

# dermalog+0003

DERMALOG Identification Systems GmbH

## Slap Fingerprint Segmentation Evaluation III

Last Updated: 27 January 2023

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# 1 Participation Information

## 1.1 Names and Dates

- **Organization Name:** DERMALOG Identification Systems GmbH
- **SlapSeg III Identifier:** dermalog+0003
- **SlapSeg III API Version:** 1.2.0
- **Provided Marketing Name:** “Dermalog Fingerprint Segmentation (version 0.0.3)”
- **Application Date:** 26 January 2023
- **First Submission Date:** 26 January 2023 (as version 0003)
- **Validation Date:** 26 January 2023
- **Completion Date:** 26 January 2023

## 1.2 Libraries

Filename	MD5 Checksum	Size
libslapsegiii_dermalog_0003.so	2576e53d3b205aed5f71481eff78c8ff	24 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.

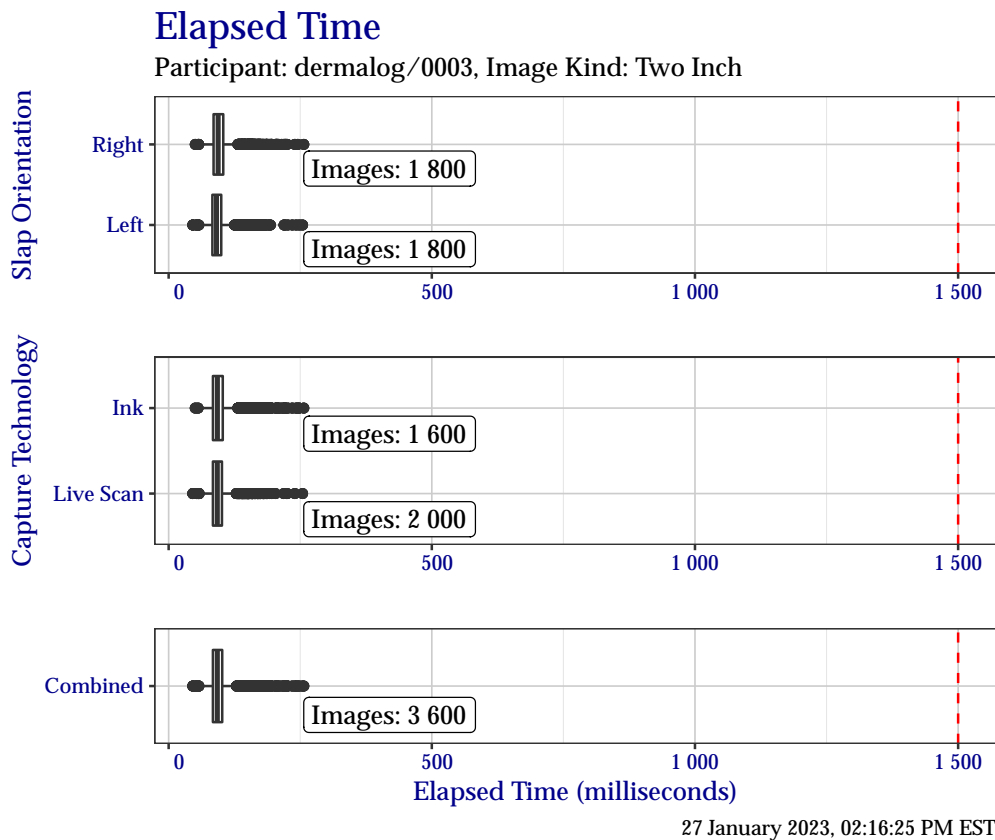


Figure 1: Box plots of elapsed time in milliseconds when segmenting the TwoInch timing test corpus, separated by slap orientation and capture technology.

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	51	46	46	51	46
25%	85	83	84	84	84
Median	94	91	92	93	92
75%	104	100	101	103	102
Maximum	257	254	254	257	257

## 2.2 Segmentation Centers and Dimensions

### 2.2.1 Segmentation Centers

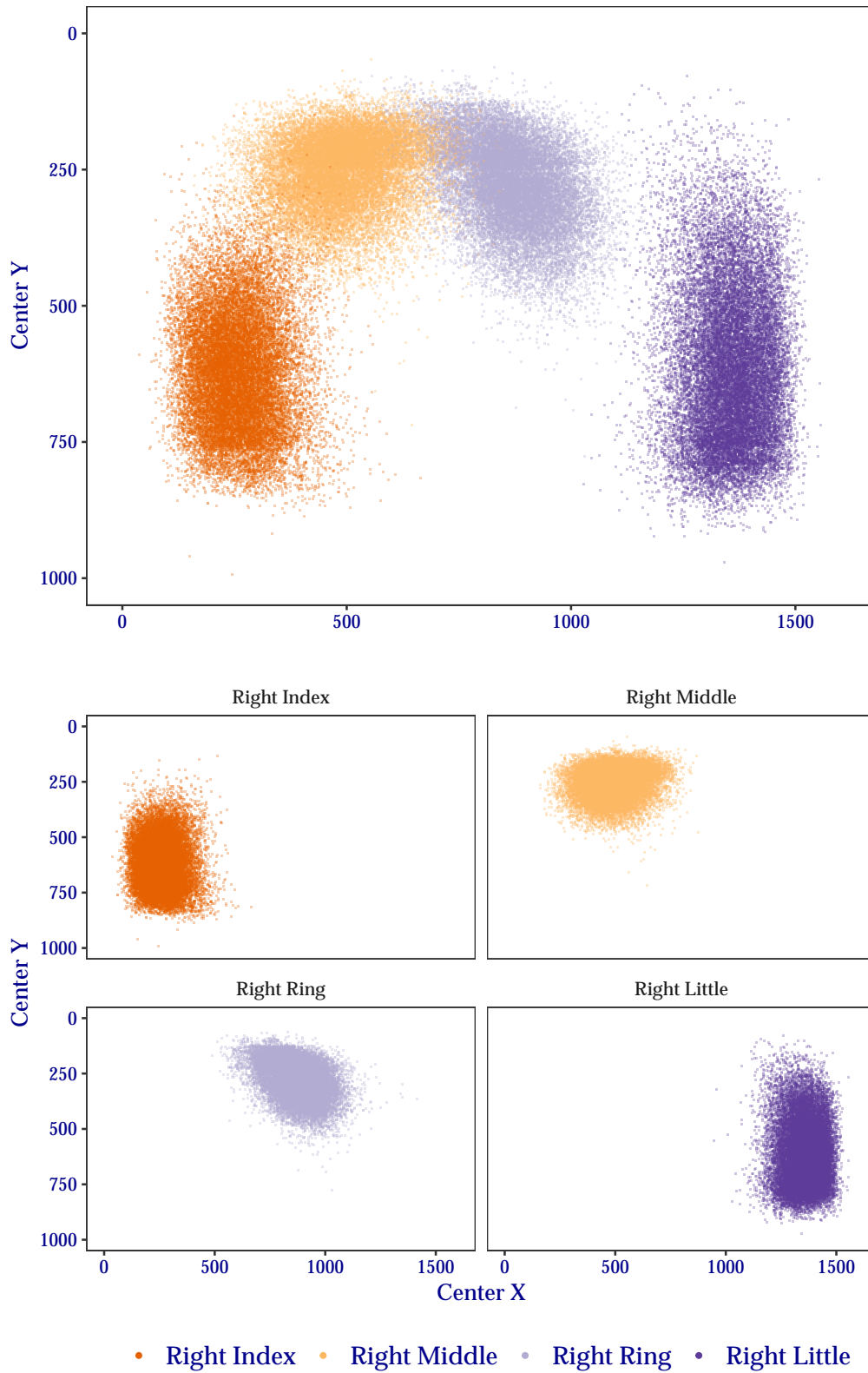
The plots in this section show the distribution of segmentation position centers  $(x, y)$  for TwoInch data. At the top of each figure is a combined plot for all finger positions of a given slap orientation. These figures are isolated in plots faceted at the bottom of the figure.

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: dermalog/0003, FRGPs: 2, 3, 4, 5, Image Kind: Two Inch

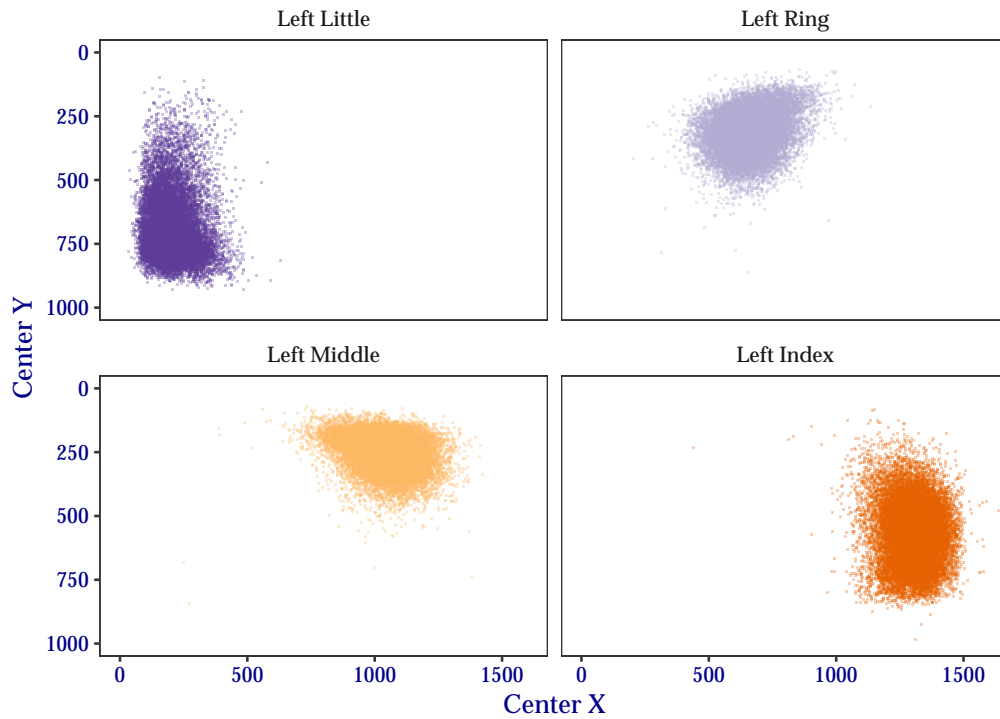
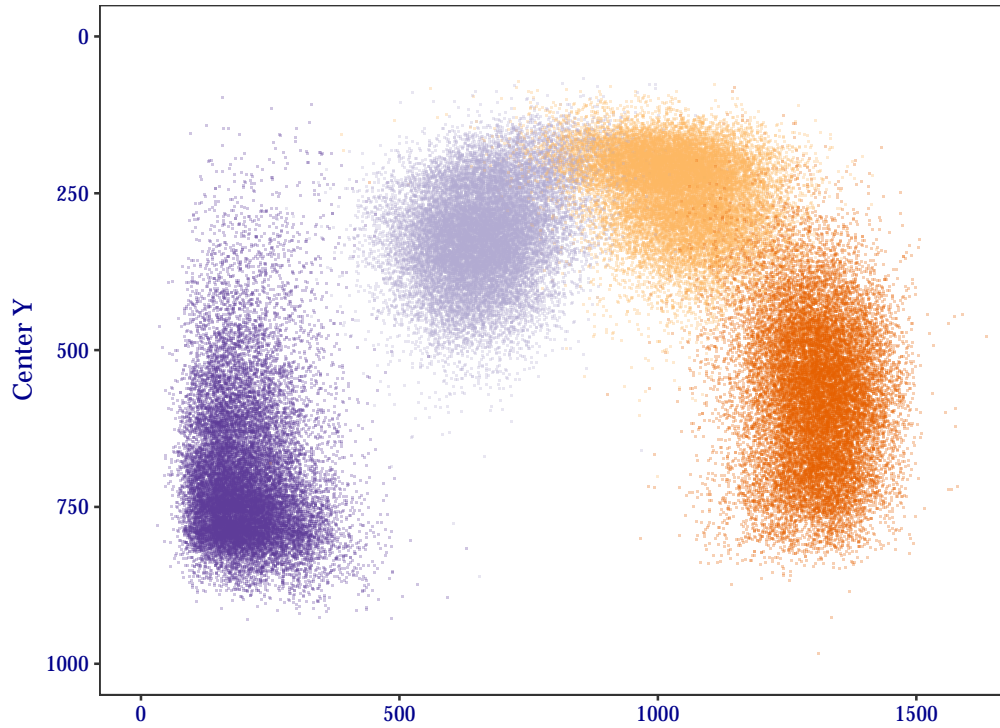


27 January 2023, 02:16:33 PM EST

Figure 2: Segmentation centers for right hand TwoInch data.

### Segmentation Position Centers

Participant: dermalog/0003, FRGPs: 7, 8, 9, 10, Image Kind: Two Inch



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

27 January 2023, 02:16:28 PM EST

Figure 3: Segmentation centers for left hand TwoInch data.



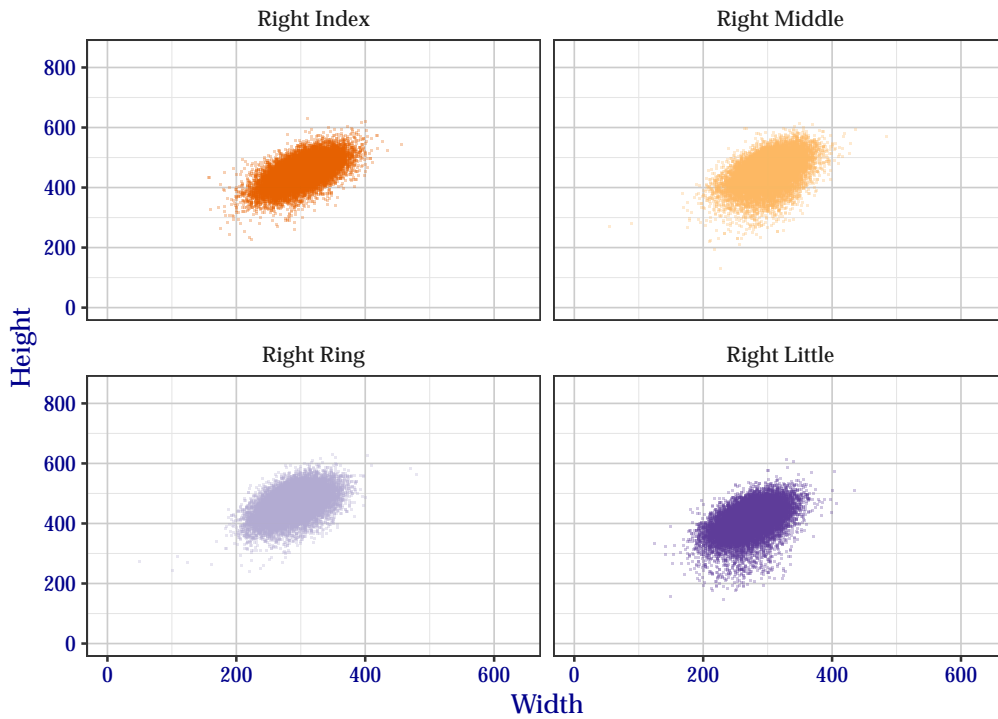
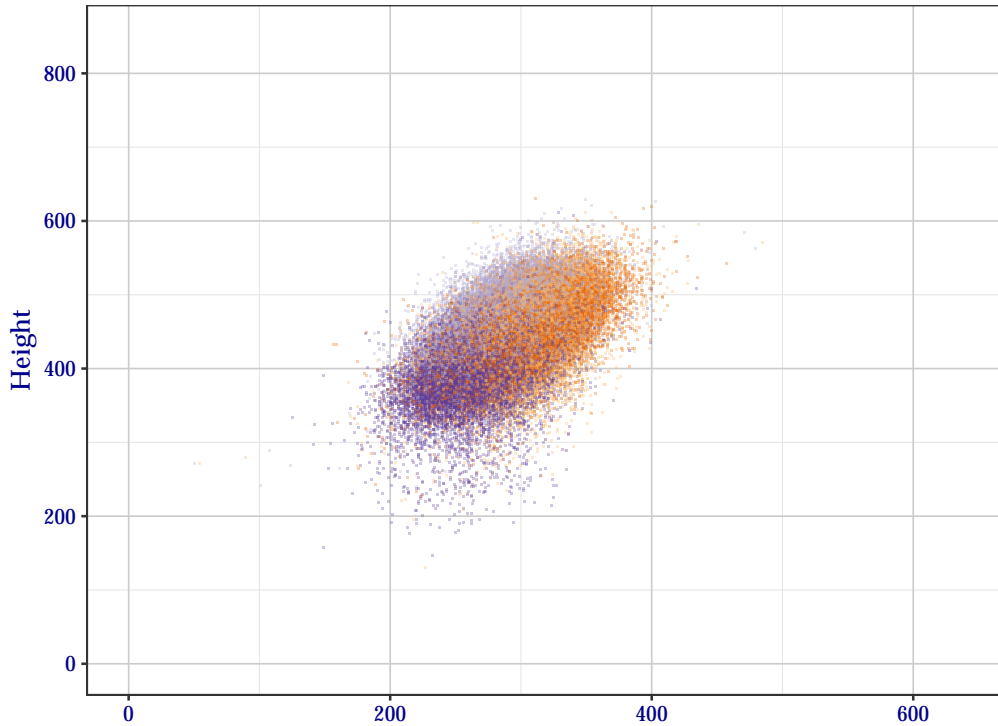
## 2.2.2 Segmentation Dimensions

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: dermalog/0003, FRGPs: 2, 3, 4, 5, Image Kind: Two Inch



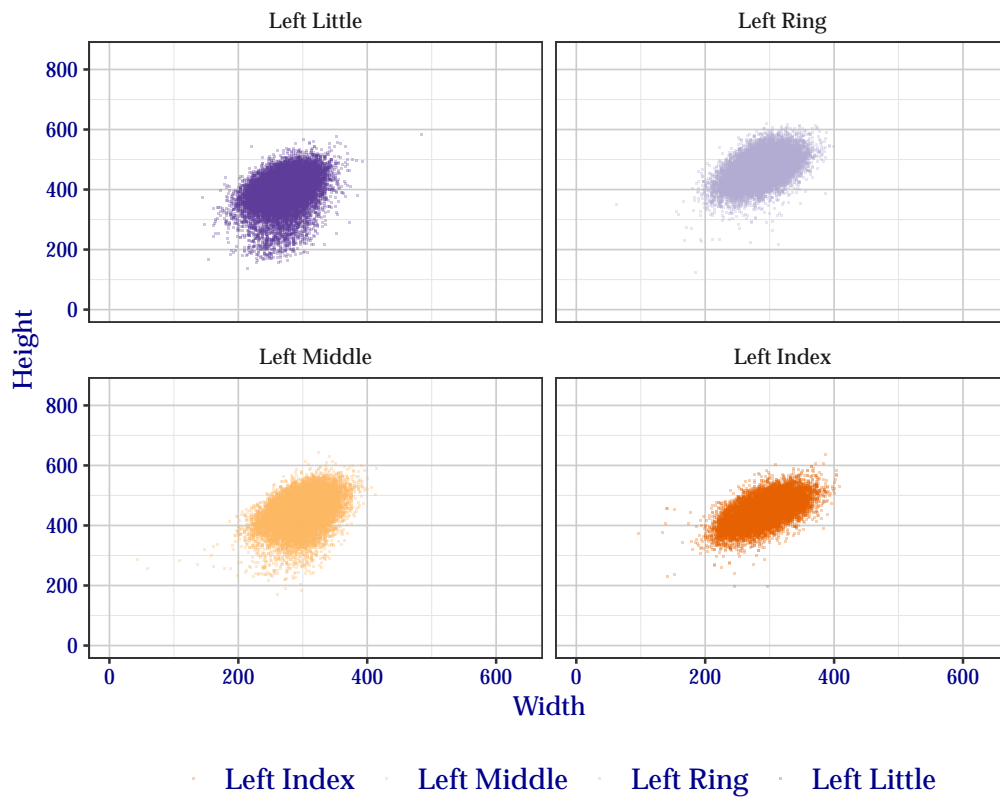
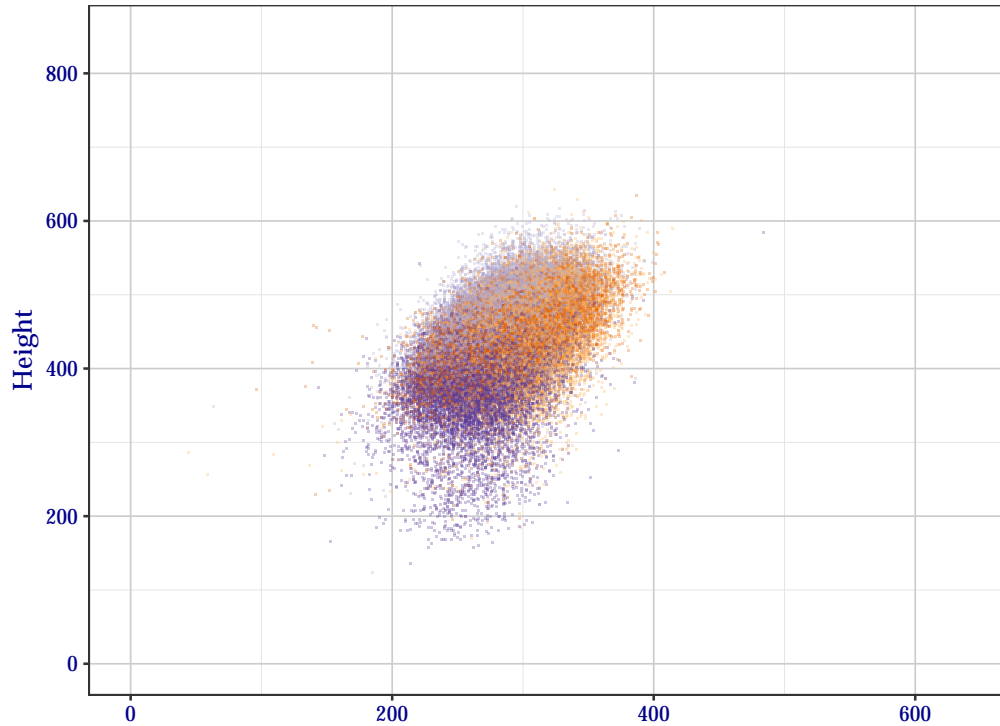
Right Index Right Middle Right Ring Right Little

27 January 2023, 02:17:05 PM EST

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

### Segmentation Position Dimensions

Participant: dermalog/0003, FRGPs: 7, 8, 9, 10, Image Kind: Two Inch



27 January 2023, 02:17:00 PM EST

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

## 2.3 Detailed Segmentation Statistics

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

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

Table 2 shows how successful dermalog+0003 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	99.8	99.8	99.9
2	99.6	99.6	99.8
3	99.3	99.4	99.5
4	98.5	98.7	98.8
5	95.1	95.1	95.4
6	94.0	94.3	94.9
7	91.2	92.1	93.0
8	79.5	83.3	84.6

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	96.1	97.1	97.5
Middle	96.4	97.1	97.7
Ring	95.9	96.8	97.4
Little	96.8	97.2	98.0
<b>Left</b>			
Index	97.1	97.6	97.8
Middle	96.8	97.6	97.9
Ring	96.6	97.6	97.8
Little	97.1	97.4	97.7

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	99.1	99.2	99.4
Both	90.3	91.5	92.0
<b>Middle</b>			
Either	99.2	99.3	99.4
Both	90.1	91.4	92.1
<b>Ring</b>			
Either	99.2	99.4	99.5
Both	89.6	91.2	92.0
<b>Little</b>			
Either	99.1	99.2	99.3
Both	90.4	91.1	92.1

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	99.6	99.6	99.7
At Least Two	99.0	99.0	99.5
At Least Three	97.5	97.8	98.5
All Four	89.2	91.7	92.8
<b>Left</b>			
Any	99.5	99.5	99.7
At Least Two	99.1	99.2	99.4
At Least Three	98.0	98.3	98.6
All Four	91.0	93.1	93.6

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	99.1	99.2	99.4
Both Index and Middle	93.5	95.0	95.8
<b>Left</b>			
Either Index or Middle	99.0	99.1	99.3
Both Index and Middle	95.0	96.1	96.4

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

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
<b>Right</b>			
Any	99.4	99.4	99.7
At Least Two	98.2	98.4	99.0
All Three	90.9	93.1	93.9
<b>Left</b>			
Any	99.4	99.4	99.6
At Least Two	98.4	98.6	98.9
All Three	92.8	94.6	95.0

## 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.

dermalog+0003 did **not** report any capture failures.

