Verification and Validation Report: Mechatronics

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1 Revision History

Date	Version	Notes
Date 1	1.0	Notes
Date 2	1.1	Notes

2 Symbols, Abbreviations and Acronyms

symbol	description
T	Test

[symbols, abbreviations or acronyms – you can reference the SRS tables if needed —SS]

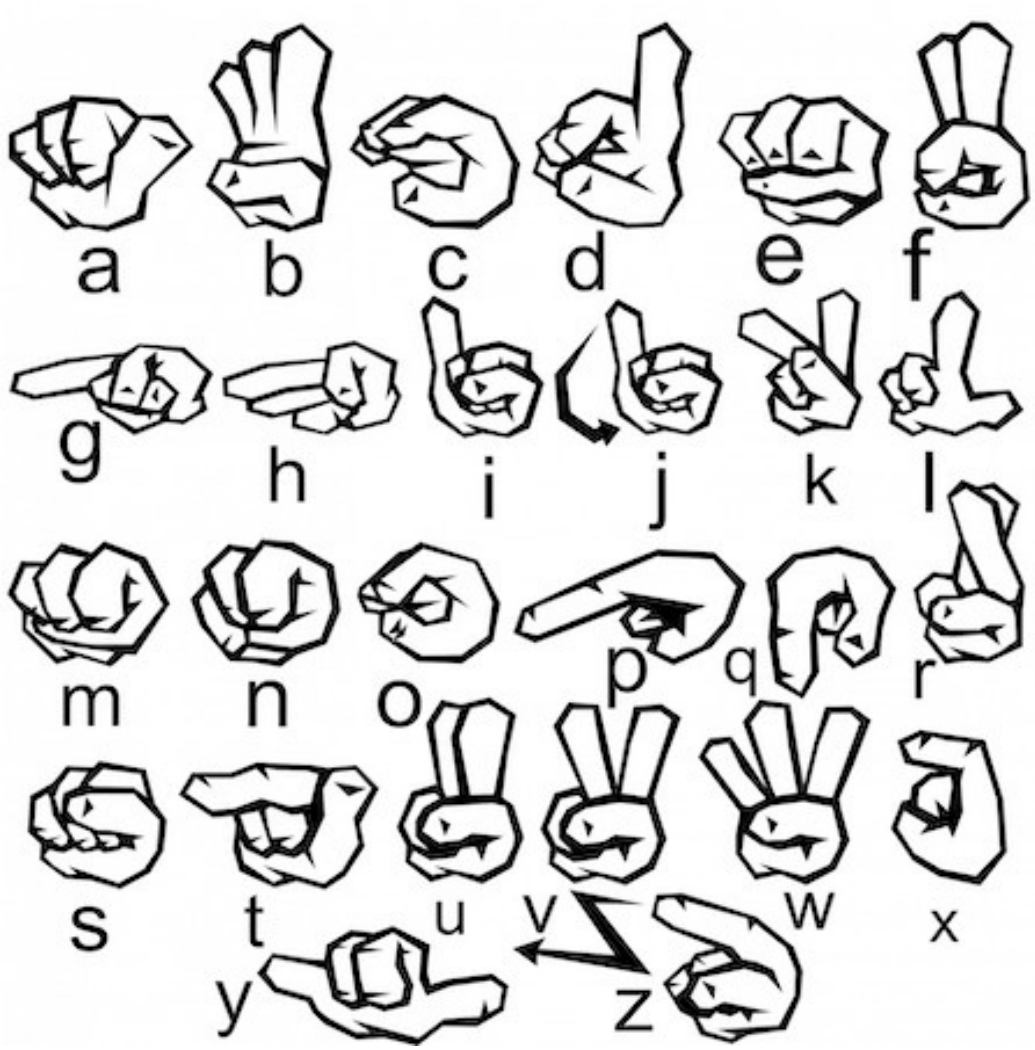

Figure 1: Lower Case

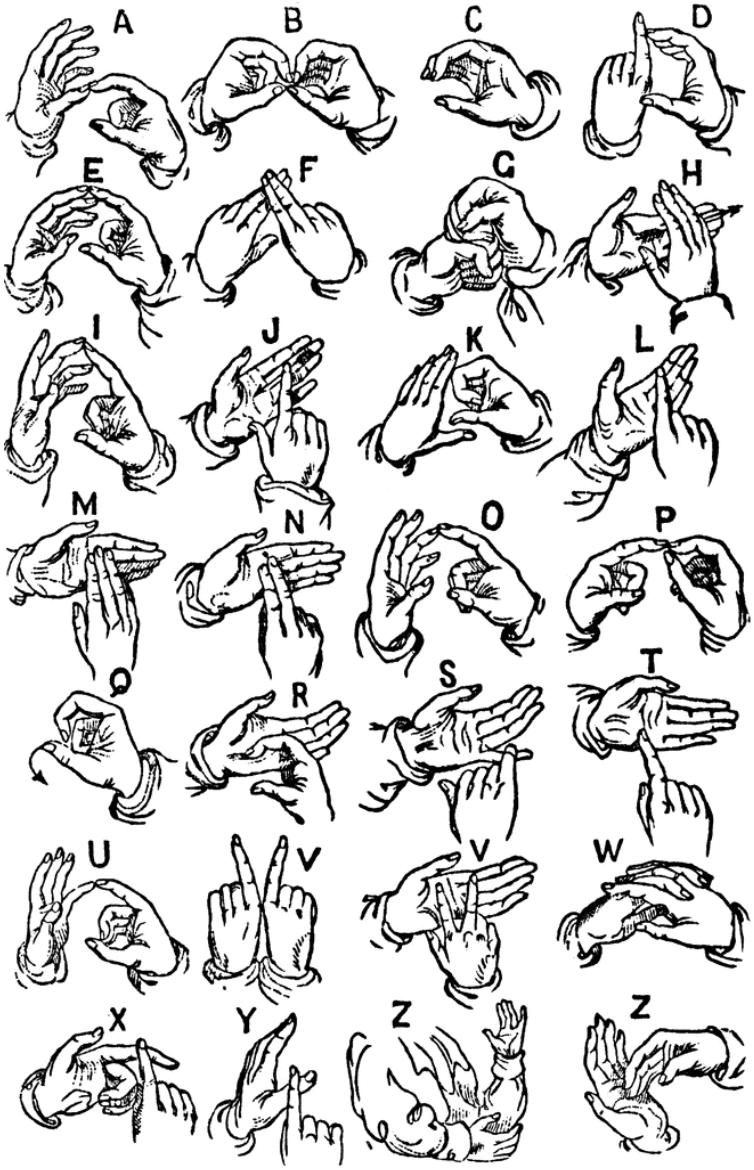

Figure 2: Upper Case

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3 Purpose

The purpose of this document is to outline the testing that was done during the development of the ASL translator. These tests were conducted to ensure that the ASL translator is able to perform as expected and is usable in a real-life setting. This document summarizes the results of those tests.

4 Test Cases

Tests for Motion Tracking Module

ID	Description	Req Ref	Input	Expected Output	Actual Output	Result
A1	Testing for joint tracking when hiding joints	MLFR1, MLFR5, NFR2	Hand Gesture for "m" and "n" (covering thumb)	Able to recognize hidden joints	Able to recognize hidden joints	Pass
A2	Testing hand detection for hand at the edges of the camera detection area	CFR1	Hand gesture for "a", "b", "c"	a b c	a b c	Pass
