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Surgical Skills Analysis with Virtual Reality: Project Plan

BACKGROUND/OVERVIEW

Previous studies have both provided ample evidence to show that higher volume surgeons with a superior technical skill tend to have better patient outcomes in the procedures that they perform. However, many factors such as restrictions of duty hours, restrictions to trainee autonomy due to logistical or ethical limitations, and an overall increase in the complexity of the procedures that trainees need to achieve competence in has reduced the number of autonomous experiences for trainees, which has only been made worse due to the COVID pandemic. As a result, it is necessary to implement effective and accurate methods by which trainees can objectively be evaluated on their competencies. Current evaluation involves a limited number of assessments that mainly rely on task-based checklists and the opinions of attending surgeons. Examples of these platforms include the OSATS, or Objective Structured Assessments of Technical Skills and the Society for Improving Medical Professional Learning. These methods, however, have numerous issues, including variability of the opinions of evaluating surgeons as well as certain personal biases that these evaluators have. Whereas other fields of surgery have made progress in testing technical skill in some sort of simulated environment, the field of Otolaryngology-Head and Neck Surgery has not yet made any significant leaps in objectively assessing technical skill in simulated environments.

GOALS

The goal of our project is to develop a machine learning model to provide an objective, technical assessment for Otolaryngology-Head and Neck Surgery (OHNS) trainees. Mastoidectomy Procedures are highly precise surgeries that require the drilling of temporal bone. Temporal Bone Simulators include stereoscopic vision and haptic feedback, but automated metrics have limited results. An objective, technical assessment is needed for Otolaryngology-Head and Neck Surgery.

Deliverables

- **Minimum:** (04/27/2022)

1. Perform data collection from surgeon and resident users at JHMI

2. Document collection practices

- **Expected:** (04/01/2022)

1. Evaluate existing algorithms for this purpose
2. Develop algorithm for surgical skill analysis
3. Documentation

- **Maximum:** (05/05/2022)

1. Conference Paper

TECHNICAL APPROACH

Our mentors Adnan Munawar, Max Li, and Dr. Danielle Trakimas have provided us with an Asynchronous Multibody Framework model. This software can generate stereoscopic RGB data in real time, which can be used to train computer vision algorithms to evaluate the competency of the trainee using the simulator. We outline the aims and technical approach to our project as follows:

1. We will use the AMBF simulator to collect simulator data from practicing surgeons and residents on the medical campus.
2. Using this data, we will define, document, and measure metrics that we find relevant to surgical skill by comparing them across simulator data from users of varying skill levels.
3. Once these metrics are collected, we can then create labels for the simulator data and use it to develop and train a machine learning or deep learning algorithm that measures the defined metrics to analyze and evaluate a trainee's competency level.
4. After tuning parameters and optimizing our model, we will have an objective assessment of surgical skill that can take real-world OHNS simulator data to evaluate a surgical trainee's level of skill.

DEPENDENCY PLANS

Initial Setup Milestones

Simulator setup on local and lab computers

In order to be able to work simultaneously on various tasks, we plan to set up the simulator on both our local computers and a computer provided to us that is housed in the robotorium. At this time, this milestone is completed.

Simulator and hardware recording and testing

To be prepared and comfortable with the data recording process, we plan to record some simulated data, using keyboard controls as well as the haptic device. At this time, we have recorded simulated data using the keyboard controls on the lab computer, but are still waiting on the haptic device to be able to record with it. Since it is taking longer, we are meeting with Adnan on Wednesday, March 2nd to use the controls on the Da Vinci machine to be able to simulate the behavior of the haptic device and the data it outputs.

Data Collection Milestones

IRB Approval

IRB approval is required before we do any data collection. At this time, all members of our team have obtained their IRB approval.

Data collection from attendings

This is the first set of data we plan to collect, which will be used to generate a “perfect” model of mastoidectomy surgery. The recruiting of attendings is done by Danielle, and we will be participating in running the simulator and collecting data. We plan to have this completed by March 10th.

Labeling of attending data

The attending data needs to be labeled, and key markers of skill extracted. This will be done simultaneously as the data collection (once an attending has done all of their trials, we will annotate the data for them, which may be before the next attending uses the simulator). We plan to have this completed by March 13th.

Data collection from resident trainees

This data will be used for testing our model, and can begin to be collected while the data collection from attendings is ongoing. Recruitment of subjects is done by Danielle. We plan to have this completed by March 22nd.

Data collection from fellows

This data will be used for testing our model, and can begin to be collected while the data collection from attendings and resident trainees is ongoing. Recruitment of subjects is done by Danielle. We plan to have this completed by March 22nd.

Labeling of trainee and fellow data

The trainee and fellow data needs to be labeled, and key markers of skill extracted. This will be done simultaneously as the data collection (once a trainee/fellow has done all of their trials, we will annotate the data for them, which may be before the next resident/trainee uses the simulator). We plan to have this completed by March 27th.

Miscellaneous Milestones

Preliminary literature review

A literature review of at least the documents in the current reading list will need to be conducted to guide the project. We plan to have this completed by March 10th.

Research skill metrics

Based on the literature review, a comprehensive list of potential skill-based metrics will need to be constructed to guide the development of the future skill-assessment algorithm. We plan to have this completed by March 28th.

Research computer vision methodologies

Additionally, a plan for the utilization of computer vision methodologies needs to be constructed to guide the development of the future skill-assessment algorithm. We plan to have this completed by April 10th.

Final Report

This includes a summary of all work done and project organization. We plan to have this completed by May 15th.

MANAGEMENT PLAN

This project will be managed through weekly meetings with mentors Max Li and Adnan Munawar in addition to weekly lab meetings. Communication between mentors and teammates will occur via Slack. Code management will be carried out using GitHub, with additional files and documentation shared on Microsoft Teams. In addition to this functional management, project milestone deadlines and updates will be maintained on the course Wiki page.

READING LIST

Ding AS, Lu A, Li Z et al. Automated Registration-Based Temporal Bone Computed Tomography Segmentation for Applications in Neurotologic Surgery. *Otolaryngol Head Neck Surg* 2021:1945998211044982.

Azari DP, Frasier LL, Quamme SRP, et al. Modeling surgical technical skill using expert assessment for automated computer rating. *Ann Surg.* 2019;269(3):574-581. doi:10.1097/SLA.0000000000002478

Munawar A, Li Z, Kunjam Pet al. Virtual Reality for Synergistic Surgical Training and Data Generation. *Computer Methods in Biomechanics and Biomedical Engineering: Imaging & Visualization* 2021.

Birkmeyer JD, Finks JF, O'Reilly Aet al. Surgical skill and complication rates after bariatric surgery. *N Engl J Med* 2013; 369:1434-1442.

Niitsu H, Hirabayashi N, Yoshimitsu Met al. Using the Objective Structured Assessment of Technical Skills (OSATS) global rating scale to evaluate the skills of surgical trainees in the operating room. *Surg Today* 2013; 43:271-275.

Sethia R, Kerwin TF, Wiet GJ. Performance Assessment for Mastoidectomy. *Otolaryngol Head Neck Surg* 2017; 156:61-69.