#### 2.4.1.1 Recovery

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

dermalog+0003 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 dermalog+0003 are enumerated in Table 8.

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

Failure Reason	Fingers
Finger Not Found	1 139
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 9 shows how successful dermalog+0003 was in correctly determining if a finger was missing. The *Missed* row shows when a segmentation position was returned for a missing finger. All possible failure reasons are enumerated, but are not considered *Correctly Identified* because the algorithm specified failure for a reason other than the finger not being found.

Table 9: Performance of dermalog+0003 at detecting fingers missing from an image.

Result	Percentage
Missed	21.9
Correctly Identified	78.1
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 10 shows cases in which a segmentation position was returned that matched a ground truth segmentation position for a different finger in the same image.

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

Hand	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Left	0.12	0.13	0.14
Right	0.04	0.04	0.04
Combined	0.08	0.08	0.09



## 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:** 99.8%

Table 11: 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	<b>99.6</b>	0.4
Right	0.1	<b>99.9</b>

### 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 12. Results are reported in milliseconds

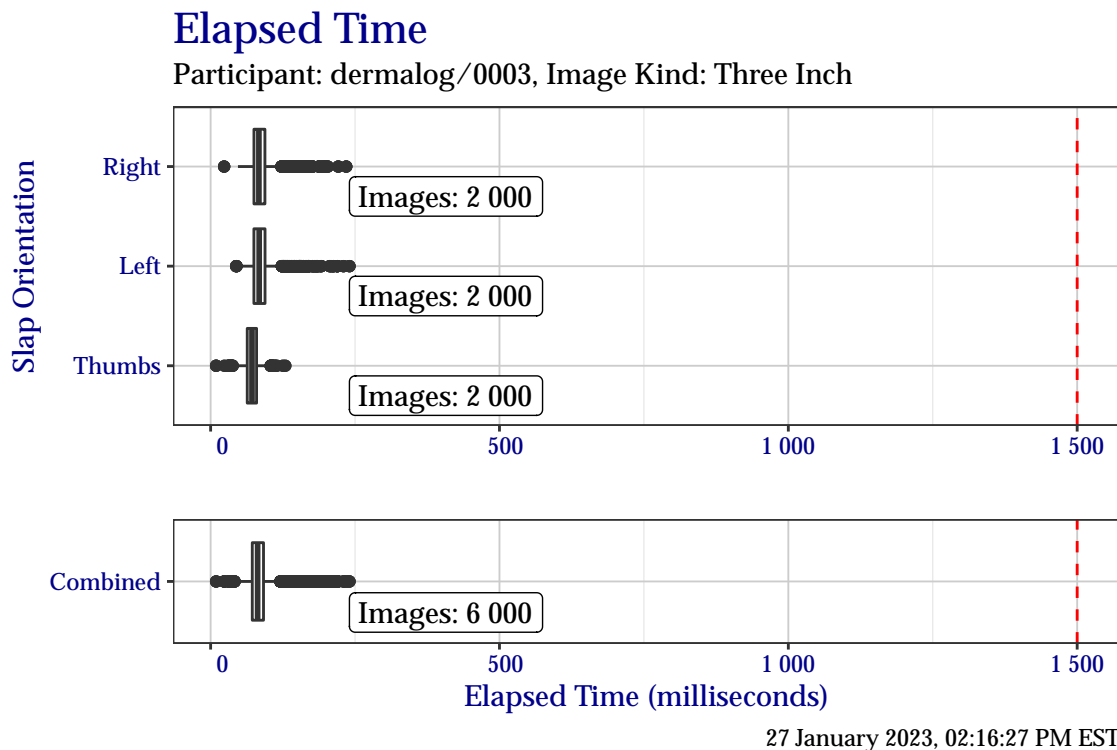


Figure 6: Box plots of elapsed time in milliseconds when segmenting the ThreeInch timing test corpus, separated by slap orientation.

Table 12: Elapsed time in milliseconds when segmenting the ThreeInch timing test corpus, separated by slap orientation.

	Right	Left	Thumbs	Combined
Minimum	23	44	9	9
25%	75	75	63	72
Median	84	84	72	81
75%	94	94	80	92
Maximum	235	240	129	240

## 3.2 Segmentation Centers and Dimensions

### 3.2.1 Segmentation Centers

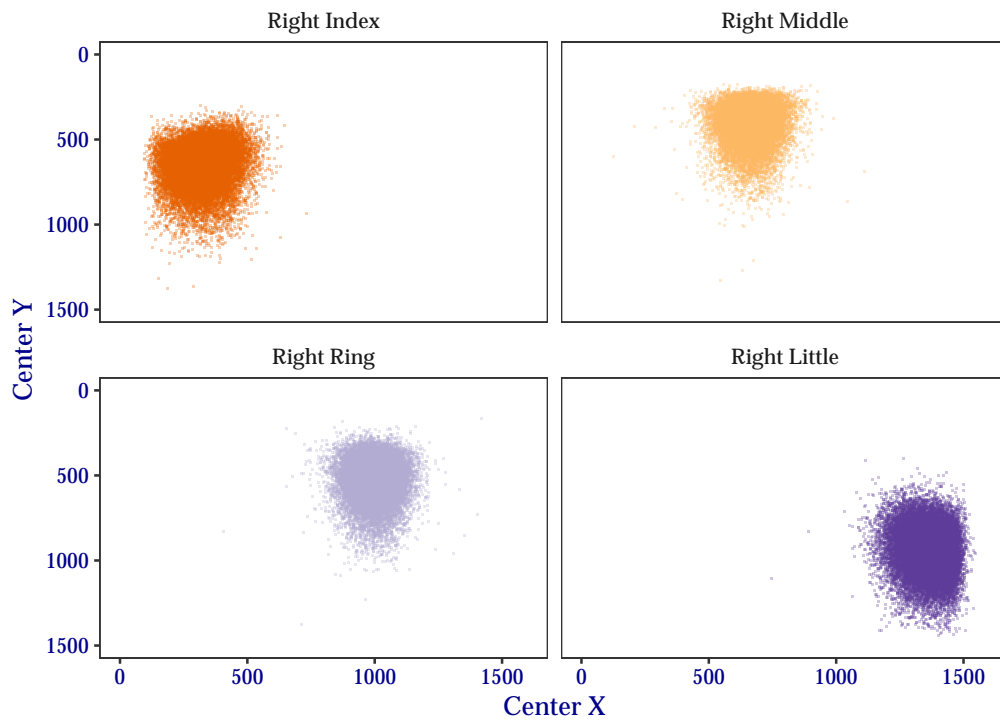
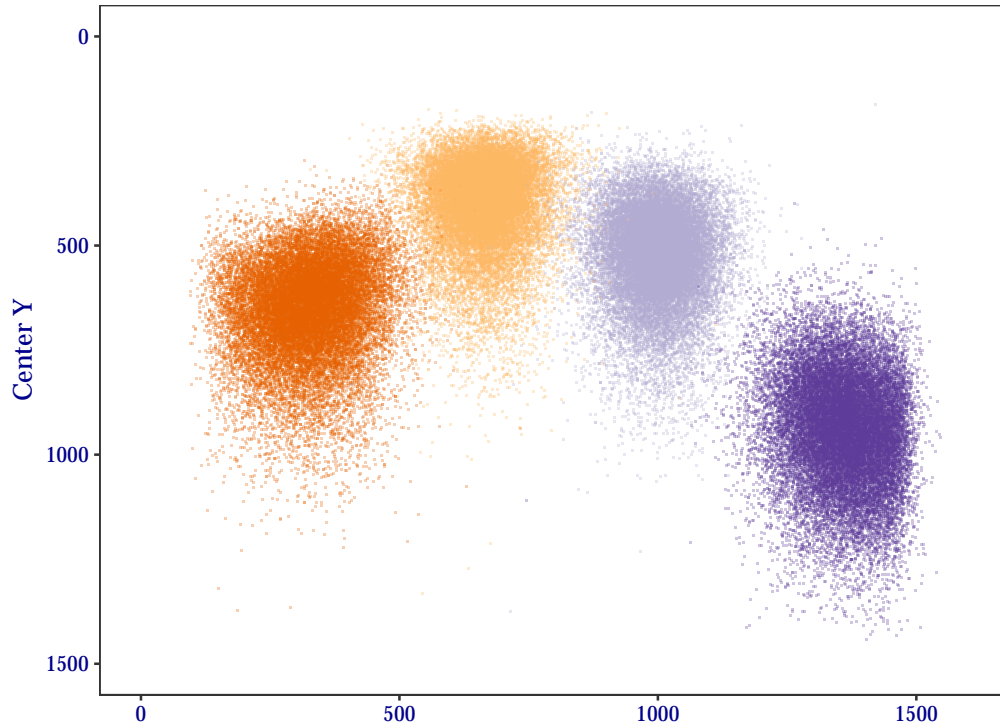
The plots in this section show the distribution of segmentation position centers  $(x, y)$  for ThreeInch data. At the top of each figure is a combined plot for all finger positions of a given hand orientation. These figures are isolated in plots faceted at the bottom of the figure.

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: dermalog/0003, FRGPs: 2, 3, 4, 5, Image Kind: Three Inch



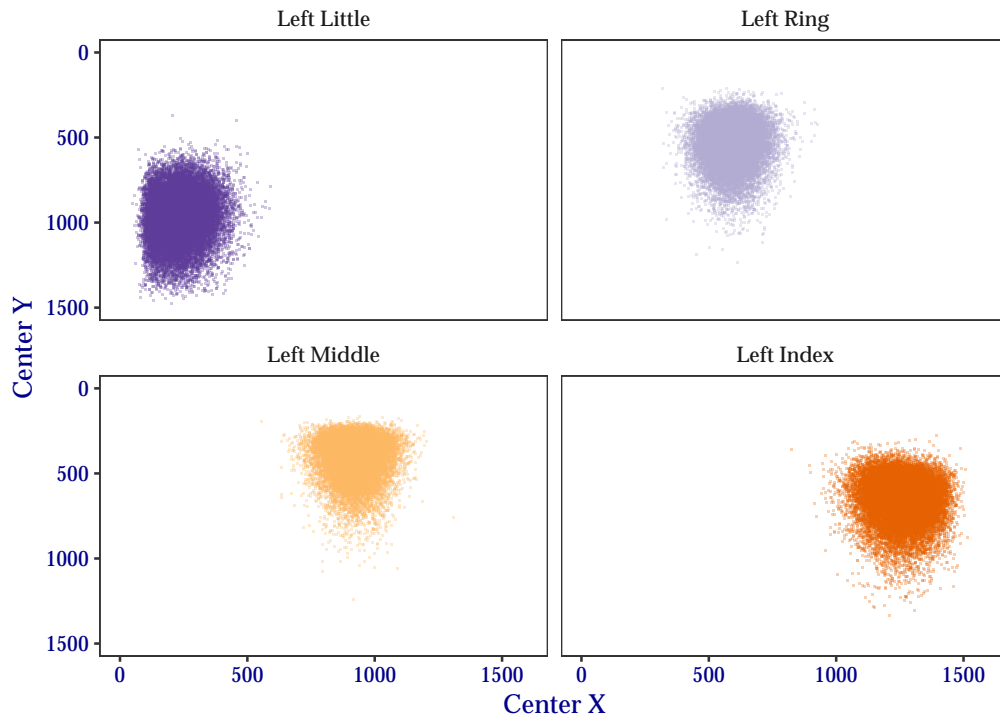
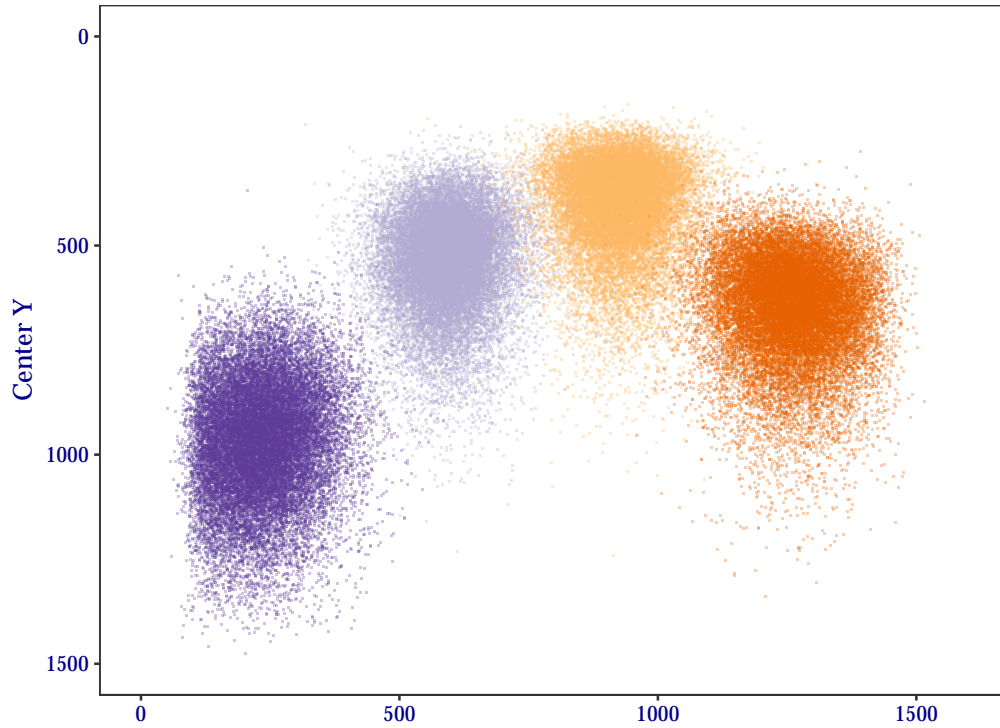
• Right Index • Right Middle • Right Ring • Right Little

27 January 2023, 02:16:44 PM EST

Figure 7: Segmentation centers for right hand ThreeInch data.

### Segmentation Position Centers

Participant: dermalog/0003, FRGPs: 7, 8, 9, 10, Image Kind: Three Inch



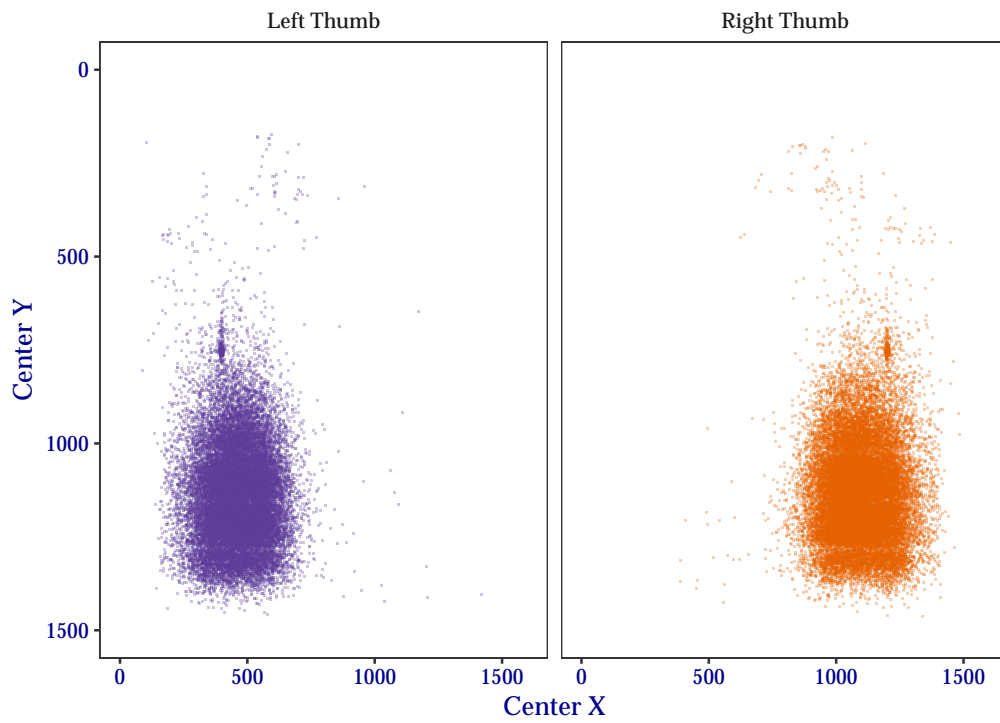
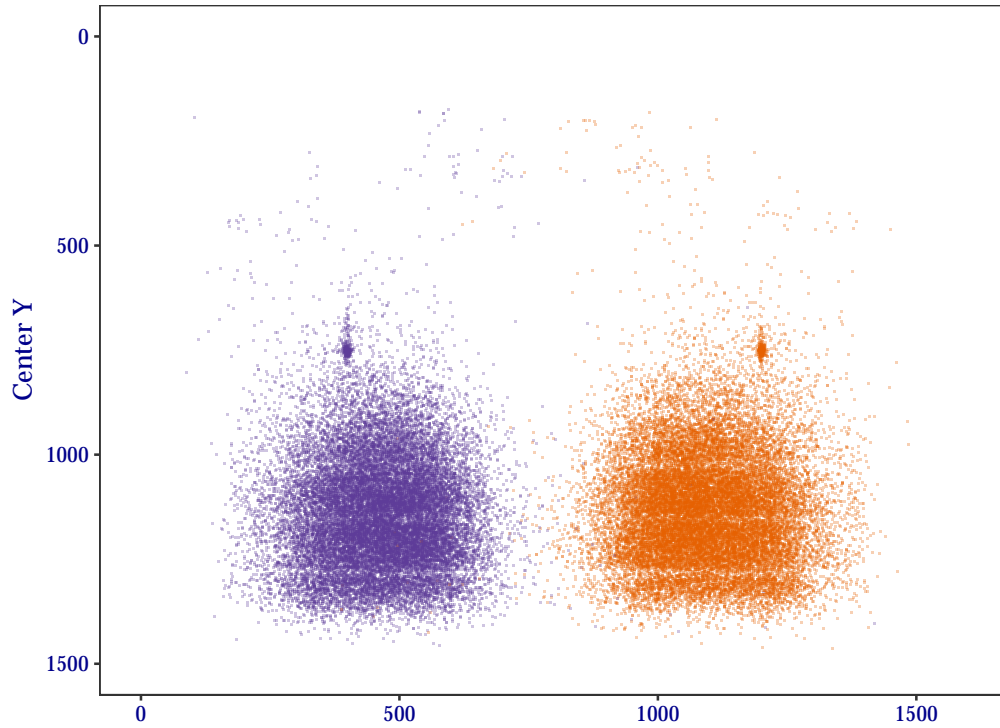
• Left Index • Left Middle • Left Ring • Left Little

27 January 2023, 02:16:38 PM EST

Figure 8: Segmentation centers for left hand ThreeInch data.

### Segmentation Position Centers

Participant: dermalog/0003, FRGPs: 1, 6, Image Kind: Three Inch



• Right Thumb • Left Thumb

27 January 2023, 02:16:50 PM EST

Figure 9: Segmentation centers for thumb ThreeInch data.

