JOHNS HOPKINS
UNIVERSITY

Evaluation of Various Sensing Modalities for Accurate Measurement of Neck Flexion Angle during Ear Surgery

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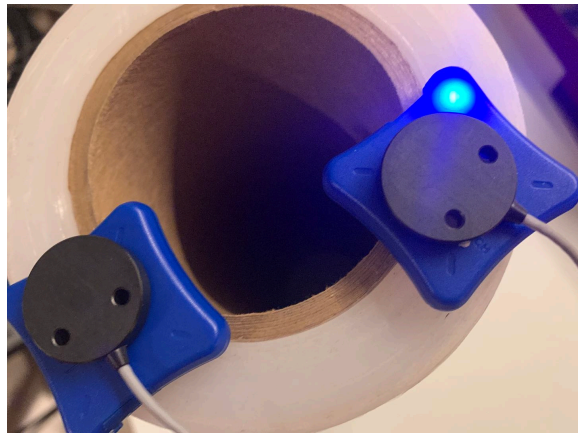
Mentors: Dr. Russell Taylor, Dr. Deepa Galaiya

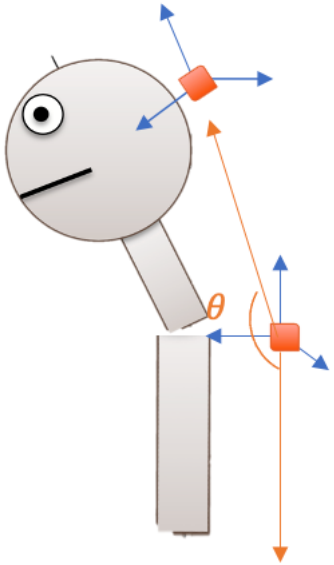
Project Summary



Goal:

Accurate Measurement of Neck Flexion Angle during Ear Surgery by using IMUs (Inertial measurement unit)

Investigate and Compare Postural Ergonomics of Ear Surgeons during Microscopic and Endoscopic Scenarios.



- **Neck Flexion Angle:** extract pitch angle between two IMUs
- **Surgeries:** Analyze neck flexion angle changes in real surgical scenarios

Figure Edit from: https://stanford.edu/class/ee267/lectures/lecture10.pdf

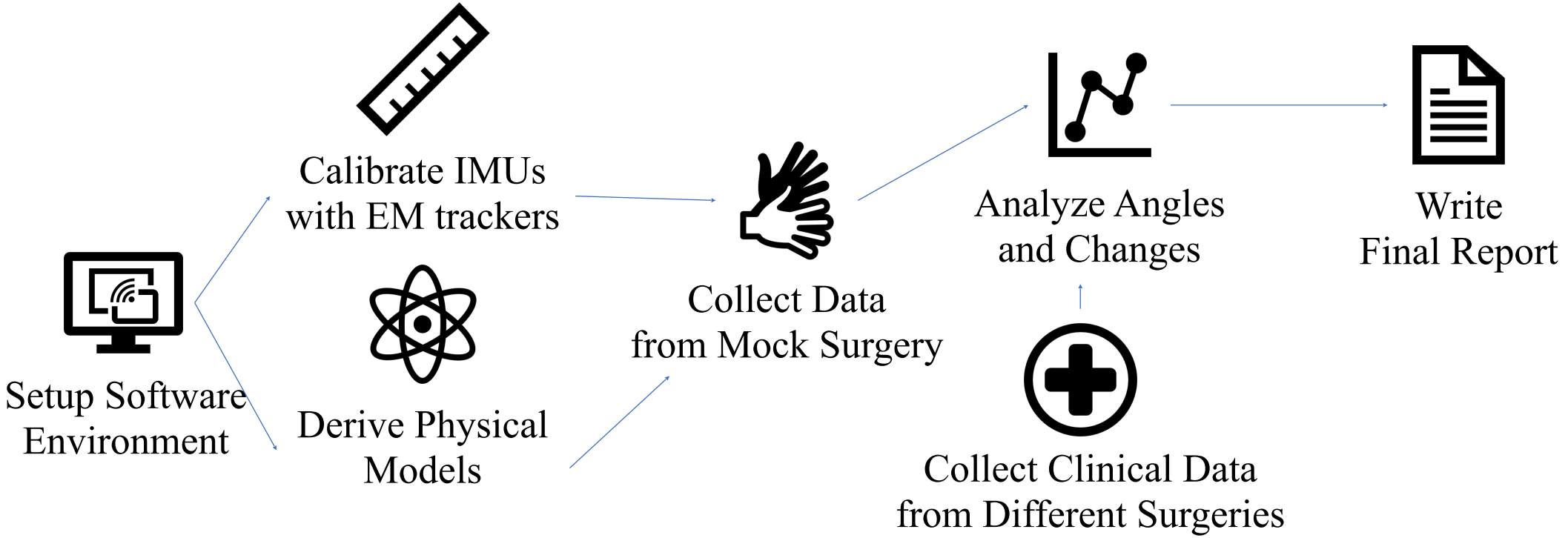
Deliverables

- Minimum:
  - ✓ Evaluation of the existing calibration steps, physical model
  - ✓ Documentation of software setting, calibration steps, physical model (doc file)
  - ✓ Data analysis and documentation of Mock OR experiment
  - • Data analysis report of surgical data collected from previous semester

- Expected:
  - ✓ Improvement to signal processing of measurement obtained from IMUs
  - • Data analysis report of real surgical scenarios

- Maximum:
  - • Clinical paper

Technical Approach



Neck Flexion Angle Model

Reference Position: surgeon stands and stays unmoved
Surgical Positions: surgeon operates

