

nec+0004

NEC

Slap Fingerprint Segmentation Evaluation III

Last Updated: 01 August 2023

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1 Participation Information

1.1 Names and Dates

- **Organization Name:** NEC
- **SlapSeg III Identifier:** nec+0004
- **SlapSeg III API Version:** 1.2.0
- **Application Date:** 31 July 2023
- **First Submission Date:** 31 July 2023 (as version 0004)
- **Validation Date:** 31 July 2023
- **Completion Date:** 01 August 2023

1.2 Libraries

Filename	MD5 Checksum	Size
libopencv_imgproc.so.406	ed7c3ad7cdf48253f496590cee5532e0	31 MB
libopencv_imgcodecs.so	656bcf41662fe4b408fd3d557b6640cc	4 MB
libopencv_imgcodecs.so.406	656bcf41662fe4b408fd3d557b6640cc	4 MB
libslapsegiii_nec_0004.so	82847796731022efdaddfb8200b32dbf	198 MB
libonnxruntime.so	99bbf84b94e6730e5948e7e2bd754970	15 MB
libopencv_core.so	56d098c873f381aa300731f23e66acfa	18 MB
libopencv_imgproc.so	ed7c3ad7cdf48253f496590cee5532e0	31 MB
libonnxruntime.so.1.12.1	99bbf84b94e6730e5948e7e2bd754970	15 MB
libopencv_core.so.406	56d098c873f381aa300731f23e66acfa	18 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.

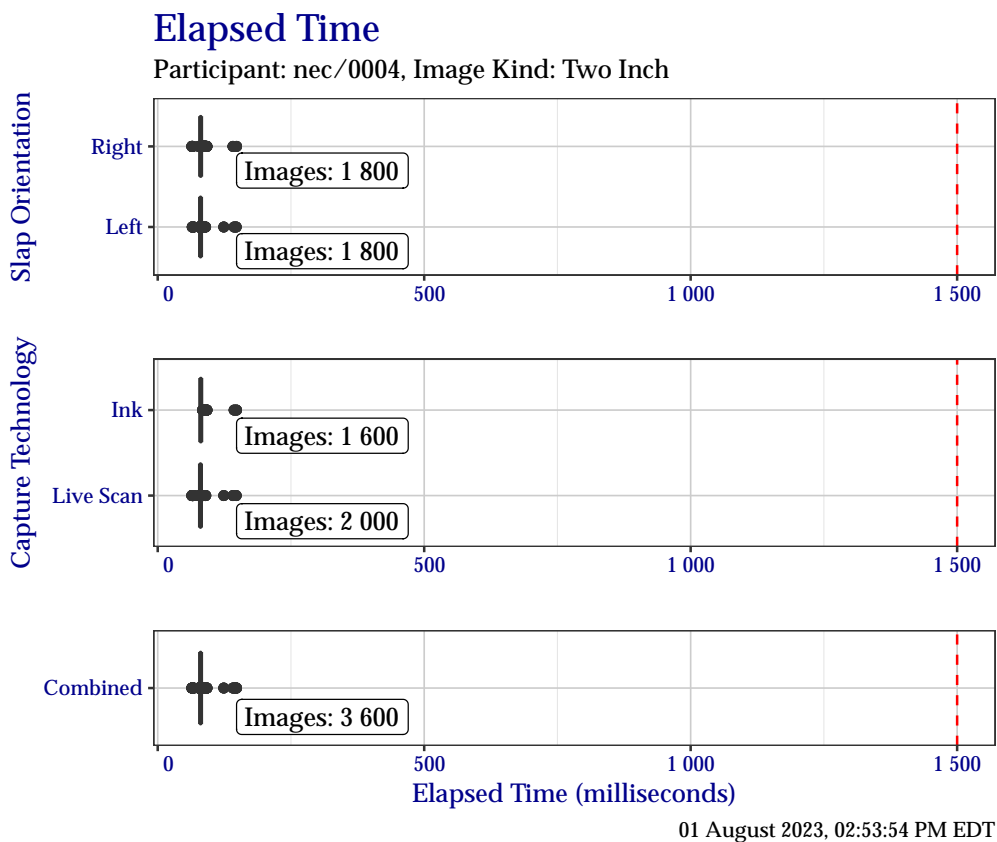


Figure 1: Box plots of elapsed time in milliseconds when segmenting the TwoInch timing test corpus, separated by slap orientation and capture technology.

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	64	65	64	78	64
25%	80	80	80	80	80
Median	81	80	80	81	80
75%	81	81	81	82	81
Maximum	148	147	147	148	148

2.2 Segmentation Centers and Dimensions

2.2.1 Segmentation Centers

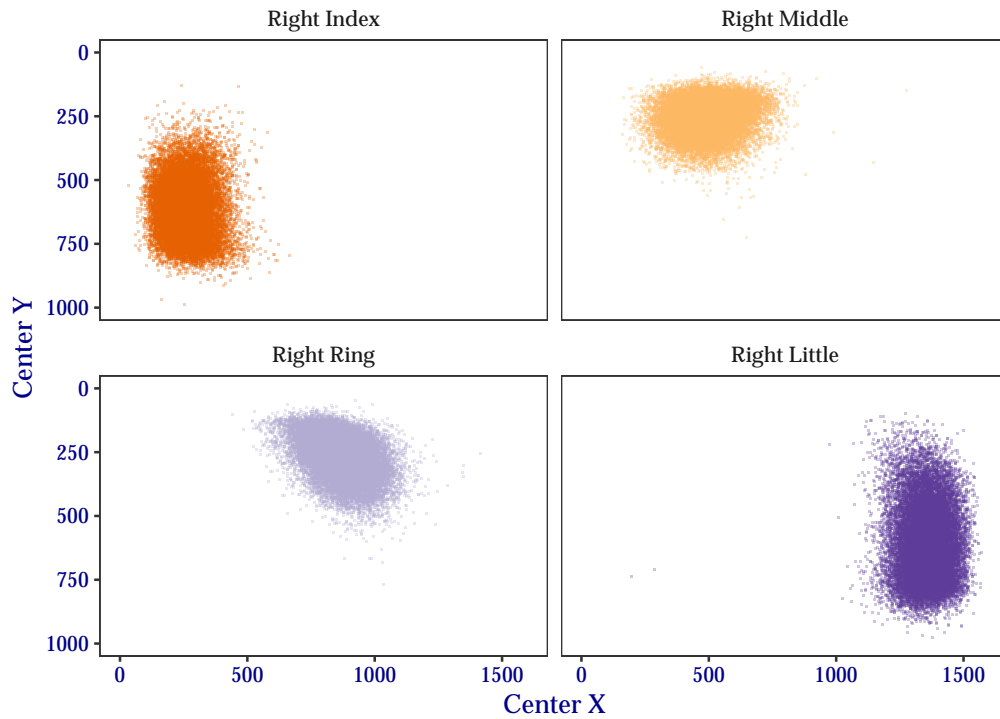
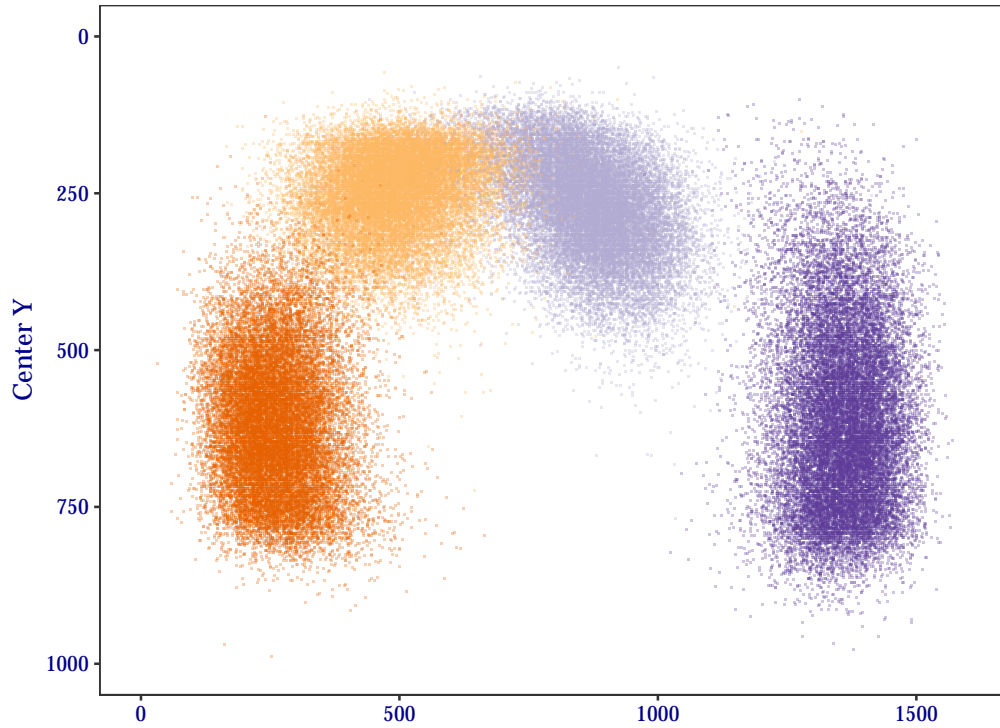
The plots in this section show the distribution of segmentation position centers (x, y) for TwoInch data. At the top of each figure is a combined plot for all finger positions of a given slap orientation. These figures are isolated in plots faceted at the bottom of the figure.

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: nec/0004, FRGPs: 2, 3, 4, 5, Image Kind: Two Inch



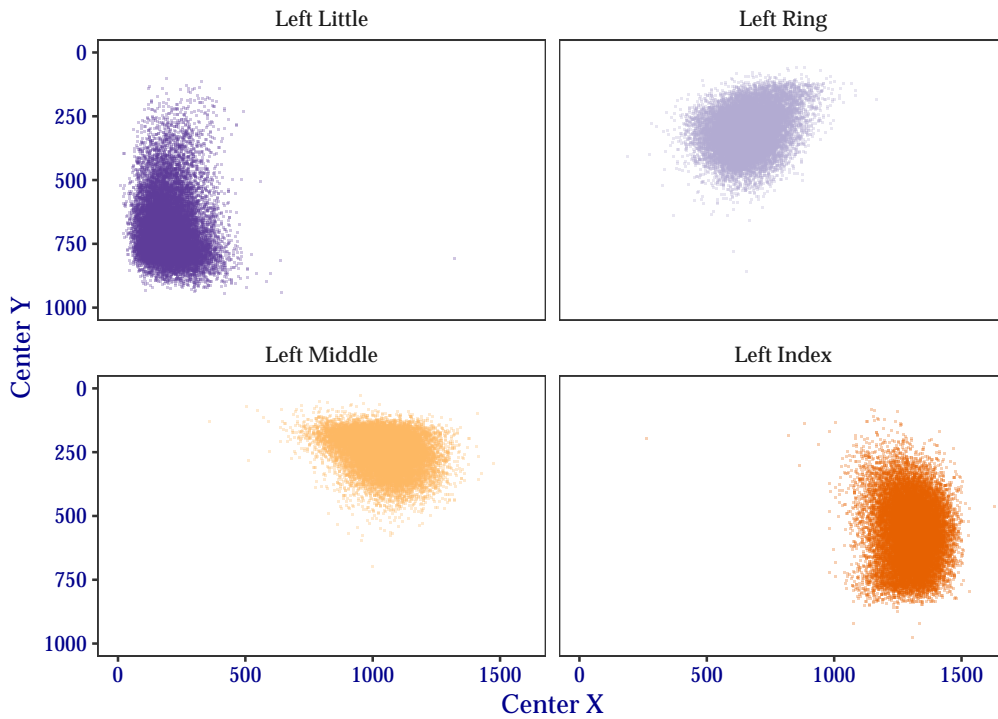
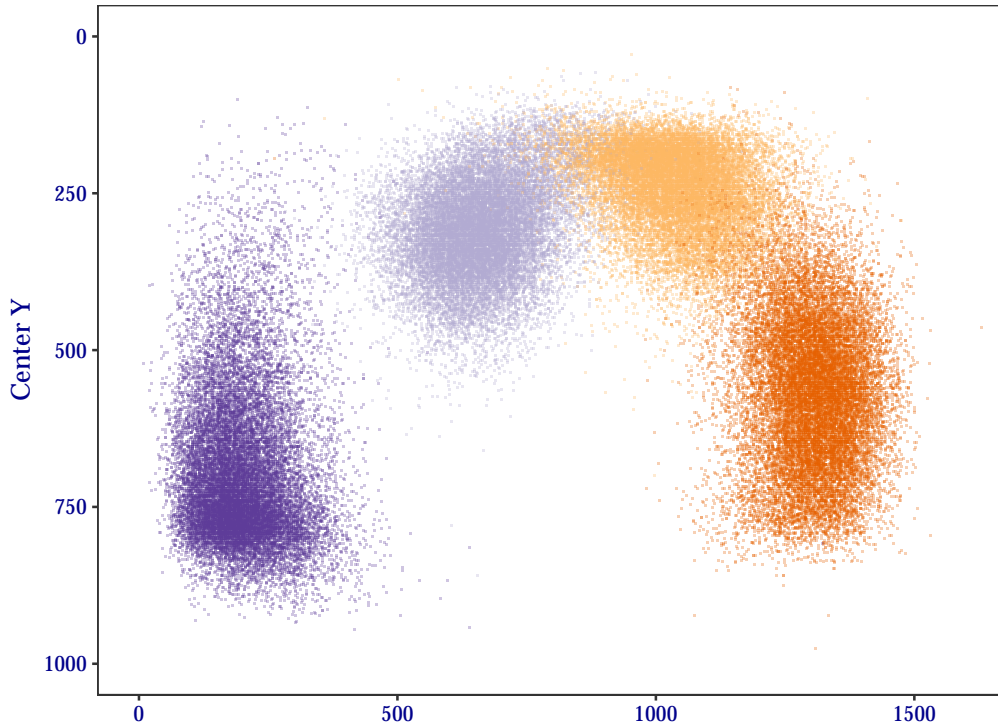
• Right Index • Right Middle • Right Ring • Right Little

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Figure 2: Segmentation centers for right hand TwoInch data.

Segmentation Position Centers

Participant: nec/0004, FRGPs: 7, 8, 9, 10, Image Kind: Two Inch



• Left Index • Left Middle • Left Ring • Left Little

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Figure 3: Segmentation centers for left hand TwoInch data.

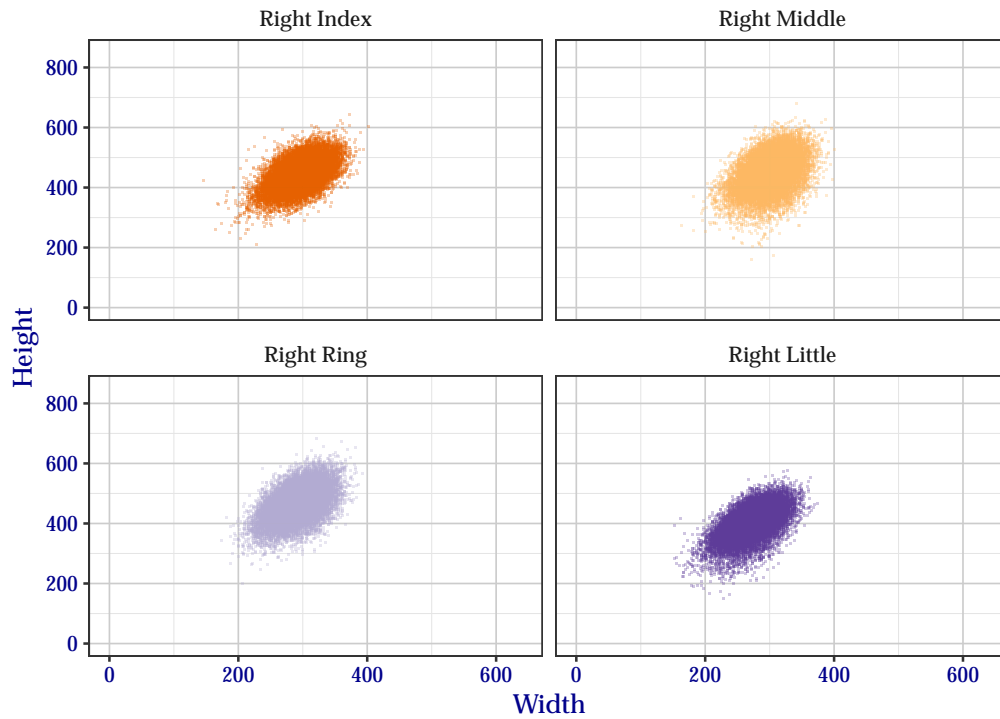
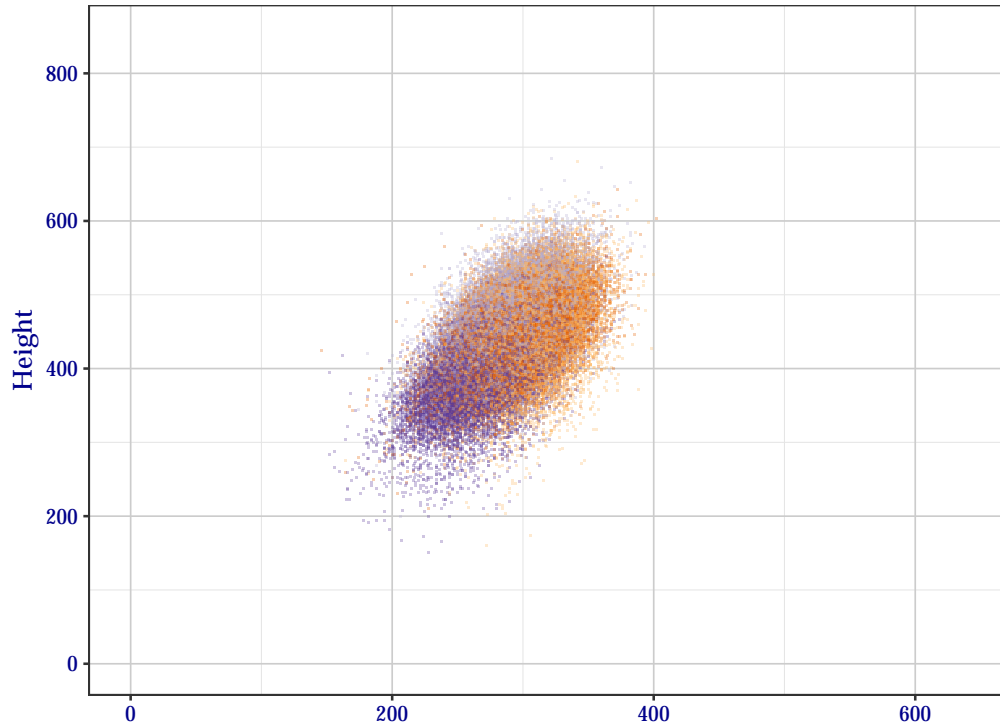
2.2.2 Segmentation Dimensions

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: nec/0004, FRGPs: 2, 3, 4, 5, Image Kind: Two Inch



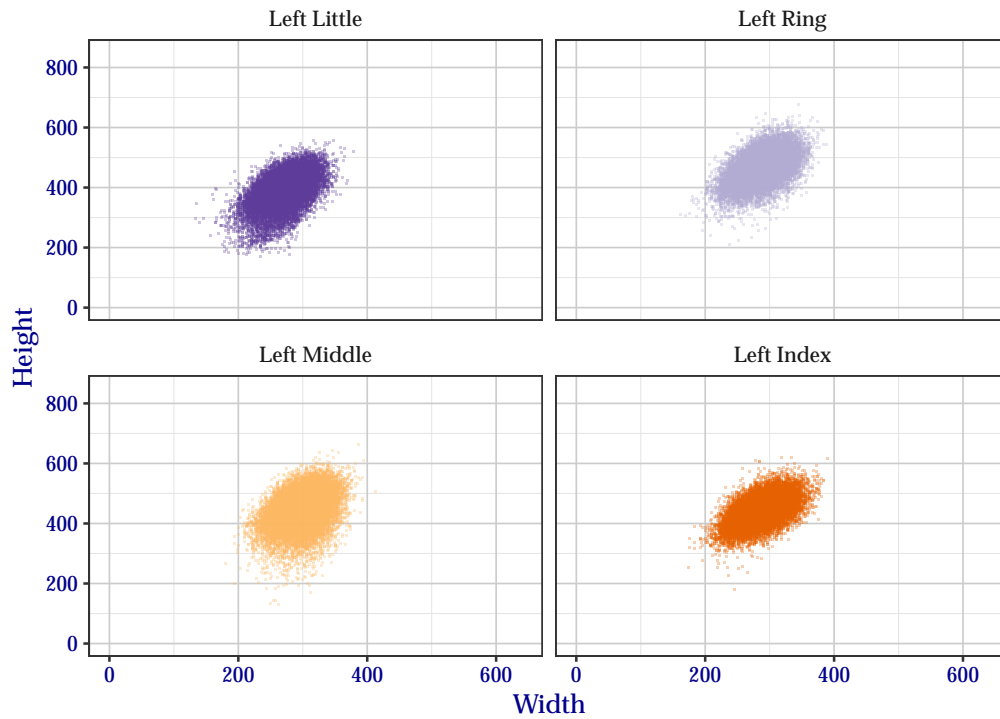
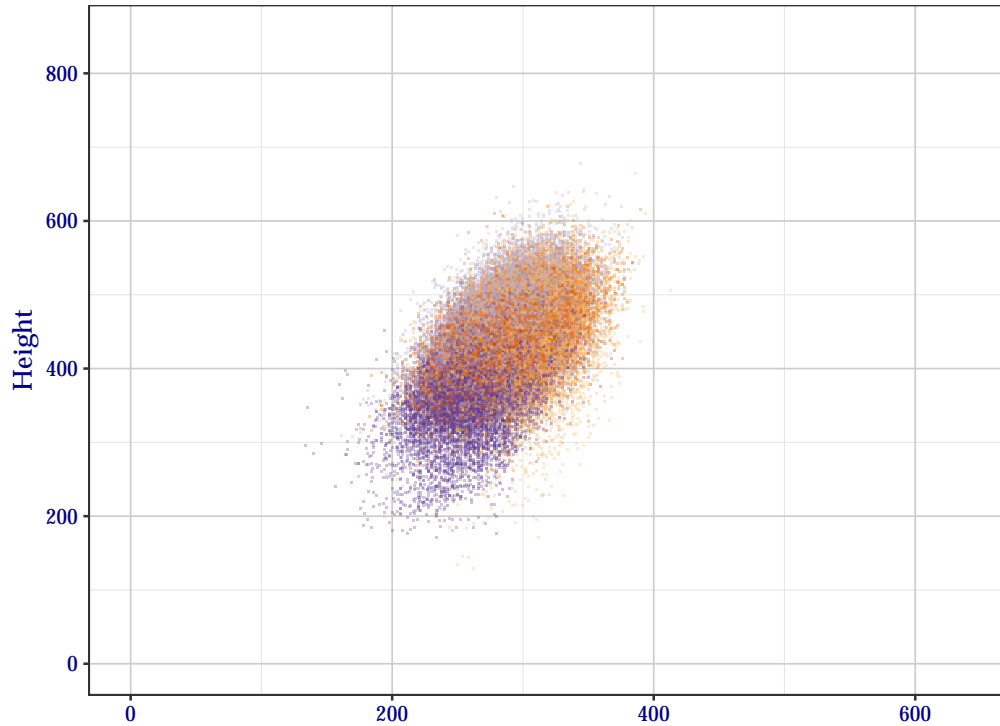
· Right Index · Right Middle · Right Ring · Right Little