A3	Testing if joint lines are properly aligned with the user's joints and move accordingly at the center	MLFR1, MLFR6, NFR2	Moving hand from one side of the screen to the other in rapid succession	Able to overlay joint lines on user's hand continually and is centered on the hand	Able to overlay joint lines on user's hand continually and is centered on the hand	Pass
A4	Testing if a joint overlay will be placed on more than two hands	MLFR1, MLFR3, NFR2	Having a third hand in the frame after the initial two	Unable to detect the third hand	Unable to detect the third hand	Pass

A5	Testing if detected joints are from one individual (the user)	MLFR1, NFR1, NFR3	Have two people with one hand each in the frame	Detects the hand from one person as opposed to two	Detects both the hands of both people	Fail
A6	Testing hand detection at a distance of 2 m	CFR1	Hand gesture for “a”, “b”, “c”	a b c	a b c	Pass
A7	Testing hand detection with multiple hands	CFR1	Hand gestures for “z”, “x”, “y”	z x y	z x y	Pass
A8	Testing for joint tracking when overlapping hands	MLFR1, MLFR3, MLFR5	Hand Gesture for “S”, “M”, “N”, “R”	Able to separate different hand joints from each other	Able to separate different hand joints from each other	Pass
A9	Switching from translating mode to training mode stop detecting hand gestures	N/A	Pressing either 2 or 3	The interface no longer tries to record hand motion	The interface no longer tries to record hand motion	Pass
A10	Testing for precision tracking	MLFR1	Making small rotations and tremors	The joint overlay makes small movements	The joint overlay makes small movements	Pass