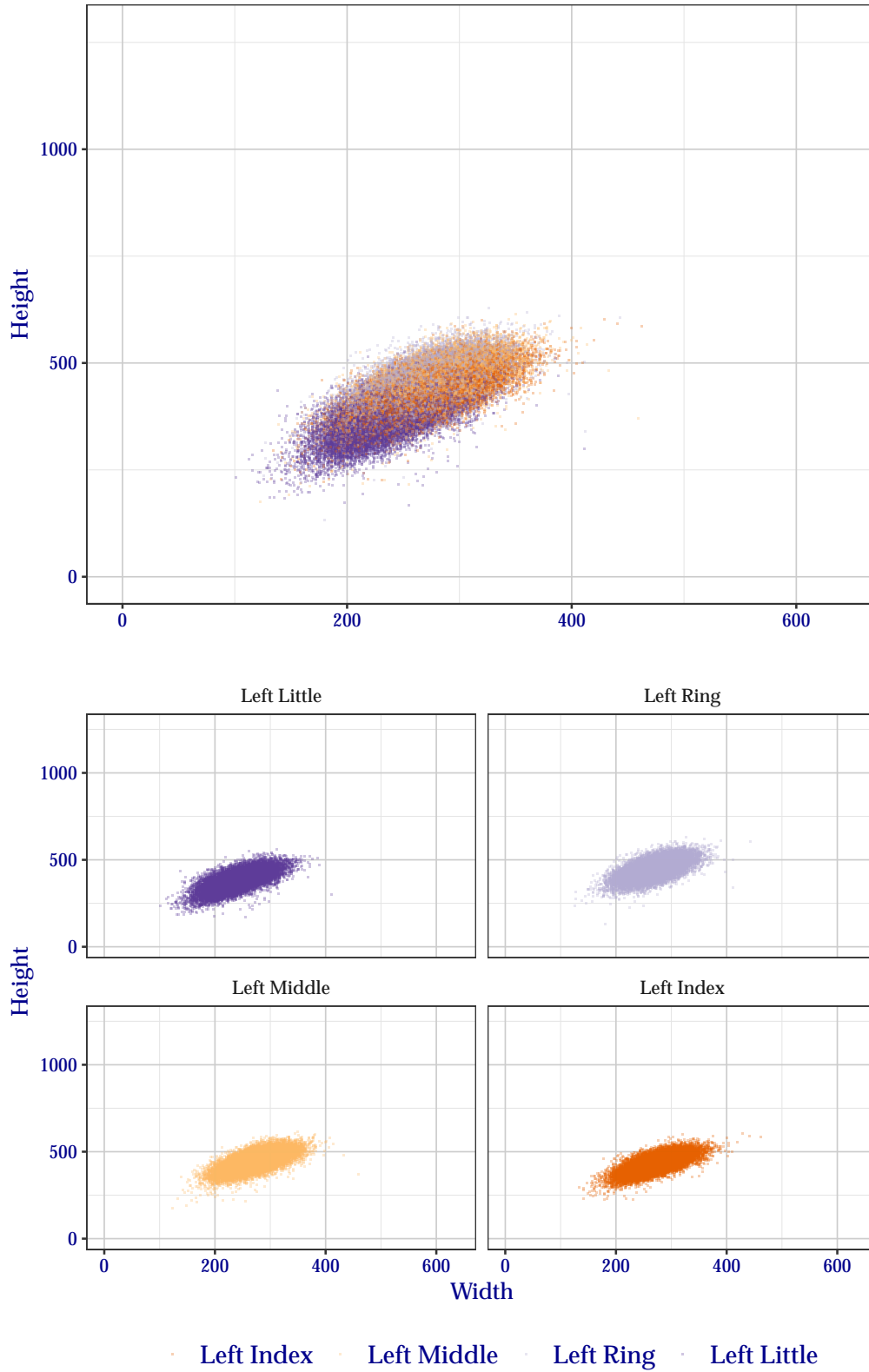
### 3.2.2 Segmentation Dimensions

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: dermalog/0003, FRGPs: 7, 8, 9, 10, Image Kind: Three Inch



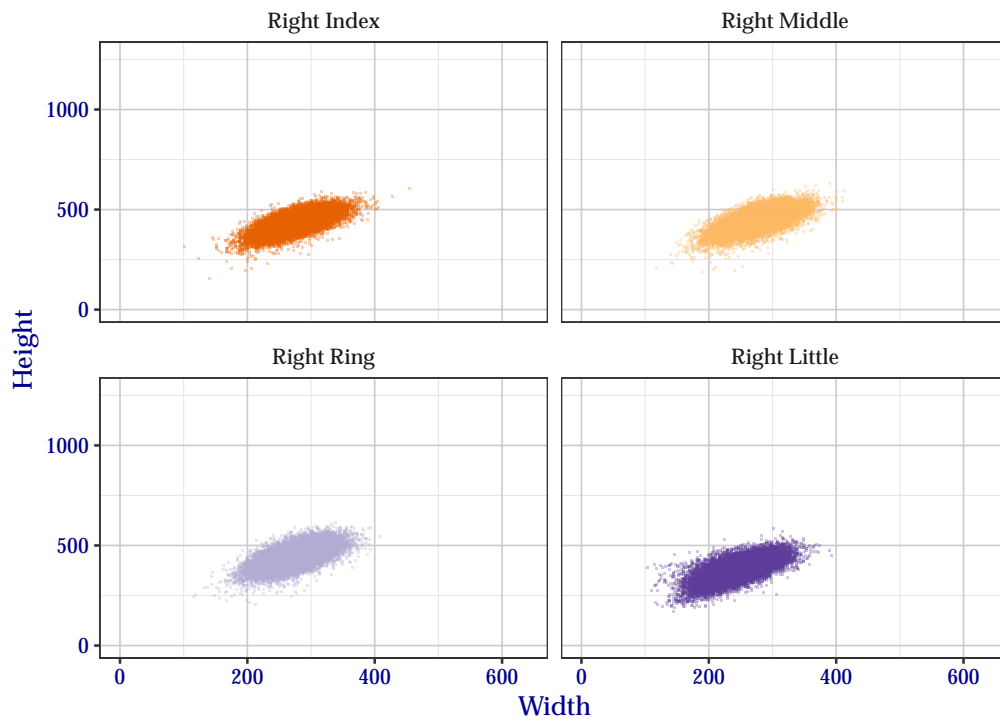
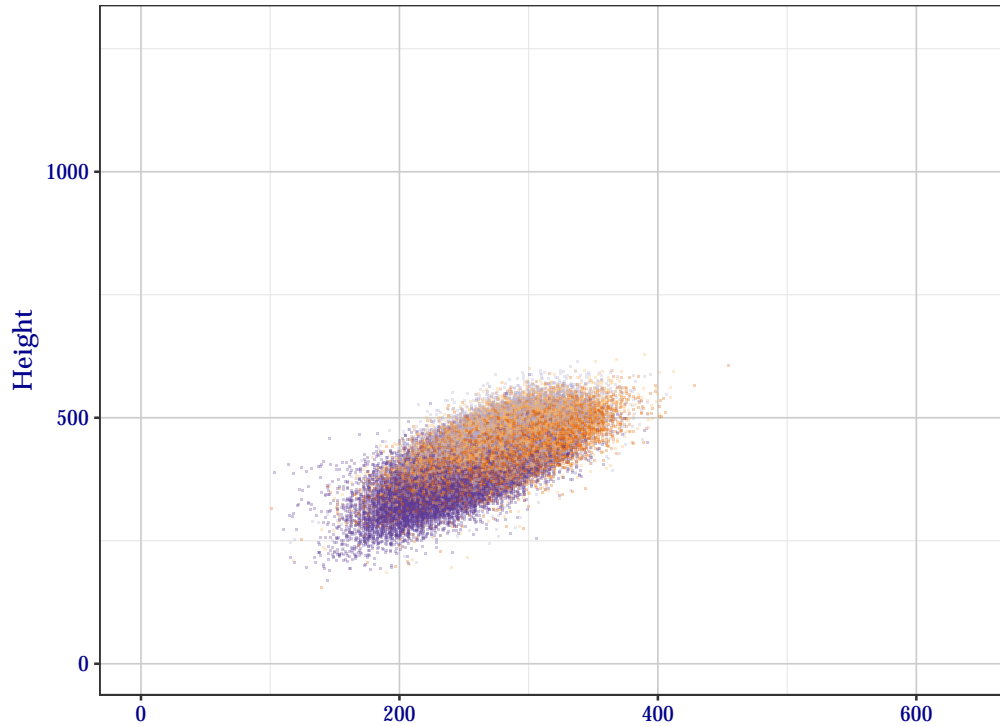
27 January 2023, 02:17:09 PM EST

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



### Segmentation Position Dimensions

Participant: dermalog/0003, FRGPs: 2, 3, 4, 5, Image Kind: Three Inch



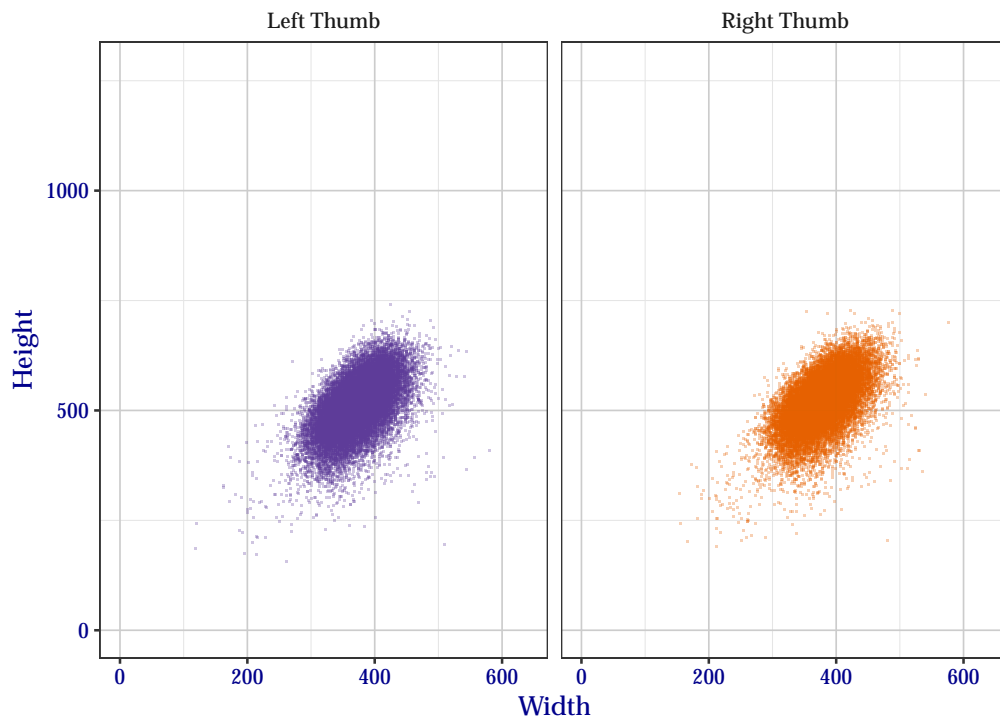
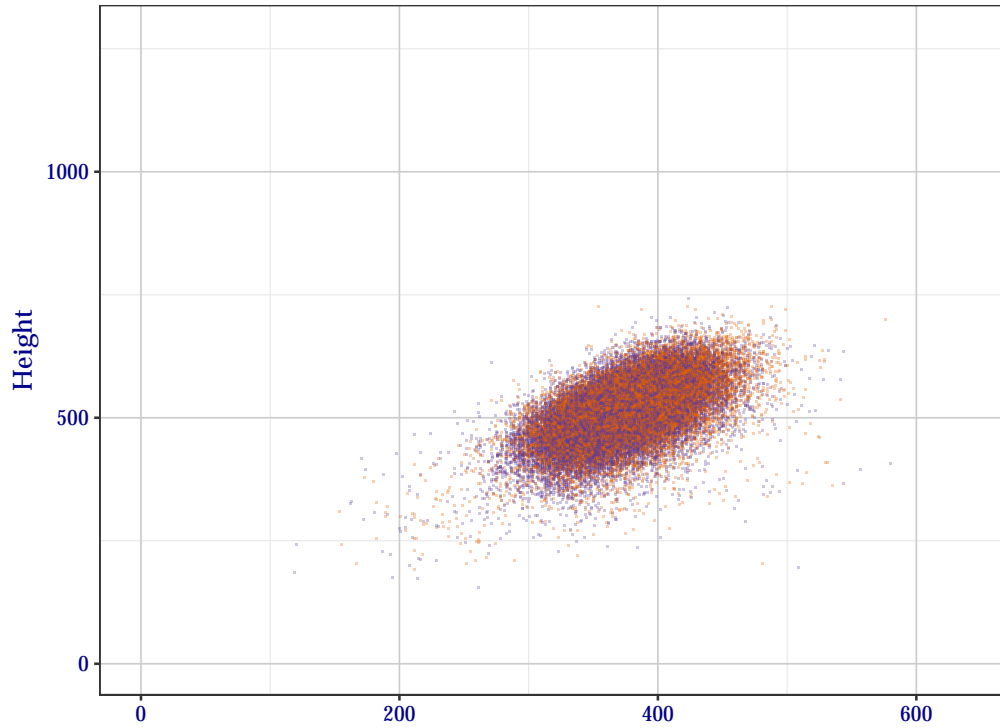
Right Index Right Middle Right Ring Right Little

27 January 2023, 02:17:15 PM EST

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

### Segmentation Position Dimensions

Participant: dermalog/0003, FRGPs: 1, 6, Image Kind: Three Inch



· Right Thumb · Left Thumb

27 January 2023, 02:17:20 PM EST

Figure 12: Segmentation position dimensions for thumb ThreeInch data.

### 3.3 Detailed Segmentation Statistics

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

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

Table 13 shows how successful dermalog+0003 segmented fingers for each subject in the test corpus. Table 14 shows success for specific finger positions over the entire test corpus. Similarly, Table 15 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 16 shows success for combinations of all fingers, Table 17 for just the index and middle fingers, and Table 18 for all except the little finger.

Table 13: 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	99.9
2	99.3	99.3	99.4
3	98.5	98.5	98.5
4	98.1	98.2	98.2
5	95.9	95.9	95.9
6	95.9	95.9	95.9
7	95.8	95.8	95.8
8	95.6	95.6	95.7
9	93.7	93.8	94.3
10	83.9	84.8	87.4

Table 14: 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	96.8	97.0	97.5
Index	99.3	99.3	99.4
Middle	98.9	99.0	99.4
Ring	98.3	98.4	98.9
Little	98.6	98.6	98.7
<b>Left</b>			
Thumb	96.6	96.9	97.6
Index	98.5	98.6	98.7
Middle	98.8	98.8	99.3
Ring	98.8	98.9	99.4
Little	98.7	98.8	98.9

Table 15: 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	99.1	99.1	99.3
Both	94.3	94.8	95.9
<b>Index</b>			
Either	99.8	99.8	99.8
Both	95.3	95.4	95.5
<b>Middle</b>			
Either	99.8	99.8	99.8
Both	95.3	95.4	96.1
<b>Ring</b>			
Either	99.7	99.8	99.9
Both	94.6	94.8	95.7
<b>Little</b>			
Either	99.7	99.8	99.8
Both	94.8	95.0	95.1

Table 16: 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	99.5	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	97.7	97.7	97.8
All Five	88.7	89.1	90.5
<b>Left</b>			
Any	99.7	99.7	99.7
At Least Two	98.5	98.5	98.5
At Least Three	98.3	98.3	98.4
At Least Four	97.6	97.6	97.8
All Five	88.2	88.7	90.2

Table 17: 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	99.9	99.9	99.9
Both	98.3	98.4	98.9
<b>Left</b>			
Either	99.8	99.8	99.8
Both	97.5	97.6	98.1

Table 18: 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	99.9	99.9	99.9
At Least Two	99.7	99.7	99.7
All Three	96.9	97.1	98.0
<b>Left</b>			
Any	99.9	99.9	99.9
At Least Two	99.6	99.6	99.7
All Three	96.5	96.7	97.7

## 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 dermalog+0003 are enumerated in Table 19.

Table 19: Count of self-reported capture-type failure reasoning.

Failure Reason	Images
Vendor Defined	2

#### 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.

dermalog+0003 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 dermalog+0003 are enumerated in Table 20.

Table 20: Count of self-reported segmentation failure reasoning.

Failure Reason	Fingers
Finger Not Found	567
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 21 shows how successful dermalog+0003 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 21: Performance of dermalog+0003 at detecting fingers missing from an image.

Result	Percentage
Missed	29.9
Correctly Identified	64.2
Other Failure: Finger Found, but Can't Segment	0.0
Other Failure: Vendor Defined	0.0
Other Failure: Segmentation Not Attempted	5.9

### 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 22 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 22: 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	0.04	0.04	0.04
Right	0.06	0.06	0.06
Thumbs	0.14	0.14	0.15
Combined	0.08	0.08	0.08

### 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: 99.7%**

Table 23: 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>99.8</b>	0.2	0	0
Right	0.6	<b>99.4</b>	0	0
Thumbs	0	0.1	0	<b>99.9</b>



## 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 24. Results are reported in milliseconds.

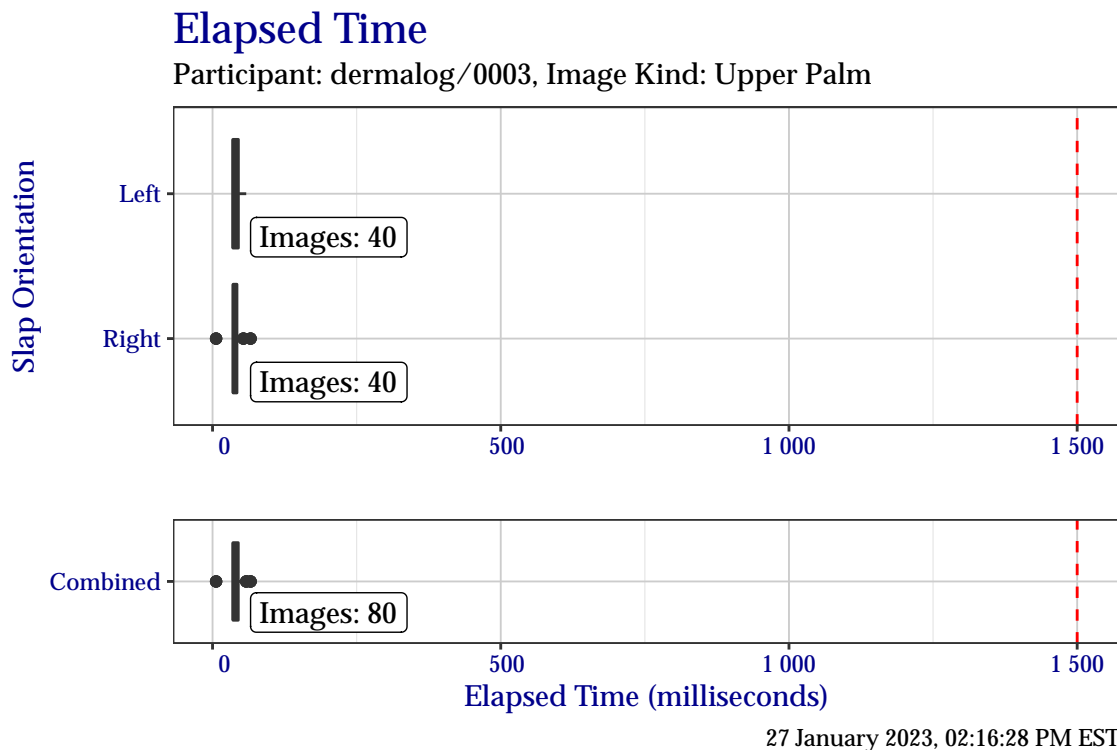


Figure 13: Box plots of elapsed time in milliseconds when segmenting the FiveInch timing test corpus, separated by slap orientation.

Table 24: Elapsed time in milliseconds when segmenting the FiveInch timing test corpus, separated by slap orientation.

	Right	Left	Combined
Minimum	6	35	6
25%	36	35	35
Median	38	38	38
75%	42	45	45
Maximum	66	58	66

## 4.2 Segmentation Centers and Dimensions

### 4.2.1 Segmentation Centers

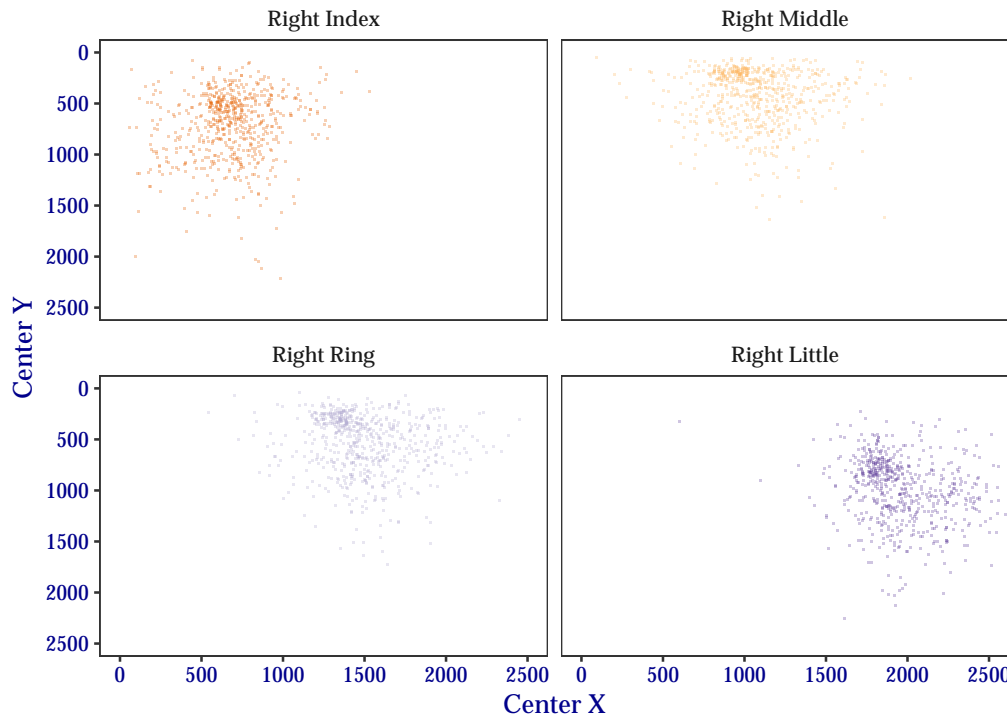
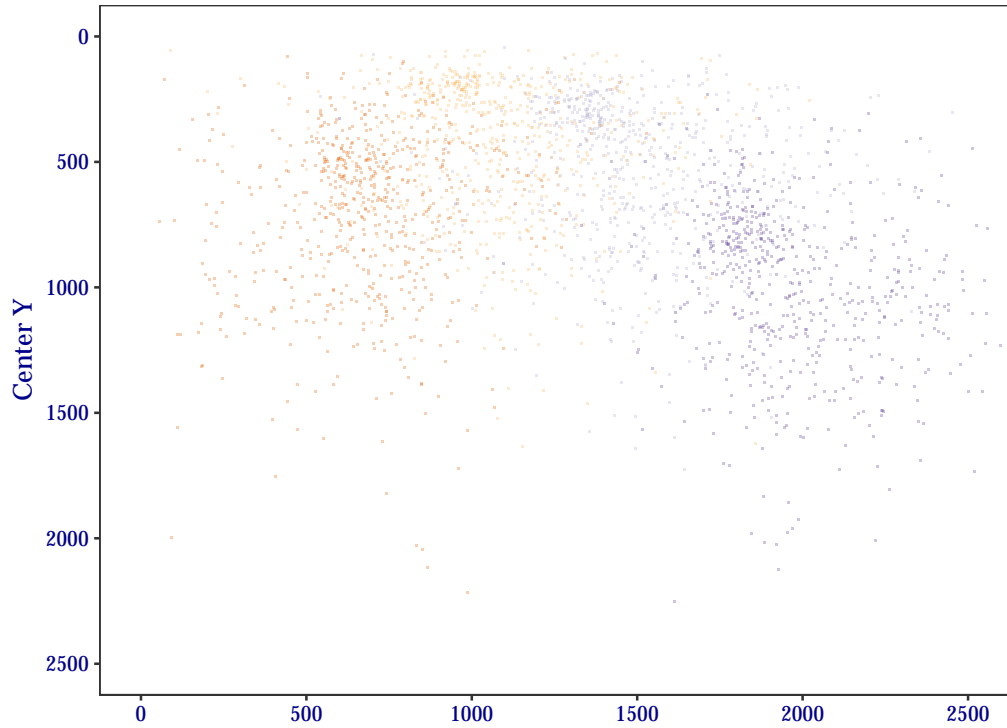
The plots in this section show the distribution of segmentation position centers  $(x, y)$  for FiveInch data. At the top of each figure is a combined plot for all finger positions of a given slap orientation. These figures are isolated in plots faceted at the bottom of the figure.