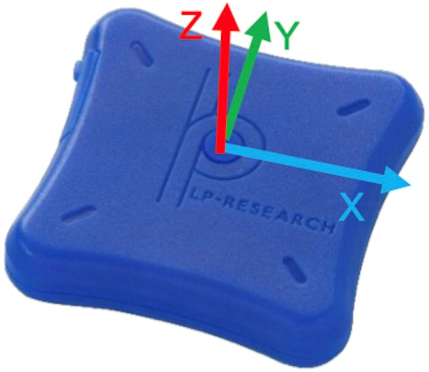
Extract reference position's quaternion

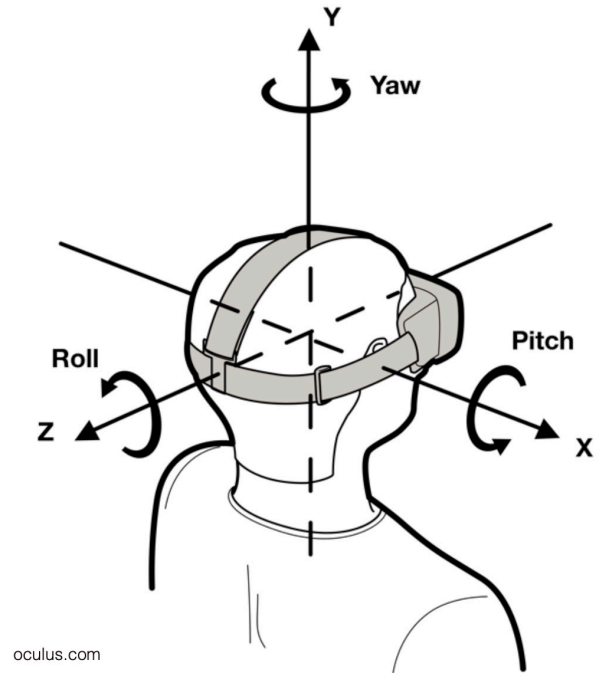
Extract surgical position's quaternion

Transfer all quaternion to rotation matrices

Calculate surgical position wrt reference position

Transfer Rotation Matrix to Euler Angles



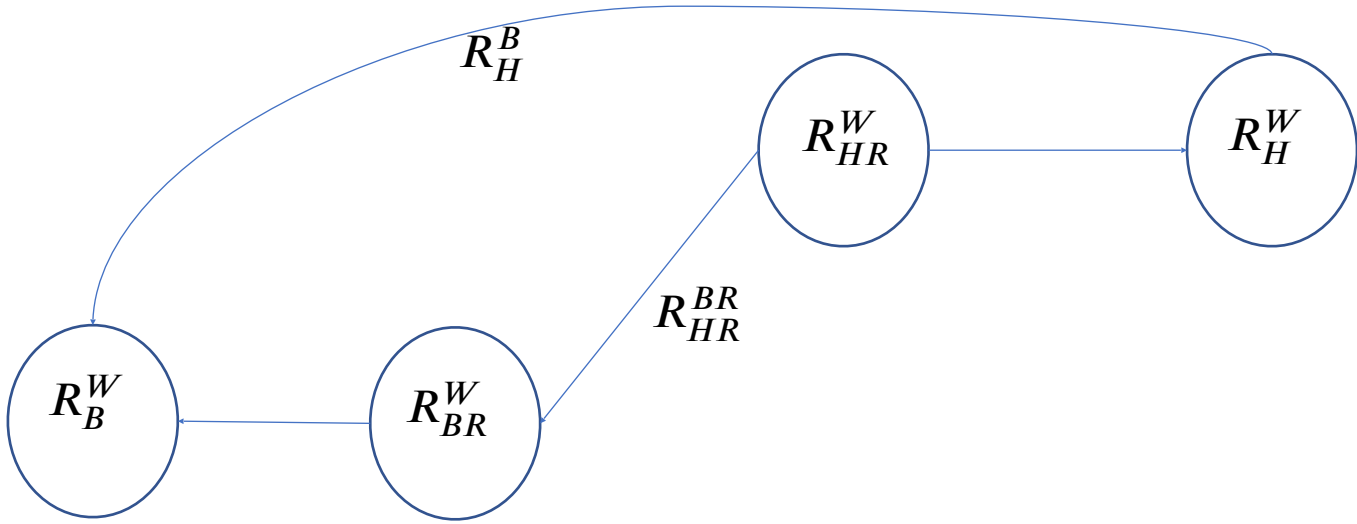


The mathematical formula

Superscript: the coordinate system that are w.r.t.

- $\boldsymbol{R_{BR}^{W}}$: The **B**ack IMU's rotation matrix in **R**eference position w . r . t . **W**orld's coordinate system.
- $\boldsymbol{R_{HR}^{W}}$: The **H**ead IMU's rotation matrix in **R**eference position w . r . t . **W**orld's coordinate system.

- $\boldsymbol{R_{B}^{W}}$: The **B**ack IMU's rotation matrix in surgical position w . r . t . **W**orld's coordinate system.
- $\boldsymbol{R_{H}^{W}}$: The **H**ead IMU's rotation matrix in surgical position w . r . t . **W**orld's coordinate system.

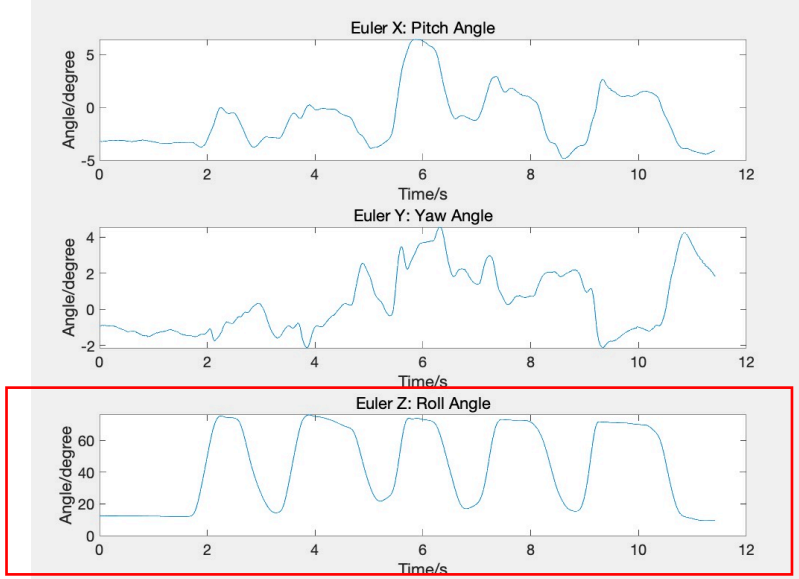


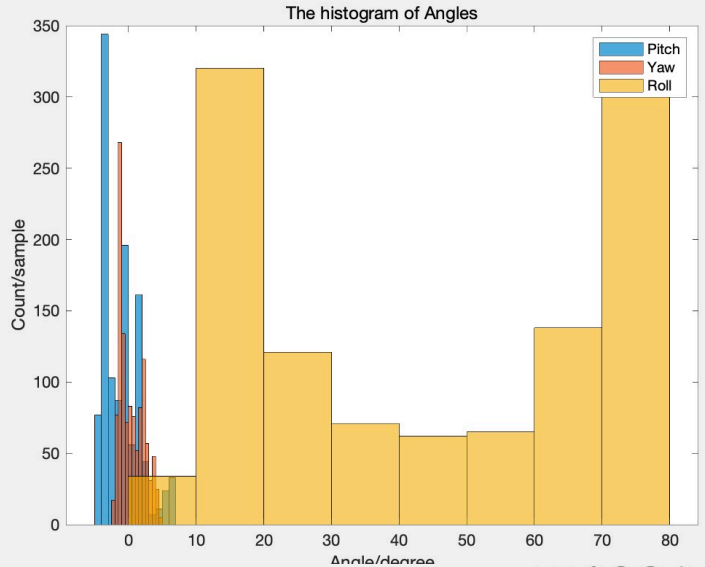
Calculation Process:

- In **R**eference position: the **H**ead IMU w . r . t . the **B**ack IMU : $\boldsymbol{R_{HR}^{BR} = R_{W}^{BR} \bullet R_{HR}^{W} = (R_{BR}^{W})^{-1} \bullet R_{HR}^{W}}$
- In surgical position: the **H**ead IMU w . r . t . the **B**ack IMU : $\boldsymbol{R_{H}^{B} = R_{W}^{B} \bullet R_{H}^{W} = (R_{B}^{W})^{-1} \bullet R_{H}^{W}}$

- **Surgical position w . r . t . reference position:** $\boldsymbol{R_{final} = (R_{HR}^{BR})^{-1} \bullet R_{H}^{B} = (R_{HR}^{W})^{-1} \bullet R_{BR}^{W} \bullet (R_{B}^{W})^{-1} \bullet R_{H}^{W}}$