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

Segmentation Position Dimensions

Participant: nec/0004, FRGPs: 7, 8, 9, 10, Image Kind: Two Inch



· Left Index · Left Middle · Left Ring · Left Little

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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 nec+0004 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	99.9
2	99.7	99.7	99.8
3	99.3	99.5	99.6
4	98.4	98.8	99.0
5	94.7	95.4	95.6
6	93.2	94.6	95.0
7	89.1	92.6	93.2
8	76.4	83.5	84.8

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	94.6	96.6	97.0
Middle	94.6	96.5	96.9
Ring	94.1	96.6	97.0
Little	96.5	98.1	98.6
Left			
Index	97.0	98.1	98.5
Middle	96.2	97.9	98.2
Ring	94.8	97.5	97.8
Little	96.9	98.1	98.5

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	99.0	99.2	99.4
Both	88.6	91.2	91.9
Middle			
Either	98.8	99.3	99.4
Both	88.6	91.3	91.9
Ring			
Either	98.5	99.4	99.5
Both	87.4	91.4	92.1
Little			
Either	99.1	99.3	99.5
Both	90.5	92.7	93.4

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

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	99.6	99.7	99.9
At Least Two	98.7	99.3	99.6
At Least Three	96.2	98.1	98.5
All Four	85.4	90.8	91.7
Left			
Any	99.8	99.8	99.9
At Least Two	99.1	99.5	99.6
At Least Three	97.2	98.6	99.0
All Four	88.9	93.7	94.5

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

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Either Index or Middle	98.5	99.1	99.3
Both Index and Middle	90.7	94.0	94.6
Left			
Either Index or Middle	99.1	99.5	99.6
Both Index and Middle	94.1	96.6	97.1

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	99.2	99.6	99.7
At Least Two	97.1	98.4	98.7
All Three	87.1	91.8	92.5
Left			
Any	99.5	99.7	99.8
At Least Two	97.8	98.9	99.2
All Three	90.8	94.9	95.6

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 nec+0004 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
Vendor Defined	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.

nec+0004 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 nec+0004 are enumerated in Table 9.

Table 9: Count of self-reported segmentation failure reasoning.

Failure Reason	Fingers
Finger Not Found	288
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 10 shows how successful nec+0004 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 10: Performance of nec+0004 at detecting fingers missing from an image.

Result	Percentage
Missed	28.1
Correctly Identified	71.9
Other Failure: Finger Found, but Can't Segment	0.0
Other Failure: Vendor Defined	0.0
Other Failure: Segmentation Not Attempted	0.0

2.4.4 Sequence Error

Sequence error occurs when a fingerprint is segmented from an image but assigned an incorrect finger position (e.g., segmenting a right middle finger but labeling it a right index finger). Table 11 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 11: 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	0.04	0.04
Right	0.07	0.07	0.08
Combined	0.05	0.05	0.06

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: 98.5%

Table 12: 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
Left	99.5	0.5
Right	2.3	97.7

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 13. Results are reported in milliseconds

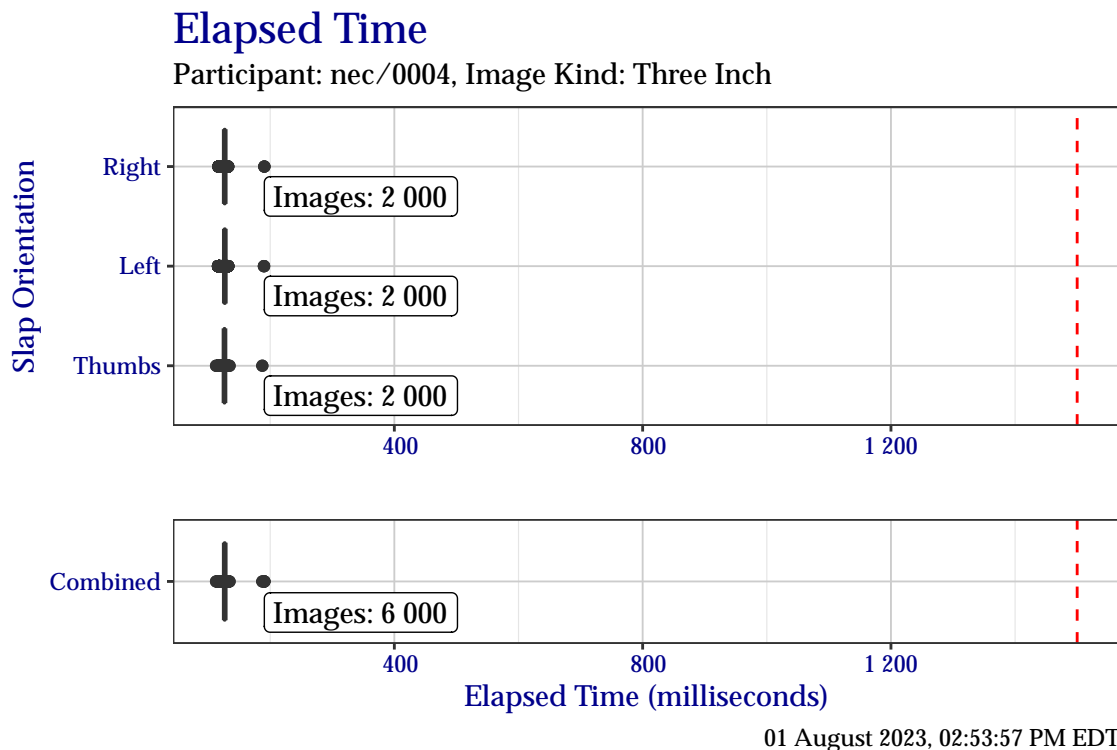


Figure 6: Box plots of elapsed time in milliseconds when segmenting the ThreeInch timing test corpus, separated by slap orientation.

Table 13: Elapsed time in milliseconds when segmenting the ThreeInch timing test corpus, separated by slap orientation.

	Right	Left	Thumbs	Combined
Minimum	116	116	113	113
25%	126	126	126	126
Median	127	127	126	127
75%	127	128	127	127
Maximum	191	190	187	191

3.2 Segmentation Centers and Dimensions

3.2.1 Segmentation Centers

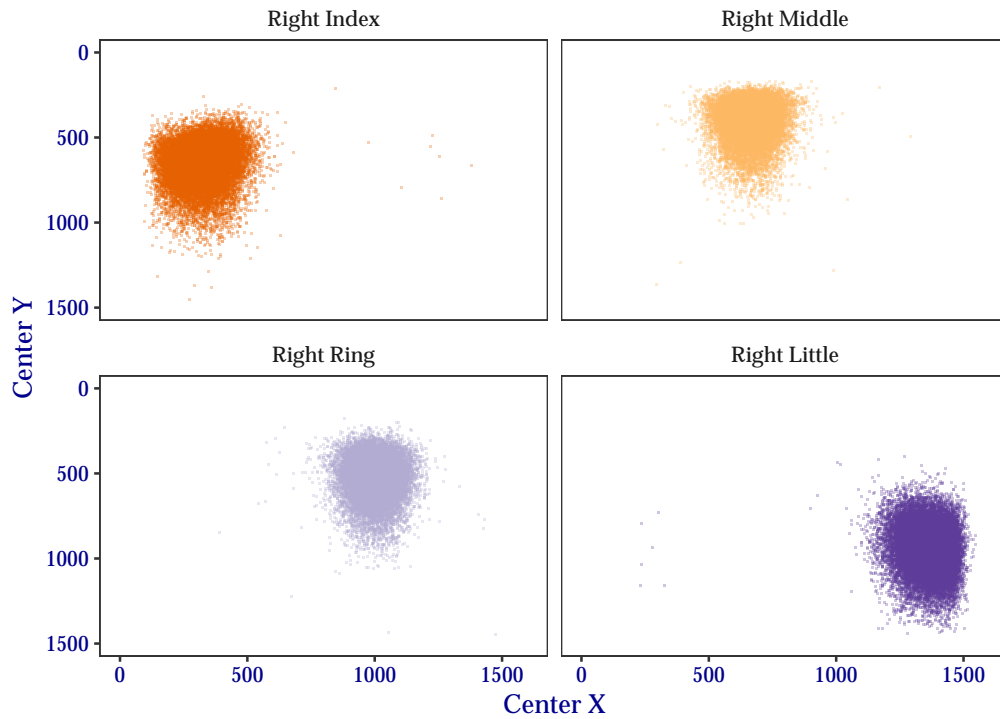
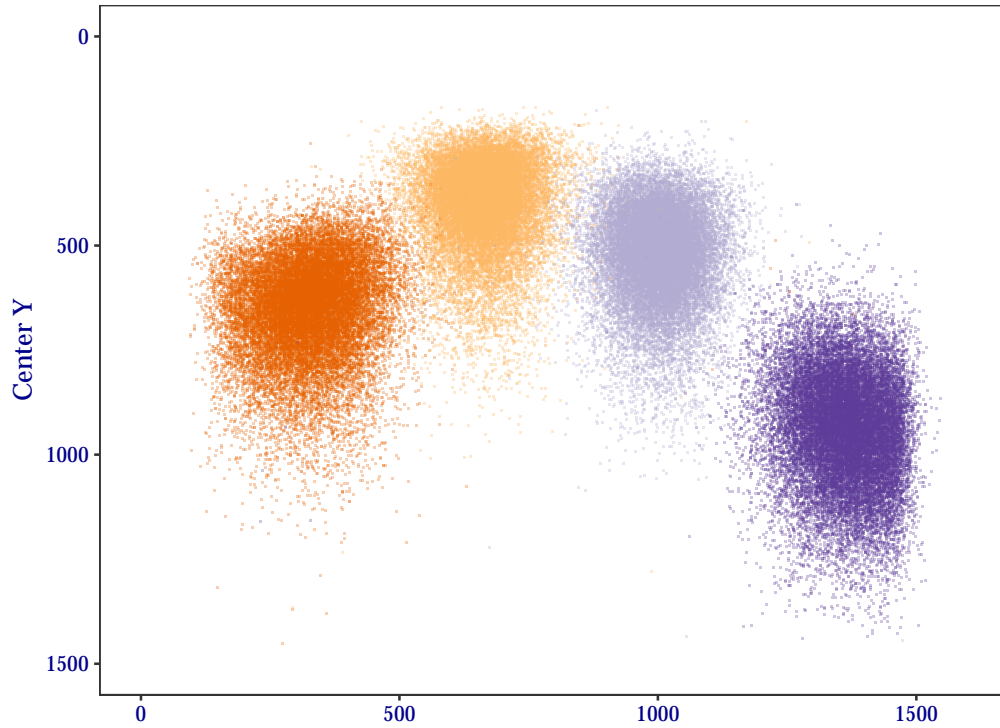
The plots in this section show the distribution of segmentation position centers (x, y) for ThreeInch data. At the top of each figure is a combined plot for all finger positions of a given hand orientation. These figures are isolated in plots faceted at the bottom of the figure.

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: nec/0004, FRGPs: 2, 3, 4, 5, Image Kind: Three Inch



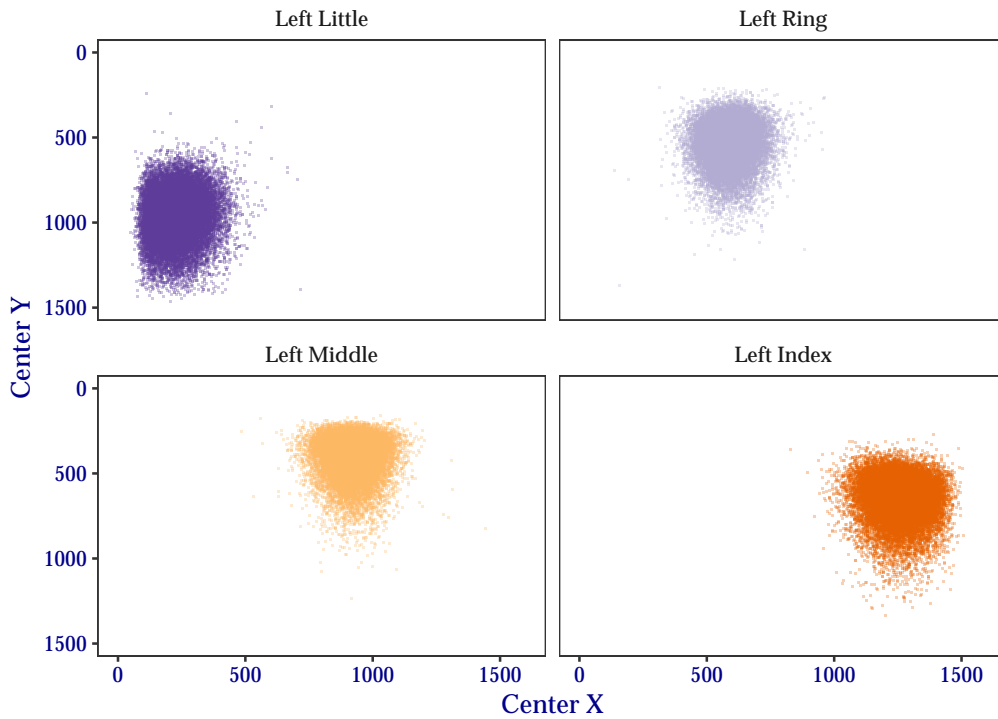
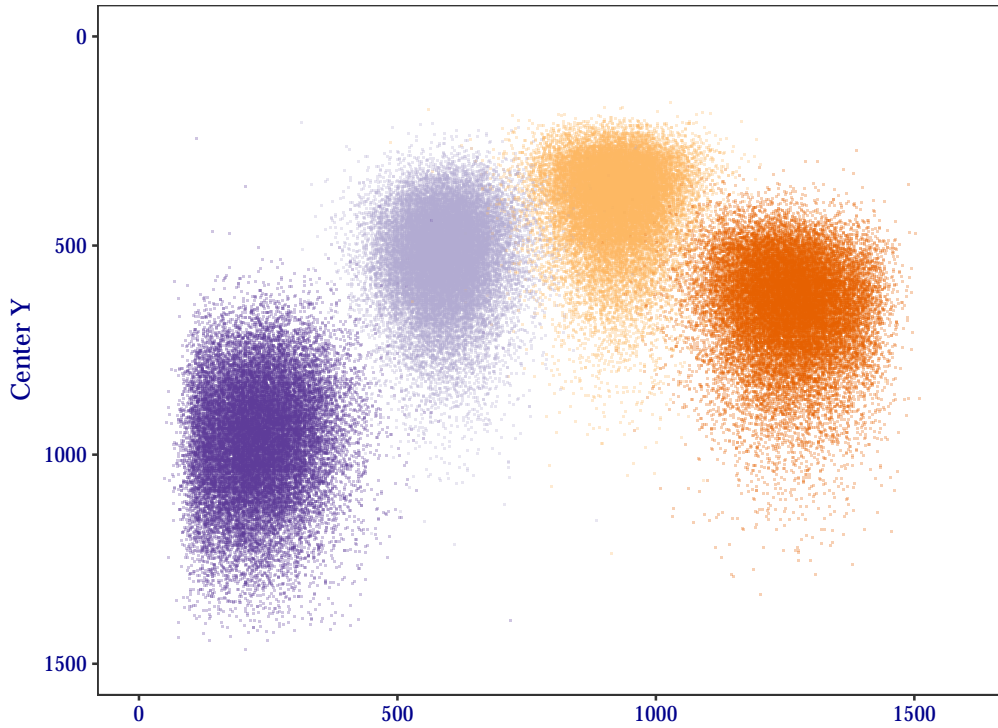
• Right Index • Right Middle • Right Ring • Right Little

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Figure 7: Segmentation centers for right hand ThreeInch data.

Segmentation Position Centers

Participant: nec/0004, FRGPs: 7, 8, 9, 10, Image Kind: Three Inch



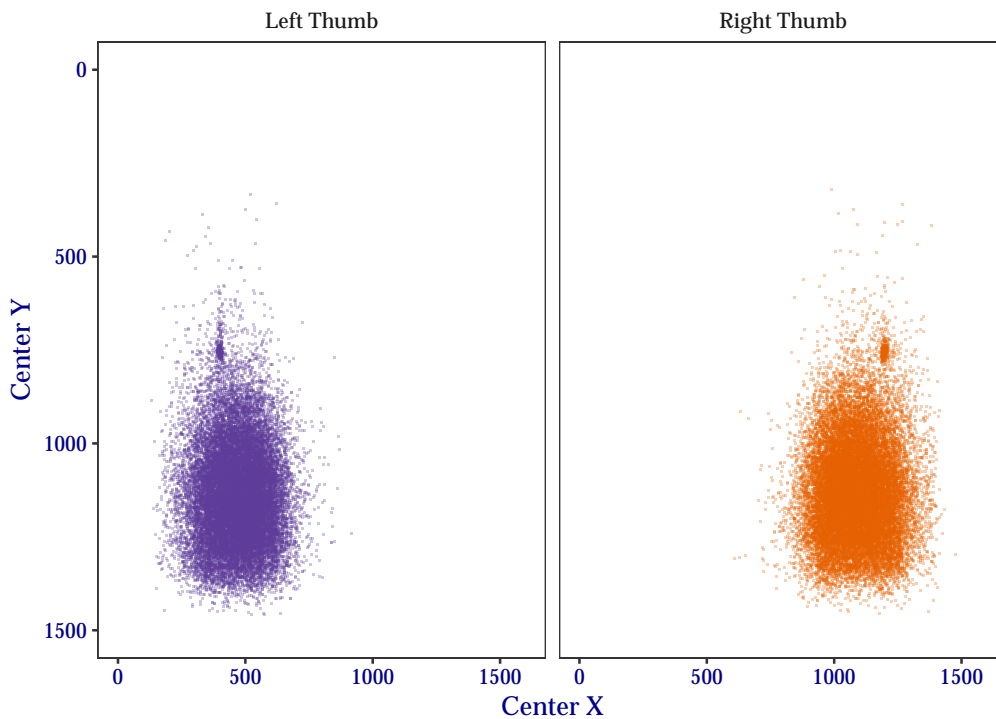
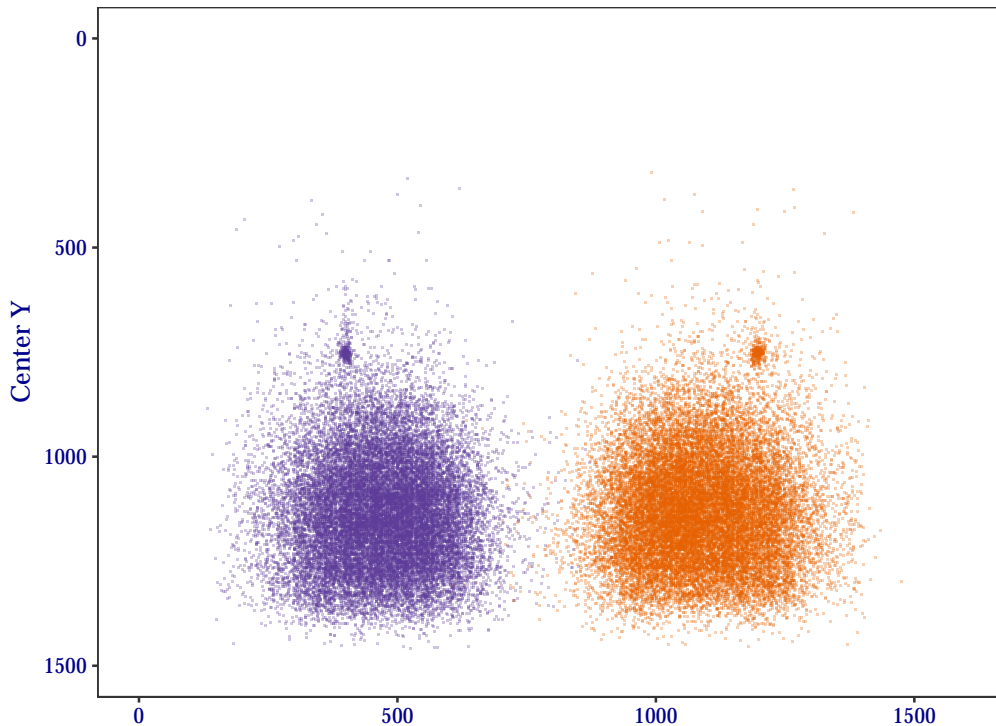
• Left Index • Left Middle • Left Ring • Left Little

01 August 2023, 03:23:04 PM EDT

Figure 8: Segmentation centers for left hand ThreeInch data.

