

# sequence+0002

Lakota Software Solutions

*Slap Fingerprint Segmentation Evaluation III*

*Last Updated: 04 September 2020*

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# 1 Participation Information

## 1.1 Names and Dates

- **Organization Name:** Lakota Software Solutions
- **SlapSeg III Identifier:** sequence+0002
- **Provided Marketing Name:** "Lakota Sequence"
- **Application Date:** 17 June 2019
- **First Submission Date:** 03 June 2019 (as version 0001)
- **Validation Date:** 05 June 2019
- **Completion Date:** 05 June 2019

## 1.2 Libraries

Filename	MD5 Checksum	Size
libslapsegiii_sequence_0002.so	0c3769c45d44800f96707d870266b796	265 Kb
sequence-0.9.3-slapseg3-rc2.jar	2a96db56e4e2f1d7f0b87ec028e7109b	2.5 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.

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.

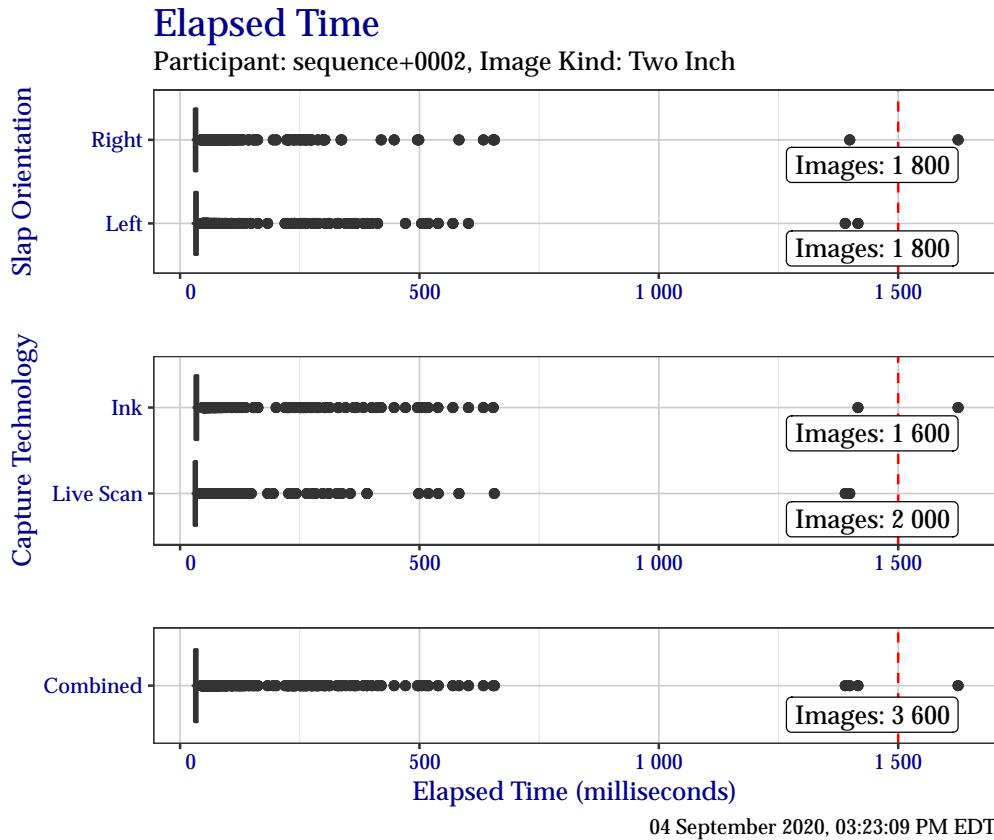


Figure 1: Box plots of elapsed time in milliseconds when segmenting the TwoInch timing test corpus, separated by slap orientation and capture technology.

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	24	24	24	26	24
25%	30	30	30	31	30
Median	32	33	31	33	32
75%	35	37	35	37	36
Maximum	1 625	1 416	1 399	1 625	1 625

## 2.2 Segmentation Centers and Dimensions

### 2.2.1 Segmentation Centers

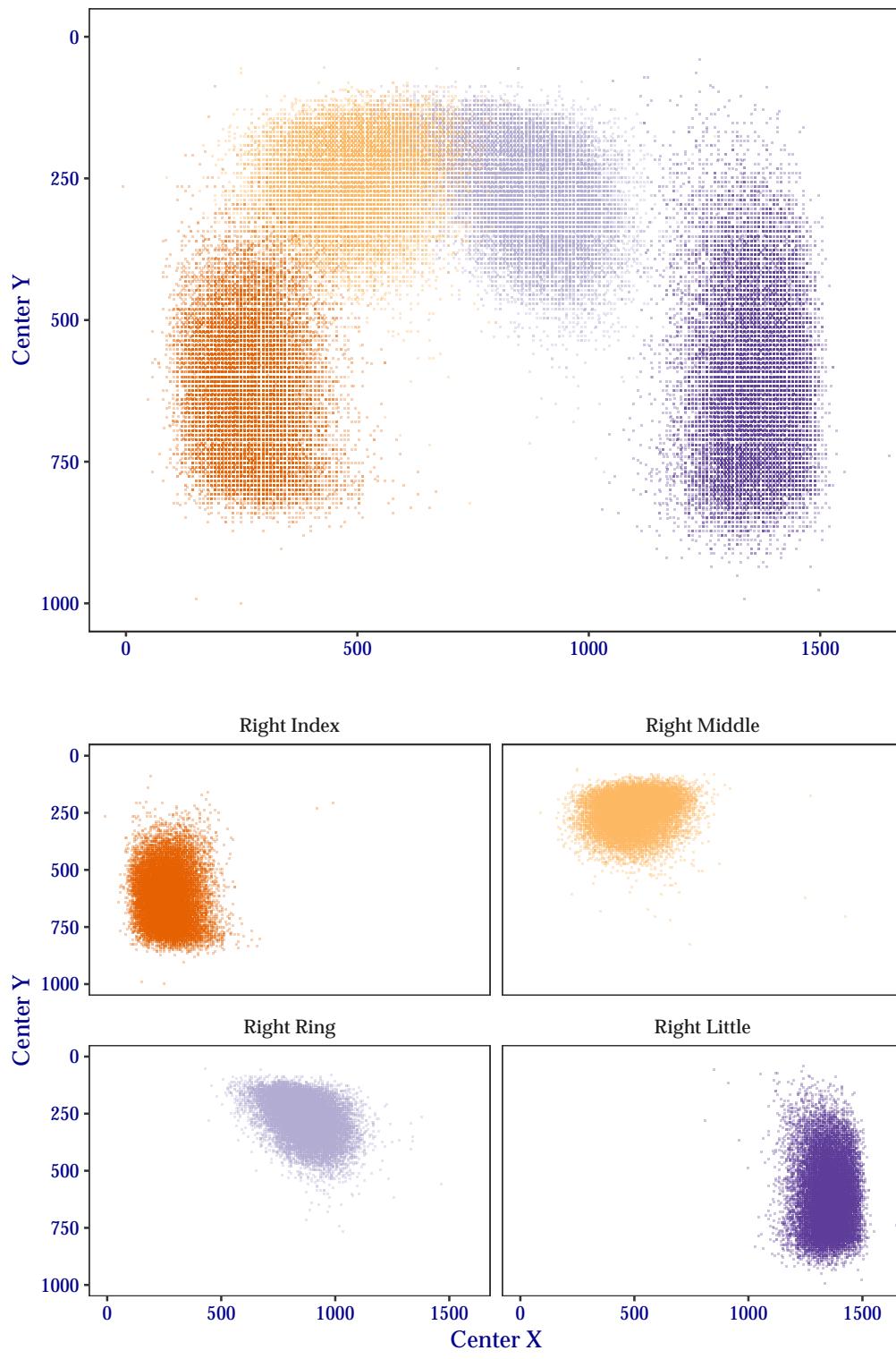
The plots in this section show the distribution of segmentation position centers ( $x, y$ ) for TwoInch data. At the top of each figure is a combined plot for all finger positions of a given slap orientation. These figures are isolated in plots faceted at the bottom of the figure.

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: sequence+0002, FRGPs: 2, 3, 4, 5, Image Kind: Two Inch



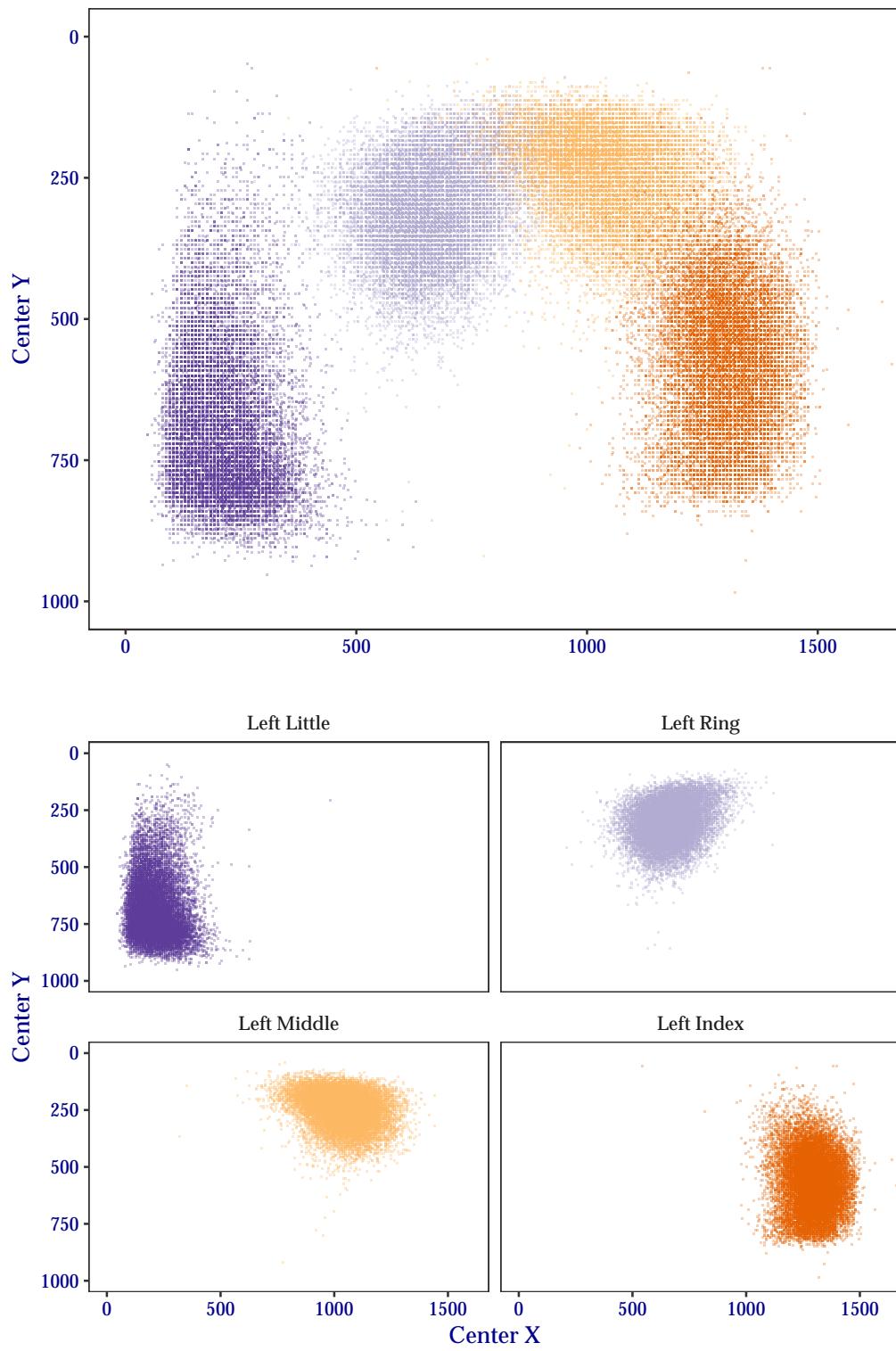
- Right Index • Right Middle • Right Ring • Right Little

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Figure 2: Segmentation centers for right hand TwoInch data.