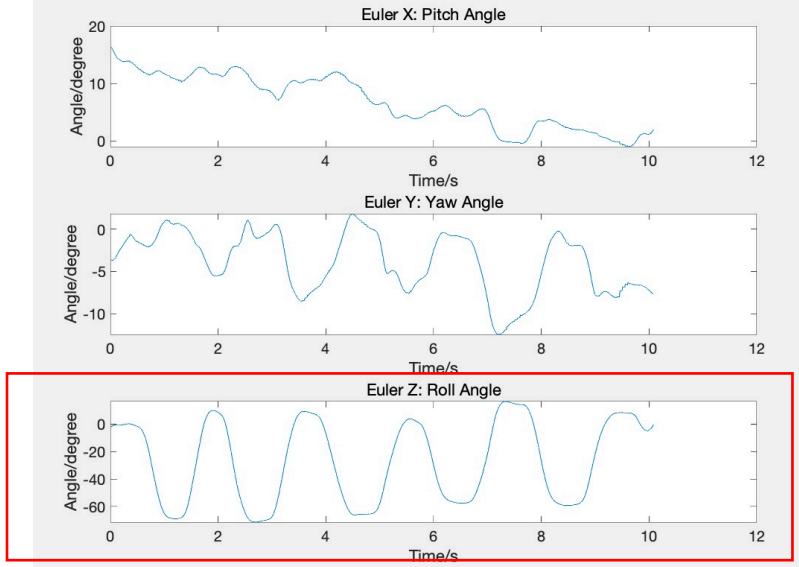
Mock OR Data Analysis – rotate to left & right

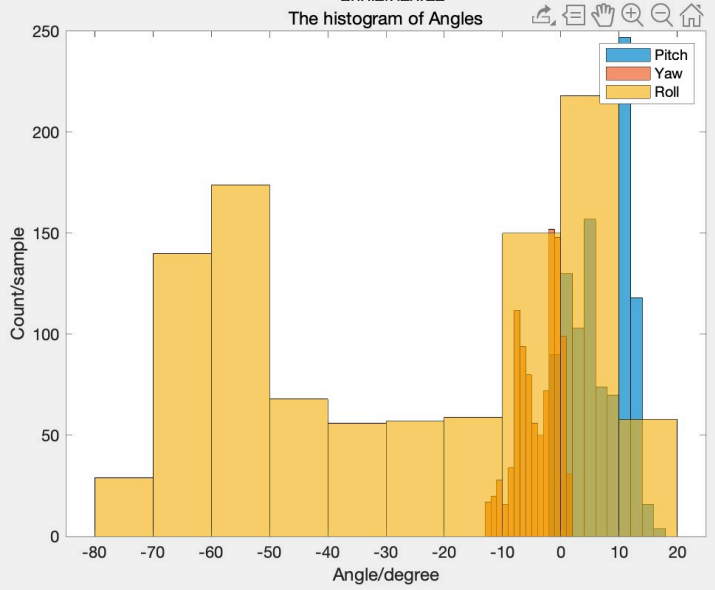


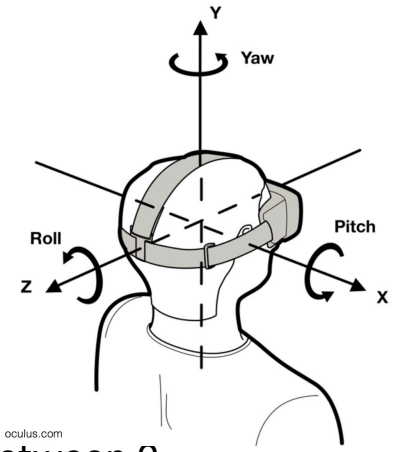


Rotate to left

- Roll angle changes between 0 degree to 80 degree periodically.







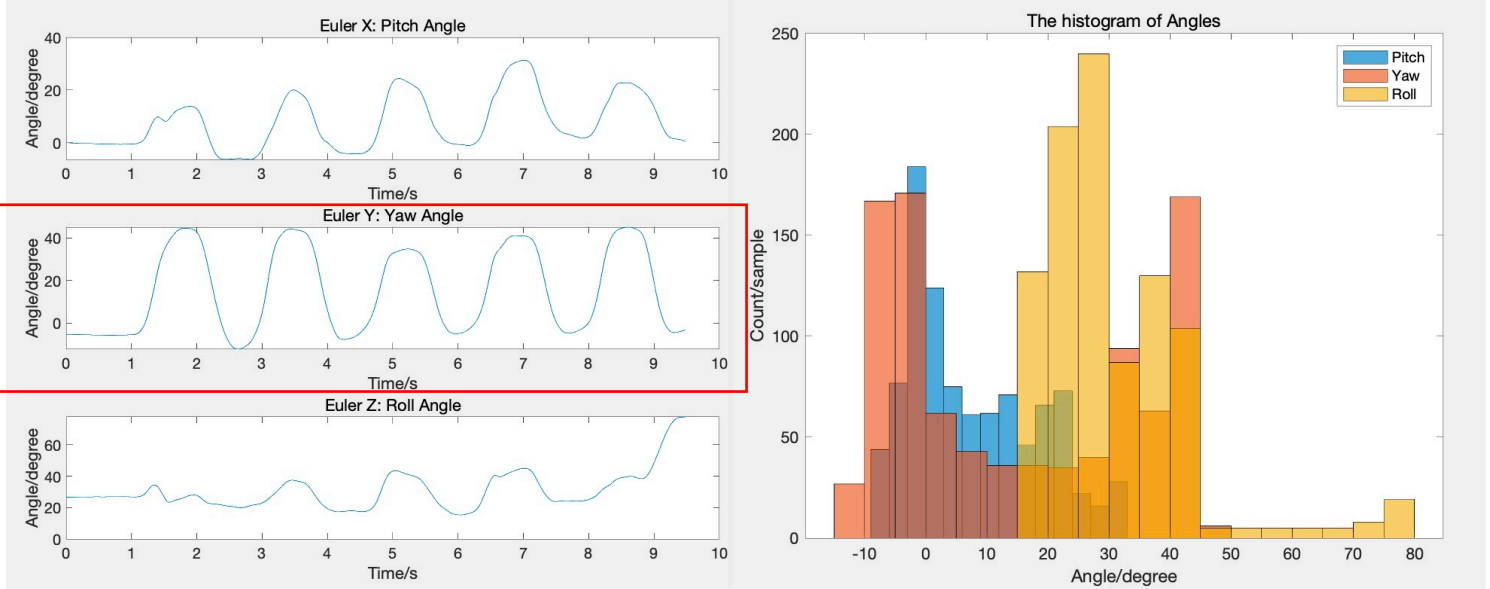
Rotate to right

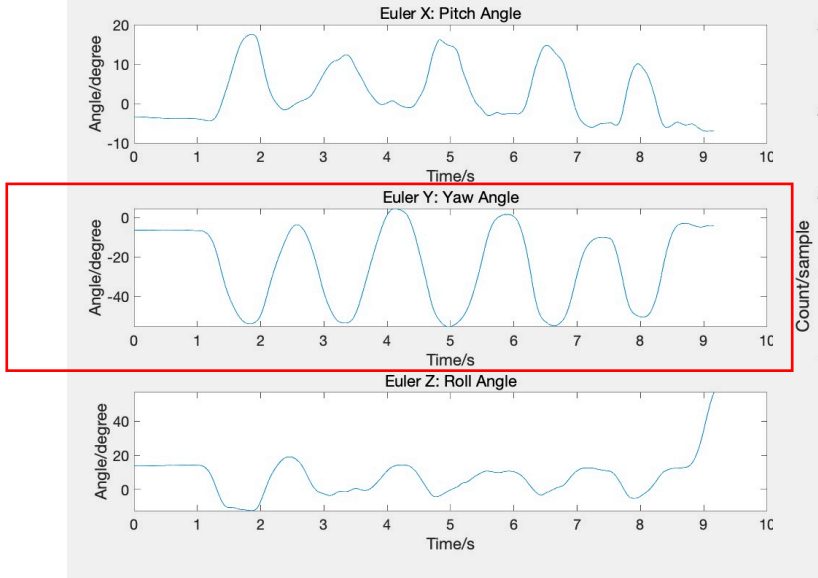
- Roll angle changes between 0 degree to -80 degree periodically.

