

UROP Fall 2024

Data Glove Hand Pose Ground Truth Optimization

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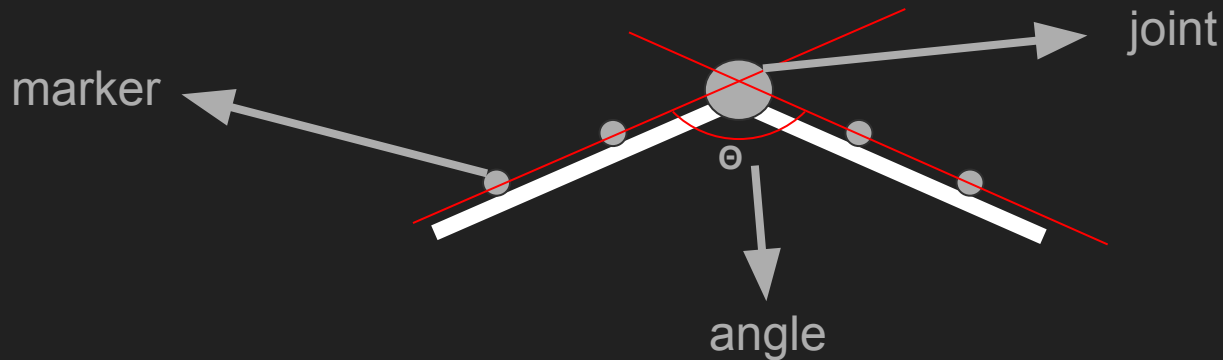
Introduction

- Data gloves are used to capture hand poses using motion capture (Vicon)
- The data representing the hand poses can be used to reconstruct poses in applications like prosthetics or virtual reality.
- Markers are placed on glove, and the software outputs marker coordinates at each frame.



Existing Method for Calculating “Ground Truth” Joint Angles

- Use 2 markers on a phalanx to measure joint angle
- Joint angles can be incorrect if markers are not perfectly aligned (which they almost never are)
- Does not give information on phalanx lengths
- Sliding of the glove relative to the hand causes artifact

