SIIT-Chiba joint student workshop
Presentation

Non-contact automatic measurement of hand joint range of motion

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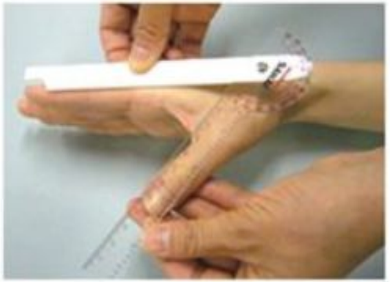
Presentation Overview

- Measuring ROM
- Division of roles
- System overview
- Demo
- Evaluation
- Problems
- Future works

Measuring ROM (Range of Motion)

Typical Measuring ROM of body joints require therapist to

- Adjust the pose of the target patient
- Use goniometer to measure the joint angles manually



Measuring ROM’s Problem

- Need physical contact
- Manual measurement is time consuming
- Large margin of error

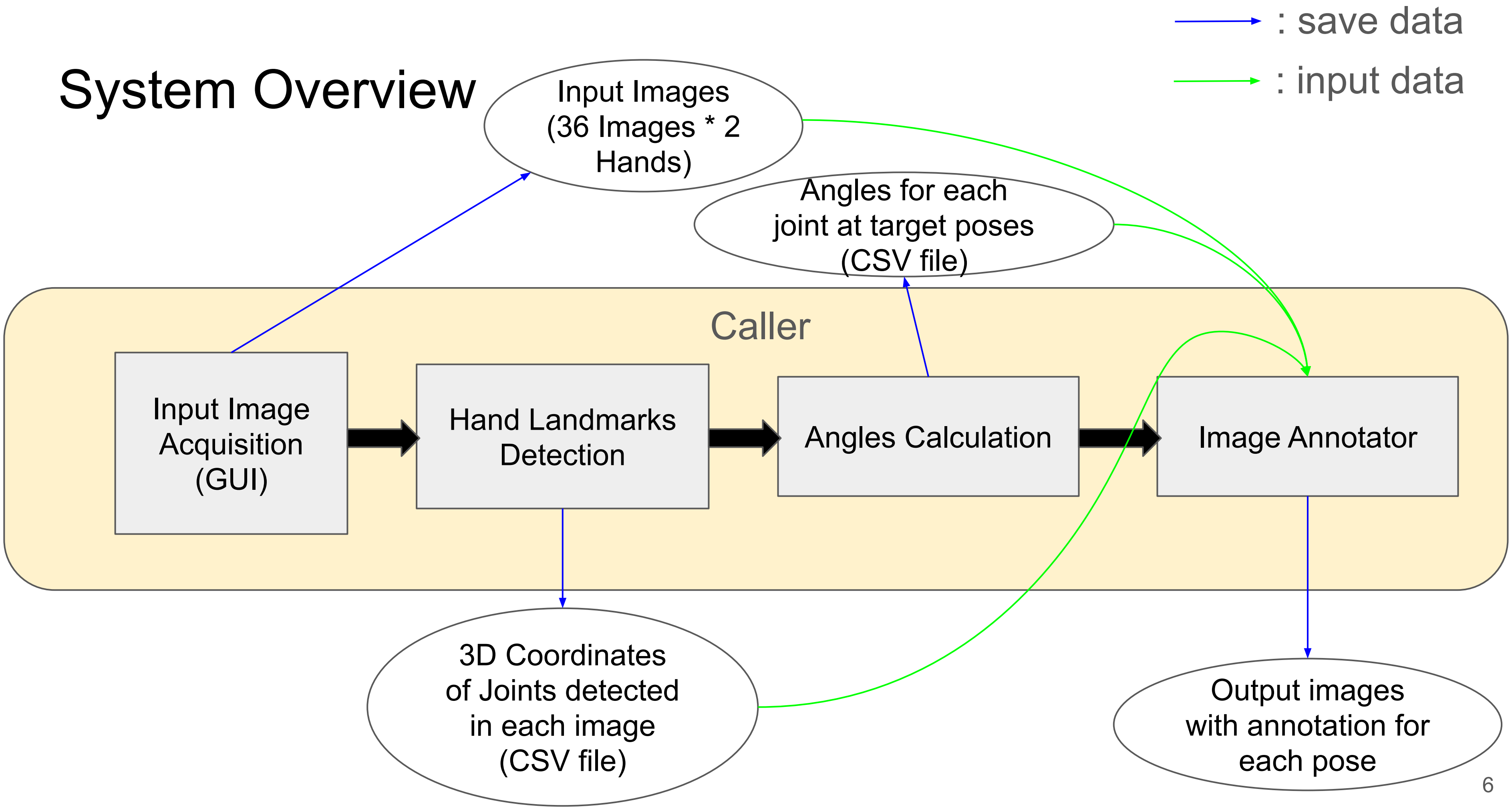
Simple and accurate measurement of ROM using image analysis is highly required

