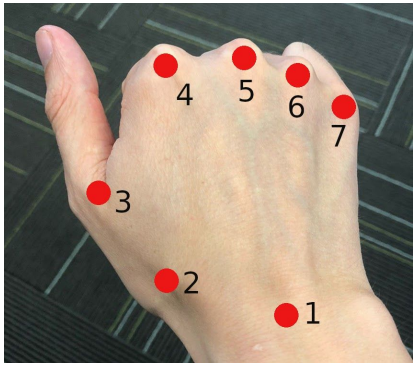
MediaPipe Hand Tracking Model

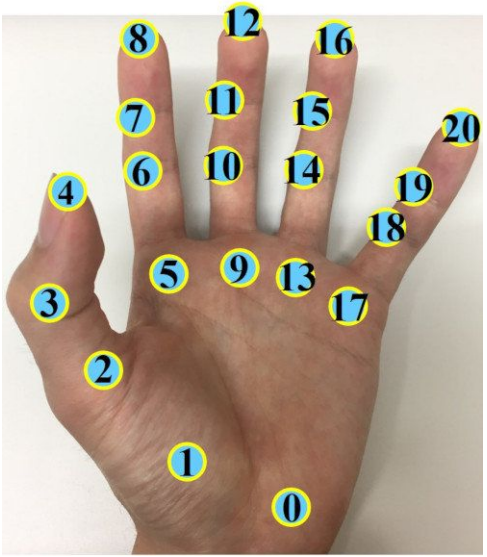
1. First detects palm in whole image using 7 keypoints.
2. Constructs a bounding box around the hand, rotated to align.
3. Detects 21 2D keypoints on cropped hand image.

[Article]

[Documentation]

[Git]

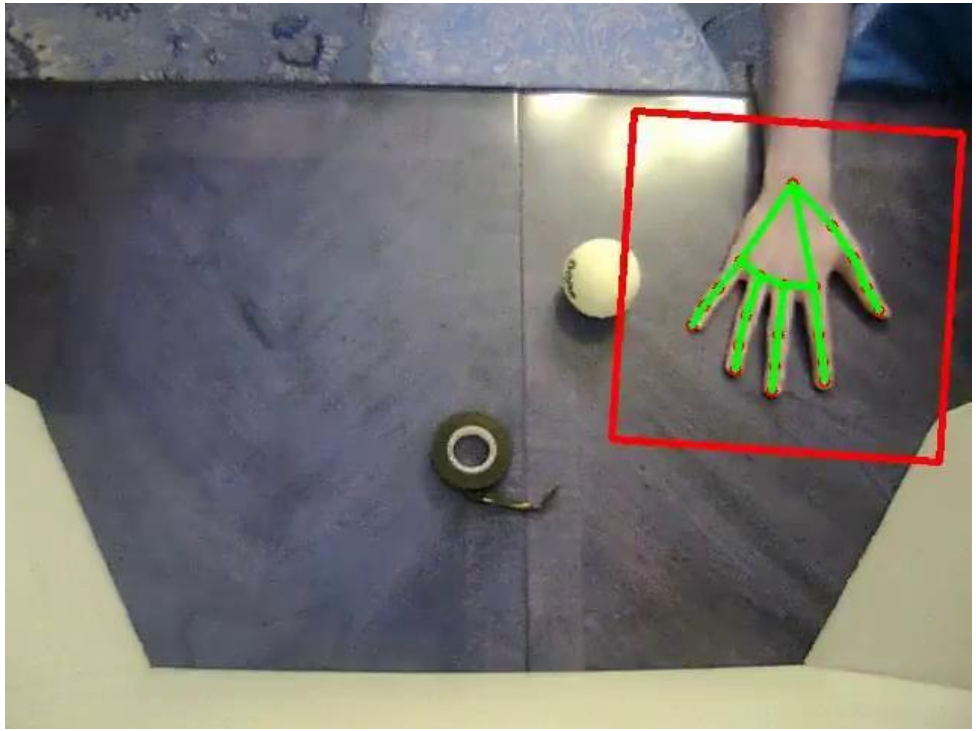




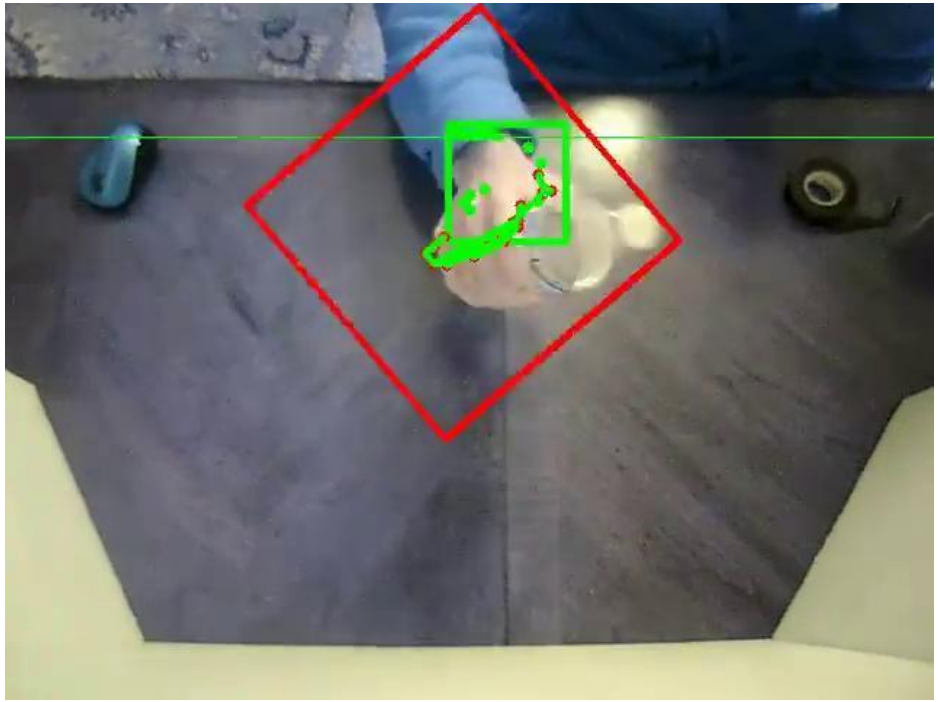
Evaluating Model Performance

- 7 different types of grasping exercises were performed and recorded.
- Pose approximation was performed using the MediaPipe model and results were overlaid onto the input video.