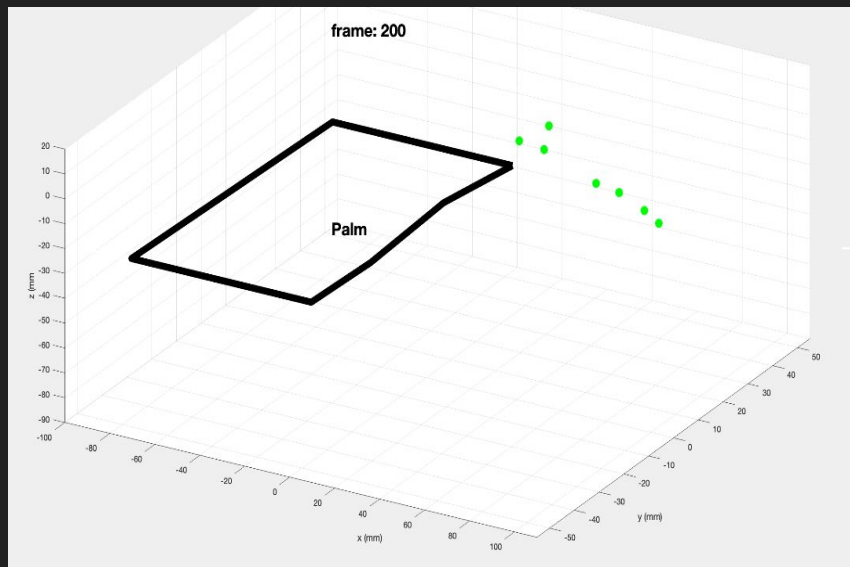


Problem Statement

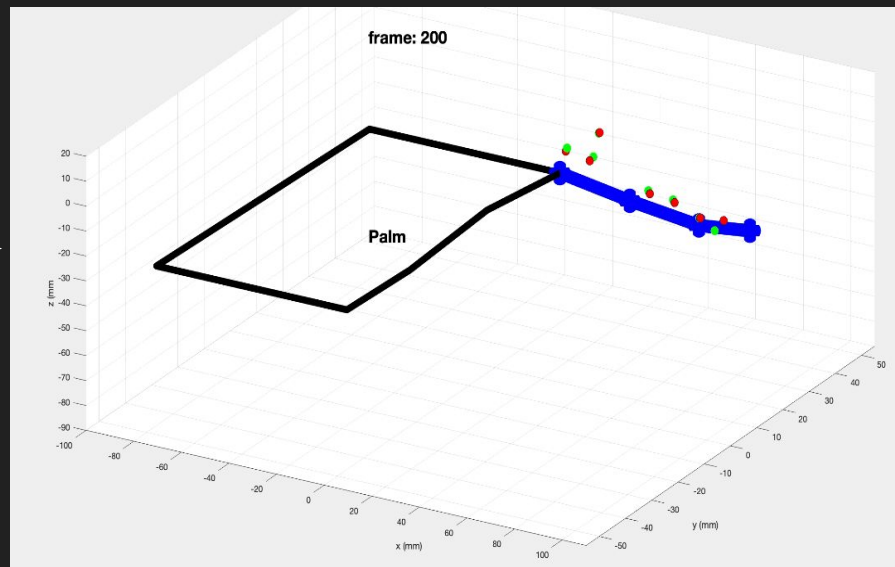
- Find an optimized hand model with markers attached to phalanges such that the markers have minimal error when compared to markers measured across all frames by motion capture
- Allows us to know the true hand geometries and joint angles based on marker coordinates

