Beyond the Scope: Using Motion Capture Data from Bronchoscopy Simulations to Build Feedback Models

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Abstract. Manikin simulators and task trainers are commonly used in health sciences training programs to teach techniques performed during medical procedures. However, there are drawbacks to their deployment. First and foremost, the cost of high-fidelity task trainers is prohibitively expensive for many programs. Additionally, the combination of manikin-to-learner and teacher-to-learner ratios often makes it difficult to efficiently teach procedures to a large number of students. This project aims to create a low-cost, game-based, easily portable task trainer to assist learners in building skills and expertise in performing bronchoscopies. This preliminary report focuses on designing a motion capture device to record hand, wrist, and thumb motions performed by experts and learners during simulated bronchoscopy procedures and then using this captured data to construct computational feedback models.

Keywords: First Keyword, Second Keyword, Third Keyword.

1 Introduction

Training students and residents to perform medical procedures can be a costly and time-consuming process. Many academic programs rely heavily on expensive manikin simulators such as Laerdal SimMan [1] or specialized task trainers such as SurgicalScience EndoSim [2]. Medical schools, hospitals, and simulation centers that do not have the resources to commit to high-fidelity task trainers often settle for less expensive options that do not provide the same quality of training or skill acquisition for learners. Effective medical simulation training requires both immediate feedback and post-training debriefing for the learner [3,4]. Feedback allows a learner to identify errors in diagnostic skills or procedure mechanics, while debriefing is necessary to reshape cognitive frameworks and allow internalization of the training objective.

To address the feedback problem, we developed an open-source hardware motion capture device to record the motions of a practitioner's hand, wrist, and thumb while performing an exploratory bronchoscopy procedure. We used the preliminary data captured from two experts and two novices to construct computational feedback models that are currently being implemented in a custom scoping simulator to generate automated feedback and debriefing.

2 Related Work

Experts by definition possess a great amount of knowledge and procedural skill in their domain of expertise, with their performance on domain-specific tasks often observed to be at least two standard deviations above those considered intermediate or novice level [5]. Such differences in performance have been observed across various domains, including the diagnosis of clinical cases [6], nursing [7], and occupational therapy [8]. Such significant differences in performance suggest that the quantitative measurement and analysis of task execution may serve to assess and guide the development of expertise.

Despite advances in sensor technology, there are very few published findings in this domain that disseminate the implementation of sensors to quantitatively measure fine motor control with the intent of classifying performance or constructing feedback models. The feasibility of implementing hand motion analysis to objectively measure dexterity in the context of medical procedures has been demonstrated using the Imperial College Surgical Assessment Device, and the resulting index of technical skill has been demonstrated to correlate with OSATS scores [9-11]. Additionally, it has been shown that metrics of efficiency and precision can be quantified and applied to exercises to provide reliable and valid assessments of technical skills [12].

3 Methodology

Figure 1. Motion capture device.

To capture user hand, wrist, and thumb motions during bronchoscopy procedures we developed a custom motion capture device (Figure 1). The device uses the open-source Arduino platform and includes an accelerometer, gyroscope, magnetometer, and a flex sensor. To ensure consistent sensor placement, we attached the "glove" to each subject's hand in such a way that the accelerometer sensor would be positioned in the middle of the back of the hand and the flex sensor would be positioned along the outside of the subject's thumb. The device captures hand motion in 3D space while the flex sensor captures the flexing motion of the scope's thumb camera control, which has only 2 degrees of freedom (forward and back). The device captured the subject's scope hand position in space every 100 milliseconds and sent the data via serial port to a custom application that recorded the data to a text file in a comma-separated values (CSV) format.

We recorded the following seven dimensions of motion data:

- Accelerometer x, y, z values measuring linear acceleration in 3D space
- Gyroscope x, y, z values measuring angular acceleration in 3D space
- Flex sensor data measuring the degree of the sensor bend determined by how far the subject pushed or pulled on the scope's camera control

4 Preliminary Results

The authors of this paper tested the motion capture device by having participants access the lower half of the right lung on a Laerdal [13] AirMan manikin simulator using an Ambu Scope single-use flexible intubation scope [14].

The initial results motion capture data allowed us to construct a spatial mapping model. We averaged the captured data across all degrees of motion to create a feedback boundary for learners. This model can be used in two different learning modalities. In the first modality, it can be used as a suggestion mechanism - as the learner navigates through the 3D representation of the airways, the system uses directional arrows to suggest how the learner should move the scope. In the second modality, the spatial boundary model can be used for feedback - as the learner navigates the simulation, the system projects a mini-map next to the rendering of the airways with experts' average path displayed in green and the learner's path drawn in real time in red (Figure 2).

5 Discussion and Future Work

This paper describes preliminary work in building real-time simulation feedback models based on 3D motion data captured with open-source sensors. In future work, we plan on recording motion capture data from clinical experts, and evaluating performance and usefulness of feedback models with learners and simulation experts. This wealth of data will be employed to create the backbone for a gamified platform that deploys real-time feedback and debriefing methods. This platform should provide a low-cost solution to providing health care trainees appropriate simulation-based educational experiences.

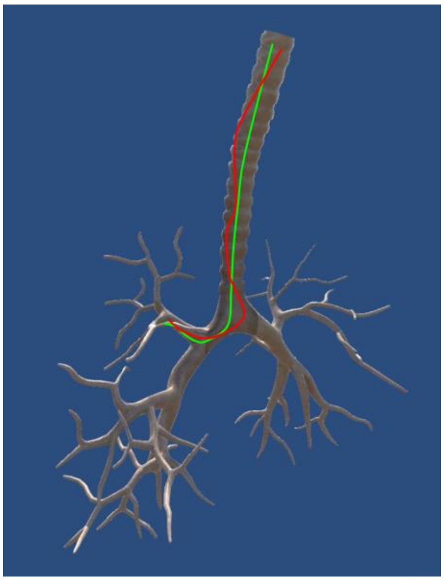

Figure 2. Feedback minimap based on spatial mapping model

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