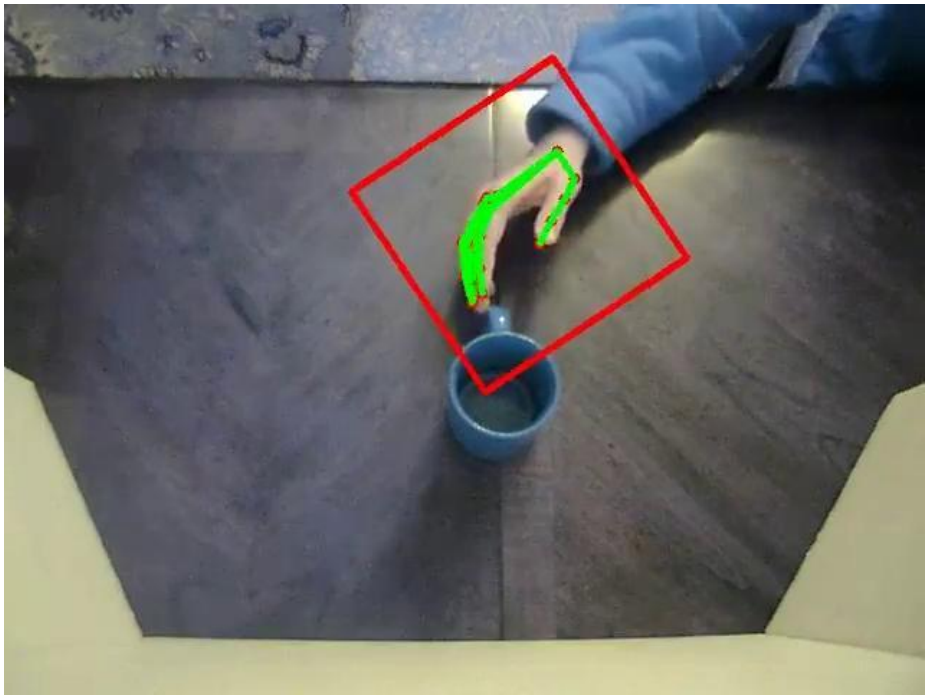
Circular Grasp



Cylindrical Grasp



Hook Grasp

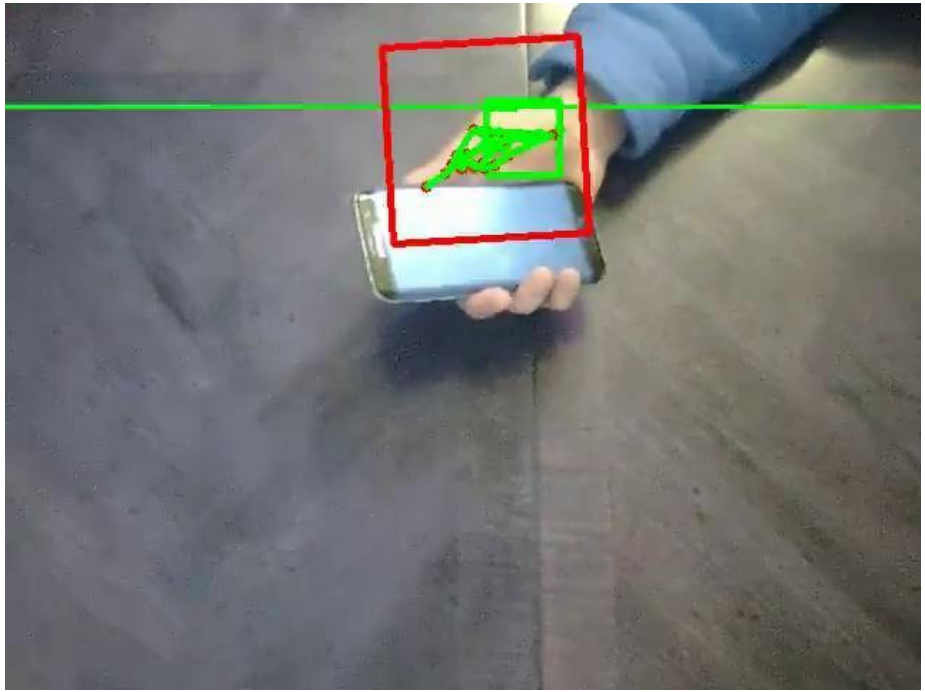


Tripod Grasp

Bottle Cap

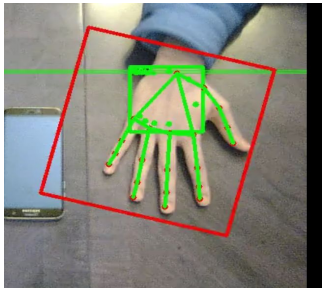
Doorknob

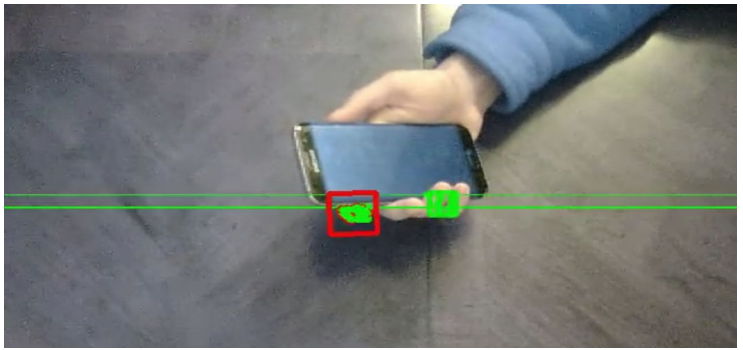
Power Grasp



Reliability

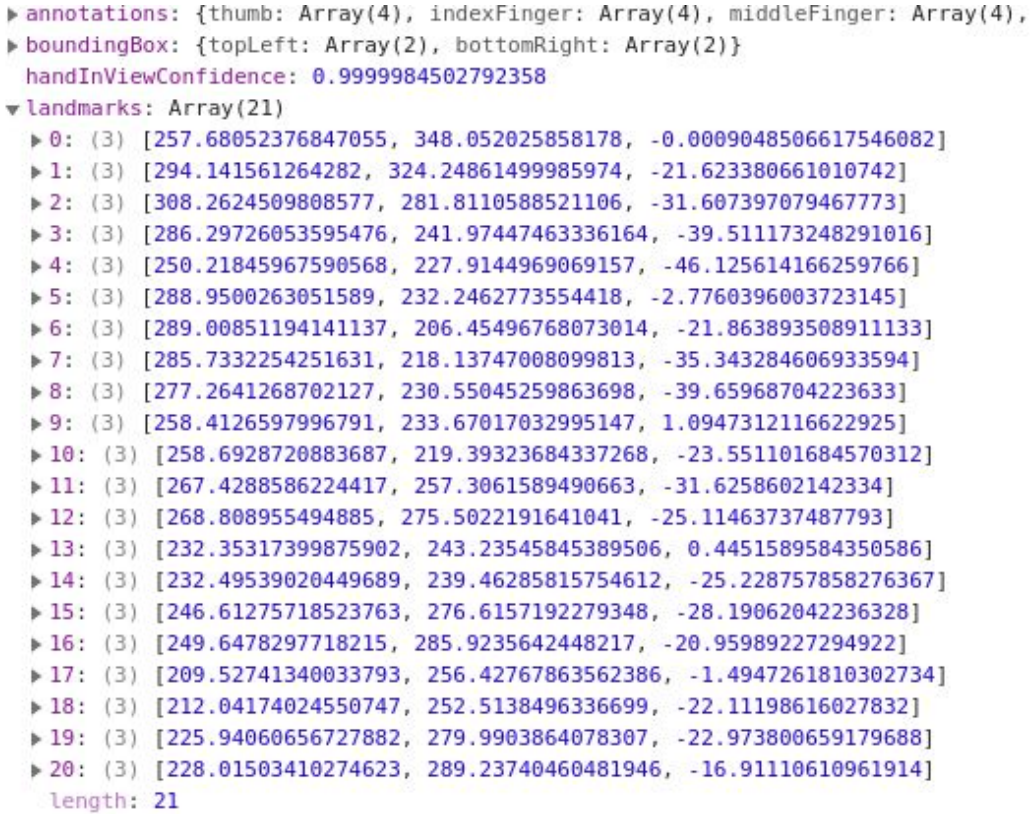
- ‘Jitter’ evident when hand is being tracked properly
  - Denoising or Savgol Filter
- When palm and the majority of fingers are obscured, tracking is lost.
- Model resumes tracking as soon as palm becomes visible again.





