

innovatrics+0005

Innovatrics, s.r.o.

Slap Fingerprint Segmentation Evaluation III

Last Updated: 28 April 2021

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1 Participation Information

1.1 Names and Dates

- **Organization Name:** Innovatrics, s.r.o.
- **SlapSeg III Identifier:** innovatrics+0005
- **Provided Marketing Name:** "Innovatrics s.r.o. iseglib implementation (version 0.0.5)"
- **Application Date:** 23 April 2021
- **First Submission Date:** 29 March 2021 (as version 0003)
- **Validation Date:** 28 April 2021
- **Completion Date:** 28 April 2021

1.2 Libraries

Filename	MD5 Checksum	Size
libonnxruntime.so.1.5.2	10daf35e31e188a866c24ca15e4f3622	13.1 Mb
libiseglibextra.so	d3a0626b49841b359b32384c3eb740a0	766.1 Mb
libslapsegiii_innovatrics_0005.so	412b6e2363711617d3658d66ebac37c1	4 Mb

2 Tenprint Cards (“TwoInch” Data)

2.1 Segmentation Timing

All algorithms are run over a small fixed corpus of TwoInch images to estimate the total runtime of the evaluation. To be evaluated under SlapSeg III, algorithms **must** segment the timing corpus, on average, in under 1 500 milliseconds. This maximum reference time is documented in the SlapSeg III test plan, and is subject to change.

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

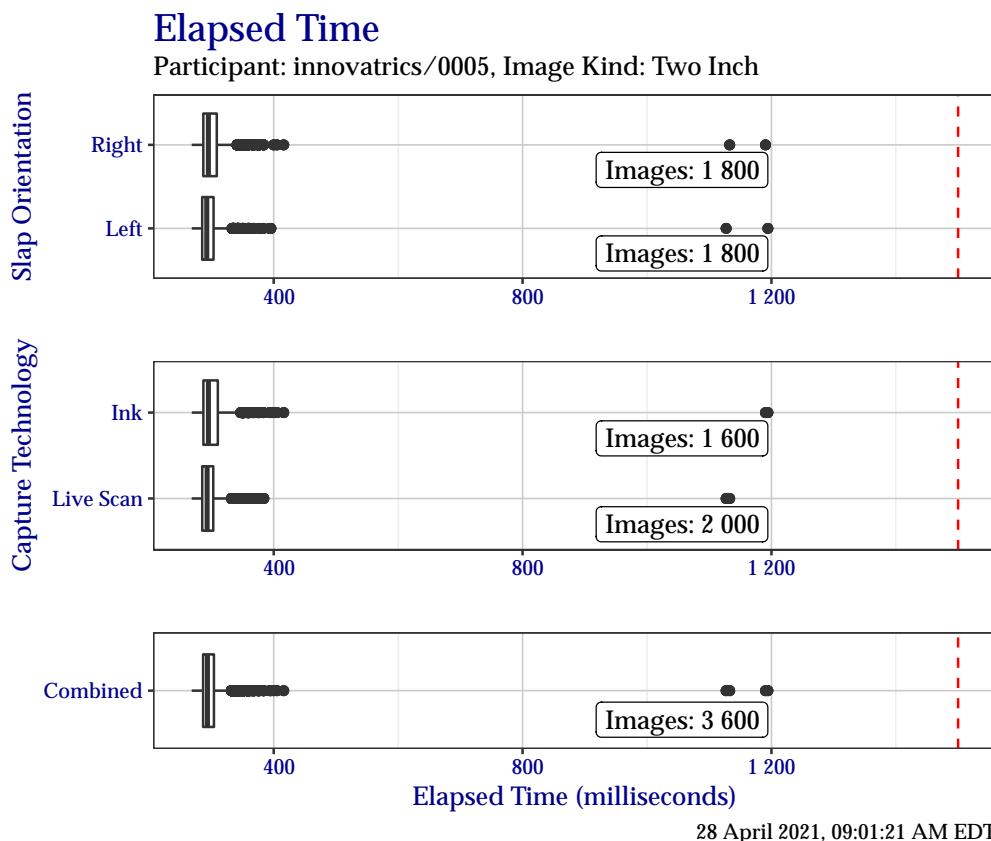


Figure 1: Box plots of elapsed time in milliseconds when segmenting the TwoInch timing test corpus, separated by slap orientation and capture technology.

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

	Right	Left	Live Scan	Ink	Combined
Minimum	268	268	268	268	268
25%	287	285	285	287	287
Median	295	292	293	295	294
75%	309	303	303	310	304
Maximum	1 190	1 194	1 133	1 194	1 194

2.2 Segmentation Centers and Dimensions

2.2.1 Segmentation Centers

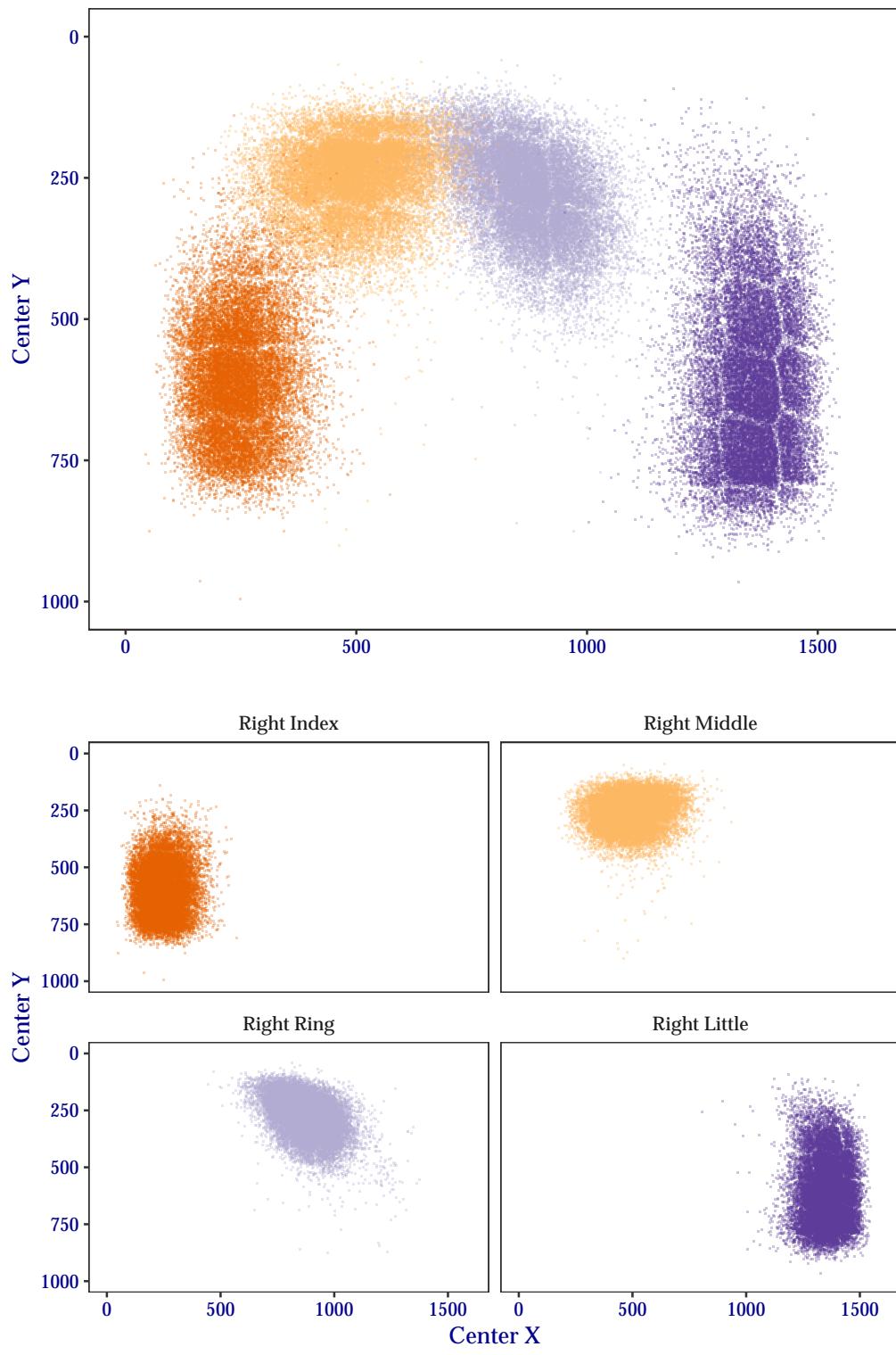
The plots in this section show the distribution of segmentation position centers (x, y) for TwoInch data. At the top of each figure is a combined plot for all finger positions of a given slap orientation. These figures are isolated in plots faceted at the bottom of the figure.

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: innovatrics/0005, FRGPs: 2, 3, 4, 5, Image Kind: Two Inch



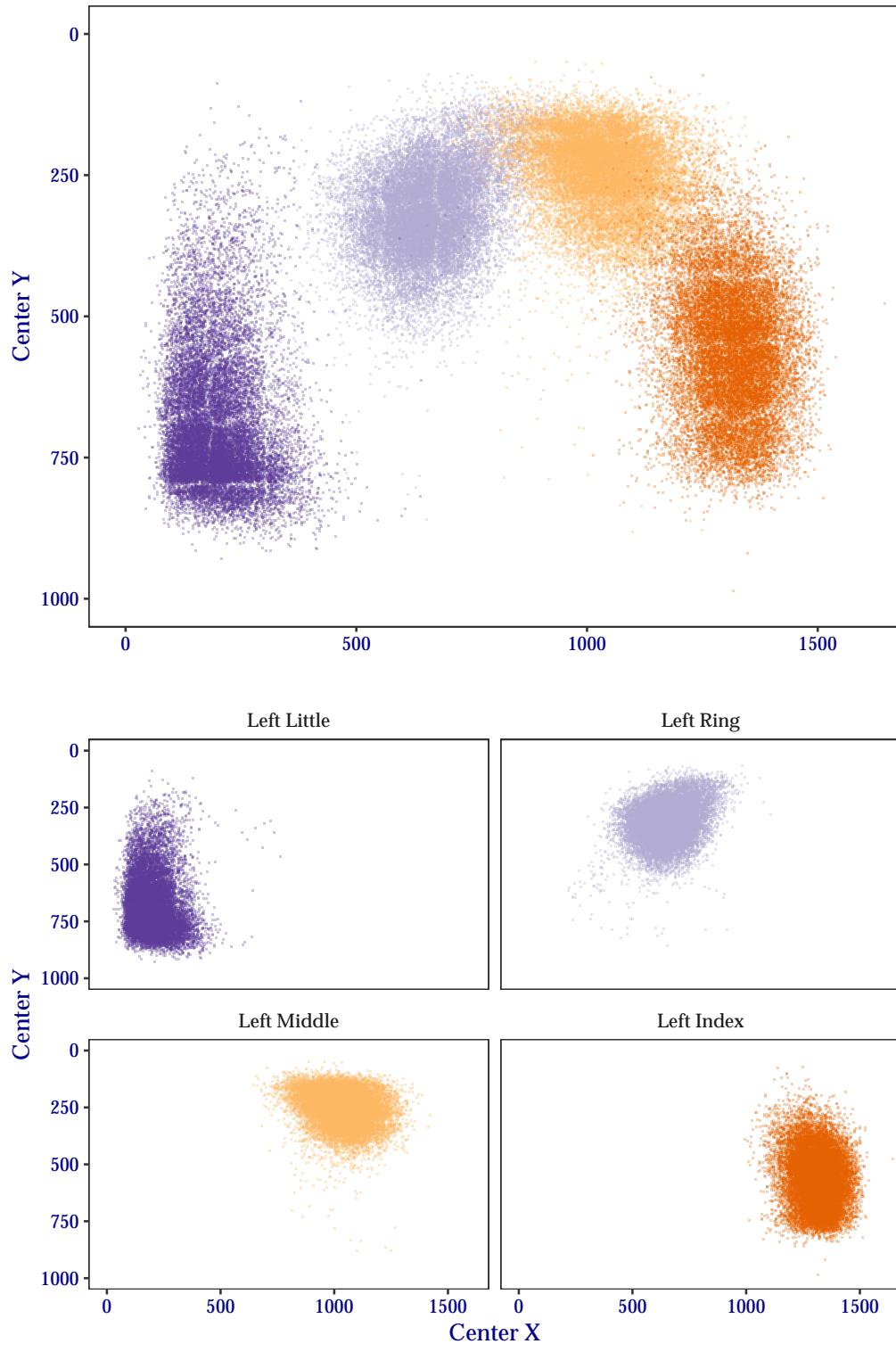
- Right Index • Right Middle • Right Ring • Right Little

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Figure 2: Segmentation centers for right hand TwoInch data.