A11	Testing for gesture recognition if the hands hand in placing with different angles	CFR1	Hand gestures for “a”, “b”, “c” with different angles for the position of the hand	“a”, “b”, “c”	“a”, “b”, “c”	Pass
A12	Testing for occlusion handling	MLFR1	Partially hiding half of the hand behind a desk	The joint overlay is able to predict the rest of the hand	Joints overlay becomes disjointed and stretches	Fail
A13	Testing the durability for accuracy and reliability	NFR1, MLFR1	Keeping the program open for over an hour and testing for similar results	The joint overlay works as intended	The frame rate decreased leading to poor performance	Fail
A14	User testing for different hand sizes and shapes	MLF1	Using different people’s hands to test the accuracy of the string “a”, “”b”, “c”, “d”	Able to translate a b c d everytime	Able to translate a b c d everytime	Pass

Table 1: Tests for Motion Tracking Module

Tests for Coordinate Normalization Module

ID	Description	Req Ref	Input	Expected Output	Actual Output	Result
B1	Testing if different webcams or cameras impact coordinates at the same position	CFR1, CFR2	Sign the sentence "how do you do" alphabetically through 5 different cameras	The same set of coordinates for all 5	The same set of coordinates for all 5	Pass
B2	Testing if the coordinates (x,y) of each joint is accurately recorded	MLFR2	Repeatedly recording the gesture "a" at the center of the screen	The same set of coordinates should be written to CSV file every time the gesture is recorded	The same set of coordinates should be written to CSV file every time the gesture is recorded	Pass
B3	Testing if the coordinates (x,y) of each joint is accurately recorded for two handed gestures	MLFR3, MLFR2	Repeatedly recording the gesture "F" at the center of the screen	The same set of coordinates should be written to CSV file every time the gesture is recorded	The same set of coordinates should be written to CSV file every time the gesture is recorded	Pass
B4	Testing for range normalization between [-1,1]	MLFR2	Testing the joints at the edge of the frame	No coordinate recorded exceeds [-1, 1]	No coordinate recorded exceeds [-1, 1]	Pass

B5	Testing for scaling normalization for hand size to be consistent	MLFR2	Testing using different sizes to hands	All coordinates recorded from each set of hands are generally the same	All coordinates recorded from each set of hands are generally the same	Pass

Table 2: Tests for Coordinate Normalization Module

Tests for Coordinate Export Module

ID	Description	Req Ref	Input	Expected Output	Actual Output	Result
C1	Testing if the relative coordinates (x,y) is written to the CSV file	RDP1, NFR5	Hand gesture for "a"	Coordinates with identifier "0" (identifier for the letter "a") are written to the CSV file	Coordinates with identifier "0" were written to the CSV file	Pass
C2	Testing if the point history coordinates (x,y) is written to the CSV file	RDP1, NFR5	Hand gesture for "j"	Multiple coordinates with identifier "9" (identifier for the letter "j") are written to the CSV file	Multiple coordinates with identifier "9" get written to the CSV file	Pass

C3	Testing to see if a coordinate for each hand joint is written to the CSV file	RDP1	Hand gesture for "b"	43 coordinates are written to the CSV file, first the identifier (for the gesture, ie 'a', 'b', etc.) followed by an x,y coordinate for each joint (21 * 2 + 1 = 43)	43 coordinates are written to the CSV file every time a gesture is recorded	Pass

Table 3: Tests for Coordinate Export Module

Tests for Machine Learning Module

ID	Description	Req Ref	Input	Expected Output	Actual Output	Result
D1	Testing hand detection for similar looking gestures	CFR1, RDP1	Hand gesture for "m"	m	n	Fail
D2	Testing hand detection for motion (no input)	CFR1, RDP1	Static hand gestures (no motions)	no output	z/d	Fail
D3	Testing hand detection for motion	CFR1, RDP1	Hand motion for "z"	z	z	Pass
D4	Testing if gestures that require movement are able to be recognized (motion gestures)	MLFR4, MLFR6, RDP1	Signing"j" and "z"	j z	j z	Pass
D5	Test model accuracy by signing different sequences of gestures / introducing variance into the system	MLFR4, NFR1, RDP1	Sign letters in sequence of a,b,c,d then sign with d, f, z, j	a,b,c,d d,f,z,j with 100% accuracy	a,b,c,d d,f,z,j	Pass