## Segmentation Position Centers

Participant: sequence+0002, 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: sequence+0002, FRGPs: 2, 3, 4, 5, Image Kind: Two Inch

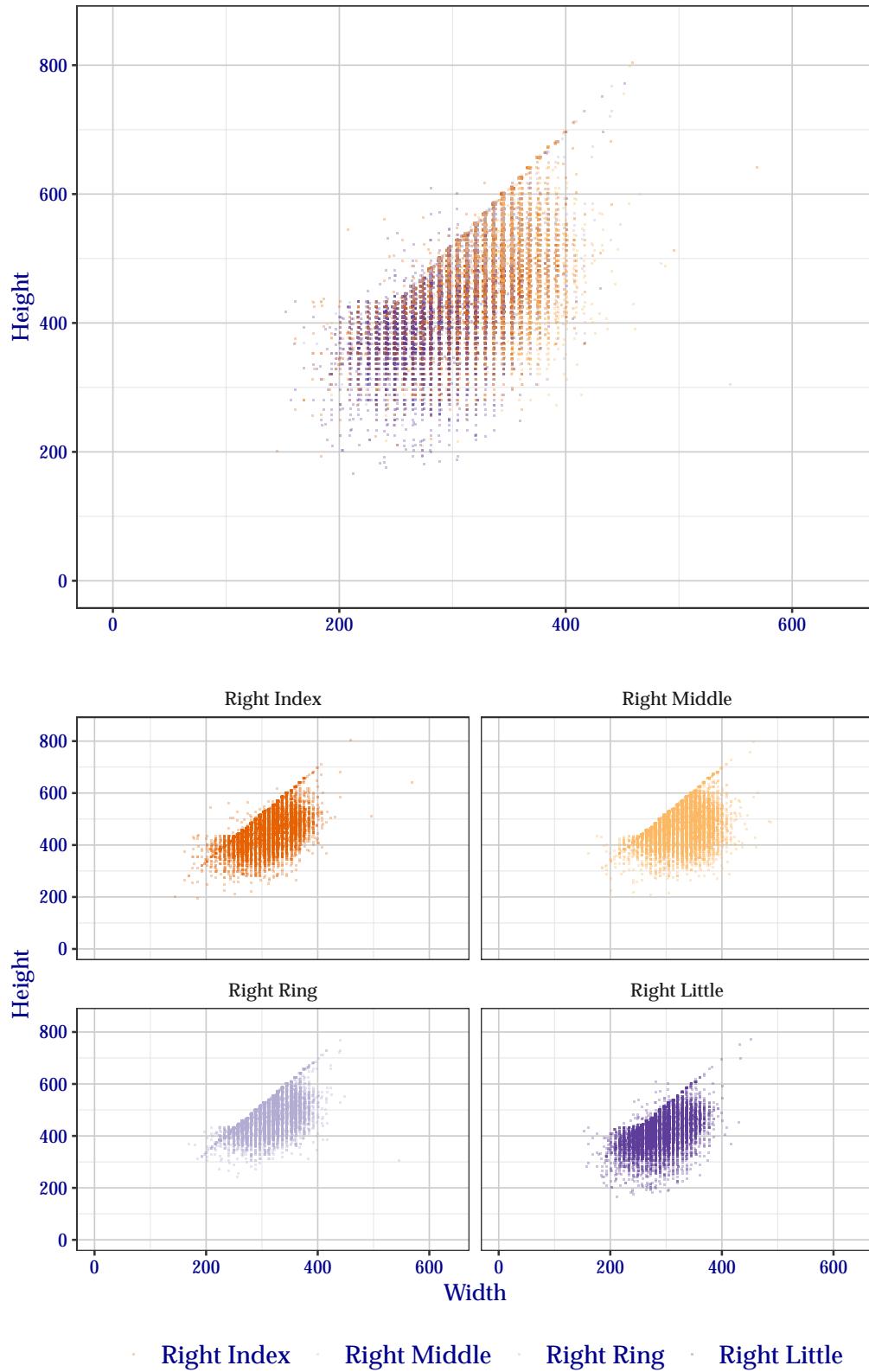
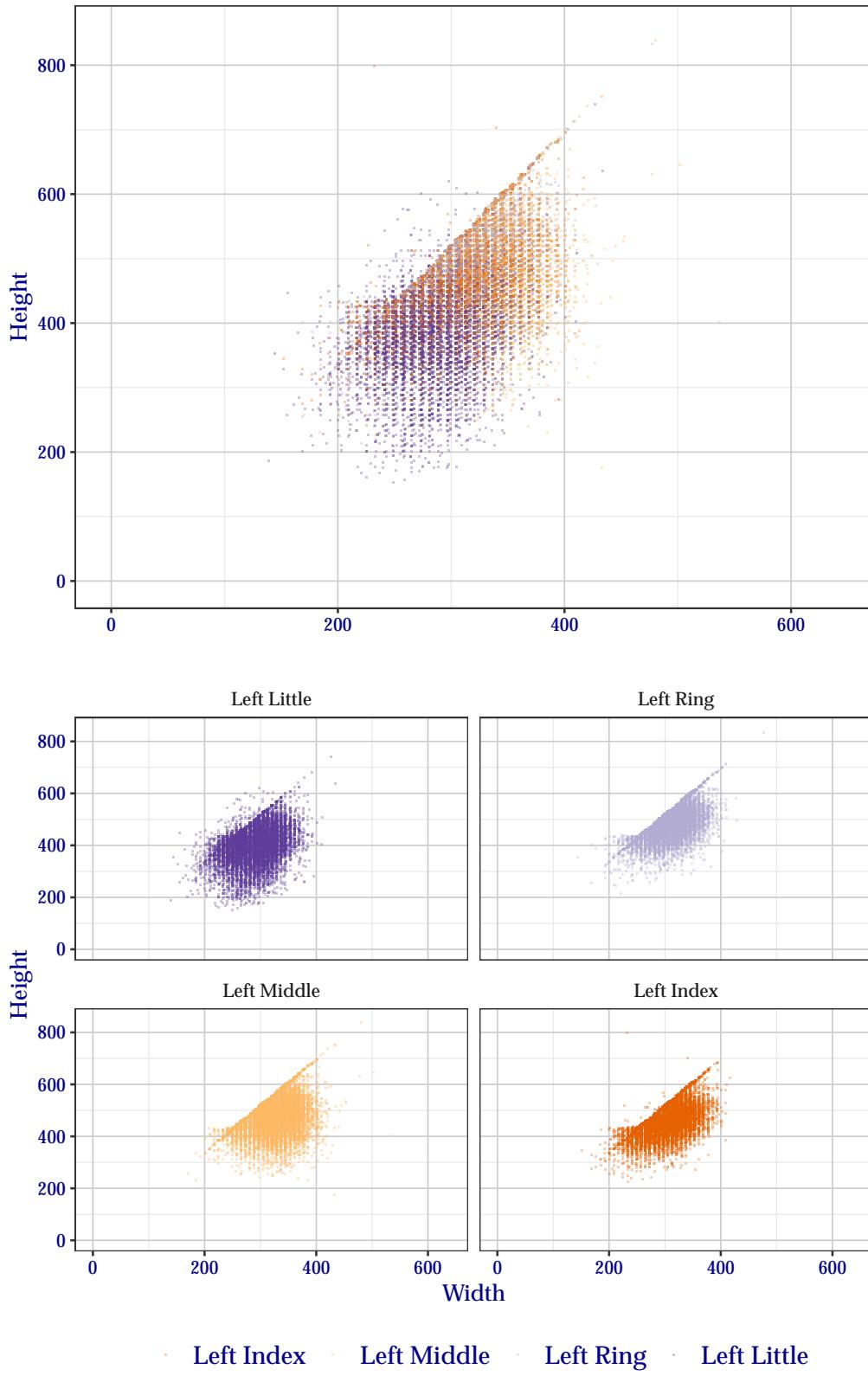


Figure 4: Segmentation position dimensions for right hand TwoInch data.

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## Segmentation Position Dimensions

Participant: sequence+0002, FRGPs: 7, 8, 9, 10, Image Kind: Two Inch



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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 sequence+0002 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	99.8	99.8	99.8
3	99.4	99.6	99.7
4	98.3	99.1	99.2
5	94.7	95.1	95.4
6	93.0	94.3	94.6
7	87.6	91.5	92.4
8	69.4	79.9	81.3

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
<b>Right</b>			
Index	92.2	93.8	94.5
Middle	95.1	97.2	97.3
Ring	95.5	97.9	98.1
Little	96.7	97.3	98.0
<b>Left</b>			
Index	93.9	95.7	96.2
Middle	94.5	97.5	97.7
Ring	94.2	98.1	98.3
Little	97.2	97.9	98.4

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

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
<b>Index</b>			
Either	98.2	98.8	99.0
Both	83.6	86.7	87.6
<b>Middle</b>			
Either	98.5	99.4	99.5
Both	86.1	91.0	91.3
<b>Ring</b>			
Either	98.8	99.6	99.7
Both	87.2	92.5	92.8
<b>Little</b>			
Either	99.4	99.6	99.6
Both	90.3	91.6	92.7

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
<b>Right</b>			
Any	99.5	99.6	99.7
At Least Two	99.1	99.3	99.5
At Least Three	97.0	98.0	98.4
All Four	83.9	89.4	90.4
<b>Left</b>			
Any	99.7	99.7	99.8
At Least Two	99.2	99.4	99.5
At Least Three	96.9	98.4	98.8
All Four	84.0	91.7	92.5

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
<b>Right</b>			
Either Index or Middle	98.6	98.9	99.1
Both Index and Middle	88.8	92.0	92.7
<b>Left</b>			
Either Index or Middle	98.7	99.2	99.3
Both Index and Middle	89.7	94.0	94.5

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
<b>Right</b>			
Any	99.4	99.5	99.6
At Least Two	97.8	98.5	98.8
All Three	85.7	90.9	91.6
<b>Left</b>			
Any	99.4	99.6	99.6
At Least Two	97.5	98.8	99.0
All Three	85.6	92.9	93.5

## 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 sequence+0002 are enumerated in Table 8. Note that for TwoInch data, images are expected to be rotated, so a capture failure of *Rotation Detected* is unacceptable.

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

Failure Reason	Images
Request Recapture (Attempt)	80

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

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

Deficiency	Count
Image Quality	80

#### 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. The result of such best-effort segmentations are shown in Table 10.

Out of 80 recovery attempts sequence+0002 attempted 229 segmentations of fingers and skipped 91 fingers. More information about skipped fingers can be found in Table 11.

Table 10: Results of best-effort segmentation when sequence+0002 reported segmentation failure (229 best-effort attempts).

Standard	Ignoring Bottom Y	Ignoring Bottom X and Y
50.2	54.6	57.2

## 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 sequence+0002 are enumerated in Table 11.

Table 11: Count of self-reported segmentation failure reasoning.

Failure Reason	Fingers
Finger Found, but Can't Segment	91
Finger Not Found	0
Vendor Defined	0

## 2.4.3 Identifying Missing Fingers

A small portion of the test corpus in SlapSeg III are missing fingers. Table 12 shows how successful sequence+0002 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 12: Performance of sequence+0002 at detecting fingers missing from an image.