Segmentation Position Centers

Participant: innovatrics/0005, FRGPs: 7, 8, 9, 10, Image Kind: Two Inch



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

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Figure 3: Segmentation centers for left hand TwoInch data.

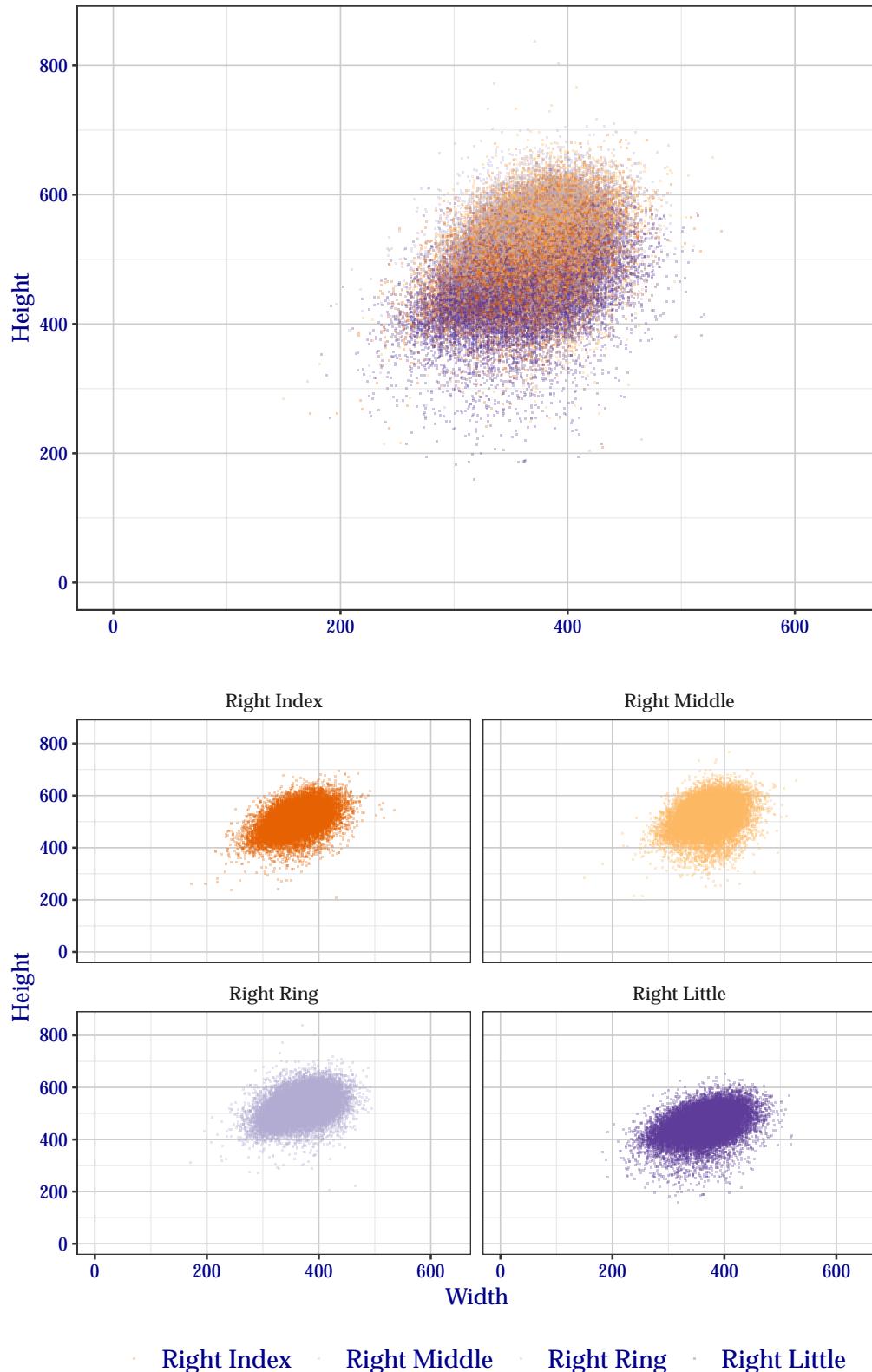
2.2.2 Segmentation Dimensions

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

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

Segmentation Position Dimensions

Participant: innovatrics/0005, FRGPs: 2, 3, 4, 5, Image Kind: Two Inch

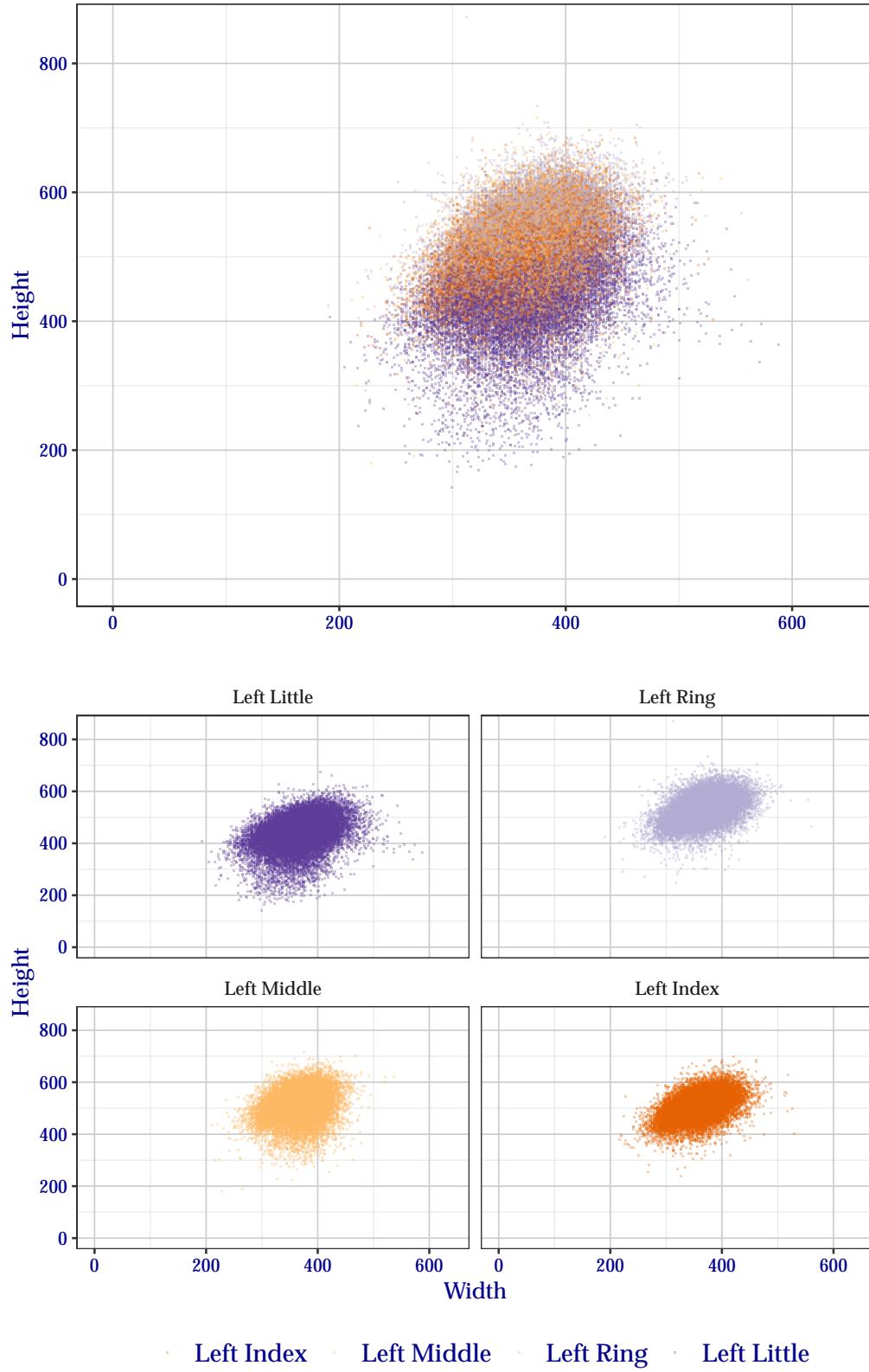


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Figure 4: Segmentation position dimensions for right hand TwoInch data.

Segmentation Position Dimensions

Participant: innovatrics/0005, FRGPs: 7, 8, 9, 10, Image Kind: Two Inch



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

2.3 Detailed Segmentation Statistics

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

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

Table 2 shows how successful innovatrics+0005 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	98.2	98.2	99.3
2	95.6	95.7	97.4
3	92.1	92.3	94.2
4	86.6	86.9	88.9
5	74.3	74.5	78.5
6	64.4	64.7	66.5
7	52.6	53.1	54.4
8	34.2	35.2	36.0

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

Finger	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Index	74.5	74.8	82.2
Middle	79.6	79.8	81.0
Ring	76.9	77.2	78.3
Little	73.4	73.6	75.4
Left			
Index	83.7	84.0	86.7
Middle	80.8	81.2	81.3
Ring	75.2	75.8	75.8
Little	67.9	68.1	68.2

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

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Index			
Either	92.4	92.6	94.9
Both	62.1	62.6	70.2
Middle			
Either	93.0	93.1	93.6
Both	63.7	64.2	65.1
Ring			
Either	90.4	90.6	91.1
Both	58.7	59.4	60.1
Little			
Either	86.8	86.9	87.9
Both	50.8	51.0	52.3

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

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	91.0	91.1	96.1
At Least Two	84.0	84.0	87.2
At Least Three	74.6	74.7	76.8
All Four	55.0	55.6	56.8
Left			
Any	92.9	93.0	95.3
At Least Two	84.7	84.9	85.3
At Least Three	74.3	74.7	74.9
All Four	55.7	56.5	56.7

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

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Either Index or Middle	88.4	88.5	94.7
Both Index and Middle	65.8	66.1	68.5
Left			
Either Index or Middle	91.2	91.3	93.9
Both Index and Middle	73.3	73.9	74.2

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

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	90.1	90.2	95.7
At Least Two	81.0	81.1	83.8
All Three	60.0	60.6	62.0
Left			
Any	92.3	92.4	94.8
At Least Two	82.4	82.8	83.1
All Three	64.9	65.9	66.0

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.

Reasons for capture-type failures reported by innovatrics+0005 are enumerated in Table 8. Note that for TwoInch data, images are expected to be rotated, so a capture failure of *Rotation Detected* is unacceptable.

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

Failure Reason	Images
Request Recapture (No Attempt)	11
Request Recapture (Attempt)	6 086

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

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

Deficiency	Count
Incomplete	6 086
Image Quality	11

2.4.1.1 Recovery

When encountering a segmentation failure, SlapSeg III algorithms are encouraged to provide a *best-effort* segmentation when possible. In some cases, that best-effort may be correct, which reduces the amount of images that need to be manually adjudicated by an operator. The result of such best-effort segmentations are shown in Table 10.

Out of 6086 recovery attempts innovatrics+0005 attempted 17265 segmentations of fingers and skipped 7079 fingers. More information about skipped fingers can be found in Table 11.

Table 10: Results of best-effort segmentation when innovatrics+0005 reported segmentation failure (17265 best-effort attempts).

Standard	Ignoring Bottom Y	Ignoring Bottom X and Y
70.2	70.5	72.8

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 innovatrics+0005 are enumerated in Table 11.