→ Non-contact automatic measurement of hand joint ROM

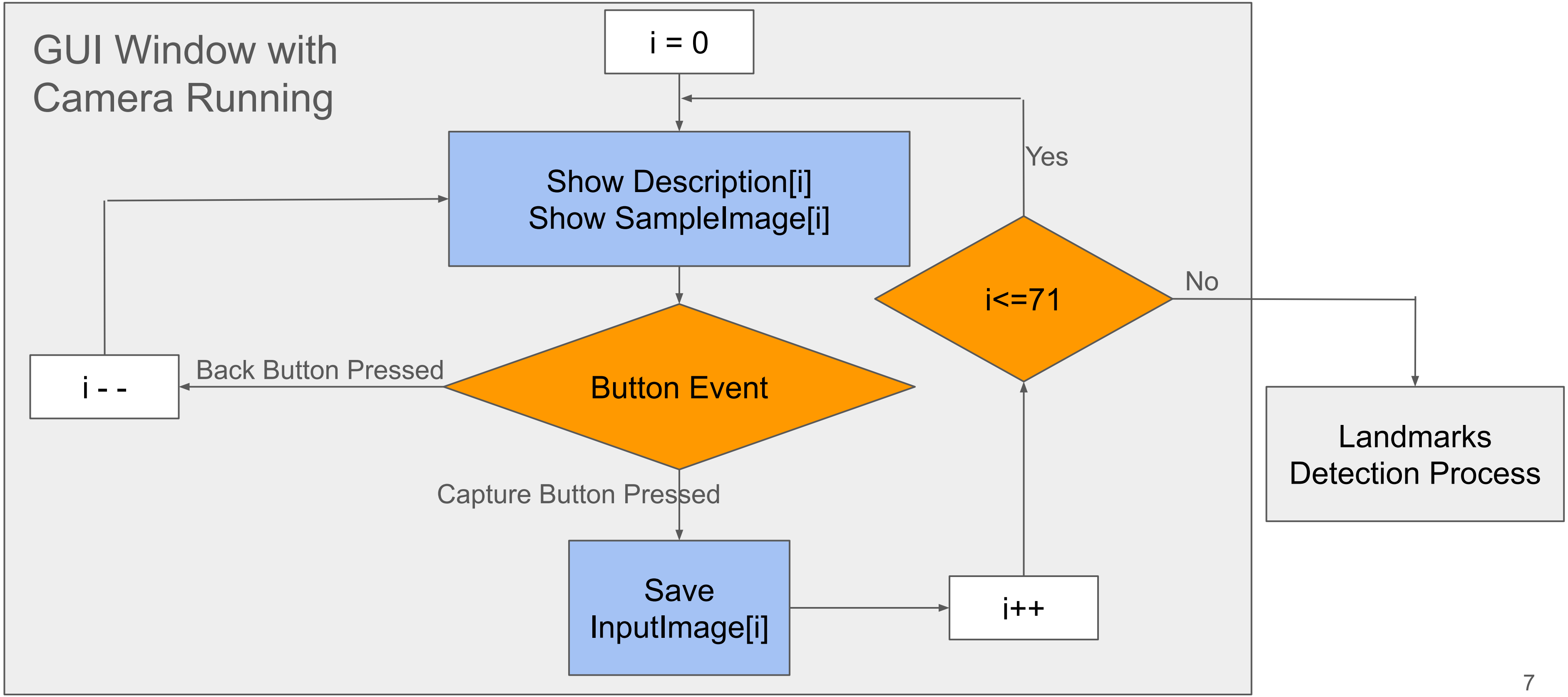
Division of Roles

- Program Flow Design
- GUI for image acquisition
- Hand Landmark Detection
- Angle calculation
- Image Annotations (Lines and Angle)
- Information organization and documentation