Problem Statement Visualization with Index Finger

Start with raw marker coordinates



Optimized finger and markers on phalanges fit to raw markers



● Raw marker coordinates

● Raw marker coordinates

● Markers from optimized model

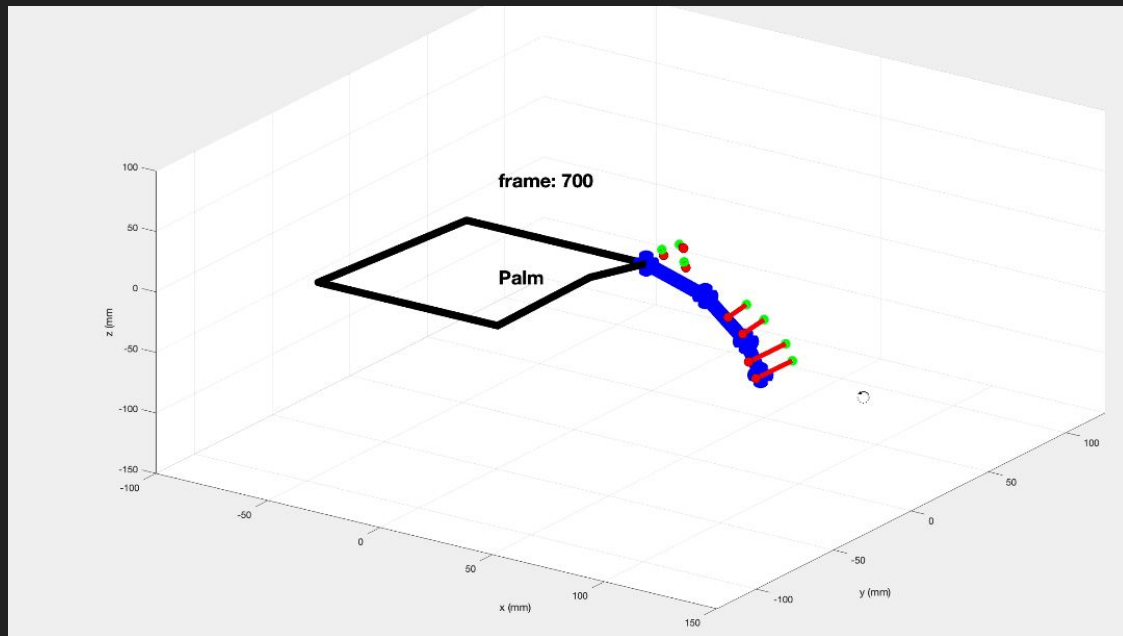
■ Phalanges from optimized model

Error Visualization with Index Finger

Minimize average root mean square error across all markers, across all frames

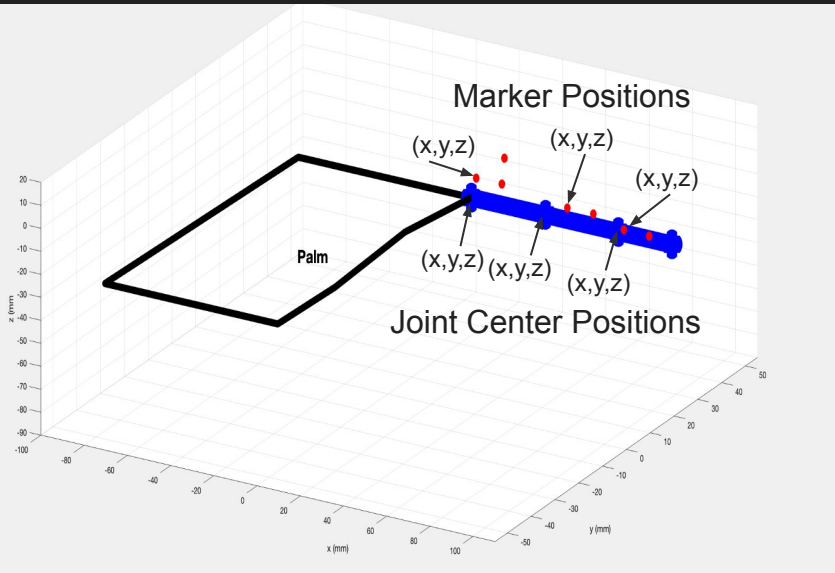
Looking at single frame,
there is some error

- Raw Marker Coordinates
- Markers from optimized model
- Error

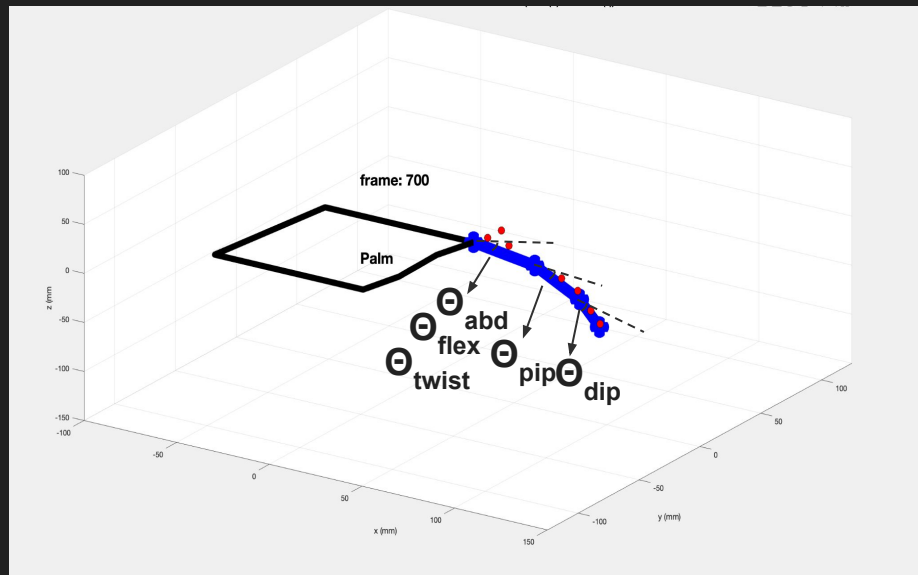


Parameters Changed in Optimized Model to Minimize Error

- 1) Changing marker and finger geometry defined in zero pose (stays constant for each frame)