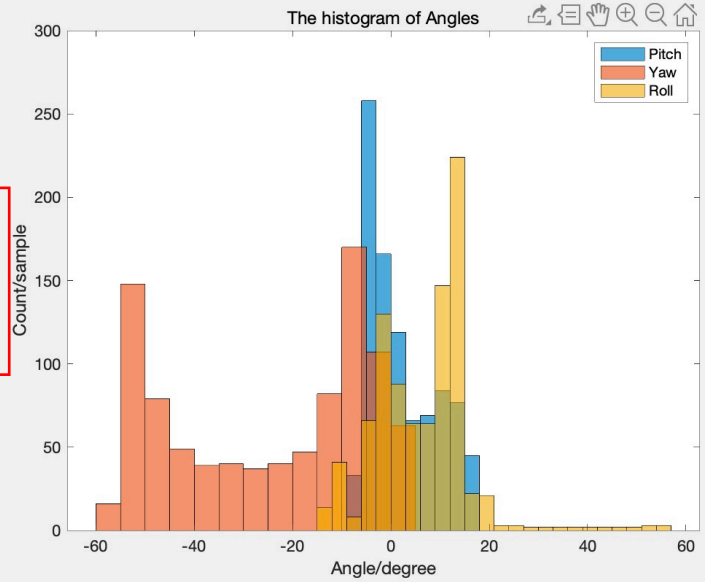
- Pitch angle and Yaw angle change little and there is no significant difference between left and right circumstances.

Coordinate system figure from: https://stanford.edu/class/ee267/lectures/lecture10.pdf

Mock OR Data Analysis – turn to left & right

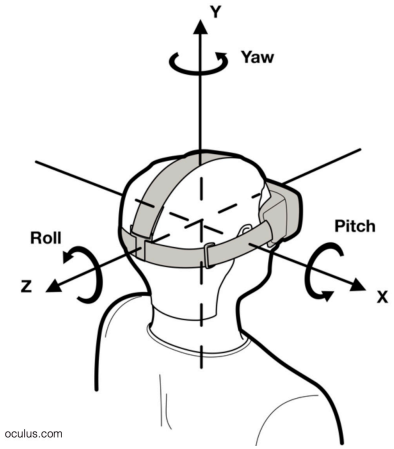






← Turn to left

- Yaw angle changes between -10 degree to 45 degree periodically.



← Turn to right

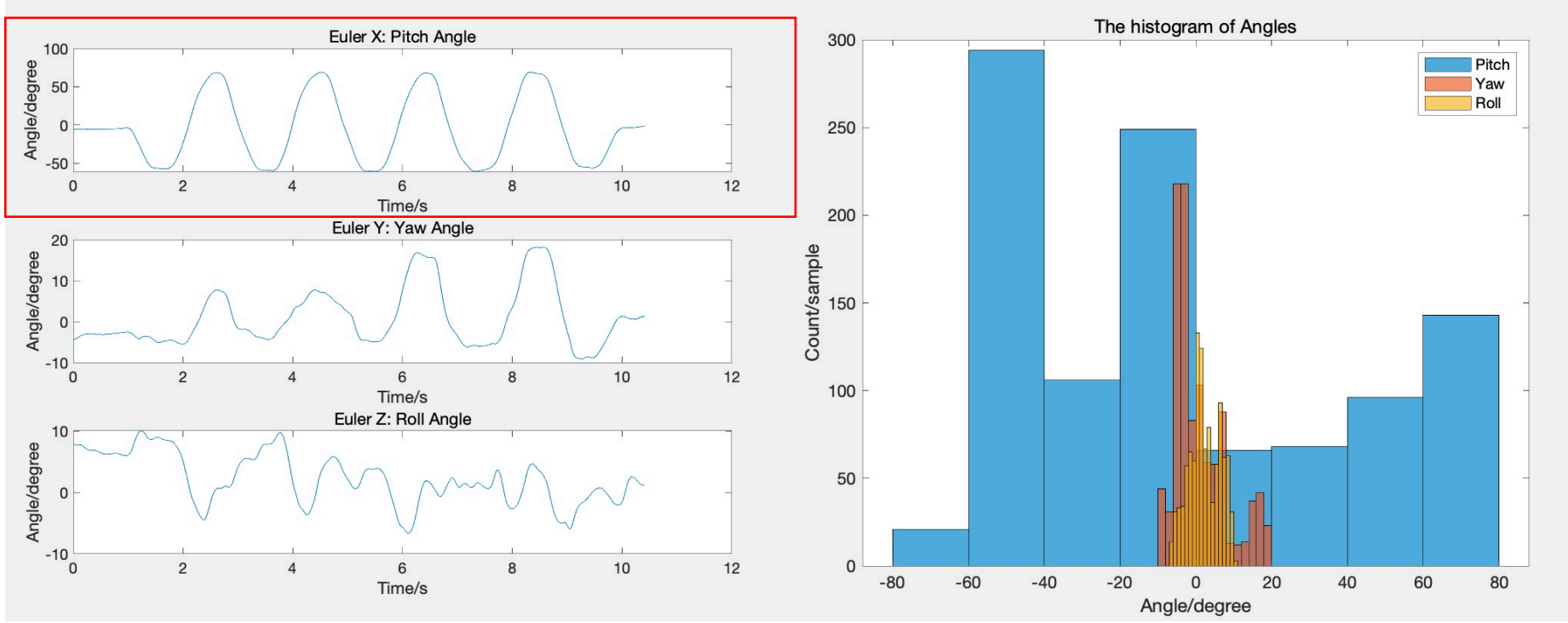
- Yaw angle changes between -5 degree to -60 degree periodically.

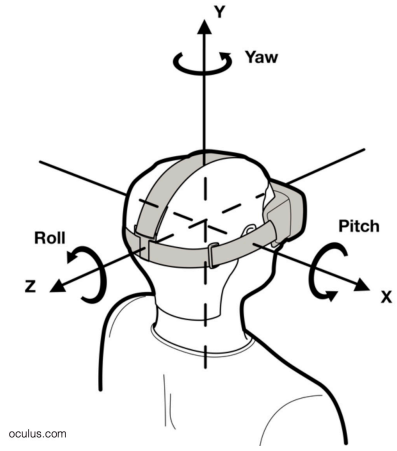
- Pitch angle and Roll angle change little, but Inevitably pitch angle also varies periodically.

Coordinate system figure from: https://stanford.edu/class/ee267/lectures/lecture10.pdf

Mock OR Data Analysis – turn up and down

- Pitch angle changes between -80 degree to 80 degree strongly and periodically.
- Yaw angle and Roll angle changes little.