Segmentation Position Centers

Participant: nec/0004, FRGPs: 1, 6, Image Kind: Three Inch



• Right Thumb • Left Thumb

01 August 2023, 03:23:14 PM EDT

Figure 9: Segmentation centers for thumb ThreeInch data.

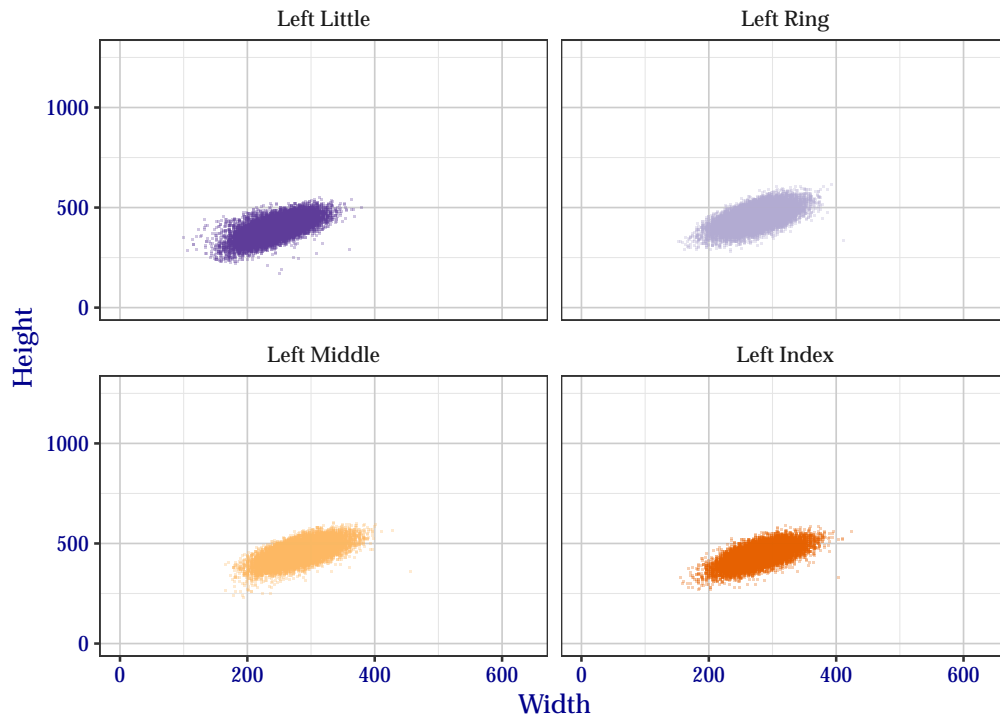
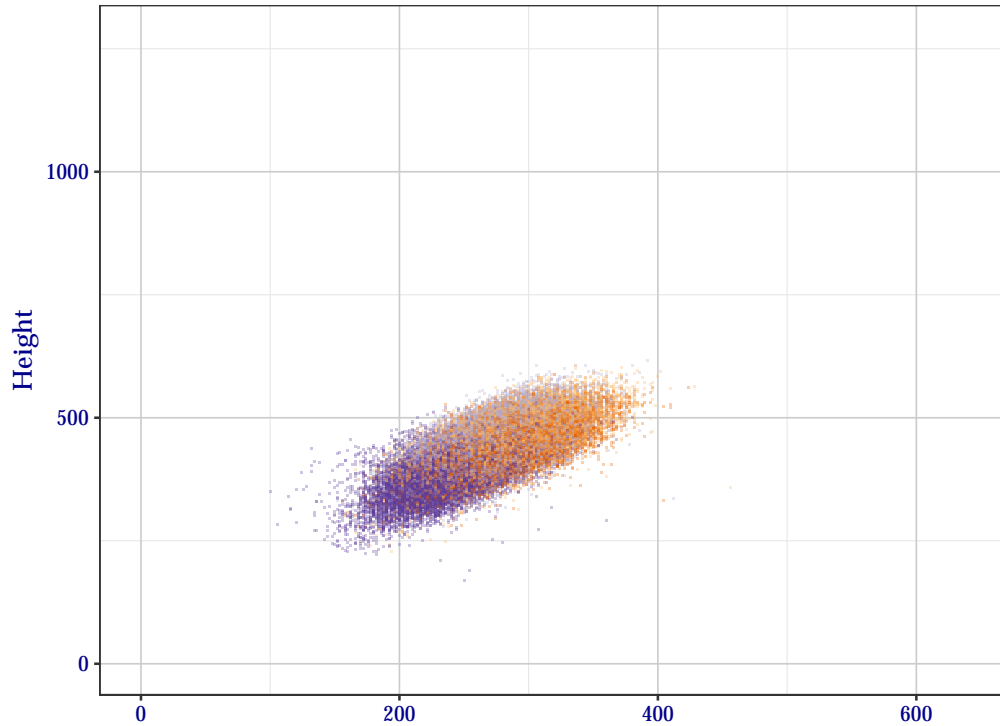
3.2.2 Segmentation Dimensions

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: nec/0004, FRGPs: 7, 8, 9, 10, Image Kind: Three Inch



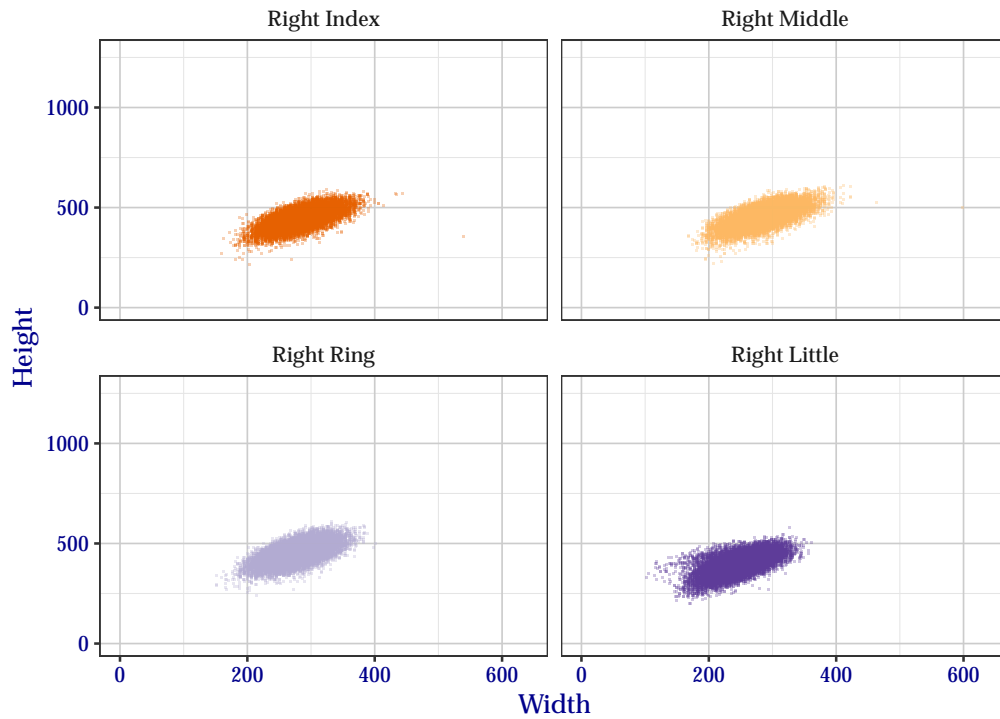
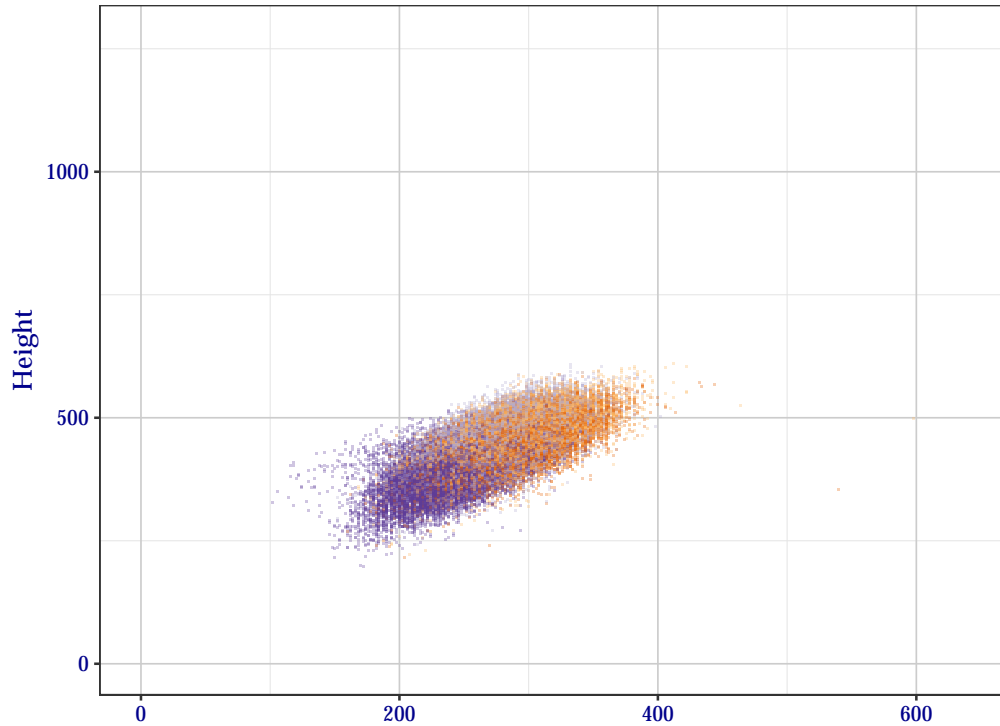
• Left Index • Left Middle • Left Ring • Left Little

01 August 2023, 03:23:30 PM EDT

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

Segmentation Position Dimensions

Participant: nec/0004, FRGPs: 2, 3, 4, 5, Image Kind: Three Inch



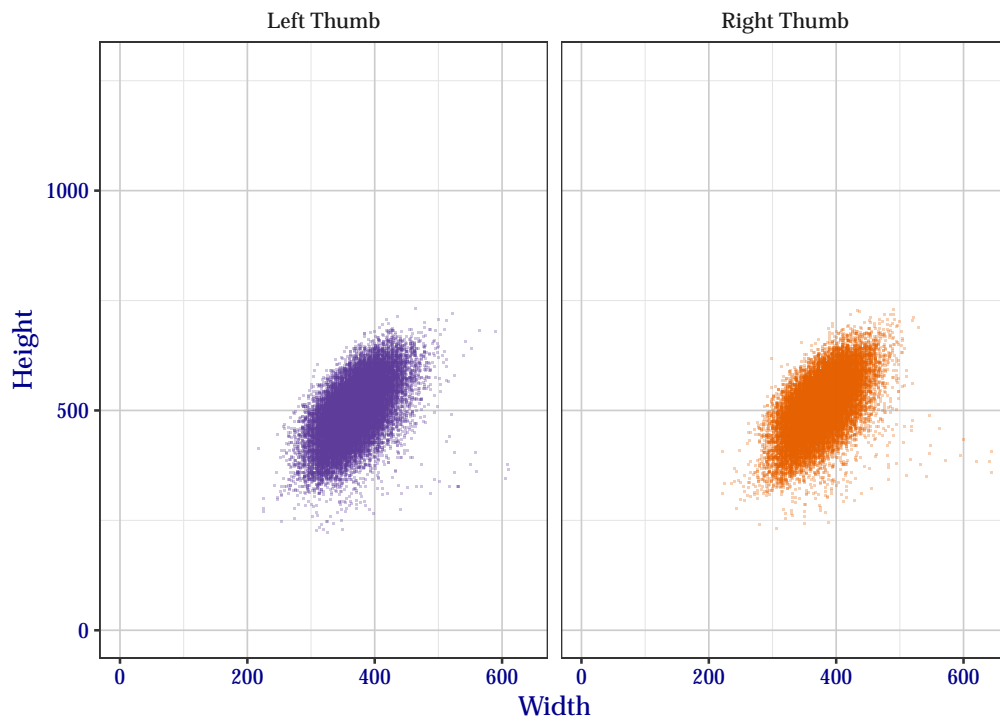
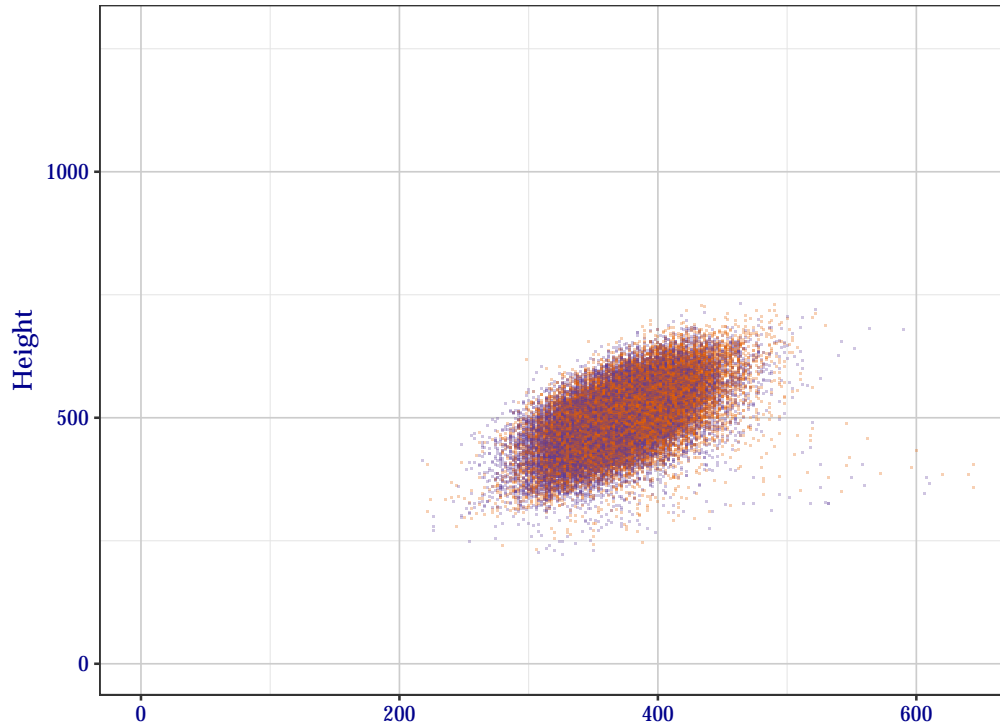
Right Index Right Middle Right Ring Right Little

01 August 2023, 03:23:35 PM EDT

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

Segmentation Position Dimensions

Participant: nec/0004, FRGPs: 1, 6, Image Kind: Three Inch



· Right Thumb · Left Thumb

01 August 2023, 03:23:40 PM EDT

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 14 shows how successful nec+0004 segmented fingers for each subject in the test corpus. Table 15 shows success for specific finger positions over the entire test corpus. Similarly, Table 16 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 17 shows success for combinations of all fingers, Table 18 for just the index and middle fingers, and Table 19 for all except the little finger.

Table 14: 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	99.3	99.3	99.3
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	95.8	95.8	95.8
8	95.3	95.3	95.5
9	91.0	91.0	91.8
10	73.5	73.6	76.4

Table 15: 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	88.6	88.6	89.3
Index	99.4	99.4	99.5
Middle	99.3	99.3	99.6
Ring	97.9	97.9	98.5
Little	98.5	98.5	98.6
Left			
Thumb	90.7	90.7	91.6
Index	98.9	98.9	99.0
Middle	99.1	99.1	99.5
Ring	98.7	98.7	99.4
Little	98.6	98.6	98.7

Table 16: Percentage that a particular type of fingerprint was correctly segmented on *Either* or *Both* hands. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Thumb			
Either	96.9	96.9	97.2
Both	82.4	82.4	83.8
Index			
Either	99.8	99.8	99.9
Both	95.7	95.8	95.9
Middle			
Either	99.8	99.9	99.9
Both	95.9	95.9	96.5
Ring			
Either	99.7	99.7	99.9
Both	94.1	94.2	95.4
Little			
Either	99.8	99.8	99.8
Both	94.6	94.6	94.8

Table 17: Percentage of segmentation success by hand for combinations of all ten fingers of a ThreeInch slap. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	99.5	99.5	99.5
At Least Two	98.5	98.5	98.5
At Least Three	98.4	98.4	98.4
At Least Four	97.4	97.4	97.6
All Five	81.1	81.2	82.7
Left			
Any	99.7	99.7	99.7
At Least Two	98.5	98.5	98.5
At Least Three	98.4	98.4	98.4
At Least Four	97.5	97.5	97.8
All Five	82.9	83.0	84.8

Table 18: 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	99.9	99.9	99.9
Both	98.8	98.9	99.2
Left			
Either	99.9	99.9	99.9
Both	98.1	98.1	98.6

Table 19: Percentage of segmentation success by hand when only considering combinations of index, middle, and ring fingers. In *Ignoring Bottom Y*, the bottom left and right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and right coordinates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	99.9	99.9	99.9
At Least Two	99.7	99.7	99.8
All Three	97.0	97.0	97.9
Left			
Any	99.9	99.9	99.9
At Least Two	99.7	99.7	99.8
All Three	97.0	97.1	98.1

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 nec+0004 are enumerated in Table 20.

Table 20: Count of self-reported capture-type failure reasoning.

Failure Reason	Images
Vendor Defined	1

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.

nec+0004 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 nec+0004 are enumerated in Table 21.

Table 21: Count of self-reported segmentation failure reasoning.

Failure Reason	Fingers
Finger Not Found	277
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 22 shows how successful nec+0004 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 22: Performance of nec+0004 at detecting fingers missing from an image.

Result	Percentage
Missed	45.3
Correctly Identified	54.7
Other Failure: Finger Found, but Can't Segment	0.0
Other Failure: Vendor Defined	0.0
Other Failure: Segmentation Not Attempted	0.0

3.4.4 Sequence Error

Sequence error occurs when a fingerprint is segmented from an image but assigned an incorrect finger position (e.g., segmenting a right middle finger but labeling it a right index finger). Table 23 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 23: 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	0.11	0.11	0.11
Right	0.13	0.13	0.13
Thumbs	0.06	0.06	0.06
Combined	0.10	0.10	0.10

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: 99.5%

Table 24: 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	Thumbs
Left	99.8	0.2	0
Right	0.2	99.8	0
Thumbs	0.8	0.4	98.8

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 25. Results are reported in milliseconds.

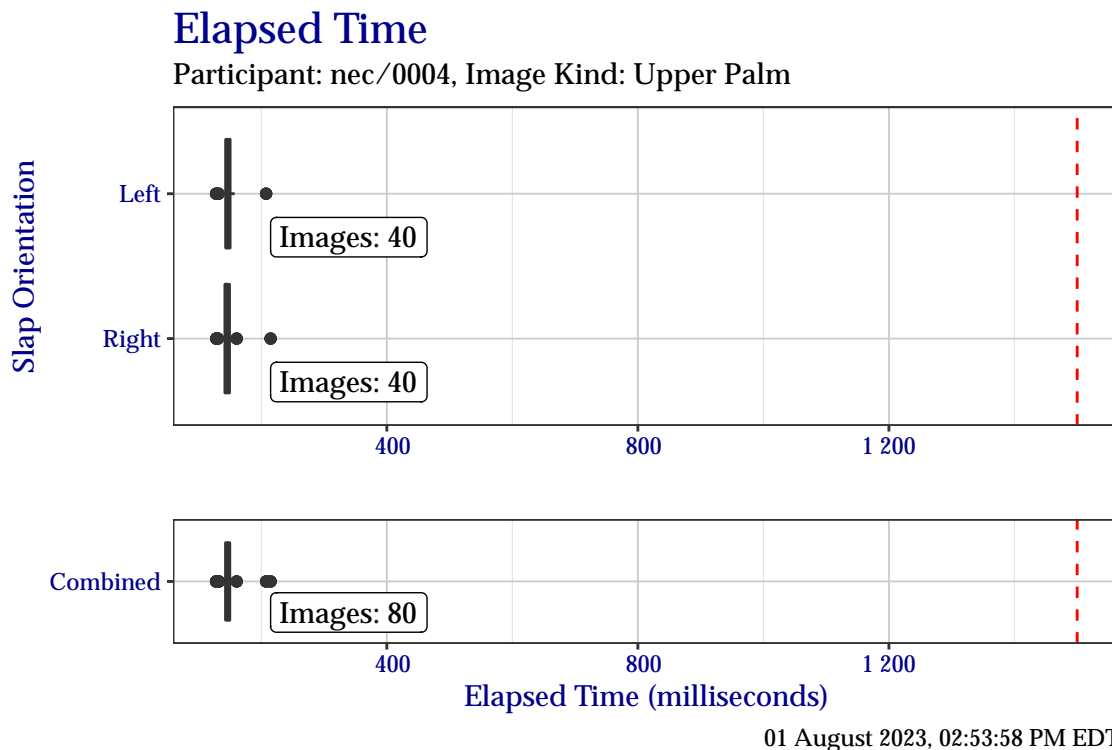


Figure 13: Box plots of elapsed time in milliseconds when segmenting the FiveInch timing test corpus, separated by slap orientation.

Table 25: Elapsed time in milliseconds when segmenting the FiveInch timing test corpus, separated by slap orientation.