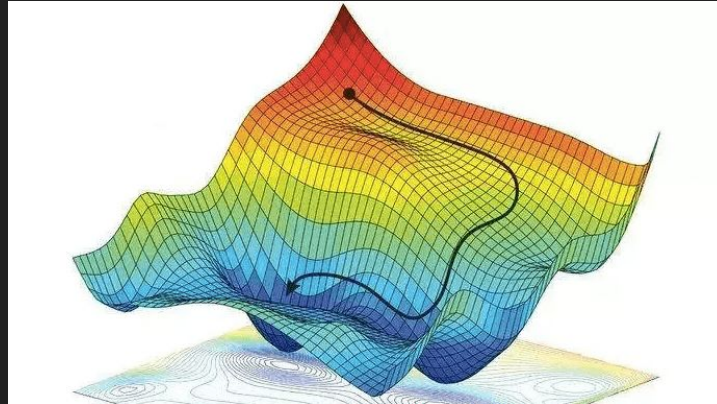


- 2) Changing joint angles at every frame



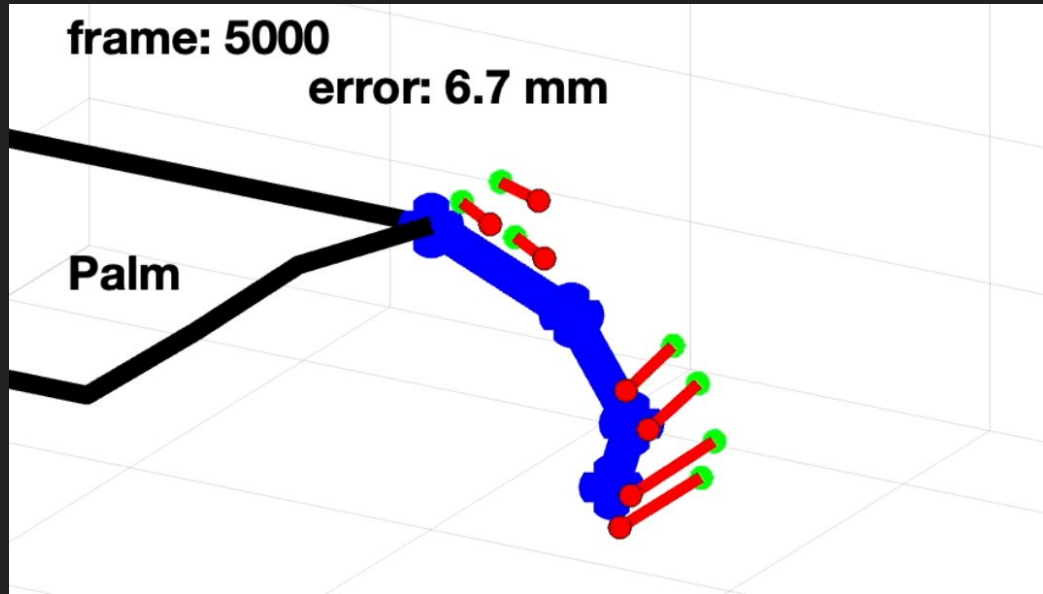
Gradient Descent

- Find the minimum possible error between marker coordinates in optimized model and measured coordinates
- Optimize all geometry and angle parameters at once using the gradient of the error function with parameters as input
- Move in gradient direction until a minimum error value is reached