Tensorflow.js Version

- Raw data from the model
  - annotations
  - bounding box
  - detection confidence
  - 21 keypoints



Annotations

- Can easily look at fingers individually


```
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  2: (3) [534.5683165905356, 245.6213560813879, -24.618398666381836]
  3: (3) [538.0665343191665, 262.3474677768197, -25.820755004882812]
  length: 4
  __proto__: Array(0)
middleFinger: Array(4)
  0: (3) [504.4905698470386, 194.578649947193, -14.893806457519531]
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  2: (3) [505.63646940124465, 253.5207848003696, -22.67425537109375]
  3: (3) [507.00126850425136, 271.9835807823637, -23.213748931884766]
  length: 4
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palmBase: Array(1)
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pinky: Array(4)
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  1: (3) [467.2122174779822, 209.19032666346544, -12.009689331054688]
  2: (3) [463.28965099991785, 224.604732671082, -13.511730194091797]
  3: (3) [460.71918659861797, 238.90564487913184, -14.570355415344238]
  length: 4
  __proto__: Array(0)
ringFinger: Array(4)
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  2: (3) [483.25008055769774, 245.39809599336812, -18.510799407958984]
  3: (3) [483.24238532626066, 263.47910325281043, -18.999591827392578]
  length: 4
  __proto__: Array(0)
thumb: Array(4)
  0: (3) [533.9069325560656, 152.78883276639914, -1.4190351963043213]