	Right	Left	Combined
Minimum	128	128	128
25%	142	143	143
Median	145	146	146
75%	149	150	150
Maximum	215	208	215

4.2 Segmentation Centers and Dimensions

4.2.1 Segmentation Centers

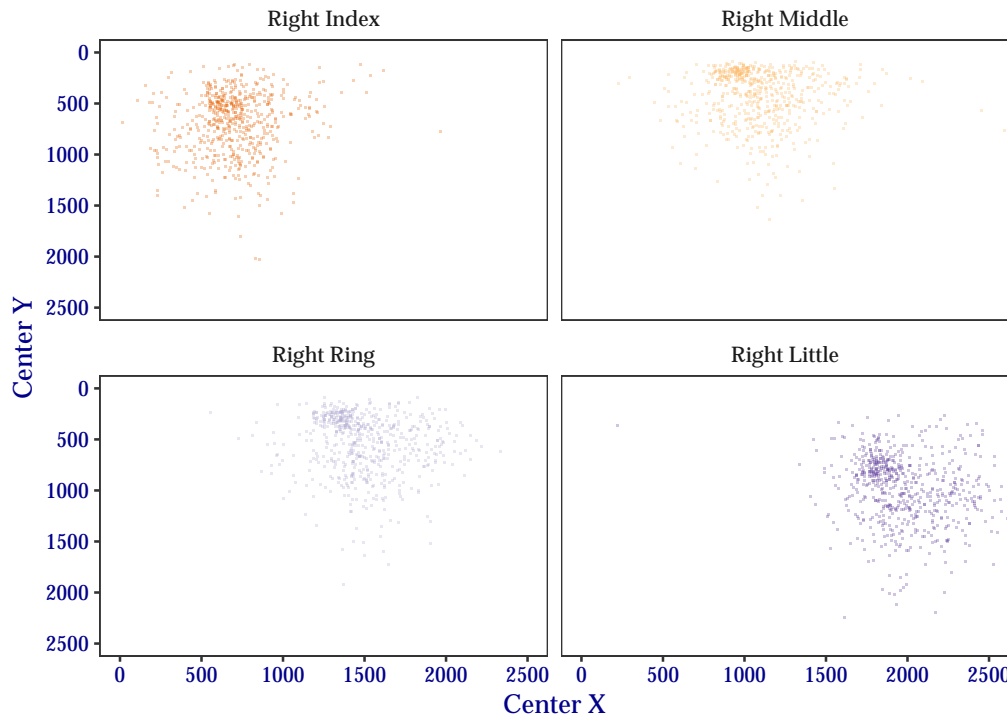
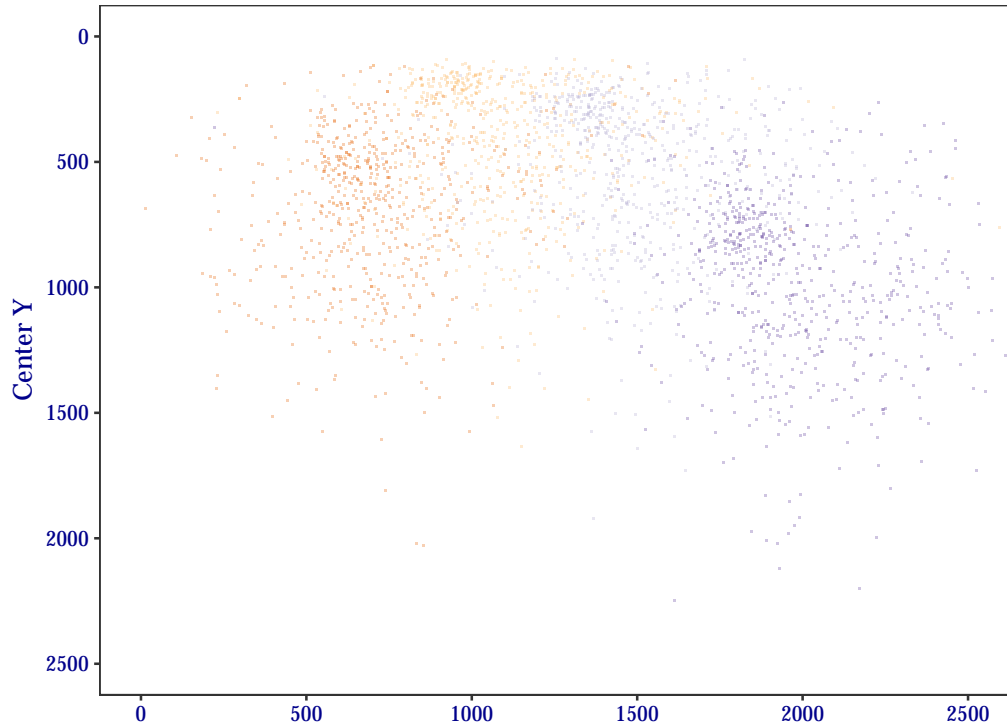
The plots in this section show the distribution of segmentation position centers (x, y) for FiveInch data. At the top of each figure is a combined plot for all finger positions of a given slap orientation. These figures are isolated in plots faceted at the bottom of the figure.

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: nec/0004, FRGPs: 2, 3, 4, 5, Image Kind: Upper Palm



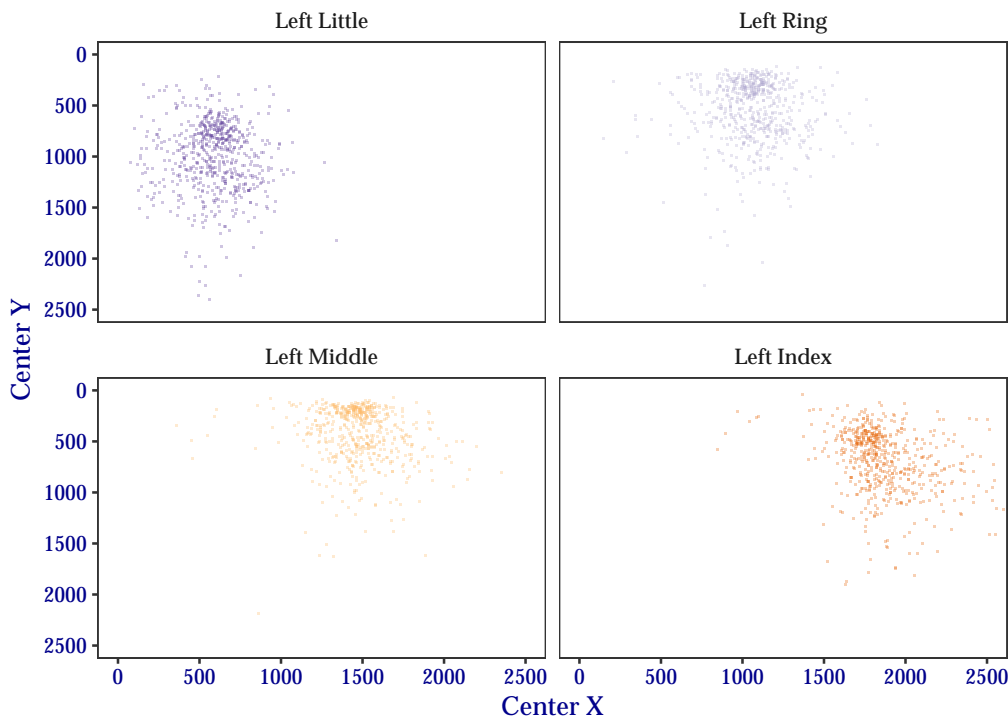
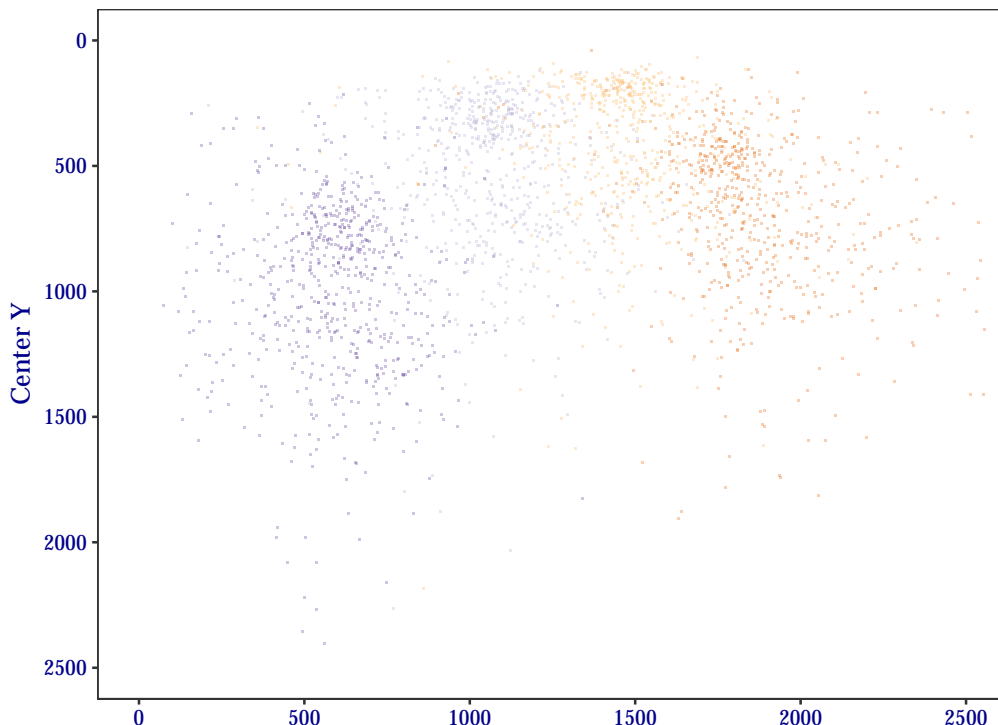
• Right Index • Right Middle • Right Ring • Right Little

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Figure 14: Segmentation centers for right hand FiveInch data.

Segmentation Position Centers

Participant: nec/0004, FRGPs: 7, 8, 9, 10, Image Kind: Upper Palm



• Left Index • Left Middle • Left Ring • Left Little

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Figure 15: Segmentation centers for left hand FiveInch data.

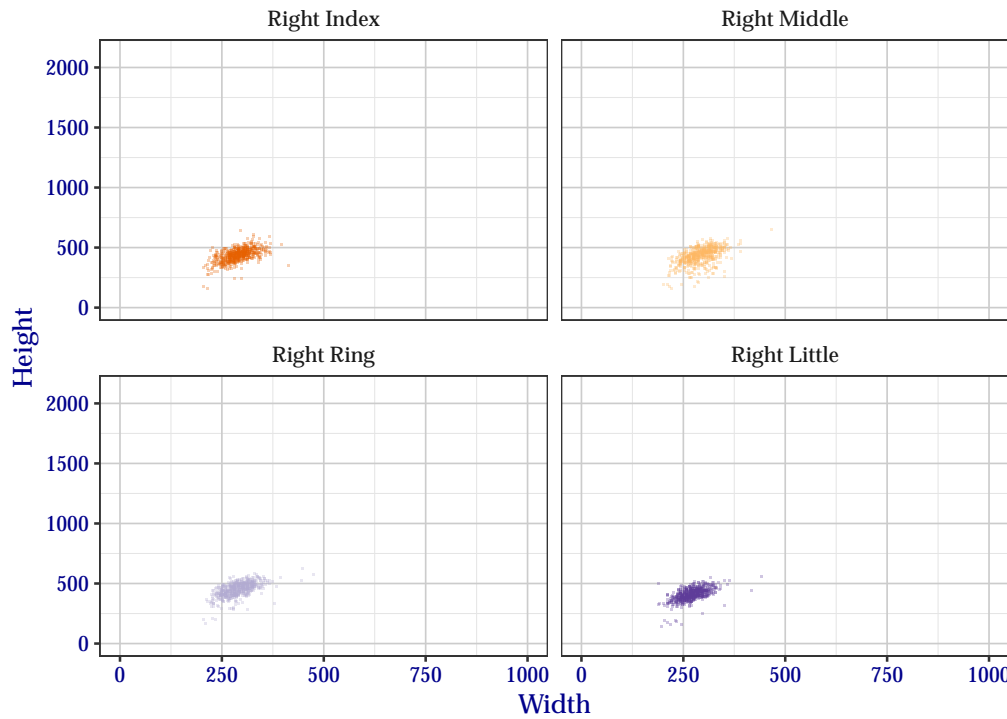
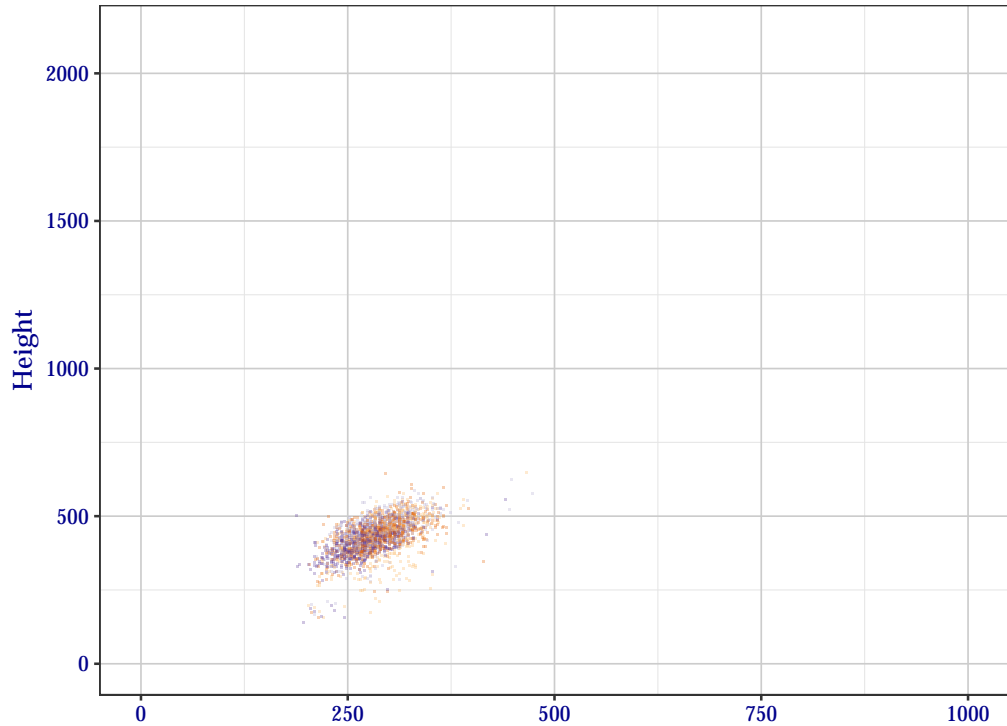
4.2.2 Segmentation Dimensions

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: nec/0004, FRGPs: 2, 3, 4, 5, Image Kind: Upper Palm



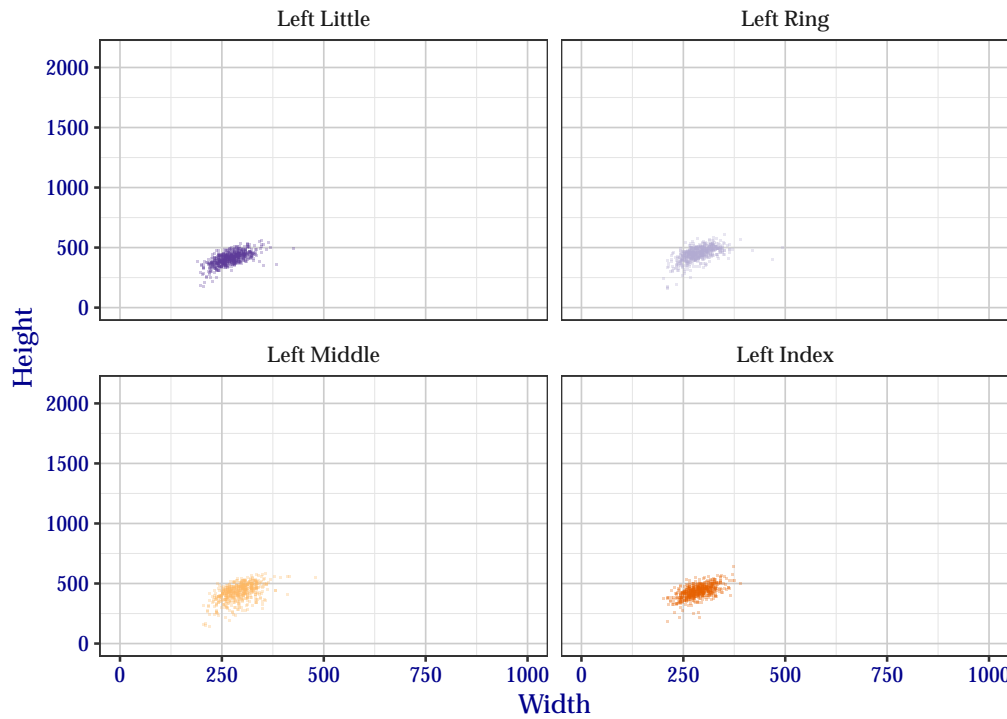
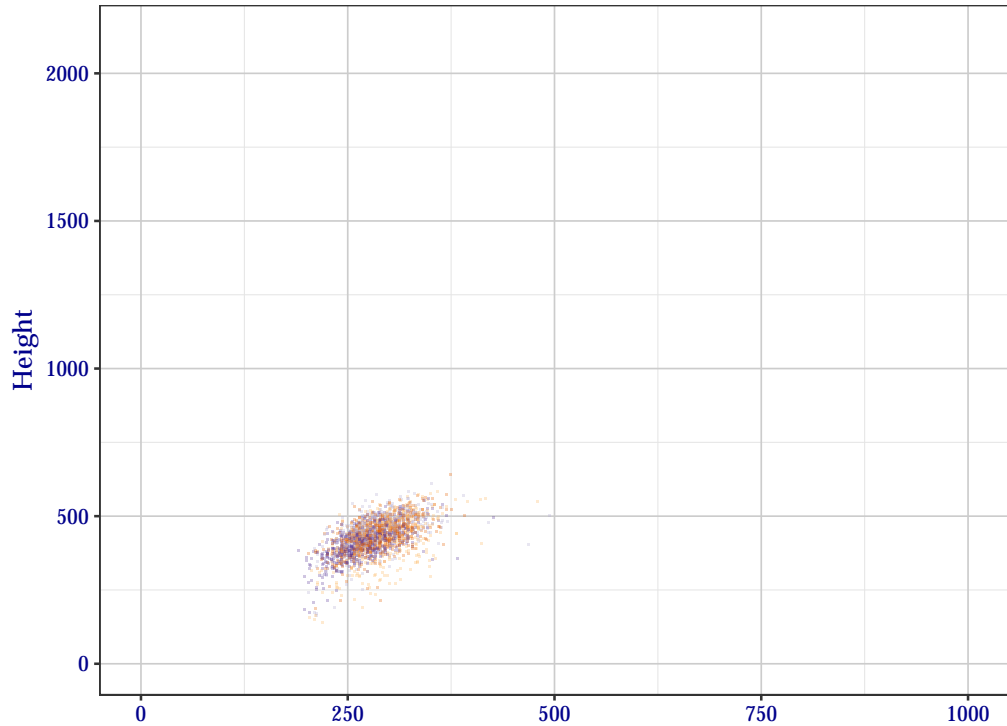
Right Index Right Middle Right Ring Right Little

01 August 2023, 03:23:44 PM EDT

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

Segmentation Position Dimensions

Participant: nec/0004, FRGPs: 7, 8, 9, 10, Image Kind: Upper Palm



· Left Index · Left Middle · Left Ring · Left Little

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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 26 shows how successful nec+0004 segmented fingers for each subject in the test corpus. Table 27 shows success for specific finger positions over the entire test corpus. Similarly, Table 28 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 29 shows success for combinations of all fingers, Table 30 for just the index and middle fingers, and Table 31 for all except the little finger.

Table 26: For each subject, the percentage that at least *Number of Fingers* fingers were correctly segmented, regardless of hand, for a maximum of eight correctly-segmented fingers. In *Standard Scoring*, scoring rules are followed exactly. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Number of Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
1	99.7	99.7	99.7
2	99.3	99.3	99.3
3	98.6	98.6	98.6
4	97.6	97.8	97.8
5	93.7	93.9	93.9
6	87.6	87.9	87.9
7	77.7	78.4	78.8
8	63.1	65.2	65.9

Table 27: 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	90.7	90.8	90.8
Middle	91.1	91.2	91.6
Ring	92.2	92.7	92.8
Little	89.4	89.6	89.6
Left			
Index	87.7	87.8	87.9
Middle	91.6	91.8	91.8
Ring	92.2	93.1	93.1
Little	88.3	89.5	89.9

Table 28: 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	96.0	96.0	96.0
Both	80.9	81.2	81.3
Middle			
Either	98.0	98.2	98.2
Both	83.3	83.4	83.8
Ring			
Either	98.0	98.2	98.2
Both	84.8	86.2	86.3
Little			
Either	96.7	96.7	96.8
Both	79.6	81.0	81.3

Table 29: 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	99.5	99.5	99.5
At Least Two	96.7	96.7	96.7
At Least Three	89.2	89.5	89.8
All Four	77.9	78.7	79.0
Left			
Any	98.8	99.1	99.1
At Least Two	96.4	96.6	96.6
At Least Three	89.7	89.9	89.9
All Four	74.9	76.7	77.2

Table 30: Percentage of segmentation success by hand when only considering combinations of index and middle fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Either Index or Middle	96.0	96.1	96.3
Both Index and Middle	85.8	85.9	86.2
Left			
Either Index or Middle	95.5	95.6	95.6
Both Index and Middle	83.8	84.0	84.1

Table 31: 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	98.5	98.5	98.5
At Least Two	92.4	92.6	92.8
All Three	83.0	83.6	83.9
Left			
Any	98.3	98.5	98.5
At Least Two	92.0	92.2	92.2
All Three	81.2	82.0	82.1

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.

nec+0004 did **not** report any capture failures.

4.4.1.1 Recovery

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

nec+0004 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 nec+0004 are enumerated in Table 32.

Table 32: Count of self-reported segmentation failure reasoning.

Failure Reason	Fingers
Finger Not Found	1 184
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 33 shows how successful nec+0004 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 33: Performance of nec+0004 at detecting fingers missing from an image.