Error Minimization Visualization for Single Frame

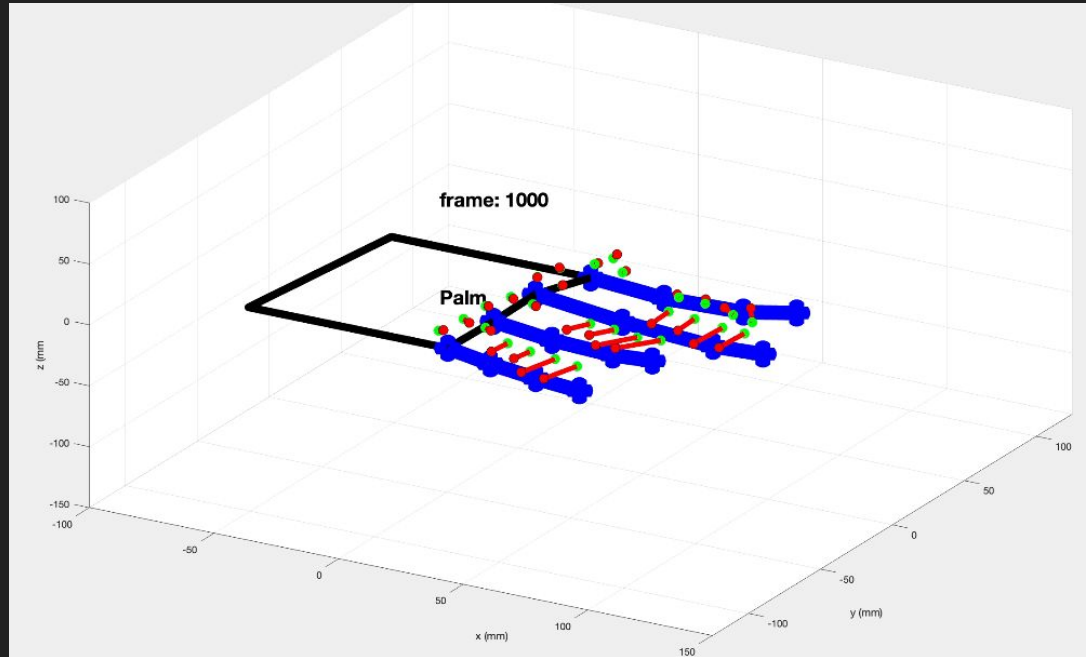
Minimize error for every frame by finger geometry, marker geometry, and joint angles → Geometry cannot change frame to frame, while angles can



