2	0.0
4	99.8	99.6	99.1	97.8	42.6	0.2	0.0
5	95.9	95.9	95.9	94.9	25.4	0.0	0
6	95.9	95.9	95.8	92.0	13.1	0	0
7	95.9	95.8	95.1	82.8	5.0	0	0
8	95.7	95.1	89.3	58.0	1.0	0	0

Table 60: 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	0.0	0.0	0.2	3.0	45.3	51.5
Middle	0.0	0.2	1.5	9.7	42.5	46.1
Ring	0.0	0.1	0.4	4.0	41.5	54.0
Little	0.1	0.1	0.3	3.6	43.3	52.6
Left						
Index	0.1	0.0	0.2	2.9	58.6	38.2
Middle	0.1	0.2	2.5	14.5	58.3	24.4
Ring	0.0	0.1	0.9	5.2	60.6	33.2
Little	0.0	0.1	0.8	9.1	64.6	25.4

Table 61: 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	100.0	100.0	100.0	99.9	81.0	17.7	0.4
At Least Two	100.0	100.0	100.0	99.6	65.1	4.3	0.0
At Least Three	100.0	100.0	99.8	96.8	41.8	0.6	0.0
All Four	99.9	99.6	97.3	80.4	16.2	0.1	0.0
Left							
Any	100.0	100.0	100.0	99.7	60.7	6.8	0.1
At Least Two	100.0	100.0	99.9	98.7	38.1	1.1	0.0
At Least Three	99.9	99.9	99.7	93.9	18.0	0.1	0.0
All Four	99.8	99.5	95.4	71.0	4.3	0.0	0.0

Table 62: 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	100.0	100.0	100.0	99.5	68.0	9.6	0.2
Both Index and Middle	99.9	99.8	98.0	85.8	29.5	0.7	0.0
Left							
Either Index or Middle	100.0	100.0	99.9	98.8	48.1	3.9	0.1
Both Index and Middle	99.9	99.7	97.0	80.7	14.4	0.2	0.0

Table 63: 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	100.0	100.0	100.0	99.9	76.2	13.7	0.3
At Least Two	100.0	100.0	99.9	97.8	52.6	2.4	0.0
All Three	99.9	99.7	97.7	83.2	22.7	0.2	0.0
Left							
Any	100.0	100.0	100.0	99.4	56.4	5.7	0.1
At Least Two	100.0	99.9	99.7	96.4	30.2	0.7	0.0
All Three	99.8	99.6	96.2	77.4	9.2	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 64, results are shown of how successful Neurotechnology+0014 segmented fingers for each subject in the test corpus. Table 65 shows success for specific finger positions over the entire test corpus. Similarly, Table 66 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 67 shows success for combinations of all fingers, Table 69 for the all except the little finger, and Table 68 for just the index and middle fingers.

Table 64: 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	99.8 [99.8, 99.9]	99.8 [99.8, 99.9]	99.8 [99.8, 99.9]
2	99.5 [99.4, 99.6]	99.5 [99.4, 99.6]	99.5 [99.5, 99.6]
3	98.5 [98.4, 98.7]	98.5 [98.4, 98.7]	98.5 [98.4, 98.7]
4	98.3 [98.1, 98.5]	98.3 [98.2, 98.5]	98.3 [98.2, 98.5]
5	95.9 [95.7, 96.2]	95.9 [95.7, 96.2]	95.9 [95.7, 96.2]
6	95.9 [95.6, 96.1]	95.9 [95.6, 96.1]	95.9 [95.6, 96.1]
7	95.7 [95.5, 96.0]	95.7 [95.5, 96.0]	95.8 [95.5, 96.0]
8	95.0 [94.7, 95.3]	95.0 [94.8, 95.3]	95.2 [94.9, 95.4]
9	90.4 [90.1, 90.8]	90.6 [90.2, 90.9]	91.1 [90.7, 91.4]
10	73.5 [72.9, 74.0]	73.9 [73.4, 74.5]	75.5 [75.0, 76.1]

Table 65: 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	92.4 [92.1, 92.8]	92.6 [92.3, 92.9]	93.0 [92.7, 93.3]
Index	99.4 [99.3, 99.5]	99.4 [99.3, 99.5]	99.4 [99.3, 99.5]
Middle	99.1 [98.9, 99.2]	99.1 [98.9, 99.2]	99.4 [99.3, 99.5]
Ring	97.2 [97.0, 97.4]	97.3 [97.1, 97.5]	97.6 [97.4, 97.8]
Little	96.1 [95.9, 96.4]	96.1 [95.9, 96.4]	96.2 [96.0, 96.4]
Left			
Thumb	91.3 [91.0, 91.7]	91.5 [91.1, 91.8]	91.9 [91.6, 92.3]
Index	98.8 [98.7, 99.0]	98.8 [98.7, 99.0]	98.9 [98.8, 99.0]
Middle	98.9 [98.7, 99.0]	98.9 [98.8, 99.0]	99.3 [99.2, 99.4]
Ring	98.6 [98.5, 98.8]	98.8 [98.7, 99.0]	99.1 [98.9, 99.2]
Little	96.8 [96.5, 97.0]	96.8 [96.5, 97.0]	96.8 [96.6, 97.1]

Table 66: 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	97.6 [97.4, 97.8]	97.7 [97.5, 97.9]	97.8 [97.6, 98.0]
Both	86.2 [85.7, 86.6]	86.4 [86.0, 86.8]	87.2 [86.8, 87.6]
Index			
Either	99.9 [99.9, 99.9]	99.9 [99.9, 99.9]	99.9 [99.9, 99.9]
Both	95.6 [95.3, 95.9]	95.6 [95.4, 95.9]	95.8 [95.5, 96.0]
Middle			
Either	99.9 [99.8, 99.9]	99.9 [99.8, 99.9]	99.9 [99.9, 100.0]
Both	95.4 [95.1, 95.7]	95.4 [95.2, 95.7]	96.1 [95.8, 96.3]
Ring			
Either	99.7 [99.7, 99.8]	99.8 [99.7, 99.9]	99.8 [99.8, 99.9]
Both	93.4 [93.1, 93.7]	93.7 [93.4, 94.0]	94.2 [93.9, 94.5]
Little			
Either	99.4 [99.3, 99.5]	99.4 [99.3, 99.5]	99.4 [99.3, 99.5]
Both	91.0 [90.6, 91.3]	91.0 [90.6, 91.3]	91.1 [90.7, 91.4]