Result	Percentage
Missed	10.7
Correctly Identified	89.3
Other Failure: Finger Found, but Can't Segment	0.0
Other Failure: Vendor Defined	0.0
Other Failure: Segmentation Not Attempted	0.0

4.4.4 Sequence Error

Sequence error occurs when a fingerprint is segmented from an image but assigned an incorrect finger position (e.g., segmenting a right middle finger but labeling it a right index finger). Table 34 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 34: 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	2.52	2.52	2.52
Right	3.06	3.19	3.19
Combined	2.79	2.86	2.86

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: 79.7%

Table 35: 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
Left	75.7	24.3
Right	16.2	83.8

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 36. Results are reported in milliseconds.

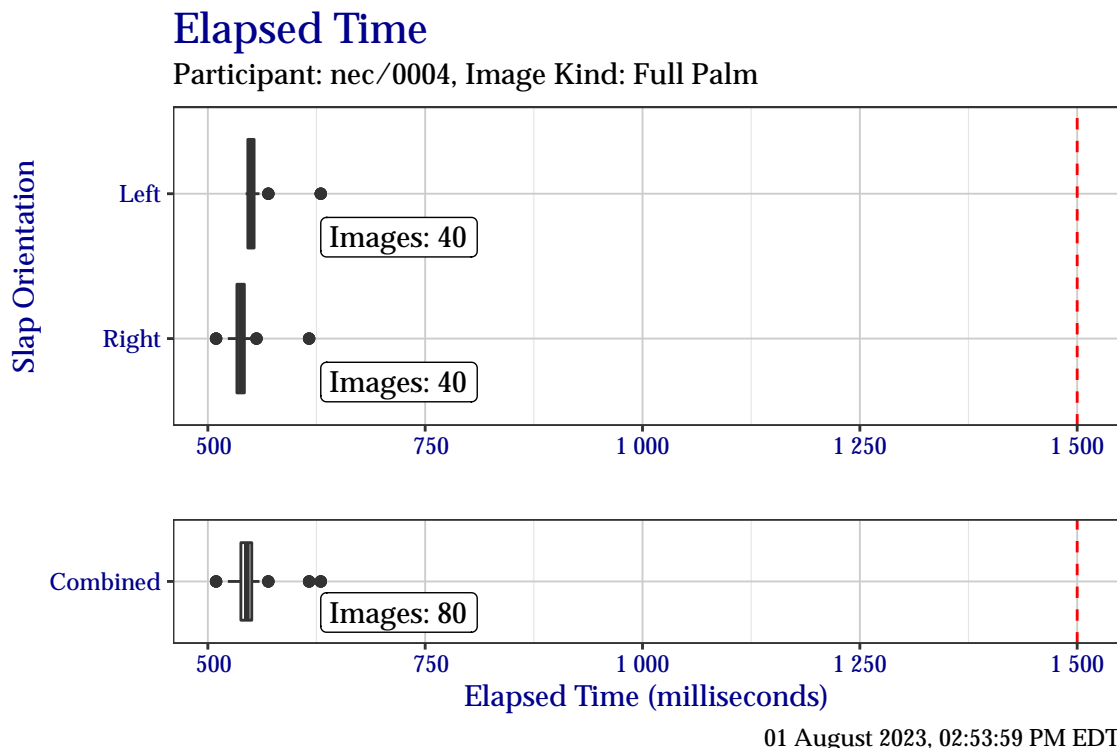


Figure 18: Box plots of elapsed time in milliseconds when segmenting the EightInch timing test corpus, separated by slap orientation.

Table 36: Elapsed time in milliseconds when segmenting the EightInch timing test corpus, separated by slap orientation and capture technology.

	Right	Left	Combined
Minimum	509	544	509
25%	533	546	538
Median	538	549	545
75%	542	553	551
Maximum	616	630	630

5.2 Segmentation Centers and Dimensions

5.2.1 Segmentation Centers

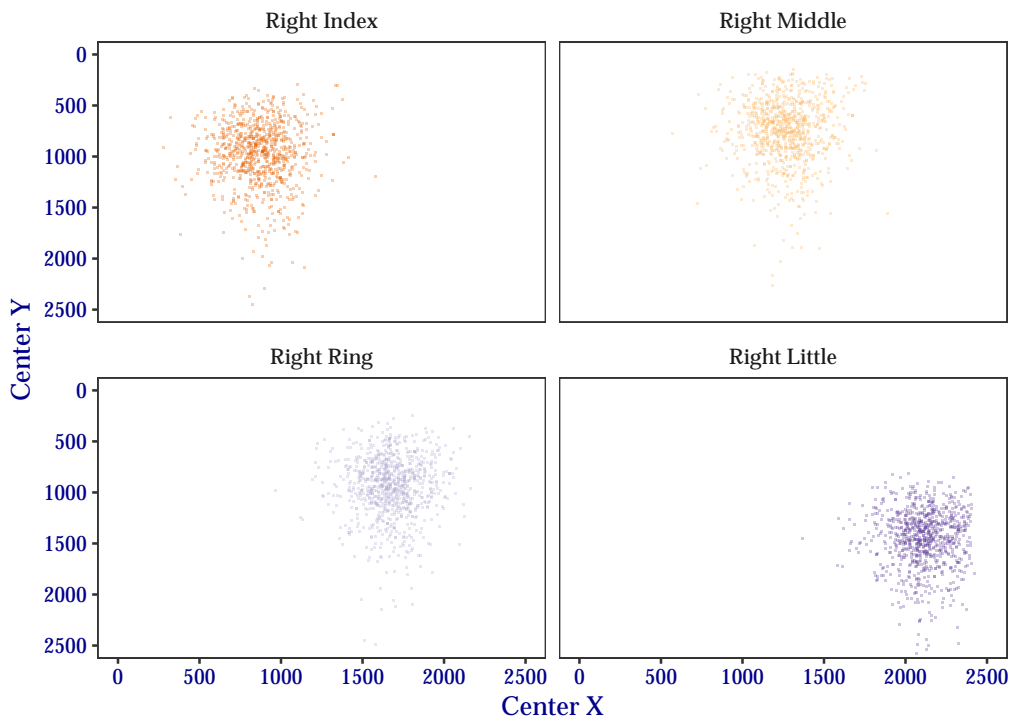
The plots in this section show the distribution of segmentation position centers (x, y) for EightInch data. At the top of each figure is a combined plot for all finger positions of a given slap orientation. These figures are isolated in plots faceted at the bottom of the figure.

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: nec/0004, FRGPs: 2, 3, 4, 5, Image Kind: Full Palm



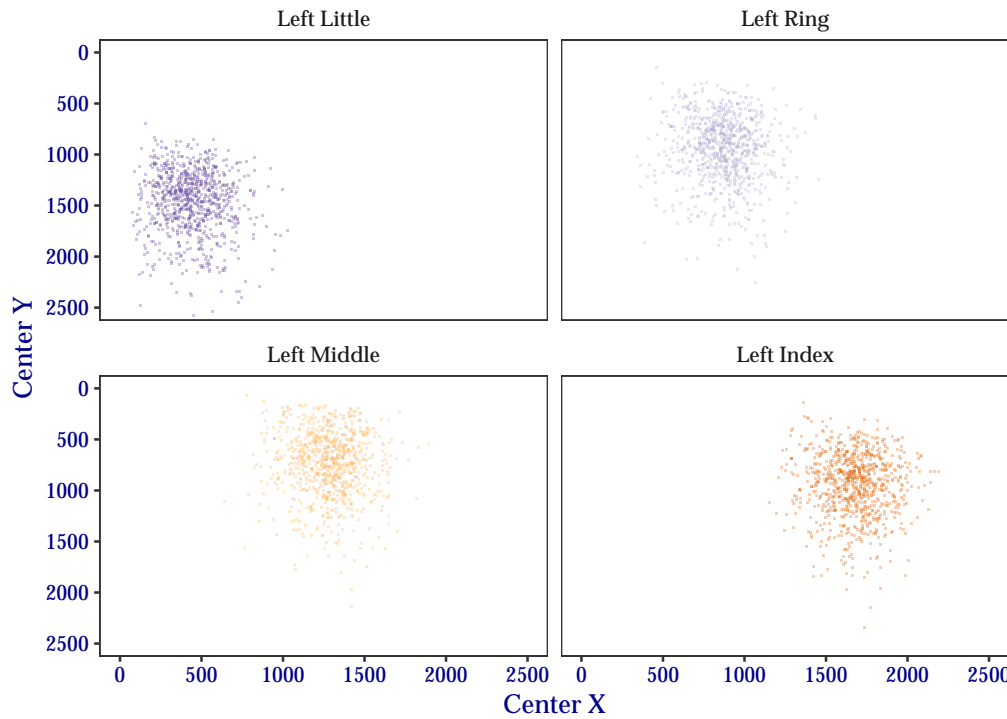
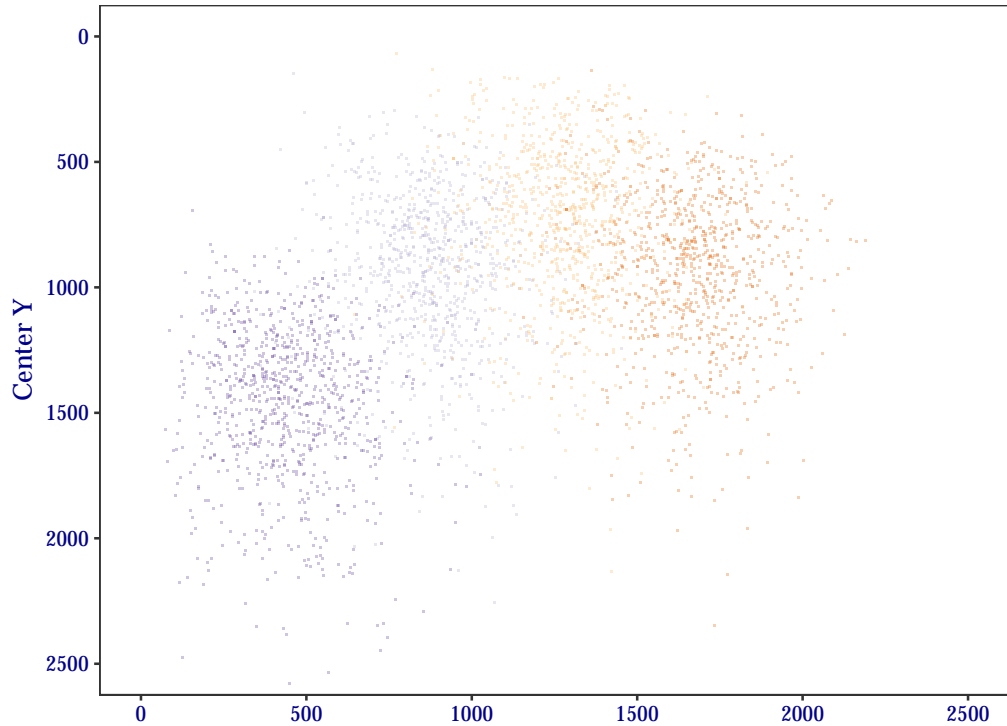
• Right Index • Right Middle • Right Ring • Right Little

01 August 2023, 03:23:21 PM EDT

Figure 19: Segmentation centers for right hand EightInch data.

Segmentation Position Centers

Participant: nec/0004, FRGPs: 7, 8, 9, 10, Image Kind: Full Palm



• Left Index • Left Middle • Left Ring • Left Little

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Figure 20: Segmentation centers for left hand EightInch data.

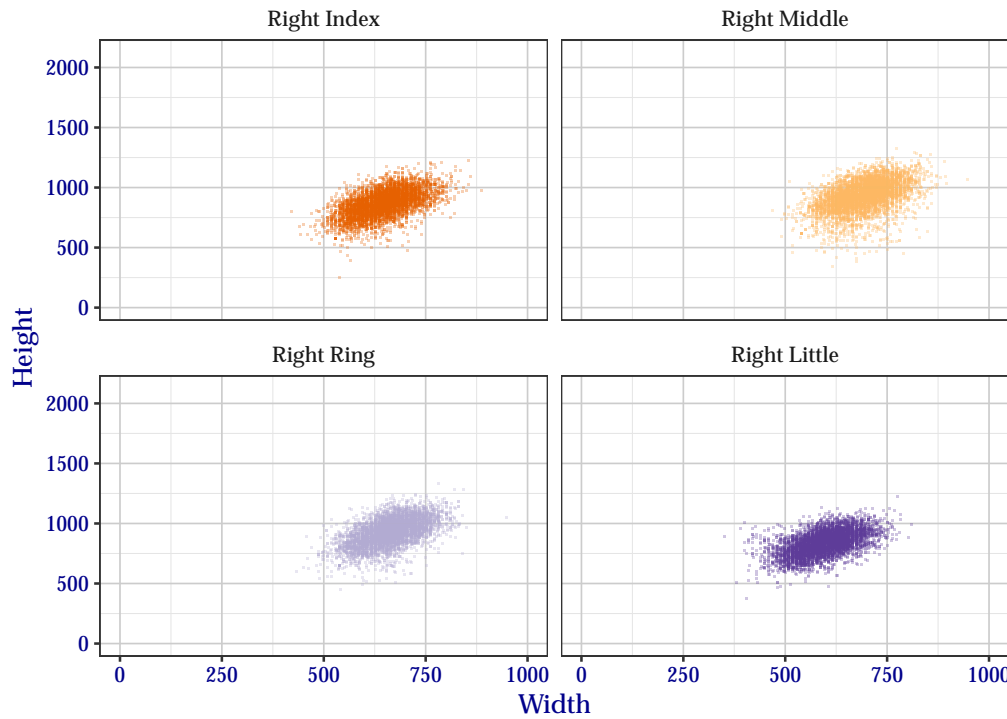
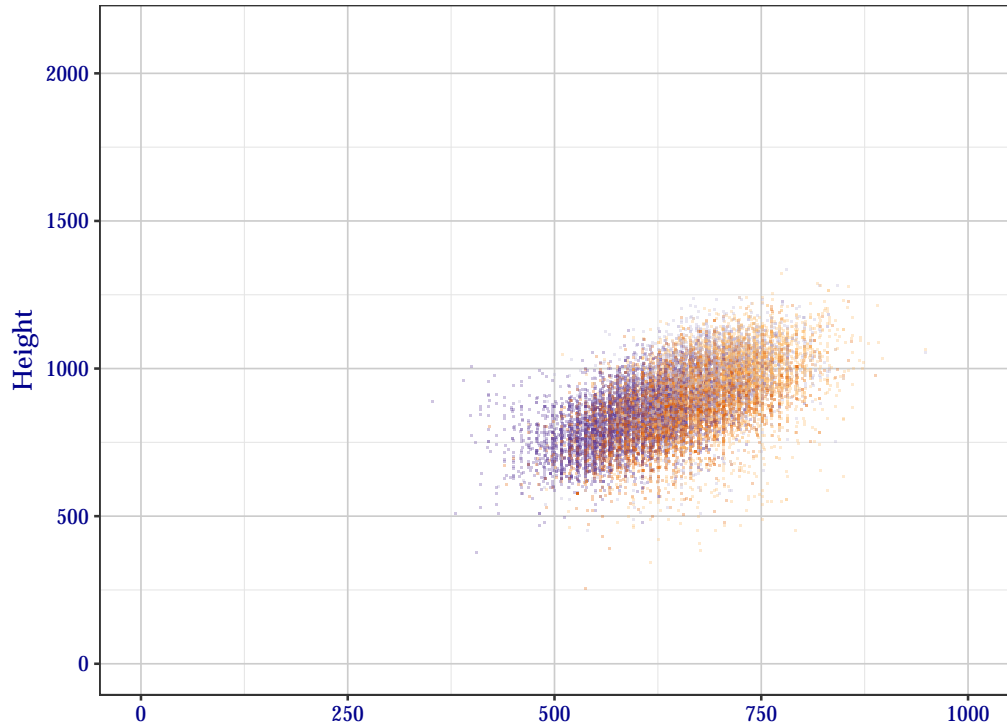
5.2.2 Segmentation Dimensions

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

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

Segmentation Position Dimensions

Participant: nec/0004, FRGPs: 2, 3, 4, 5, Image Kind: Full Palm



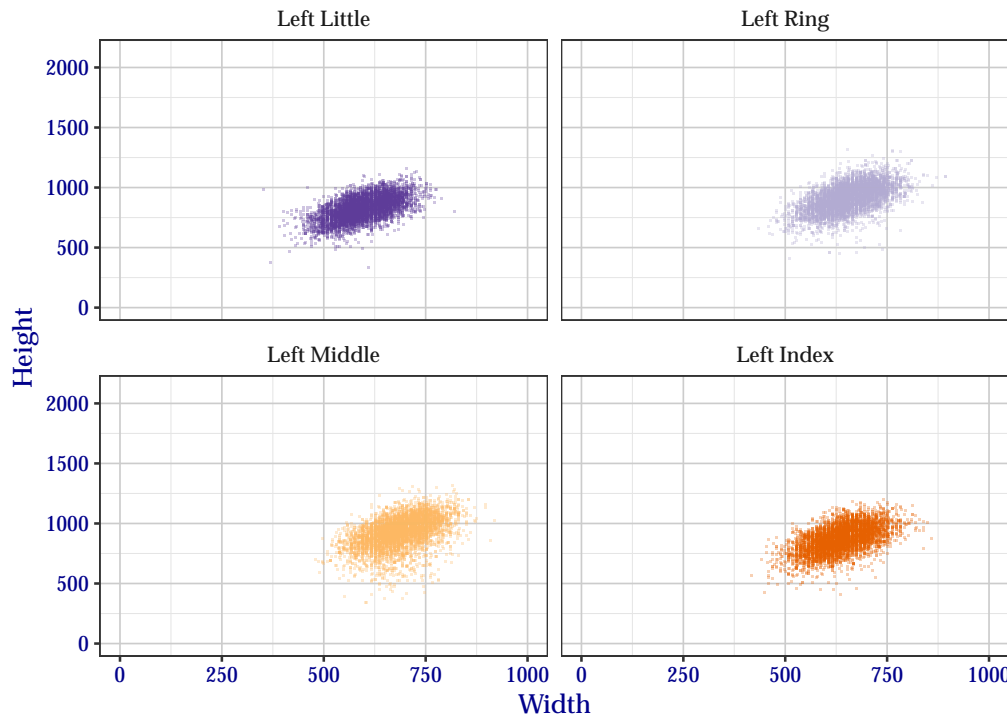
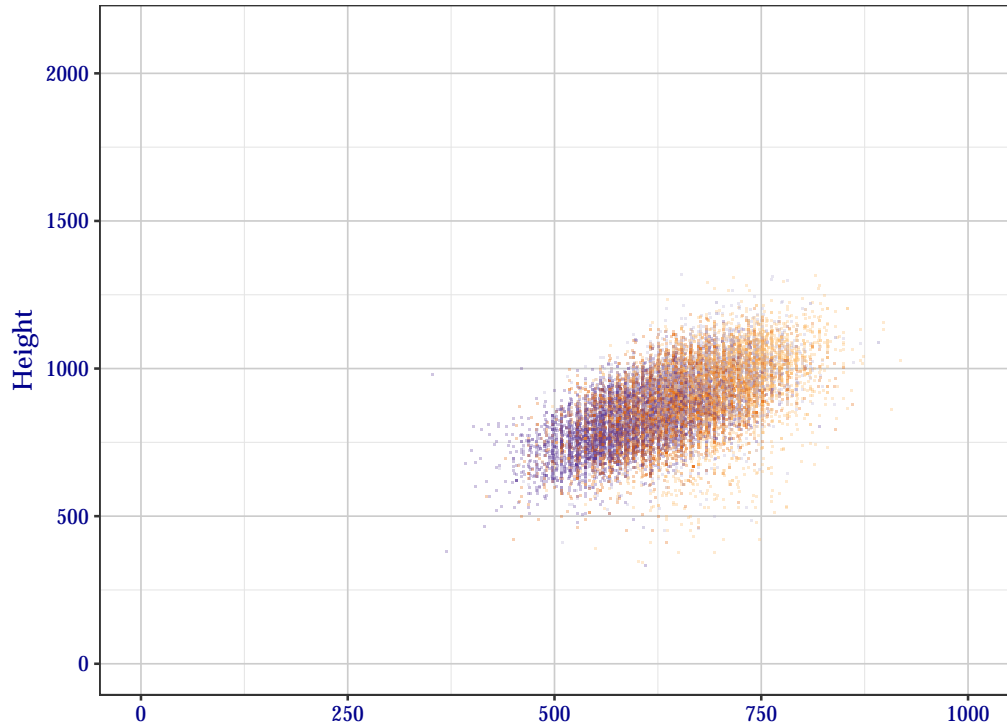
Right Index Right Middle Right Ring Right Little

01 August 2023, 03:23:47 PM EDT

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

Segmentation Position Dimensions

Participant: nec/0004, FRGPs: 7, 8, 9, 10, Image Kind: Full Palm



• Left Index • Left Middle • Left Ring • Left Little

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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 37 shows how successful nec+0004 segmented fingers for each subject in the test corpus. Table 38 shows success for specific finger positions over the entire test corpus. Similarly, Table 39 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 40 shows success for combinations of all fingers, Table 41 for just the index and middle fingers, and Table 42 for all except the little finger.

Table 37: 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	100.0	100.0	100.0
5	100.0	100.0	100.0
6	100.0	100.0	100.0
7	99.7	99.8	99.8
8	96.7	97.7	97.8

Table 38: 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	99.8	99.8	99.8
Middle	99.8	99.8	99.8
Ring	99.4	99.8	99.8
Little	99.4	99.5	99.5
Left			
Index	99.2	99.3	99.3
Middle	99.8	99.9	99.9
Ring	99.3	99.8	99.9
Little	99.7	99.7	99.7

Table 39: 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	99.0	99.1	99.1
Middle			
Either	100.0	100.0	100.0
Both	99.5	99.7	99.7
Ring			
Either	100.0	100.0	100.0
Both	98.7	99.5	99.7
Little			
Either	100.0	100.0	100.0
Both	99.1	99.2	99.2

Table 40: 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	99.8
All Four	98.6	99.1	99.1
Left			
Any	100.0	100.0	100.0
At Least Two	100.0	100.0	100.0
At Least Three	99.9	100.0	100.0
All Four	98.0	98.6	98.7

Table 41: 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	99.9	99.9	99.9
Both Index and Middle	99.7	99.7	99.7
Left			
Either Index or Middle	100.0	100.0	100.0
Both Index and Middle	99.0	99.2	99.2

Table 42: 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	99.8	99.8	99.8
All Three	99.2	99.5	99.5
Left			
Any	100.0	100.0	100.0
At Least Two	99.9	100.0	100.0
All Three	98.4	99.0	99.1

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.

nec+0004 did **not** report any capture failures.