Initial Guess → Optimized Model

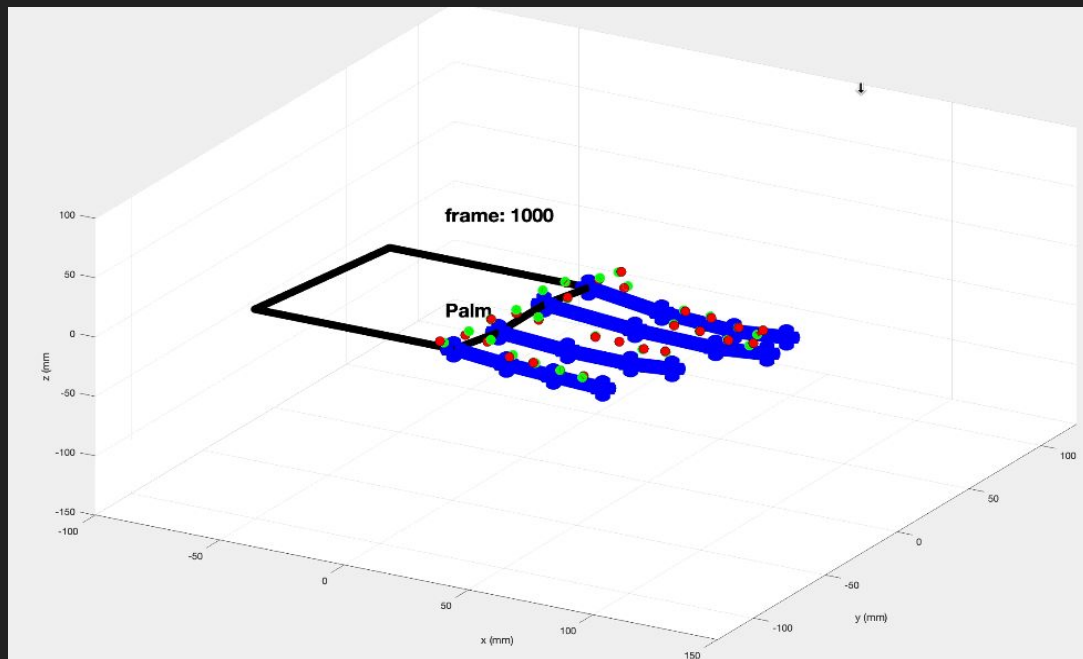
Optimization for Hand

Initial Guess of Parameters (error = 10.12 mm)



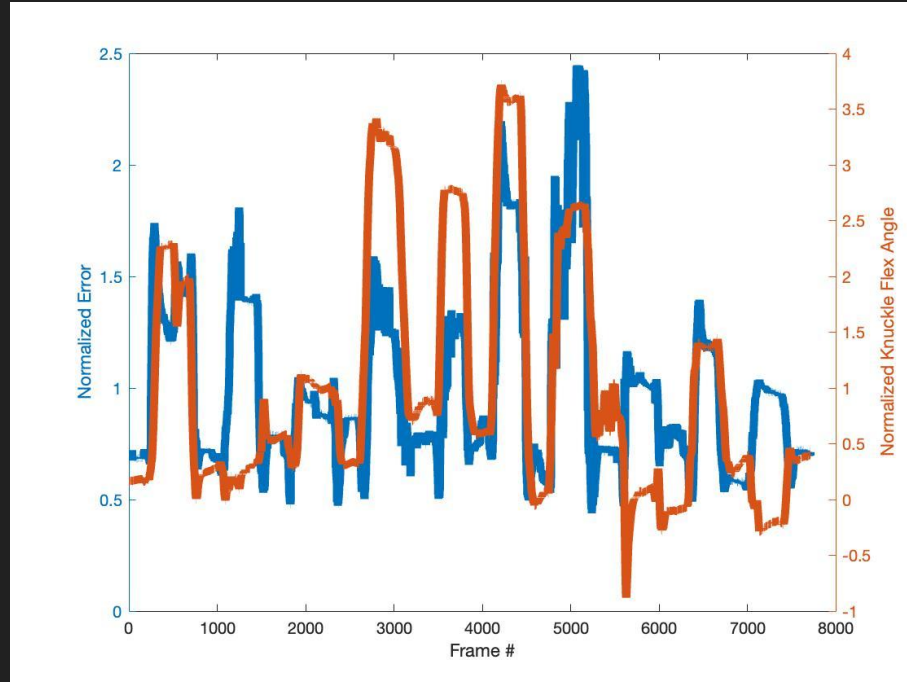
Optimization for Hand

Optimized (error = 2.17 mm)



Error Analysis

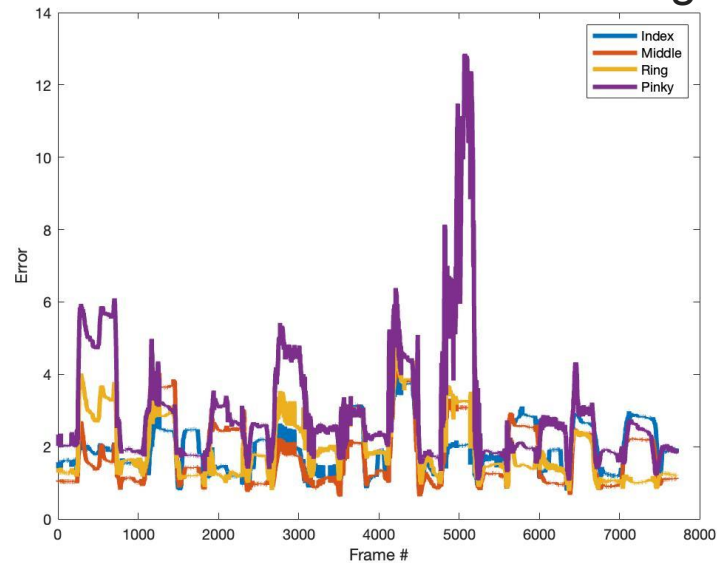
Knuckle Flexion Angle and Error vs. Frame Number (Index Finger)



