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

Project Proposal

Team Members:

Zihao Lin

Millan Patel

Mentors:

Dr. Russell Taylor

Dr. Deepa Galaiya

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Goals

Increasing evidence demonstrates that a surgeon's operating posture can contribute to chronic pain. Specifically, trapezius muscle fatigue has been shown to be highest when neck flexion exceeds 30°. This study sought to accurately measure the surgeon's neck flexion angle while performing ear surgery, comparing the postural ergonomics of traditional "heads down" surgery to that of "heads up" endoscopic surgery.

Background

Nowadays, there is increasing evidence suggesting that specific posture of surgeon while operating can contribute to discomfort, cervical musculoskeletal strain, and chronic pain. Postural neck pain can be caused by several factors. The persistent neck flexion, long periods of static posture, and the long-time use of microscopes and magnifiers lead the microsurgeons to a particularly considerable risk to the pain mentioned above.

In this project, we are focusing on the surgeon's posture during ear surgery. There are two kinds of surgical sceneries: traditional case and endoscopic case. Traditional ear surgery includes microscopic and open surgery scenarios, as shown in F**igure 1 and 2**. In these scenarios, surgeons must bend their necks or their bodies to finish specific operations. This persistent neck flexion is the main factor that causes discomfort. However, as for endoscopic cases shown in F**igure 3**, surgeons can make full use of the monitors. It is easier for them to keep the correct upright posture most of the time.

Figure 1. microscopic surgery[1]

Figure 2. open surgery[2]

Figure 3. Endoscopic surgery[3]

[1] Figure 1 from https://oklahoman.com/gallery/articleid/3808606/
[2] Figure 2 from http://amandeepmedicity.org/specialities/bariatric-metabolic-surgery
[3] Figure 3 from http://www.tristonekidneyhospital.com/index.html
[4] Khansa I, Khansa L, Westvik TS, Ahmad J, Lista F, Janis JE. Work-related musculoskeletal injuries in plastic surgeons in the United States, Canada, and Norway. Plast Reconstr Surg. 2018;141(1):165e-175e.

Significance

Poor surgical ergonomics may lead to surgeon disability:

- A recent survey of plastic surgeons in the United States, Canada, and Norway showed that nearly two-third of respondents reported neck discomfort related to their occupation [1].
- Among surveyed laparoscopic, ophthalmic, and general surgeons, the reported prevalence of musculoskeletal symptoms in the neck and shoulders is as high as 87% [2].
- Dangers of Forward Head Posture (FHP) can be described as a "DOMINO EFFECT" [3]: Surgeons have their heads moving forward → shifting the center of gravity → upper body drifting backward → hips tilting forward. Therefore, FHP can not only cause neck pain but can also be a root cause of middle and lower back pain.

It is crucial and meaningful for us to investigate:

- The region of the neck flexion angle which the surgeon feels comfortable while operating.
- The neck flexion angle data which will be used to correct the new surgeons' posture, preventing them from chronic injury again.
- The data which contributes to figuring out whether endoscopic surgery has more advantages than traditional surgery by comparison.

Technical Approach

We hypothesize that neck flexion angle is greater than 30 degrees for a higher proportion of time during traditional open surgery, such as microscopic ear surgery, than during minimally invasive endoscopic surgery, such as endoscopic ear surgery.

1.Khansa I, Khansa L, Westvik TS, Ahmad J, Lista F, Janis JE. Work-related musculoskeletal injuries in plastic surgeons in the United States, Canada, and Norway. Plast Reconstr Surg. 2018;141(1):165e-175e.

2.Capone AC, Parikh PM, Gatti ME, Davidson BJ, Davison SP. Occupational injury in plastic surgeons. Plast Reconstr Surg. 2010;125(5):1555-1561.

3. Naresh-Babu, J et al. "Surgeon's Neck Posture during Spine Surgeries: "The Unrecognised Potential Occupational Hazard"." Indian journal of orthopaedics vol. 53,6 (2019): 758-762. doi:10.4103/ortho.IJOrtho_677_18

For this study, the software and the surgical simulation environments for data collection were arranged. Two Inertial Measurement Units (IMUs) were utilized, with one banded to the forehead and the other attached to the back as shown in **Figure 4**. Neck flexion angle was indicated by the pitch angle between the two IMUs. In order to confirm the accuracy of neck flexion measurements, the IMUs' pitch angle was calibrated against a known angle measured by an electromagnetic tracker (EM tracker), and a linear regression model is used to derive the calibration.

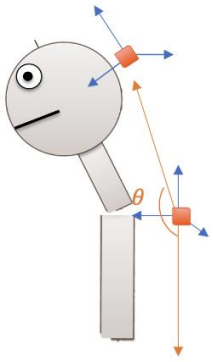

Figure 4. Measurement method

Figure 5. Inertial Measurement Units

Next, the mathematical model for pitch angle calculation was derived using quaternion and rotation matrices. The quaternions of the IMUs were collected for both the reference posture (standing normally and neutrally for one minute) and in the operating posture. We converted the quaternions to Euler angles to calibrate the pitch component using the linear regression model mentioned above. Then, the calibrated Euler angles were converted into rotation matrices. For both IMUs, we calculated the difference rotation matrices between the reference position data and the surgical position data. Finally, the difference rotation matrix between the two IMUs was calculated and converted into Euler angles with X, Y, and Z components. The X component, or the pitch angle, was the neck flexion angle of our interest.