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

Failure Reason	Fingers
Finger Not Found	7 079
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 12 shows how successful innovatrics+0005 was in correctly determining if a finger was missing. The *Missed* row shows when a segmentation position was returned for a missing finger. All possible failure reasons are enumerated, but are not considered *Correctly Identified* because the algorithm specified failure for a reason other than the finger not being found.

Table 12: Performance of innovatrics+0005 at detecting fingers missing from an image.

Result	Percentage
Missed	21.9
Correctly Identified	34.4
Other Failure: Finger Found, but Can't Segment	0.0
Other Failure: Vendor Defined	0.0
Other Failure: Segmentation Not Attempted	43.7

2.4.4 Sequence Error

Sequence error occurs when a fingerprint is segmented from an image but assigned an incorrect finger position (e.g., segmenting a right middle finger but labeling it a right index finger). Table 13 shows cases in which a segmentation position was returned that matched a ground truth segmentation position for a different finger in the same image.

Table 13: Percentage of images in the dataset where one or more segmentation positions correctly matched an incorrect finger position within the same image, indicating sequence error.

Hand	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Left	0.63	0.63	0.64
Right	0.44	0.44	0.48
Combined	0.53	0.53	0.56

3 Identification Flats (“ThreeInch” Data)

3.1 Segmentation Timing

All algorithms are run over a small fixed corpus of ThreeInch images to estimate the total runtime of the evaluation. To be evaluated under SlapSeg III, algorithms **must** segment the timing corpus, on average, in under 1 500 milliseconds. This maximum reference time is documented in the SlapSeg III test plan, and is subject to change.

Box plots of segmentation times are separated by hand in Figure 6, with tabular representations are enumerated in Table 14. Results are reported in milliseconds

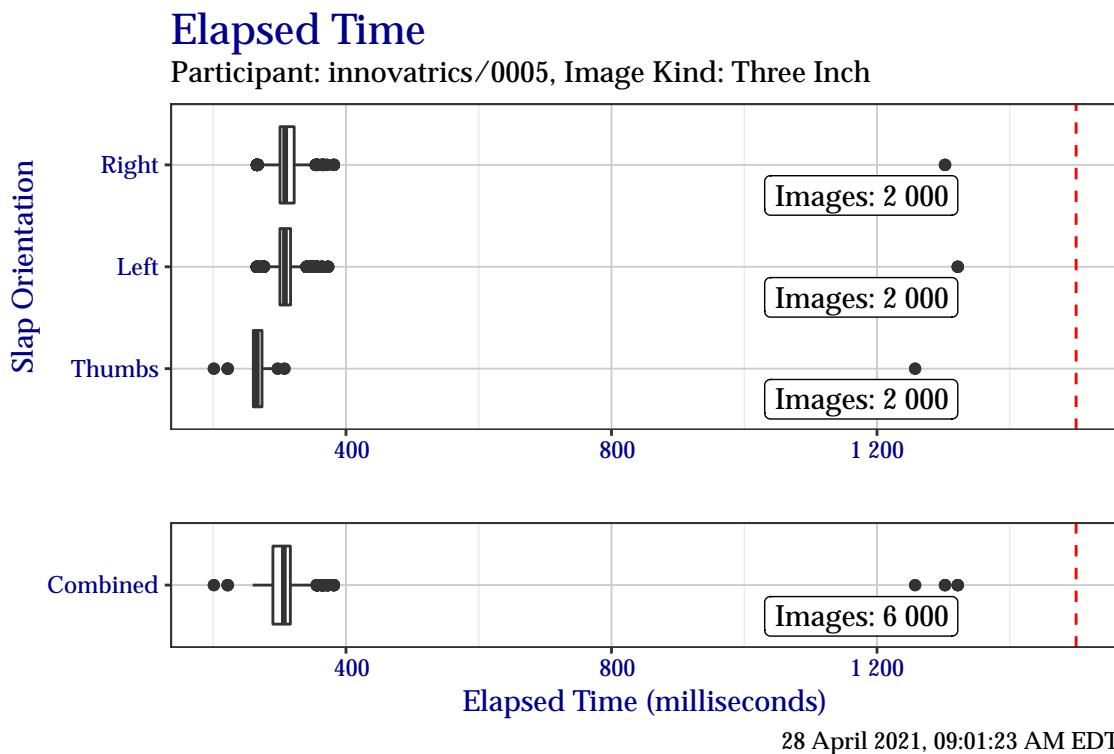


Figure 6: Box plots of elapsed time in milliseconds when segmenting the ThreeInch timing test corpus, separated by slap orientation.

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

	Right	Left	Thumbs	Combined
Minimum	266	266	201	201
25%	301	300	260	290
Median	308	308	266	306
75%	322	316	273	316
Maximum	1 303	1 322	1 257	1 322

3.2 Segmentation Centers and Dimensions

3.2.1 Segmentation Centers

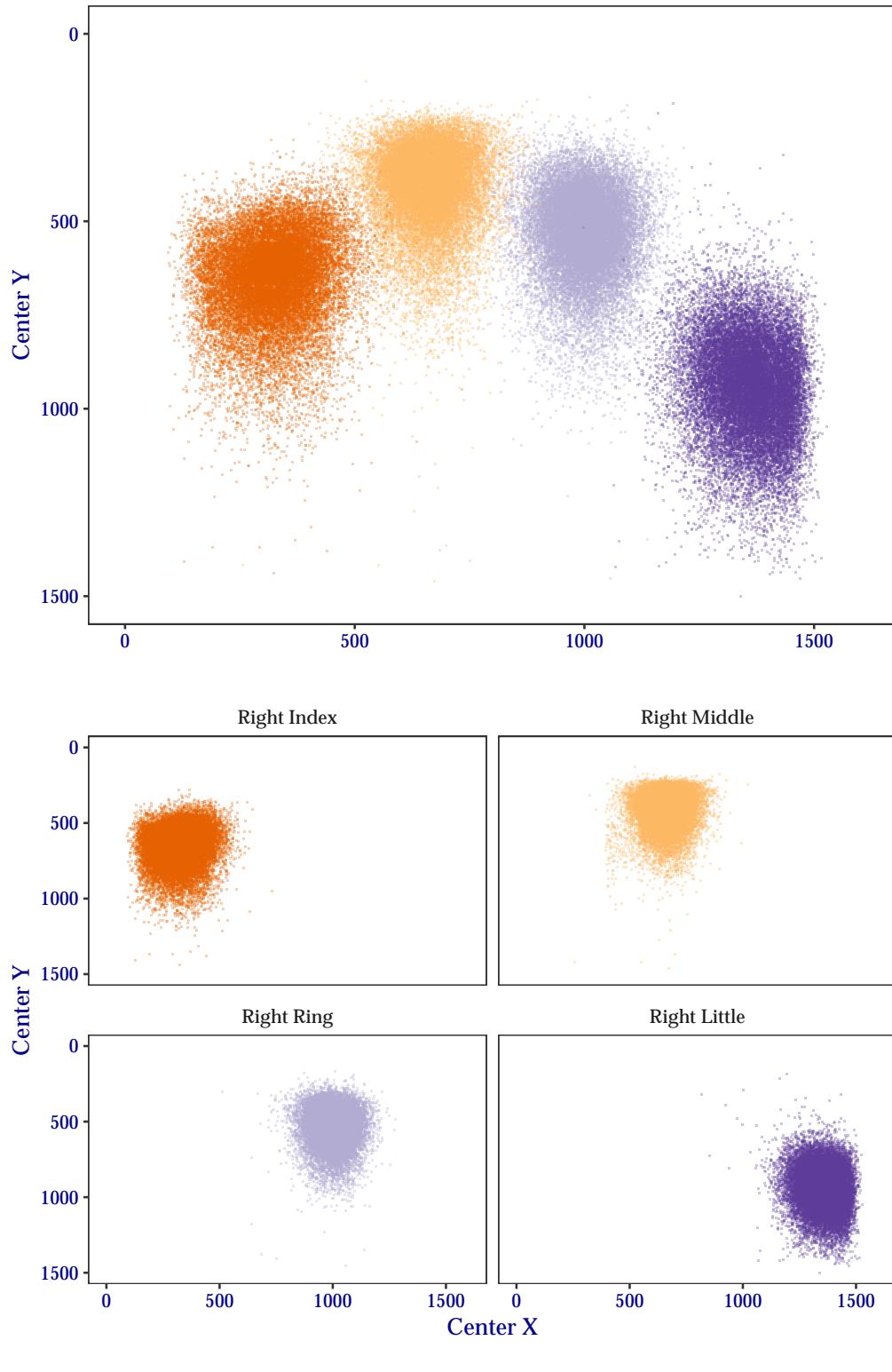
The plots in this section show the distribution of segmentation position centers (x, y) for ThreeInch data. At the top of each figure is a combined plot for all finger positions of a given hand orientation. These figures are isolated in plots faceted at the bottom of the figure.

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: innovatrics/0005, FRGPs: 2, 3, 4, 5, Image Kind: Three Inch

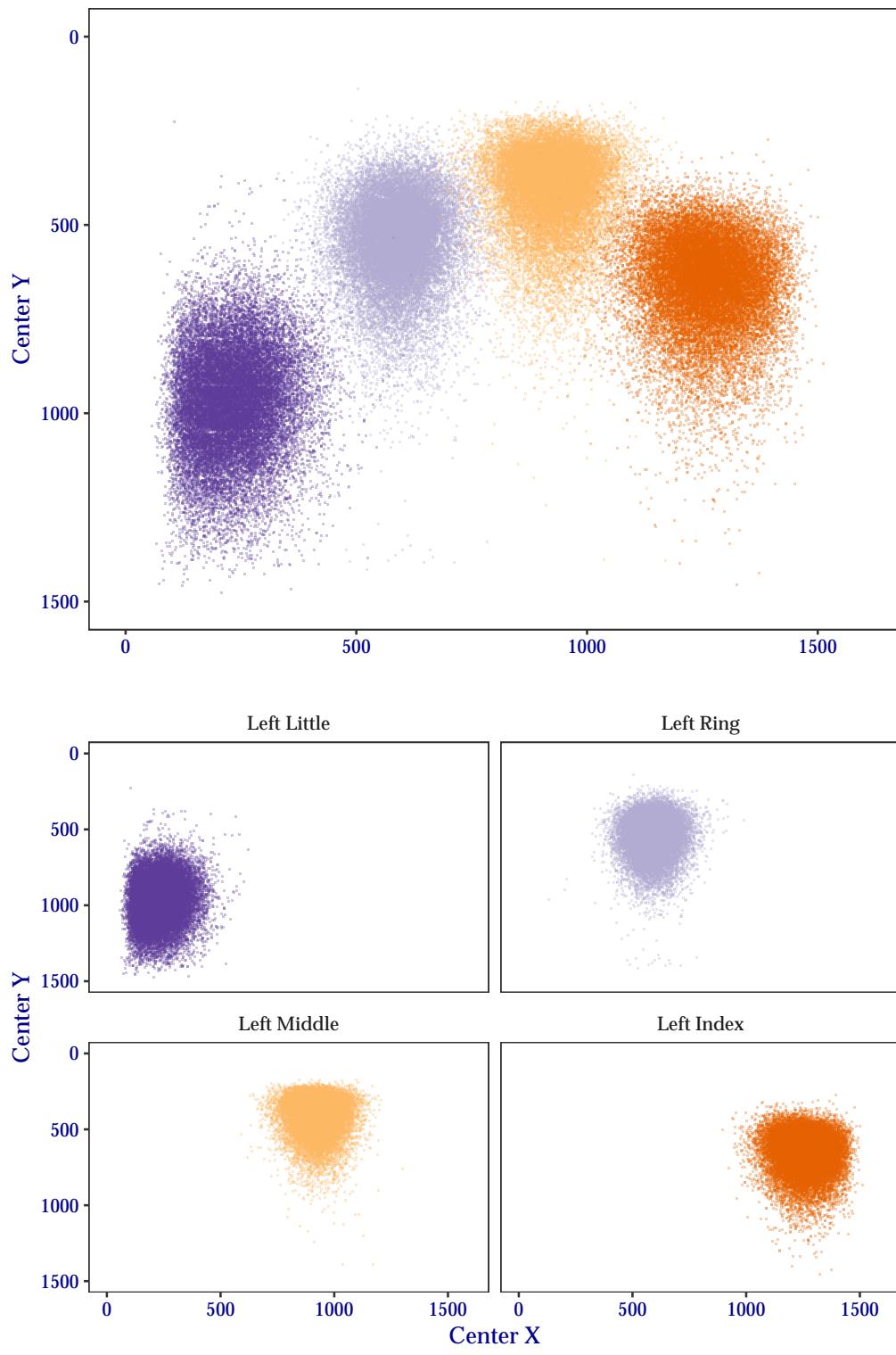


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Figure 7: Segmentation centers for right hand ThreeInch data.