D6	Testing gesture recognition between point history (movement gestures) and key-point history (static gestures"	MLFR4	Sign letters in sequence "a", "b", "j", "c", "z"	a b j c z	j a j z b c z	Fail

Table 4: Tests for Machine Learning Module

Tests for Training Module

ID	Description	Req Ref	Input	Expected Output	Actual Output	Result
E1	Mode Selection	N/A	Program is in "Normal Mode", press number "2" on keyboard	Program goes into "Training Mode"	Program goes into "Training Mode"	Pass
E2	Test if a .tflite file can be generated from the CSV files	MLFR5, NFR5	A CSV file with data points from different ASL gestures	A .tflite file that can be used to recognize the gestures that were recorded	A .tflite file that can be used to recognize the gestures that were recorded	Pass
E3	Testing if retraining by adding new data points can change recognition	MLFR7, NFR1, NFR5	Adding 50 accurate data points to the gesture "Hello"	The accuracy prediction increases	The accuracy prediction decrease from 60% to 80%	Pass
E4	Testing for gesture variation based on user habits through retraining	MLFR7, NFR1, NFR3, NFR7	Retraining the model with a different method of signing "Hello"	Hello	Hello	Pass

Table 5: Tests for Training Module

Tests for Text to Speech Module

ID	Description	Req Ref	Input	Expected Output	Actual Output	Result
F1	Text-to-speech in real-time for individual letters	RDP1, RDP2	Hand gestures for "a", "b" and "c", then hand gesture for "Speak"	Audio output for letters "a", "b" and "c"	Audio output for letters "a", "b" and "c"	Pass
F2	Text-to-speech in real-time for sentence	RDP1, RDP2	Hand gesture for "I love you", then hand gesture for "Speak"	Audio output for "I love you"	Audio output for "I love you"	Pass
F3	Testing hand detection for a series of hand gestures (fast)	MLFR7, CFR1	A series of hand gestures performed in a very fast speed	Letters for corresponding hand gestures	Some letters are missing	Fail (need to increase fps)
F4	Test if gesture for "Speak" does not work when in training mode	RDP2, MLFR5	Program is started, in training mode, and gestures are performed, then gesture "Speak" is performed	No audio output	No audio output	Pass

Table 6: Tests for Text to Speech Module

Tests for Hardware

ID	Description	Req Ref	Input	Expected Output	Actual Output	Result
G1	Camera is set up on the Raspberry Pi	CFR1	Raspistill command to take a picture	A picture	A picture	Pass
G2	Test if the Raspberry Pi can capture the input from the camera and translate ASL in real time	???	Program is started on the Raspberry Pi	The Raspberry Pi should be able to use the camera to detect and translate ASL in real time	The Raspberry Pi camera does not display the video with an adequate frame rate, making translation undoable	Fail
G3	Real-time video is captured and displayed on screen	CFR1, CFR2	Views in front of the camera	Views in front of the camera are displayed	Views in front of the camera are displayed	Pass

Table 7: Tests for Hardware

Text and String Display

ID	Description	Req Ref	Input	Expected Output	Actual Output	Result
H1	Real-time text display for hand gestures (normal speed)	RDP1	hand gestures for "d" and "a" performed in a reasonable speed	Output the corresponding letters "d" and "a" besides user's hand	Output the corresponding letters "d" and "a" besides user's hand	Pass
H2	Real-time text display for hand gestures (super fast)	RDP1	hand gestures performed in a super fast speed	Letters for corresponding hand gestures	Some letters output are missing	Fail (need to increase fps)
H3	String display for one hand gesture	MLFR6, MLFR4, NFR1	hand gestures for "d"	"d" is displayed as string at the bottom of the screen	"d" is displayed as string at the bottom of the screen	Pass
H4	String display for a series of hand gestures (slow speed)	MLFR6, MLFR4, NFR1	hand gestures for "d" and "a" and "I love you" with a pause of 4 seconds	"d a I love you" is displayed as string at the bottom of the screen	"d d a a I love you I love you" is displayed as string at the bottom of the screen	Fail