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: dermalog/0003, FRGPs: 2, 3, 4, 5, Image Kind: Upper Palm



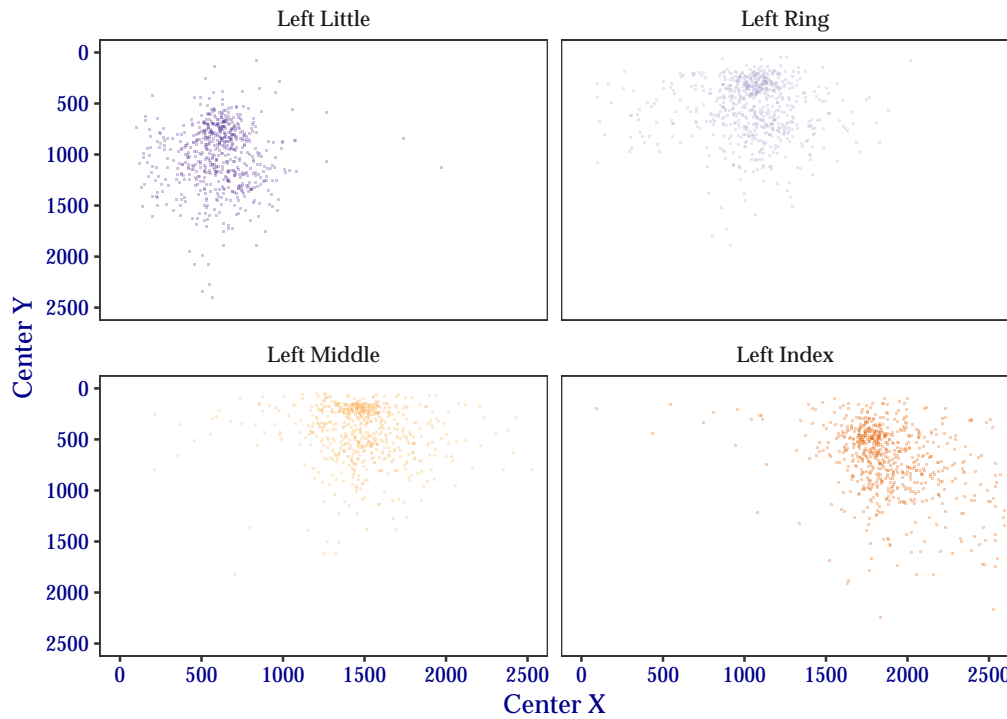
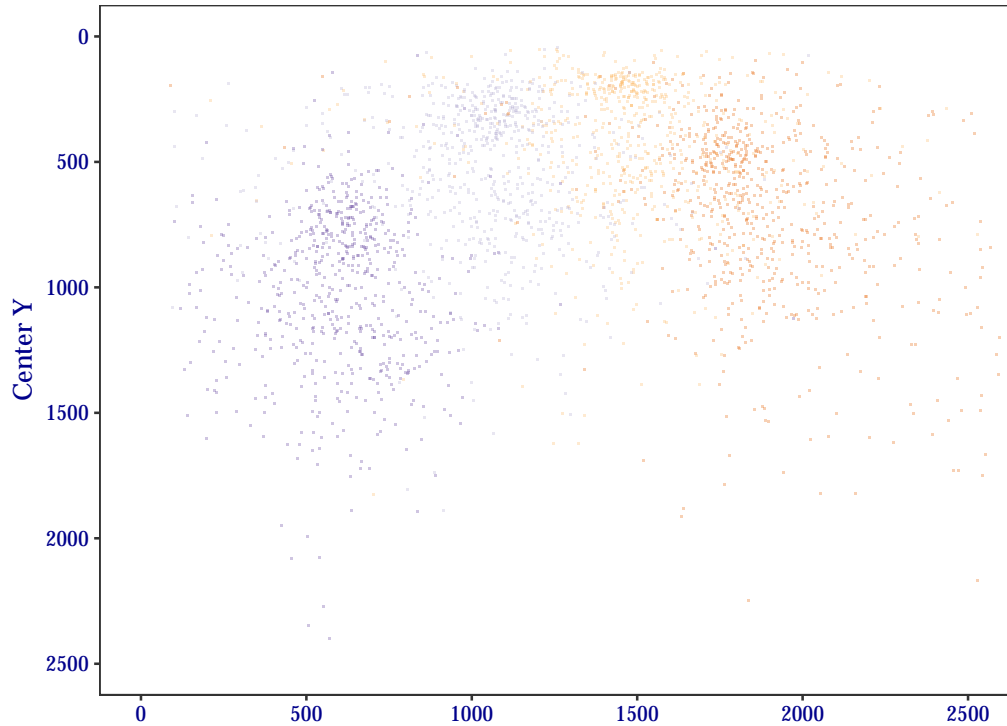
• Right Index • Right Middle • Right Ring • Right Little

27 January 2023, 02:16:55 PM EST

Figure 14: Segmentation centers for right hand FiveInch data.

### Segmentation Position Centers

Participant: dermalog/0003, FRGPs: 7, 8, 9, 10, Image Kind: Upper Palm



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

27 January 2023, 02:16:54 PM EST

Figure 15: Segmentation centers for left hand FiveInch data.

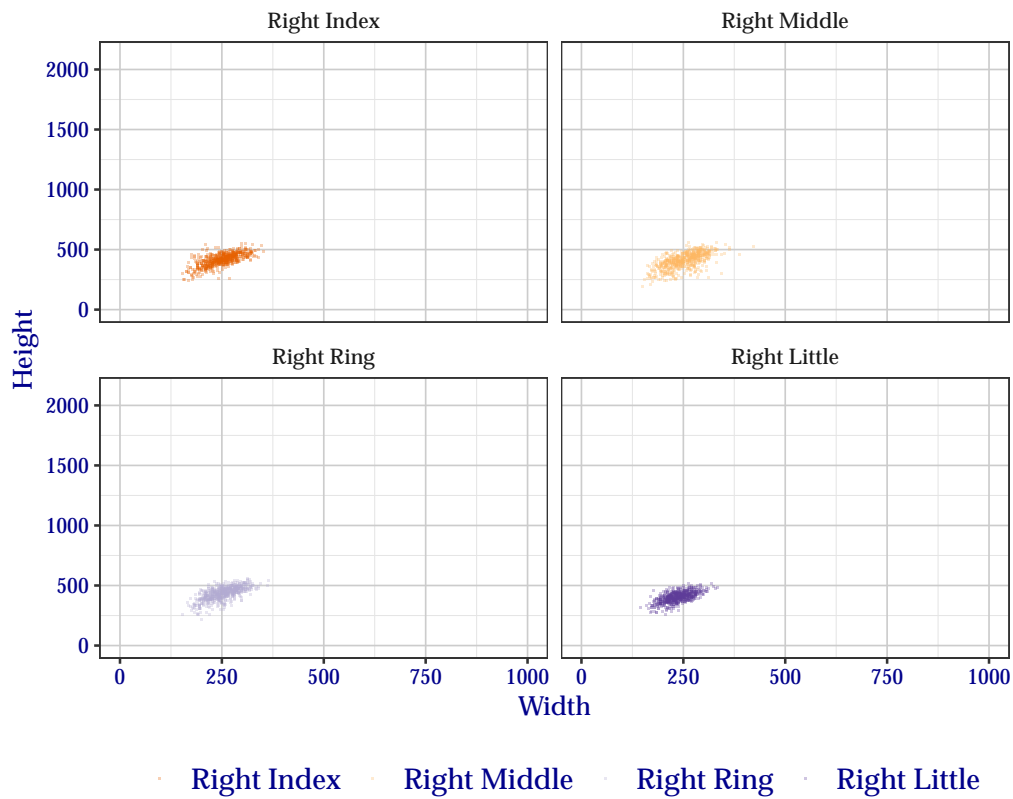
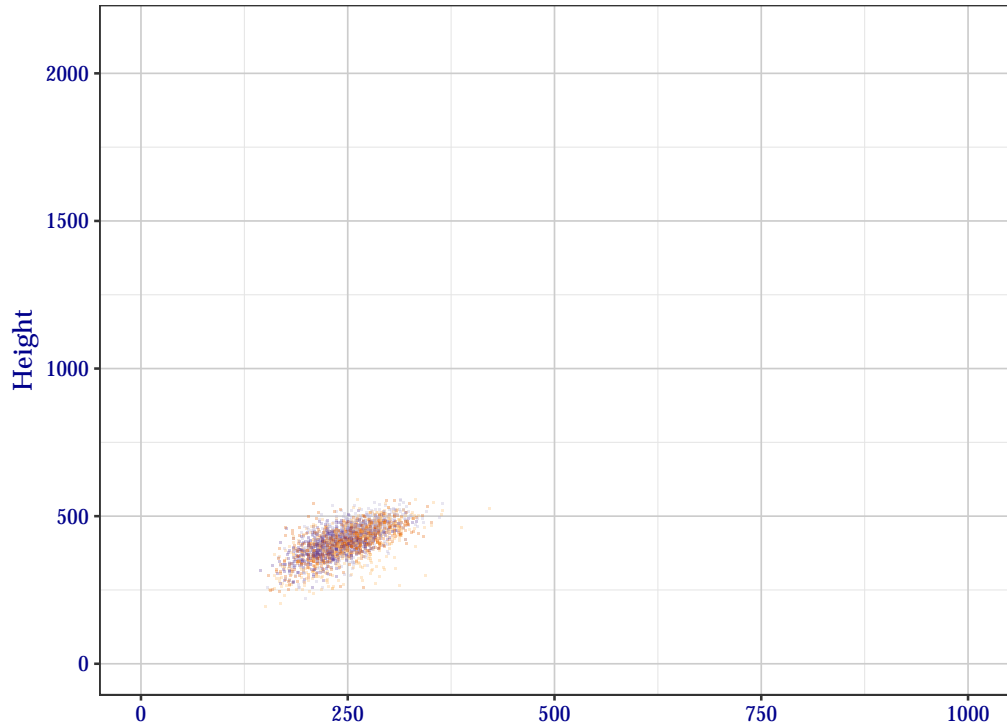
#### 4.2.2 Segmentation Dimensions

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

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

## Segmentation Position Dimensions

Participant: dermalog/0003, FRGPs: 2, 3, 4, 5, Image Kind: Upper Palm

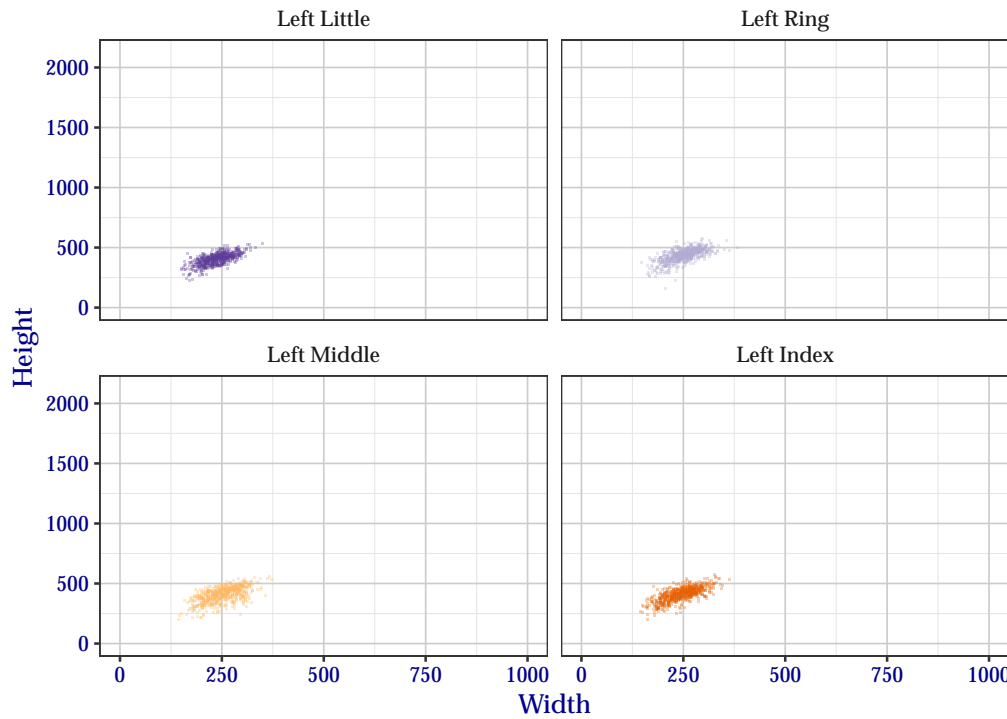
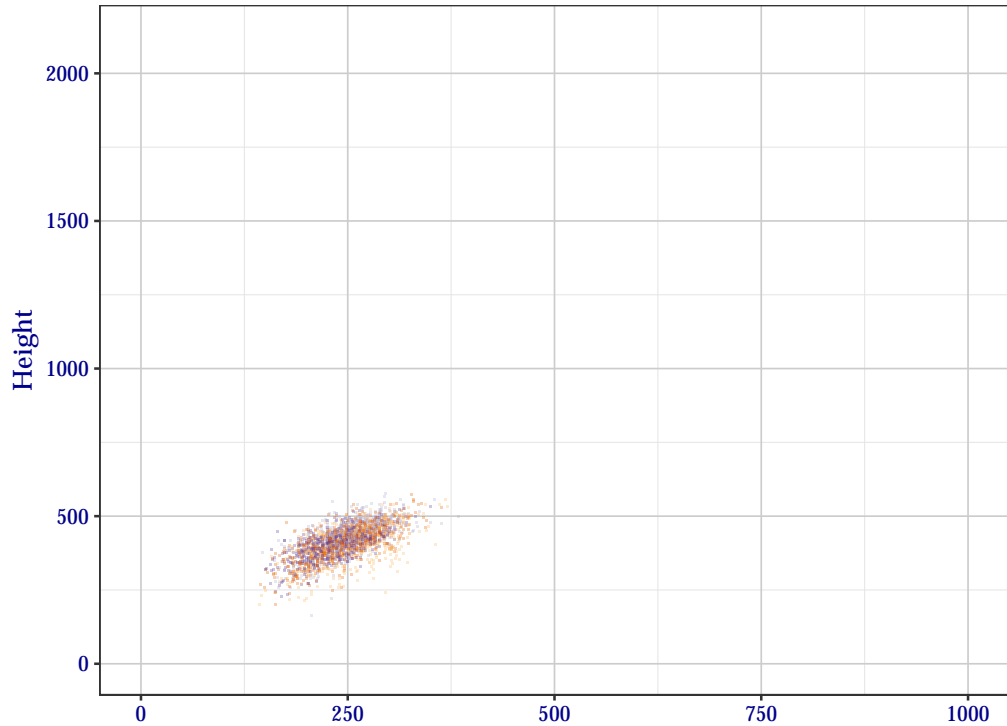


27 January 2023, 02:17:24 PM EST

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

### Segmentation Position Dimensions

Participant: dermalog/0003, FRGPs: 7, 8, 9, 10, Image Kind: Upper Palm



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

27 January 2023, 02:17:23 PM EST

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

### 4.3 Detailed Segmentation Statistics

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

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

Table 25 shows how successful dermalog+0003 segmented fingers for each subject in the test corpus. Table 26 shows success for specific finger positions over the entire test corpus. Similarly, Table 27 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 28 shows success for combinations of all fingers, Table 29 for just the index and middle fingers, and Table 30 for all except the little finger.

Table 25: 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	98.9	98.9	98.9
2	98.0	98.0	98.0
3	96.4	96.6	96.7
4	93.3	93.4	93.5
5	86.3	86.7	86.8
6	79.3	80.1	80.9
7	67.5	68.4	70.5
8	42.2	43.1	46.9

Table 26: 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	87.5	87.8	87.9
Middle	85.1	85.5	87.0
Ring	87.8	88.8	89.5
Little	79.8	79.8	82.0
<b>Left</b>			
Index	85.3	85.4	85.5
Middle	83.3	83.4	83.7
Ring	86.2	87.3	87.7
Little	72.3	72.5	74.4



Table 27: 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	95.5	95.7	95.7
Both	75.9	76.2	76.4
<b>Middle</b>			
Either	94.9	94.9	95.1
Both	72.2	72.7	74.2
<b>Ring</b>			
Either	95.8	96.4	96.4
Both	76.8	78.3	79.3
<b>Little</b>			
Either	92.9	92.9	93.1
Both	58.0	58.2	62.1

Table 28: 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
<b>Right</b>			
Any	95.7	95.7	95.7
At Least Two	92.4	92.4	92.6
At Least Three	86.3	86.7	87.8
All Four	65.7	67.0	70.3
<b>Left</b>			
Any	95.2	95.4	95.4
At Least Two	91.0	91.0	91.0
At Least Three	82.6	83.6	84.4
All Four	58.2	58.8	60.6

Table 29: 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	91.9	92.0	92.3
Both Index and Middle	80.7	81.2	82.6
<b>Left</b>			
Either Index or Middle	91.5	91.5	91.6
Both Index and Middle	77.1	77.3	77.6

Table 30: 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	94.1	94.1	94.1
At Least Two	89.4	89.6	90.0
All Three	76.9	78.3	80.2
<b>Left</b>			
Any	93.5	93.6	93.6
At Least Two	87.9	88.5	88.7
All Three	73.3	74.0	74.5

## 4.4 Handling Troublesome Images

### 4.4.1 Capture Failures

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

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

Reasons for capture-type failures reported by dermalog+0003 are enumerated in Table 31.

Table 31: Count of self-reported capture-type failure reasoning.

Failure Reason	Images
Vendor Defined	16

#### 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.

dermalog+0003 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 dermalog+0003 are enumerated in Table 32.

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

Failure Reason	Fingers
Finger Not Found	872
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 dermalog+0003 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 dermalog+0003 at detecting fingers missing from an image.

Result	Percentage
Missed	28.4
Correctly Identified	65.5
Other Failure: Finger Found, but Can't Segment	0.0
Other Failure: Vendor Defined	0.0
Other Failure: Segmentation Not Attempted	6.1

#### 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	5.97	6.10	6.63
Right	4.92	5.05	5.05
Combined	5.44	5.58	5.84

## 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:** 91.2%

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	Skip
Left	<b>91.5</b>	7.6	0.9
Right	7.5	<b>90.9</b>	1.6

## 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.

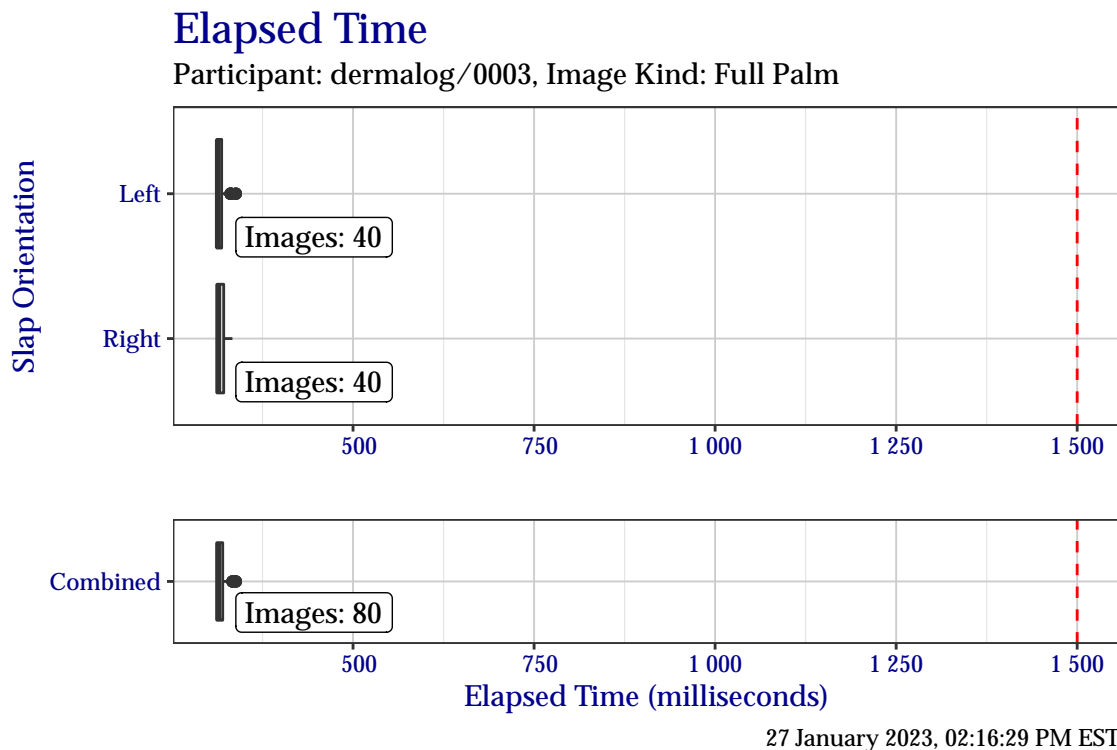


Figure 18: Box plots of elapsed time in milliseconds when segmenting the EightInch timing test corpus, separated by slap orientation.