Result	Percentage
Missed	62.5
Correctly Identified	0.0
Other Failure: Finger Found, but Can't Segment	37.5
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 13 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 13: Percentage of images in the dataset where one or more segmentation positions correctly matched an incorrect finger position within the same image, indicating sequence error.

Hand	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Left	0.02	0.02	0.02
Right	0.04	0.04	0.05
Combined	0.03	0.03	0.04

## 2.5 Determining Orientation

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

**Overall Two Inch accuracy:** 99.7%

Table 14: 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	99.8	0.2
Right	0.3	99.7

### 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.

Box plots of segmentation times are separated by hand in Figure 6, with tabular representations are enumerated in Table 15. Results are reported in milliseconds

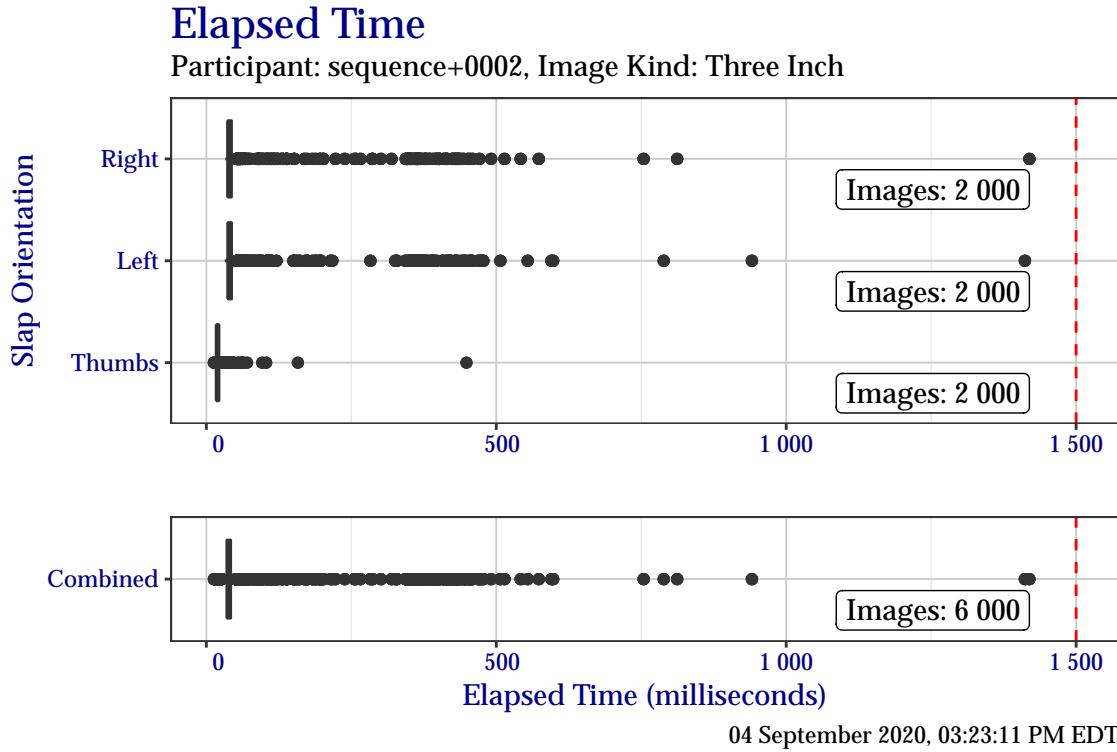


Figure 6: Box plots of elapsed time in milliseconds when segmenting the ThreeInch timing test corpus, separated by slap orientation.

Table 15: Elapsed time in milliseconds when segmenting the ThreeInch timing test corpus, separated by slap orientation.

	Right	Left	Thumbs	Combined
Minimum	33	32	13	13
25%	37	38	18	36
Median	39	39	19	38
75%	43	43	21	42
Maximum	1 419	1 412	449	1 419

## 3.2 Segmentation Centers and Dimensions

### 3.2.1 Segmentation Centers

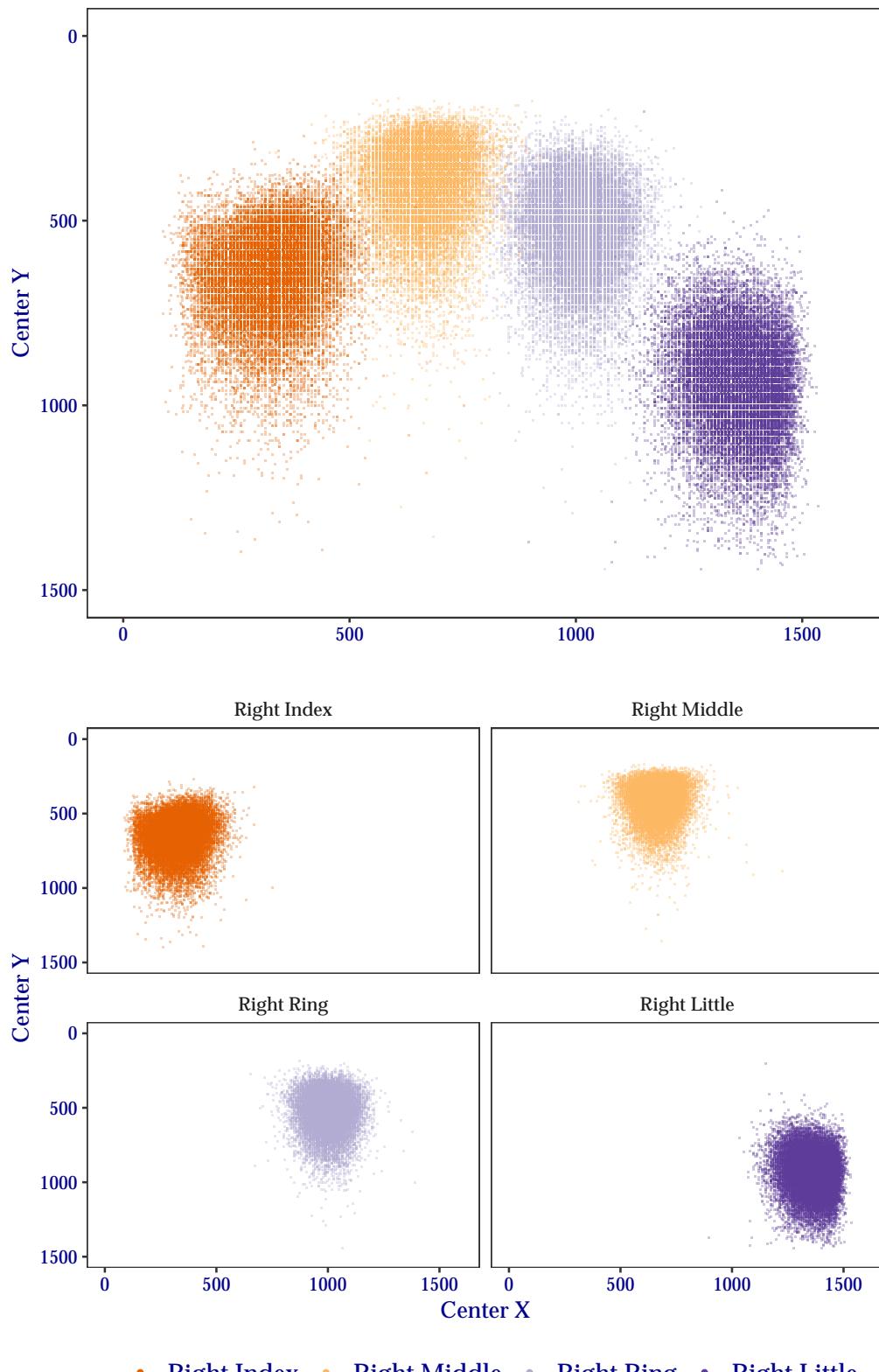
The plots in this section show the distribution of segmentation position centers  $(x, y)$  for ThreeInch data. At the top of each figure is a combined plot for all finger positions of a given hand orientation. These figures are isolated in plots faceted at the bottom of the figure.

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: sequence+0002, FRGPs: 2, 3, 4, 5, Image Kind: Three Inch

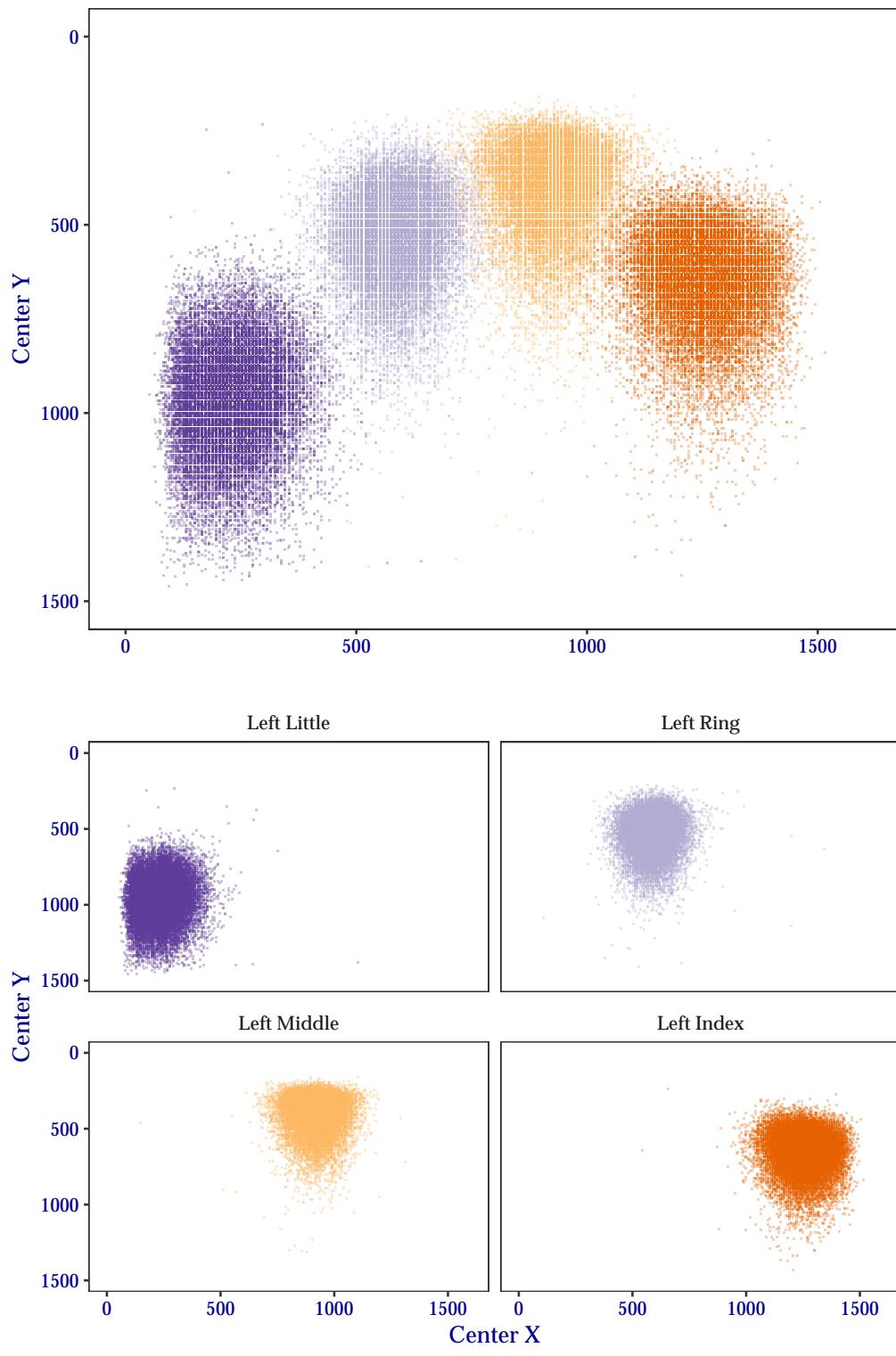


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Figure 7: Segmentation centers for right hand ThreeInch data.