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  2: (3) [560.3668451999756, 201.3174221334839, -5.182585716247559]
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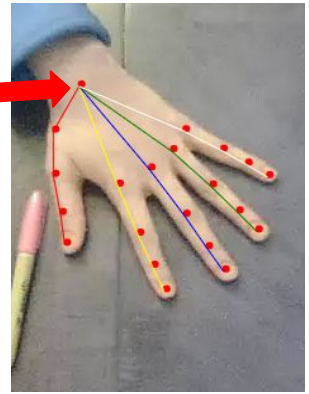
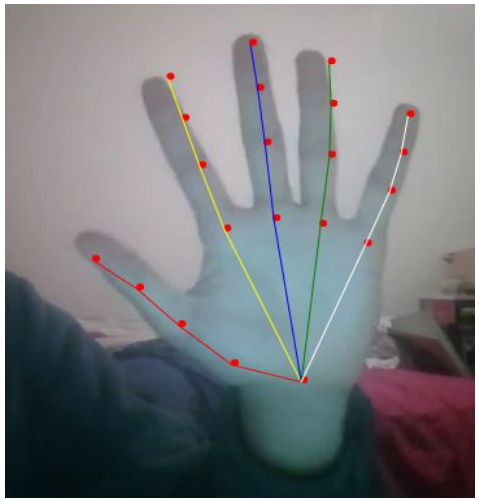
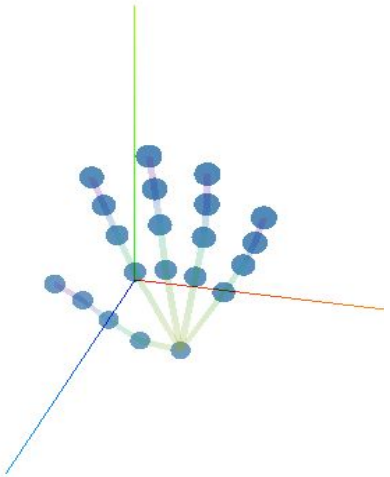


Visualizing Data

- We can draw the hand and track its movements in 3D as opposed to a video overlay

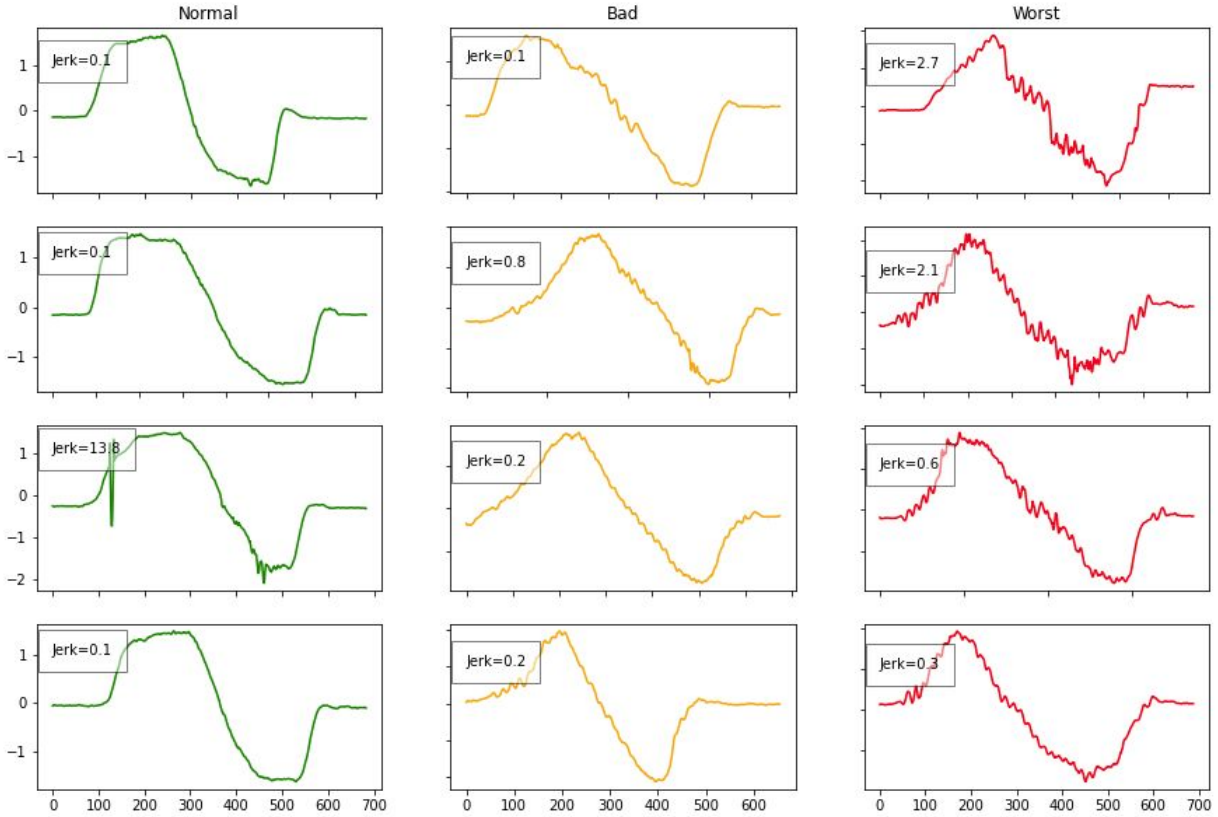




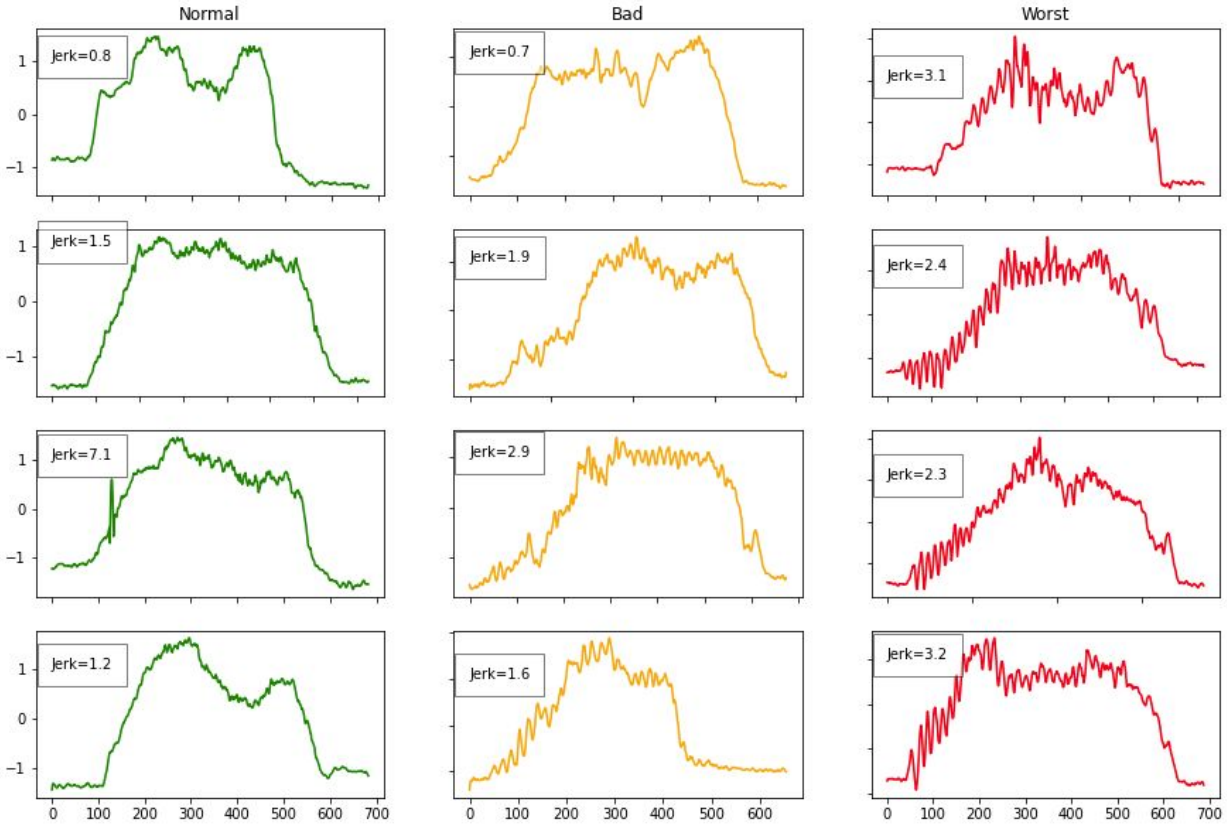
Measuring Exercise Performance

- Task: Move ball across table
- Recorded 3 sets of videos ~10 seconds long
  - Normal: smooth movement, “healthy control”
  - Bad: slight tremors
  - Worst: severe tremors
- Performed pose estimation for all videos