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

	Right	Left	Combined
Minimum	312	311	311
25%	312	312	312
Median	314	313	314
75%	321	319	320
Maximum	333	338	338

## 5.2 Segmentation Centers and Dimensions

### 5.2.1 Segmentation Centers

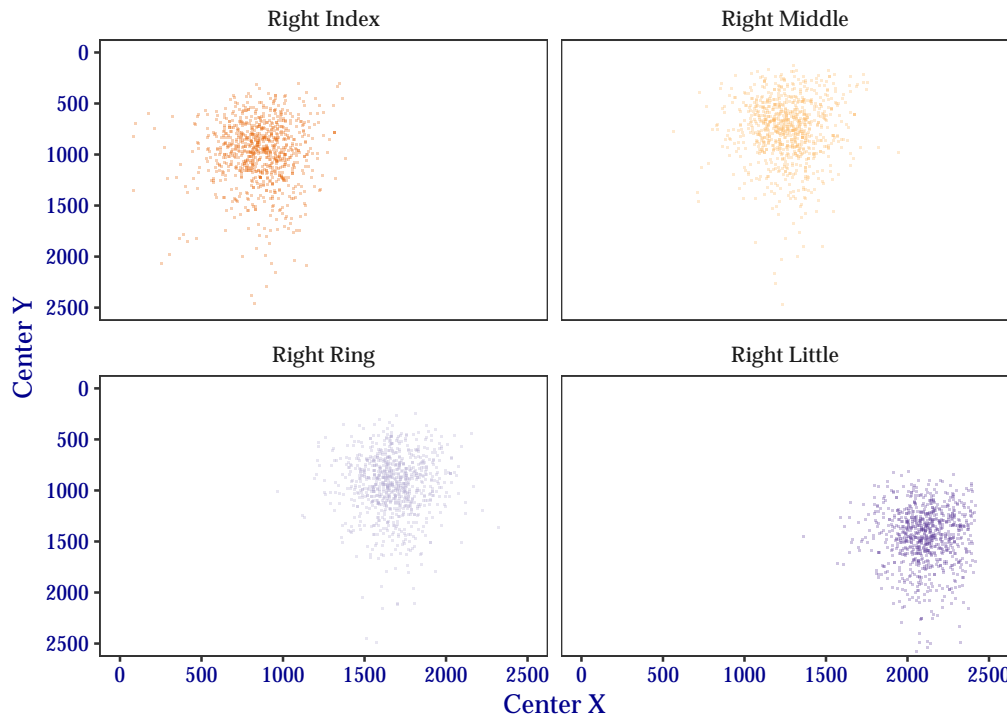
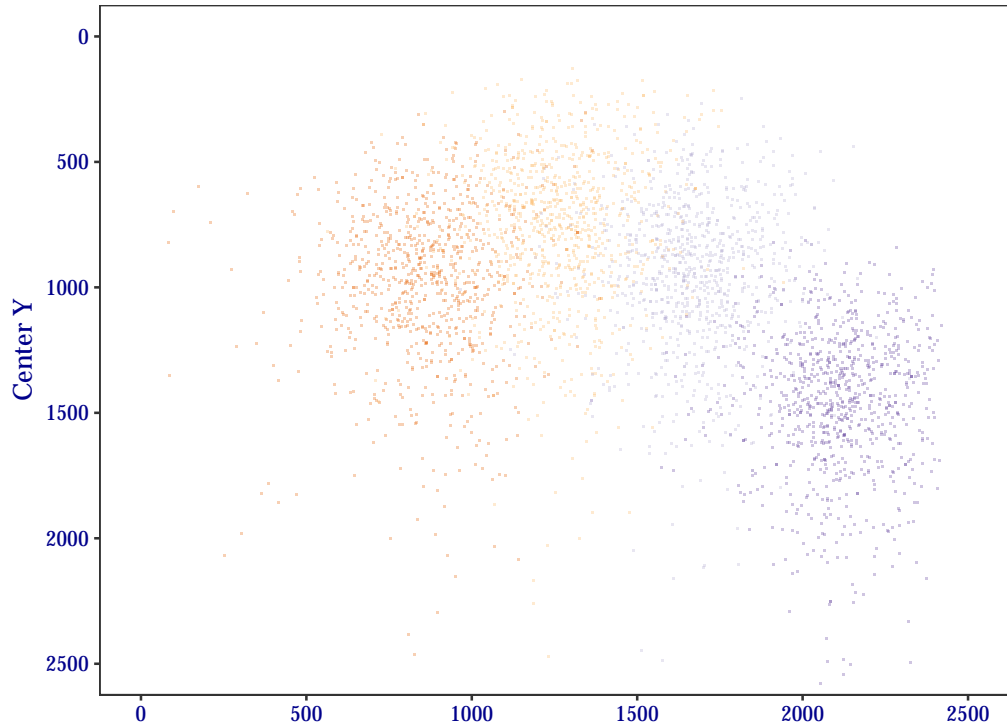
The plots in this section show the distribution of segmentation position centers  $(x, y)$  for EightInch data. At the top of each figure is a combined plot for all finger positions of a given slap orientation. These figures are isolated in plots faceted at the bottom of the figure.

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: dermalog/0003, FRGPs: 2, 3, 4, 5, Image Kind: Full Palm



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

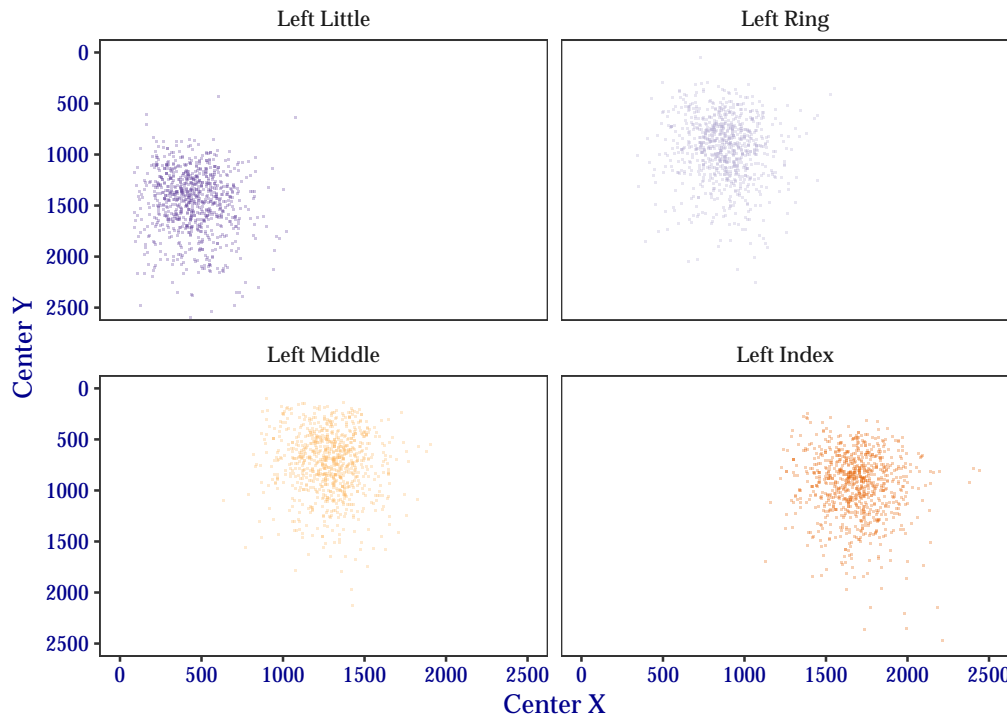
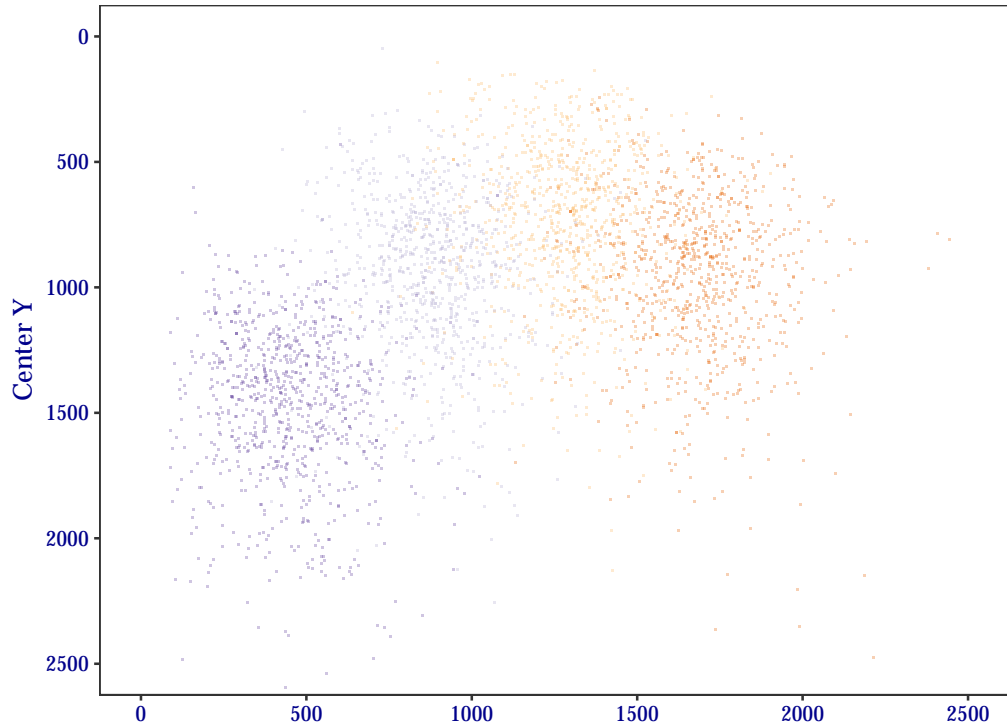
27 January 2023, 02:16:58 PM EST

Figure 19: Segmentation centers for right hand EightInch data.



### Segmentation Position Centers

Participant: dermalog/0003, FRGPs: 7, 8, 9, 10, Image Kind: Full Palm



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

27 January 2023, 02:16:57 PM EST

Figure 20: Segmentation centers for left hand EightInch data.

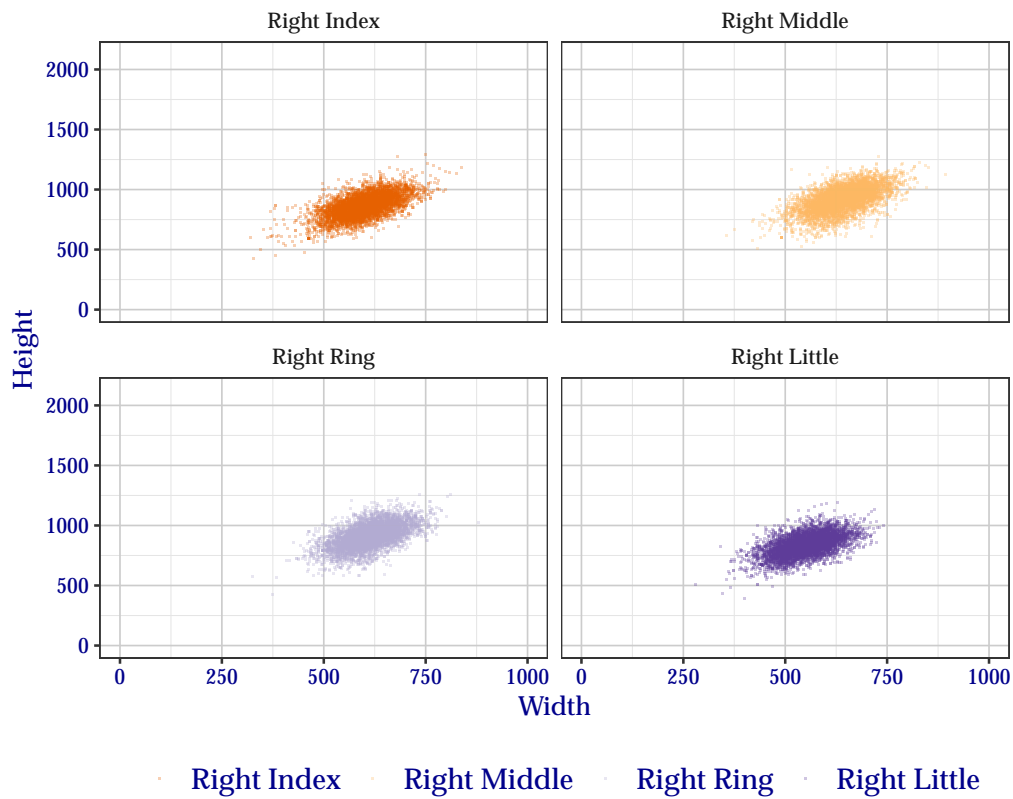
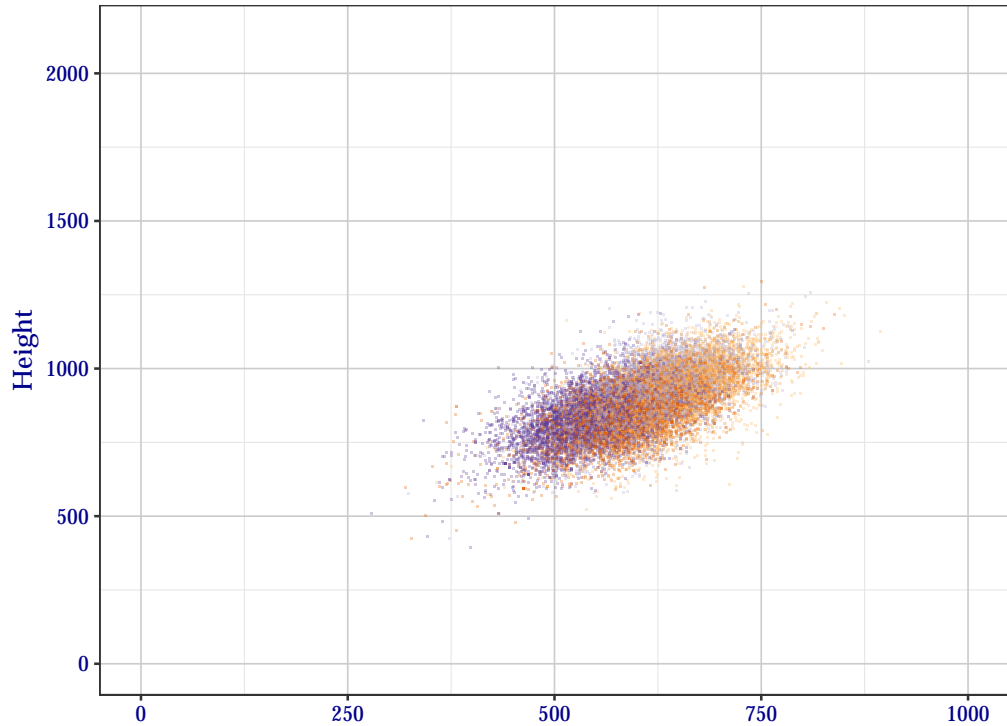
## 5.2.2 Segmentation Dimensions

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: dermalog/0003, FRGPs: 2, 3, 4, 5, Image Kind: Full Palm

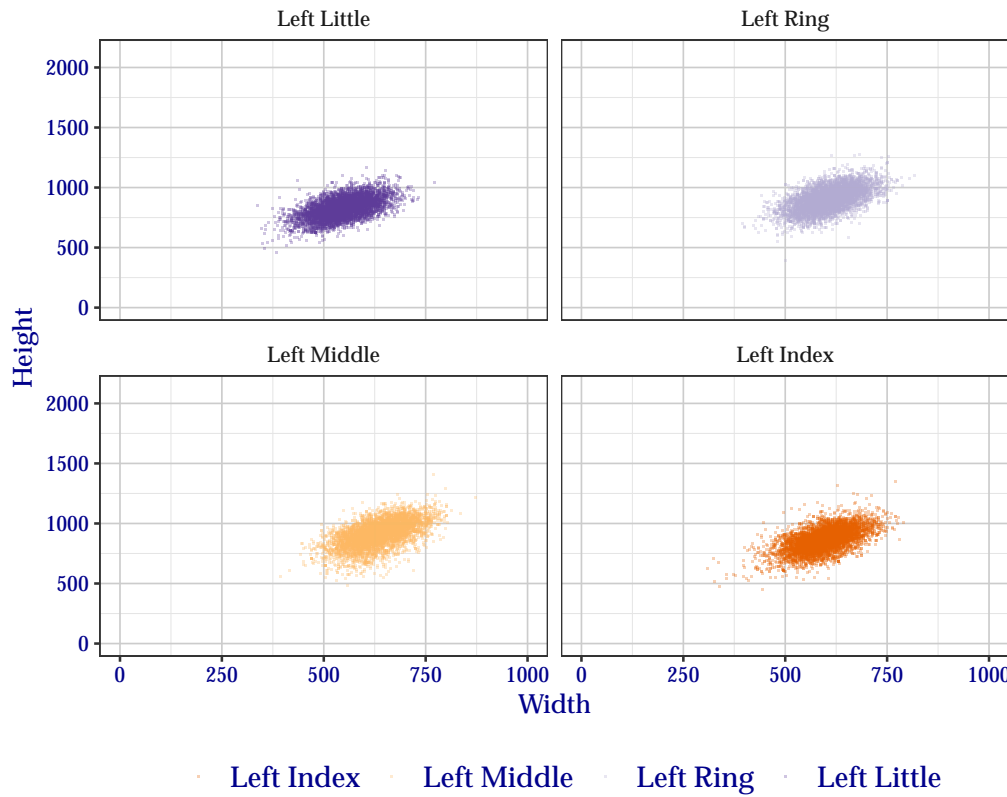
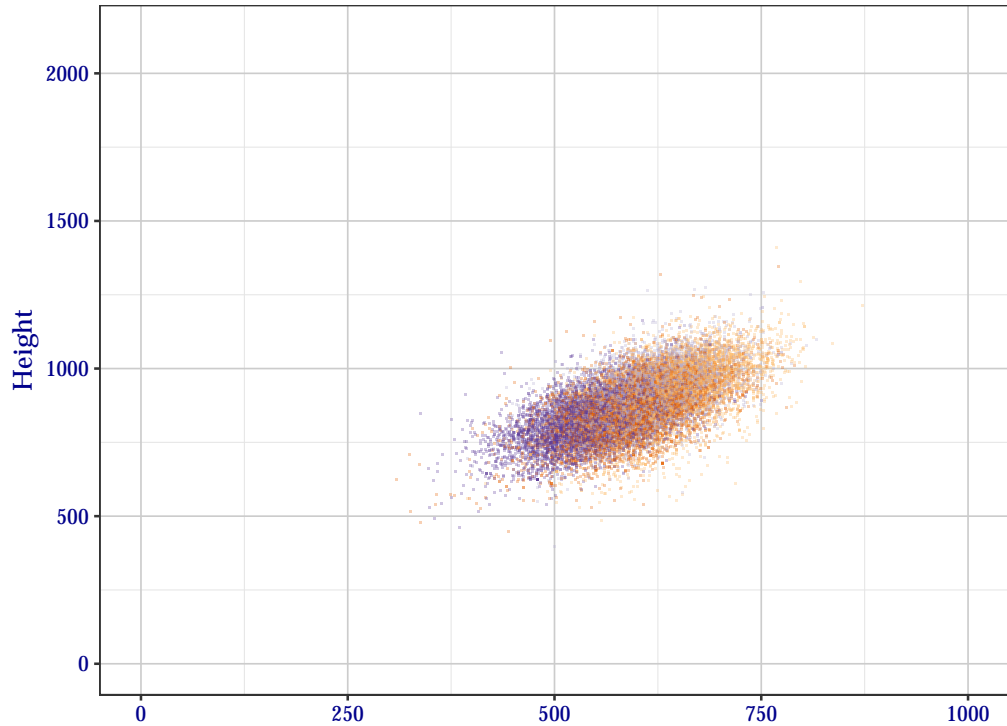


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Figure 21: Segmentation position dimensions for right hand EightInch data.

### Segmentation Position Dimensions

Participant: dermalog/0003, FRGPs: 7, 8, 9, 10, Image Kind: Full Palm



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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 dermalog+0003 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	99.9	99.9	99.9
3	99.5	99.5	99.7
4	99.0	99.3	99.3
5	98.3	98.4	98.5
6	96.2	96.2	97.0
7	90.5	91.1	92.5
8	71.5	72.8	75.3

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
<b>Right</b>			
Index	94.5	94.8	94.9
Middle	95.1	95.3	96.1
Ring	94.7	95.4	95.9
Little	93.3	93.6	94.3
<b>Left</b>			
Index	95.7	96.1	96.3
Middle	94.4	94.6	95.4
Ring	93.9	94.3	95.5
Little	93.2	93.2	93.8

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
<b>Index</b>			
Either	99.4	99.4	99.4
Both	90.8	91.5	91.8
<b>Middle</b>			
Either	98.9	99.1	99.1
Both	90.6	90.8	92.4
<b>Ring</b>			
Either	98.9	99.0	99.2
Both	89.8	90.7	92.2
<b>Little</b>			
Either	99.3	99.4	99.5
Both	87.2	87.4	88.5

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
<b>Right</b>			
Any	99.3	99.4	99.4
At Least Two	98.7	98.9	99.1
At Least Three	96.0	96.4	97.0
All Four	83.6	84.4	85.6
<b>Left</b>			
Any	99.8	99.8	99.8
At Least Two	98.5	98.5	99.0
At Least Three	96.2	96.3	96.8
All Four	82.8	83.6	85.5

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
<b>Right</b>			
Either Index or Middle	98.0	98.3	98.4
Both Index and Middle	91.5	91.8	92.6
<b>Left</b>			
Either Index or Middle	98.5	98.5	98.5
Both Index and Middle	91.6	92.2	93.2

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
<b>Right</b>			
Any	99.0	99.2	99.3
At Least Two	97.1	97.4	97.8
All Three	88.2	89.0	89.8
<b>Left</b>			
Any	99.2	99.2	99.2
At Least Two	97.1	97.2	97.8
All Three	87.7	88.5	90.2

## 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.

dermalog+0003 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.

dermalog+0003 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 dermalog+0003 are enumerated in Table 43.