Table 67: 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	99.6 [99.6, 99.7]	99.6 [99.6, 99.7]	99.7 [99.6, 99.7]
At Least Two	98.5 [98.4, 98.6]	98.5 [98.4, 98.6]	98.5 [98.4, 98.6]
At Least Three	98.3 [98.2, 98.4]	98.3 [98.2, 98.4]	98.3 [98.2, 98.5]
At Least Four	96.6 [96.7, 97.0]	96.7 [96.7, 97.0]	96.9 [96.9, 97.2]
All Five	82.2 [81.8, 82.4]	82.5 [82.0, 82.7]	83.3 [83.0, 83.6]
Left			
Any	99.7 [99.6, 99.7]	99.7 [99.6, 99.7]	99.7 [99.6, 99.7]
At Least Two	98.5 [98.4, 98.6]	98.5 [98.4, 98.6]	98.5 [98.4, 98.6]
At Least Three	98.3 [98.2, 98.4]	98.3 [98.2, 98.4]	98.4 [98.2, 98.5]
At Least Four	97.0 [96.7, 97.0]	97.0 [96.7, 97.0]	97.2 [96.9, 97.2]
All Five	82.0 [81.8, 82.4]	82.3 [82.0, 82.7]	83.3 [83.0, 83.6]

Table 68: 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	99.9 [99.9, 99.9]	99.9 [99.9, 99.9]	99.9 [99.9, 99.9]
Both Index and Middle	98.5 [98.0, 98.3]	98.5 [98.1, 98.3]	98.9 [98.5, 98.7]
Left			
Either Index or Middle	99.9 [99.9, 99.9]	99.9 [99.9, 99.9]	99.9 [99.9, 99.9]
Both Index and Middle	97.8 [98.0, 98.3]	97.9 [98.1, 98.3]	98.3 [98.5, 98.7]

Table 69: 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	100.0 [99.9, 100.0]	100.0 [99.9, 100.0]	100.0 [99.9, 100.0]
At Least Two	99.7 [99.6, 99.7]	99.7 [99.6, 99.7]	99.7 [99.7, 99.8]
All Three	96.0 [96.2, 96.5]	96.1 [96.4, 96.7]	96.7 [97.0, 97.3]
Left			
Any	100.0 [99.9, 100.0]	100.0 [99.9, 100.0]	100.0 [99.9, 100.0]
At Least Two	99.7 [99.6, 99.7]	99.7 [99.6, 99.7]	99.8 [99.7, 99.8]
All Three	96.7 [96.2, 96.5]	96.9 [96.4, 96.7]	97.5 [97.0, 97.3]

B.2   Jaccard Index

Jaccard Similarity by Traditional Success Metric
Participant: Neurotechnology/0014, Image Kind: Three Inch
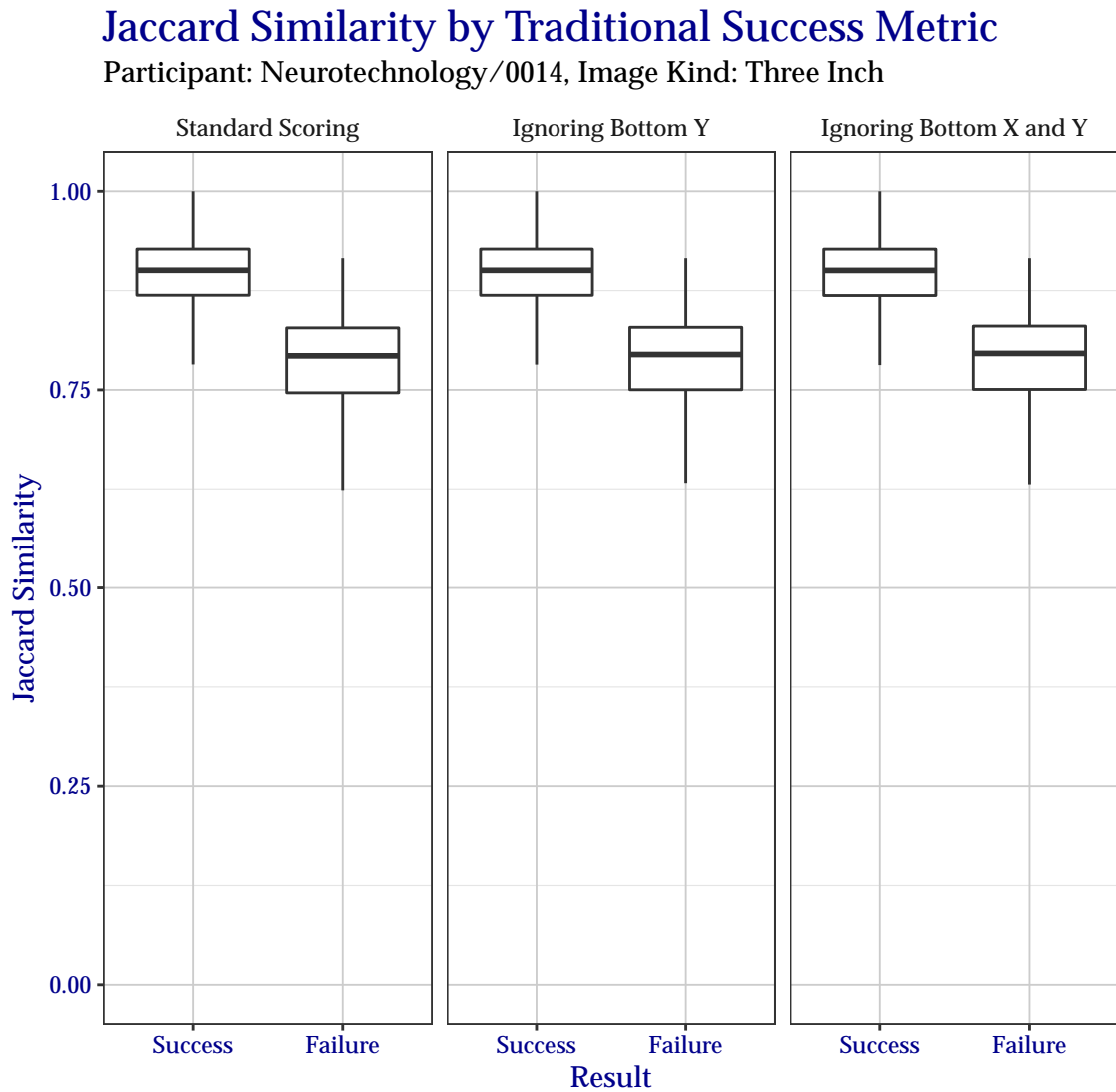
25 November 2024, 07:37:29 AM EST