- Normalized Jerk Score for each keypoint
- DTW distance for trajectory comparison

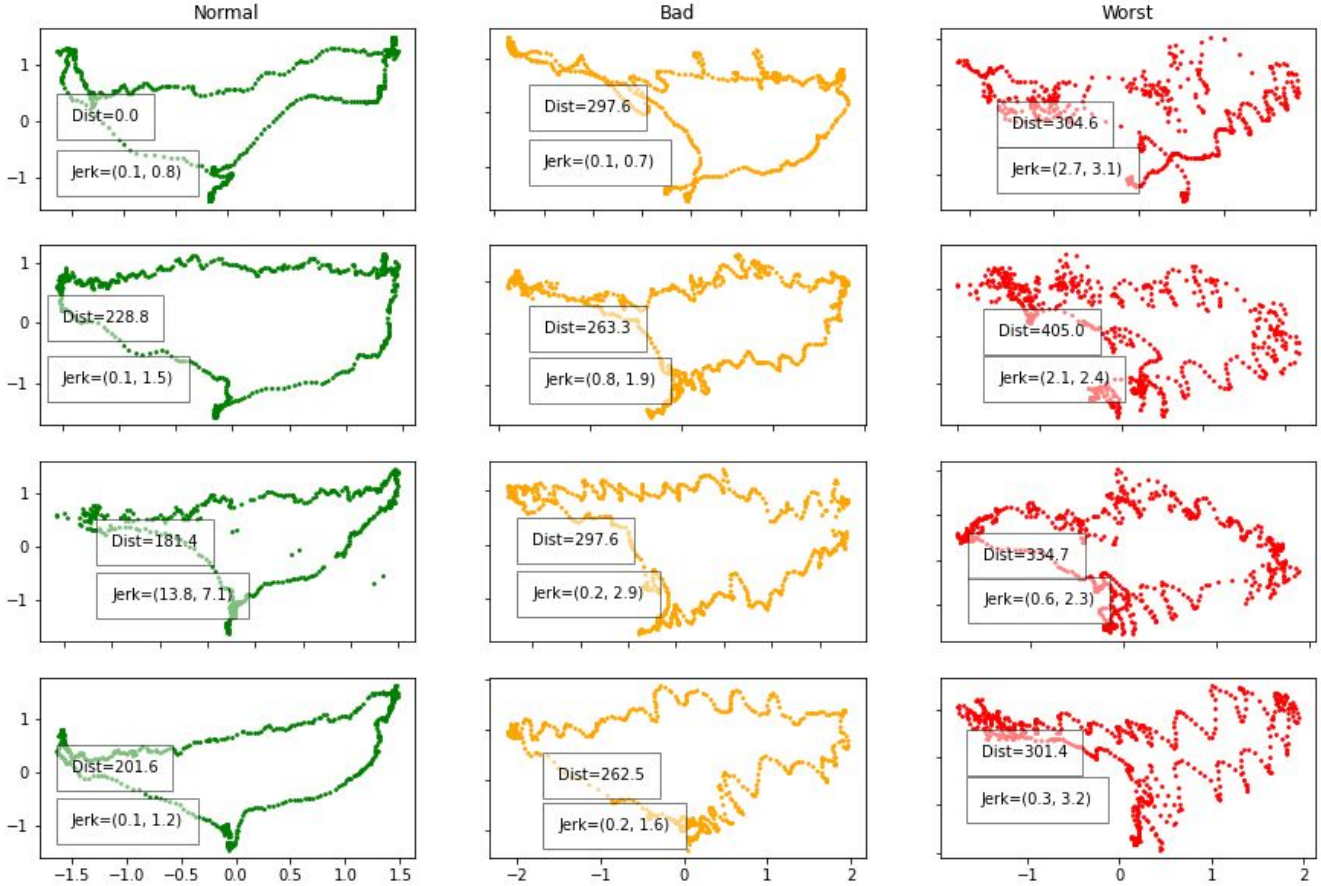
Wrist Keypoint X Values



Wrist Keypoint Y Values



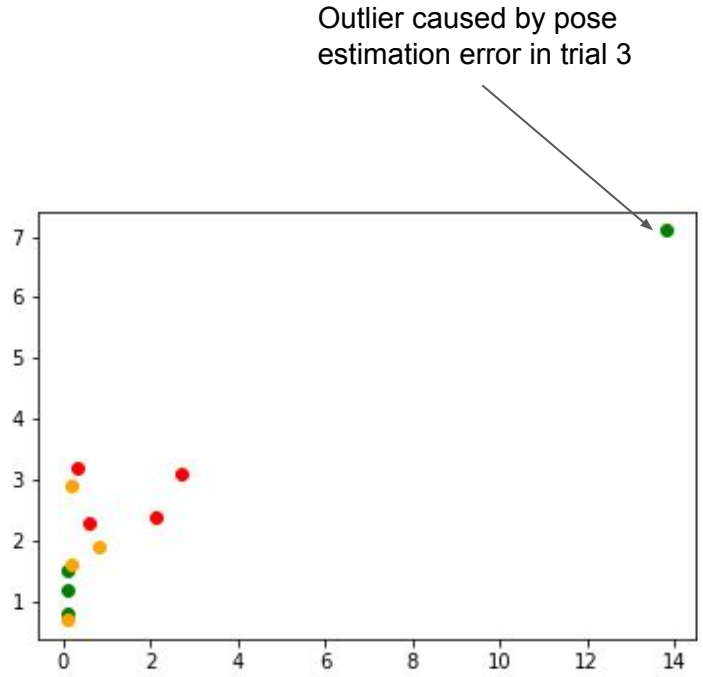
Wrist Keypoint Trajectory



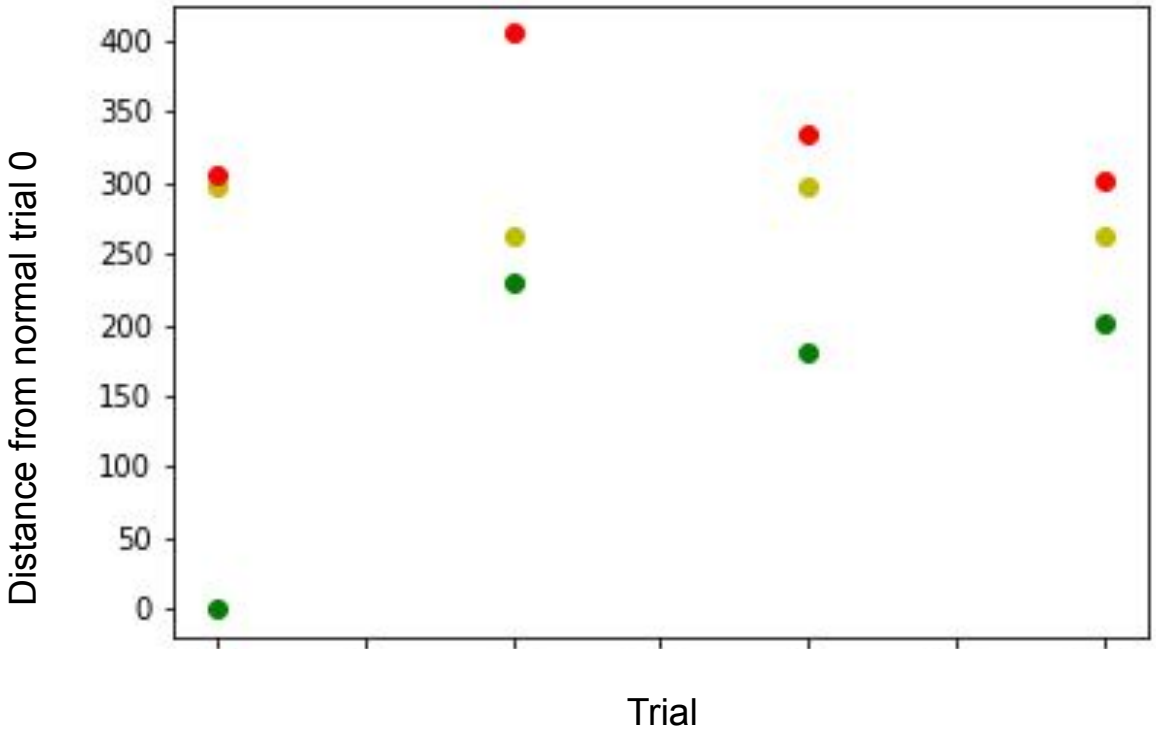
Jerk Score Data

- Jerk is computed via numerical differentiation of trajectory data
- Normalized Jerk:

$$NJ = \sqrt{1/2 \int j^2(t) * (\text{duration}^5/\text{length}^2)\, dt}$$



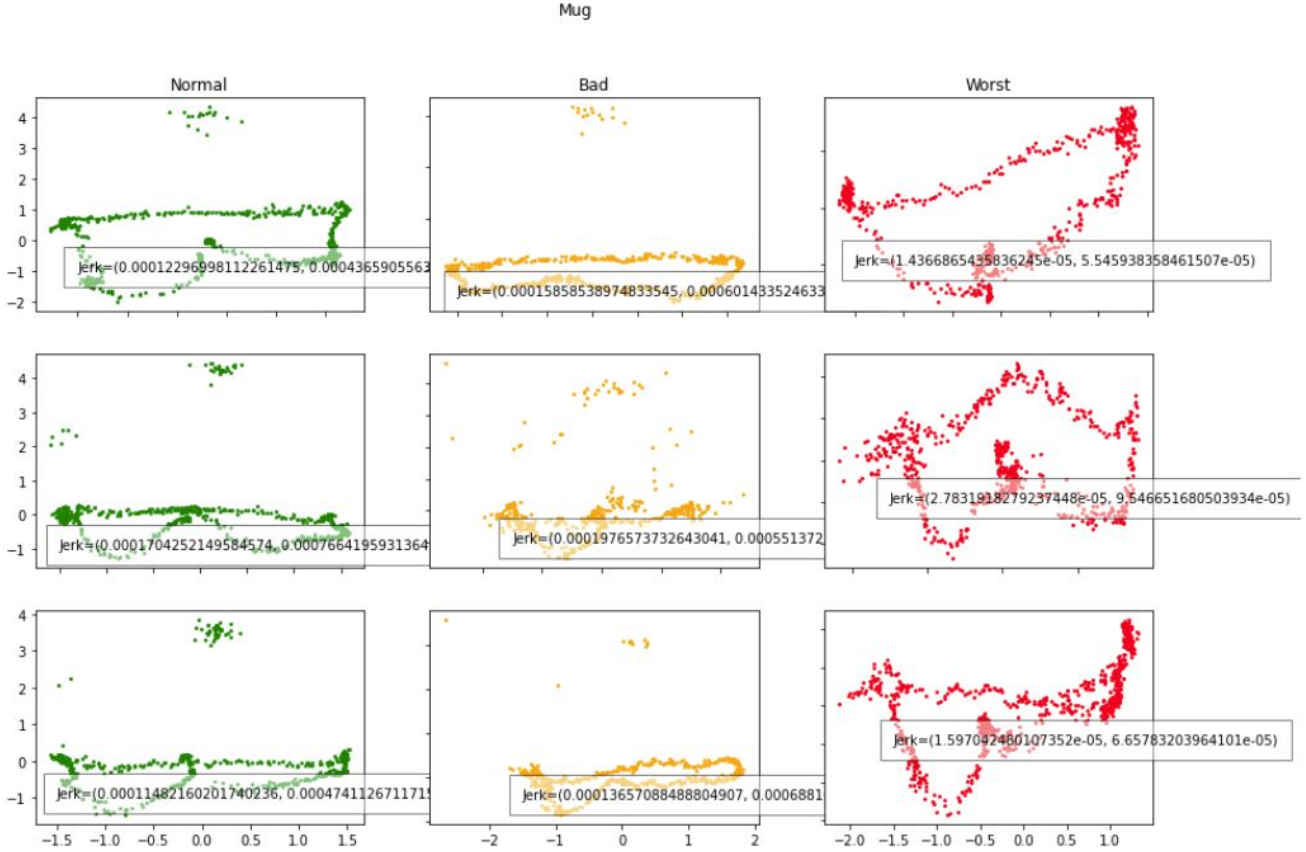
DTW Distance Data



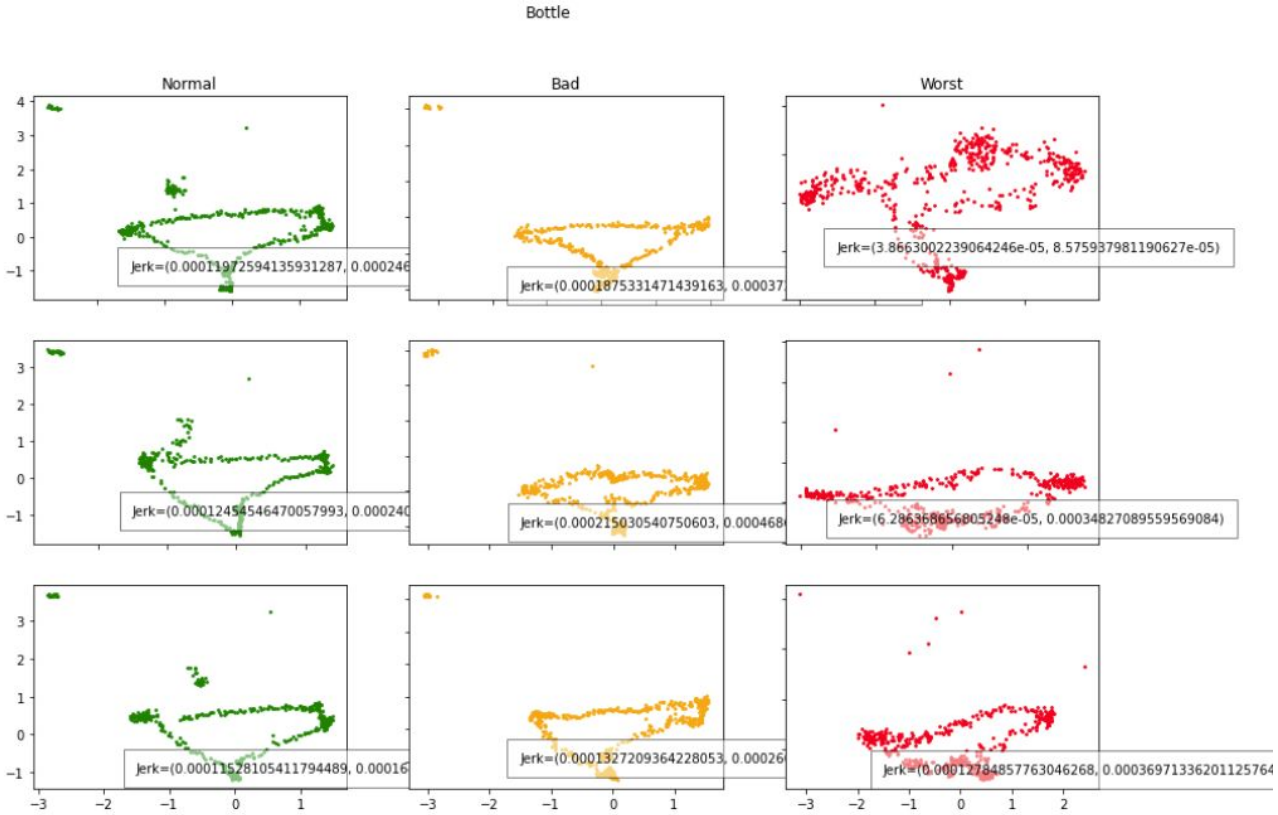
Evaluating Additional Exercises

- Tasks
  - Hook Grasp: Pick up a mug and move it across the table
  - Unscrewing: Remove the cap from a bottle and place it on the table