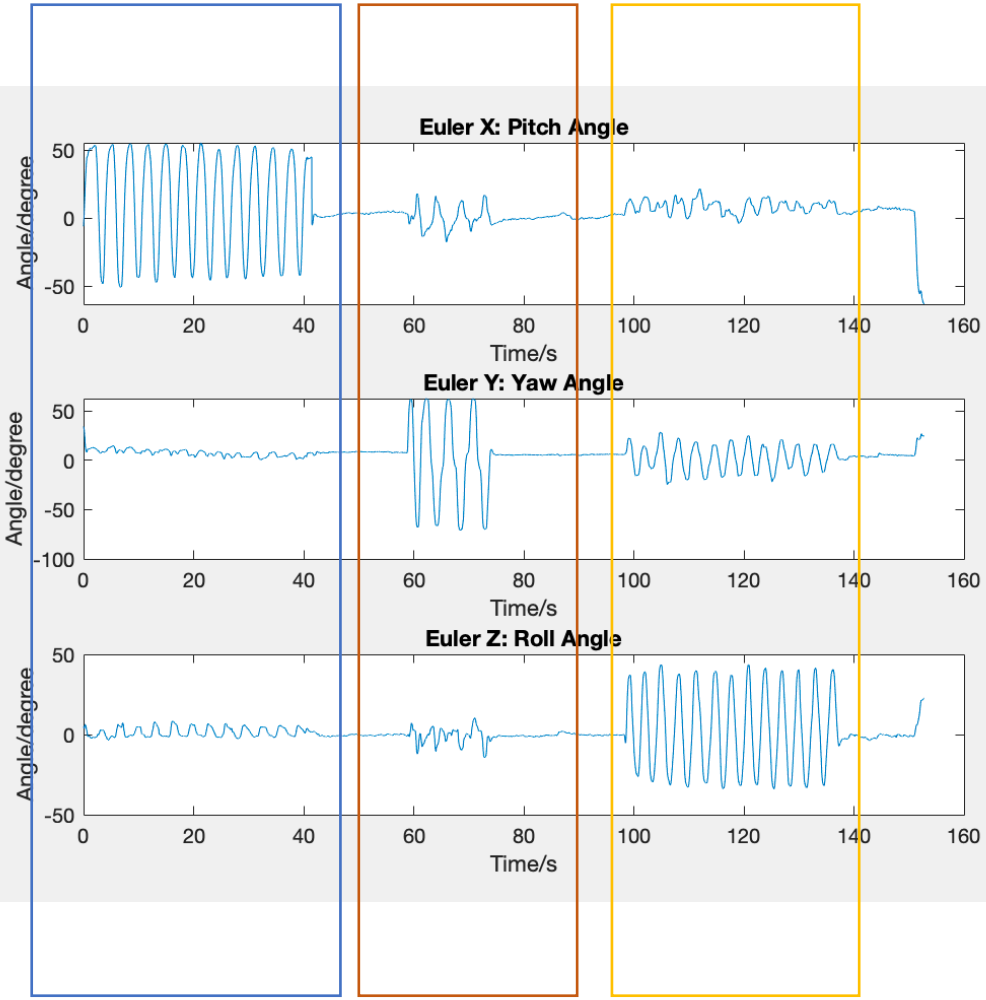


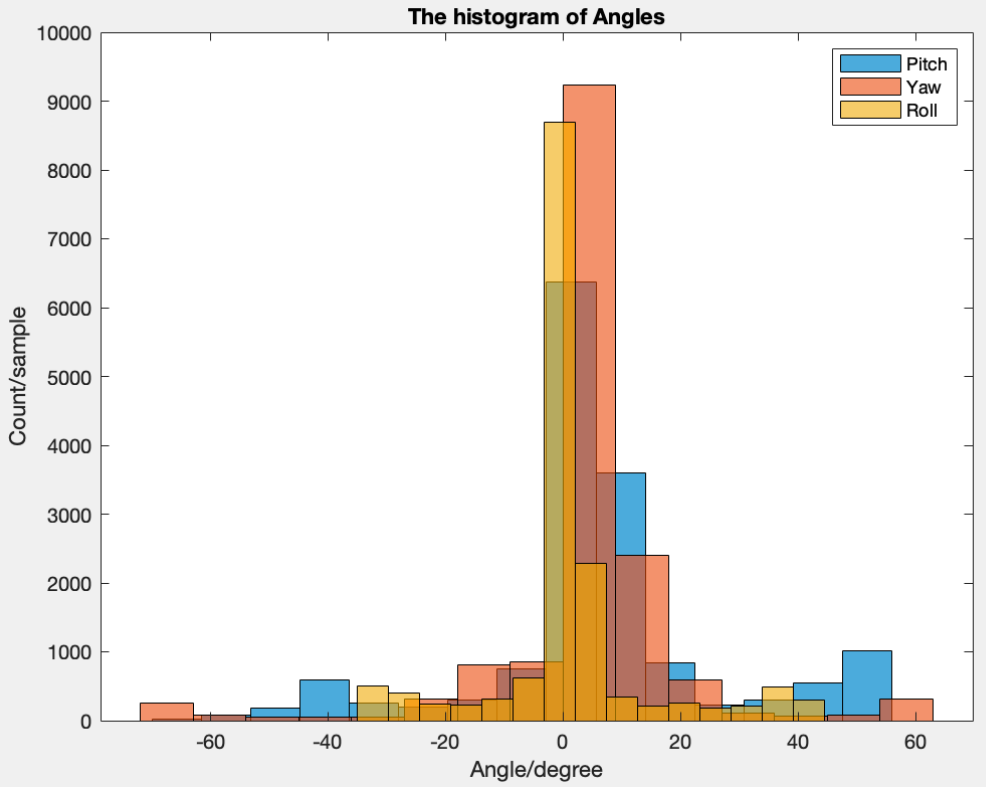


Coordinate system figure from: https://stanford.edu/class/ee267/lectures/

Mock OR Data Analysis – combine all motions

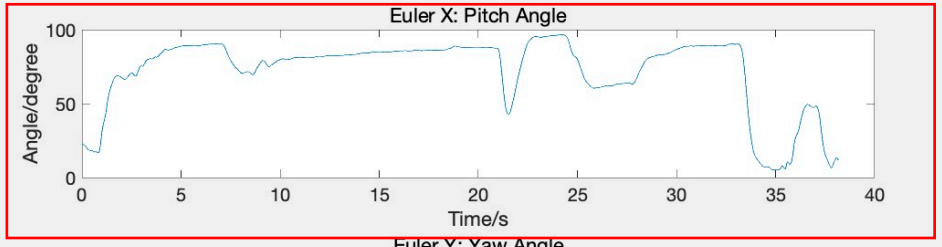
- Turn up and down, followed by turn to left and right, and then followed by rotate to left and right
- Normal distribution for Pitch, Yaw and Roll angle.