5.4.1.1 Recovery

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

nec+0004 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 nec+0004 are enumerated in Table 43.

Table 43: Count of self-reported segmentation failure reasoning.

Failure Reason	Fingers
Finger Not Found	53
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 44 shows how successful nec+0004 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 44: Performance of nec+0004 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 45 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 45: 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	0.11	0.11	0.11
Combined	0.06	0.06	0.06

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: 99.0%

Table 46: 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
Left	98.3	1.7
Right	0.2	99.8

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 47, results are shown of how successful nec+0004 segmented fingers for each subject in the test corpus. Table 48 shows success for specific finger positions over the entire test corpus. Similarly, Table 49 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 50 shows success for combinations of all fingers, Table 52 for the all except the little finger, and Table 51 for just the index and middle fingers.

Table 47: 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 [99.8, 99.9]	99.9 [99.8, 99.9]	99.9 [99.9, 100.0]
2	99.7 [99.5, 99.7]	99.7 [99.7, 99.8]	99.8 [99.8, 99.9]
3	99.3 [99.1, 99.4]	99.5 [99.3, 99.6]	99.6 [99.5, 99.7]
4	98.4 [98.2, 98.6]	98.8 [98.6, 99.0]	99.0 [98.8, 99.2]
5	94.7 [94.3, 95.1]	95.4 [95.0, 95.8]	95.6 [95.2, 95.9]
6	93.2 [92.7, 93.6]	94.6 [94.1, 95.0]	95.0 [94.7, 95.4]
7	89.1 [88.5, 89.7]	92.6 [92.1, 93.0]	93.2 [92.8, 93.7]
8	76.4 [75.6, 77.1]	83.5 [82.8, 84.1]	84.8 [84.2, 85.4]

Table 48: 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	94.6 [94.3, 94.9]	96.6 [96.4, 96.8]	97.0 [96.8, 97.2]
Middle	94.6 [94.3, 94.9]	96.5 [96.2, 96.7]	96.9 [96.7, 97.1]
Ring	94.1 [93.9, 94.4]	96.6 [96.4, 96.9]	97.0 [96.8, 97.2]
Little	96.5 [96.3, 96.8]	98.1 [97.9, 98.3]	98.6 [98.5, 98.8]
Left			
Index	97.0 [96.8, 97.3]	98.1 [98.0, 98.3]	98.5 [98.3, 98.6]
Middle	96.2 [95.9, 96.5]	97.9 [97.7, 98.1]	98.2 [98.0, 98.4]
Ring	94.8 [94.5, 95.1]	97.5 [97.3, 97.7]	97.8 [97.6, 98.0]
Little	96.9 [96.6, 97.2]	98.1 [97.9, 98.3]	98.5 [98.3, 98.7]

Table 49: 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	99.0 [98.8, 99.1]	99.2 [99.0, 99.3]	99.4 [99.2, 99.5]
Both	88.6 [88.0, 89.2]	91.2 [90.8, 91.7]	91.9 [91.4, 92.3]
Middle			
Either	98.8 [98.6, 99.0]	99.3 [99.1, 99.4]	99.4 [99.3, 99.6]
Both	88.6 [88.1, 89.1]	91.3 [90.9, 91.8]	91.9 [91.5, 92.4]
Ring			
Either	98.5 [98.3, 98.7]	99.4 [99.2, 99.5]	99.5 [99.4, 99.6]
Both	87.4 [86.8, 88.0]	91.4 [91.0, 91.9]	92.1 [91.6, 92.5]
Little			
Either	99.1 [98.9, 99.3]	99.3 [99.2, 99.5]	99.5 [99.3, 99.6]
Both	90.5 [90.0, 91.0]	92.7 [92.2, 93.1]	93.4 [92.9, 93.8]

Table 50: Percentage of segmentation success by hand for combinations of all eight fingers of a TwoInch slap. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95% confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	99.6 [99.6, 99.7]	99.7 [99.7, 99.8]	99.9 [99.8, 99.9]
At Least Two	98.7 [98.8, 99.0]	99.3 [99.3, 99.5]	99.6 [99.5, 99.7]
At Least Three	96.2 [96.5, 96.8]	98.1 [98.2, 98.5]	98.5 [98.6, 98.8]
All Four	85.4 [86.7, 87.4]	90.8 [91.9, 92.4]	91.7 [92.8, 93.3]
Left			
Any	99.8 [99.6, 99.7]	99.8 [99.7, 99.8]	99.9 [99.8, 99.9]
At Least Two	99.1 [98.8, 99.0]	99.5 [99.3, 99.5]	99.6 [99.5, 99.7]
At Least Three	97.2 [96.5, 96.8]	98.6 [98.2, 98.5]	99.0 [98.6, 98.8]
All Four	88.9 [86.7, 87.4]	93.7 [91.9, 92.4]	94.5 [92.8, 93.3]

Table 51: 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	98.5 [98.7, 98.9]	99.1 [99.2, 99.3]	99.3 [99.4, 99.5]
Both Index and Middle	90.7 [92.1, 92.6]	94.0 [95.0, 95.4]	94.6 [95.6, 96.0]
Left			
Either Index or Middle	99.1 [98.7, 98.9]	99.5 [99.2, 99.3]	99.6 [99.4, 99.5]
Both Index and Middle	94.1 [92.1, 92.6]	96.6 [95.0, 95.4]	97.1 [95.6, 96.0]

Table 52: 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	99.2 [99.3, 99.4]	99.6 [99.6, 99.7]	99.7 [99.7, 99.8]
At Least Two	97.1 [97.2, 97.5]	98.4 [98.6, 98.8]	98.7 [98.9, 99.1]
All Three	87.1 [88.5, 89.1]	91.8 [93.0, 93.5]	92.5 [93.7, 94.1]
Left			
Any	99.5 [99.3, 99.4]	99.7 [99.6, 99.7]	99.8 [99.7, 99.8]
At Least Two	97.8 [97.2, 97.5]	98.9 [98.6, 98.8]	99.2 [98.9, 99.1]
All Three	90.8 [88.5, 89.1]	94.9 [93.0, 93.5]	95.6 [93.7, 94.1]

A.2 Jaccard Index

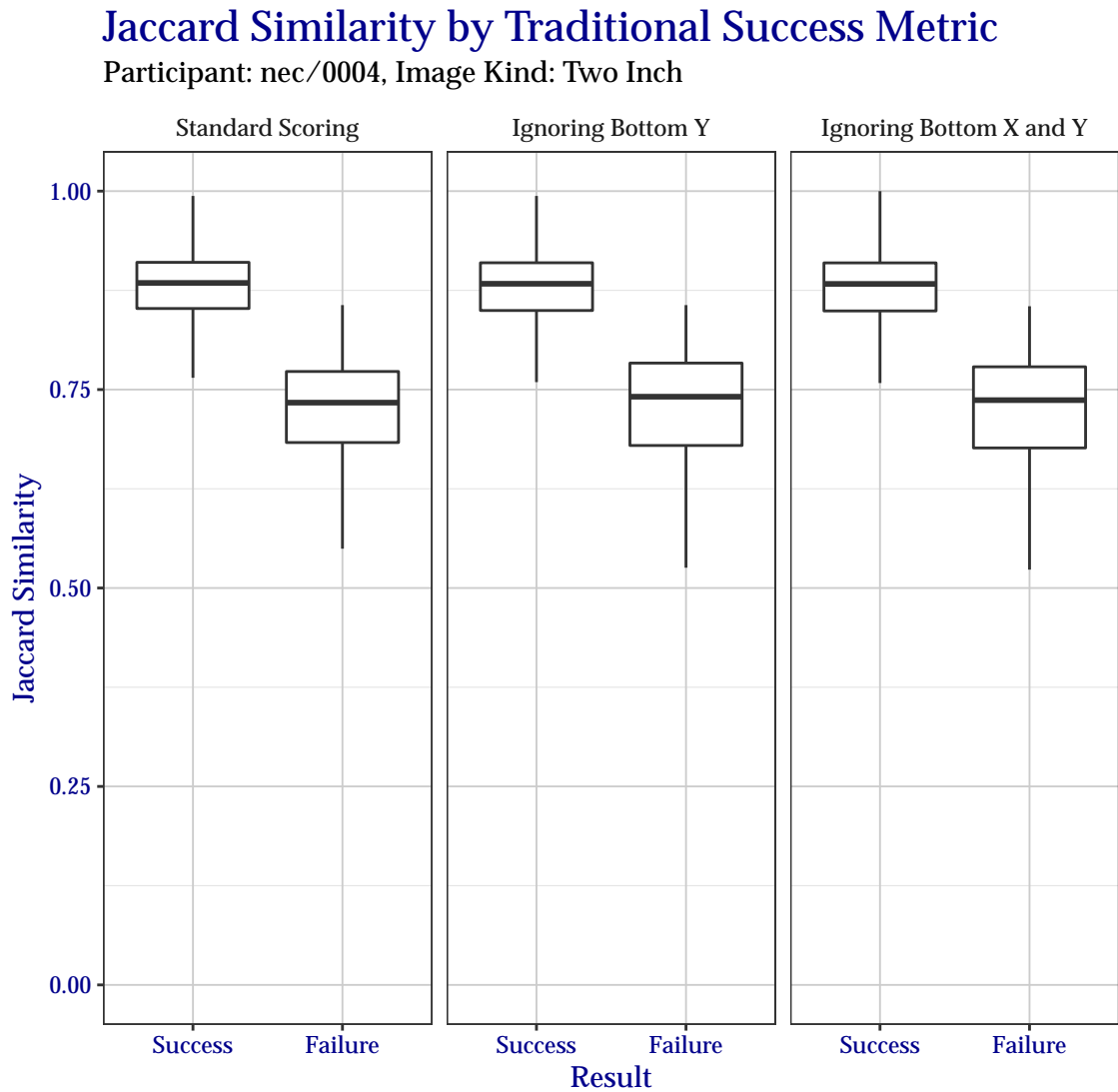
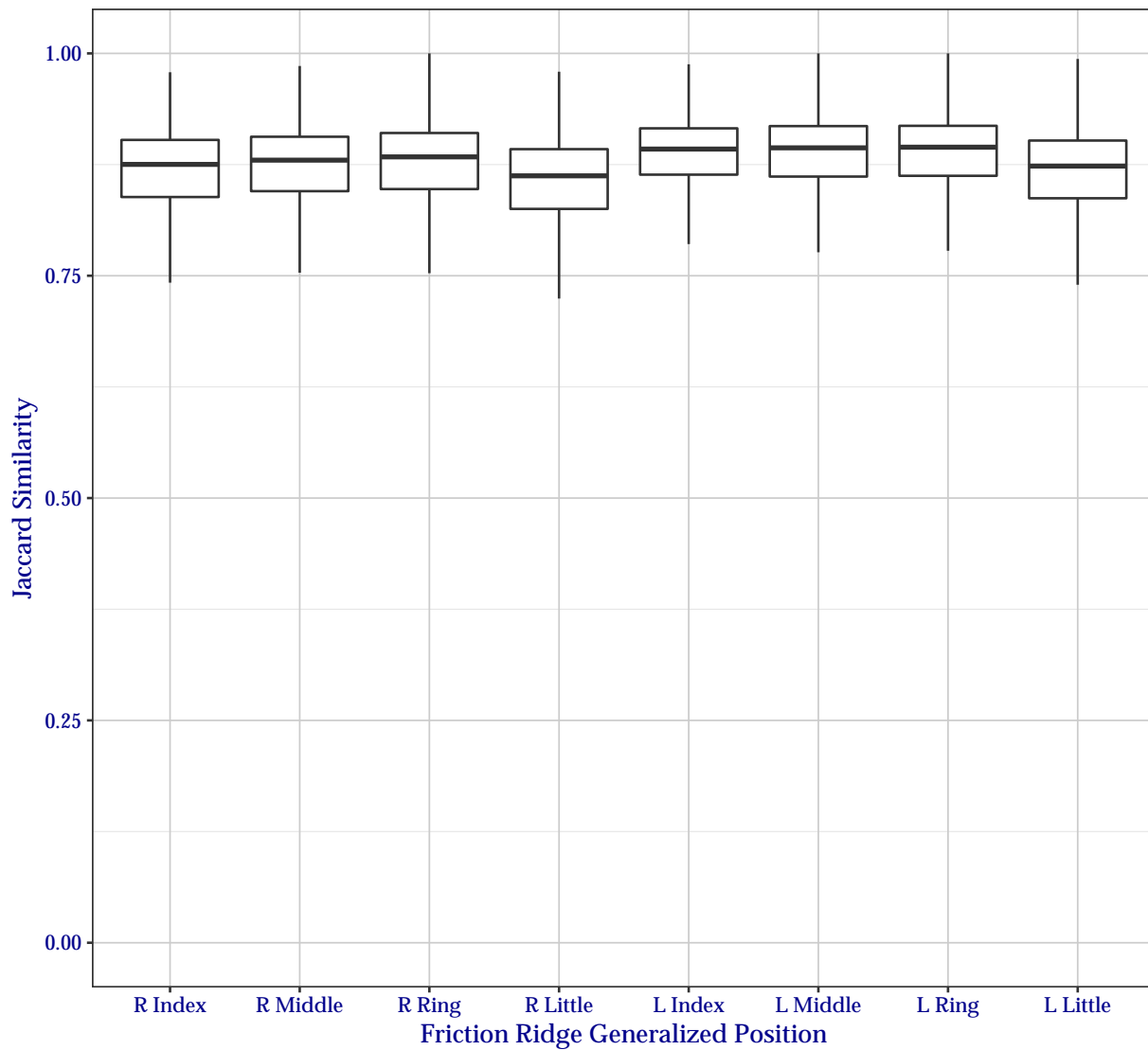


Figure 23: Boxplot of Jaccard similarity indices as compared to the traditional success metrics. Outliers have been removed for clarity.

Jaccard Similarity by Friction Ridge Generalized Position

Participant: nec/0004, Image Kind: Two Inch



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

Table 53: 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	99.7	84.4	15.2	0.2
2	99.9	99.9	99.8	99.2	69.2	2.3	0.0
3	99.8	99.8	99.6	98.1	51.8	0.3	0.0
4	99.7	99.6	99.2	95.9	33.4	0.1	0.0
5	95.8	95.8	95.6	91.0	18.2	0	0
6	95.7	95.7	95.0	86.7	7.7	0	0
7	95.6	95.4	93.8	78.3	2.2	0	0
8	94.9	93.9	87.8	56.7	0.3	0	0

Table 54: 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	0.3	0.2	1.4	9.6	61.1	27.4
Middle	0.3	0.2	1.4	8.9	58.3	30.9
Ring	0.2	0.2	1.5	8.9	54.3	34.9
Little	0.2	0.3	1.8	12.6	65.9	19.2
Left						
Index	0.2	0.1	0.6	4.6	52.5	42.0
Middle	0.3	0.1	0.9	6.0	48.5	44.2
Ring	0.2	0.1	1.1	6.6	47.8	44.2
Little	0.2	0.1	1.3	9.9	61.9	26.6

Table 55: Percentage of segmentation obtaining a Jaccard index in the indicated ranges, by hand, for combinations of all eight fingers of a TwoInch slap.

Fingers	≥ 0.5	≥ 0.6	≥ 0.7	≥ 0.8	≥ 0.9	≥ 0.95	≥ 0.98
Right							
Any	99.9	99.9	99.9	98.4	61.7	5.3	0.0
At Least Two	99.9	99.9	99.5	95.3	34.8	0.4	0.0
At Least Three	99.8	99.7	98.6	88.5	13.2	0.0	0.0
All Four	99.3	98.5	93.9	69.6	2.6	0.0	0.0
Left							
Any	100.0	100.0	99.9	99.4	72.4	10.6	0.1
At Least Two	99.9	99.9	99.8	97.7	50.3	1.5	0.0
At Least Three	99.8	99.8	99.2	93.2	26.7	0.2	0.0
All Four	99.5	99.1	95.8	77.4	7.5	0.0	0.0

Table 56: Percentage of segmentation obtaining a Jaccard index in the indicated ranges, by hand, for combinations of index and middle fingers of a TwoInch slap.

Fingers	≥ 0.5	≥ 0.6	≥ 0.7	≥ 0.8	≥ 0.9	≥ 0.95	≥ 0.98
Right							
Either Index or Middle	99.9	99.8	99.5	96.0	45.7	2.8	0.0
Both Index and Middle	99.5	99.1	96.6	81.6	12.6	0.1	0.0
Left							
Either Index or Middle	99.9	99.9	99.8	98.1	60.9	6.2	0.1
Both Index and Middle	99.6	99.5	98.1	89.2	25.3	0.3	0.0

Table 57: Percentage of segmentation obtaining a Jaccard index in the indicated ranges, by hand, for combinations of index, middle, and ring fingers of a TwoInch slap.

Fingers	≥ 0.5	≥ 0.6	≥ 0.7	≥ 0.8	≥ 0.9	≥ 0.95	≥ 0.98
Right							
Any	99.9	99.9	99.7	97.7	58.2	4.8	0.0
At Least Two	99.8	99.7	99.0	92.3	28.0	0.3	0.0
All Three	99.4	98.9	95.4	76.8	6.9	0.0	0.0
Left							
Any	99.9	99.9	99.9	98.9	69.4	9.5	0.1
At Least Two	99.8	99.8	99.5	95.5	43.7	1.1	0.0
All Three	99.6	99.3	97.1	84.8	17.4	0.1	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 58, results are shown of how successful nec+0004 segmented fingers for each subject in the test corpus. Table 59 shows success for specific finger positions over the entire test corpus. Similarly, Table 60 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 61 shows success for combinations of all fingers, Table 63 for the all except the little finger, and Table 62 for just the index and middle fingers.

Table 58: 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	99.3 [99.2, 99.4]	99.3 [99.2, 99.4]	99.3 [99.2, 99.4]
3	98.5 [98.3, 98.7]	98.5 [98.4, 98.7]	98.5 [98.4, 98.7]
4	98.3 [98.1, 98.4]	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 [95.7, 96.2]	95.9 [95.6, 96.1]	95.9 [95.6, 96.2]
7	95.8 [95.5, 96.0]	95.8 [95.5, 96.0]	95.8 [95.6, 96.0]
8	95.3 [95.0, 95.6]	95.3 [95.0, 95.6]	95.5 [95.2, 95.8]
9	91.0 [90.6, 91.3]	91.0 [90.7, 91.4]	91.8 [91.5, 92.2]
10	73.5 [73.0, 74.1]	73.6 [73.1, 74.2]	76.4 [75.8, 76.9]

Table 59: 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	88.6 [88.1, 89.0]	88.6 [88.2, 89.0]	89.3 [88.9, 89.7]
Index	99.4 [99.3, 99.5]	99.4 [99.3, 99.5]	99.5 [99.4, 99.6]
Middle	99.3 [99.2, 99.4]	99.3 [99.2, 99.4]	99.6 [99.5, 99.7]
Ring	97.9 [97.7, 98.0]	97.9 [97.8, 98.1]	98.5 [98.4, 98.7]
Little	98.5 [98.3, 98.6]	98.5 [98.3, 98.6]	98.6 [98.4, 98.7]
Left			
Thumb	90.7 [90.3, 91.1]	90.7 [90.3, 91.1]	91.6 [91.2, 91.9]
Index	98.9 [98.7, 99.0]	98.9 [98.7, 99.0]	99.0 [98.9, 99.1]
Middle	99.1 [99.0, 99.2]	99.1 [99.0, 99.3]	99.5 [99.4, 99.6]
Ring	98.7 [98.5, 98.8]	98.7 [98.6, 98.8]	99.4 [99.3, 99.5]
Little	98.6 [98.4, 98.7]	98.6 [98.4, 98.7]	98.7 [98.6, 98.9]

Table 60: Percentage that a particular type of fingerprint was correctly segmented on *Either* or *Both* hands. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95% confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Thumb			
Either	96.9 [96.7, 97.1]	96.9 [96.7, 97.1]	97.2 [97.0, 97.4]
Both	82.4 [81.9, 82.9]	82.4 [81.9, 82.9]	83.8 [83.3, 84.2]
Index			
Either	99.8 [99.8, 99.9]	99.8 [99.8, 99.9]	99.9 [99.8, 99.9]
Both	95.7 [95.5, 96.0]	95.8 [95.5, 96.0]	95.9 [95.7, 96.2]
Middle			
Either	99.8 [99.8, 99.9]	99.9 [99.8, 99.9]	99.9 [99.8, 99.9]
Both	95.9 [95.6, 96.1]	95.9 [95.7, 96.2]	96.5 [96.2, 96.7]
Ring			
Either	99.7 [99.7, 99.8]	99.7 [99.7, 99.8]	99.9 [99.8, 99.9]
Both	94.1 [93.8, 94.4]	94.2 [93.9, 94.5]	95.4 [95.1, 95.6]
Little			
Either	99.8 [99.7, 99.8]	99.8 [99.7, 99.8]	99.8 [99.7, 99.9]
Both	94.6 [94.3, 94.9]	94.6 [94.3, 94.9]	94.8 [94.6, 95.1]