Segmentation Position Centers

Participant: innovatrics/0005, FRGPs: 7, 8, 9, 10, Image Kind: Three Inch



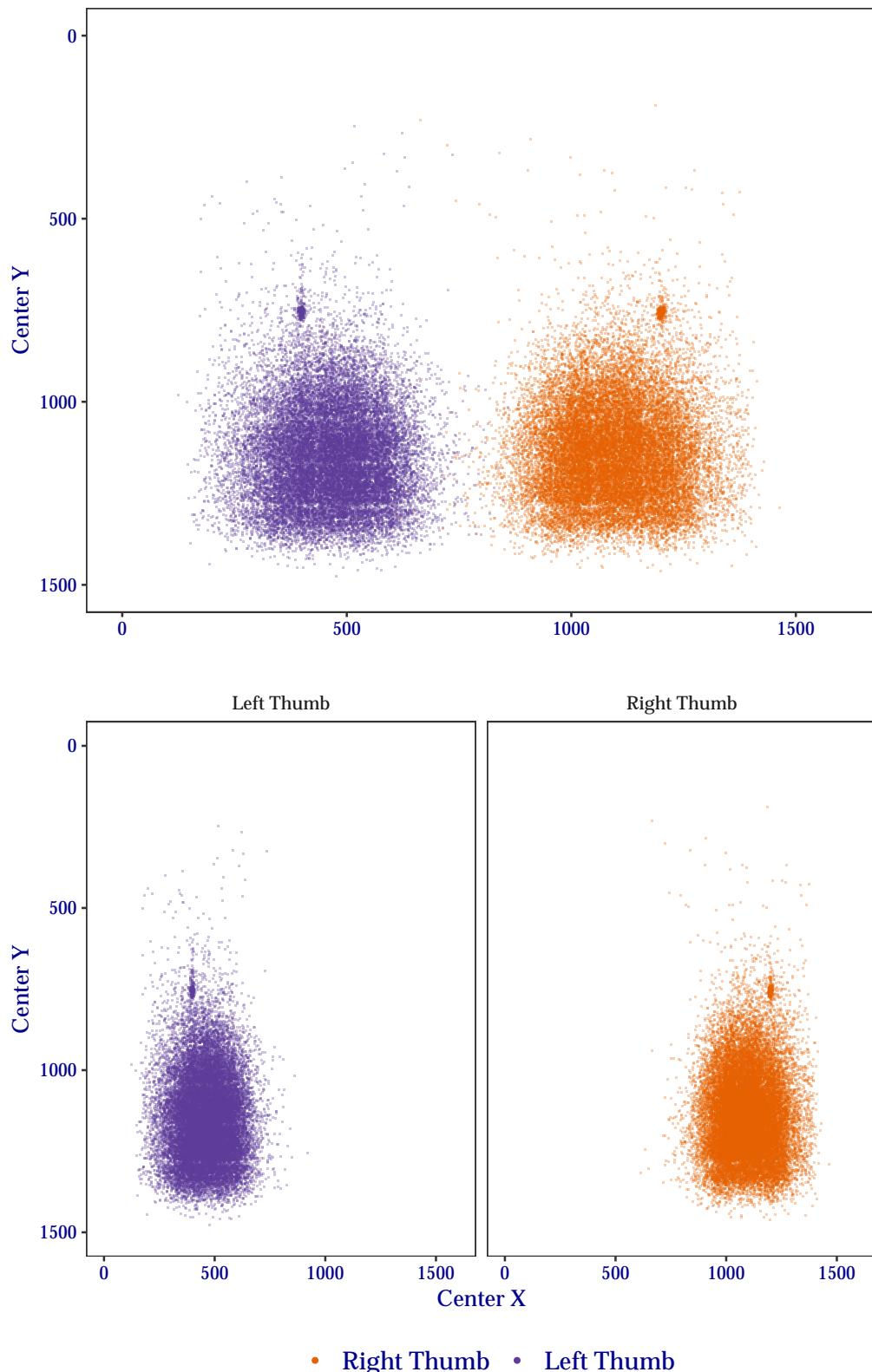
- Left Index • Left Middle • Left Ring • Left Little

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Figure 8: Segmentation centers for left hand ThreeInch data.

Segmentation Position Centers

Participant: innovatrics/0005, FRGPs: 1, 6, Image Kind: Three Inch



- Right Thumb
- Left Thumb

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Figure 9: Segmentation centers for thumb ThreeInch data.

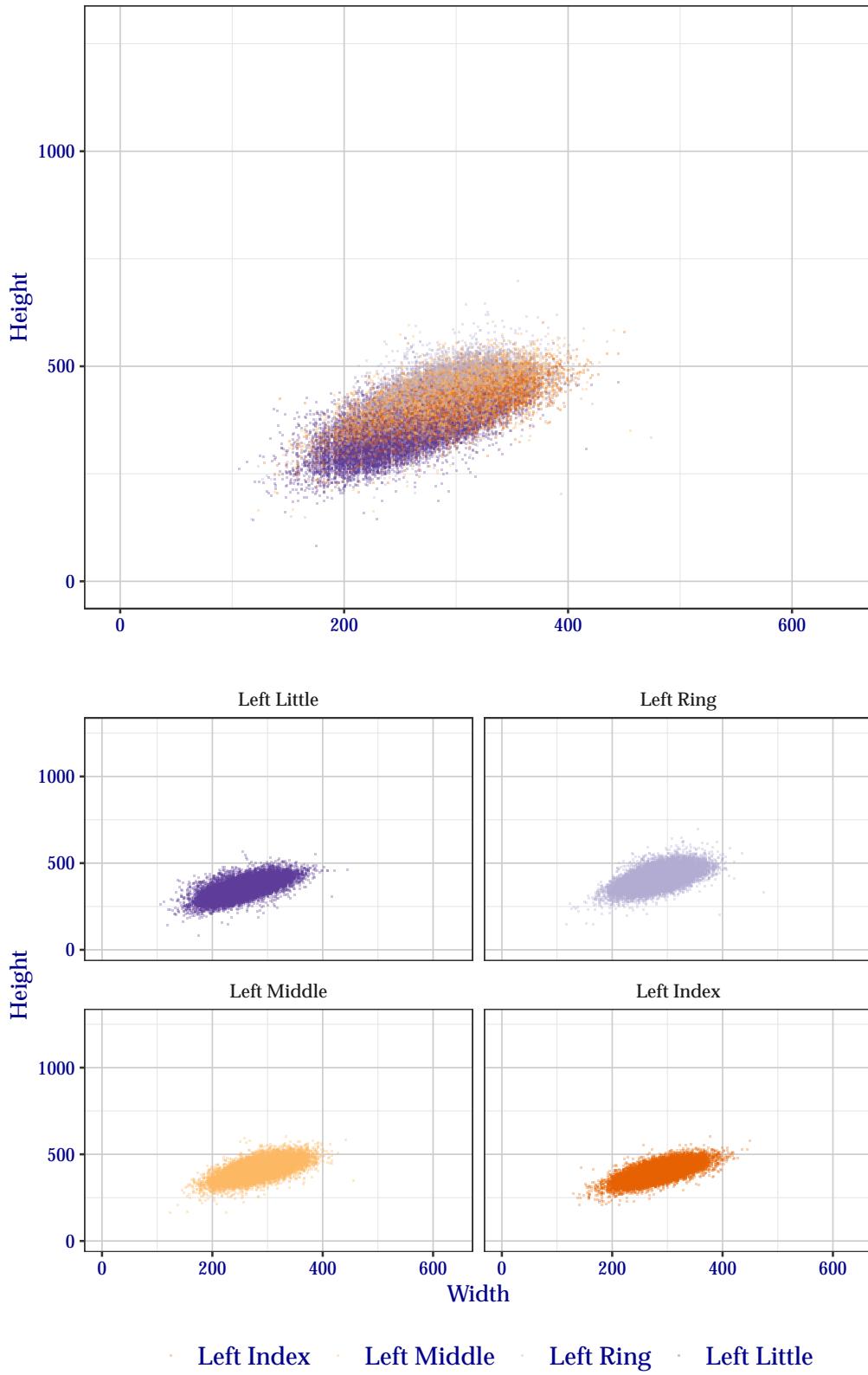
3.2.2 Segmentation Dimensions

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

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

Segmentation Position Dimensions

Participant: innovatrics/0005, FRGPs: 7, 8, 9, 10, Image Kind: Three Inch

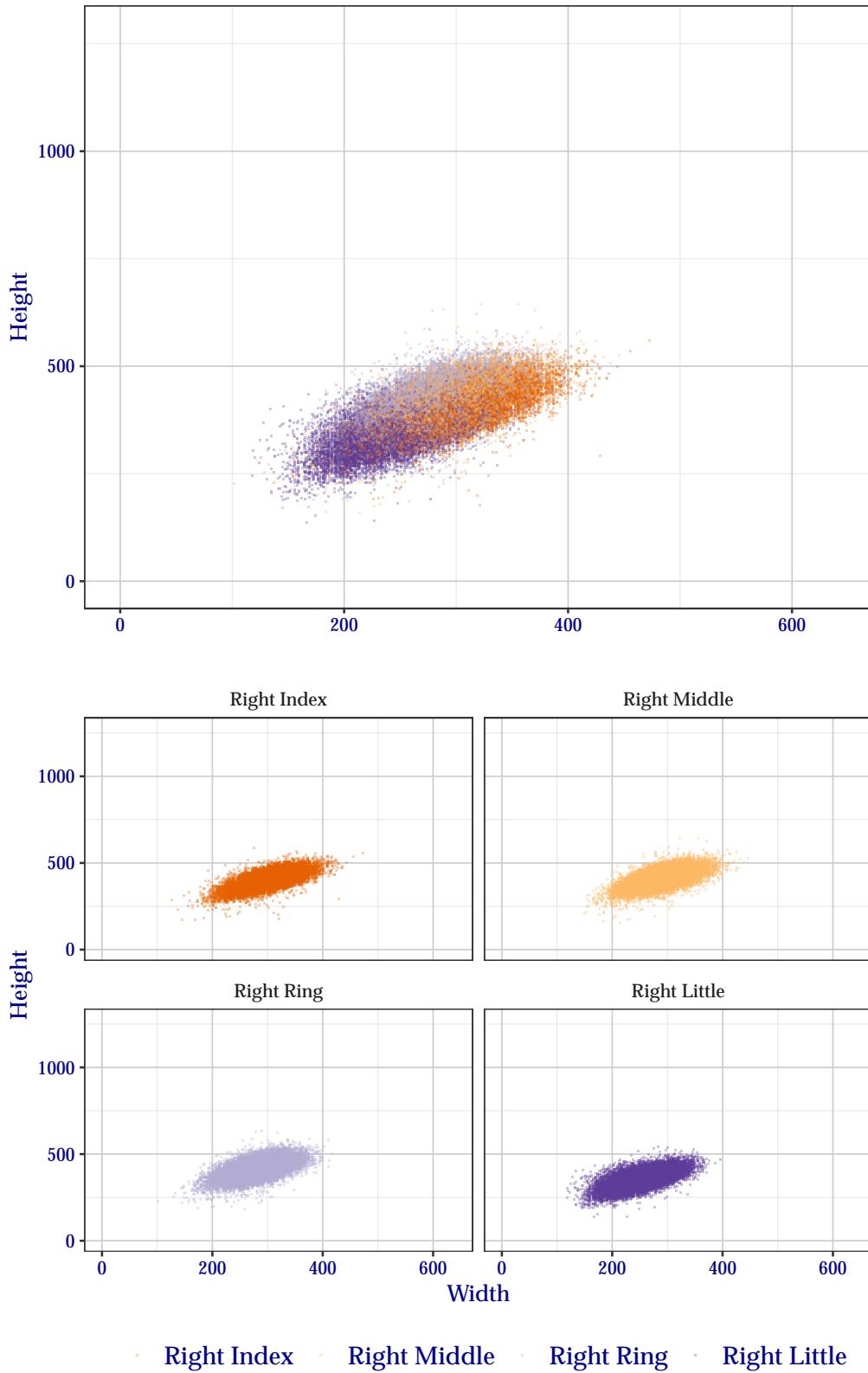


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Figure 10: Segmentation position dimensions for left hand ThreeInch data.

