EVALUATION OF VARIOUS SENSING MODALITIES FOR ACCURATE MEASUREMENT OF NECK FLEXION ANGLE DURING THYROID AND EAR SURGERY

Project Proposal

Team Member:

Zhen Hu zhu2@jh.edu

Hanqing Duan hduan2@jh.edu

Mentors:

Dr. Russell Taylor

Dr. Deepa Galaiya

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Goals

In order to have a better understanding of the surgical ergonomics and propose some strategies for injury mitigation, our goal of this project is to evaluate various sensing modalities for accurate measurement of neck flexion angle during thyroid and ear surgery using two IMUs.

Background

There is more and more evidence nowadays suggesting that specific posture of surgeon while operating can contribute to cervical musculoskeletal strain, discomfort, and chronic pain. The persistent neck flexion, long periods of static posture and the long time use of microscopes and magnifiers lead the microsurgeons in a particularly high risk to the pain mentioned above.

Figure 1. Traditional ear surgery[1]

Figure 2. Traditional thyroid surgery[2]

Figure 3. Endoscopic[3]

In this project, we are focusing on the surgeon posture during two surgery: Thyroid and Ear surgery. As for both ear surgery and thyroid surgery, there are two kinds of cases: traditional case and endoscopic case. When the surgeons do ear surgery in a traditional way, as shown in **Figure 1**, they have to look through microscopes. For thyroid surgery in a traditional way, as shown in **Figure 2**, surgeons have to stand over the patient. It's obvious that the surgeons have to band their necks, sometimes they even need to band over their bodies in order to finish specific operations. However, as for endoscopic cases, as shown in **Figure 3**, surgeons can make full use of the monitors, it's easier for them to keep their head and body in a line for most of the time.

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[4]. Among surveyed laparoscopic, ophthalmic, and general surgeons, the reported prevalence of musculoskeletal symptoms in the neck and

[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.

shoulders is as high as 87%[5]. So, it's crucial and meaningful for us to investigate the region of the neck flexion angle which the surgeon feels good while operating. The angle data can also be used to correct the new surgeons' posture, preventing them from chronic injury again. What's more, the data may help showing the advantages of endoscopic surgery.

Technical Approach

We will use two IMUs (Inertial measurement unit) to do neck flexion angle measurements. One will be banded in front of surgeon's head, and the other will be stabilized in front of surgeon's chest. The pitch angle we measured is the θ shown in **Figure 4**.

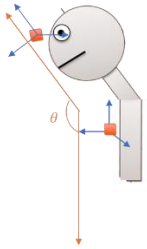

Figure 4. Measurement method

The whole project will be done following the workflow shown below (**Figure 5**).

Step 1: Set up EM tracker and IMUs software in Linux and ROS system.

Step 2: Calibrate every IMU's angle in one direction by the ground truth derived from EM trackers.

Step 3: Derive the mathematical model of pitch angle from 6 sensors data (including two 3-axis gyroscopes, two 3-axis accelerometers, and two 3-axis magnetometers).

Step 4: Collect data from once mock surgery and analyze it to ensure Step 2, Step 3, and data collection process are correct.

Step 5: Collect clinical data from 20 different surgeries for 8 different scenarios.

Step 6: Analyze all clinical data to find interesting things, like the largest neck flexion angle, the angle last for a long time, difference between traditional case and endoscopic case, and difference between young residents and surgeons with expertise.

Step 7: Write a clinical paper.

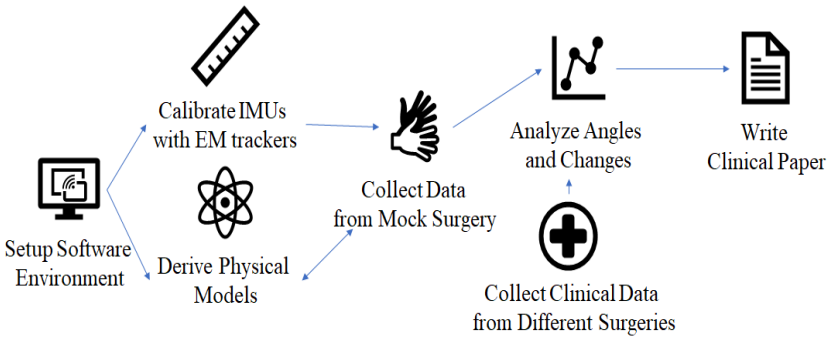

Figure 5. Project workflow

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

The calibration data of both IMUs and EM trackers are planned to be collected with timestamp using the *rosbag* package in ROS. The mock surgery data and clinical data will be collected by using *LPMS-control* interface in Windows. All the calibration data, mock surgery data, and clinical data are planned to be analyzed by using MATLAB.