Table 61: Percentage of segmentation success by hand for combinations of all ten fingers of a ThreeInch slap. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	99.5 [99.5, 99.6]	99.5 [99.5, 99.6]	99.5 [99.5, 99.6]
At Least Two	98.5 [98.4, 98.6]	98.5 [98.4, 98.6]	98.5 [98.4, 98.6]
At Least Three	98.4 [98.3, 98.5]	98.4 [98.3, 98.5]	98.4 [98.3, 98.5]
At Least Four	97.4 [97.3, 97.6]	97.4 [97.3, 97.6]	97.6 [97.6, 97.8]
All Five	81.1 [81.7, 82.4]	81.2 [81.8, 82.4]	82.7 [83.4, 84.1]
Left			
Any	99.7 [99.5, 99.6]	99.7 [99.5, 99.6]	99.7 [99.5, 99.6]
At Least Two	98.5 [98.4, 98.6]	98.5 [98.4, 98.6]	98.5 [98.4, 98.6]
At Least Three	98.4 [98.3, 98.5]	98.4 [98.3, 98.5]	98.4 [98.3, 98.5]
At Least Four	97.5 [97.3, 97.6]	97.5 [97.3, 97.6]	97.8 [97.6, 97.8]
All Five	82.9 [81.7, 82.4]	83.0 [81.8, 82.4]	84.8 [83.4, 84.1]

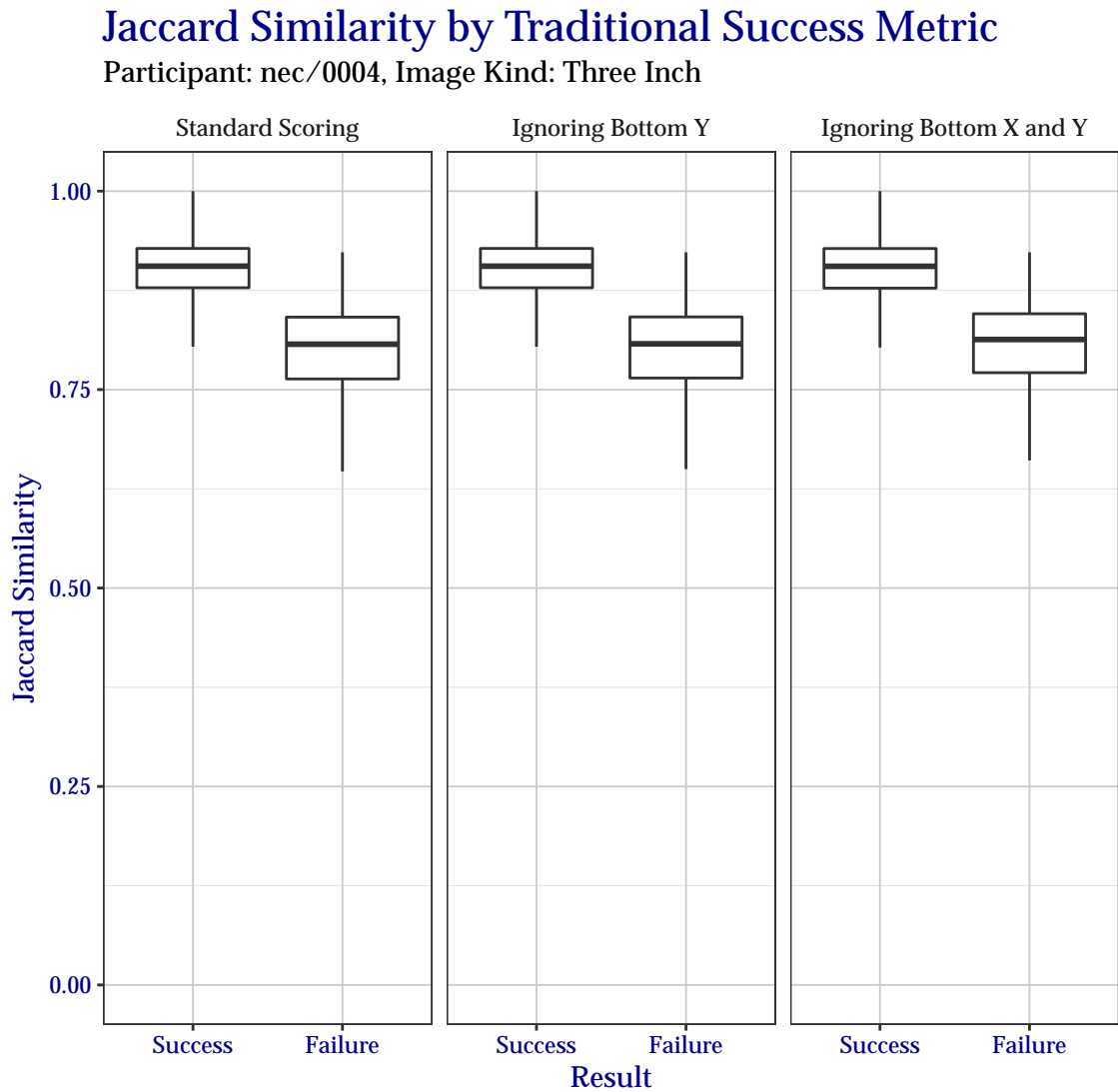
Table 62: Percentage of segmentation success by hand when only considering combinations of index and middle fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values 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	98.8 [98.3, 98.6]	98.9 [98.4, 98.6]	99.2 [98.8, 99.0]
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	98.1 [98.3, 98.6]	98.1 [98.4, 98.6]	98.6 [98.8, 99.0]

Table 63: 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.

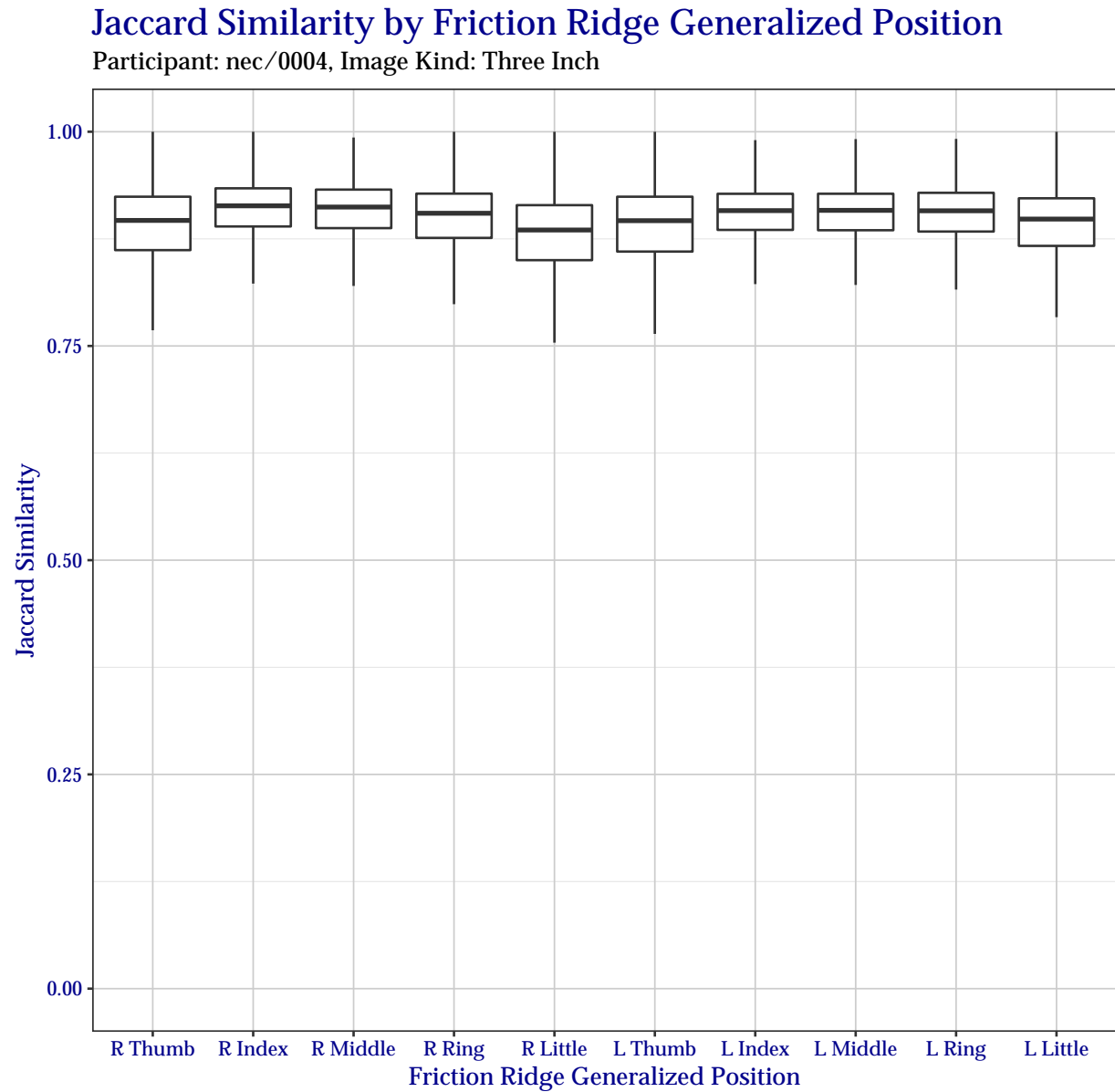
Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	99.9 [99.9, 99.9]	99.9 [99.9, 99.9]	99.9 [99.9, 100.0]
At Least Two	99.7 [99.7, 99.8]	99.7 [99.7, 99.8]	99.8 [99.7, 99.8]
All Three	97.0 [96.8, 97.1]	97.0 [96.9, 97.2]	97.9 [97.9, 98.1]
Left			
Any	99.9 [99.9, 99.9]	99.9 [99.9, 99.9]	99.9 [99.9, 100.0]
At Least Two	99.7 [99.7, 99.8]	99.7 [99.7, 99.8]	99.8 [99.7, 99.8]
All Three	97.0 [96.8, 97.1]	97.1 [96.9, 97.2]	98.1 [97.9, 98.1]

B.2 Jaccard Index



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



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

Table 64: 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	99.9	99.8	97.8	46.7	2.3
2	99.9	99.9	99.8	99.4	94.3	16.1	0.1
3	98.6	98.6	98.5	98.3	88.4	4.7	0.0
4	98.4	98.4	98.3	97.8	79.1	1.1	0.0
5	95.9	95.9	95.9	95.9	65.5	0.2	0.0
6	95.9	95.9	95.9	95.7	48.8	0.0	0
7	95.9	95.9	95.9	95.0	31.5	0.0	0
8	95.8	95.8	95.8	93.3	16.4	0	0
9	95.7	95.7	95.5	88.7	6.1	0	0
10	95.3	95.1	93.3	72.2	1.3	0	0

Table 65: 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	0.1	0.0	0.4	4.9	47.7	46.9
Index	0.2	0.0	0.3	2.2	32.1	65.2
Middle	0.1	0.0	0.2	2.7	33.1	63.9
Ring	0.2	0.0	0.3	3.8	40.6	55.1
Little	0.2	0.1	0.4	6.9	55.4	37.0
Left						
Thumb	0.1	0.0	0.3	5.5	47.3	46.8
Index	0.1	0.0	0.0	1.1	39.0	59.8
Middle	0.1	0.0	0.1	1.5	38.2	60.1
Ring	0.2	0.0	0.2	1.9	38.7	59.0
Little	0.2	0.0	0.3	3.8	47.7	48.0

Table 66: 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	99.6	92.5	29.5	1.3
At Least Two	98.5	98.5	98.5	98.0	77.9	6.6	0.0
At Least Three	98.5	98.5	98.4	96.8	55.1	1.4	0.0
At Least Four	98.4	98.3	98.1	94.1	29.4	0.2	0.0
All Five	94.7	94.6	93.4	79.8	8.6	0.0	0.0
Left							
Any	100.0	99.9	99.9	99.7	93.8	26.3	1.0
At Least Two	98.5	98.5	98.5	98.4	80.0	4.4	0.0
At Least Three	98.5	98.5	98.4	98.0	57.5	0.6	0.0
At Least Four	98.3	98.3	98.2	96.3	29.6	0.1	0.0
All Five	94.6	94.6	93.8	83.1	7.9	0.0	0.0

Table 67: Percentage of segmentation obtaining a Jaccard index in the indicated ranges, by hand, for combinations of index and middle fingers of a ThreeInch slap.

Fingers	≥ 0.5	≥ 0.6	≥ 0.7	≥ 0.8	≥ 0.9	≥ 0.95	≥ 0.98
Right							
Either Index or Middle	99.9	99.9	99.9	98.8	82.6	17.5	0.7
Both Index and Middle	99.7	99.7	99.3	95.6	46.5	1.9	0.0
Left							
Either Index or Middle	99.9	99.9	99.9	99.8	80.3	11.7	0.4
Both Index and Middle	99.8	99.8	99.6	97.3	39.5	0.8	0.0

Table 68: Percentage of segmentation obtaining a Jaccard index in the indicated ranges, by hand, for combinations of index, middle, and ring fingers of a ThreeInch slap.

Fingers	≥ 0.5	≥ 0.6	≥ 0.7	≥ 0.8	≥ 0.9	≥ 0.95	≥ 0.98
Right							
Any	99.9	99.9	99.9	99.3	87.9	22.5	0.9
At Least Two	99.9	99.9	99.8	97.8	65.2	3.9	0.0
All Three	99.7	99.6	99.0	92.9	31.3	0.5	0.0
Left							
Any	99.9	99.9	99.9	99.9	88.6	17.4	0.6
At Least Two	99.9	99.9	99.9	99.4	63.3	2.0	0.0
All Three	99.7	99.7	99.3	95.5	27.0	0.2	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 69, results are shown of how successful nec+0004 segmented fingers for each subject in the test corpus. Table 70 shows success for specific finger positions over the entire test corpus. Similarly, Table 71 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 72 shows success for combinations of all fingers, Table 74 for the all except the little finger, and Table 73 for just the index and middle fingers.

Table 69: For each subject, the percentage that at least *Number of Fingers* fingers were correctly segmented, regardless of hand, for a maximum of eight correctly-segmented fingers. In *Standard Scoring*, scoring rules are followed exactly. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Number of Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
1	99.7 [99.3, 100.0]	99.7 [99.3, 100.0]	99.7 [99.3, 100.0]
2	99.3 [98.7, 99.9]	99.3 [98.7, 99.9]	99.3 [98.7, 99.9]
3	98.6 [97.6, 99.3]	98.6 [97.6, 99.3]	98.6 [97.6, 99.3]
4	97.6 [96.4, 98.6]	97.8 [96.7, 98.7]	97.8 [96.6, 98.7]
5	93.7 [91.8, 95.3]	93.9 [92.2, 95.5]	93.9 [92.1, 95.5]
6	87.6 [85.1, 89.9]	87.9 [85.5, 90.1]	87.9 [85.6, 90.1]
7	77.7 [74.7, 80.6]	78.4 [75.4, 81.3]	78.8 [75.9, 81.8]
8	63.1 [59.8, 66.9]	65.2 [61.8, 68.6]	65.9 [62.3, 69.2]

Table 70: 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	90.7 [88.6, 92.8]	90.8 [88.7, 92.9]	90.8 [88.6, 92.8]
Middle	91.1 [89.0, 93.0]	91.2 [89.1, 93.2]	91.6 [89.6, 93.5]
Ring	92.2 [90.0, 94.0]	92.7 [90.8, 94.5]	92.8 [91.0, 94.7]
Little	89.4 [87.1, 91.6]	89.6 [87.5, 91.6]	89.6 [87.4, 91.9]
Left			
Index	87.7 [85.1, 89.9]	87.8 [85.3, 90.2]	87.9 [85.5, 90.3]
Middle	91.6 [89.5, 93.5]	91.8 [89.8, 93.8]	91.8 [89.7, 93.8]
Ring	92.2 [90.2, 94.0]	93.1 [91.1, 94.8]	93.1 [91.4, 94.8]
Little	88.3 [85.9, 90.6]	89.5 [87.3, 91.6]	89.9 [87.5, 92.2]

Table 71: 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	96.0 [94.6, 97.5]	96.0 [94.6, 97.2]	96.0 [94.6, 97.4]
Both	80.9 [78.0, 83.7]	81.2 [78.3, 84.1]	81.3 [78.5, 84.1]
Middle			
Either	98.0 [97.1, 98.9]	98.2 [97.1, 98.9]	98.2 [97.1, 99.2]
Both	83.3 [80.6, 85.6]	83.4 [80.8, 86.2]	83.8 [81.3, 86.3]
Ring			
Either	98.0 [97.0, 98.9]	98.2 [97.0, 99.1]	98.2 [97.2, 99.1]
Both	84.8 [82.3, 87.5]	86.2 [83.7, 88.7]	86.3 [83.9, 88.8]
Little			
Either	96.7 [95.4, 97.9]	96.7 [95.4, 98.0]	96.8 [95.7, 98.0]
Both	79.6 [76.8, 82.2]	81.0 [78.3, 83.9]	81.3 [78.4, 83.8]

Table 72: 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	99.5 [98.7, 99.5]	99.5 [98.9, 99.7]	99.5 [98.8, 99.7]
At Least Two	96.7 [95.6, 97.4]	96.7 [95.6, 97.5]	96.7 [95.7, 97.5]
At Least Three	89.2 [87.8, 90.9]	89.5 [88.2, 91.2]	89.8 [88.2, 91.4]
All Four	77.9 [74.1, 78.5]	78.7 [75.6, 79.7]	79.0 [76.1, 80.2]
Left			
Any	98.8 [98.7, 99.5]	99.1 [98.9, 99.7]	99.1 [98.8, 99.7]
At Least Two	96.4 [95.6, 97.4]	96.6 [95.6, 97.5]	96.6 [95.7, 97.5]
At Least Three	89.7 [87.8, 90.9]	89.9 [88.2, 91.2]	89.9 [88.2, 91.4]
All Four	74.9 [74.1, 78.5]	76.7 [75.6, 79.7]	77.2 [76.1, 80.2]

Table 73: Percentage of segmentation success by hand when only considering combinations of index and middle fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95% confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Either Index or Middle	96.0 [94.7, 96.7]	96.1 [94.8, 96.8]	96.3 [95.0, 96.9]
Both Index and Middle	85.8 [82.9, 86.5]	85.9 [83.0, 86.7]	86.2 [83.3, 87.0]
Left			
Either Index or Middle	95.5 [94.7, 96.7]	95.6 [94.8, 96.8]	95.6 [95.0, 96.9]
Both Index and Middle	83.8 [82.9, 86.5]	84.0 [83.0, 86.7]	84.1 [83.3, 87.0]

Table 74: 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	98.5 [97.7, 99.0]	98.5 [97.9, 99.1]	98.5 [97.9, 99.1]
At Least Two	92.4 [90.8, 93.6]	92.6 [91.0, 93.7]	92.8 [91.2, 93.8]
All Three	83.0 [80.1, 84.1]	83.6 [80.9, 84.8]	83.9 [81.1, 84.8]
Left			
Any	98.3 [97.7, 99.0]	98.5 [97.9, 99.1]	98.5 [97.9, 99.1]
At Least Two	92.0 [90.8, 93.6]	92.2 [91.0, 93.7]	92.2 [91.2, 93.8]
All Three	81.2 [80.1, 84.1]	82.0 [80.9, 84.8]	82.1 [81.1, 84.8]