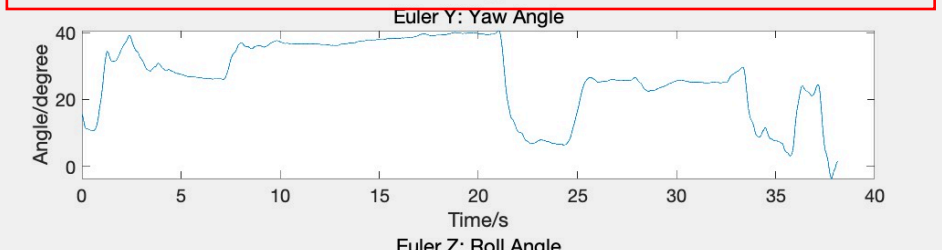


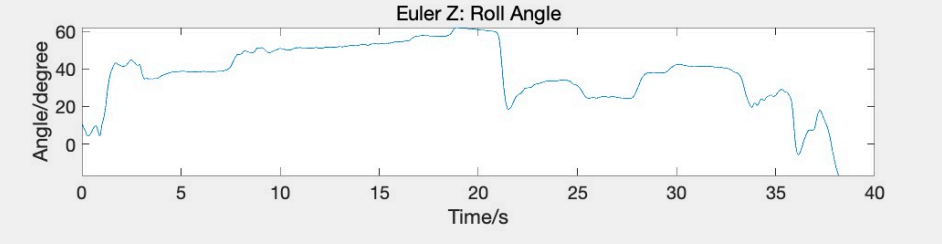


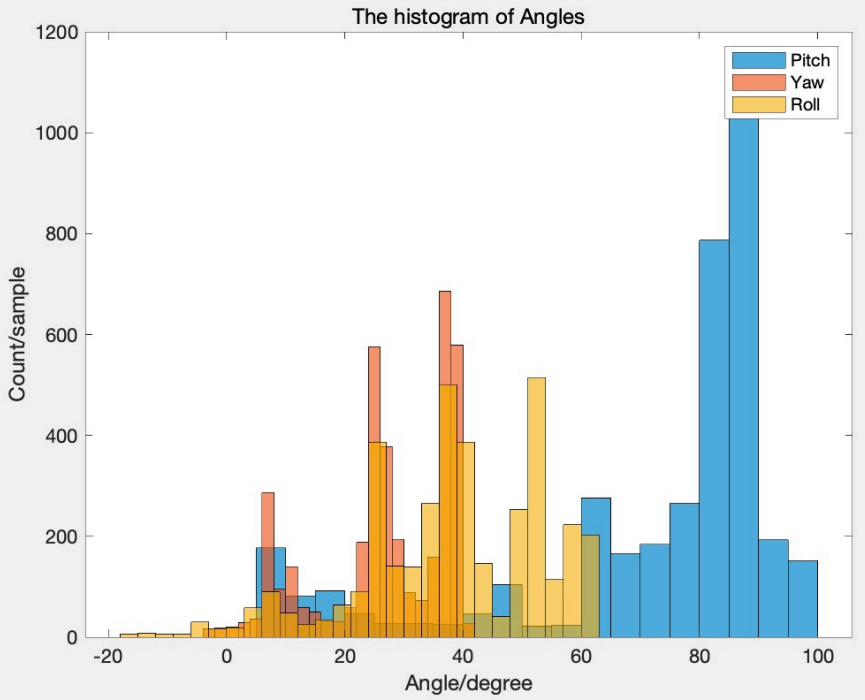
Mock OR Data Analysis – traditional case

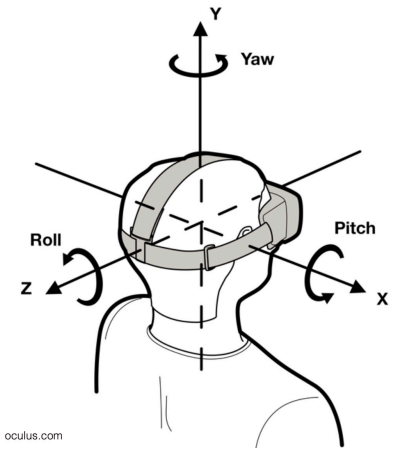
- Pitch angle keeps at 85 to 90 degree for a long time;
- Yaw angle and Roll angle change between 0 to 60 degree, but they are not variables we are concerned about.







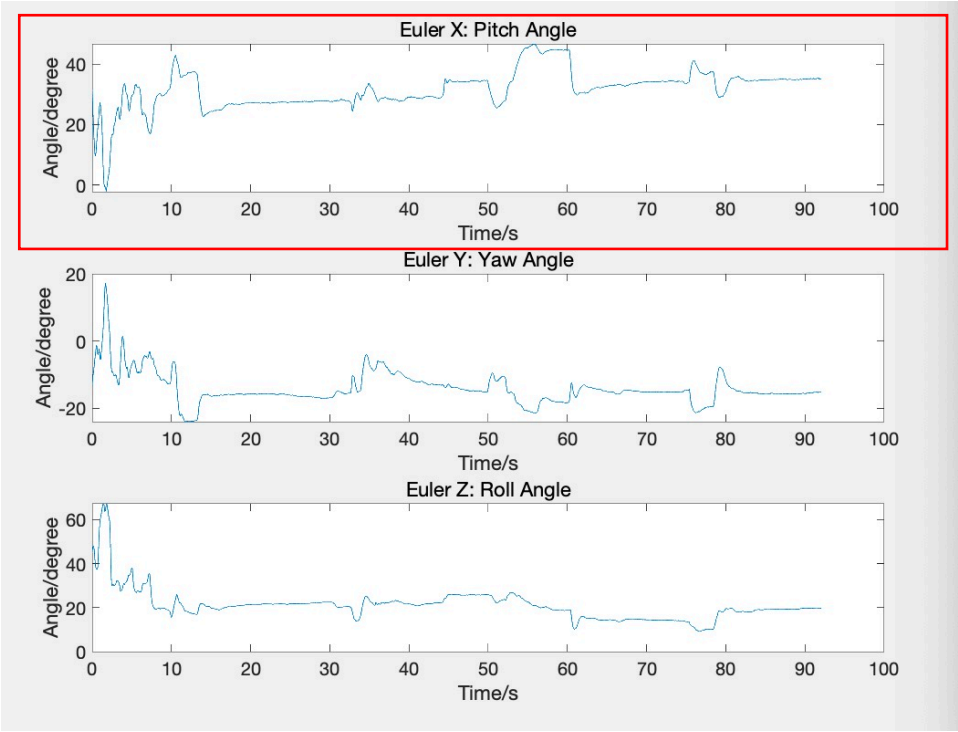


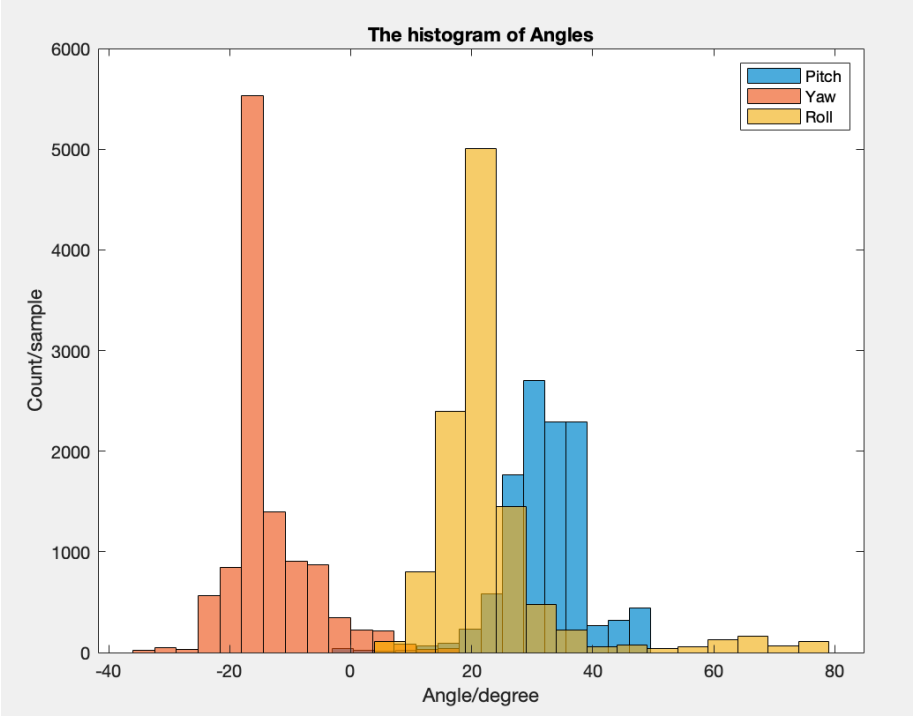


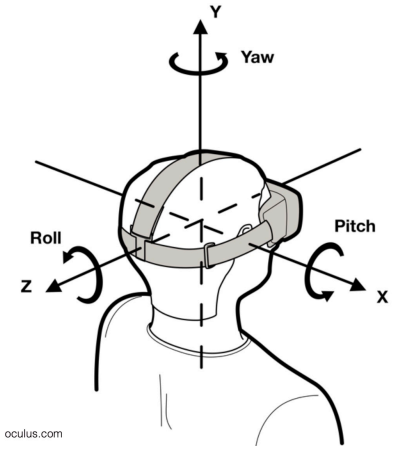
Coordinate system figure from: https://stanford.edu/class/ee267/lectures/

Mock OR Data Analysis – endoscopic case

- Pitch angle keeps at 25 to 35 degree for a long time;
- Yaw angle changes between -20 to 0 degree, and Roll angle changes between 10 to 30 degree, but they are not variables we are concerned about.