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

Jaccard Similarity by Friction Ridge Generalized Position

Participant: Neurotechnology/0014, Image Kind: Three Inch
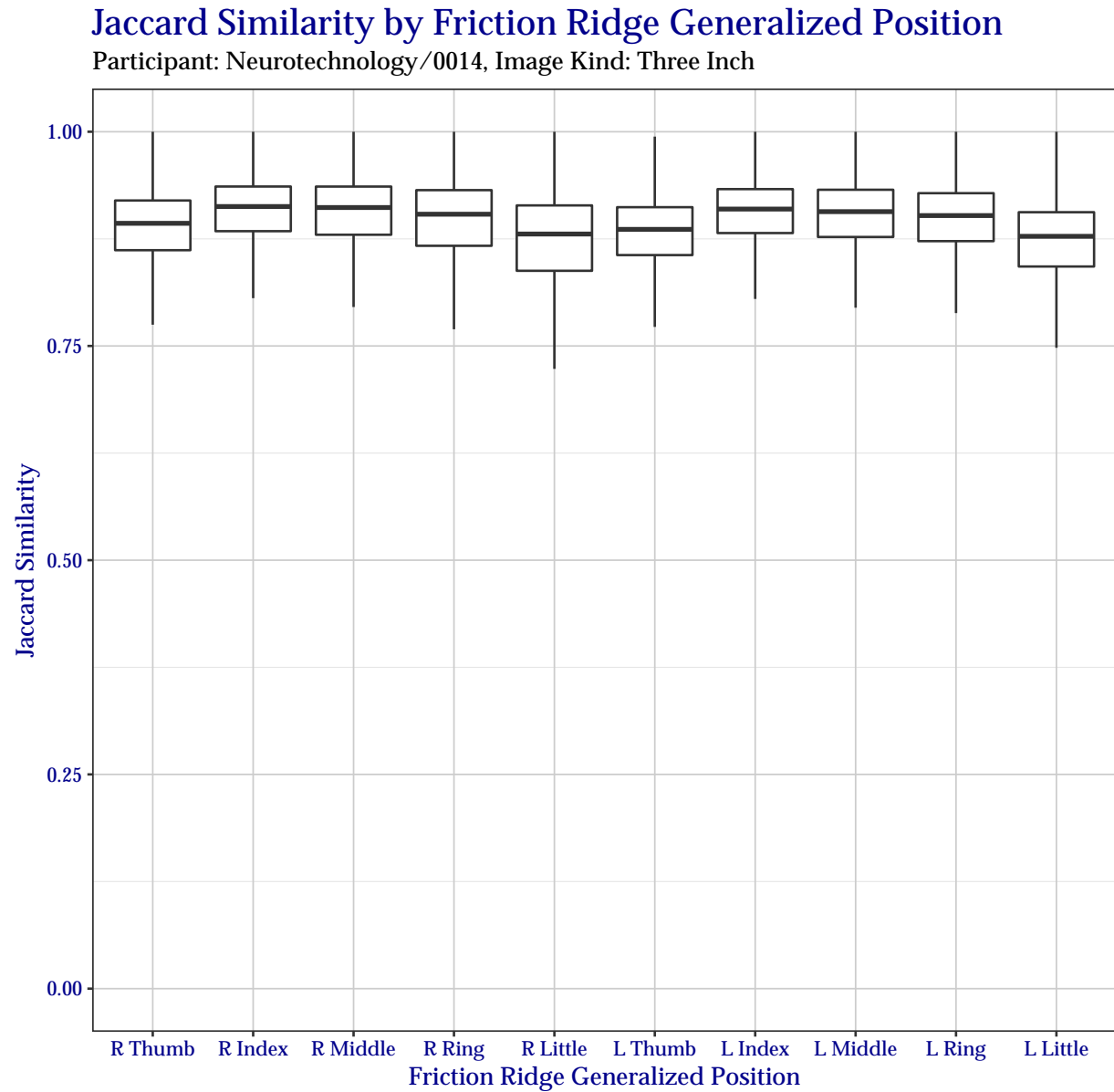
25 November 2024, 07:37:24 AM EST

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

Table 70: 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	100.0	99.9	99.9	99.8	97.5	51.1	3.6
2	99.9	99.9	99.8	99.7	92.3	21.0	0.2
3	98.6	98.6	98.6	98.5	83.5	7.2	0.0
4	98.5	98.5	98.4	97.9	70.9	2.1	0.0
5	95.9	95.9	95.9	95.8	55.6	0.4	0.0
6	95.9	95.9	95.9	95.5	39.4	0.1	0
7	95.9	95.9	95.9	94.2	23.7	0.0	0
8	95.9	95.9	95.8	91.8	11.4	0	0
9	95.9	95.8	95.3	85.0	3.7	0	0
10	95.6	95.4	92.1	65.5	0.7	0	0

Table 71: 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	0.2	0.1	0.3	4.3	51.8	43.3
Index	0.1	0.0	0.2	2.3	35.1	62.3
Middle	0.1	0.0	0.2	3.6	35.6	60.5
Ring	0.1	0.0	0.5	5.4	40.8	53.2
Little	0.1	0.1	1.1	11.0	52.1	35.6
Left						
Thumb	0.2	0.1	0.3	4.9	58.4	36.1
Index	0.0	0.0	0.1	1.6	38.7	59.6
Middle	0.1	0.0	0.2	2.1	41.2	56.4
Ring	0.1	0.0	0.4	2.5	45.0	52.0
Little	0.1	0.1	0.9	8.4	60.2	30.3

Table 72: 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	99.9	99.9	99.9	99.7	91.1	35.1	2.2
At Least Two	98.6	98.6	98.6	97.8	74.0	9.7	0.1
At Least Three	98.5	98.5	98.5	96.5	52.0	1.9	0.0
At Least Four	98.5	98.5	98.1	92.4	26.7	0.2	0.0
All Five	94.8	94.7	92.7	75.2	6.6	0.0	0.0
Left							
Any	99.9	99.9	99.8	99.7	89.8	28.3	1.5
At Least Two	98.5	98.5	98.5	98.3	70.2	6.1	0.0
At Least Three	98.5	98.5	98.5	97.8	45.5	0.8	0.0
At Least Four	98.5	98.4	98.2	94.8	20.4	0.0	0.0
All Five	94.8	94.7	93.2	78.5	4.4	0.0	0.0

Table 73: 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	100.0	100.0	99.9	98.6	77.6	22.5	1.2
Both Index and Middle	99.9	99.9	99.5	94.9	45.2	3.2	0.0
Left							
Either Index or Middle	100.0	100.0	100.0	99.6	76.3	19.2	0.9
Both Index and Middle	99.9	99.9	99.7	96.4	39.8	2.2	0.0

Table 74: 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	100.0	100.0	100.0	99.1	83.4	29.1	1.7
At Least Two	100.0	100.0	99.9	97.2	61.3	6.9	0.1
All Three	99.9	99.8	99.0	91.2	31.2	0.9	0.0
Left							
Any	100.0	100.0	100.0	99.8	83.2	24.7	1.3
At Least Two	100.0	100.0	99.9	99.0	58.0	4.9	0.0
All Three	99.9	99.8	99.3	94.2	26.9	0.4	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 75, results are shown of how successful Neurotechnology+0014 segmented fingers for each subject in the test corpus. Table 76 shows success for specific finger positions over the entire test corpus. Similarly, Table 77 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 78 shows success for combinations of all fingers, Table 80 for the all except the little finger, and Table 79 for just the index and middle fingers.