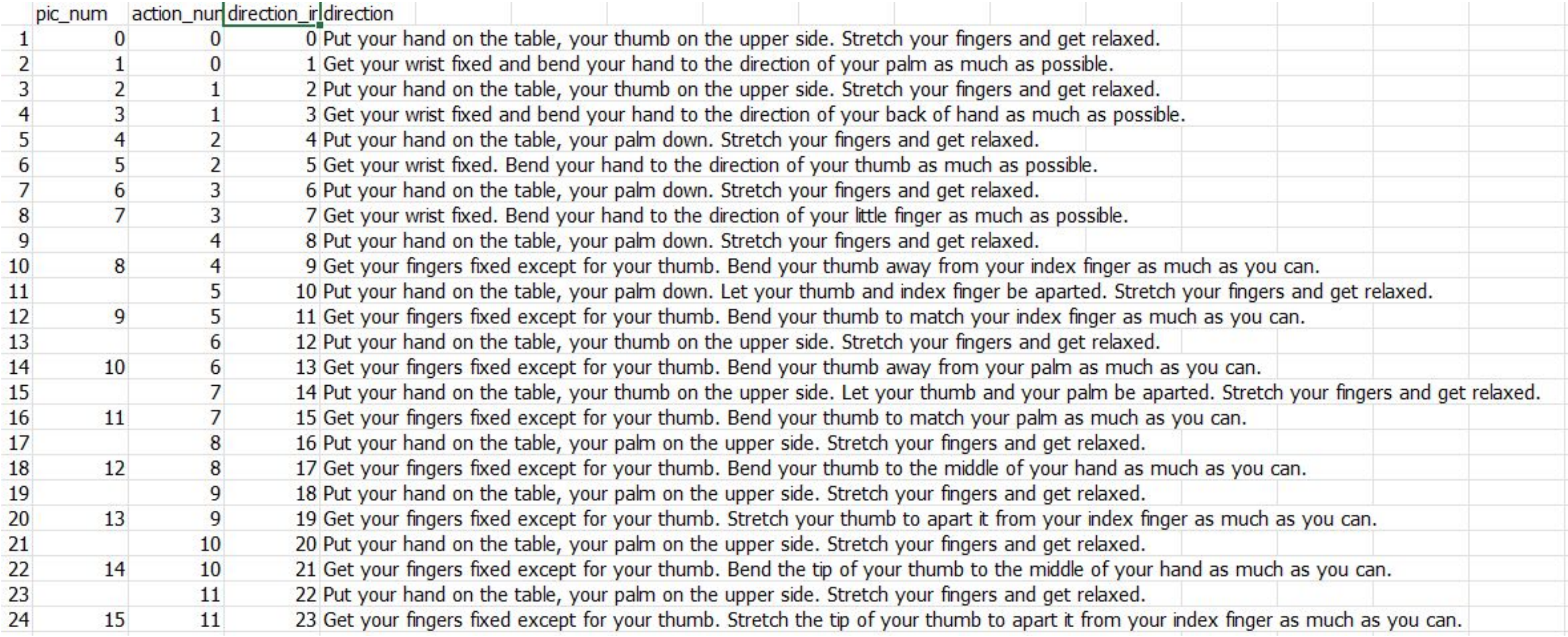
System Overview


→ : save data
→ : input data
Input Images (36 Images * 2 Hands)
Angles for each joint at target poses (CSV file)
Caller
Input Image Acquisition (GUI)
Hand Landmarks Detection
Angles Calculation
Image Annotator
3D Coordinates of Joints detected in each image (CSV file)
Output images with annotation for each pose

System Overview : Input image acquisition (GUI)