→ Error is greater during flexion

Finger	Average Error across all markers and frames
Index	1.9353 mm
Middle	1.7852 mm
Ring	1.9623 mm
Pinky	3.0036 mm

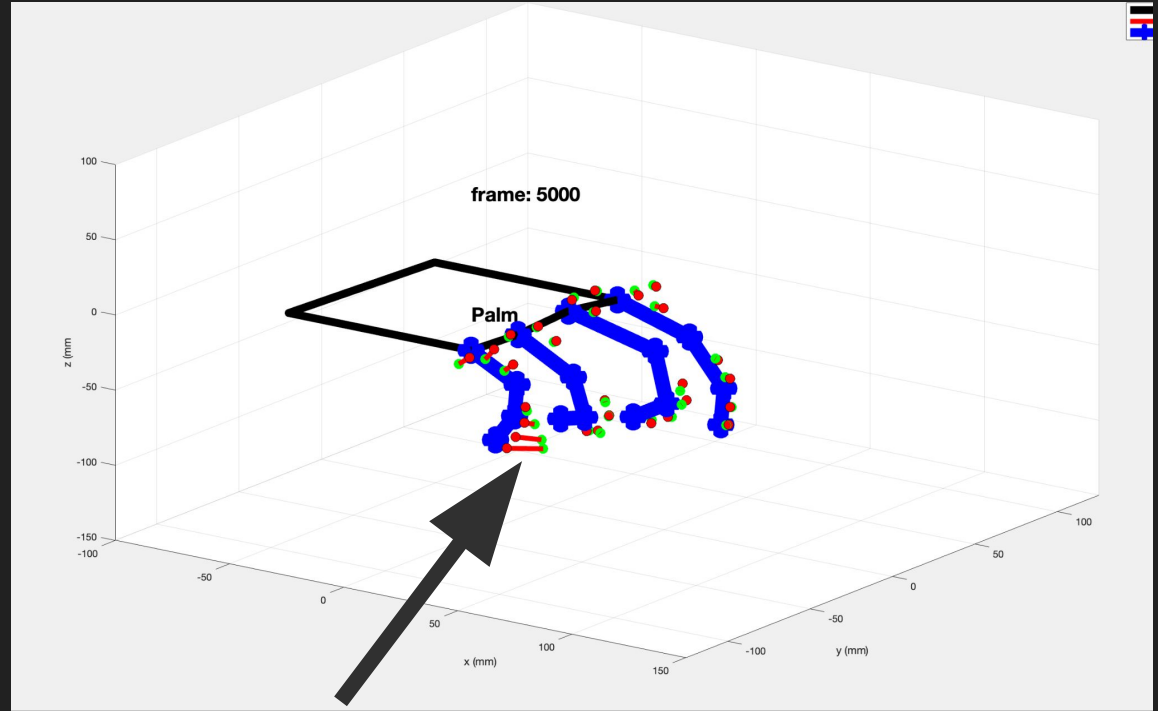
Error vs. Frame # for Each Finger



Further Error Mitigation

Model does not include palmar adduction/abduction

Could allow markers in optimized model to change position on phalanx for each frame



Conclusion

- Create code that can take motion capture marker coordinates and fit a feasible hand model
- Hand is very complicated, difficult to model