C.2 Jaccard Index

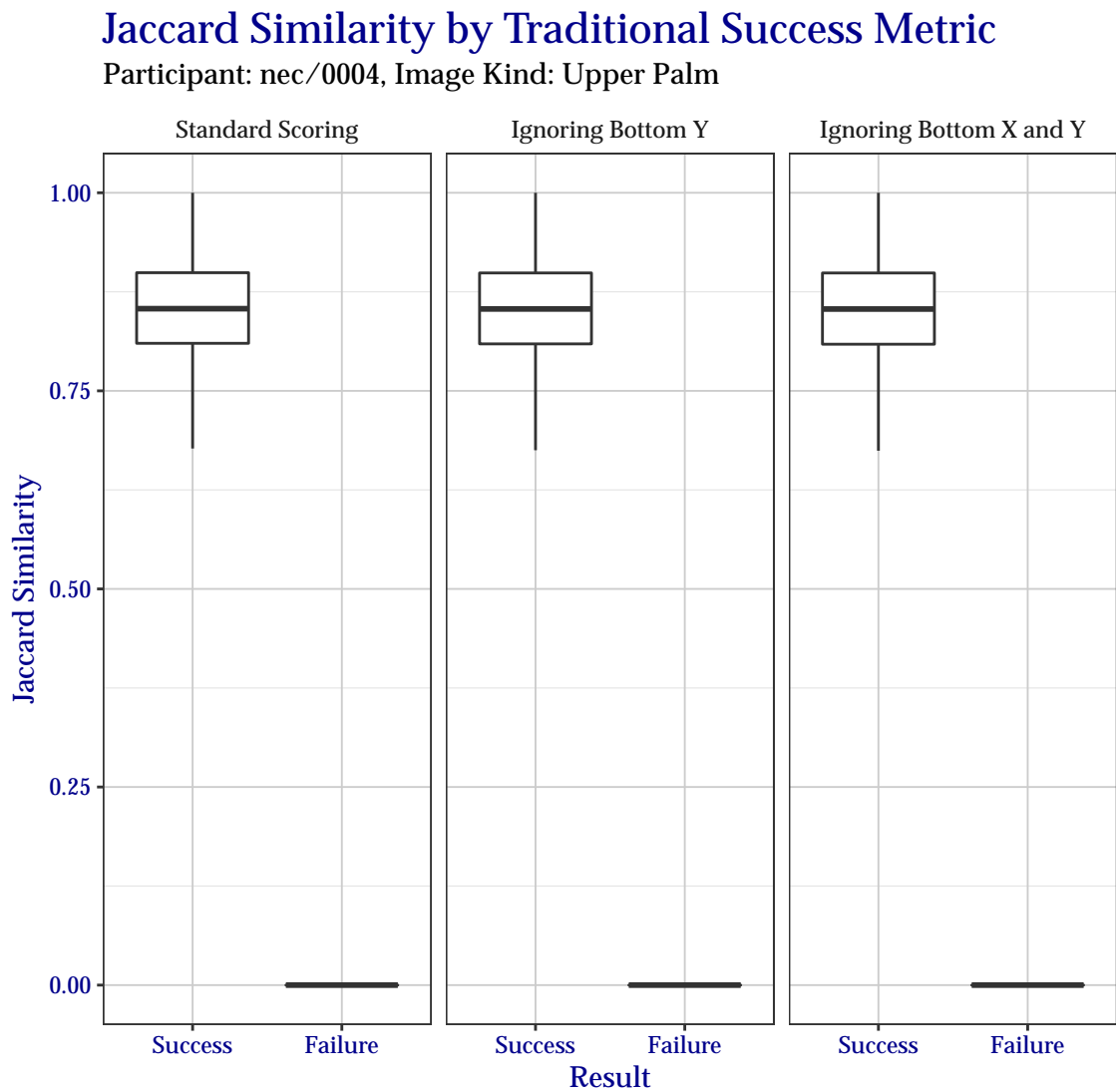
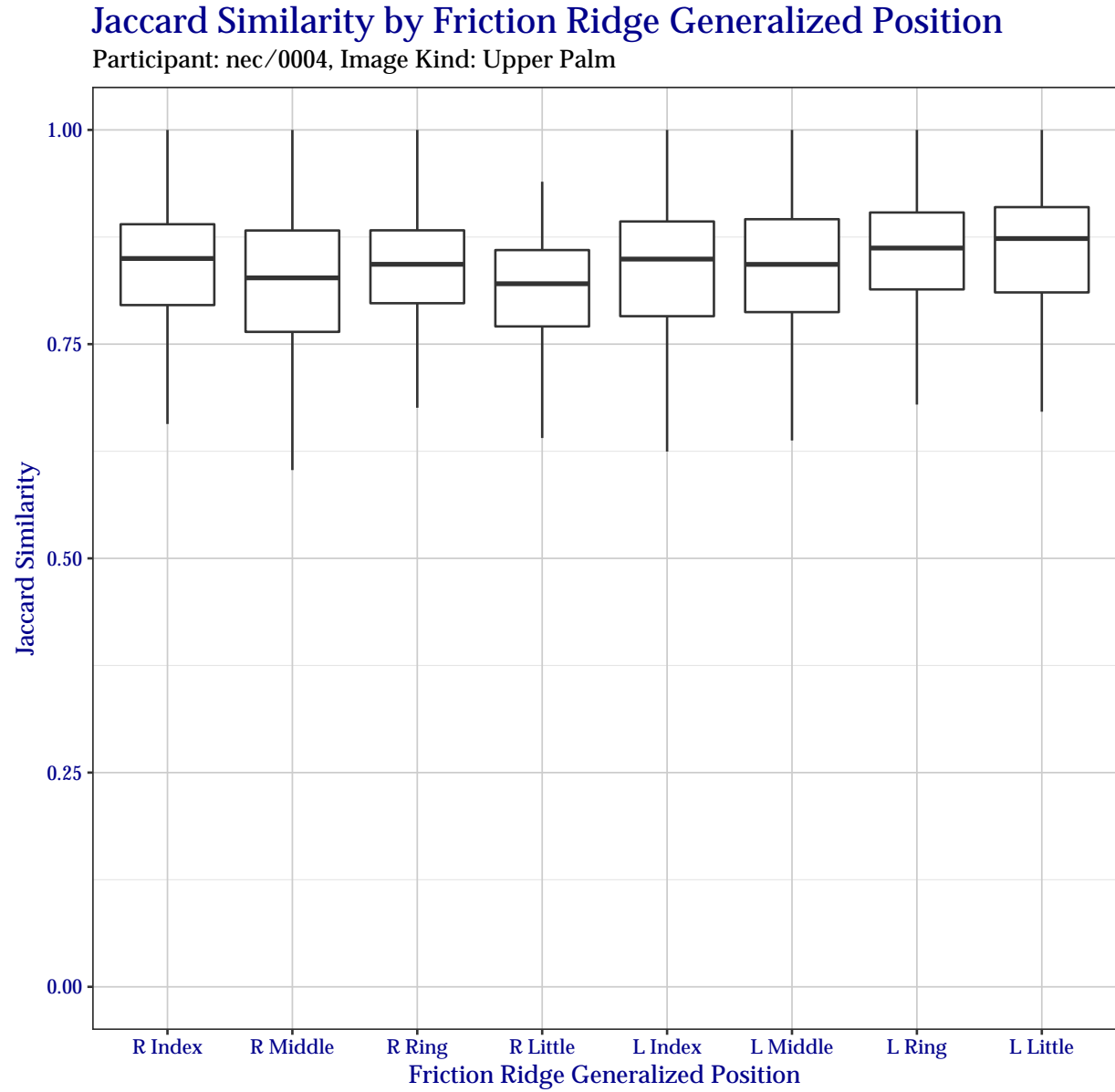


Figure 27: Boxplot of Jaccard similarity indices as compared to the traditional success metrics. Outliers have been removed for clarity.



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

Table 75: For each subject, the percentage that at least *Number of Fingers* fingers were segmented with a Jaccard index in the indicated range.

Number of Fingers	≥ 0.5	≥ 0.6	≥ 0.7	≥ 0.8	≥ 0.9	≥ 0.95	≥ 0.98
1	99.7	99.7	99.6	98.0	68.5	30.4	27.9
2	99.3	99.3	99.1	94.7	38.9	21.3	21.2
3	98.7	98.7	97.6	90.3	23.7	16.7	16.7
4	97.9	97.6	95.5	84.1	15.8	14.0	14.0
5	94.2	93.4	90.6	73.0	11.2	10.7	10.7
6	88.4	87.4	83.5	58.5	7.5	7.5	7.5
7	80.2	78.0	73.6	43.7	6.3	6.3	6.3
8	68.6	65.5	58.5	24.6	4.0	4.0	4.0

Table 76: 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	9.0	0.5	2.1	15.2	52.7	20.5
Middle	7.6	1.5	4.2	24.1	41.5	21.1
Ring	6.5	0.9	2.3	16.5	54.9	18.9
Little	9.4	0.4	2.8	24.9	51.5	11.0
Left						
Index	11.0	0.8	3.1	13.4	48.5	23.2
Middle	8.0	1.9	2.9	17.0	46.1	24.1
Ring	6.9	0.5	2.3	11.1	52.1	27.1
Little	8.6	1.1	2.0	10.2	46.8	31.3

Table 77: 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	99.5	99.5	98.8	92.6	35.2	21.5	21.4
At Least Two	96.8	96.7	95.5	81.5	18.0	15.8	15.8
At Least Three	90.3	89.9	86.8	63.2	11.4	11.2	11.2
All Four	80.9	78.1	71.5	34.8	6.9	6.9	6.9
Left							
Any	99.2	98.9	98.3	95.2	59.2	24.4	22.0
At Least Two	97.1	96.8	95.4	87.5	27.6	15.5	15.4
At Least Three	90.6	89.9	87.0	70.7	12.9	10.5	10.5
All Four	78.6	75.6	70.4	45.9	6.1	6.0	6.0

Table 78: 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	96.5	96.3	94.9	83.4	29.3	19.8	19.7
Both Index and Middle	86.8	85.1	80.1	52.4	12.4	11.7	11.7
Left							
Either Index or Middle	95.5	95.2	93.8	85.4	33.6	20.4	19.9
Both Index and Middle	85.5	83.2	78.6	56.6	13.8	12.1	12.1

Table 79: 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	98.5	98.5	98.0	90.7	32.7	21.1	21.0
At Least Two	93.2	93.0	90.6	72.7	17.2	15.4	15.4
All Three	85.1	82.4	76.7	46.1	10.6	10.6	10.6
Left							
Any	98.5	98.3	97.3	92.6	43.5	22.7	21.5
At Least Two	92.4	92.0	89.9	76.1	19.9	15.1	15.1
All Three	83.2	80.6	75.5	52.5	11.0	10.2	10.2

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 80, results are shown of how successful nec+0004 segmented fingers for each subject in the test corpus. Table 81 shows success for specific finger positions over the entire test corpus. Similarly, Table 82 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 83 shows success for combinations of all fingers, Table 85 for the all except the little finger, and Table 84 for just the index and middle fingers.

Table 80: 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	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]
5	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]
6	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]
7	99.7 [99.2, 100.0]	99.8 [99.4, 100.0]	99.8 [99.4, 100.0]
8	96.7 [95.4, 97.8]	97.7 [96.7, 98.6]	97.8 [96.8, 98.7]

Table 81: 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	99.8 [99.4, 100.0]	99.8 [99.4, 100.0]	99.8 [99.4, 100.0]
Middle	99.8 [99.4, 100.0]	99.8 [99.4, 100.0]	99.8 [99.4, 100.0]
Ring	99.4 [98.9, 99.9]	99.8 [99.4, 100.0]	99.8 [99.4, 100.0]
Little	99.4 [99.0, 99.9]	99.5 [99.1, 99.9]	99.5 [99.0, 99.9]
Left			
Index	99.2 [98.4, 99.8]	99.3 [98.7, 99.8]	99.3 [98.7, 99.9]
Middle	99.8 [99.4, 100.0]	99.9 [99.7, 100.0]	99.9 [99.7, 100.0]
Ring	99.3 [98.7, 99.9]	99.8 [99.4, 100.0]	99.9 [99.7, 100.0]
Little	99.7 [99.2, 100.0]	99.7 [99.3, 100.0]	99.7 [99.2, 100.0]

Table 82: 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	99.0 [98.3, 99.5]	99.1 [98.4, 99.7]	99.1 [98.4, 99.7]
Middle			
Either	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]
Both	99.5 [99.1, 99.9]	99.7 [99.2, 100.0]	99.7 [99.2, 100.0]
Ring			
Either	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]
Both	98.7 [97.9, 99.4]	99.5 [99.1, 99.9]	99.7 [99.2, 100.0]
Little			
Either	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]
Both	99.1 [98.5, 99.7]	99.2 [98.5, 99.8]	99.2 [98.5, 99.8]

Table 83: 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 [100.0, 100.0]	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]
At Least Two	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]
At Least Three	99.8 [99.6, 100.0]	99.8 [99.7, 100.0]	99.8 [99.7, 100.0]
All Four	98.6 [97.8, 98.9]	99.1 [98.3, 99.3]	99.1 [98.4, 99.4]
Left			
Any	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]
At Least Two	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]
At Least Three	99.9 [99.6, 100.0]	100.0 [99.7, 100.0]	100.0 [99.7, 100.0]
All Four	98.0 [97.8, 98.9]	98.6 [98.3, 99.3]	98.7 [98.4, 99.4]

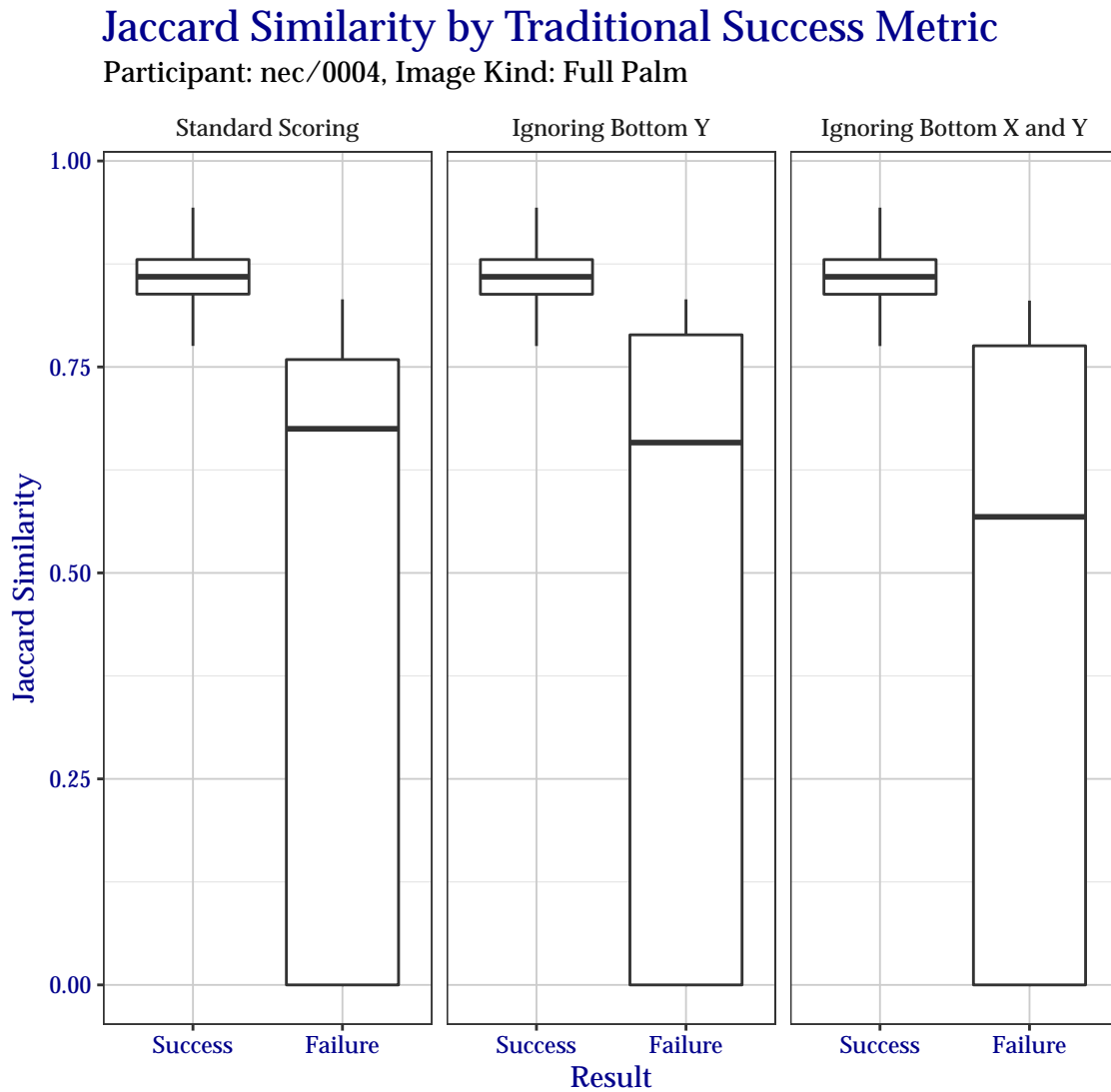
Table 84: Percentage of segmentation success by hand when only considering combinations of index and middle fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values 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 [99.8, 100.0]	99.9 [99.8, 100.0]	99.9 [99.8, 100.0]
Both Index and Middle	99.7 [98.9, 99.7]	99.7 [99.0, 99.8]	99.7 [99.0, 99.8]
Left			
Either Index or Middle	100.0 [99.8, 100.0]	100.0 [99.8, 100.0]	100.0 [99.8, 100.0]
Both Index and Middle	99.0 [98.9, 99.7]	99.2 [99.0, 99.8]	99.2 [99.0, 99.8]

Table 85: 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.

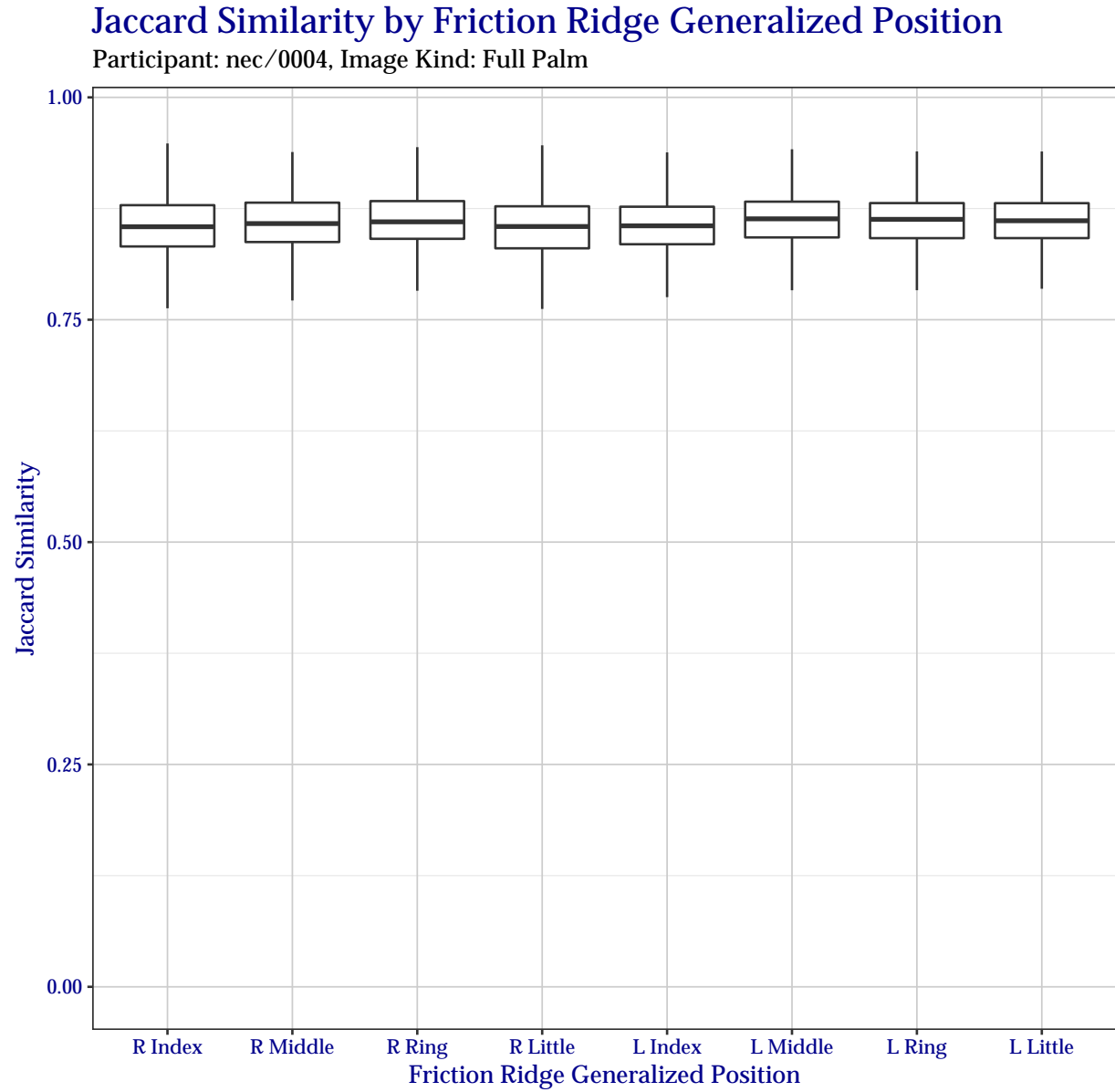
Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]
At Least Two	99.8 [99.6, 100.0]	99.8 [99.7, 100.0]	99.8 [99.7, 100.0]
All Three	99.2 [98.2, 99.3]	99.5 [98.8, 99.7]	99.5 [98.9, 99.7]
Left			
Any	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]	100.0 [100.0, 100.0]
At Least Two	99.9 [99.6, 100.0]	100.0 [99.7, 100.0]	100.0 [99.7, 100.0]
All Three	98.4 [98.2, 99.3]	99.0 [98.8, 99.7]	99.1 [98.9, 99.7]

D.2 Jaccard Index



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



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

Table 86: 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
1	100.0	100.0	100.0	100.0	44.3	1.0
2	100.0	100.0	100.0	100.0	18.3	0
3	100.0	100.0	100.0	100.0	7.8	0
4	100.0	100.0	100.0	99.9	3.3	0
5	100.0	100.0	100.0	98.9	1.0	0
6	100.0	100.0	100.0	97.0	0.2	0
7	99.8	99.8	99.5	91.8	0	0
8	99.1	98.6	96.8	72.1	0	0

Table 87: 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	0.1	0.1	0.2	5.3	83.9	10.4
Middle	0.2	0	0.4	4.6	84.8	10.0
Ring	0.1	0	0.6	3.1	86.5	9.7
Little	0	0.1	0.1	8.0	83.6	8.2
Left						
Index	0.5	0.1	0	4.1	86.4	8.9
Middle	0	0	0.1	3.8	87.5	8.6
Ring	0.2	0	0.5	3.8	86.7	8.8
Little	0	0.1	0.2	3.9	85.3	10.5

Table 88: 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
Right						
Any	100.0	100.0	100.0	99.8	28.5	0.2
At Least Two	100.0	100.0	100.0	99.0	8.0	0.0
At Least Three	99.8	99.8	99.7	95.9	1.4	0.0
All Four	99.8	99.5	98.4	82.4	0.2	0.0
Left						
Any	100.0	100.0	100.0	99.9	27.0	0.8
At Least Two	100.0	100.0	100.0	99.5	7.4	0.0
At Least Three	100.0	100.0	100.0	98.2	2.1	0.0
All Four	99.3	99.1	98.3	85.1	0.3	0.0

Table 89: Percentage of segmentation obtaining a Jaccard index in the indicated ranges, by hand, for combinations of index and middle fingers of a EightInch slap.

Fingers	≥ 0.5	≥ 0.6	≥ 0.7	≥ 0.8	≥ 0.9	≥ 0.95
Right						
Either Index or Middle	99.9	99.9	99.8	98.6	18.2	0.1
Both Index and Middle	99.8	99.7	99.2	90.5	2.2	0
Left						
Either Index or Middle	100.0	100.0	100.0	99.3	15.3	0.3
Both Index and Middle	99.5	99.4	99.3	92.1	2.2	0

Table 90: 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
Right						
Any	100.0	100.0	100.0	99.5	23.7	0.2
At Least Two	99.8	99.8	99.7	97.4	5.2	0
All Three	99.8	99.7	98.6	88.4	1.1	0
Left						
Any	100.0	100.0	100.0	99.7	20.8	0.6
At Least Two	100.0	100.0	100.0	98.9	4.7	0
All Three	99.3	99.2	98.6	88.4	0.8	0