## Segmentation Position Centers

Participant: sequence+0002, FRGPs: 7, 8, 9, 10, Image Kind: Three Inch



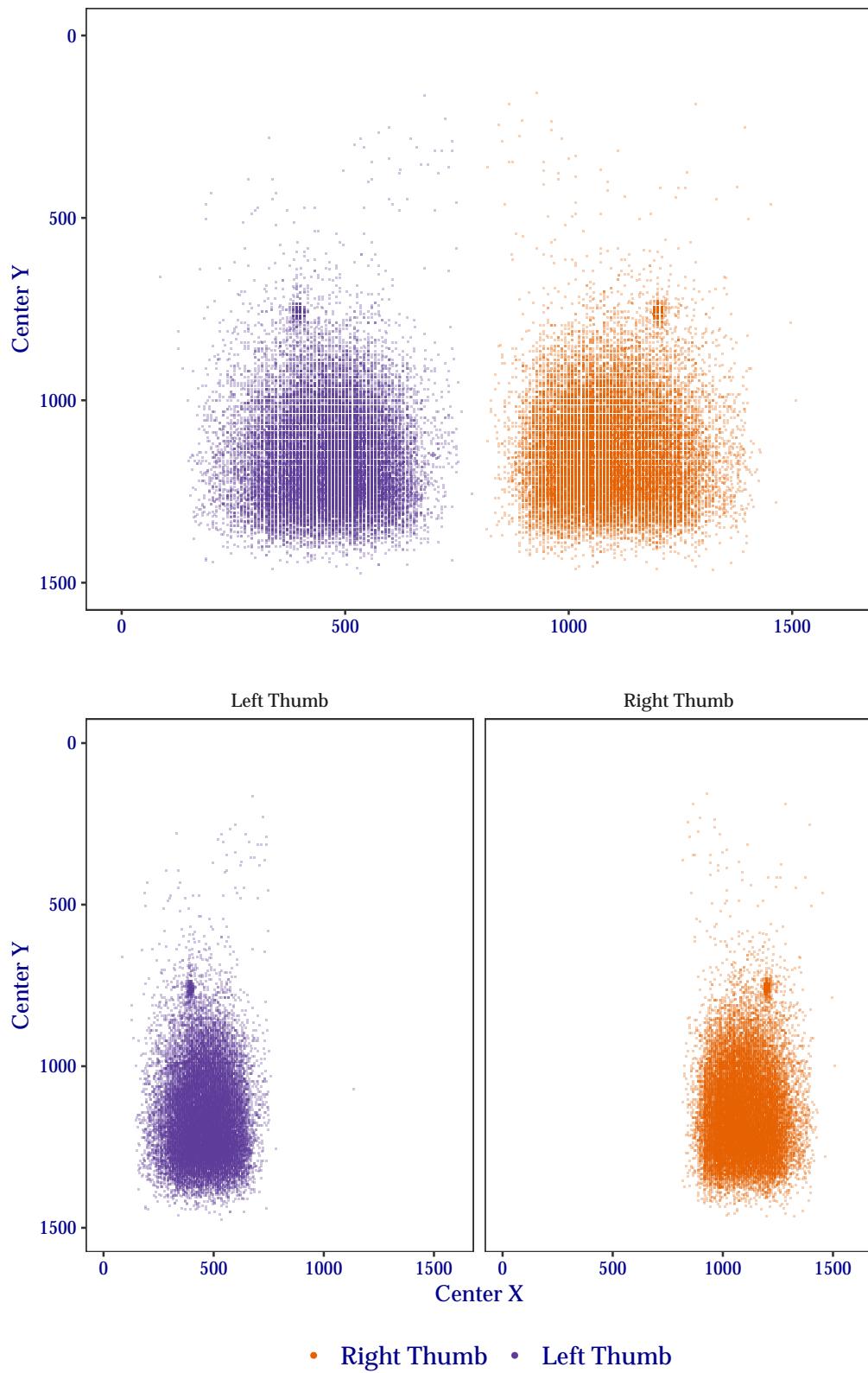
- Left Index • Left Middle • Left Ring • Left Little

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Figure 8: Segmentation centers for left hand ThreeInch data.

## Segmentation Position Centers

Participant: sequence+0002, FRGPs: 1, 6, Image Kind: Three Inch



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Figure 9: Segmentation centers for thumb ThreeInch data.

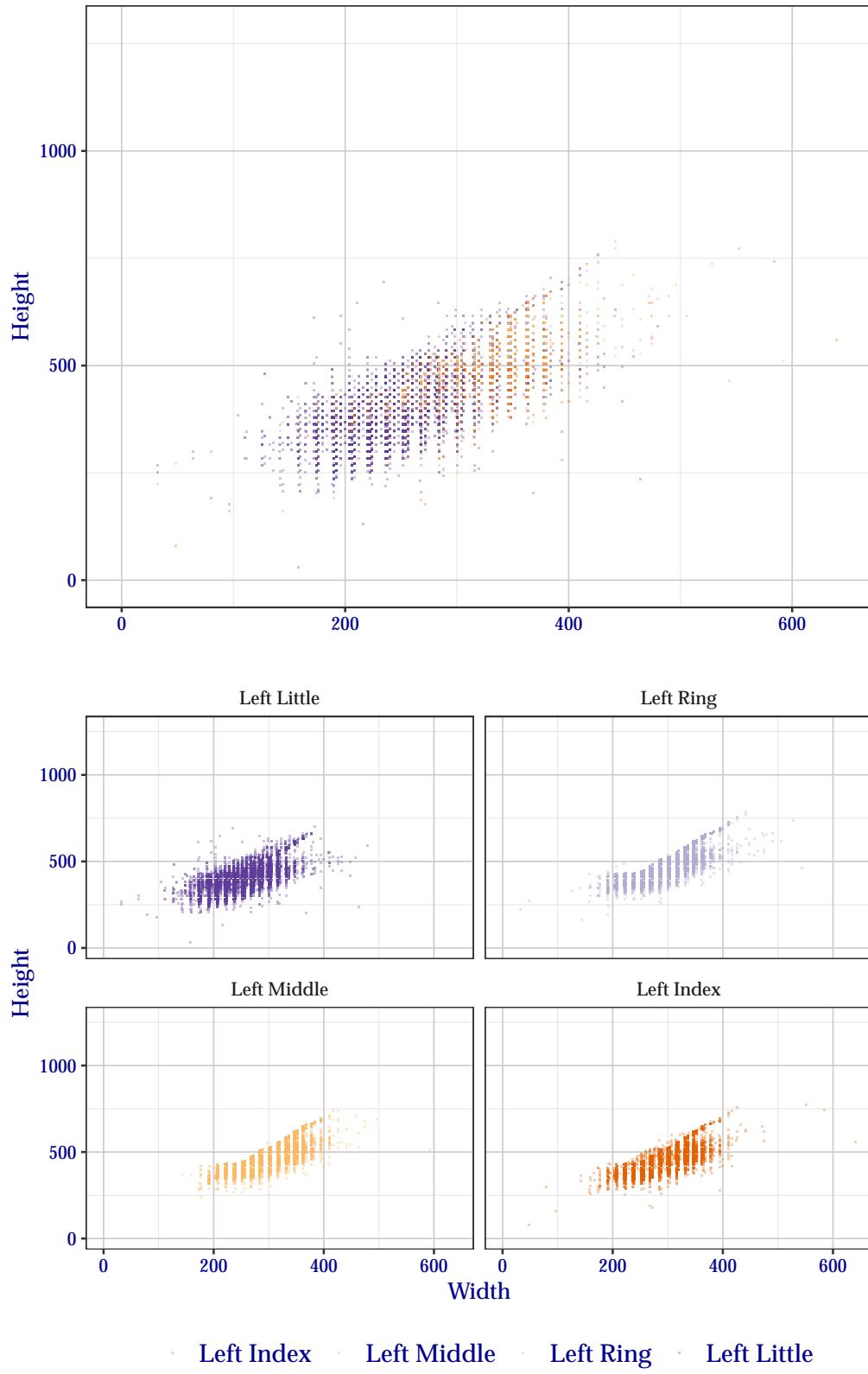
### 3.2.2 Segmentation Dimensions

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: sequence+0002, FRGPs: 7, 8, 9, 10, Image Kind: Three Inch