Segmentation Position Dimensions

Participant: innovatrics/0005, FRGPs: 2, 3, 4, 5, Image Kind: Three Inch

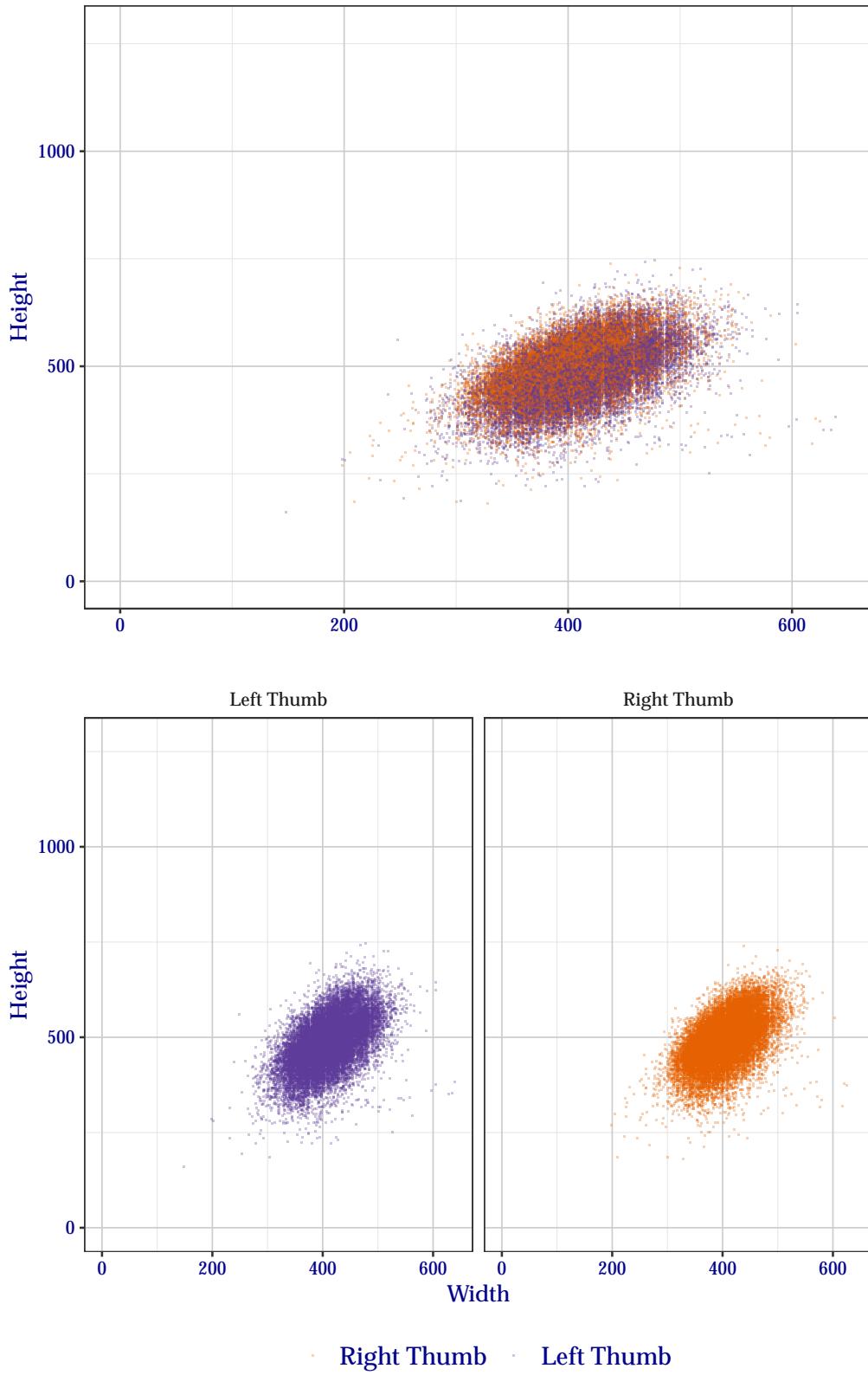


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Figure 11: Segmentation position dimensions for right hand ThreeInch data.

Segmentation Position Dimensions

Participant: innovatrics/0005, FRGPs: 1, 6, Image Kind: Three Inch



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Figure 12: Segmentation position dimensions for thumb ThreeInch data.

3.3 Detailed Segmentation Statistics

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

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

Table 15 shows how successful innovatrics+0005 segmented fingers for each subject in the test corpus. Table 16 shows success for specific finger positions over the entire test corpus. Similarly, Table 17 shows success for segmenting the same finger position from both hands.

The remainder of the tables show success per subject when considering combinations of subsets of the fingers on each slap image. Table 18 shows success for combinations of all fingers, Table 19 for just the index and middle fingers, and Table 20 for all except the little finger.

Table 15: For each subject, the percentage that at least *Number of Fingers* fingers were correctly segmented, regardless of hand, for a maximum of eight correctly-segmented fingers. In *Standard Scoring*, scoring rules are followed exactly. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Number of Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
1	99.9	99.9	99.9
2	99.4	99.4	99.5
3	98.4	98.4	98.4
4	98.0	98.0	98.0
5	95.9	95.9	95.9
6	95.9	95.9	95.9
7	95.7	95.7	95.7
8	95.2	95.2	95.3
9	93.0	93.4	93.8
10	80.8	82.8	85.0

Table 16: For all subjects, percentage that a particular friction ridge generalized position was correctly segmented. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Finger	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Thumb	97.5	98.1	98.7
Index	99.0	99.0	99.1
Middle	98.6	98.7	99.0
Ring	98.0	98.2	98.4
Little	95.9	96.0	96.1
Left			
Thumb	97.3	98.2	99.0
Index	98.2	98.3	98.4
Middle	98.6	98.7	99.1
Ring	98.5	98.9	99.2
Little	96.8	96.8	96.9

Table 17: Percentage that a particular type of fingerprint was correctly segmented on *Either* or *Both* hands. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Thumb			
Either	99.5	99.7	99.8
Both	95.4	96.7	98.0
Index			
Either	99.7	99.7	99.8
Both	94.9	94.9	95.1
Middle			
Either	99.7	99.7	99.8
Both	94.8	95.0	95.7
Ring			
Either	99.8	99.8	99.9
Both	93.9	94.6	95.0
Little			
Either	99.3	99.3	99.3
Both	90.9	91.0	91.2

Table 18: Percentage of segmentation success by hand for combinations of all ten fingers of a ThreeInch slap. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	99.6	99.6	99.6
At Least Two	98.4	98.4	98.4
At Least Three	98.0	98.0	98.0
At Least Four	97.0	97.1	97.3
All Five	86.9	87.8	88.9
Left			
Any	99.8	99.8	99.9
At Least Two	98.5	98.5	98.5
At Least Three	98.2	98.2	98.3
At Least Four	97.0	97.1	97.3
All Five	86.8	88.2	89.5

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

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Either	99.5	99.5	99.5
Both	98.1	98.2	98.7
Left			
Either	99.8	99.8	99.8
Both	97.0	97.2	97.7

Table 20: Percentage of segmentation success by hand when only considering combinations of index, middle, and ring fingers. In *Ignoring Bottom Y*, the bottom left and right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and right coordinates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	99.8	99.8	99.8
At Least Two	99.3	99.3	99.4
All Three	96.4	96.8	97.4
Left			
Any	99.9	99.9	99.9
At Least Two	99.5	99.5	99.6
All Three	95.9	96.5	97.1

3.4 Handling Troublesome Images

3.4.1 Capture Failures

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

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

Reasons for capture-type failures reported by innovatrics+0005 are enumerated in Table 21.

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

Failure Reason	Images
Request Recapture (No Attempt)	4
Request Recapture (Attempt)	1 316

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

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

Deficiency	Count
Incomplete	1 316
Image Quality	4

3.4.1.1 Recovery

When encountering a segmentation failure, SlapSeg III algorithms are encouraged to provide a *best-effort* segmentation when possible. In some cases, that best-effort may be correct, which reduces the amount of images that need to be manually adjudicated by an operator. The result of such best-effort segmentations are shown in Table 23.

Out of 1316 recovery attempts innovatrics+0005 attempted 3581 segmentations of fingers and skipped 1555 fingers. More information about skipped fingers can be found in Table 24.

Table 23: Results of best-effort segmentation when innovatrics+0005 reported segmentation failure (3581 best-effort attempts).

Standard	Ignoring Bottom Y	Ignoring Bottom X and Y
92.1	92.4	92.6

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 innovatrics+0005 are enumerated in Table 24.

Table 24: Count of self-reported segmentation failure reasoning.

Failure Reason	Fingers
Finger Not Found	1 555
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 25 shows how successful innovatrics+0005 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 25: Performance of innovatrics+0005 at detecting fingers missing from an image.

Result	Percentage
Missed	36.5
Correctly Identified	57.7
Other Failure: Finger Found, but Can't Segment	0.0
Other Failure: Vendor Defined	0.0
Other Failure: Segmentation Not Attempted	5.8

3.4.4 Sequence Error

Sequence error occurs when a fingerprint is segmented from an image but assigned an incorrect finger position (e.g., segmenting a right middle finger but labeling it a right index finger). Table 26 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 26: 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	0.19	0.20	0.20
Right	0.52	0.52	0.52
Thumbs	0.05	0.05	0.05
Combined	0.26	0.26	0.26

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 27, results are shown of how successful innovatrics+0005 segmented fingers for each subject in the test corpus. Table 28 shows success for specific finger positions over the entire test corpus. Similarly, Table 29 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 30 shows success for combinations of all fingers, Table 32 for the all except the little finger, and Table 31 for just the index and middle fingers.