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

Failure Reason	Fingers
Finger Not Found	412
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 dermalog+0003 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 dermalog+0003 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	0.92	0.92	0.92
Right	0.34	0.34	0.34
Combined	0.63	0.63	0.63

## 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: 98.3%**

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	<b>98.8</b>	1.2
Right	2.1	<b>97.9</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 47, results are shown of how successful dermalog+0003 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	99.8 [99.7, 99.9]	99.8 [99.8, 99.9]	99.9 [99.8, 99.9]
2	99.6 [99.5, 99.7]	99.6 [99.5, 99.7]	99.8 [99.7, 99.8]
3	99.3 [99.2, 99.4]	99.4 [99.2, 99.5]	99.5 [99.4, 99.6]
4	98.5 [98.3, 98.7]	98.7 [98.5, 98.9]	98.8 [98.6, 99.0]
5	95.1 [94.7, 95.4]	95.1 [94.7, 95.5]	95.4 [95.0, 95.8]
6	94.0 [93.6, 94.4]	94.3 [93.8, 94.7]	94.9 [94.5, 95.2]
7	91.2 [90.7, 91.7]	92.1 [91.6, 92.5]	93.0 [92.5, 93.4]
8	79.5 [78.8, 80.2]	83.3 [82.6, 84.0]	84.6 [83.9, 85.2]

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
<b>Right</b>			
Index	96.1 [95.9, 96.3]	97.1 [96.9, 97.4]	97.5 [97.3, 97.7]
Middle	96.4 [96.2, 96.7]	97.1 [96.9, 97.3]	97.7 [97.5, 97.9]
Ring	95.9 [95.7, 96.2]	96.8 [96.6, 97.0]	97.4 [97.2, 97.6]
Little	96.8 [96.5, 97.0]	97.2 [96.9, 97.4]	98.0 [97.8, 98.1]
<b>Left</b>			
Index	97.1 [96.9, 97.3]	97.6 [97.3, 97.8]	97.8 [97.6, 98.0]
Middle	96.8 [96.6, 97.1]	97.6 [97.4, 97.8]	97.9 [97.7, 98.1]
Ring	96.6 [96.3, 96.8]	97.6 [97.3, 97.8]	97.8 [97.6, 98.0]
Little	97.1 [96.8, 97.3]	97.4 [97.1, 97.6]	97.7 [97.5, 97.9]

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
<b>Index</b>			
Either	99.1 [99.0, 99.3]	99.2 [99.1, 99.4]	99.4 [99.2, 99.5]
Both	90.3 [89.7, 90.8]	91.5 [91.1, 92.0]	92.0 [91.5, 92.5]
<b>Middle</b>			
Either	99.2 [99.0, 99.3]	99.3 [99.1, 99.4]	99.4 [99.3, 99.5]
Both	90.1 [89.6, 90.6]	91.4 [90.9, 91.9]	92.1 [91.7, 92.6]
<b>Ring</b>			
Either	99.2 [99.1, 99.4]	99.4 [99.3, 99.6]	99.5 [99.4, 99.7]
Both	89.6 [89.0, 90.2]	91.2 [90.7, 91.7]	92.0 [91.5, 92.4]
<b>Little</b>			
Either	99.1 [99.0, 99.3]	99.2 [99.0, 99.3]	99.3 [99.2, 99.5]
Both	90.4 [89.9, 90.9]	91.1 [90.6, 91.5]	92.1 [91.6, 92.5]

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
<b>Right</b>			
Any	99.6 [99.5, 99.6]	99.6 [99.5, 99.6]	99.7 [99.7, 99.8]
At Least Two	99.0 [98.9, 99.1]	99.0 [99.0, 99.2]	99.5 [99.4, 99.5]
At Least Three	97.5 [97.6, 97.9]	97.8 [97.9, 98.2]	98.5 [98.4, 98.6]
All Four	89.2 [89.8, 90.3]	91.7 [92.1, 92.6]	92.8 [92.9, 93.4]
<b>Left</b>			
Any	99.5 [99.5, 99.6]	99.5 [99.5, 99.6]	99.7 [99.7, 99.8]
At Least Two	99.1 [98.9, 99.1]	99.2 [99.0, 99.2]	99.4 [99.4, 99.5]
At Least Three	98.0 [97.6, 97.9]	98.3 [97.9, 98.2]	98.6 [98.4, 98.6]
All Four	91.0 [89.8, 90.3]	93.1 [92.1, 92.6]	93.6 [92.9, 93.4]

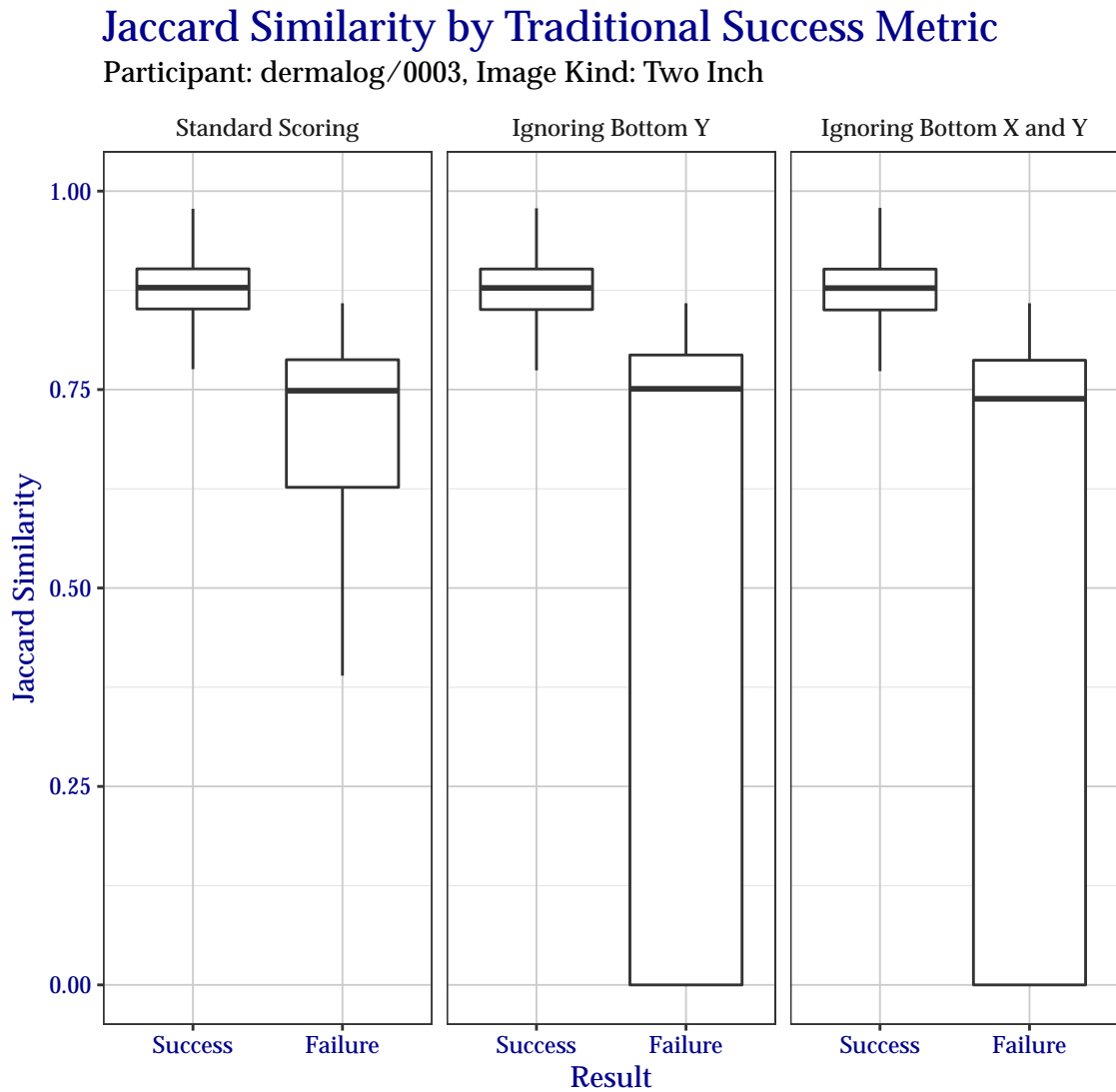
Table 51: Percentage of segmentation success by hand when only considering combinations of index and middle fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values 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
<b>Right</b>			
Either Index or Middle	99.1 [98.9, 99.1]	99.2 [99.0, 99.2]	99.4 [99.3, 99.4]
Both Index and Middle	93.5 [93.9, 94.4]	95.0 [95.3, 95.7]	95.8 [95.9, 96.2]
<b>Left</b>			
Either Index or Middle	99.0 [98.9, 99.1]	99.1 [99.0, 99.2]	99.3 [99.3, 99.4]
Both Index and Middle	95.0 [93.9, 94.4]	96.1 [95.3, 95.7]	96.4 [95.9, 96.2]

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
<b>Right</b>			
Any	99.4 [99.3, 99.4]	99.4 [99.4, 99.5]	99.7 [99.6, 99.7]
At Least Two	98.2 [98.2, 98.4]	98.4 [98.4, 98.6]	99.0 [98.8, 99.0]
All Three	90.9 [91.5, 92.0]	93.1 [93.6, 94.1]	93.9 [94.2, 94.6]
<b>Left</b>			
Any	99.4 [99.3, 99.4]	99.4 [99.4, 99.5]	99.6 [99.6, 99.7]
At Least Two	98.4 [98.2, 98.4]	98.6 [98.4, 98.6]	98.9 [98.8, 99.0]
All Three	92.8 [91.5, 92.0]	94.6 [93.6, 94.1]	95.0 [94.2, 94.6]

## A.2 Jaccard Index

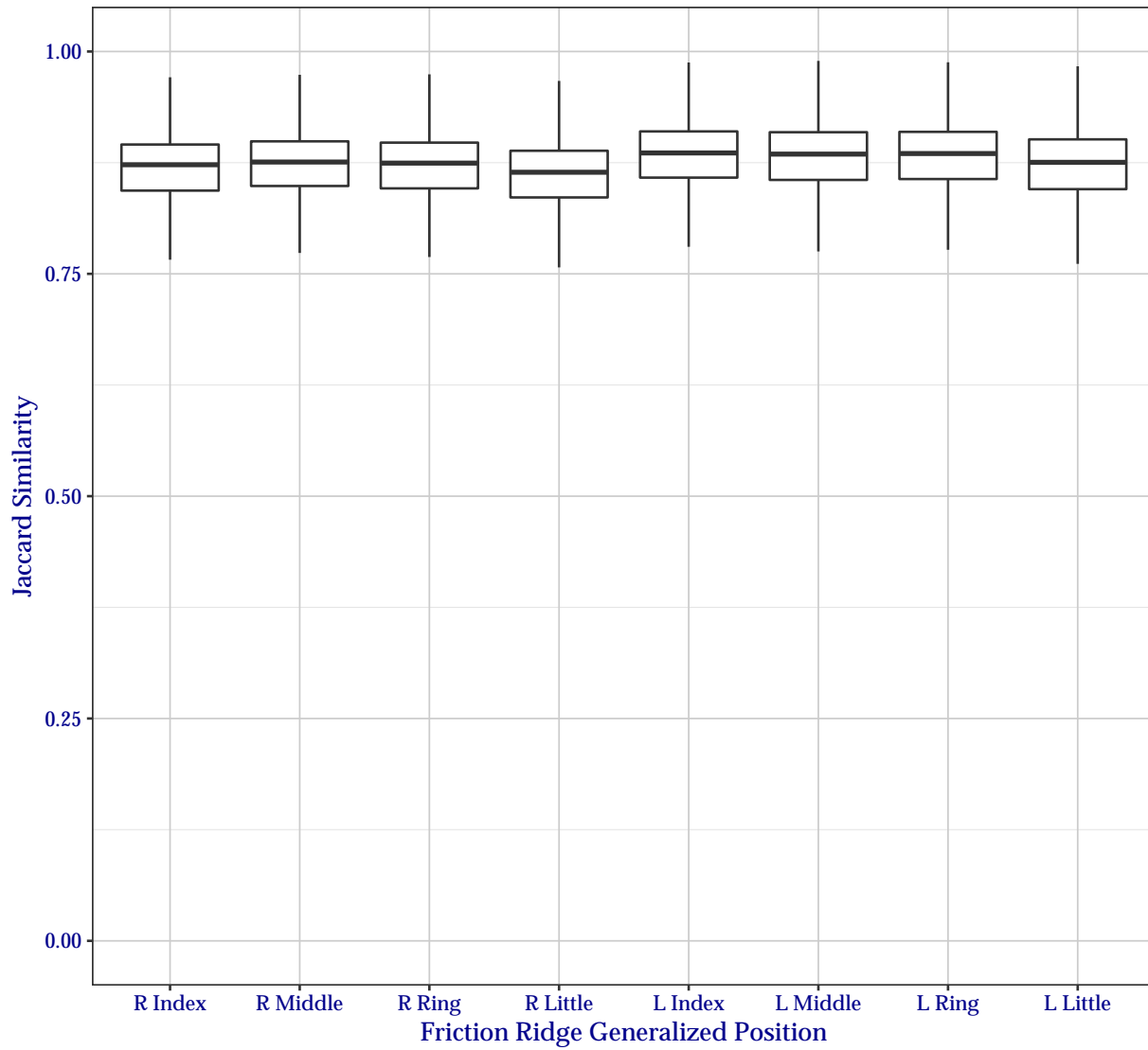


27 January 2023, 02:31:32 PM EST

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

### Jaccard Similarity by Friction Ridge Generalized Position

Participant: dermalog/0003, 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	$\geq 0.5$	$\geq 0.6$	$\geq 0.7$	$\geq 0.8$	$\geq 0.9$	$\geq 0.95$	$\geq 0.98$
1	100.0	100.0	99.9	99.7	79.2	10.2	0.3
2	99.9	99.9	99.9	99.3	59.3	1.9	0.0
3	99.8	99.8	99.7	98.6	37.9	0.3	0.0
4	99.6	99.5	99.1	97.2	20.0	0.0	0.0
5	95.8	95.8	95.7	94.2	8.6	0	0
6	95.7	95.7	95.6	91.3	3.0	0	0
7	95.3	95.2	94.6	83.3	0.7	0	0
8	91.4	91.0	87.5	60.2	0.1	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
<b>Right</b>						
Index	1.4	0.0	0.4	6.8	71.2	20.2
Middle	0.3	0.1	0.4	5.7	69.4	24.1
Ring	0.2	0.1	0.5	6.6	70.1	22.5
Little	0.6	0.0	0.6	8.2	75.6	15.0
<b>Left</b>						
Index	1.3	0.0	0.4	3.8	59.4	35.1
Middle	0.6	0.1	0.6	5.1	59.2	34.4
Ring	0.4	0.1	0.8	5.1	59.2	34.4
Little	1.3	0.1	0.6	6.4	65.6	26.0

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	$\geq 0.5$	$\geq 0.6$	$\geq 0.7$	$\geq 0.8$	$\geq 0.9$	$\geq 0.95$	$\geq 0.98$
<b>Right</b>							
Any	100.0	100.0	100.0	99.4	49.1	1.7	0.0
At Least Two	100.0	99.9	99.9	98.3	23.5	0.1	0.0
At Least Three	99.8	99.8	99.7	94.2	7.8	0.0	0.0
All Four	97.7	97.5	95.8	76.1	1.3	0.0	0.0
<b>Left</b>							
Any	99.9	99.9	99.9	99.5	65.5	8.3	0.2
At Least Two	99.8	99.8	99.8	98.6	40.2	1.6	0.0
At Least Three	99.6	99.5	99.3	95.5	19.1	0.2	0.0
All Four	97.0	96.8	94.9	79.9	5.2	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	$\geq 0.5$	$\geq 0.6$	$\geq 0.7$	$\geq 0.8$	$\geq 0.9$	$\geq 0.95$	$\geq 0.98$
<b>Right</b>							
Either Index or Middle	99.9	99.9	99.9	98.4	36.1	1.0	0.0
Both Index and Middle	98.4	98.3	97.5	86.4	8.1	0.0	0.0
<b>Left</b>							
Either Index or Middle	99.8	99.8	99.7	98.6	52.3	5.2	0.2
Both Index and Middle	98.4	98.2	97.3	89.5	17.2	0.4	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	$\geq 0.5$	$\geq 0.6$	$\geq 0.7$	$\geq 0.8$	$\geq 0.9$	$\geq 0.95$	$\geq 0.98$
<b>Right</b>							
Any	100.0	100.0	100.0	99.2	45.1	1.5	0.0
At Least Two	99.9	99.9	99.8	96.3	17.8	0.1	0.0
All Three	98.2	98.0	96.9	81.9	3.8	0.0	0.0
<b>Left</b>							
Any	99.9	99.9	99.8	99.2	61.3	7.0	0.2
At Least Two	99.7	99.7	99.5	97.0	32.3	1.1	0.0
All Three	98.1	97.9	96.4	85.5	10.3	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 dermalog+0003 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]	99.9 [99.8, 99.9]
2	99.3 [99.2, 99.4]	99.3 [99.2, 99.4]	99.4 [99.3, 99.5]
3	98.5 [98.3, 98.6]	98.5 [98.3, 98.6]	98.5 [98.4, 98.6]
4	98.1 [98.0, 98.3]	98.2 [98.0, 98.3]	98.2 [98.1, 98.4]
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 [95.6, 96.1]	95.8 [95.6, 96.1]	95.8 [95.6, 96.1]
8	95.6 [95.3, 95.8]	95.6 [95.3, 95.9]	95.7 [95.4, 95.9]
9	93.7 [93.4, 94.0]	93.8 [93.6, 94.1]	94.3 [94.0, 94.6]
10	83.9 [83.5, 84.4]	84.8 [84.4, 85.2]	87.4 [87.0, 87.8]

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
<b>Right</b>			
Thumb	96.8 [96.5, 97.0]	97.0 [96.7, 97.2]	97.5 [97.3, 97.7]
Index	99.3 [99.1, 99.4]	99.3 [99.2, 99.4]	99.4 [99.3, 99.5]
Middle	98.9 [98.8, 99.1]	99.0 [98.9, 99.1]	99.4 [99.2, 99.4]
Ring	98.3 [98.1, 98.4]	98.4 [98.2, 98.5]	98.9 [98.7, 99.0]
Little	98.6 [98.4, 98.7]	98.6 [98.5, 98.8]	98.7 [98.5, 98.8]
<b>Left</b>			
Thumb	96.6 [96.4, 96.8]	96.9 [96.7, 97.1]	97.6 [97.4, 97.8]
Index	98.5 [98.4, 98.7]	98.6 [98.4, 98.7]	98.7 [98.5, 98.8]
Middle	98.8 [98.6, 98.9]	98.8 [98.7, 98.9]	99.3 [99.2, 99.4]
Ring	98.8 [98.6, 98.9]	98.9 [98.8, 99.0]	99.4 [99.3, 99.5]
Little	98.7 [98.6, 98.8]	98.8 [98.7, 98.9]	98.9 [98.7, 99.0]

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
<b>Thumb</b>			
Either	99.1 [99.0, 99.2]	99.1 [99.0, 99.2]	99.3 [99.2, 99.4]
Both	94.3 [94.0, 94.6]	94.8 [94.5, 95.1]	95.9 [95.6, 96.1]
<b>Index</b>			
Either	99.8 [99.8, 99.9]	99.8 [99.8, 99.9]	99.8 [99.8, 99.9]
Both	95.3 [95.0, 95.5]	95.4 [95.1, 95.6]	95.5 [95.3, 95.8]
<b>Middle</b>			
Either	99.8 [99.7, 99.8]	99.8 [99.7, 99.8]	99.8 [99.8, 99.9]
Both	95.3 [95.0, 95.6]	95.4 [95.1, 95.6]	96.1 [95.9, 96.4]
<b>Ring</b>			
Either	99.7 [99.7, 99.8]	99.8 [99.7, 99.8]	99.9 [99.8, 99.9]
Both	94.6 [94.3, 94.9]	94.8 [94.5, 95.1]	95.7 [95.4, 95.9]
<b>Little</b>			
Either	99.7 [99.7, 99.8]	99.8 [99.7, 99.8]	99.8 [99.7, 99.8]
Both	94.8 [94.6, 95.1]	95.0 [94.7, 95.3]	95.1 [94.8, 95.4]

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
<b>Right</b>			
Any	99.5 [99.5, 99.6]	99.5 [99.5, 99.6]	99.5 [99.6, 99.7]
At Least Two	98.5 [98.4, 98.6]	98.5 [98.4, 98.6]	98.5 [98.4, 98.6]
At Least Three	98.4 [98.2, 98.5]	98.4 [98.2, 98.5]	98.4 [98.3, 98.5]
At Least Four	97.7 [97.5, 97.8]	97.7 [97.5, 97.8]	97.8 [97.7, 97.9]
All Five	88.7 [88.2, 88.7]	89.1 [88.6, 89.2]	90.5 [90.1, 90.6]
<b>Left</b>			
Any	99.7 [99.5, 99.6]	99.7 [99.5, 99.6]	99.7 [99.6, 99.7]
At Least Two	98.5 [98.4, 98.6]	98.5 [98.4, 98.6]	98.5 [98.4, 98.6]
At Least Three	98.3 [98.2, 98.5]	98.3 [98.2, 98.5]	98.4 [98.3, 98.5]
At Least Four	97.6 [97.5, 97.8]	97.6 [97.5, 97.8]	97.8 [97.7, 97.9]
All Five	88.2 [88.2, 88.7]	88.7 [88.6, 89.2]	90.2 [90.1, 90.6]

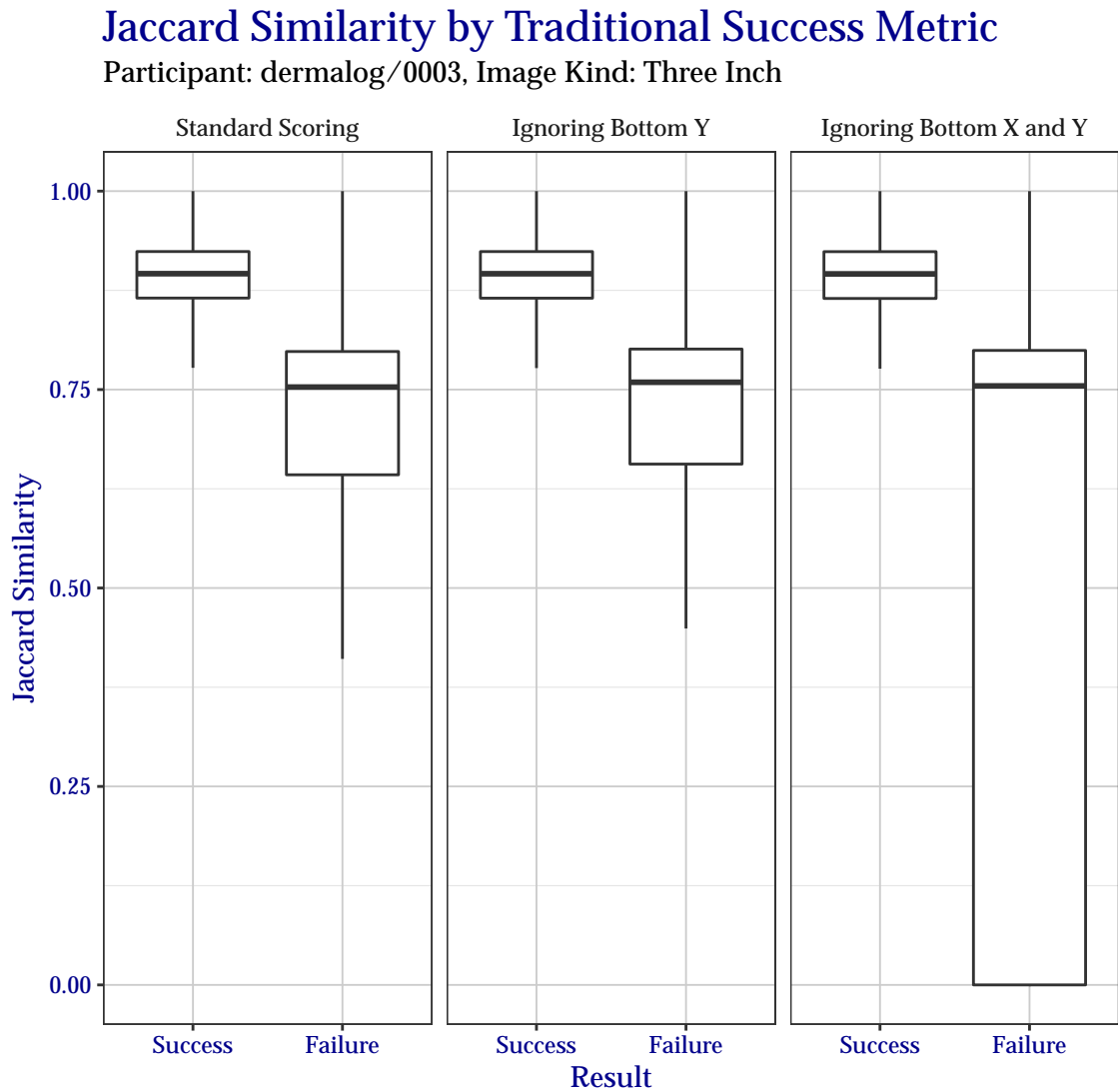
Table 62: Percentage of segmentation success by hand when only considering combinations of index and middle fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values 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
<b>Right</b>			
Either Index or Middle	99.9 [99.8, 99.9]	99.9 [99.8, 99.9]	99.9 [99.8, 99.9]
Both Index and Middle	98.3 [97.8, 98.0]	98.4 [97.9, 98.1]	98.9 [98.4, 98.6]
<b>Left</b>			
Either Index or Middle	99.8 [99.8, 99.9]	99.8 [99.8, 99.9]	99.8 [99.8, 99.9]
Both Index and Middle	97.5 [97.8, 98.0]	97.6 [97.9, 98.1]	98.1 [98.4, 98.6]

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.