CSV table for descriptions



	pic_num	action_nur	direction_ir	direction
1	0	0	0	Put your hand on the table, your thumb on the upper side. Stretch your fingers and get relaxed.
2	1	0	1	Get your wrist fixed and bend your hand to the direction of your palm as much as possible.
3	2	1	2	Put your hand on the table, your thumb on the upper side. Stretch your fingers and get relaxed.
4	3	1	3	Get your wrist fixed and bend your hand to the direction of your back of hand as much as possible.
5	4	2	4	Put your hand on the table, your palm down. Stretch your fingers and get relaxed.
6	5	2	5	Get your wrist fixed. Bend your hand to the direction of your thumb as much as possible.
7	6	3	6	Put your hand on the table, your palm down. Stretch your fingers and get relaxed.
8	7	3	7	Get your wrist fixed. Bend your hand to the direction of your little finger as much as possible.
9		4	8	Put your hand on the table, your palm down. Stretch your fingers and get relaxed.
10	8	4	9	Get your fingers fixed except for your thumb. Bend your thumb away from your index finger as much as you can.
11		5	10	Put your hand on the table, your palm down. Let your thumb and index finger be aparted. Stretch your fingers and get relaxed.
12	9	5	11	Get your fingers fixed except for your thumb. Bend your thumb to match your index finger as much as you can.
13		6	12	Put your hand on the table, your thumb on the upper side. Stretch your fingers and get relaxed.
14	10	6	13	Get your fingers fixed except for your thumb. Bend your thumb away from your palm as much as you can.
15		7	14	Put your hand on the table, your thumb on the upper side. Let your thumb and your palm be aparted. Stretch your fingers and get relaxed.
16	11	7	15	Get your fingers fixed except for your thumb. Bend your thumb to match your palm as much as you can.
17		8	16	Put your hand on the table, your palm on the upper side. Stretch your fingers and get relaxed.
18	12	8	17	Get your fingers fixed except for your thumb. Bend your thumb to the middle of your hand as much as you can.
19		9	18	Put your hand on the table, your palm on the upper side. Stretch your fingers and get relaxed.
20	13	9	19	Get your fingers fixed except for your thumb. Stretch your thumb to apart it from your index finger as much as you can.
21		10	20	Put your hand on the table, your palm on the upper side. Stretch your fingers and get relaxed.
22	14	10	21	Get your fingers fixed except for your thumb. Bend the tip of your thumb to the middle of your hand as much as you can.
23		11	22	Put your hand on the table, your palm on the upper side. Stretch your fingers and get relaxed.
24	15	11	23	Get your fingers fixed except for your thumb. Stretch the tip of your thumb to apart it from your index finger as much as you can.

Joint coordinates detection

- MediaPipe (Our choice)
  - Fan Zhang, Valentin Bazarevsky, Andrey Vakunov, Andrei Tkachenka, George Sung, Chuo-Ling Chang, & Matthias Grundmann. (2020). MediaPipe Hands: On-device Real-time Hand Tracking.
  - Detect hand joints' position from single RGB camera
- Leap Motion
  - "The Ultraleap's LeapMotion Controller 2", Ultraleap. Available: https://www.ultraleap.com/product/leap-2/. Accessed on : December 21, 2023.
  - Used a specific device to detect hand joints' position
    - Includes of 2 cameras and an infrared sensor

Hand LandMark Detection

Image Input

Mediapipe Hand Application

Output of Landmarks

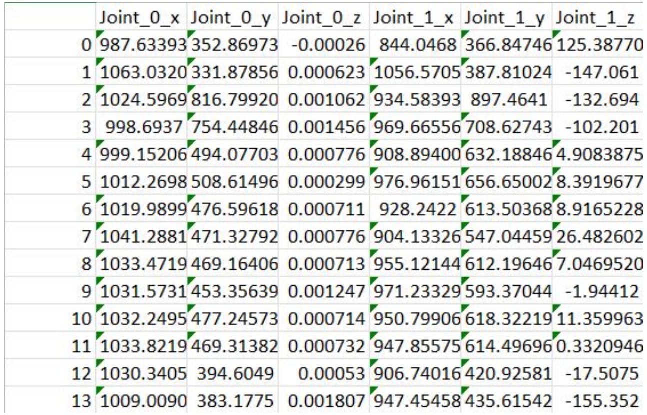
Image Captured from GUI
Stored into specified
folder(to_process)

Fed Images to MediaPipe Library and obtained Hand Landmarks

All landmarks accumulated and saved as CSV, for further processing.
(21 * 3 rows and 36 * 2 columns)