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

## Segmentation Position Dimensions

Participant: sequence+0002, FRGPs: 2, 3, 4, 5, Image Kind: Three Inch

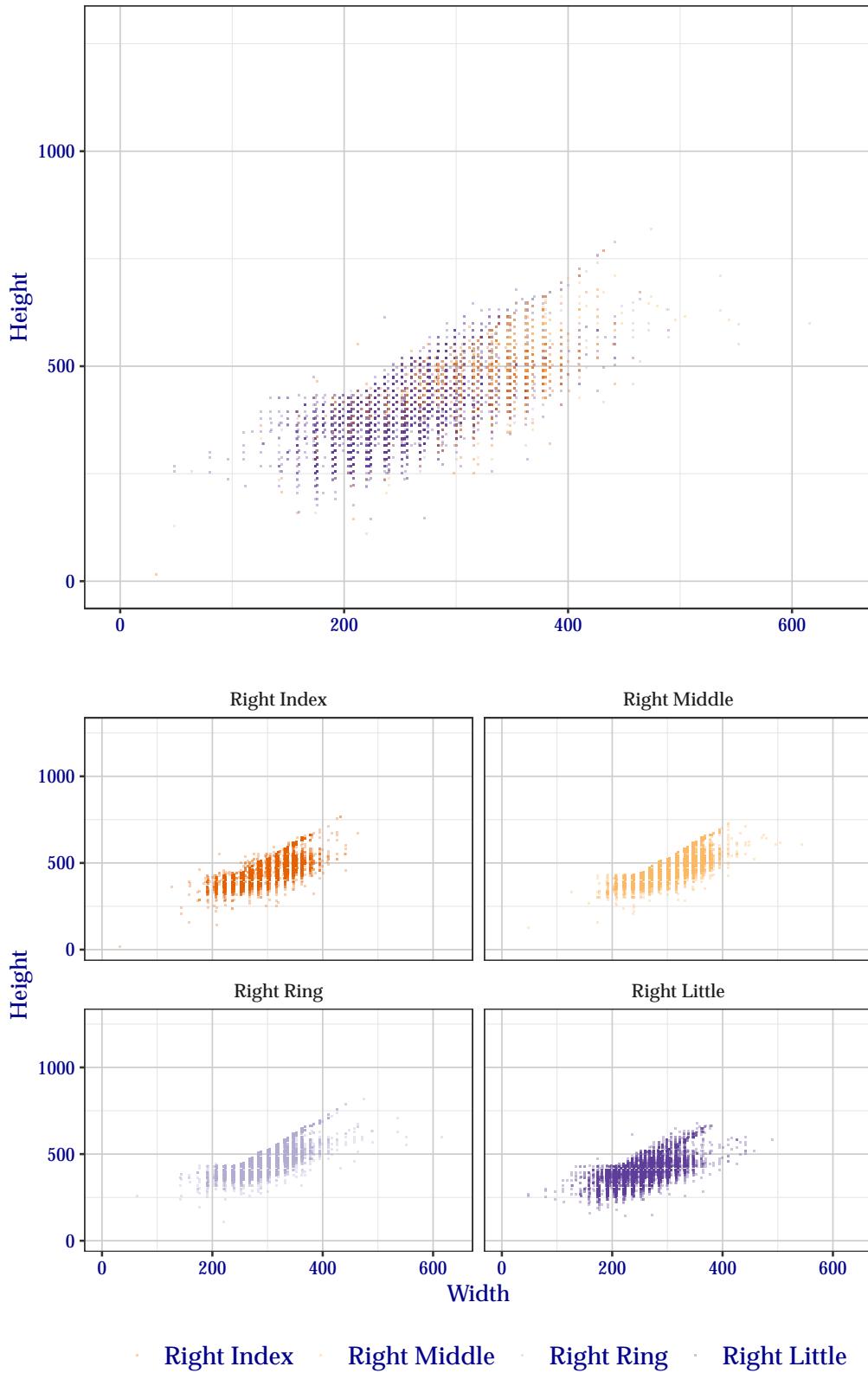
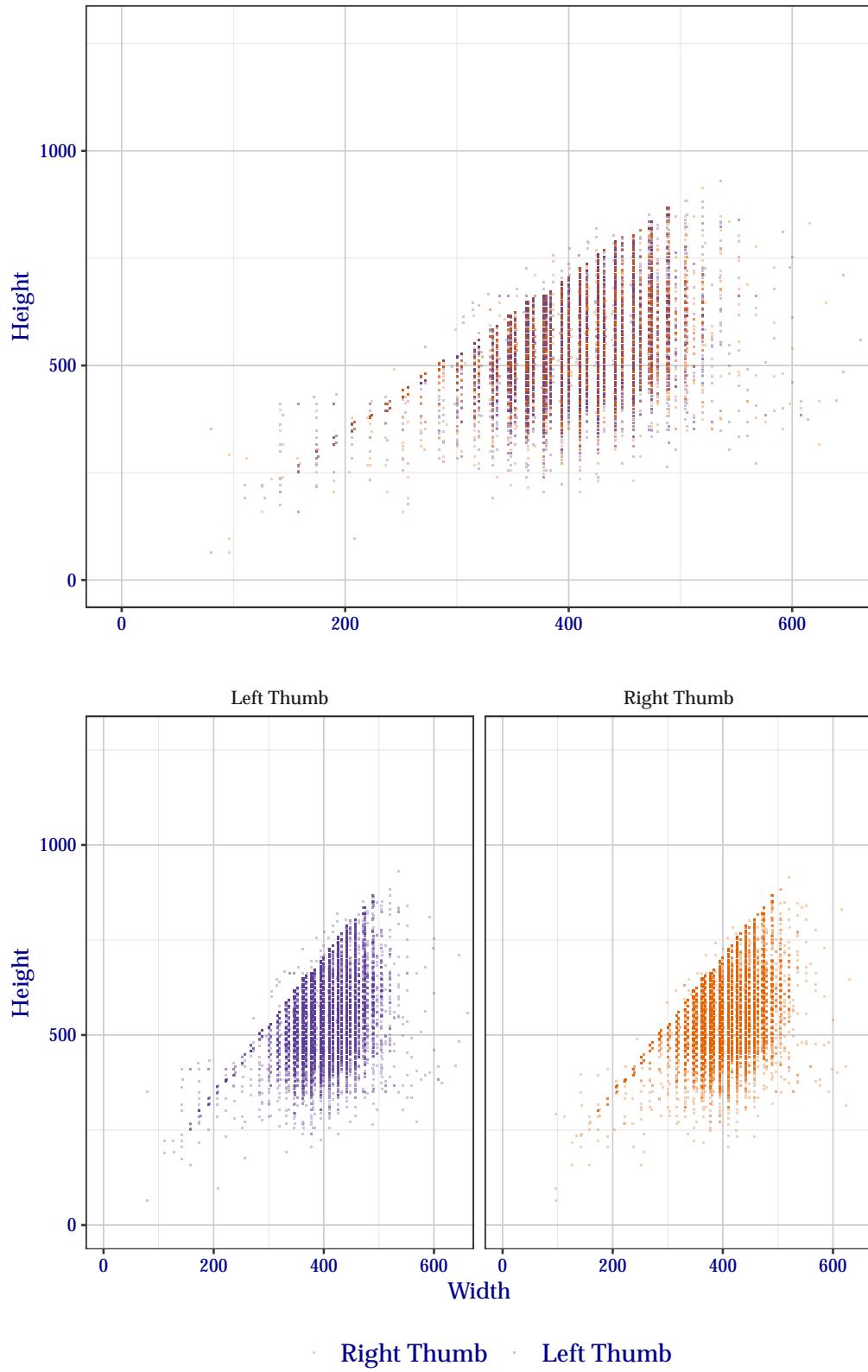


Figure 11: Segmentation position dimensions for right hand ThreeInch data.

## Segmentation Position Dimensions

Participant: sequence+0002, FRGPs: 1, 6, Image Kind: Three Inch



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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 16 shows how successful sequence+0002 segmented fingers for each subject in the test corpus. Table 17 shows success for specific finger positions over the entire test corpus. Similarly, Table 18 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 19 shows success for combinations of all fingers, Table 20 for just the index and middle fingers, and Table 21 for all except the little finger.

Table 16: 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	99.4	99.5	99.6
3	98.2	98.3	98.4
4	97.6	97.9	98.1
5	95.6	95.8	95.9
6	94.9	95.6	95.8
7	93.3	95.1	95.5
8	88.7	93.6	95.0
9	75.6	88.5	92.2
10	50.3	70.3	79.1

Table 17: 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
<b>Right</b>			
Thumb	82.4	94.9	95.3
Index	97.2	98.2	98.8
Middle	94.8	97.3	99.0
Ring	92.5	95.2	97.8
Little	95.0	96.4	97.4
<b>Left</b>			
Thumb	80.1	96.0	96.4
Index	95.8	96.8	97.6
Middle	93.7	96.2	98.7
Ring	91.4	93.3	97.4
Little	95.0	96.1	97.1

Table 18: 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
<b>Thumb</b>			
Either	90.8	99.1	99.2
Both	71.7	91.9	92.6
<b>Index</b>			
Either	99.2	99.5	99.7
Both	91.2	92.9	94.2
<b>Middle</b>			
Either	98.4	99.2	99.7
Both	87.7	91.7	95.4
<b>Ring</b>			
Either	97.7	98.5	99.5
Both	83.8	87.5	93.1
<b>Little</b>			
Either	99.0	99.3	99.5
Both	88.4	90.6	92.3

Table 19: 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
<b>Right</b>			
Any	99.6	99.7	99.7
At Least Two	98.2	98.4	98.4
At Least Three	97.0	98.0	98.2
At Least Four	92.1	95.9	97.1
All Five	66.6	81.1	86.0
<b>Left</b>			
Any	99.6	99.7	99.8
At Least Two	98.1	98.3	98.3
At Least Three	96.6	97.7	98.0
At Least Four	90.6	94.8	96.6
All Five	62.8	79.0	85.4

Table 20: 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
<b>Right</b>			
Either	99.2	99.6	99.7
Both	92.7	95.8	98.1
<b>Left</b>			
Either	98.9	99.3	99.6
Both	90.6	93.8	96.7

Table 21: 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
<b>Right</b>			
Any	99.6	99.8	99.8
At Least Two	97.6	98.8	99.5
All Three	87.2	92.2	96.4
<b>Left</b>			
Any	99.4	99.6	99.7
At Least Two	96.7	97.9	99.1
All Three	84.8	88.8	94.8

## 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 sequence+0002 are enumerated in Table 22.

Table 22: Count of self-reported capture-type failure reasoning.

Failure Reason	Images
Request Recapture (Attempt)	119

In situations where the algorithm feels that the presented image should be recaptured (Table 22), one or more image deficiencies must be identified. These deficiencies are enumerated in Table 23. At this point, NIST does not have a groundtruth of image deficiencies, but plans to update this table with the accuracy of deficiency observations in the future.

Table 23: Count of image deficiencies reported when requesting a recapture.

Deficiency	Count
Image Quality	119

#### 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. The result of such best-effort segmentations are shown in Table 24.

Out of 119 recovery attempts sequence+0002 attempted 327 segmentations of fingers and skipped 145 fingers. More information about skipped fingers can be found in Table 25.

Table 24: Results of best-effort segmentation when sequence+0002 reported segmentation failure (327 best-effort attempts).

Standard	Ignoring Bottom Y	Ignoring Bottom X and Y
55.7	58.4	61.8

### 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 sequence+0002 are enumerated in Table 25.

Table 25: Count of self-reported segmentation failure reasoning.

Failure Reason	Fingers
Finger Found, but Can't Segment	145
Finger Not Found	0
Vendor Defined	0

### 3.4.3 Identifying Missing Fingers

A small portion of the test corpus in SlapSeg III are missing fingers. Table 26 shows how successful sequence+0002 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 26: Performance of sequence+0002 at detecting fingers missing from an image.

Result	Percentage
Missed	65.0
Correctly Identified	0.0
Other Failure: Finger Found, but Can't Segment	35.0
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 27 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 27: 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	0.06	0.06	0.07
Right	0.07	0.07	0.07
Thumbs	0.03	0.03	0.03
Combined	0.06	0.06	0.06

### 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:** 97.7%

Table 28: Percentage of accuracy when determining hand orientation of a three inch image. The first column indicates the true hand orientation. Subsequent columns indicate the percentage of the time in which the indicated hand orientation was hypothesized.

	Left	Right	Skip	Thumbs
Left	<b>99.3</b>	0.6	0	0.1
Right	0.8	<b>99.2</b>	0	0
Thumbs	3	2.5	0	<b>94.5</b>

## 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 29, results are shown of how successful sequence+0002 segmented fingers for each subject in the test corpus. Table 30 shows success for specific finger positions over the entire test corpus. Similarly, Table 31 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 32 shows success for combinations of all fingers, Table 34 for the all except the little finger, and Table 33 for just the index and middle fingers.