Table 27: 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	98.2 [98.0, 98.4]	98.2 [98.0, 98.5]	99.3 [99.1, 99.4]
2	95.6 [95.3, 96.0]	95.7 [95.3, 96.0]	97.4 [97.2, 97.7]
3	92.1 [91.7, 92.6]	92.3 [91.8, 92.7]	94.2 [93.8, 94.6]
4	86.6 [86.0, 87.2]	86.9 [86.3, 87.5]	88.9 [88.3, 89.5]
5	74.3 [73.5, 75.0]	74.5 [73.8, 75.3]	78.5 [77.7, 79.2]
6	64.4 [63.5, 65.1]	64.7 [63.9, 65.5]	66.5 [65.7, 67.2]
7	52.6 [51.7, 53.4]	53.1 [52.3, 54.0]	54.4 [53.6, 55.3]
8	34.2 [33.4, 35.0]	35.2 [34.5, 36.1]	36.0 [35.2, 36.8]

Table 28: For all subjects, Percentage that a particular friction ridge generalized position was correctly segmented. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Finger	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Index	74.5 [73.9, 75.1]	74.8 [74.2, 75.4]	82.2 [81.8, 82.7]
Middle	79.6 [79.1, 80.2]	79.8 [79.2, 80.3]	81.0 [80.4, 81.5]
Ring	76.9 [76.4, 77.5]	77.2 [76.7, 77.7]	78.3 [77.8, 78.9]
Little	73.4 [72.8, 74.0]	73.6 [73.0, 74.1]	75.4 [74.8, 75.9]
Left			
Index	83.7 [83.2, 84.2]	84.0 [83.5, 84.5]	86.7 [86.3, 87.2]
Middle	80.8 [80.2, 81.3]	81.2 [80.7, 81.8]	81.3 [80.7, 81.8]
Ring	75.2 [74.6, 75.7]	75.8 [75.2, 76.4]	75.8 [75.3, 76.5]
Little	67.9 [67.3, 68.6]	68.1 [67.4, 68.8]	68.2 [67.6, 68.9]

Table 29: Percentage that a particular type of fingerprint was correctly segmented on *Either* or *Both* hands. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Index			
Either	92.4 [92.0, 92.9]	92.6 [92.1, 93.1]	94.9 [94.6, 95.3]
Both	62.1 [61.2, 62.9]	62.6 [61.8, 63.6]	70.2 [69.4, 71.0]
Middle			
Either	93.0 [92.6, 93.4]	93.1 [92.7, 93.6]	93.6 [93.1, 94.0]
Both	63.7 [62.9, 64.5]	64.2 [63.4, 65.0]	65.1 [64.3, 65.9]
Ring			
Either	90.4 [89.9, 90.9]	90.6 [90.1, 91.1]	91.1 [90.6, 91.6]
Both	58.7 [57.9, 59.6]	59.4 [58.6, 60.3]	60.1 [59.3, 60.9]
Little			
Either	86.8 [86.3, 87.4]	86.9 [86.4, 87.5]	87.9 [87.3, 88.5]
Both	50.8 [49.9, 51.6]	51.0 [50.2, 51.9]	52.3 [51.4, 53.2]

Table 30: Percentage of segmentation success by hand for combinations of all eight fingers of a TwoInch slap. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	91.0 [91.6, 92.1]	91.1 [91.7, 92.2]	96.1 [95.5, 95.9]
At Least Two	84.0 [84.0, 84.7]	84.0 [84.1, 84.8]	87.2 [86.0, 86.6]
At Least Three	74.6 [74.0, 74.8]	74.7 [74.3, 75.1]	76.8 [75.5, 76.3]
All Four	55.0 [54.8, 55.7]	55.6 [55.5, 56.5]	56.8 [56.3, 57.2]
Left			
Any	92.9 [91.6, 92.1]	93.0 [91.7, 92.2]	95.3 [95.5, 95.9]
At Least Two	84.7 [84.0, 84.7]	84.9 [84.1, 84.8]	85.3 [86.0, 86.6]
At Least Three	74.3 [74.0, 74.8]	74.7 [74.3, 75.1]	74.9 [75.5, 76.3]
All Four	55.7 [54.8, 55.7]	56.5 [55.5, 56.5]	56.7 [56.3, 57.2]

Table 31: Percentage of segmentation success by hand when only considering combinations of index and middle fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Either Index or Middle	88.4 [89.4, 89.9]	88.5 [89.5, 90.1]	94.7 [94.1, 94.5]
Both Index and Middle	65.8 [68.9, 69.7]	66.1 [69.3, 70.2]	68.5 [70.7, 71.6]
Left			
Either Index or Middle	91.2 [89.4, 89.9]	91.3 [89.5, 90.1]	93.9 [94.1, 94.5]
Both Index and Middle	73.3 [68.9, 69.7]	73.9 [69.3, 70.2]	74.2 [70.7, 71.6]

Table 32: Percentage of segmentation success by hand when only considering combinations of index, middle, and ring fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	90.1 [90.8, 91.4]	90.2 [90.9, 91.5]	95.7 [95.1, 95.5]
At Least Two	81.0 [81.3, 82.1]	81.1 [81.5, 82.2]	83.8 [83.1, 83.8]
All Three	60.0 [61.8, 62.8]	60.6 [62.6, 63.5]	62.0 [63.4, 64.3]
Left			
Any	92.3 [90.8, 91.4]	92.4 [90.9, 91.5]	94.8 [95.1, 95.5]
At Least Two	82.4 [81.3, 82.1]	82.8 [81.5, 82.2]	83.1 [83.1, 83.8]
All Three	64.9 [61.8, 62.8]	65.9 [62.6, 63.5]	66.0 [63.4, 64.3]

A.2 Jaccard Index

Table 33: For each subject, the percentage that at least *Number of Fingers* fingers were segmented with a Jaccard index in the indicated range.

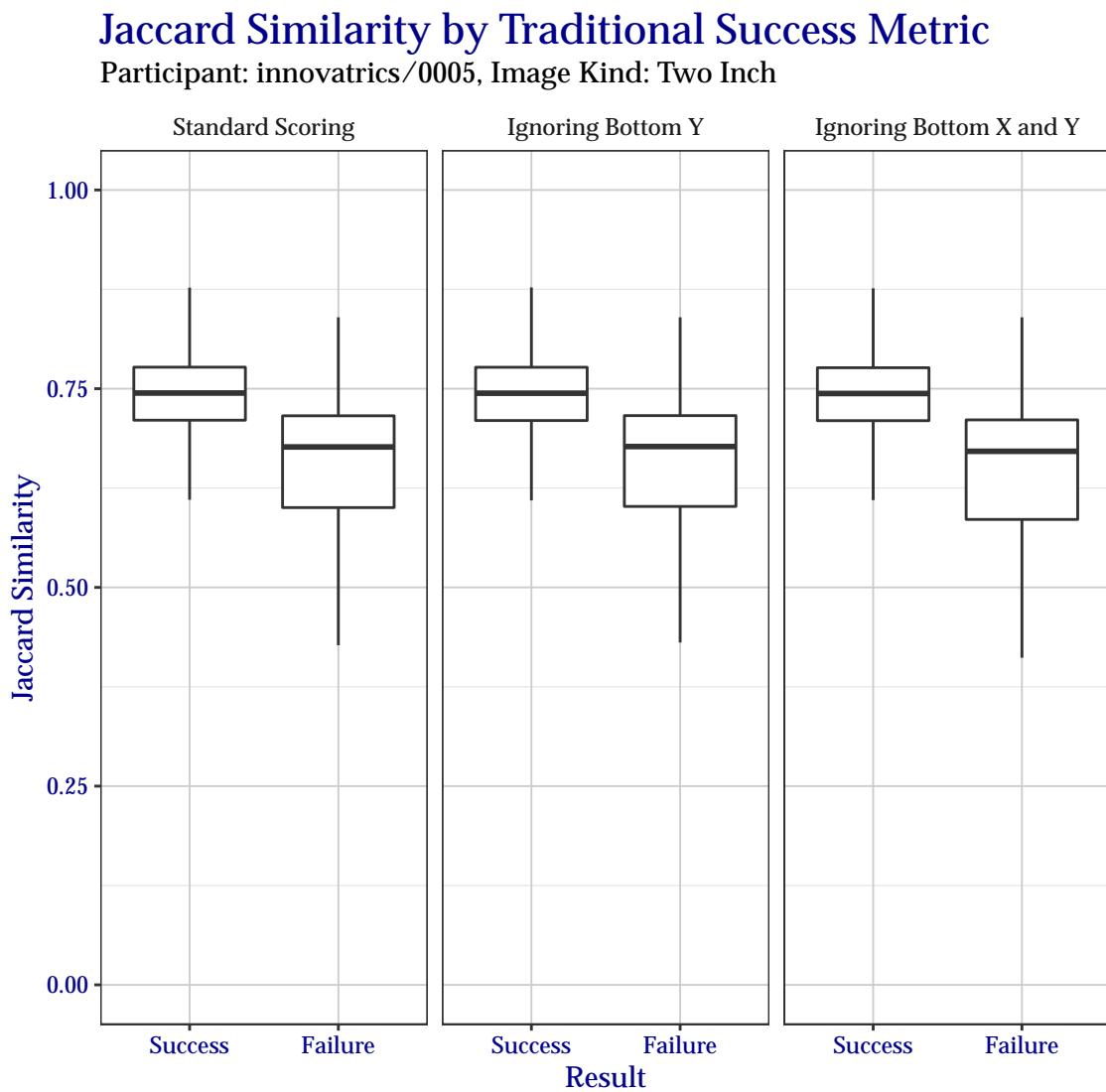
Number of Fingers	≥ 0.5	≥ 0.6	≥ 0.7	≥ 0.8	≥ 0.9	≥ 0.95	≥ 0.98
1	100.0	100.0	99.6	47.8	0.6	0.1	0.1
2	99.9	99.8	98.0	19.5	0.0	0.0	0.0
3	99.6	99.5	93.7	6.6	0.0	0.0	0.0
4	99.0	98.7	85.0	1.6	0.0	0.0	0.0
5	95.1	94.2	68.8	0.3	0	0	0
6	93.2	91.1	51.8	0.1	0	0	0
7	88.3	83.5	31.4	0.0	0	0	0
8	70.9	62.9	11.9	0.0	0	0	0

Table 34: For all subjects, percentage that a particular friction ridge generalized position was segmented with a Jaccard index in the indicated range.

Finger	$0-0.5$	$0.5-0.6$	$0.6-0.7$	$0.7-0.8$	$0.8-0.9$	$0.9-1.0$
Right						
Index	14.6	0.2	8.0	58.3	18.8	0.1
Middle	1.6	0.3	12.7	67.7	17.5	0.2
Ring	2.0	0.4	16.5	71.9	9.2	0.0
Little	3.2	1.6	29.7	59.5	6.0	0.0
Left						
Index	8.3	1.6	22.1	62.1	5.9	0.0
Middle	2.1	1.8	21.4	64.3	10.3	0.1
Ring	2.0	3.3	36.2	54.4	4.1	0.0
Little	3.0	6.6	44.9	42.7	2.8	0.0

Table 35: Percentage of segmentation obtaining a Jaccard index in the indicated ranges, by hand, for combinations of all eight fingers of a TwoInch slap.

Fingers	≥ 0.5	≥ 0.6	≥ 0.7	≥ 0.8	≥ 0.9	≥ 0.95	≥ 0.98
Right							
Any	99.8	99.8	97.6	37.1	0.4	0.0	0.0
At Least Two	99.1	99.0	91.6	11.9	0.0	0.0	0.0
At Least Three	97.0	96.2	75.9	2.7	0.0	0.0	0.0
All Four	82.7	81.2	44.3	0.4	0.0	0.0	0.0
Left							
Any	99.8	99.5	90.1	19.1	0.2	0.0	0.0
At Least Two	99.0	98.1	76.9	3.7	0.0	0.0	0.0
At Least Three	97.7	94.2	54.4	0.5	0.0	0.0	0.0
All Four	88.0	79.5	25.5	0.0	0.0	0.0	0.0