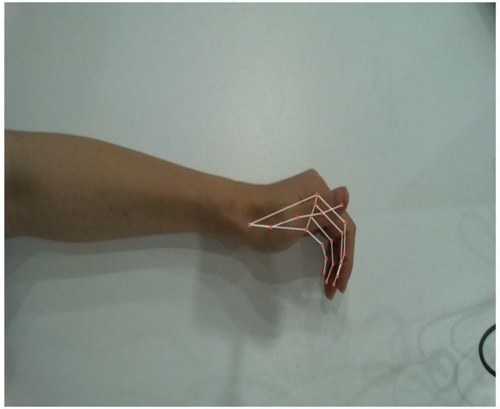
Outputs After Landmark Detection

Output CSV

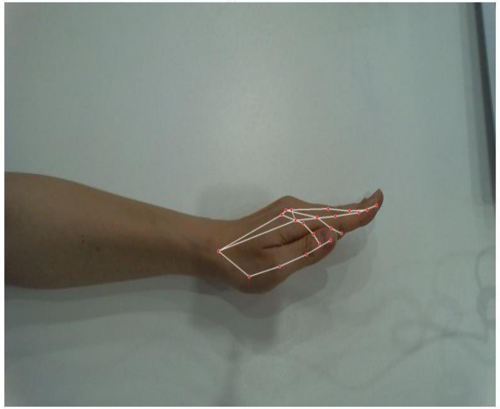


	Joint_0_x	Joint_0_y	Joint_0_z	Joint_1_x	Joint_1_y	Joint_1_z
0	987.63393	352.86973	-0.00026	844.0468	366.84746	125.38770
1	1063.0320	331.87856	0.000623	1056.5705	387.81024	-147.061
2	1024.5969	816.79920	0.001062	934.58393	897.4641	-132.694
3	998.6937	754.44846	0.001456	969.66556	708.62743	-102.201
4	999.15206	494.07703	0.000776	908.89400	632.18846	4.9083875
5	1012.2698	508.61496	0.000299	976.96151	656.65002	8.3919677
6	1019.9899	476.59618	0.000711	928.2422	613.50368	8.9165228
7	1041.2881	471.32792	0.000776	904.13326	547.04459	26.482602
8	1033.4719	469.16406	0.000713	955.12144	612.19646	7.0469520
9	1031.5731	453.35639	0.001247	971.23329	593.37044	-1.94412
10	1032.2495	477.24573	0.000714	950.79906	618.32219	11.359963
11	1033.8219	469.31382	0.000732	947.85575	614.49696	0.3320946
12	1030.3405	394.6049	0.00053	906.74016	420.92581	-17.5075
13	1009.0090	383.1775	0.001807	947.45458	435.61542	-155.352

65_processed



71_processed



63_processed

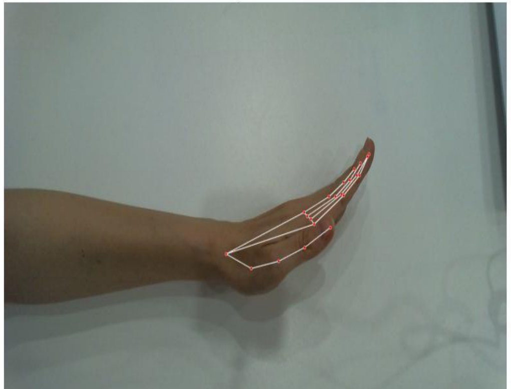
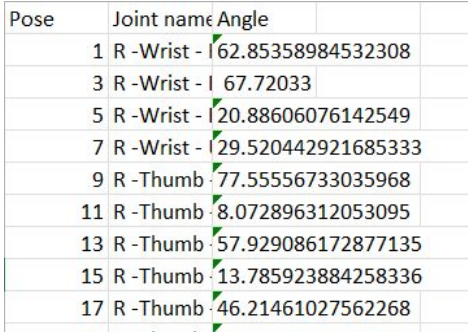