Table 75: 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	99.9 [99.6, 100.0]	99.9 [99.6, 100.0]	99.9 [99.6, 100.0]
2	99.9 [99.6, 100.0]	99.9 [99.6, 100.0]	99.9 [99.6, 100.0]
3	99.2 [98.6, 99.7]	99.2 [98.6, 99.7]	99.2 [98.6, 99.7]
4	98.7 [97.9, 99.3]	98.7 [97.8, 99.5]	99.1 [98.4, 99.7]
5	95.0 [93.4, 96.6]	95.1 [93.4, 96.6]	95.8 [94.3, 97.2]
6	89.9 [87.6, 92.0]	90.3 [87.9, 92.4]	91.0 [89.1, 93.0]
7	80.2 [77.3, 83.0]	80.4 [77.3, 83.0]	81.8 [79.1, 84.7]
8	58.0 [54.4, 61.5]	58.6 [55.2, 61.9]	62.5 [59.0, 66.0]

Table 76: 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	93.1 [91.1, 94.8]	93.1 [91.1, 94.8]	94.5 [92.8, 96.1]
Middle	91.2 [89.1, 93.2]	91.4 [89.2, 93.4]	92.8 [90.8, 94.7]
Ring	91.5 [89.5, 93.4]	91.8 [89.8, 93.6]	92.2 [90.0, 94.0]
Little	90.4 [88.2, 92.4]	90.4 [88.3, 92.3]	91.2 [89.1, 93.4]
Left			
Index	92.4 [90.5, 94.3]	92.7 [90.7, 94.4]	93.2 [91.4, 95.0]
Middle	90.2 [87.9, 92.3]	90.2 [87.9, 92.3]	90.3 [88.2, 92.3]
Ring	91.0 [88.7, 93.0]	91.5 [89.4, 93.5]	92.2 [90.2, 94.0]
Little	86.6 [84.1, 89.0]	86.7 [84.0, 89.1]	88.5 [86.1, 90.7]

Table 77: 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	97.8 [96.7, 98.7]	97.8 [96.7, 98.7]	98.2 [97.1, 99.1]
Both	86.3 [83.5, 88.7]	86.6 [84.1, 88.8]	88.1 [85.9, 90.5]
Middle			
Either	97.9 [96.8, 98.8]	97.9 [96.8, 98.8]	98.0 [97.0, 98.9]
Both	82.1 [79.3, 84.7]	82.2 [79.4, 84.8]	83.7 [81.0, 86.3]
Ring			
Either	98.0 [97.0, 98.9]	98.2 [97.1, 99.1]	98.3 [97.4, 99.1]
Both	83.0 [80.4, 85.8]	83.7 [80.8, 86.2]	84.6 [81.9, 87.0]
Little			
Either	98.4 [97.5, 99.2]	98.4 [97.5, 99.2]	98.8 [98.0, 99.6]
Both	77.2 [74.2, 80.2]	77.3 [74.3, 80.1]	79.4 [76.4, 82.5]

Table 78: 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	99.6 [99.2, 99.9]	99.6 [99.3, 99.9]	99.7 [99.5, 99.9]
At Least Two	97.7 [96.9, 98.5]	97.7 [97.0, 98.5]	97.9 [97.2, 98.7]
At Least Three	91.4 [89.8, 92.6]	91.5 [89.7, 92.6]	92.0 [90.4, 93.2]
All Four	77.5 [72.7, 77.0]	77.8 [73.0, 77.4]	81.1 [75.8, 79.9]
Left			
Any	99.5 [99.2, 99.9]	99.6 [99.3, 99.9]	99.7 [99.5, 99.9]
At Least Two	97.7 [96.9, 98.5]	97.9 [97.0, 98.5]	98.0 [97.2, 98.7]
At Least Three	91.0 [89.8, 92.6]	91.0 [89.7, 92.6]	91.6 [90.4, 93.2]
All Four	72.0 [72.7, 77.0]	72.7 [73.0, 77.4]	74.8 [75.8, 79.9]

Table 79: 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	98.1 [97.6, 98.9]	98.1 [97.6, 98.9]	98.3 [97.8, 99.0]
Both Index and Middle	86.2 [83.4, 86.9]	86.3 [83.6, 87.0]	89.1 [85.3, 88.8]
Left			
Either Index or Middle	98.4 [97.6, 98.9]	98.4 [97.6, 98.9]	98.5 [97.8, 99.0]
Both Index and Middle	84.2 [83.4, 86.9]	84.5 [83.6, 87.0]	85.0 [85.3, 88.8]

Table 80: 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 [98.6, 99.5]	99.1 [98.7, 99.5]	99.2 [98.7, 99.7]
At Least Two	95.2 [94.2, 96.3]	95.2 [94.1, 96.2]	95.5 [94.4, 96.5]
All Three	81.5 [78.4, 82.3]	81.9 [79.0, 82.9]	84.8 [80.8, 84.7]
Left			
Any	99.1 [98.6, 99.5]	99.2 [98.7, 99.5]	99.3 [98.7, 99.7]
At Least Two	95.2 [94.2, 96.3]	95.2 [94.1, 96.2]	95.5 [94.4, 96.5]
All Three	79.3 [78.4, 82.3]	80.0 [79.0, 82.9]	80.9 [80.8, 84.7]