H5	String display for a series of hand gestures (normal speed)	MLFR6, MLFR4, NFR1	hand gestures for "d" and "a" and "I love you" with a pause of 1 to 2 seconds	"d a I love you" is displayed as string at the bottom of the screen	"d a I love you" is displayed as string at the bottom of the screen	Pass
H6	String display for a series of hand gestures (fast speed)	MLFR6, MLFR4, NFR1	hand gestures for "d" and "a" and "I love you" without pause	"d a I love you" is displayed as string at the bottom of the screen	"d I love you" is displayed as string at the bottom of the screen	Fail
H7	Modifying string display	N/A	Pressing "Backspace" or "Space"	"Backspace" deletes a character in string, "Space" adds a space in string	"Backspace" deletes a character in string, "Space" adds a space in string	Pass
H8	String display is cleared after audio output	RDP1, RDP2	Hand gestures are performed, and then perform hand gesture for "Speak"	Current string is cleared	Current string is cleared	Pass

H9	Test if gestures are not written to string when in training mode	N/A	Program is started, in training mode, and gestures are being performed	Nothing is being added to the string and nothing is displayed at the bottom	Nothing is added to the string and nothing is displayed at the bottom	Pass

Table 8: Text and String Display

Tests for Nonfunctional Requirements accuracy, usability, portability, cultural

ID	Description	Req Ref	Input	Expected Output	Actual Output	Result
I1	Test if GUI is displayed on screen	N/A	Program is started and camera is turned on	The resolution, FPS, mode, and current text are displayed on screen	The resolution, FPS, mode, and current text are displayed on screen	Pass
I2	Test if output is accurate for variations in user gestures	NFR7	Trying three variations of "Hello"	Hello	Hello	Pass
I3	Usability: the ease of use of a user without the knowledge of ASL	N/A	Instructions and example hand gestures are provided to the user	The user should know how to use the ASL device and can input some sample ASL words after reading the instructions.	The user is able to use the ASL device and input some sample ASL words after reading the instructions	Pass

Table 9: Tests for Nonfunctional Requirements accuracy, usability, portability, cultural

5 Trace to Requirements

Requirements	**ID**
CFR1	A2 A6 A7 A11 B1 D1 D2 D3 G1 G3
CFR2	B1 G3
MLFR1	A1 A3 A4 A5 A8 A10 A12 A13
MLFR2	B2 B3 B4 B5
MLFR3	A2 A4 A8 B3
MLFR4	D4 D5 D6
MLFR5	A1 A8 E2
MLFR6	A3 D4
MLFR7	E3 E4
NFR1	A5 A13 D5 E3 E4
NFR2	A1 A2 A4
NFR3	A5 E4
NFR4	A14 B 5
NFR5	C1 C2 E2 E3
NFR6	G2
NFR7	E4
RDP1	C1 C2 C3 D1 D2 D3 D4 D5
RDP2	H8