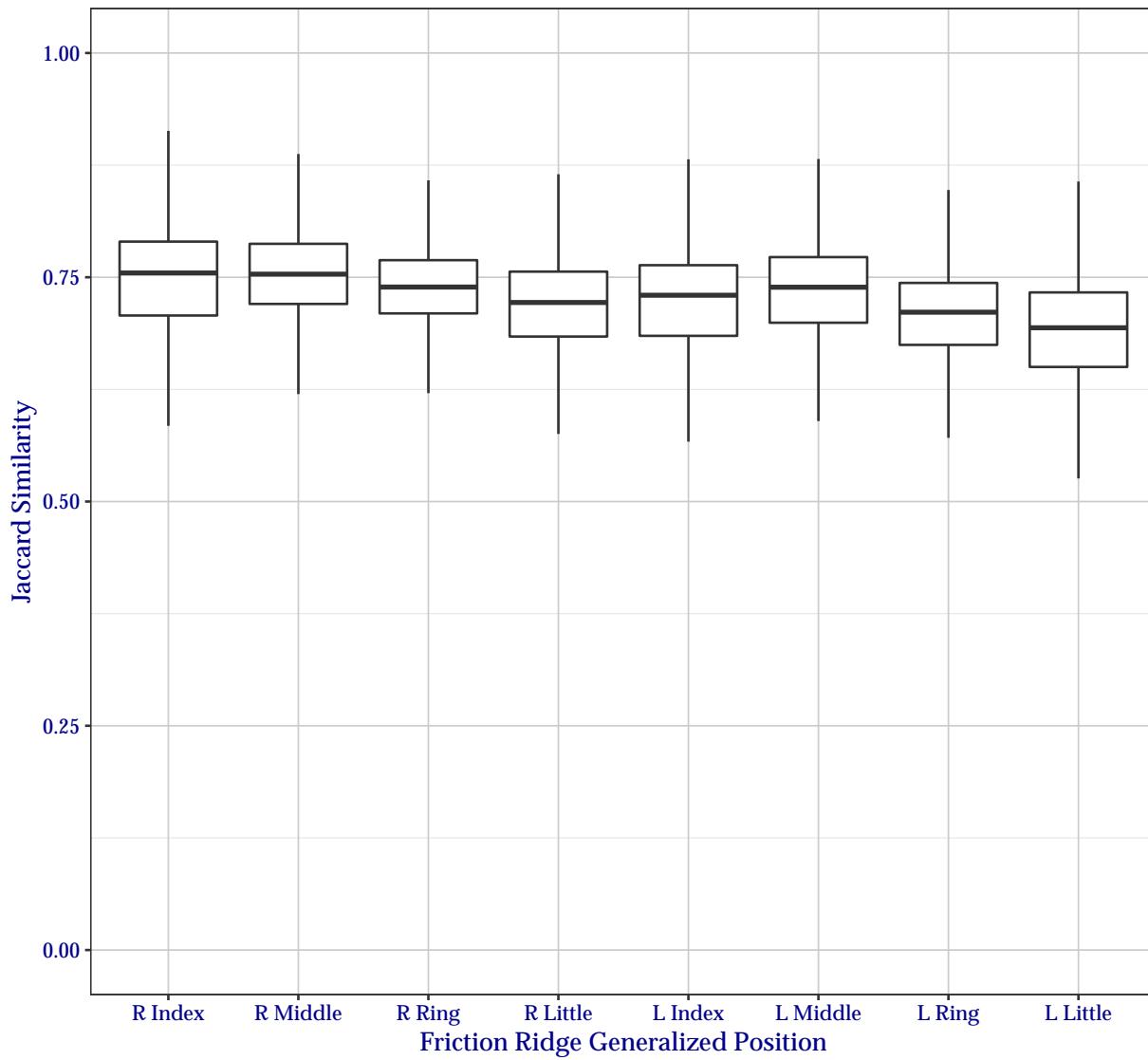


28 April 2021, 09:09:10 AM EDT

Figure 13: Boxplot of Jaccard similarity indices as compared to the traditional success metrics. Outliers have been removed for clarity.

Jaccard Similarity by Friction Ridge Generalized Position

Participant: innovatrics/0005, Image Kind: Two Inch



28 April 2021, 09:09:06 AM EDT

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

Table 36: Percentage of segmentation obtaining a Jaccard index in the indicated ranges, by hand, for combinations of index and middle fingers of a TwoInch slap.

Fingers	≥ 0.5	≥ 0.6	≥ 0.7	≥ 0.8	≥ 0.9	≥ 0.95	≥ 0.98
Right							
Either Index or Middle	99.4	99.4	93.5	30.2	0.3	0.0	0.0
Both Index and Middle	84.4	84.0	69.2	6.5	0.0	0.0	0.0
Left							
Either Index or Middle	99.1	98.4	84.2	14.8	0.1	0.0	0.0
Both Index and Middle	90.5	87.8	58.6	1.5	0.0	0.0	0.0

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

Fingers	≥ 0.5	≥ 0.6	≥ 0.7	≥ 0.8	≥ 0.9	≥ 0.95	≥ 0.98
Right							
Any	99.6	99.6	96.9	34.7	0.3	0.0	0.0
At Least Two	98.3	98.1	87.7	9.9	0.0	0.0	0.0
All Three	83.9	83.3	59.3	1.4	0.0	0.0	0.0
Left							
Any	99.5	99.2	88.1	17.4	0.1	0.0	0.0
At Least Two	98.3	96.8	72.0	2.9	0.0	0.0	0.0
All Three	89.7	84.9	41.1	0.2	0.0	0.0	0.0

B Identification Flats (“ThreeInch” Data)

B.1 Bootstrap Confidence for Segmentation Statistics

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

In Table 38, results are shown of how successful innovatrics+0005 segmented fingers for each subject in the test corpus. Table 39 shows success for specific finger positions over the entire test corpus. Similarly, Table 40 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 41 shows success for combinations of all fingers, Table 43 for the all except the little finger, and Table 42 for just the index and middle fingers.

Table 38: For each subject, the percentage that at least *Number of Fingers* fingers were correctly segmented, regardless of hand, for a maximum of eight correctly-segmented fingers. In *Standard Scoring*, scoring rules are followed exactly. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Number of Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
1	99.9 [99.8, 99.9]	99.9 [99.8, 99.9]	99.9 [99.9, 99.9]
2	99.4 [99.3, 99.5]	99.4 [99.4, 99.5]	99.5 [99.4, 99.6]
3	98.4 [98.2, 98.5]	98.4 [98.2, 98.6]	98.4 [98.3, 98.6]
4	98.0 [97.8, 98.1]	98.0 [97.8, 98.1]	98.0 [97.8, 98.2]
5	95.9 [95.7, 96.1]	95.9 [95.7, 96.2]	95.9 [95.7, 96.2]
6	95.9 [95.6, 96.1]	95.9 [95.6, 96.1]	95.9 [95.7, 96.1]
7	95.7 [95.5, 96.0]	95.7 [95.5, 96.0]	95.7 [95.5, 96.0]
8	95.2 [94.9, 95.4]	95.2 [95.0, 95.5]	95.3 [95.1, 95.6]
9	93.0 [92.6, 93.3]	93.4 [93.1, 93.7]	93.8 [93.5, 94.1]
10	80.8 [80.3, 81.2]	82.8 [82.3, 83.3]	85.0 [84.6, 85.4]

Table 39: For all subjects, Percentage that a particular friction ridge generalized position was correctly segmented. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Finger	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Thumb	97.5 [97.3, 97.7]	98.1 [97.9, 98.2]	98.7 [98.6, 98.9]
Index	99.0 [98.9, 99.1]	99.0 [98.9, 99.1]	99.1 [99.0, 99.2]
Middle	98.6 [98.4, 98.7]	98.7 [98.5, 98.8]	99.0 [98.9, 99.1]
Ring	98.0 [97.8, 98.1]	98.2 [98.1, 98.4]	98.4 [98.3, 98.6]
Little	95.9 [95.7, 96.2]	96.0 [95.7, 96.2]	96.1 [95.8, 96.3]
Left			
Thumb	97.3 [97.1, 97.6]	98.2 [98.1, 98.4]	99.0 [98.9, 99.2]
Index	98.2 [98.1, 98.4]	98.3 [98.1, 98.4]	98.4 [98.2, 98.5]
Middle	98.6 [98.4, 98.7]	98.7 [98.6, 98.9]	99.1 [99.0, 99.3]
Ring	98.5 [98.3, 98.6]	98.9 [98.8, 99.1]	99.2 [99.0, 99.3]
Little	96.8 [96.6, 97.0]	96.8 [96.6, 97.0]	96.9 [96.7, 97.1]

Table 40: Percentage that a particular type of fingerprint was correctly segmented on *Either* or *Both* hands. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Thumb			
Either	99.5 [99.5, 99.6]	99.7 [99.6, 99.7]	99.8 [99.7, 99.8]
Both	95.4 [95.1, 95.7]	96.7 [96.5, 96.9]	98.0 [97.9, 98.2]
Index			
Either	99.7 [99.7, 99.8]	99.7 [99.7, 99.8]	99.8 [99.7, 99.8]
Both	94.9 [94.6, 95.1]	94.9 [94.7, 95.2]	95.1 [94.8, 95.4]
Middle			
Either	99.7 [99.6, 99.7]	99.7 [99.6, 99.8]	99.8 [99.7, 99.8]
Both	94.8 [94.5, 95.1]	95.0 [94.8, 95.3]	95.7 [95.5, 96.0]
Ring			
Either	99.8 [99.8, 99.9]	99.8 [99.8, 99.9]	99.9 [99.8, 99.9]
Both	93.9 [93.6, 94.2]	94.6 [94.4, 94.9]	95.0 [94.8, 95.3]
Little			
Either	99.3 [99.2, 99.4]	99.3 [99.2, 99.4]	99.3 [99.2, 99.4]
Both	90.9 [90.5, 91.3]	91.0 [90.7, 91.4]	91.2 [90.8, 91.5]

Table 41: Percentage of segmentation success by hand for combinations of all ten fingers of a ThreeInch slap. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	99.6 [99.7, 99.8]	99.6 [99.7, 99.8]	99.6 [99.7, 99.8]
At Least Two	98.4 [98.3, 98.5]	98.4 [98.3, 98.5]	98.4 [98.3, 98.5]
At Least Three	98.0 [98.0, 98.2]	98.0 [98.0, 98.2]	98.0 [98.0, 98.3]
At Least Four	97.0 [96.8, 97.2]	97.1 [97.0, 97.3]	97.3 [97.1, 97.4]
All Five	86.9 [86.6, 87.1]	87.8 [87.7, 88.3]	88.9 [89.0, 89.5]
Left			
Any	99.8 [99.7, 99.8]	99.8 [99.7, 99.8]	99.9 [99.7, 99.8]
At Least Two	98.5 [98.3, 98.5]	98.5 [98.3, 98.5]	98.5 [98.3, 98.5]
At Least Three	98.2 [98.0, 98.2]	98.2 [98.0, 98.2]	98.3 [98.0, 98.3]
At Least Four	97.0 [96.8, 97.2]	97.1 [97.0, 97.3]	97.3 [97.1, 97.4]
All Five	86.8 [86.6, 87.1]	88.2 [87.7, 88.3]	89.5 [89.0, 89.5]

Table 42: Percentage of segmentation success by hand when only considering combinations of index and middle fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Either Index or Middle	99.5 [99.6, 99.7]	99.5 [99.6, 99.7]	99.5 [99.6, 99.7]
Both Index and Middle	98.1 [97.4, 97.7]	98.2 [97.6, 97.9]	98.7 [98.1, 98.3]
Left			
Either Index or Middle	99.8 [99.6, 99.7]	99.8 [99.6, 99.7]	99.8 [99.6, 99.7]
Both Index and Middle	97.0 [97.4, 97.7]	97.2 [97.6, 97.9]	97.7 [98.1, 98.3]

Table 43: Percentage of segmentation success by hand when only considering combinations of index, middle, and ring fingers. In *Ignoring Bottom Y*, the bottom left and bottom right Y coordinates are ignored. *Ignoring Bottom X and Y* only checks the locations of the top left and top right coordinates. Values in square brackets represent a 95 % confidence interval after bootstrapping with 1 000 replicates.