Image Annotations

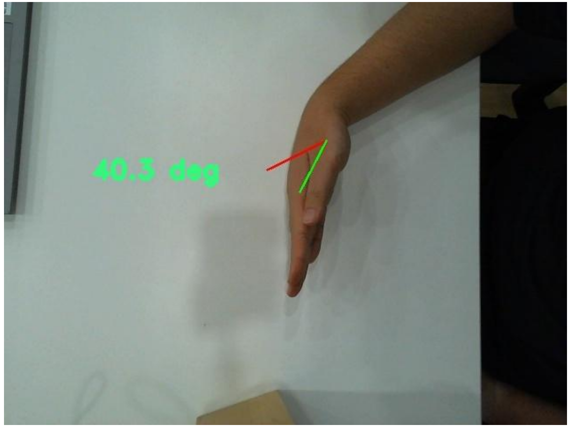
- Used OpenCV - cv2 Library for annotating images
- Outputs from Angle Calculation Program were read in
- Calculation of intersection and projection of points required for some lines.

Angle.csv

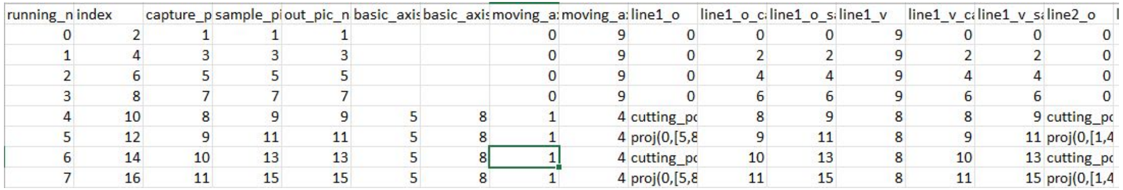


Pose	Joint name	Angle
1	R -Wrist -	62.85358984532308
3	R -Wrist -	67.72033
5	R -Wrist -	20.88606076142549
7	R -Wrist -	29.52044292168533
9	R -Thumb -	77.55556733035968
11	R -Thumb -	8.072896312053095
13	R -Thumb -	57.929086172877135
15	R -Thumb -	13.785923884258336
17	R -Thumb -	46.21461027562268

Read In



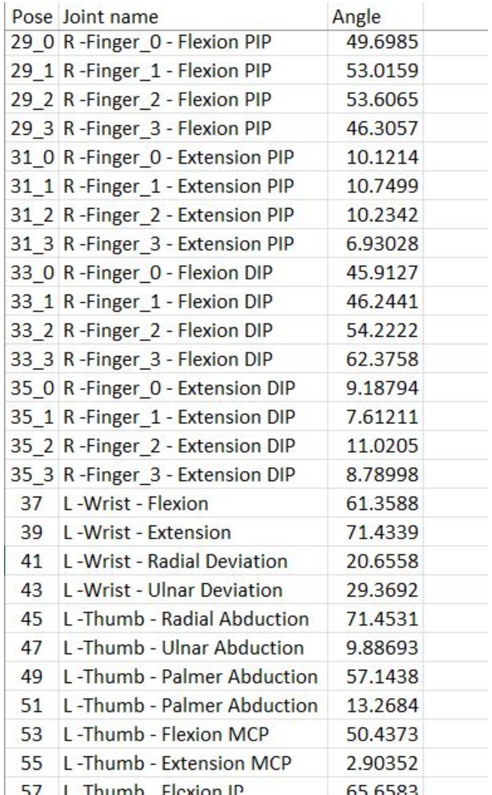
Lines Calculation



running_n	index	capture_p	sample_pi	out_pic_n	basic_axis	basic_axis	moving_a	moving_a	line1_o	line1_o_c	line1_o_s	line1_v	line1_v_c	line1_v_s	line2_o	l
0	2	1	1	1			0	9	0	0	0	9	0	0	0	
1	4	3	3	3			0	9	0	2	2	9	2	2	0	
2	6	5	5	5			0	9	0	4	4	9	4	4	0	
3	8	7	7	7			0	9	0	6	6	9	6	6	0	
4	10	8	9	9	5	8	1	4	cutting_pc	8	9	8	8	9	cutting_pc	
5	12	9	11	11	5	8	1	4	proj(0,[5,8	9	11	8	9	11	proj(0,[1,4	
6	14	10	13	13	5	8	1	4	cutting_pc	10	13	8	10	13	cutting_pc	
7	16	11	15	15	5	8	1	4	proj(0,[5,8	11	15	8	11	15	proj(0,[1,4	