Table 29: 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, 100.0]	99.9 [99.8, 100.0]	99.9 [99.9, 100.0]
2	99.8 [99.7, 99.8]	99.8 [99.7, 99.9]	99.8 [99.8, 99.9]
3	99.4 [99.3, 99.5]	99.6 [99.5, 99.7]	99.7 [99.6, 99.8]
4	98.3 [98.1, 98.5]	99.1 [99.0, 99.3]	99.2 [99.0, 99.3]
5	94.7 [94.3, 95.1]	95.1 [94.7, 95.5]	95.4 [95.0, 95.7]
6	93.0 [92.6, 93.5]	94.3 [93.9, 94.7]	94.6 [94.2, 95.0]
7	87.6 [87.0, 88.2]	91.5 [91.0, 92.0]	92.4 [91.9, 92.8]
8	69.4 [68.6, 70.2]	79.9 [79.2, 80.5]	81.3 [80.6, 82.0]

Table 30: 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
<b>Right</b>			
Index	92.2 [91.9, 92.6]	93.8 [93.5, 94.1]	94.5 [94.2, 94.8]
Middle	95.1 [94.9, 95.4]	97.2 [96.9, 97.4]	97.3 [97.1, 97.6]
Ring	95.5 [95.2, 95.7]	97.9 [97.7, 98.1]	98.1 [98.0, 98.3]
Little	96.7 [96.5, 97.0]	97.3 [97.2, 97.5]	98.0 [97.9, 98.2]
<b>Left</b>			
Index	93.9 [93.6, 94.2]	95.7 [95.5, 96.0]	96.2 [95.9, 96.4]
Middle	94.5 [94.2, 94.8]	97.5 [97.3, 97.7]	97.7 [97.5, 97.9]
Ring	94.2 [93.8, 94.5]	98.1 [97.9, 98.3]	98.3 [98.1, 98.5]
Little	97.2 [96.9, 97.4]	97.9 [97.7, 98.1]	98.4 [98.2, 98.6]

Table 31: 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
<b>Index</b>			
Either	98.2 [98.0, 98.4]	98.8 [98.6, 99.0]	99.0 [98.8, 99.2]
Both	83.6 [83.0, 84.3]	86.7 [86.1, 87.3]	87.6 [87.0, 88.2]
<b>Middle</b>			
Either	98.5 [98.3, 98.7]	99.4 [99.3, 99.6]	99.5 [99.4, 99.6]
Both	86.1 [85.5, 86.7]	91.0 [90.5, 91.4]	91.3 [90.9, 91.8]
<b>Ring</b>			
Either	98.8 [98.6, 99.0]	99.6 [99.5, 99.7]	99.7 [99.6, 99.8]
Both	87.2 [86.6, 87.7]	92.5 [92.1, 92.9]	92.8 [92.4, 93.3]
<b>Little</b>			
Either	99.4 [99.3, 99.6]	99.6 [99.4, 99.7]	99.6 [99.5, 99.7]
Both	90.3 [89.7, 90.8]	91.6 [91.1, 92.1]	92.7 [92.2, 93.1]

Table 32: 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
<b>Right</b>			
Any	99.5 [99.5, 99.7]	99.6 [99.6, 99.7]	99.7 [99.7, 99.8]
At Least Two	99.1 [99.0, 99.2]	99.3 [99.2, 99.4]	99.5 [99.4, 99.5]
At Least Three	97.0 [96.8, 97.1]	98.0 [98.1, 98.3]	98.4 [98.5, 98.7]
All Four	83.9 [83.6, 84.3]	89.4 [90.2, 90.8]	90.4 [91.1, 91.7]
<b>Left</b>			
Any	99.7 [99.5, 99.7]	99.7 [99.6, 99.7]	99.8 [99.7, 99.8]
At Least Two	99.2 [99.0, 99.2]	99.4 [99.2, 99.4]	99.5 [99.4, 99.5]
At Least Three	96.9 [96.8, 97.1]	98.4 [98.1, 98.3]	98.8 [98.5, 98.7]
All Four	84.0 [83.6, 84.3]	91.7 [90.2, 90.8]	92.5 [91.1, 91.7]

Table 33: 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
<b>Right</b>			
Either Index or Middle	98.6 [98.5, 98.7]	98.9 [99.0, 99.2]	99.1 [99.1, 99.3]
Both Index and Middle	88.8 [88.9, 89.5]	92.0 [92.7, 93.2]	92.7 [93.3, 93.8]
<b>Left</b>			
Either Index or Middle	98.7 [98.5, 98.7]	99.2 [99.0, 99.2]	99.3 [99.1, 99.3]
Both Index and Middle	89.7 [88.9, 89.5]	94.0 [92.7, 93.2]	94.5 [93.3, 93.8]

Table 34: 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
<b>Right</b>			
Any	99.4 [99.3, 99.5]	99.5 [99.4, 99.6]	99.6 [99.6, 99.7]
At Least Two	97.8 [97.5, 97.8]	98.5 [98.6, 98.8]	98.8 [98.8, 99.0]
All Three	85.7 [85.3, 86.0]	90.9 [91.6, 92.1]	91.6 [92.2, 92.7]
<b>Left</b>			
Any	99.4 [99.3, 99.5]	99.6 [99.4, 99.6]	99.6 [99.6, 99.7]
At Least Two	97.5 [97.5, 97.8]	98.8 [98.6, 98.8]	99.0 [98.8, 99.0]
All Three	85.6 [85.3, 86.0]	92.9 [91.6, 92.1]	93.5 [92.2, 92.7]

## A.2 Jaccard Index

Table 35: For each subject, the percentage that at least *Number of Fingers* fingers were segmented with a Jaccard index in the indicated range.

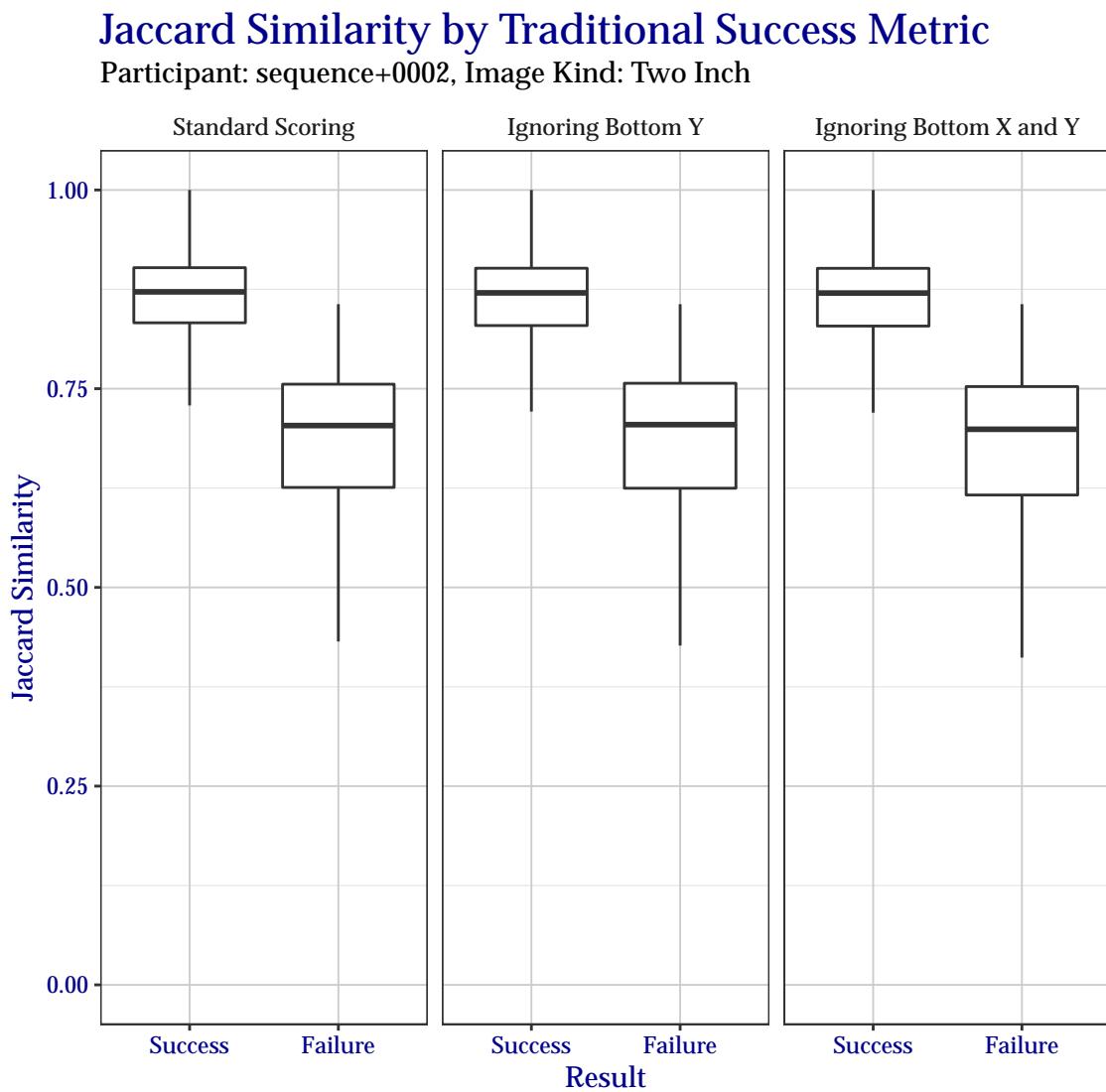
Number of Fingers	$\geq 0.5$	$\geq 0.6$	$\geq 0.7$	$\geq 0.8$	$\geq 0.9$	$\geq 0.95$	$\geq 0.98$
1	100.0	100.0	99.9	99.7	82.3	9.9	0.6
2	99.9	99.9	99.9	98.6	56.6	0.8	0.0
3	99.8	99.8	99.5	96.2	32.1	0.1	0
4	99.7	99.4	98.4	91.7	15.4	0	0
5	95.8	95.7	95.0	84.3	5.8	0	0
6	95.7	95.5	93.3	74.3	1.5	0	0
7	95.4	94.4	88.7	58.6	0.3	0	0
8	93.5	88.5	72.9	33.3	0.0	0	0

Table 36: For all subjects, percentage that a particular friction ridge generalized position was segmented with a Jaccard index in the indicated range.

Finger	$0-0.5$	$0.5-0.6$	$0.6-0.7$	$0.7-0.8$	$0.8-0.9$	$0.9-1.0$
<b>Right</b>						
Index	0.4	0.8	3.3	15.8	60.9	18.8
Middle	0.5	0.6	2.4	11.4	56.7	28.4
Ring	0.2	0.3	1.7	9.6	54.4	33.8
Little	0.4	0.3	1.5	9.1	61.2	27.5
<b>Left</b>						
Index	0.4	1.1	3.9	14.8	55.6	24.2
Middle	0.8	1.3	4.7	15.8	51.9	25.5
Ring	0.3	0.7	3.4	14.8	54.0	26.8
Little	0.3	0.6	2.5	15.2	63.9	17.5

Table 37: Percentage of segmentation obtaining a Jaccard index in the indicated ranges, by hand, for combinations of all eight fingers of a TwoInch slap.

Fingers	$\geq 0.5$	$\geq 0.6$	$\geq 0.7$	$\geq 0.8$	$\geq 0.9$	$\geq 0.95$	$\geq 0.98$
<b>Right</b>							
Any	99.9	99.9	99.9	99.0	66.1	5.9	0.3
At Least Two	99.9	99.9	99.7	96.6	31.9	0.4	0.0
At Least Three	99.8	99.7	98.5	87.1	9.2	0.0	0.0
All Four	98.9	96.9	89.3	58.8	1.3	0.0	0.0
<b>Left</b>							
Any	100.0	100.0	99.8	97.8	58.0	4.6	0.3
At Least Two	99.9	99.8	99.2	91.8	27.1	0.2	0.0
At Least Three	99.7	99.3	96.7	78.7	7.7	0.0	0.0
All Four	98.5	95.3	84.3	51.0	1.2	0.0	0.0