Fingers	Standard Scoring	Ignoring Bottom Y	Ignoring Bottom X and Y
Right			
Any	99.8 [99.8, 99.9]	99.8 [99.9, 99.9]	99.8 [99.9, 99.9]
At Least Two	99.3 [99.3, 99.5]	99.3 [99.3, 99.5]	99.4 [99.4, 99.5]
All Three	96.4 [95.9, 96.3]	96.8 [96.5, 96.8]	97.4 [97.1, 97.4]
Left			
Any	99.9 [99.8, 99.9]	99.9 [99.9, 99.9]	99.9 [99.9, 99.9]
At Least Two	99.5 [99.3, 99.5]	99.5 [99.3, 99.5]	99.6 [99.4, 99.5]
All Three	95.9 [95.9, 96.3]	96.5 [96.5, 96.8]	97.1 [97.1, 97.4]

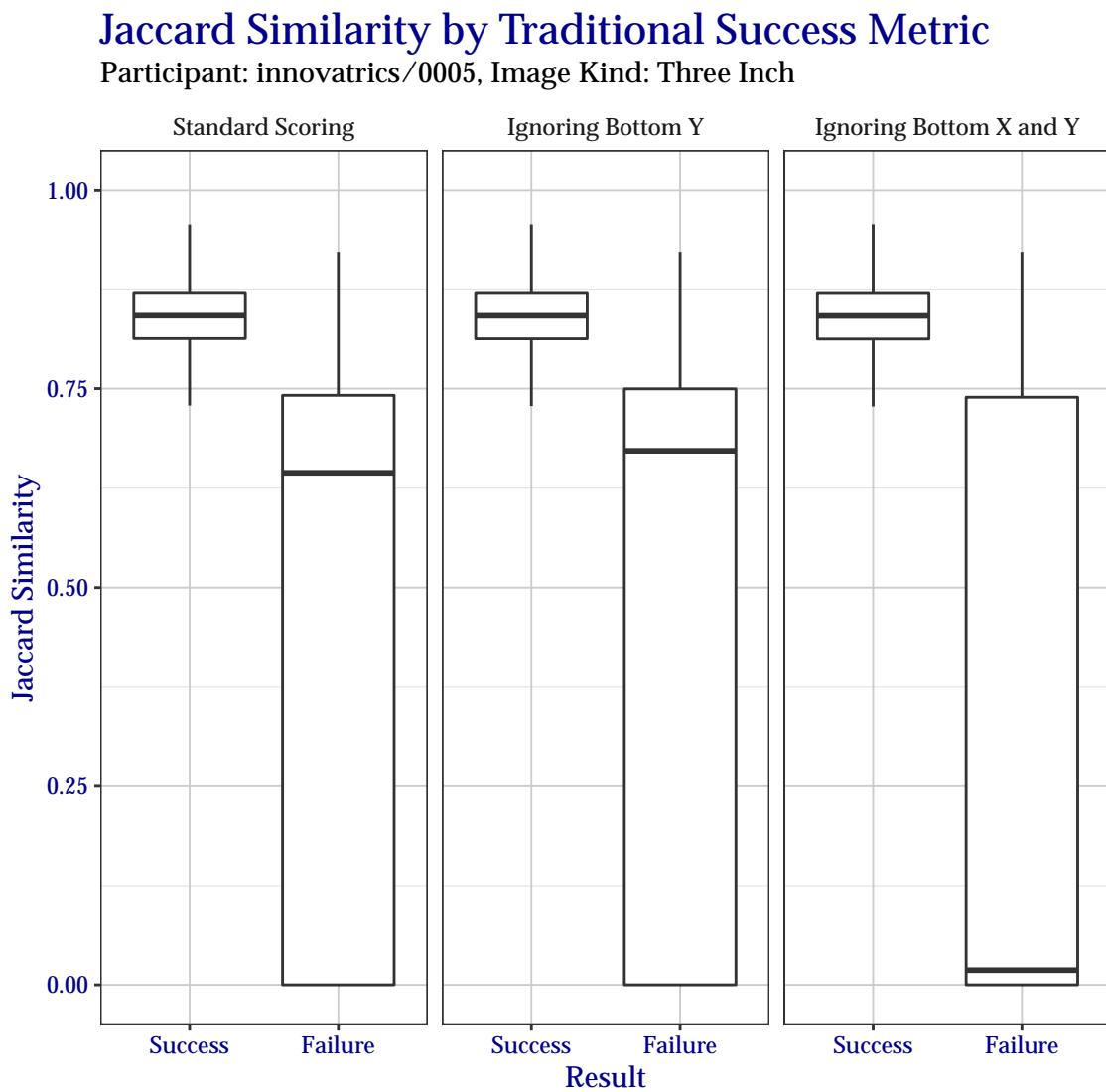
B.2 Jaccard Index

Table 44: For each subject, the percentage that at least *Number of Fingers* fingers were segmented with a Jaccard index in the indicated range.

Number of Fingers	≥ 0.5	≥ 0.6	≥ 0.7	≥ 0.8	≥ 0.9	≥ 0.95	≥ 0.98
1	100.0	100.0	99.9	99.6	50.3	1.5	0.2
2	99.8	99.8	99.7	98.9	18.4	0.0	0.0
3	98.4	98.4	98.4	97.7	5.1	0.0	0.0
4	98.1	98.1	97.9	96.6	1.2	0.0	0.0
5	95.9	95.9	95.9	93.6	0.2	0.0	0.0
6	95.9	95.9	95.9	90.3	0.0	0	0
7	95.8	95.8	95.7	83.2	0.0	0	0
8	95.4	95.4	95.0	70.2	0	0	0
9	94.7	94.6	93.2	48.8	0	0	0
10	90.8	89.7	83.0	22.1	0	0	0

Table 45: For all subjects, percentage that a particular friction ridge generalized position was segmented with a Jaccard index in the indicated range.

Finger	0-0.5	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1.0
Right						
Thumb	0.2	0.2	0.9	8.4	70.6	19.7
Index	0.6	0.0	0.4	18.4	77.6	3.0
Middle	0.5	0.1	0.5	12.9	78.7	7.3
Ring	0.3	0.1	1.4	15.9	74.0	8.3
Little	2.7	0.1	1.1	18.4	68.7	9.0
Left						
Thumb	0.3	0.3	1.5	13.5	76.3	8.1
Index	0.7	0.0	0.4	14.8	77.5	6.6
Middle	0.3	0.1	0.8	15.7	76.1	7.0
Ring	0.5	0.3	1.4	17.0	76.0	4.8
Little	2.2	0.1	1.0	24.0	69.0	3.7

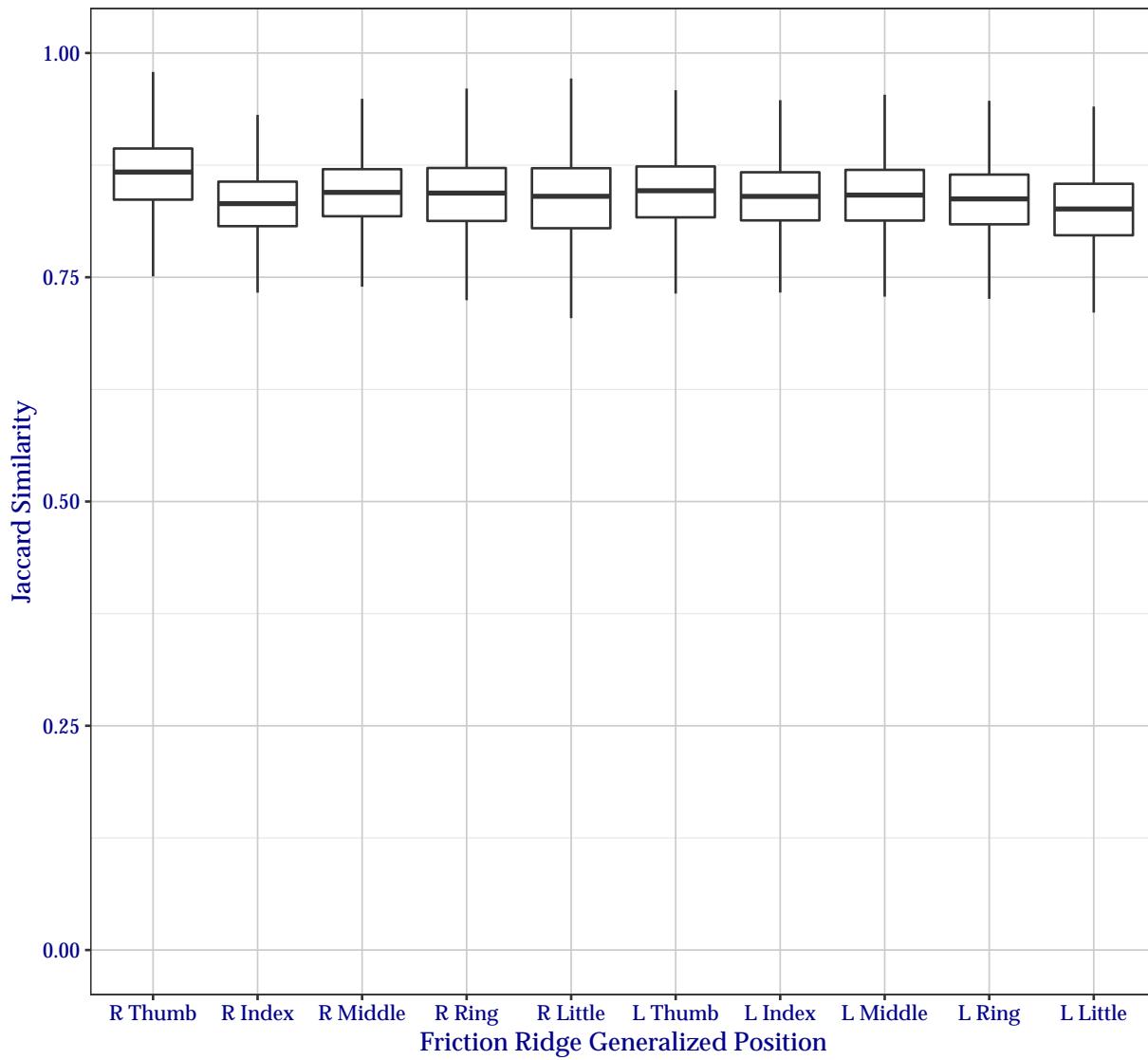


28 April 2021, 09:12:12 AM EDT

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

Jaccard Similarity by Friction Ridge Generalized Position

Participant: innovatrics/0005, Image Kind: Three Inch



28 April 2021, 09:12:06 AM EDT

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

Table 46: Percentage of segmentation obtaining a Jaccard index in the indicated ranges, by hand, for combinations of all ten fingers of a ThreeInch slap.

Fingers	≥ 0.5	≥ 0.6	≥ 0.7	≥ 0.8	≥ 0.9	≥ 0.95	≥ 0.98
Right							
Any	99.9	99.9	99.8	99.2	36.1	1.0	0.1
At Least Two	98.4	98.4	98.4	96.3	8.0	0.0	0.0
At Least Three	98.1	98.1	97.9	90.6	1.7	0.0	0.0
At Least Four	97.7	97.7	97.0	76.4	0.2	0.0	0.0
All Five	92.2	91.8	88.4	46.3	0.0	0.0	0.0
Left							
Any	99.9	99.9	99.9	99.1	24.6	0.5	0.2
At Least Two	98.5	98.5	98.4	96.1	4.4	0.0	0.0
At Least Three	98.3	98.3	98.1	89.6	0.5	0.0	0.0
At Least Four	97.6	97.6	96.9	73.1	0.0	0.0	0.0
All Five	92.4	91.7	87.5	39.5	0.0	0.0	0.0

Table 47: Percentage of segmentation obtaining a Jaccard index in the indicated ranges, by hand, for combinations of index and middle fingers of a ThreeInch slap.

Fingers	≥ 0.5	≥ 0.6	≥ 0.7	≥ 0.8	≥ 0.9	≥ 0.95	≥ 0.98
Right							
Either Index or Middle	99.5	99.5	99.4	94.7	9.6	0.2	0.0
Both Index and Middle	99.3	99.2	98.3	71.8	0.7	0.0	0.0
Left							
Either Index or Middle	99.8	99.8	99.7	94.5	12.2	0.2	0.0
Both Index and Middle	99.2	99.1	98.0	72.7	1.4	0.0	0.0

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

Fingers	≥ 0.5	≥ 0.6	≥ 0.7	≥ 0.8	≥ 0.9	≥ 0.95	≥ 0.98
Right							
Any	99.9	99.9	99.8	97.4	15.9	0.3	0.0
At Least Two	99.5	99.5	99.2	88.9	2.4	0.0	0.0
All Three	99.1	98.9	96.8	62.3	0.2	0.0	0.0
Left							
Any	99.9	99.9	99.9	97.6	15.8	0.2	0.1
At Least Two	99.7	99.7	99.4	88.3	2.5	0.0	0.0
All Three	98.9	98.5	96.2	62.2	0.2	0	0