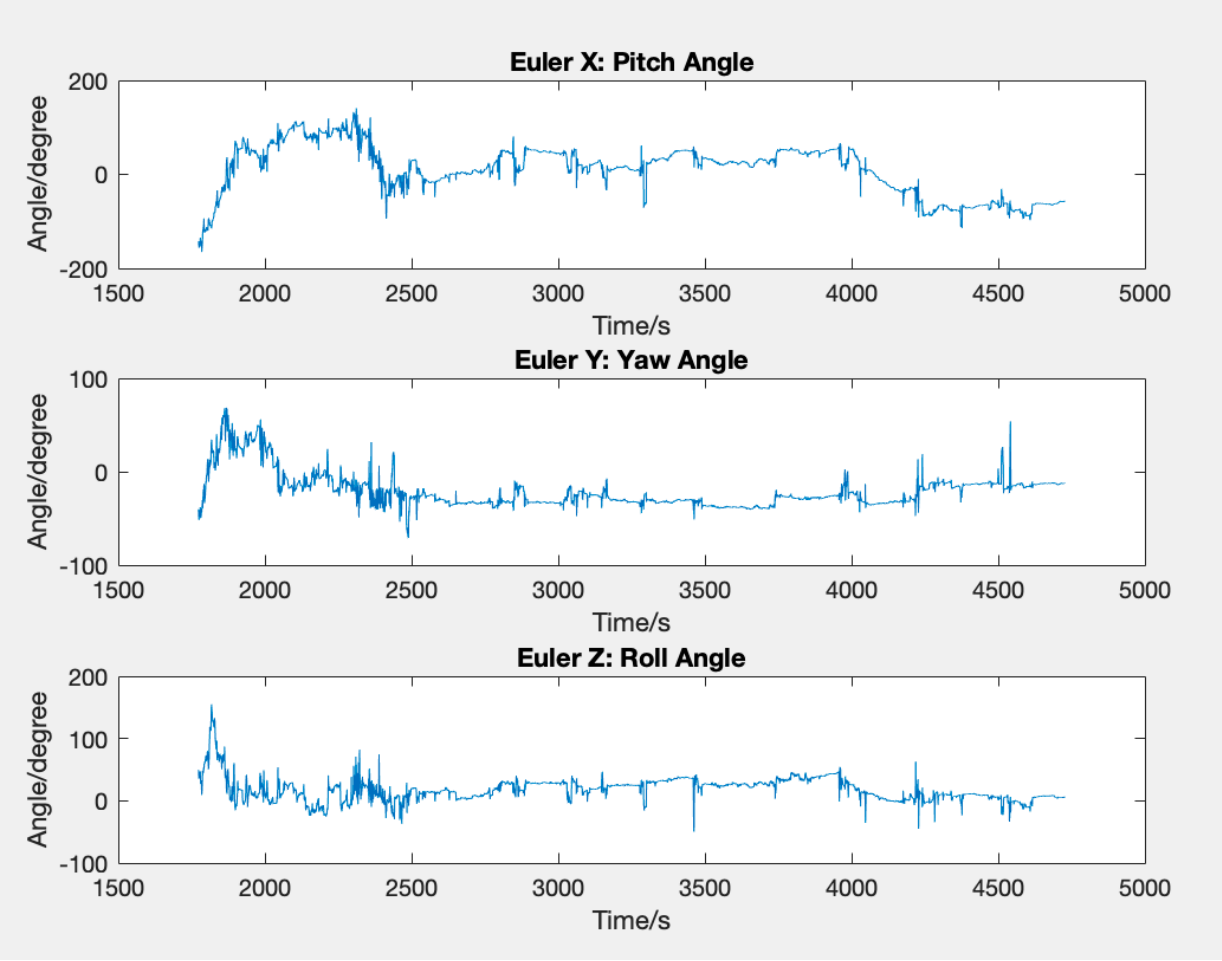


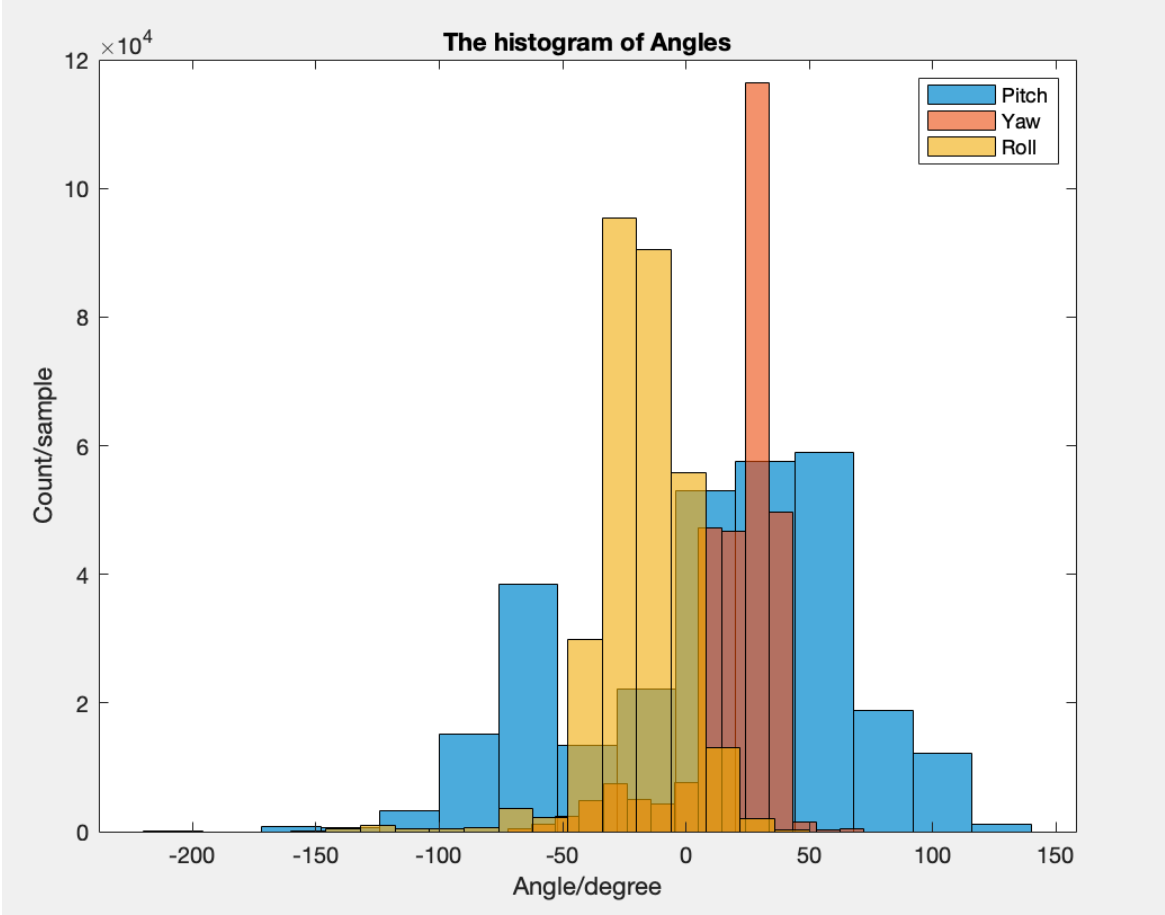




Coordinate system figure from: https://stanford.edu/class/ee267/lectures/

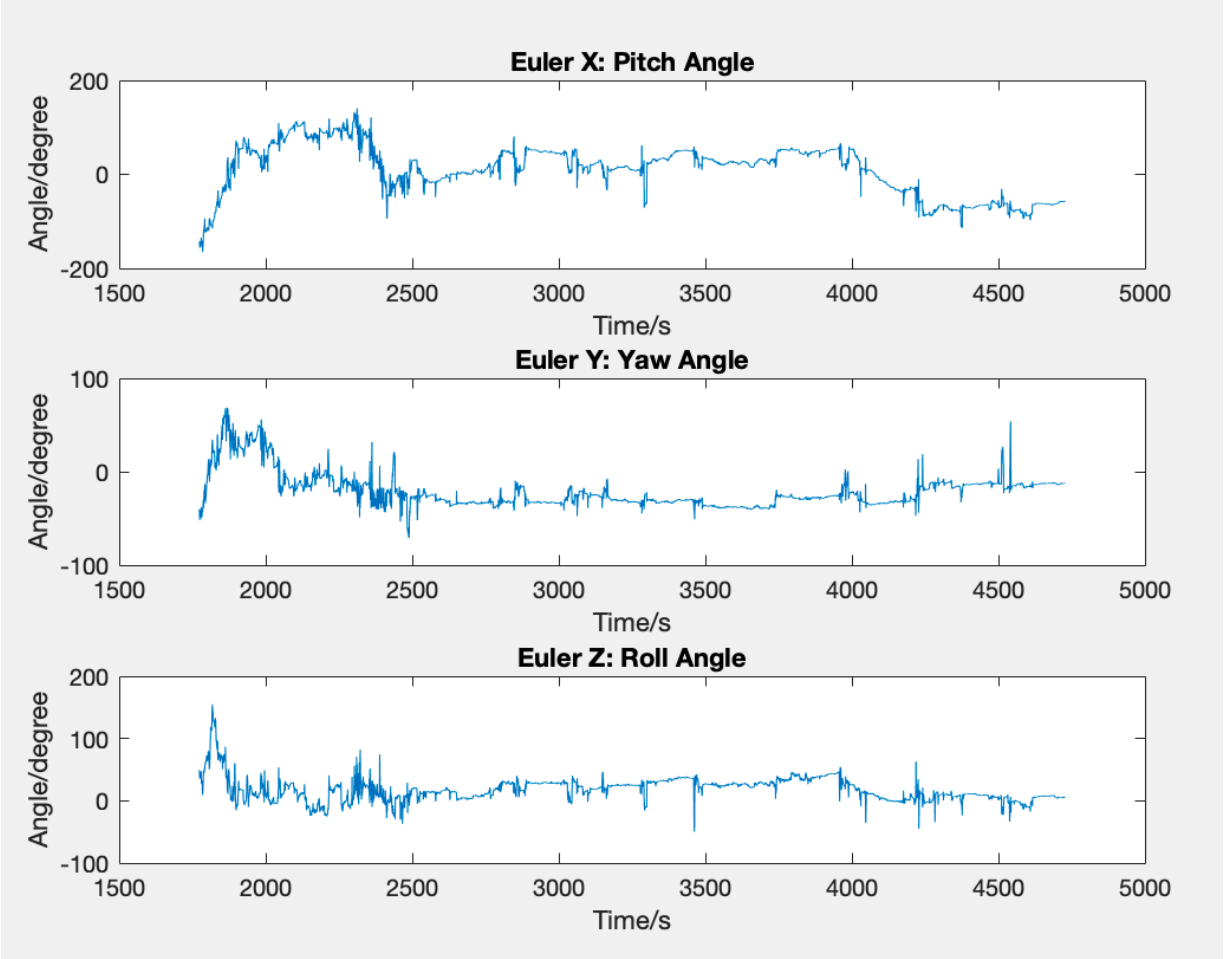
Real Surgery Data Analysis – microscopic case 01-29 cochlear implant fellow





Surgical Data Analysis Plan

- Metrics
  - Mean and Median Angle
  - Range of angles (excluding outliers)
  - Time spent in favorable/unfavorable positions
- Comparisons
  - Endoscopic vs Microscopic vs Open
  - Resident vs Fellow
  - Type of Surgery



Milestones

Added

Changed

Date	Detailed Description
February, 22	Linux and ROS environment configuration finished
March, 2	Evaluation of IMU calibration and mathematic model finished
March, 11	First measure in Mock OR and analysis of the data finished
March, 27	Complete documentation of Mock OR data analysis
~~March, 27~~ April,10	Data Analysis of existing surgical measurement finished
Apr 3	Collect Mock OR measurement from eggshell drilling experiment finished
Apr 10	Data Analysis of Mock OR measurement from eggshell drilling experiment finished
Apr 17	Complete documentation of eggshell drilling experiment and existing surgical data
April, 24	Data Analysis of new surgical measurement ~~among various surgery scenarios~~ finished (at least one for each microscopic and endoscopic case)
April, 24	Complete documentation of surgical data collection and data analysis
May, 4	Clinical paper finished

Time schedule

	Feb,7 -Feb,13	Feb,14- Feb, 22	Feb,23- Mar, 2	Mar,3- Mar,11	Mar,12- Mar,20	Mar,21- Mar,27	Mar,28- Apr,3	Apr,4 - Apr,10	Apr,11- Apr,17	Apr,18- Apr,24	Apr,25- May,1	May,1- May,5