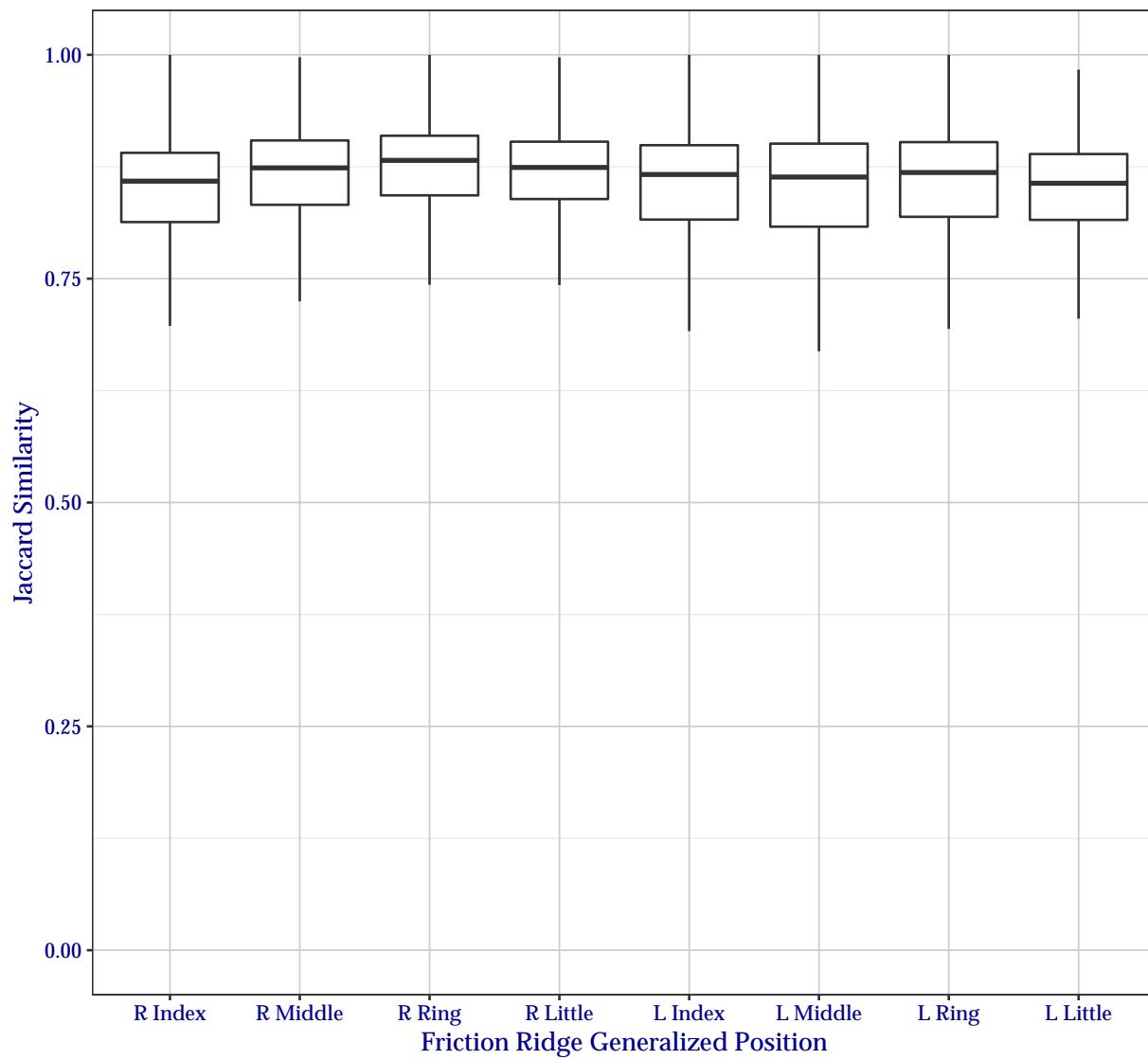


04 September 2020, 03:33:16 PM EDT

Figure 13: 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: sequence+0002, Image Kind: Two Inch



04 September 2020, 03:33:10 PM EDT

Figure 14: Boxplot of Jaccard similarity indices for each friction ridge generalized position. Outliers have been removed for clarity.

Table 38: 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	$\geq 0.5$	$\geq 0.6$	$\geq 0.7$	$\geq 0.8$	$\geq 0.9$	$\geq 0.95$	$\geq 0.98$
<b>Right</b>							
Either Index or Middle	99.9	99.8	99.4	94.7	40.4	2.3	0.1
Both Index and Middle	99.2	97.8	92.6	70.1	6.8	0.0	0
<b>Left</b>							
Either Index or Middle	99.9	99.7	98.6	91.3	41.0	2.6	0.2
Both Index and Middle	98.9	96.6	89.2	65.8	8.6	0.0	0

Table 39: 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	$\geq 0.5$	$\geq 0.6$	$\geq 0.7$	$\geq 0.8$	$\geq 0.9$	$\geq 0.95$	$\geq 0.98$
<b>Right</b>							
Any	99.9	99.9	99.8	98.1	57.0	4.3	0.2
At Least Two	99.8	99.8	99.0	90.6	20.7	0.2	0
All Three	99.1	97.5	90.9	64.3	3.3	0.0	0
<b>Left</b>							
Any	99.9	99.9	99.5	95.5	52.3	3.8	0.3
At Least Two	99.8	99.5	97.4	84.2	20.3	0.1	0.0
All Three	98.7	96.0	86.6	58.3	3.8	0.0	0

## B Identification Flats (“ThreeInch” Data)

### B.1 Bootstrap Confidence for Segmentation Statistics

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

In Table 40, results are shown of how successful sequence+0002 segmented fingers for each subject in the test corpus. Table 41 shows success for specific finger positions over the entire test corpus. Similarly, Table 42 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 43 shows success for combinations of all fingers, Table 45 for the all except the little finger, and Table 44 for just the index and middle fingers.

Table 40: 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 [99.7, 99.8]	99.8 [99.8, 99.9]	99.8 [99.8, 99.9]
2	99.4 [99.3, 99.5]	99.5 [99.5, 99.6]	99.6 [99.5, 99.7]
3	98.2 [98.0, 98.4]	98.3 [98.2, 98.5]	98.4 [98.2, 98.5]
4	97.6 [97.4, 97.8]	97.9 [97.7, 98.1]	98.1 [97.9, 98.3]
5	95.6 [95.3, 95.8]	95.8 [95.6, 96.1]	95.9 [95.6, 96.2]
6	94.9 [94.6, 95.2]	95.6 [95.4, 95.9]	95.8 [95.6, 96.1]
7	93.3 [93.0, 93.6]	95.1 [94.8, 95.4]	95.5 [95.3, 95.8]
8	88.7 [88.3, 89.1]	93.6 [93.3, 94.0]	95.0 [94.7, 95.2]
9	75.6 [75.1, 76.2]	88.5 [88.1, 88.9]	92.2 [91.8, 92.5]
10	50.3 [49.7, 50.9]	70.3 [69.7, 70.9]	79.1 [78.6, 79.6]

Table 41: 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
<b>Right</b>			
Thumb	82.4 [81.9, 82.8]	94.9 [94.6, 95.1]	95.3 [95.0, 95.5]
Index	97.2 [96.9, 97.4]	98.2 [98.0, 98.3]	98.8 [98.7, 99.0]
Middle	94.8 [94.5, 95.0]	97.3 [97.1, 97.5]	99.0 [98.9, 99.1]
Ring	92.5 [92.2, 92.8]	95.2 [95.0, 95.5]	97.8 [97.6, 98.0]
Little	95.0 [94.7, 95.2]	96.4 [96.2, 96.6]	97.4 [97.2, 97.6]
<b>Left</b>			
Thumb	80.1 [79.5, 80.6]	96.0 [95.7, 96.2]	96.4 [96.1, 96.6]
Index	95.8 [95.5, 96.0]	96.8 [96.6, 97.1]	97.6 [97.4, 97.8]
Middle	93.7 [93.4, 94.0]	96.2 [96.0, 96.5]	98.7 [98.5, 98.8]
Ring	91.4 [91.1, 91.8]	93.3 [93.0, 93.6]	97.4 [97.2, 97.6]
Little	95.0 [94.7, 95.2]	96.1 [95.9, 96.3]	97.1 [96.9, 97.3]

Table 42: 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
<b>Thumb</b>			
Either	90.8 [90.5, 91.2]	99.1 [98.9, 99.2]	99.2 [99.1, 99.3]
Both	71.7 [71.1, 72.3]	91.9 [91.6, 92.3]	92.6 [92.2, 92.9]
<b>Index</b>			
Either	99.2 [99.1, 99.3]	99.5 [99.4, 99.6]	99.7 [99.6, 99.7]
Both	91.2 [90.8, 91.5]	92.9 [92.6, 93.2]	94.2 [93.9, 94.5]
<b>Middle</b>			
Either	98.4 [98.2, 98.6]	99.2 [99.1, 99.3]	99.7 [99.7, 99.8]
Both	87.7 [87.3, 88.1]	91.7 [91.4, 92.1]	95.4 [95.1, 95.7]
<b>Ring</b>			
Either	97.7 [97.5, 97.9]	98.5 [98.3, 98.6]	99.5 [99.4, 99.6]
Both	83.8 [83.3, 84.2]	87.5 [87.1, 87.9]	93.1 [92.8, 93.4]
<b>Little</b>			
Either	99.0 [98.9, 99.2]	99.3 [99.2, 99.4]	99.5 [99.4, 99.6]
Both	88.4 [88.0, 88.8]	90.6 [90.2, 91.0]	92.3 [92.0, 92.7]

Table 43: 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
<b>Right</b>			
Any	99.6 [99.5, 99.7]	99.7 [99.7, 99.8]	99.7 [99.7, 99.8]
At Least Two	98.2 [98.0, 98.3]	98.4 [98.2, 98.5]	98.4 [98.3, 98.5]
At Least Three	97.0 [96.6, 97.0]	98.0 [97.7, 97.9]	98.2 [97.9, 98.2]
At Least Four	92.1 [91.1, 91.6]	95.9 [95.2, 95.5]	97.1 [96.7, 97.0]
All Five	66.6 [64.3, 65.1]	81.1 [79.7, 80.4]	86.0 [85.4, 86.0]
<b>Left</b>			
Any	99.6 [99.5, 99.7]	99.7 [99.7, 99.8]	99.8 [99.7, 99.8]
At Least Two	98.1 [98.0, 98.3]	98.3 [98.2, 98.5]	98.3 [98.3, 98.5]
At Least Three	96.6 [96.6, 97.0]	97.7 [97.7, 97.9]	98.0 [97.9, 98.2]
At Least Four	90.6 [91.1, 91.6]	94.8 [95.2, 95.5]	96.6 [96.7, 97.0]
All Five	62.8 [64.3, 65.1]	79.0 [79.7, 80.4]	85.4 [85.4, 86.0]

Table 44: 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
<b>Right</b>			
Either Index or Middle	99.2 [99.0, 99.1]	99.6 [99.4, 99.5]	99.7 [99.6, 99.7]
Both Index and Middle	92.7 [91.4, 91.9]	95.8 [94.6, 95.0]	98.1 [97.3, 97.6]
<b>Left</b>			
Either Index or Middle	98.9 [99.0, 99.1]	99.3 [99.4, 99.5]	99.6 [99.6, 99.7]
Both Index and Middle	90.6 [91.4, 91.9]	93.8 [94.6, 95.0]	96.7 [97.3, 97.6]

Table 45: 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
<b>Right</b>			
Any	99.6 [99.4, 99.5]	99.8 [99.6, 99.7]	99.8 [99.7, 99.8]
At Least Two	97.6 [97.0, 97.3]	98.8 [98.2, 98.5]	99.5 [99.2, 99.4]
All Three	87.2 [85.7, 86.3]	92.2 [90.2, 90.8]	96.4 [95.4, 95.8]
<b>Left</b>			
Any	99.4 [99.4, 99.5]	99.6 [99.6, 99.7]	99.7 [99.7, 99.8]
At Least Two	96.7 [97.0, 97.3]	97.9 [98.2, 98.5]	99.1 [99.2, 99.4]
All Three	84.8 [85.7, 86.3]	88.8 [90.2, 90.8]	94.8 [95.4, 95.8]

## B.2 Jaccard Index

Table 46: 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	$\geq 0.5$	$\geq 0.6$	$\geq 0.7$	$\geq 0.8$	$\geq 0.9$	$\geq 0.95$	$\geq 0.98$
1	99.9	99.9	99.9	99.5	92.2	29.7	1.4
2	99.9	99.8	99.6	98.5	80.1	6.6	0.1
3	98.5	98.3	98.0	96.2	64.4	1.3	0.0
4	98.2	98.0	97.3	93.7	46.8	0.2	0.0
5	95.9	95.9	95.2	89.7	30.3	0.0	0
6	95.9	95.7	94.2	84.4	17.0	0.0	0
7	95.8	95.3	92.1	76.4	7.7	0	0
8	95.6	94.3	87.3	64.3	2.8	0	0
9	94.8	90.8	76.7	46.7	0.7	0	0
10	90.5	79.1	55.4	24.8	0.1	0	0