We collected data for seven head movements, including turning the head in the X, Y and Z planes periodically, rotating the head in all directions, and shaking the shoulders to confirm the rationality of our algorithm. We then performed mock surgical procedures in a simulated operating room setting. Two surgical scenarios were simulated to compare traditional surgery and endoscopic surgery.

Deliverables

- Minimum
    - Evaluation of the Existing Calibration Steps & Physical Model
        - Expected by 3/2/22
    - Data Analysis Report of Surgical Data from Previous Semester
        - Expected by 3/27/22
    - Data Analysis Report of Mock OR Experiment
        - Expected by 4/10/22
- Expected
    - Improvement to Signal Processing of Measurements Obtained from IMUs
        - Expected by 3/11/22
    - Data Analysis Report of Real Surgical Scenarios
        - Expected by 4/17/22
- Maximum
    - Clinical Paper
        - Expected by 5/4/22

Milestones

1. Linux and ROS Environment Configuration Finished (Zihao, Millan)
    - Planned Date: 2/22/22
    - Expected Date: 2/22/22
    - Status: Complete
2. Evaluation of IMU Calibration and Mathematical Model Finished (Zihao, Millan)
    - Planned Date: 3/2/22
    - Expected Date: 3/2/22
    - Status: Complete
3. First Measure in Mock OR and Analysis of the Data Finished (Millan)
    - Planned Date: 3/11/22
    - Expected Date: 3/11/22
    - Status: Incomplete
4. Data Analysis of Existing Surgical Measurement Finished (Zihao, Millan)
    - Planned Date: 3/27/22
    - Expected Date: 3/27/22
    - Status: Incomplete
5. Collect Mock OR Measurement from Eggshell Drilling Experiment Finished (Zihao, Millan)
    - Planned Date: 4/3/22
    - Expected Date: 4/3/22
    - Status: Incomplete

6. Data Analysis of Mock OR Measurement from Eggshell Drilling Experiment Finished (Millan)
    - Planned Date: 4/10/22
    - Expected Date: 4/10/22
    - Status: Incomplete
7. Data Analysis of New Surgical Measurement Among Various Surgery Scenarios Finished (Zihao)
    - Planned Date: 4/17/22
    - Expected Date: 4/17/22
    - Status: Incomplete
8. Documentation of Data Collection and Data Analysis Finished (Zihao, Millan)
    - Planned Date: 4/24/22
    - Expected Date: 4/24/22
    - Status: Incomplete
9. Clinical Paper Finished (Zihao, Millan)
    - Planned Date: 5/4/22
    - Expected Date: 5/4/22
    - Status: Incomplete

Dependencies

Dependencies	Effect	Resolution Plan	Alternative Plan	Date Expected	Date Needed
Computer with Linux & ROS	Affects ability to analyze experimental data and run the calibration	1. Our own computers for calibration 2. Another computer from CIIS lab	Use backup files in another computer	1. 2/14 2. 3/6	1. 2/19 (Solved) 2. 2/22 (Solved)
Two IMUs	Affects ability to collect data during Mock and real surgeries	Provided by Dr. Deepa Galaiya	Purchase two new IMUs	2/7	2/7 (Solved)
MATLAB for data analysis Dropbox for data saving	Affects ability to analyze experimental data and run the calibration	Installation	Use Python (Google Collab)	3/1	3/1 (Solved)
Actual surgery data	Real surgical data is needed for the analysis and clinical paper	Get data from Samuel who is responsible for collecting actual surgery data in medical school	Do all the measurements in Mock OR	3/3	3/21 (Not Started)
Eggshell drilling experiment data	This data is needed to compare favorable and unfavorable ergonomics for the clinical paper	Dr. Galaiya performs mock surgery in Mock OR	Gain assistance from other graduate students	3/12	3/21 (Not Started)

Management Plan

- Minimum once a week working meeting between team members
- Attend the group meeting with Dr. Taylor weekly
- Regular weekly update meeting with Dr. Deepa Galaiya
- Maintain communication via Email and Microsoft Teams
- Documentation and code update in OneDrive folder

Reading List

- Du, Y., Shih, C., Fan, S. et al. An IMU-compensated skeletal tracking system using Kinect for the upper limb. Microsyst Technol 24, 4317–4327 (2018).
- Islam, Tariqul, et al. "Comparison of complementary and Kalman filter based data fusion for attitude heading reference system." AIP Conference Proceedings. Vol. 1919. No. 1. AIP Publishing LLC, 2017.
- Won, Seong-hoon, William Melek, and Farid Golnaraghi. "Position and orientation estimation using Kalman filtering and particle diltering with one IMU and one position sensor." 2008 34th Annual Conference of IEEE Industrial Electronics. IEEE, 2008.
- Lakhiani C, Fisher SM, Janhofer DE, Song DH. Ergonomics in microsurgery. J Surg Oncol. 2018;118(5):840–844. doi:10.1002/jso.25197
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- Wang R, Liang Z, Zihni AM, Ray S, Awad MM. Which causes more ergonomic stress: Laparoscopic or open surgery?. Surg Endosc. 2017;31(8):3286–3290. doi:10.1007/s00464-016-5360-5
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- Nguyen NT, Ho HS, Smith WD, et al. An ergonomic evaluation of surgeons' axial skeletal and upper extremity movements during laparoscopic and open surgery. Am J Surg. 2001;182(6):720–724. doi:10.1016/s0002-9610(01)00801-7