  - Cylindrical Grasp: Pick up a water bottle and move it across the table
- Data Collected
  - 9 videos for each exercise, separated into groups of 3 based on quality
  - pose estimation applied to video

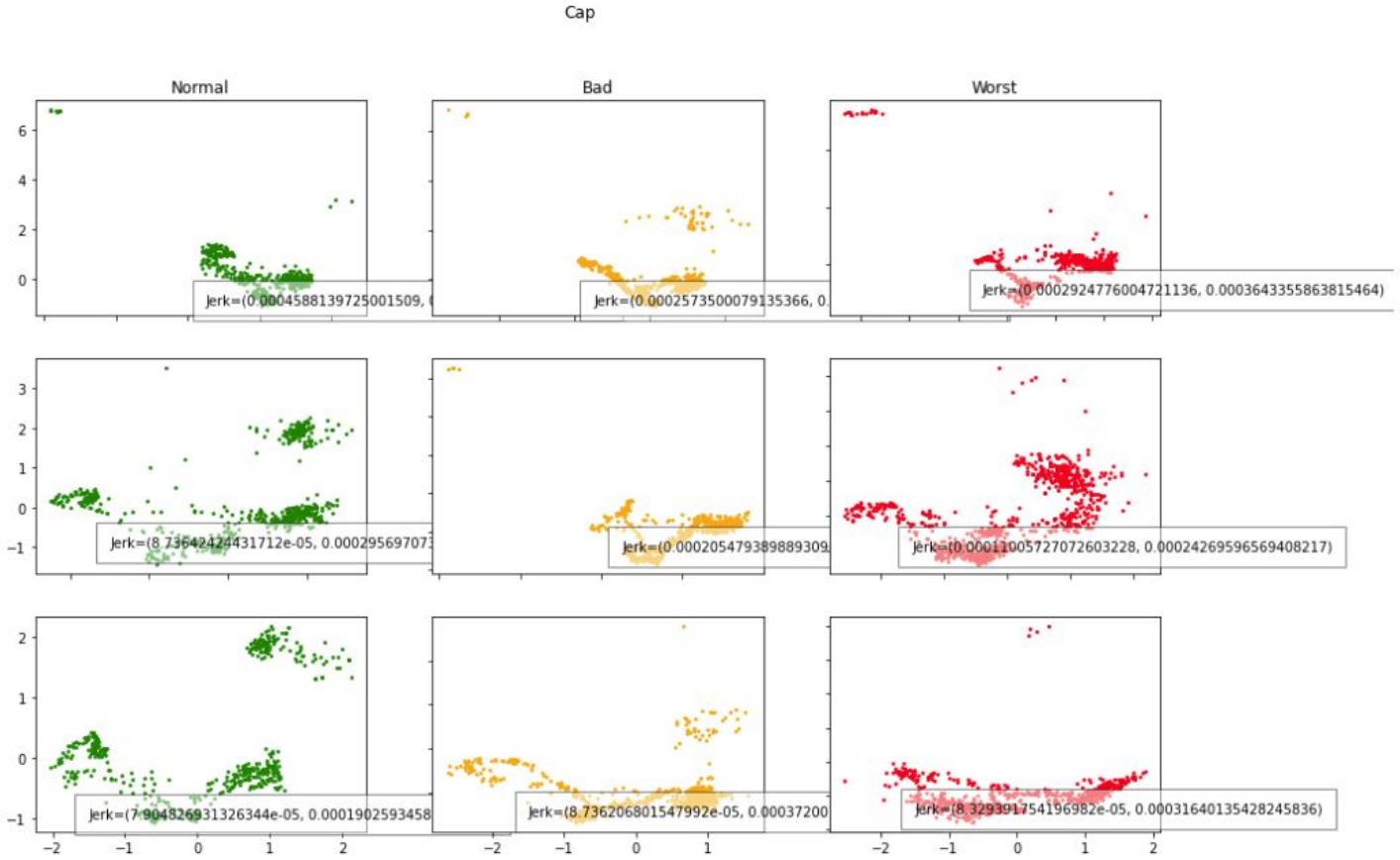
Wrist Keypoint Trajectory



Wrist Keypoint Trajectory

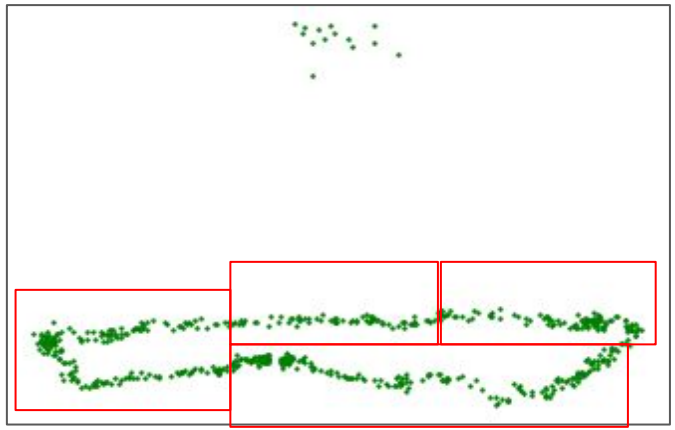


Wrist Keypoint Trajectory



Splitting Input

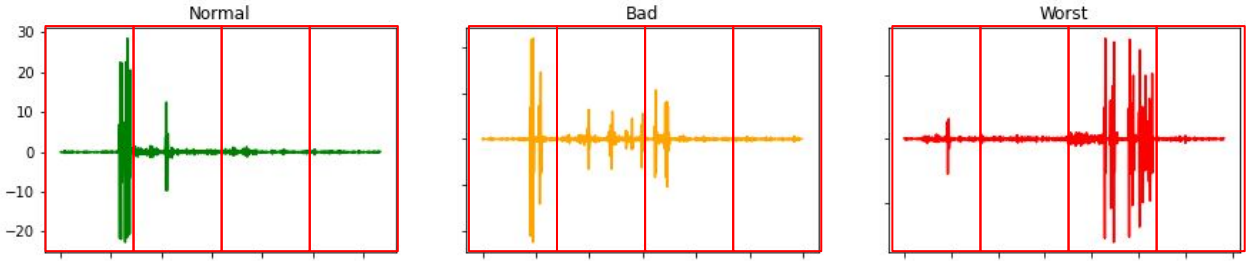
- Jerk Score is currently calculated across entire video
  - It may be useful to obtain the jerk score for certain segments, such as when a patient has just picked up the object.
- Data is temporally ordered
  - Splitting each video into K equal parts, then calculating NJS of each part individually.