Table 47: 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
<b>Right</b>						
Thumb	1.0	3.0	8.6	12.4	44.1	30.9
Index	0.5	0.6	2.2	9.5	44.8	42.4
Middle	0.5	1.1	4.4	14.4	42.6	37.0
Ring	0.8	2.0	6.2	15.1	39.4	36.5
Little	1.0	1.7	3.6	8.6	44.3	40.8
<b>Left</b>						
Thumb	1.3	3.9	10.4	15.2	42.9	26.3
Index	0.5	0.8	2.8	9.8	46.9	39.2
Middle	0.7	1.3	4.9	15.4	45.2	32.5
Ring	1.0	2.3	6.5	16.2	41.8	32.2
Little	1.4	1.9	3.7	9.3	51.7	32.0

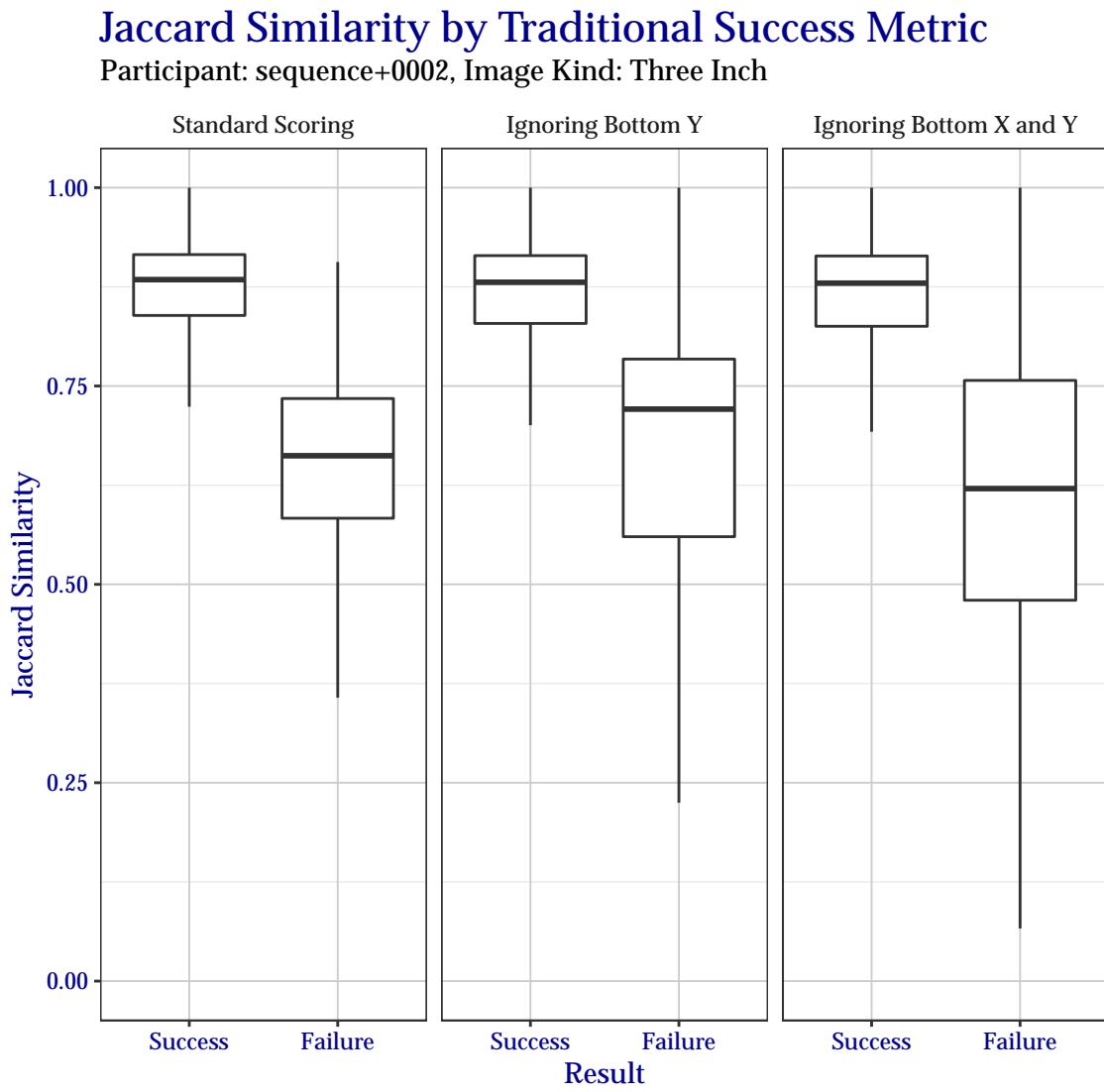
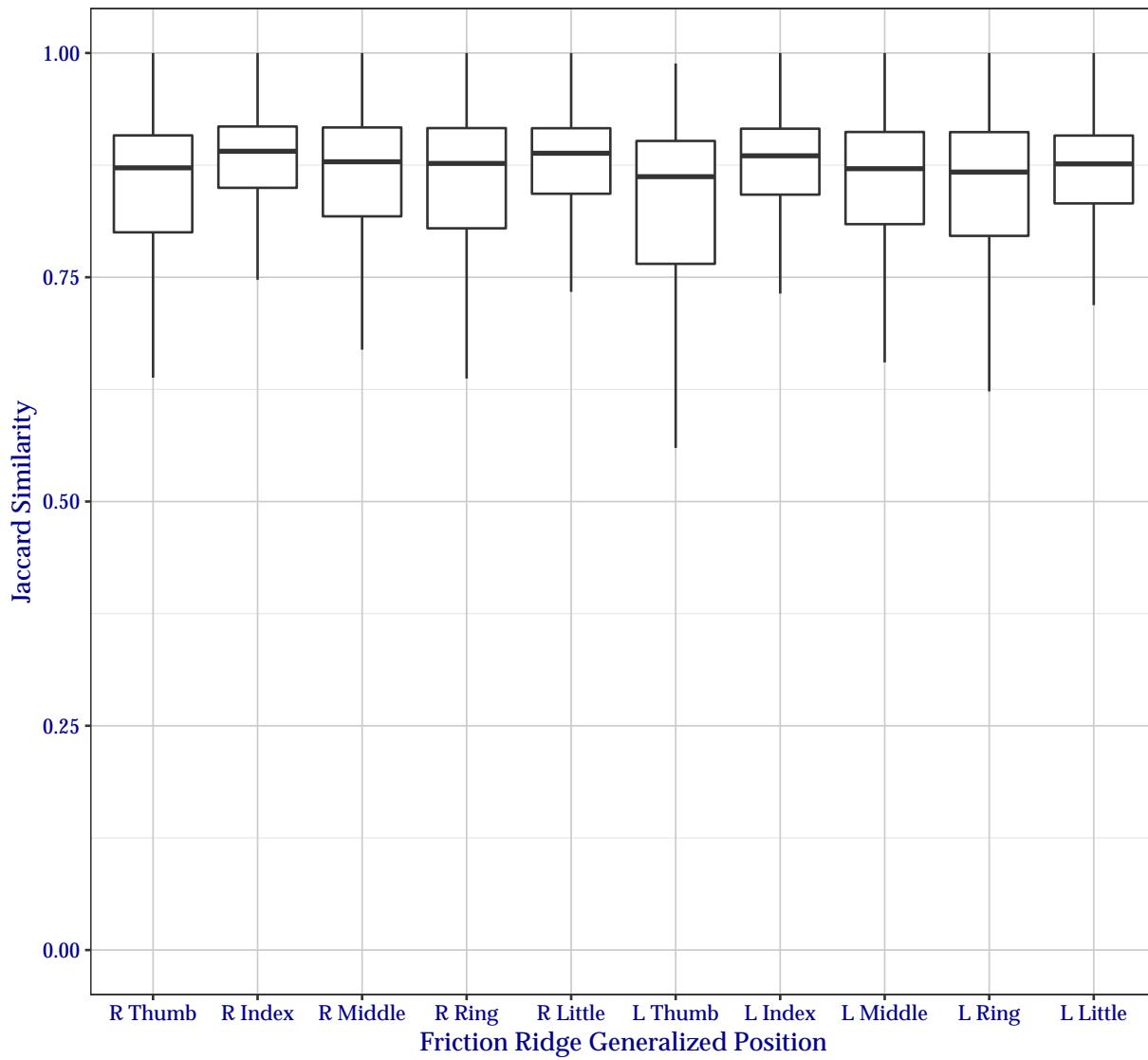


Figure 15: Boxplot of Jaccard similarity indices as compared to the traditional success metrics. Outliers have been removed for clarity.

## Jaccard Similarity by Friction Ridge Generalized Position

Participant: sequence+0002, Image Kind: Three Inch



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Figure 16: Boxplot of Jaccard similarity indices for each friction ridge generalized position. Outliers have been removed for clarity.

Table 48: Percentage of segmentation obtaining a Jaccard index in the indicated ranges, by hand, for combinations of all ten fingers of a ThreeInch slap.

Fingers	$\geq 0.5$	$\geq 0.6$	$\geq 0.7$	$\geq 0.8$	$\geq 0.9$	$\geq 0.95$	$\geq 0.98$
<b>Right</b>							
Any	99.9	99.9	99.7	98.5	82.4	19.1	0.8
At Least Two	98.4	98.3	97.8	93.8	56.8	2.4	0.0
At Least Three	98.3	98.1	96.2	86.8	31.6	0.2	0.0
At Least Four	98.0	96.6	90.9	72.7	11.5	0.0	0.0
All Five	92.3	86.1	69.9	43.8	2.1	0.0	0.0
<b>Left</b>							
Any	99.9	99.8	99.7	98.5	76.9	15.0	0.6
At Least Two	98.4	98.3	97.6	93.5	48.8	1.7	0.0
At Least Three	98.3	97.7	95.5	85.0	24.4	0.1	0.0
At Least Four	97.7	95.9	89.3	68.6	8.1	0.0	0.0
All Five	91.7	84.2	66.2	38.1	1.3	0.0	0.0

Table 49: 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	$\geq 0.5$	$\geq 0.6$	$\geq 0.7$	$\geq 0.8$	$\geq 0.9$	$\geq 0.95$	$\geq 0.98$
<b>Right</b>							
Either Index or Middle	99.8	99.7	98.7	92.8	59.2	8.8	0.3
Both Index and Middle	99.2	97.7	92.1	74.1	20.3	0.4	0.0
<b>Left</b>							
Either Index or Middle	99.8	99.5	98.3	92.8	53.9	7.2	0.3
Both Index and Middle	99.0	97.2	90.7	71.1	17.8	0.3	0

Table 50: 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	$\geq 0.5$	$\geq 0.6$	$\geq 0.7$	$\geq 0.8$	$\geq 0.9$	$\geq 0.95$	$\geq 0.98$
<b>Right</b>							
Any	99.9	99.8	99.2	94.9	67.9	12.7	0.5
At Least Two	99.7	99.2	96.5	85.0	36.7	1.1	0.0
All Three	98.7	95.7	86.2	62.9	11.4	0.1	0.0
<b>Left</b>							
Any	99.9	99.7	98.9	95.1	63.0	10.6	0.5
At Least Two	99.6	98.8	95.7	83.6	31.6	0.9	0
All Three	98.3	94.8	84.5	59.2	9.3	0.0	0