Table 10: Trace to Requirements

6 Non-Functional Quality 1

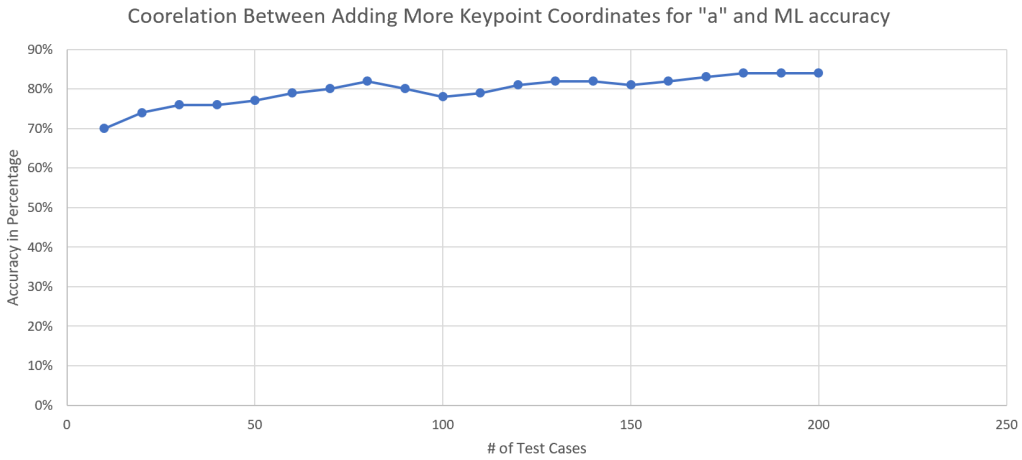

Figure 3: Coorelation

7 Non-Functional Quality 2

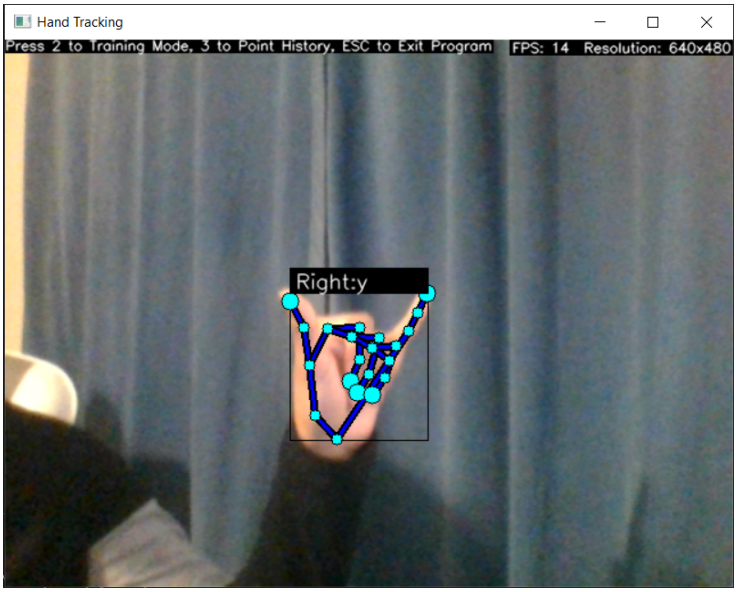

Figure 4: Angled y

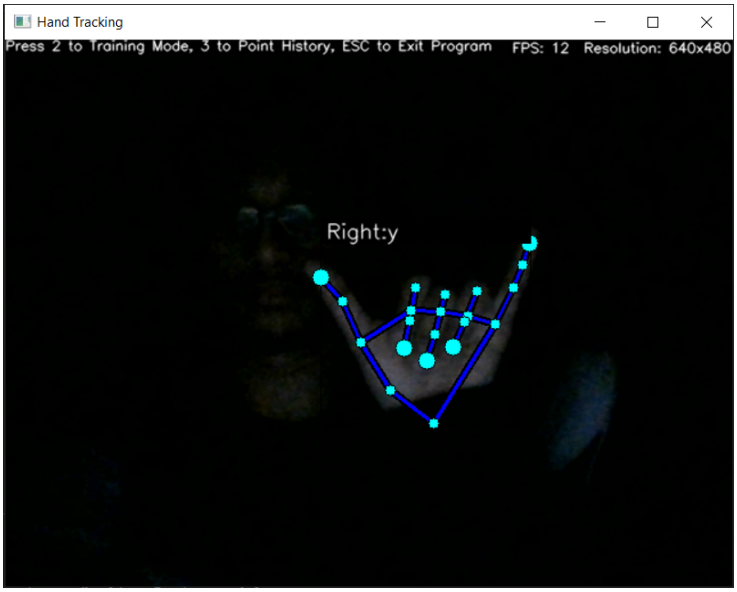

Figure 5: Low Light y

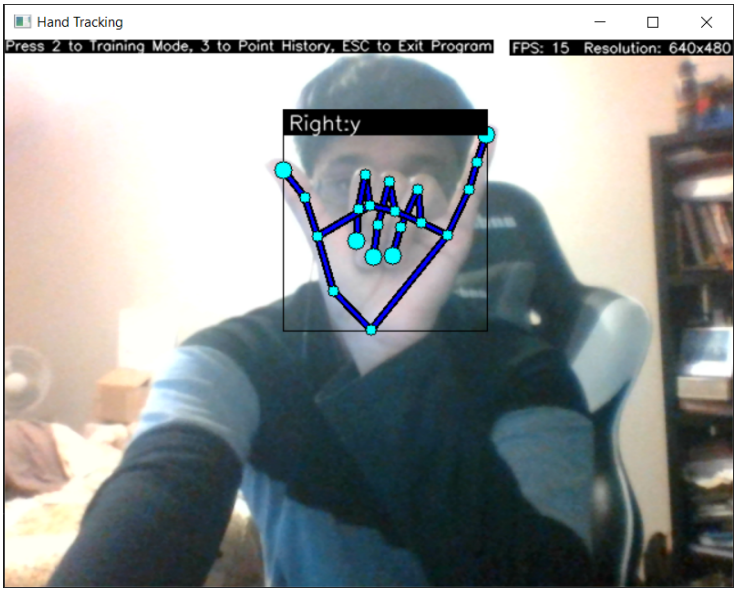

Figure 6: Normal y

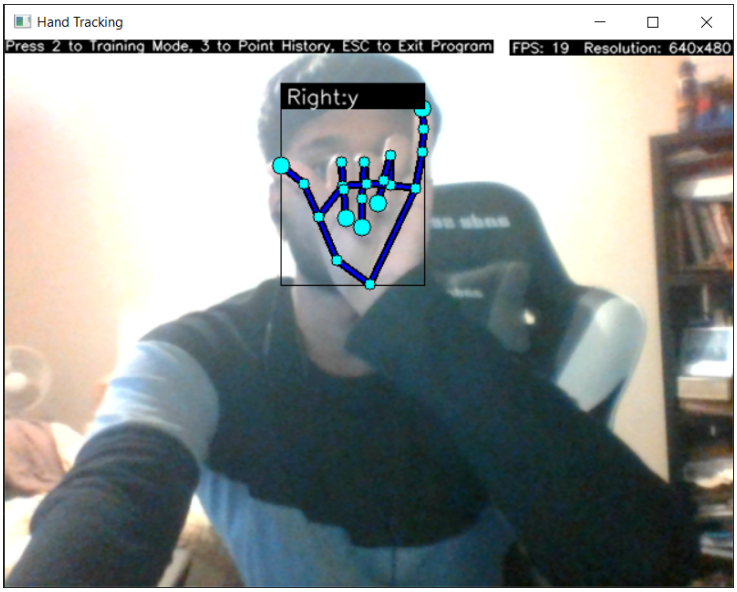

Figure 7: Tilted Left

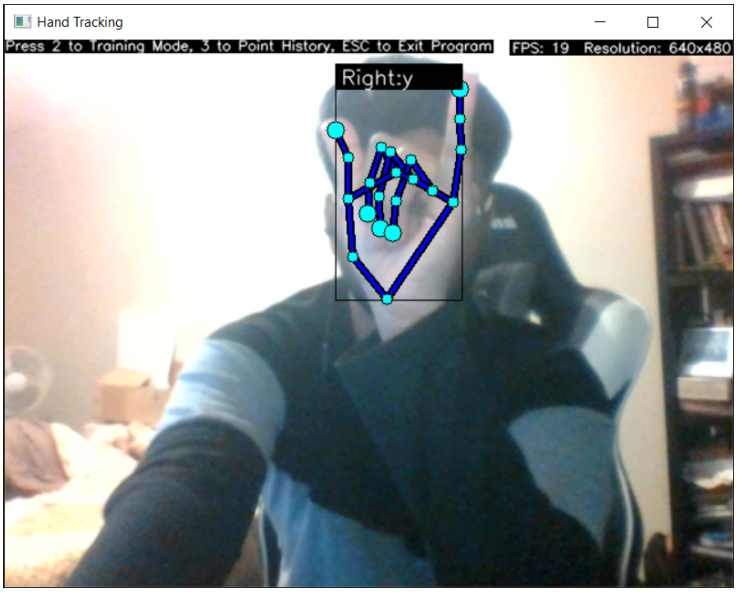

Figure 8: Tilted Right

8 Changes due to Testing

9 Automated Testing

10 Code Coverage Metrics

Appendix — Reflection

The information in this section will be used to evaluate the team members on the graduate attribute of Reflection. Please answer the following question:

1. In what ways was the Verification and Validation (VnV) Plan different from the activities that were actually conducted for VnV? If there were differences, what changes required the modification in the plan? Why did these changes occur? Would you be able to anticipate these changes in future projects? If there weren't any differences, how was your team able to clearly predict a feasible amount of effort and the right tasks needed to build the evidence that demonstrates the required quality? (It is expected that most teams will have had to deviate from their original VnV Plan.)