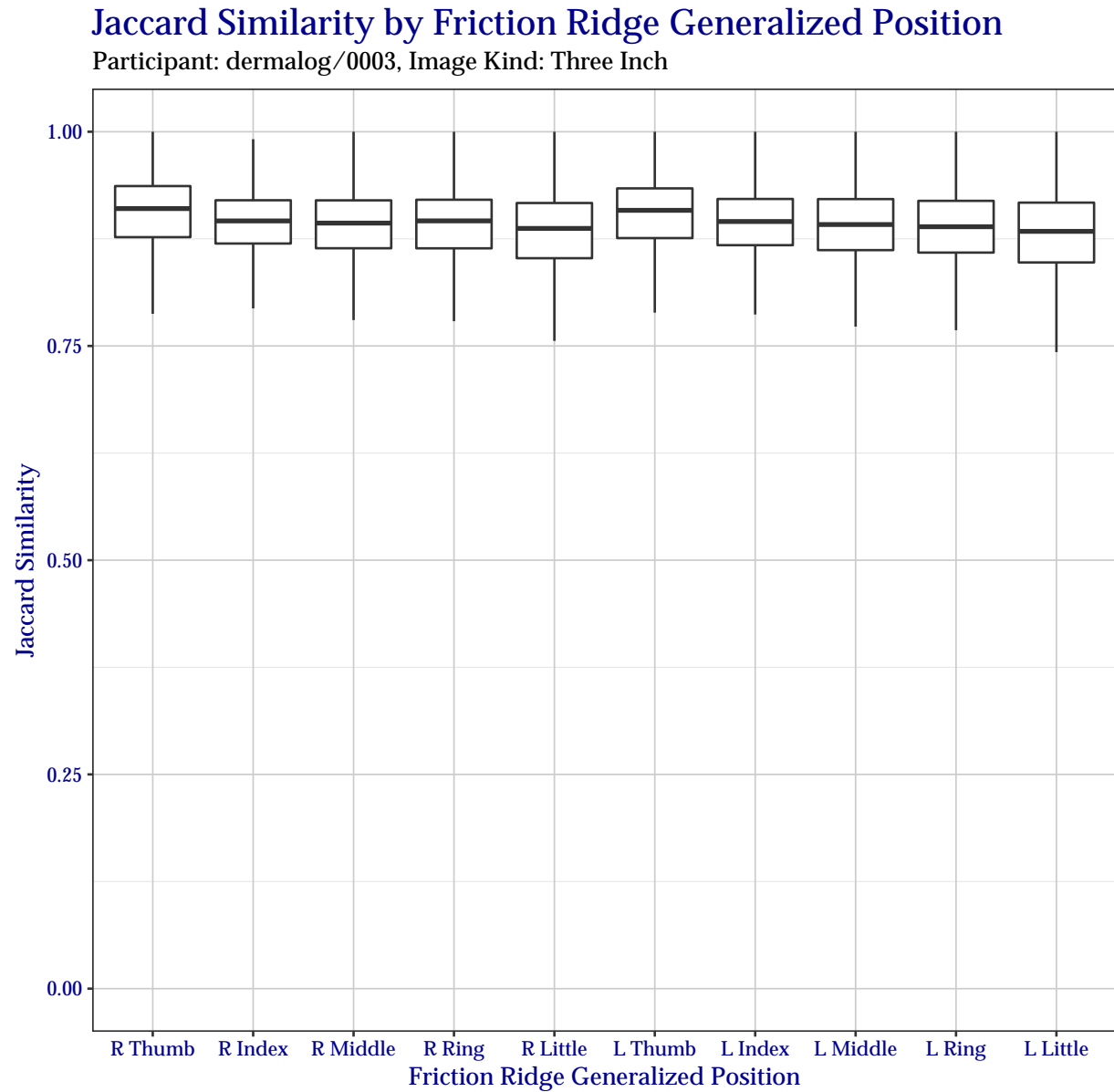
Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
<b>Right</b>			
Any	99.9 [99.9, 99.9]	99.9 [99.9, 100.0]	99.9 [99.9, 100.0]
At Least Two	99.7 [99.6, 99.7]	99.7 [99.6, 99.7]	99.7 [99.7, 99.8]
All Three	96.9 [96.5, 96.8]	97.1 [96.7, 97.0]	98.0 [97.7, 97.9]
<b>Left</b>			
Any	99.9 [99.9, 99.9]	99.9 [99.9, 100.0]	99.9 [99.9, 100.0]
At Least Two	99.6 [99.6, 99.7]	99.6 [99.6, 99.7]	99.7 [99.7, 99.8]
All Three	96.5 [96.5, 96.8]	96.7 [96.7, 97.0]	97.7 [97.7, 97.9]

## 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.



27 January 2023, 02:45:12 PM EST

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	$\geq 0.5$	$\geq 0.6$	$\geq 0.7$	$\geq 0.8$	$\geq 0.9$	$\geq 0.95$	$\geq 0.98$
1	100.0	100.0	100.0	99.8	96.2	49.8	4.3
2	99.9	99.9	99.8	99.3	89.7	21.1	0.2
3	98.6	98.5	98.5	98.3	79.1	7.3	0.0
4	98.4	98.3	98.2	97.9	65.2	2.0	0.0
5	95.9	95.9	95.9	95.8	48.6	0.5	0.0
6	95.9	95.9	95.9	95.4	32.6	0.1	0
7	95.9	95.9	95.8	94.4	19.2	0.0	0
8	95.8	95.8	95.7	92.1	9.4	0	0
9	95.4	95.4	95.0	86.0	3.6	0	0
10	94.0	93.6	91.0	66.8	0.8	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
<b>Right</b>						
Thumb	1.0	0.1	0.3	2.9	36.9	58.8
Index	0.2	0.0	0.2	2.9	51.3	45.4
Middle	0.1	0.0	0.3	4.0	52.2	43.4
Ring	0.1	0.0	0.5	4.9	48.5	46.0
Little	0.2	0.1	0.5	6.7	53.6	38.9
<b>Left</b>						
Thumb	1.1	0.1	0.4	3.1	37.8	57.5
Index	0.1	0.1	0.1	2.9	51.7	45.1
Middle	0.2	0.0	0.2	3.8	53.6	42.2
Ring	0.1	0.1	0.4	4.0	55.1	40.3
Little	0.3	0.1	0.5	6.7	54.9	37.5

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	$\geq 0.5$	$\geq 0.6$	$\geq 0.7$	$\geq 0.8$	$\geq 0.9$	$\geq 0.95$	$\geq 0.98$
<b>Right</b>							
Any	99.9	99.9	99.9	99.5	87.5	28.5	2.1
At Least Two	98.5	98.5	98.5	98.0	66.1	7.5	0.1
At Least Three	98.5	98.5	98.4	96.8	43.7	2.0	0.0
At Least Four	98.4	98.3	98.0	93.5	23.2	0.4	0.0
All Five	93.9	93.7	92.4	78.4	7.5	0.0	0.0
<b>Left</b>							
Any	99.9	99.9	99.9	99.7	87.0	31.7	2.3
At Least Two	98.5	98.5	98.5	98.2	62.5	8.7	0.1
At Least Three	98.5	98.4	98.4	97.4	40.8	2.0	0.0
At Least Four	98.3	98.3	98.1	94.1	21.7	0.3	0.0
All Five	93.8	93.6	92.2	77.5	6.2	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	$\geq 0.5$	$\geq 0.6$	$\geq 0.7$	$\geq 0.8$	$\geq 0.9$	$\geq 0.95$	$\geq 0.98$
<b>Right</b>							
Either Index or Middle	99.9	99.9	99.9	98.7	61.9	11.3	0.8
Both Index and Middle	99.8	99.7	99.3	93.6	27.0	1.8	0.0
<b>Left</b>							
Either Index or Middle	99.9	99.9	99.9	99.2	60.4	14.4	1.1
Both Index and Middle	99.8	99.7	99.4	93.5	26.9	2.3	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	$\geq 0.5$	$\geq 0.6$	$\geq 0.7$	$\geq 0.8$	$\geq 0.9$	$\geq 0.95$	$\geq 0.98$
<b>Right</b>							
Any	99.9	99.9	99.9	99.2	72.5	14.9	1.1
At Least Two	99.9	99.9	99.8	97.5	43.8	3.5	0.0
All Three	99.7	99.7	98.8	90.0	18.5	0.6	0.0
<b>Left</b>							
Any	100.0	100.0	99.9	99.7	68.7	18.9	1.4
At Least Two	99.9	99.9	99.8	98.2	41.1	4.8	0.0
All Three	99.7	99.6	98.9	90.2	17.8	0.6	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 dermalog+0003 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	98.9 [98.2, 99.6]	98.9 [98.2, 99.6]	98.9 [98.2, 99.6]
2	98.0 [97.0, 98.9]	98.0 [97.0, 98.9]	98.0 [97.0, 98.9]
3	96.4 [95.1, 97.6]	96.6 [95.3, 97.8]	96.7 [95.5, 97.9]
4	93.3 [91.6, 95.0]	93.4 [91.7, 95.1]	93.5 [91.8, 95.1]
5	86.3 [83.8, 88.8]	86.7 [84.3, 89.1]	86.8 [84.2, 89.3]
6	79.3 [76.4, 82.1]	80.1 [77.2, 82.9]	80.9 [78.1, 83.7]
7	67.5 [64.0, 70.9]	68.4 [64.8, 71.5]	70.5 [67.3, 73.9]
8	42.2 [38.5, 45.6]	43.1 [39.5, 46.5]	46.9 [43.2, 50.6]

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
<b>Right</b>			
Index	87.5 [85.0, 89.8]	87.8 [85.2, 90.2]	87.9 [85.5, 90.2]
Middle	85.1 [82.6, 87.5]	85.5 [82.8, 88.0]	87.0 [84.7, 89.4]
Ring	87.8 [85.4, 90.0]	88.8 [86.6, 91.1]	89.5 [87.2, 91.8]
Little	79.8 [76.7, 82.7]	79.8 [76.7, 82.6]	82.0 [79.0, 84.8]
<b>Left</b>			
Index	85.3 [82.6, 87.9]	85.4 [82.8, 87.8]	85.5 [83.0, 88.1]
Middle	83.3 [80.4, 85.8]	83.4 [80.8, 86.1]	83.7 [80.9, 86.3]
Ring	86.2 [83.7, 88.5]	87.3 [84.9, 89.7]	87.7 [85.4, 89.9]
Little	72.3 [68.8, 75.3]	72.5 [69.4, 75.6]	74.4 [71.2, 77.6]

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
<b>Index</b>			
Either	95.5 [93.9, 97.0]	95.7 [94.1, 97.0]	95.7 [94.1, 97.0]
Both	75.9 [72.7, 78.7]	76.2 [73.3, 79.1]	76.4 [73.4, 79.4]
<b>Middle</b>			
Either	94.9 [93.4, 96.6]	94.9 [93.1, 96.3]	95.1 [93.5, 96.6]
Both	72.2 [68.8, 75.5]	72.7 [69.8, 75.9]	74.2 [71.0, 77.2]
<b>Ring</b>			
Either	95.8 [94.3, 97.1]	96.4 [95.1, 97.8]	96.4 [95.0, 97.8]
Both	76.8 [73.9, 79.8]	78.3 [75.4, 81.2]	79.3 [76.4, 82.2]
<b>Little</b>			
Either	92.9 [90.9, 94.6]	92.9 [90.9, 94.7]	93.1 [91.4, 95.0]
Both	58.0 [54.5, 61.3]	58.2 [54.8, 61.9]	62.1 [58.5, 65.3]

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
<b>Right</b>			
Any	95.7 [94.5, 96.5]	95.7 [94.4, 96.5]	95.7 [94.5, 96.6]
At Least Two	92.4 [90.3, 93.2]	92.4 [90.3, 93.1]	92.6 [90.4, 93.2]
At Least Three	86.3 [82.7, 86.3]	86.7 [83.3, 87.0]	87.8 [84.3, 87.8]
All Four	65.7 [59.5, 64.5]	67.0 [60.2, 65.3]	70.3 [63.1, 67.7]
<b>Left</b>			
Any	95.2 [94.5, 96.5]	95.4 [94.4, 96.5]	95.4 [94.5, 96.6]
At Least Two	91.0 [90.3, 93.2]	91.0 [90.3, 93.1]	91.0 [90.4, 93.2]
At Least Three	82.6 [82.7, 86.3]	83.6 [83.3, 87.0]	84.4 [84.3, 87.8]
All Four	58.2 [59.5, 64.5]	58.8 [60.2, 65.3]	60.6 [63.1, 67.7]

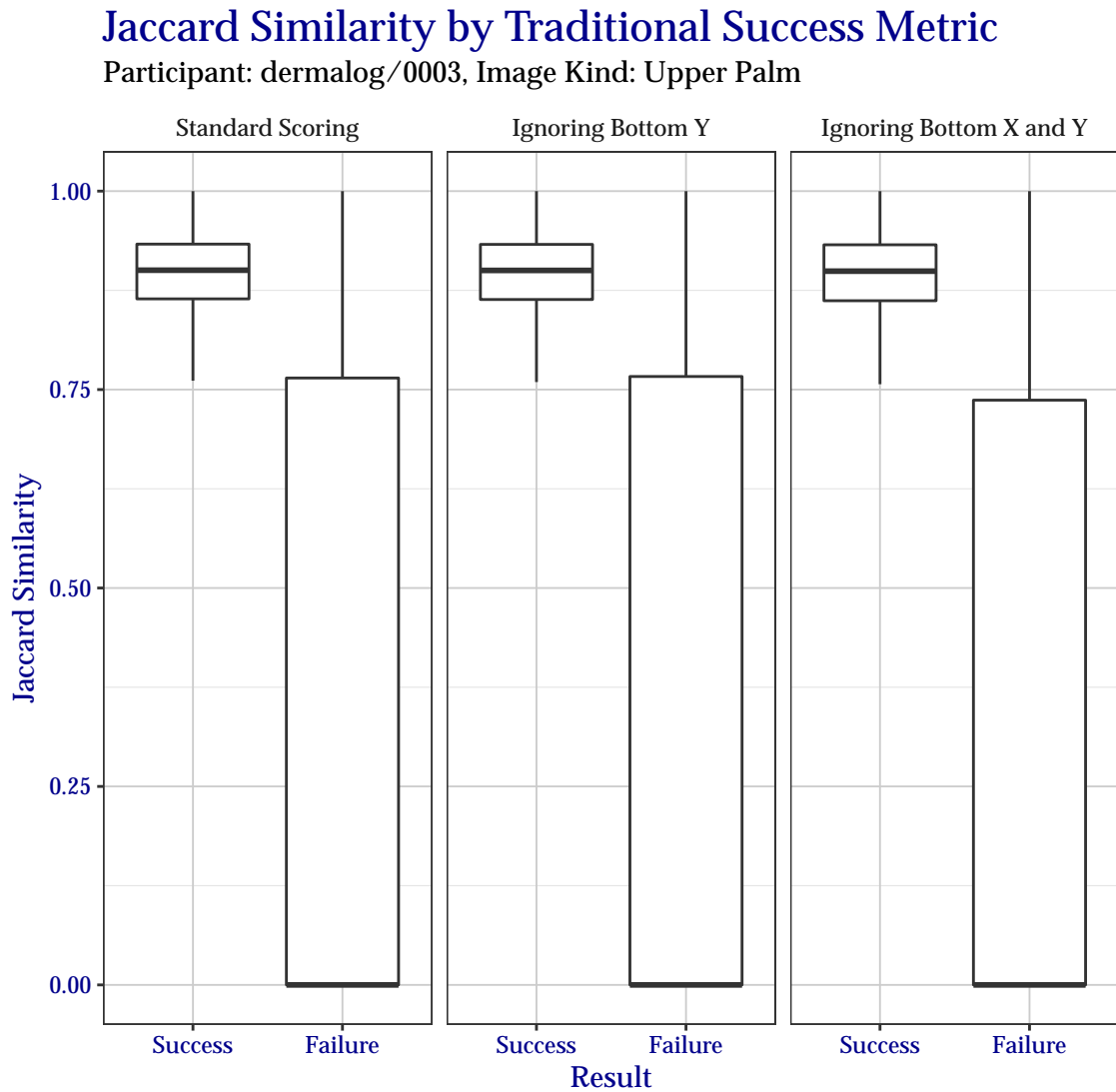
Table 73: Percentage of segmentation success by hand when only considering combinations of index and middle fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values 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
<b>Right</b>			
Either Index or Middle	91.9 [90.2, 93.0]	92.0 [90.4, 93.2]	92.3 [90.6, 93.3]
Both Index and Middle	80.7 [76.9, 80.9]	81.2 [77.4, 81.3]	82.6 [78.0, 82.1]
<b>Left</b>			
Either Index or Middle	91.5 [90.2, 93.0]	91.5 [90.4, 93.2]	91.6 [90.6, 93.3]
Both Index and Middle	77.1 [76.9, 80.9]	77.3 [77.4, 81.3]	77.6 [78.0, 82.1]

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.