C.2 Jaccard Index
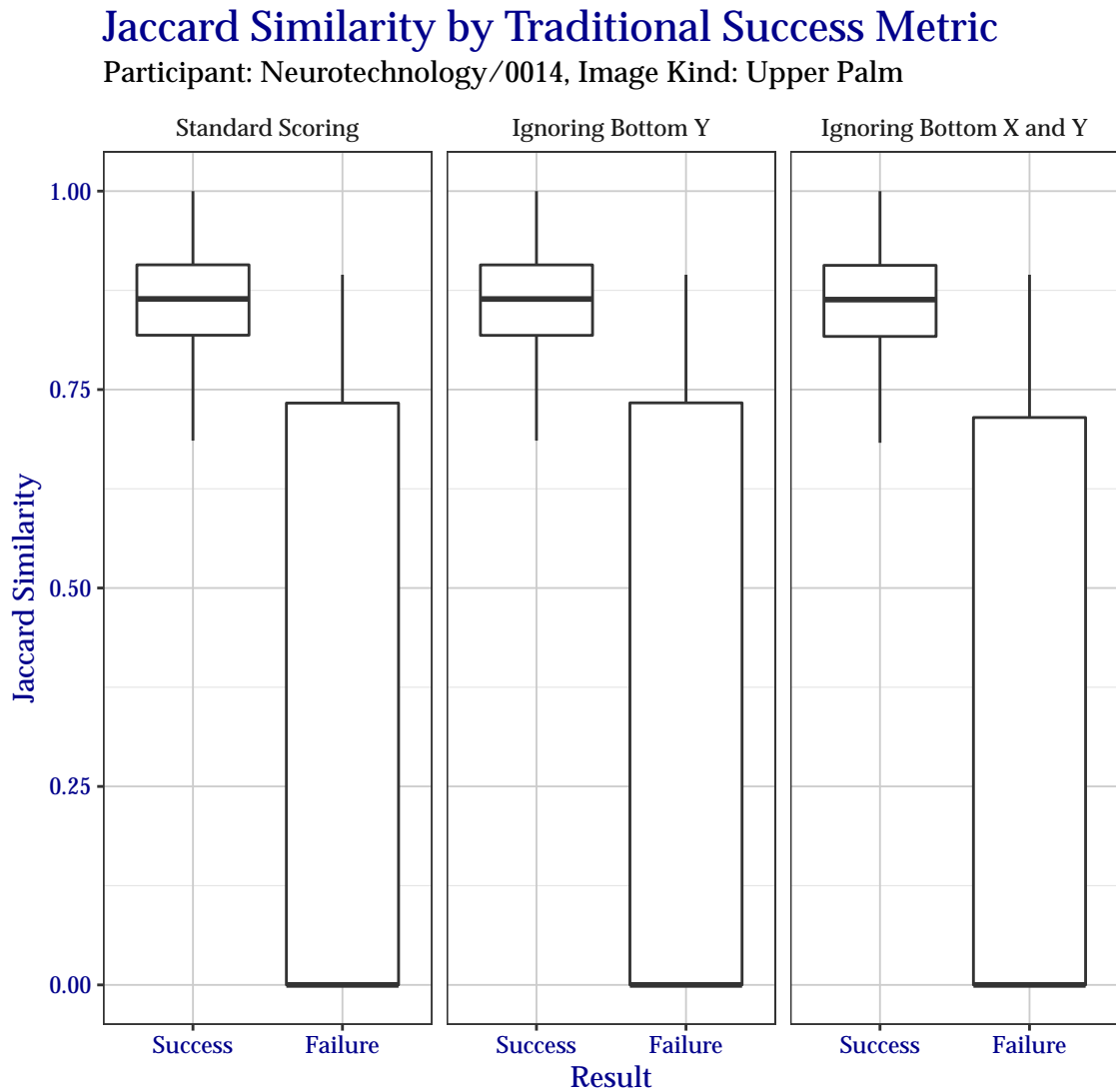
Figure 27: Boxplot of Jaccard similarity indices as compared to the traditional success metrics. Outliers have been removed for clarity.

Jaccard Similarity by Friction Ridge Generalized Position

Participant: Neurotechnology/0014, Image Kind: Upper Palm
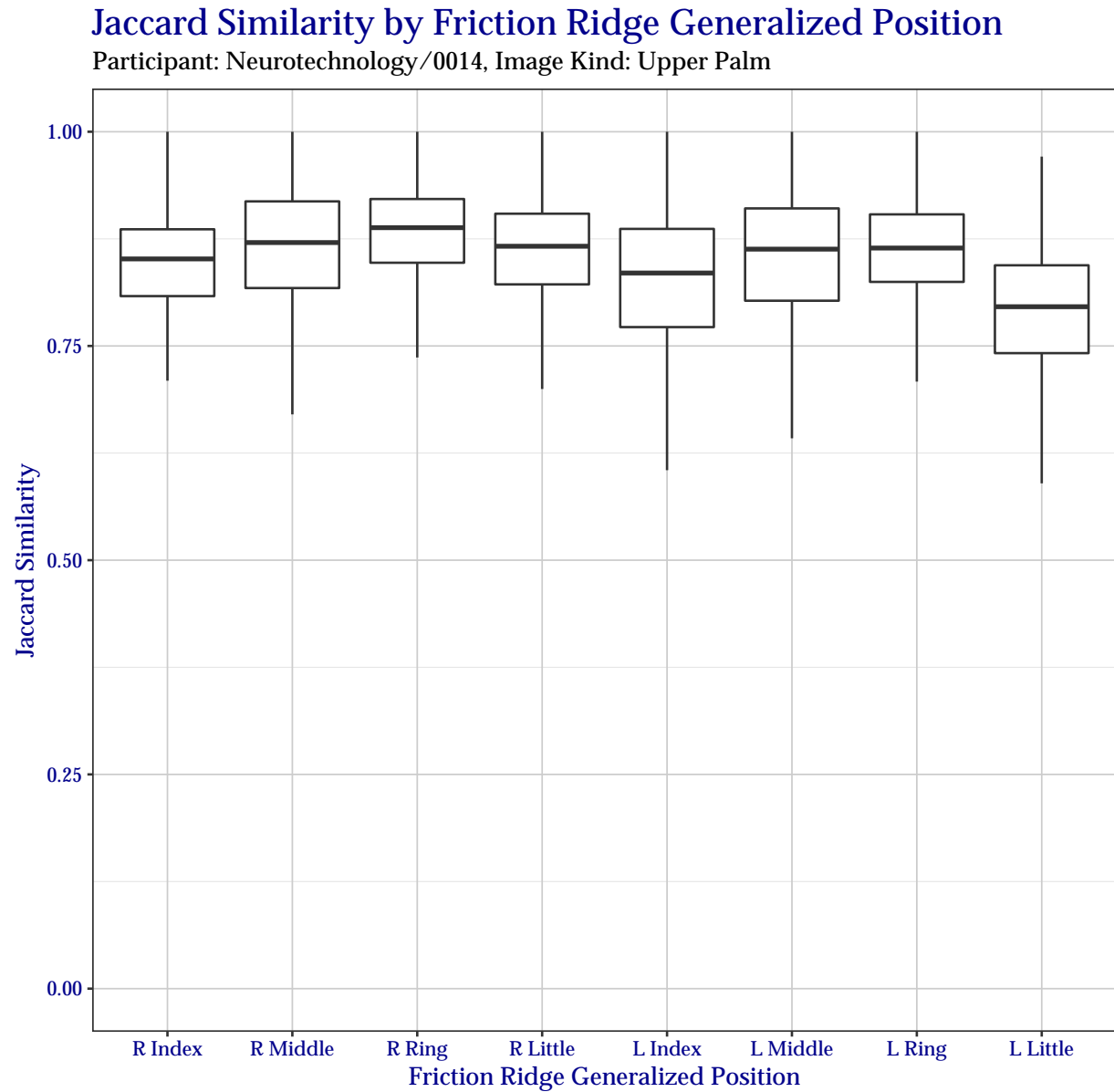
25 November 2024, 07:08:50 AM EST