Set up the computer and document installation steps	✅	✅										
Evaluation of calibration and mathematical model of neck angle		✅	✅									
First measurement in Mock OR & First data analysis				✅	✅	✅						
Data analysis of existing measurement in real surgery scenarios				⎍	⎍	⎍	⎍	⎍				
Collect mock surgery data from eggshell drilling experiments					✅	✅	✅					
Data analysis of mock surgery measurement						✅	✅	✅				
Data analysis of new measurement in real surgery scenarios (at least one for each microscopic and endoscopic)						⎍	⎍	⎍	⎍	⎍		
Overall analysis and documentation of the difference between microscopic and endoscopic scenarios								⎍	⎍	⎍		
Write clinical paper										⎍	⎍	⎍

✅ : Finished ☑ : Planned

Dependencies

Dependencies	How to resolve	Alternative Plan	Date Expected	Date Needed
Computer with Linux & ROS	1. Our own computers for calibration 2. Another computer from CIIS lab	Use backup files in another computer	1. Feb, 14 2. Mar, 6	1. Feb, 19th (Solved) 2. Feb, 22th (Solved)
Two IMUs	Provided by Dr. Deepa Galaiya	Purchase two new IMUs	Feb, 7	Feb, 7 (Solved)
MATLAB for data analysis Dropbox for data saving	Installation	Python Google drive	Mar, 1	Mar, 1 (Solved)
Actual surgery data	Get data from Hyonoo who is responsible for collecting actual surgery data in medical school	Do all the measurement in Mock OR	Mar, 3	Mar, 21 (In progress)
Eggshell drilling experiment data	Dr. Galaiya performs mock surgery in Mock OR	Assisted by other graduate students	Mar, 12	Mar, 21 (Solved)

Thanks!