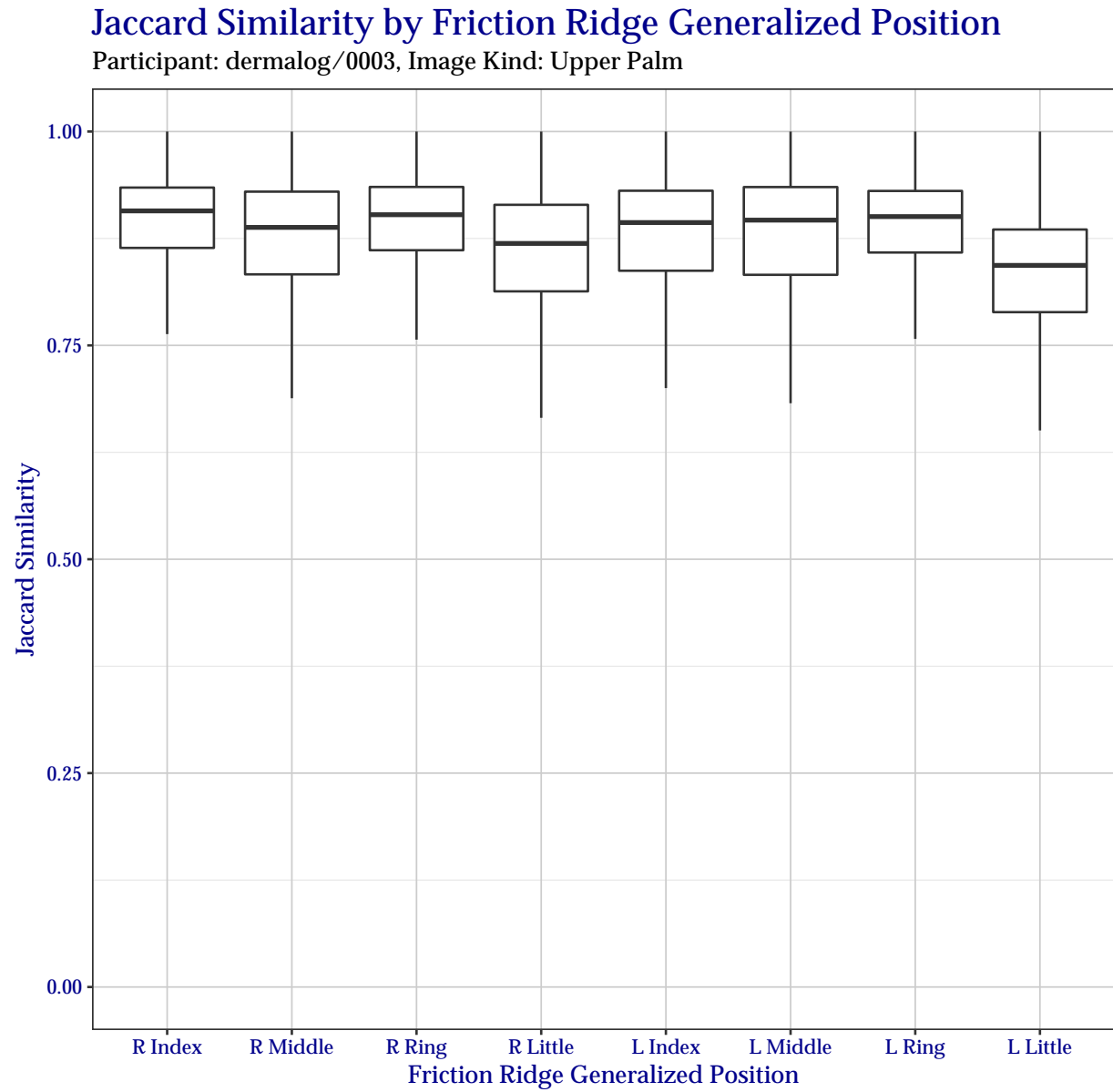
Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
<b>Right</b>			
Any	94.1 [92.6, 95.0]	94.1 [92.6, 95.1]	94.1 [92.5, 95.1]
At Least Two	89.4 [87.0, 90.3]	89.6 [87.5, 90.6]	90.0 [87.7, 90.9]
All Three	76.9 [72.9, 77.4]	78.3 [74.1, 78.4]	80.2 [75.2, 79.3]
<b>Left</b>			
Any	93.5 [92.6, 95.0]	93.6 [92.6, 95.1]	93.6 [92.5, 95.1]
At Least Two	87.9 [87.0, 90.3]	88.5 [87.5, 90.6]	88.7 [87.7, 90.9]
All Three	73.3 [72.9, 77.4]	74.0 [74.1, 78.4]	74.5 [75.2, 79.3]

## C.2 Jaccard Index



27 January 2023, 02:17:07 PM EST

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



27 January 2023, 02:17:06 PM EST

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	$\geq 0.5$	$\geq 0.6$	$\geq 0.7$	$\geq 0.8$	$\geq 0.9$	$\geq 0.95$	$\geq 0.98$
1	99.3	99.3	99.2	99.1	95.0	49.3	24.6
2	98.7	98.4	98.3	97.8	84.3	22.5	17.0
3	97.5	97.5	97.4	96.0	67.9	14.2	13.2
4	94.5	94.5	93.9	91.8	45.6	10.0	9.9
5	88.7	88.7	88.0	84.2	25.0	7.5	7.4
6	84.3	83.9	83.1	77.1	12.8	6.3	6.2
7	79.4	79.2	76.9	63.1	6.5	5.4	5.4
8	68.4	67.6	63.5	40.3	3.8	3.7	3.7

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
<b>Right</b>						
Index	9.3	0.4	0.6	2.1	33.1	54.5
Middle	10.6	0.3	1.6	5.7	39.0	42.8
Ring	7.4	0.3	1.1	3.8	34.7	52.7
Little	9.6	0.3	0.6	9.3	48.0	32.2
<b>Left</b>						
Index	11.2	0.1	1.1	5.8	35.8	46.0
Middle	12.8	0.3	1.6	6.1	32.5	46.7
Ring	10.0	0.1	0.7	3.8	34.9	50.5
Little	12.6	0	1.6	14.6	53.0	18.2

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	$\geq 0.5$	$\geq 0.6$	$\geq 0.7$	$\geq 0.8$	$\geq 0.9$	$\geq 0.95$	$\geq 0.98$
<b>Right</b>							
Any	97.3	97.3	97.1	96.1	85.6	32.4	17.7
At Least Two	94.1	93.9	93.6	92.4	57.3	14.1	12.6
At Least Three	90.4	90.4	89.9	85.4	29.3	10.5	10.5
All Four	81.1	80.2	77.4	63.0	10.0	6.6	6.6
<b>Left</b>							
Any	96.0	96.0	95.8	95.2	81.3	31.6	17.4
At Least Two	92.2	92.2	91.6	89.4	52.3	12.3	10.9
At Least Three	87.5	87.4	86.3	78.8	21.5	7.7	7.7
All Four	77.7	77.3	74.3	54.2	6.4	4.6	4.6

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	$\geq 0.5$	$\geq 0.6$	$\geq 0.7$	$\geq 0.8$	$\geq 0.9$	$\geq 0.95$	$\geq 0.98$
<b>Right</b>							
Either Index or Middle	94.0	94.0	93.9	92.7	71.0	23.7	15.2
Both Index and Middle	86.0	85.4	83.4	76.7	26.3	10.1	9.7
<b>Left</b>							
Either Index or Middle	93.1	93.1	92.7	90.1	66.0	26.3	15.3
Both Index and Middle	82.9	82.5	80.2	71.0	26.7	7.7	7.3

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	$\geq 0.5$	$\geq 0.6$	$\geq 0.7$	$\geq 0.8$	$\geq 0.9$	$\geq 0.95$	$\geq 0.98$
<b>Right</b>							
Any	95.7	95.6	95.3	94.3	81.6	29.5	16.5
At Least Two	91.8	91.6	91.2	88.8	49.6	13.4	12.4
All Three	85.1	84.4	81.9	73.7	18.8	9.3	9.3
<b>Left</b>							
Any	94.4	94.4	94.2	93.2	78.6	30.0	16.3
At Least Two	90.6	90.5	89.4	86.2	48.0	11.8	10.6
All Three	81.0	80.6	78.6	67.0	16.6	6.5	6.5

## D Full Palm (“EightInch” Data)

### D.1 Bootstrap Confidence for Segmentation Statistics

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

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

In Table 80, results are shown of how successful dermalog+0003 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	99.9 [99.7, 100.0]	99.9 [99.7, 100.0]	99.9 [99.7, 100.0]
3	99.5 [99.0, 99.9]	99.5 [99.0, 99.9]	99.7 [99.2, 100.0]
4	99.0 [98.3, 99.5]	99.3 [98.7, 99.8]	99.3 [98.7, 99.8]
5	98.3 [97.4, 99.1]	98.4 [97.6, 99.2]	98.5 [97.7, 99.2]
6	96.2 [94.8, 97.5]	96.2 [94.7, 97.4]	97.0 [96.0, 98.2]
7	90.5 [88.4, 92.3]	91.1 [89.2, 93.0]	92.5 [90.7, 94.1]
8	71.5 [68.4, 74.3]	72.8 [69.9, 75.6]	75.3 [72.3, 78.0]

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
<b>Right</b>			
Index	94.5 [92.9, 96.0]	94.8 [93.3, 96.3]	94.9 [93.4, 96.4]
Middle	95.1 [93.6, 96.6]	95.3 [93.9, 96.6]	96.1 [94.8, 97.4]
Ring	94.7 [93.1, 96.1]	95.4 [94.0, 96.8]	95.9 [94.5, 97.2]
Little	93.3 [91.5, 94.9]	93.6 [92.0, 95.1]	94.3 [92.5, 95.6]
<b>Left</b>			
Index	95.7 [94.4, 97.1]	96.1 [94.7, 97.4]	96.3 [95.1, 97.6]
Middle	94.4 [92.9, 95.7]	94.6 [93.0, 96.1]	95.4 [94.1, 96.7]
Ring	93.9 [92.3, 95.4]	94.3 [92.6, 95.7]	95.5 [94.0, 96.8]
Little	93.2 [91.6, 94.8]	93.2 [91.5, 94.8]	93.8 [92.3, 95.3]



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
<b>Index</b>			
Either	99.4 [98.9, 99.9]	99.4 [98.9, 99.9]	99.4 [98.9, 99.9]
Both	90.8 [89.0, 92.8]	91.5 [89.4, 93.3]	91.8 [90.0, 93.7]
<b>Middle</b>			
Either	98.9 [98.0, 99.5]	99.1 [98.4, 99.7]	99.1 [98.4, 99.7]
Both	90.6 [88.6, 92.5]	90.8 [88.9, 92.6]	92.4 [90.3, 94.1]
<b>Ring</b>			
Either	98.9 [98.2, 99.5]	99.0 [98.3, 99.5]	99.2 [98.5, 99.8]
Both	89.8 [87.7, 91.7]	90.7 [88.9, 92.6]	92.2 [90.5, 93.9]
<b>Little</b>			
Either	99.3 [98.7, 99.8]	99.4 [98.9, 99.9]	99.5 [99.1, 99.9]
Both	87.2 [84.9, 89.5]	87.4 [85.2, 89.5]	88.5 [86.4, 90.6]

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
<b>Right</b>			
Any	99.3 [99.2, 99.8]	99.4 [99.3, 99.9]	99.4 [99.3, 99.9]
At Least Two	98.7 [98.0, 99.1]	98.9 [98.1, 99.2]	99.1 [98.5, 99.5]
At Least Three	96.0 [95.2, 96.9]	96.4 [95.5, 97.2]	97.0 [96.1, 97.7]
All Four	83.6 [81.3, 84.8]	84.4 [82.1, 85.6]	85.6 [84.0, 87.3]
<b>Left</b>			
Any	99.8 [99.2, 99.8]	99.8 [99.3, 99.9]	99.8 [99.3, 99.9]
At Least Two	98.5 [98.0, 99.1]	98.5 [98.1, 99.2]	99.0 [98.5, 99.5]
At Least Three	96.2 [95.2, 96.9]	96.3 [95.5, 97.2]	96.8 [96.1, 97.7]
All Four	82.8 [81.3, 84.8]	83.6 [82.1, 85.6]	85.5 [84.0, 87.3]

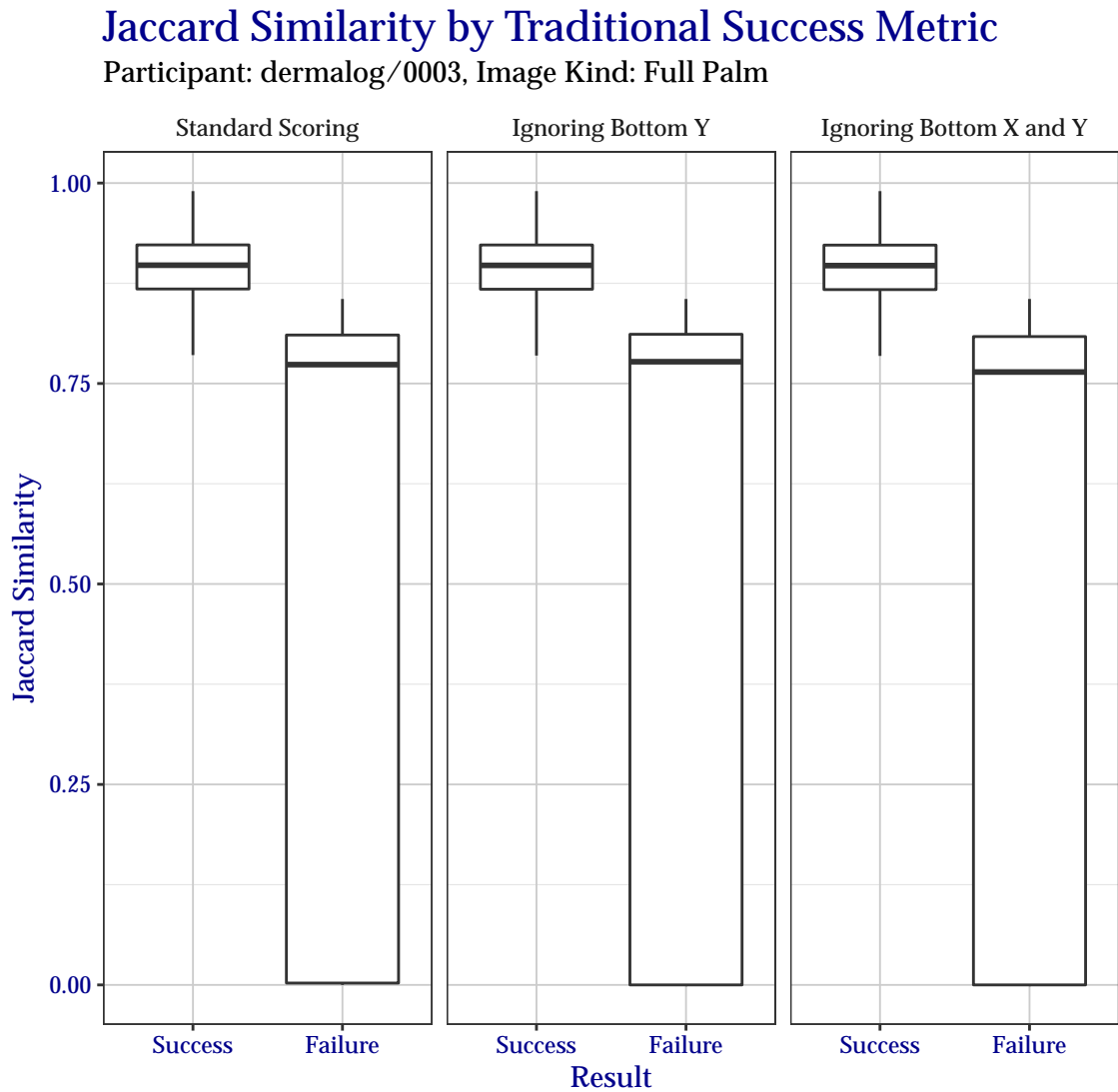
Table 84: Percentage of segmentation success by hand when only considering combinations of index and middle fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values 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
<b>Right</b>			
Either Index or Middle	98.0 [97.6, 98.9]	98.3 [97.8, 99.0]	98.4 [97.9, 99.1]
Both Index and Middle	91.5 [90.3, 92.8]	91.8 [90.8, 93.3]	92.6 [91.7, 94.1]
<b>Left</b>			
Either Index or Middle	98.5 [97.6, 98.9]	98.5 [97.8, 99.0]	98.5 [97.9, 99.1]
Both Index and Middle	91.6 [90.3, 92.8]	92.2 [90.8, 93.3]	93.2 [91.7, 94.1]

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.

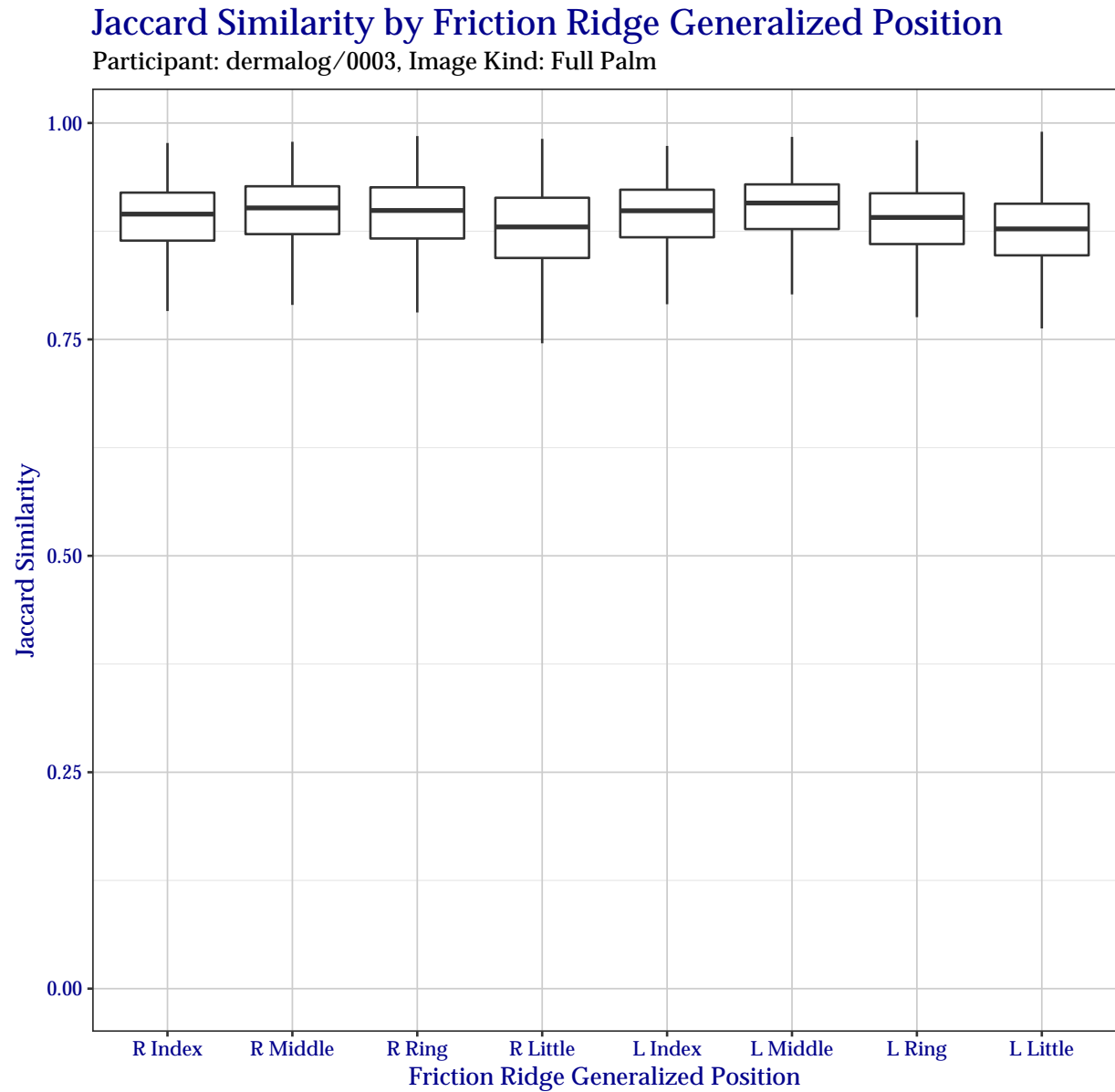
Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
<b>Right</b>			
Any	99.0 [98.6, 99.5]	99.2 [98.8, 99.6]	99.3 [98.8, 99.7]
At Least Two	97.1 [96.3, 97.9]	97.4 [96.6, 98.0]	97.8 [97.1, 98.4]
All Three	88.2 [86.4, 89.4]	89.0 [87.2, 90.3]	89.8 [88.4, 91.3]
<b>Left</b>			
Any	99.2 [98.6, 99.5]	99.2 [98.8, 99.6]	99.2 [98.8, 99.7]
At Least Two	97.1 [96.3, 97.9]	97.2 [96.6, 98.0]	97.8 [97.1, 98.4]
All Three	87.7 [86.4, 89.4]	88.5 [87.2, 90.3]	90.2 [88.4, 91.3]

## D.2 Jaccard Index



27 January 2023, 02:17:09 PM EST

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



27 January 2023, 02:17:08 PM EST

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	$\geq 0.5$	$\geq 0.6$	$\geq 0.7$	$\geq 0.8$	$\geq 0.9$	$\geq 0.95$	$\geq 0.98$
1	100.0	100.0	100.0	100.0	96.1	35.2	1.0
2	100.0	100.0	100.0	99.8	87.1	7.4	0
3	99.9	99.9	99.8	99.3	70.1	1.8	0
4	99.8	99.7	99.5	98.6	51.4	0.1	0
5	99.0	98.7	98.4	97.6	31.0	0	0
6	98.3	98.2	98.0	95.4	14.9	0	0
7	97.5	97.2	96.4	89.2	5.3	0	0
8	93.3	92.5	89.3	69.4	0.9	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
<b>Right</b>						
Index	2.8	0.3	0.9	4.2	47.4	44.4
Middle	1.7	0	0.6	3.0	41.9	52.8
Ring	0.9	0.2	0.6	3.3	46.7	48.3
Little	0.8	0.2	0.5	7.2	56.2	35.1
<b>Left</b>						
Index	2.1	0.3	0.2	3.0	45.8	48.6
Middle	1.7	0	0.6	2.4	38.3	57.0
Ring	1.3	0.1	0.7	3.3	53.9	40.7
Little	1.1	0.2	0.7	5.6	62.3	30.1

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	$\geq 0.5$	$\geq 0.6$	$\geq 0.7$	$\geq 0.8$	$\geq 0.9$	$\geq 0.95$	$\geq 0.98$
<b>Right</b>							
Any	99.5	99.4	99.4	99.1	84.6	21.5	0.5
At Least Two	99.3	99.2	99.2	98.4	57.1	2.5	0.0
At Least Three	98.5	98.5	98.4	95.1	29.9	0.2	0.0
All Four	96.4	95.9	93.4	80.1	8.9	0.0	0.0
<b>Left</b>							
Any	99.8	99.8	99.8	99.8	84.8	17.8	0.6
At Least Two	99.3	99.2	99.0	98.6	58.0	2.2	0.0
At Least Three	98.6	98.5	98.2	95.9	27.1	0.2	0.0
All Four	96.2	95.7	94.1	82.4	6.4	0.0	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	$\geq 0.5$	$\geq 0.6$	$\geq 0.7$	$\geq 0.8$	$\geq 0.9$	$\geq 0.95$	$\geq 0.98$
<b>Right</b>							
Either Index or Middle	98.6	98.6	98.6	97.4	70.0	12.6	0
Both Index and Middle	96.9	96.6	95.1	89.1	27.1	0.7	0
<b>Left</b>							
Either Index or Middle	98.9	98.9	98.7	98.6	74.1	12.0	0.2
Both Index and Middle	97.4	97.0	96.3	91.0	31.5	0.6	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	$\geq 0.5$	$\geq 0.6$	$\geq 0.7$	$\geq 0.8$	$\geq 0.9$	$\geq 0.95$	$\geq 0.98$
<b>Right</b>							
Any	99.4	99.3	99.3	98.7	80.1	18.6	0.3
At Least Two	98.5	98.5	98.5	96.7	48.5	1.7	0
All Three	96.7	96.2	94.1	86.0	16.8	0	0
<b>Left</b>							
Any	99.4	99.4	99.3	99.2	81.4	16.0	0.3
At Least Two	98.7	98.6	98.4	97.2	49.2	0.9	0
All Three	96.8	96.4	95.3	87.8	15.7	0.1	0