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

Table 81: 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	99.9	99.9	99.9	99.5	71.4	29.6	25.7
2	99.9	99.9	99.7	98.2	48.0	19.5	19.0
3	99.6	99.6	98.9	94.3	32.0	16.5	16.5
4	99.2	99.1	98.4	88.4	20.7	12.6	12.6
5	96.8	96.6	94.9	78.8	12.9	10.1	10.0
6	93.0	92.5	90.3	66.1	9.1	7.9	7.9
7	87.4	86.6	81.6	48.2	6.6	6.3	6.3
8	79.2	75.9	62.3	23.6	4.5	4.5	4.5

Table 82: 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	3.6	0.8	2.0	15.0	60.6	18.0
Middle	4.2	0.5	1.9	12.1	48.3	33.0
Ring	6.5	0.3	0.5	5.9	46.0	40.8
Little	5.3	0.1	0.7	10.5	56.0	27.4
Left						
Index	3.7	1.5	5.6	21.9	47.7	19.6
Middle	5.3	0.7	4.4	13.5	46.4	29.7
Ring	6.0	0.1	1.6	10.2	56.1	26.0
Little	4.4	1.1	7.6	40.7	33.9	12.3

Table 83: 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	99.7	99.7	99.7	98.3	61.2	23.4	19.9
At Least Two	98.1	98.1	97.6	93.1	33.5	14.9	14.8
At Least Three	94.0	93.5	93.0	80.7	16.2	10.8	10.8
All Four	88.4	87.2	83.2	58.0	8.2	7.4	7.4
Left							
Any	100.0	99.9	99.3	95.4	47.7	21.2	20.2
At Least Two	98.4	98.3	97.6	83.8	22.1	14.1	14.1
At Least Three	94.4	94.2	90.3	61.8	11.4	9.8	9.8
All Four	87.8	85.0	71.0	30.9	6.4	6.4	6.4

Table 84: 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	98.8	98.8	98.4	91.9	37.0	20.5	19.0
Both Index and Middle	93.4	92.0	88.6	68.0	14.0	11.2	11.2
Left							
Either Index or Middle	98.9	98.9	97.2	88.2	36.7	19.6	19.0
Both Index and Middle	92.0	89.9	81.7	55.3	12.6	11.0	11.0

Table 85: 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	99.3	99.3	99.2	97.5	55.5	22.1	19.7
At Least Two	96.8	96.3	95.6	86.0	25.3	14.4	14.4
All Three	89.5	88.4	84.8	63.2	11.0	9.6	9.6
Left							
Any	99.6	99.6	98.9	94.0	44.8	20.4	19.5
At Least Two	96.3	96.0	94.0	80.5	20.6	13.8	13.8
All Three	89.1	87.1	78.2	51.1	9.9	9.5	9.5

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 86, results are shown of how successful `Neurotechnology+0014` segmented fingers for each subject in the test corpus. Table 87 shows success for specific finger positions over the entire test corpus. Similarly, Table 88 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 89 shows success for combinations of all fingers, Table 91 for the all except the little finger, and Table 90 for just the index and middle fingers.

Table 86: 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	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]
2	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]
3	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]
4	99.9 [99.7, 100.0]	99.9 [99.7, 100.0]	100.0 [100.0, 100.0]
5	99.9 [99.7, 100.0]	99.9 [99.5, 100.0]	100.0 [100.0, 100.0]
6	99.9 [99.7, 100.0]	99.9 [99.5, 100.0]	99.9 [99.7, 100.0]
7	98.9 [98.0, 99.5]	98.9 [98.2, 99.5]	99.2 [98.5, 99.8]
8	92.9 [91.0, 94.5]	93.2 [91.6, 94.8]	94.3 [92.8, 95.9]

Table 87: 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	98.4 [97.5, 99.2]	98.5 [97.7, 99.2]	98.6 [97.8, 99.3]
Middle	99.2 [98.5, 99.8]	99.2 [98.5, 99.8]	99.3 [98.7, 99.9]
Ring	99.1 [98.4, 99.7]	99.1 [98.4, 99.7]	99.5 [99.1, 100.0]
Little	98.9 [98.2, 99.5]	98.9 [98.0, 99.5]	99.1 [98.3, 99.7]
Left			
Index	99.0 [98.3, 99.5]	99.0 [98.3, 99.5]	99.0 [98.2, 99.5]
Middle	99.3 [98.7, 99.8]	99.4 [98.9, 99.9]	99.5 [99.0, 99.9]
Ring	99.0 [98.2, 99.5]	99.1 [98.5, 99.7]	99.5 [99.1, 100.0]
Little	98.6 [97.7, 99.3]	98.6 [97.8, 99.3]	98.7 [97.9, 99.4]

Table 88: 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	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]
Both	97.4 [96.3, 98.3]	97.5 [96.4, 98.5]	97.6 [96.6, 98.5]
Middle			
Either	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]
Both	98.5 [97.7, 99.2]	98.6 [97.8, 99.3]	98.9 [98.0, 99.4]
Ring			
Either	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]
Both	98.0 [97.1, 98.9]	98.2 [97.1, 99.1]	99.1 [98.4, 99.7]
Little			
Either	99.9 [99.7, 100.0]	99.9 [99.7, 100.0]	100.0 [100.0, 100.0]
Both	97.6 [96.7, 98.6]	97.6 [96.6, 98.6]	97.8 [96.8, 98.7]

Table 89: 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.