Deliverables

- **Minimum:** **Expected before Mar. 6, 2020**
  - Calibration result of two IMUs separately against EM tracker (excel file)
  - Validation result of the pitch angle (excel file)
  - Documentation of software setting and calibration steps (doc file)
- **Expected:** **Expected before Mar. 12, 2020**
  - Data analysis report of phantom study
- **Maximum:** **Expected before May. 5, 2020**
  - Data analysis report of real surgical scenarios
  - Clinical paper

Time Schedules

	Feb,15 - Feb,21	Feb,22- Feb, 28	Feb,29- Mar, 6	Mar,7- 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 (Zhen and Hanqing)	☑	☑	☑									
Calibration and document steps (Hanqing) Derive mathematical model of neck angle and document steps (Zhen)		☑	☑									
First measurement in Mock OR & First data analysis (Zhen and Hanqing)				☑								
Human Subjects Research Training and IRB approval	☑	☑	☑	☑								
20 measurement in real surgery scenarios & Each one do data analysis (Zhen and Hanqing)					☑	☑	☑	☑	☑			
Overall analysis and documentation of the difference between various scenarios (Zhen and Hanqing)								☑	☑	☑		
Write clinical paper (Zhen and Hanqing)										☑	☑	☑

Table 1. Time schedules ☑ : Finished stuff ☑ : Planned stuff

Milestones

Feb. 21 Linux and ROS environment configuration finished
Feb. 26 Project proposal finished
Feb. 26 Human Subjects Research Training finished
Mar. 6 Calibration of IMUs and mathematical model derivation finished
Mar. 6 Documentation of environment configuration and calibration method finished
Mar. 11 IRB approval
Mar. 11 First measure in Mock OR and analysis of the data finished

Apr. 17 20 measurements in real surgery and analysis of the data finished
Apr. 24 Analysis of the difference between various surgery scenarios finished
Apr. 24 Documentation of data collection and data analysis finished
May, 4 Clinical paper finished

Dependencies

Dependencies	How to resolve	Alternative Plan	Date Expected	Date Needed
IRB approval	1. Finish Human Subjects Research Training on Mylearning 2. Get IRB approval with the help of Dr. Deepa Galaiya	Do all the measurement in Mock OR	1. Feb,24 2. Mar,6	1. Feb,26(Solved) 2. Mar,11(In progress)
Computer with Linux & ROS	1. Our own computers for calibration 2. Another computer for data collection sponsored by Dr. Taylor, discussed with Deepa and Anton	Use backup files in another computer	1. Feb, 14 2. Mar, 6	1. Feb,19th (Solved) 2. Mar,12th (Solved)
Two IMUs	Provided by Dr. Deepa Galaiya	Buy two new IMUs sponsored by Dr. Taylor, discussed with Anton	Feb, 14	Feb,19 (Solved)
IMU related software in Linux (Packages included *Lpms-imu and ndi_tracker_ros*)	Installation from *Galen-Trackers* GitLab with the help of Anton	In Windows, install *Lpms_control* Software	Feb,19	Feb,21 (Solved)
EM tracker for Calibration	Get the access to Mock OR	Optical Tracker	Feb, 19	Feb,21 (Solved)
Phantom study data	Deepa do mock surgery in Mock OR	With the help of graduate student	Mar,1	Mar,6 (Not start)
Actual surgery data	Get data from Samuel who is responsible for collecting actual surgery data in medical school	Do all the measurement in Mock OR	Mar,10	Mar,12 (Not start)
MATLAB for data analysis Dropbox for data saving	Installation	Python Google drive	Mar,1	Mar,6 (Solved)

Table 2. Dependencies

Management & Contribution

• Attend the group meeting with Dr. Taylor weekly
• Make appointments ahead of time and discuss with Deepa weekly
• Weekly meeting between Hanqing and Zhen every Monday evening
• Make appointments with Anton if needed

Hanqing and Zhen will do preparation work and the first data analysis together for the phantom study in Mock OR. When the real study in OR starts, we will do data analysis individually

Reading List

1. 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).
2. 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.

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4. Lakhiani C, Fisher SM, Janhofer DE, Song DH. Ergonomics in microsurgery. *J Surg Oncol*. 2018;118(5):840–844. doi:10.1002/jso.25197
5. Vaisbuch Y, Aaron KA, Moore JM, et al. Ergonomic hazards in otolaryngology. *Laryngoscope*. 2019;129(2):370–376. doi:10.1002/lary.27496
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7. 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
8. Zihni AM, Cavallo JA, Ray S, Ohu I, Cho S, Awad MM. Ergonomic analysis of primary and assistant surgical roles. *J Surg Res*. 2016;203(2):301–305. doi:10.1016/j.jss.2016.03.058
9. 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