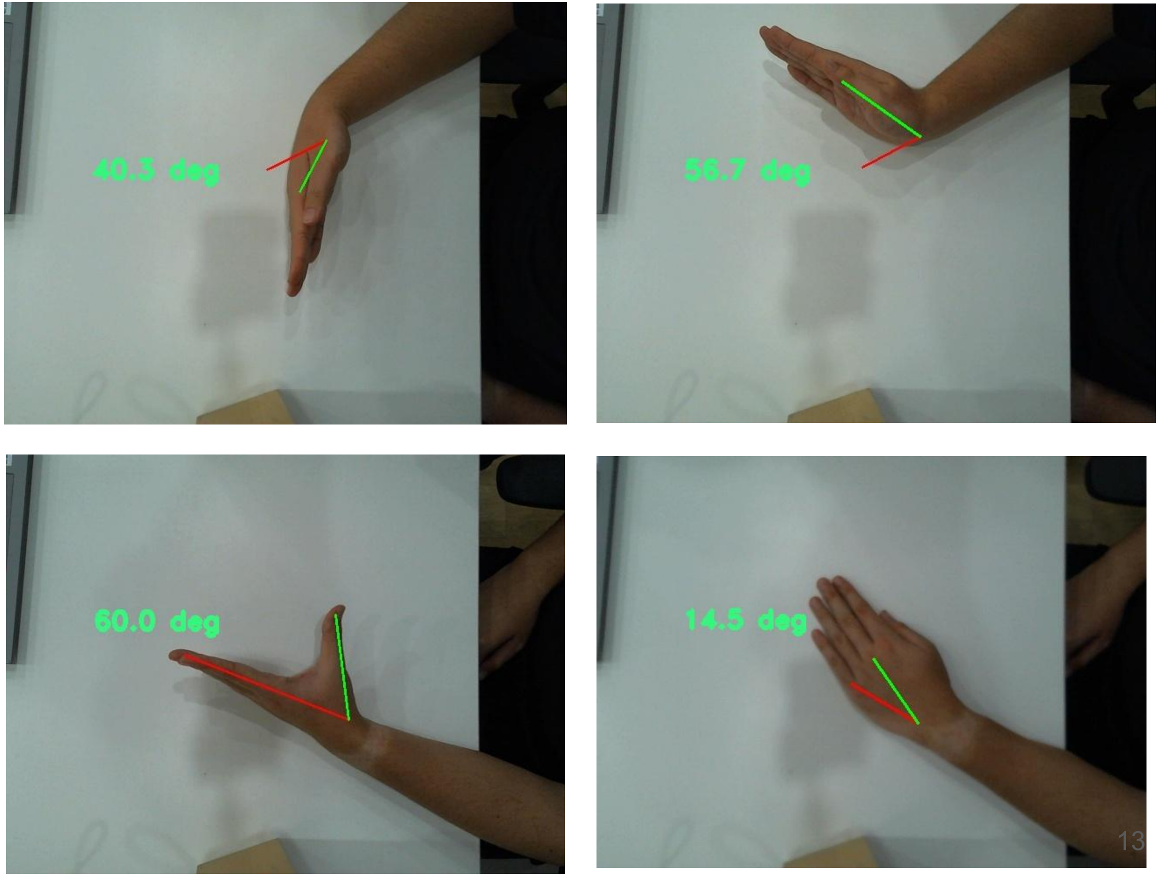
Output Examples

1) CSV Table List



Pose	Joint name	Angle
29_0	R -Finger_0 - Flexion PIP	49.6985
29_1	R -Finger_1 - Flexion PIP	53.0159
29_2	R -Finger_2 - Flexion PIP	53.6065
29_3	R -Finger_3 - Flexion PIP	46.3057
31_0	R -Finger_0 - Extension PIP	10.1214
31_1	R -Finger_1 - Extension PIP	10.7499
31_2	R -Finger_2 - Extension PIP	10.2342
31_3	R -Finger_3 - Extension PIP	6.93028
33_0	R -Finger_0 - Flexion DIP	45.9127
33_1	R -Finger_1 - Flexion DIP	46.2441
33_2	R -Finger_2 - Flexion DIP	54.2222
33_3	R -Finger_3 - Flexion DIP	62.3758
35_0	R -Finger_0 - Extension DIP	9.18794
35_1	R -Finger_1 - Extension DIP	7.61211
35_2	R -Finger_2 - Extension DIP	11.0205
35_3	R -Finger_3 - Extension DIP	8.78998
37	L -Wrist - Flexion	61.3588
39	L -Wrist - Extension	71.4339
41	L -Wrist - Radial Deviation	20.6558
43	L -Wrist - Ulnar Deviation	29.3692
45	L -Thumb - Radial Abduction	71.4531
47	L -Thumb - Ulnar Abduction	9.88693