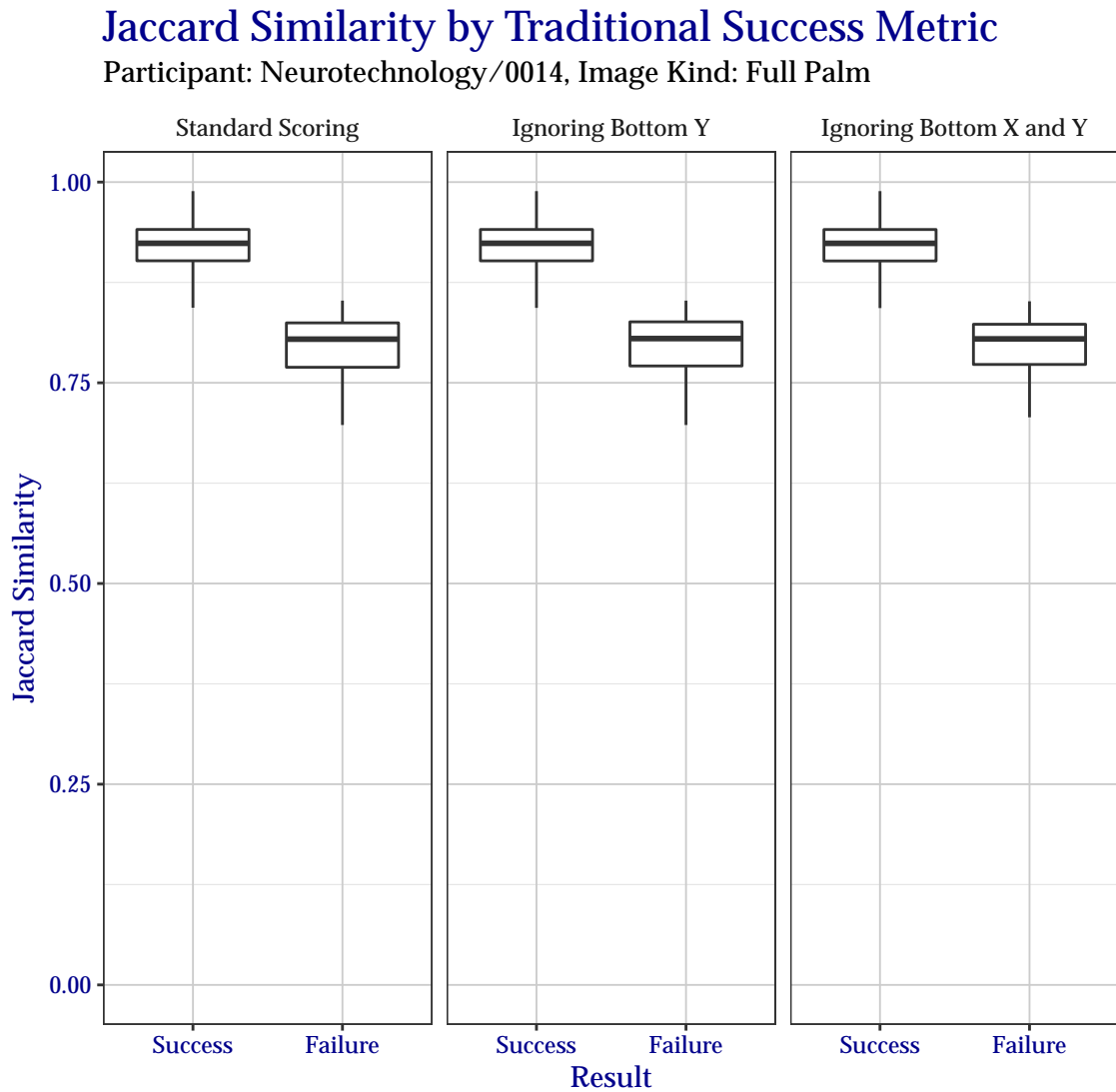| Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	100.0 [99.8, 100.0]	100.0 [99.8, 100.0]	100.0 [100.0, 100.0]
At Least Two	100.0 [99.8, 100.0]	100.0 [99.8, 100.0]	100.0 [100.0, 100.0]
At Least Three	99.8 [99.3, 99.8]	99.8 [99.3, 99.9]	99.9 [99.4, 99.9]
All Four	95.7 [95.3, 97.0]	95.9 [95.5, 97.2]	96.7 [96.1, 97.8]
Left			
Any	99.9 [99.8, 100.0]	99.9 [99.8, 100.0]	100.0 [100.0, 100.0]
At Least Two	99.9 [99.8, 100.0]	99.9 [99.8, 100.0]	100.0 [100.0, 100.0]
At Least Three	99.4 [99.3, 99.8]	99.4 [99.3, 99.9]	99.5 [99.4, 99.9]
All Four	96.7 [95.3, 97.0]	96.9 [95.5, 97.2]	97.2 [96.1, 97.8]

Table 90: 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	100.0 [99.7, 100.0]	100.0 [99.7, 100.0]	100.0 [99.7, 100.0]
Both Index and Middle	97.6 [97.4, 98.7]	97.7 [97.5, 98.9]	97.9 [97.6, 98.9]
Left			
Either Index or Middle	99.8 [99.7, 100.0]	99.8 [99.7, 100.0]	99.8 [99.7, 100.0]
Both Index and Middle	98.5 [97.4, 98.7]	98.6 [97.5, 98.9]	98.7 [97.6, 98.9]

Table 91: 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	100.0 [99.8, 100.0]	100.0 [99.8, 100.0]	100.0 [100.0, 100.0]
At Least Two	99.9 [99.6, 100.0]	99.9 [99.6, 100.0]	100.0 [99.7, 100.0]
All Three	96.8 [96.4, 97.9]	96.9 [96.6, 98.1]	97.5 [97.2, 98.5]
Left			
Any	99.9 [99.8, 100.0]	99.9 [99.8, 100.0]	100.0 [100.0, 100.0]
At Least Two	99.8 [99.6, 100.0]	99.8 [99.6, 100.0]	99.8 [99.7, 100.0]
All Three	97.6 [96.4, 97.9]	97.8 [96.6, 98.1]	98.3 [97.2, 98.5]