  - Videos are approximately the same length



K = 4
Each rectangle will have its own NJS

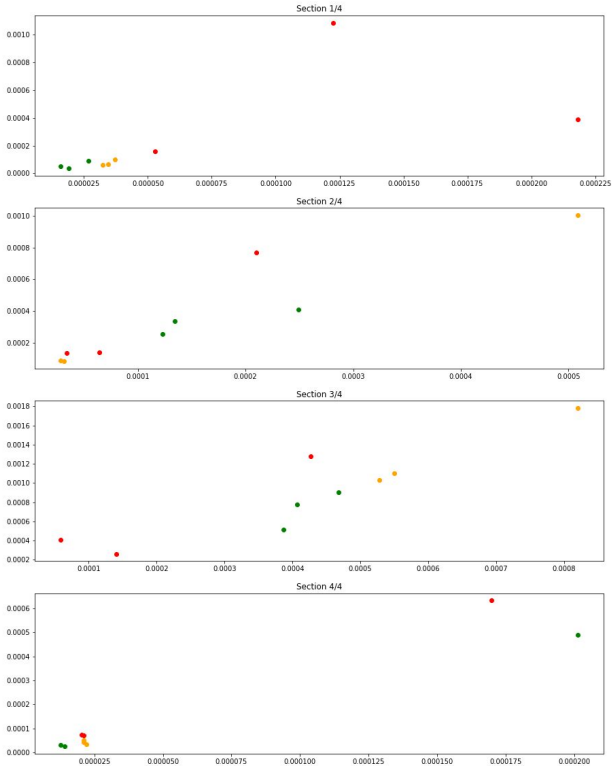
Splitting Input

- X-Coordinate Jerk Plot

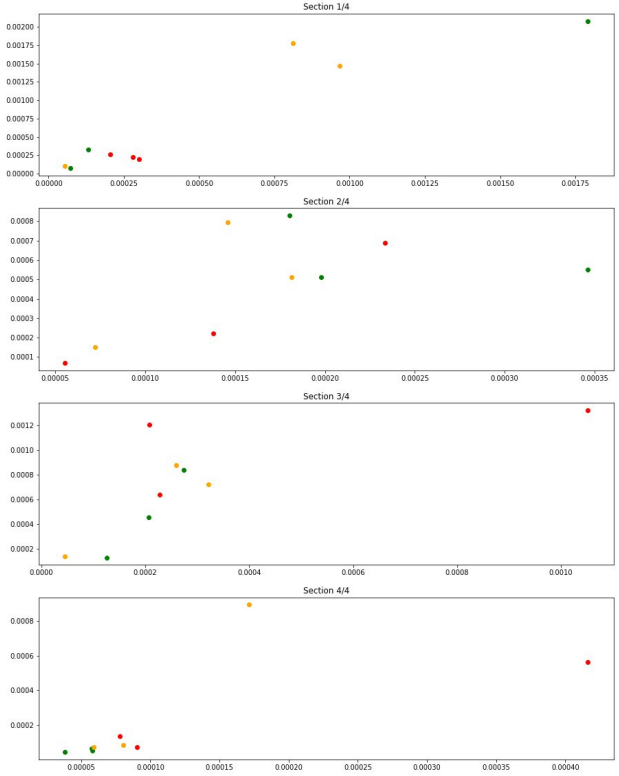


- Collected data across exercise and quality groups

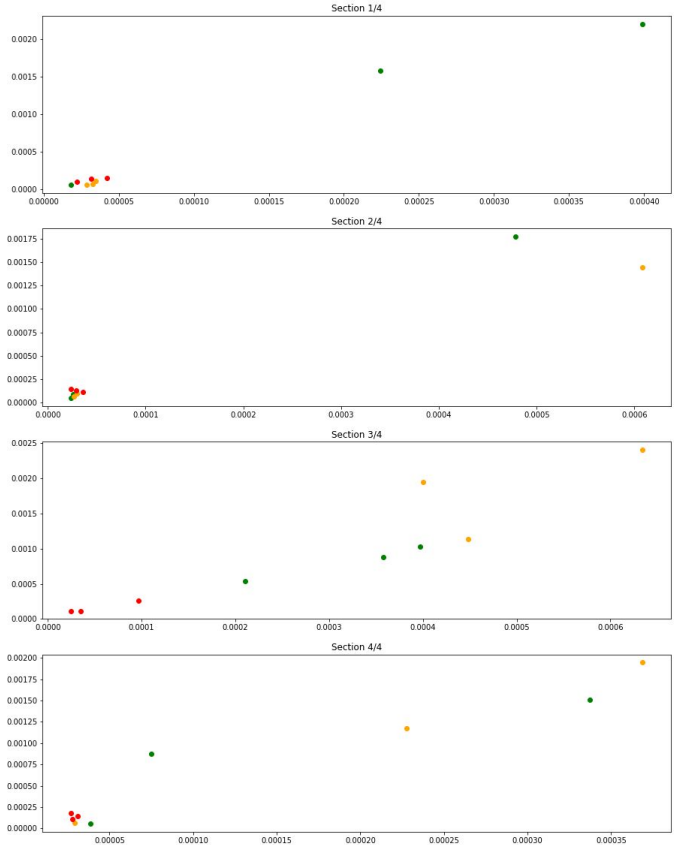
Sectional Jerk Scores - Bottle



Sectional Jerk Scores - Cap

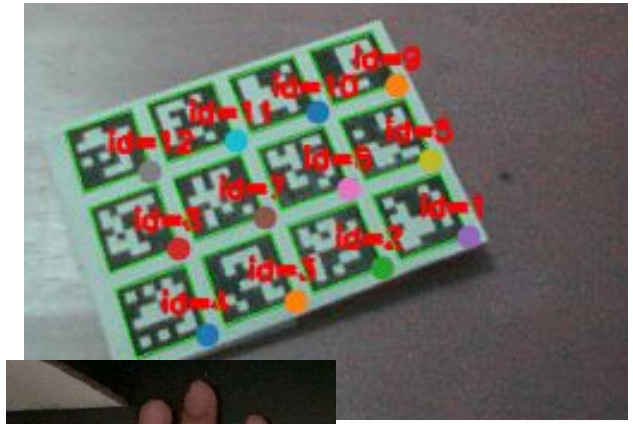


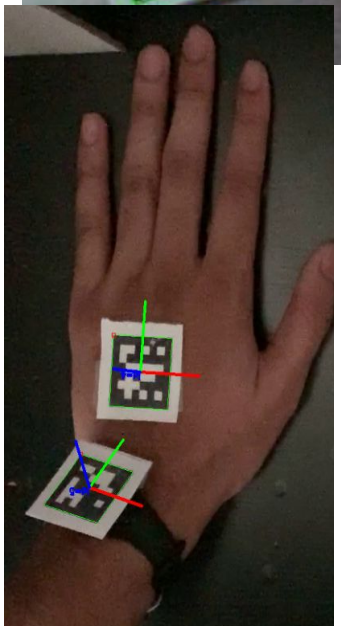
Sectional Jerk Scores - Mug



Aruco Markers

- Printable markers that allow for robust tracking
- Corners of each tag are detected
  - relative 3D pose can be approximated





Aruco Markers

- Two markers placed
- 3 cases of simple movement
  - saved (x,y) pixel locations for each marker