49	L -Thumb - Palmer Abduction	57.1438
51	L -Thumb - Palmer Abduction	13.2684
53	L -Thumb - Flexion MCP	50.4373
55	L -Thumb - Extension MCP	2.90352
57	L -Thumb - Flexion IP	65.6583

2) Measured Angles

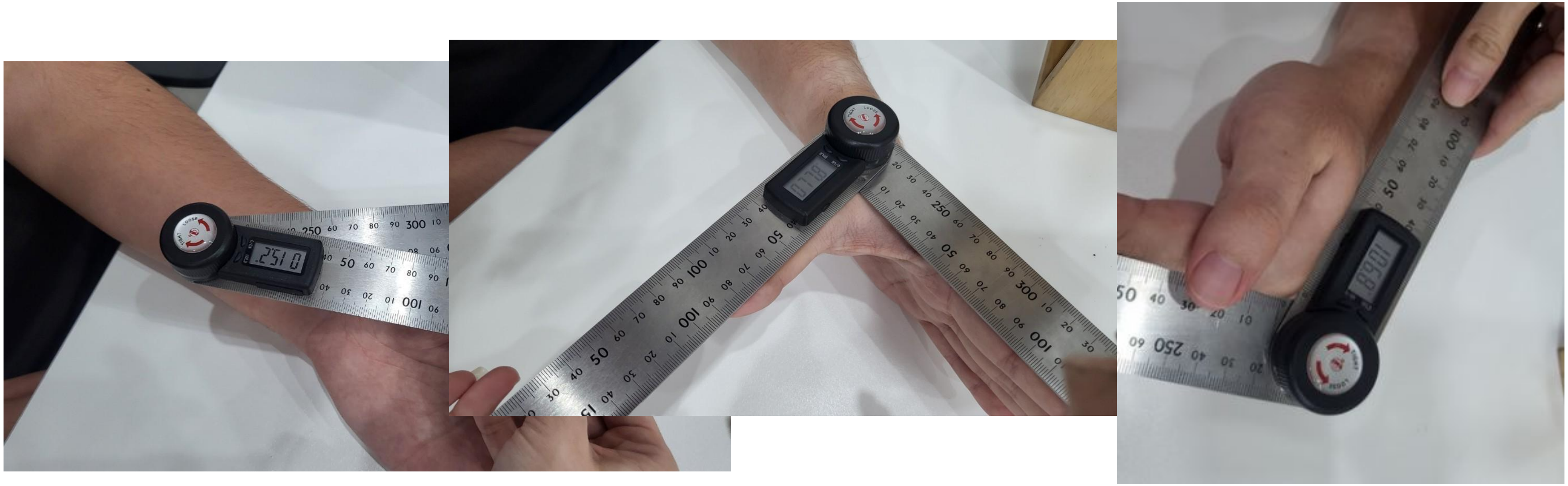


Demo

Evaluation

Our angles measured manually may be not accurate because we do not know how to measure rightly

Mean squared error value is 14.32 degrees (middle-ring-little fingers not included)



Problems and Future Works

- Joint landmarks detection
  - Media Pipe : Inaccurate joint landmark detection in case of occlusion
  - Leap Motion : More accurate results, but difficult coding on python (other parts of the system are on python)
- Axis - Corresponding Landmarks Decision
  - Many cases to consider without common factor → have to be manually prepared
- Future works :
  - Using multi-camera to improve the performance of joint detection
  - Adding a retake function if the user are not satisfied with the captured image