D.2 Jaccard Index

Jaccard Similarity by Traditional Success Metric

Participant: Neurotechnology/0014, Image Kind: Full Palm

25 November 2024, 07:08:53 AM EST

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

Jaccard Similarity by Friction Ridge Generalized Position

Participant: Neurotechnology/0014, Image Kind: Full Palm
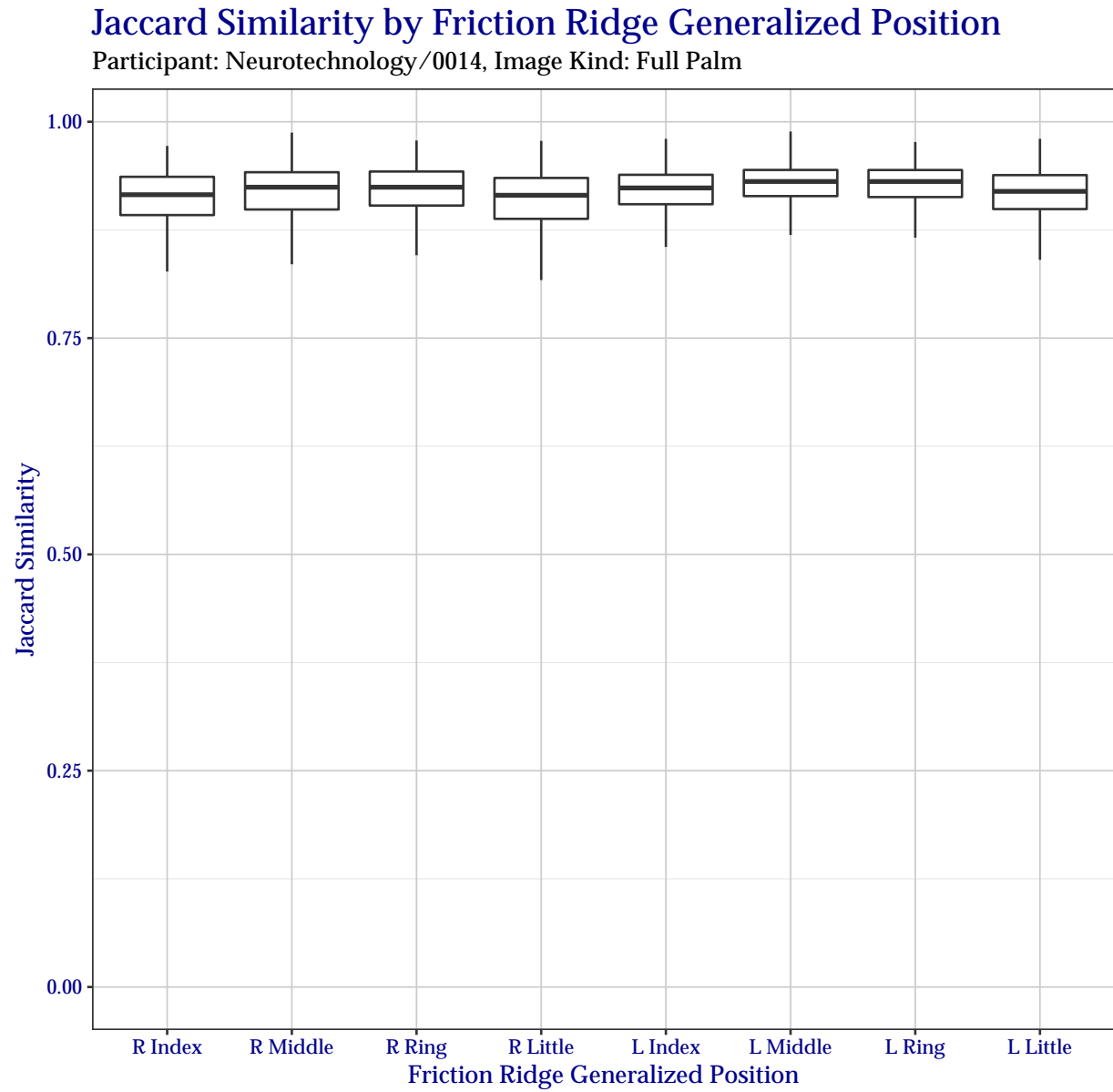

25 November 2024, 07:08:52 AM EST

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

Table 92: 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	100.0	100.0	100.0	100.0	98.4	58.6	0.9
2	100.0	100.0	100.0	100.0	96.8	27.8	0
3	100.0	100.0	100.0	100.0	94.4	10.1	0
4	100.0	100.0	100.0	100.0	90.8	3.4	0
5	100.0	100.0	100.0	99.5	83.1	0.7	0
6	100.0	100.0	100.0	99.2	70.2	0.1	0
7	100.0	100.0	99.9	98.0	49.8	0.1	0
8	99.5	99.4	98.3	91.8	22.8	0	0

Table 93: 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	0	0	0.2	1.5	31.2	67.1
Middle	0.1	0	0.1	0.7	24.8	74.3
Ring	0	0	0.2	1.4	21.0	77.4
Little	0	0	0.2	1.5	32.9	65.4
Left						
Index	0.2	0	0	1.6	18.6	79.6
Middle	0	0	0	0.6	13.7	85.7
Ring	0.1	0	0.2	0.6	15.8	83.3
Little	0	0.1	0.2	1.7	24.5	73.5

Table 94: 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	100.0	100.0	100.0	99.9	94.8	34.5	0.2
At Least Two	100.0	100.0	100.0	99.5	86.7	10.5	0.0
At Least Three	100.0	100.0	100.0	99.0	67.9	2.3	0.0
All Four	99.9	99.9	99.1	95.6	34.7	0.6	0.0
Left							
Any	100.0	100.0	100.0	100.0	95.4	39.0	0.7
At Least Two	100.0	100.0	100.0	99.9	92.4	11.4	0.0
At Least Three	100.0	100.0	100.0	99.5	80.2	2.5	0.0
All Four	99.7	99.5	99.1	95.2	54.0	0.2	0.0

Table 95: 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	≥0.98
Right							
Either Index or Middle	100.0	100.0	100.0	99.7	87.0	19.9	0.2
Both Index and Middle	99.9	99.9	99.5	97.7	54.4	2.4	0
Left							
Either Index or Middle	100.0	100.0	100.0	100.0	92.0	23.7	0.6
Both Index and Middle	99.8	99.8	99.8	97.6	73.3	3.0	0

Table 96: 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	100.0	100.0	100.0	99.8	93.6	29.1	0.2
At Least Two	100.0	100.0	100.0	99.3	78.9	7.7	0
All Three	99.9	99.9	99.3	96.7	46.3	1.1	0
Left							
Any	100.0	100.0	100.0	100.0	94.6	33.3	0.6
At Least Two	100.0	100.0	100.0	99.9	88.4	7.7	0
All Three	99.7	99.7	99.4	96.8	65.6	1.8	0