Directed Feedback and Coaching for Training in Robot-assisted Minimally Invasive Surgery

Date of Report: September 6, 2016

Fellow: **Anand Malpani**

Advisor: **Gregory D. Hager, Professor**

Institution: **The Johns Hopkins University**

Department: **Computer Science**

Contents

1. Narrative

Introduction

Surgical educators have recommended the need for objective and automated teaching tools for technical skills training (henceforth “skill”, “performance” and “evaluation” refer to technical skills and not medical knowledge of the surgeon). Current training platforms provide automated or manual global assessments that are based on postoperative performance review. Approaches like these lack task segment specific feedback that informs the trainee of where, why and what went wrong that led to the lower performance scores, if at all. Coaching with targeted feedback is crucial not only for new trainees, but also equally critical for experienced surgeons to retain their skills and maintain higher levels of performance.

Most surgical skill training follows an apprenticeship model where the resident learns alongside the faculty surgeon while operating on the patient. This can potentially lead to undesirable events including adverse patient outcomes and complications. Additionally, personal instructor based evaluations and feedback can be subjective as well as biased by their preferred operating styles. However, apprenticeship is the current model of surgical training mostly for two reasons: 1) most of the faculty surgeons cannot devote time for running training labs and 2) the automated solutions have not been successfully deployed in training labs. There is an increasing need of an automated coaching framework that can evaluate segment-level performance and provide targeted feedback and relevant demonstrations.

Virtual reality (VR) simulation can provide true task segmentation and scene contextual knowledge that facilitates the making of a coaching system. Unlike traditional style, VR simulation-based training is structured, uniform and can be easily expanded to different forms of surgery. Moreover, VR systems are conveniently scalable and can prove to be efficient training platforms.

The objective of my thesis project is to develop a virtual coach that can provide directed feedback to the trainee. This includes step-by-step performance evaluation, skill deficiency or error detection, and relevant demonstration presentation. Our framework mainly consists of three components – a) task segmentation, b) segment-level evaluation, and c) feedback generation for targeted practice and improvement. We pursued the following approaches in order to implement these components and realize a working virtual coach:

1. System events and sensor data obtained during a surgical task performance contain surgical phase specific information that can be used to develop phase prediction models.
2. Crowdsourced bits of information about the scene context over snippets of a surgery from an intra-operative video can be used to piece together a summary as well as phase segmentation of the procedure.
3. Combination of information from multiple data modalities viz. a) video, b) tool motion, c) system events and sensors, and d) crowd-sourced summarizations can lead to more accurate task segmentations.
4. A virtual coach framework can be implemented on a VR simulation platform capable of 1) task segmentation, 2) segment-level evaluation, 3) targeted feedback generation, and 4) providing deliberate practice.

Results

Approach 1: Our proposed method for task segmentation collects energy usage and tool identification information over 90 second chunks of the surgery. Energy usages have different patterns over the timeline of a surgical procedure. Similarly, different combination of tools are used for the different steps (phases) of a surgery. This representation of the procedure timeline is fed to a machine learning algorithm to predict the correct sequence and duration of the constituent phases of the surgery being analyzed. We tested our hypothesis using a support vector machine (SVM), random forest classifier and a temporal convolutional neural network (CNN). Our validation experiments, showed approximately 75% accuracy in prediction overall, with approximately 90% precision in prediction for certain surgical phases like suturing. This work was published in the International Journal of Computer Assisted Radiology and Surgery (IJCARS 2016, reference in later section).

Approach 2: On similar lines of the previous work listed, surgical phase information is contained across other data sources as well. For example, tool motion data contain the surgeon's hand motions and provide information about their intent and planning, while sensor data like energy activation, tool usage contain some contextual information, whereas the intra-operative video data contain almost all of the contextual information available. However, computer vision algorithms are not yet mature to extract and understand this information reliably. A recent alternative for such intellectual tasks has been crowdsourcing. We hypothesize that the crowd can provide reliable and valid contextual information about a snippet of the surgery video, and that we can use this crowdsourced information for surgical task segmentation. Recently, we completed a pilot study for the crowd validation and reliability using Amazon's Mechanical Turk (a crowdsourcing marketplace). We are currently designing a large scale study to compare our results from system events and sensor data from the previous work.

Approach 3: We plan to combine outcomes and data from the above two approaches to test whether task segmentation accuracy improved using multiple data modalities.

Approach 4: Prior to the start of the fellowship period, I had been working with the VR simulation platform at Intuitive Surgical Inc. (ISI). Following the end of my internship at ISI, I have been able to successfully establish a NDA (non-disclosure agreement) between The Johns Hopkins University (JHU), ISI and SenseGraphics AB (SG). This has allowed me to obtain the proprietary VR software framework and continue the developmental work of a virtual coaching framework at JHU for my doctoral thesis. I was able to obtain the software framework in spring of 2016 and am working towards the implementation and validation of segment-level evaluation and feedback for the coaching framework using the da Vinci Skills Simulator hardware. We have conducted a user study to understand the effect of providing feedback on learning using a randomized control design. We plan to perform a subjective validation of the framework upon completion by the end of the year.

Significance and Impact

We made first steps towards coaching and training based on operating room performance with our work on task segmentation of operating room procedures. For this, we first showed that sensor data from the surgical systems can produce accurate task segmentation. Next, we demonstrated that crowdsourcing can generate valid summarizations of surgical activity. We have now started the development of the first closed-loop coaching system using VR simulation.

Where might this lead?

My goal over the last three years has been to create a stand-alone virtual coach for surgical training and education. The coach should provide directed feedback and practice based on operating room performance and complete the full circle from operating room back to the training lab. I should have a functional coaching framework using VR simulation by the end of my thesis in December 2016. The culmination of this preliminary work will provide a glimpse of how VR simulation can provide directed feedback and move training out of the operating room, away from the patient and into the training lab where it belongs.

2. How did the fellowship make a difference?

The fellowship has been important factor in allowing me to continue my work on the virtual coaching framework. After the completion of the summer internship at ISI in 2015, it was important to continue and finish the remaining work. The fellowship helped extend my doctoral work over a year in order to fulfil this by providing stipend support for the academic year of 2015-2016.

3. Future Plans

Current timeline for my doctoral thesis is to finish by December of 2016. I should have finished a working version of the coaching framework described above by then. I intend to work in the specific domain of medical/surgical devices with focus on training and simulation. I will be open to exploring opportunities in the broader area of education and training where such coaching can be useful. I am still open to both academia and industrial positions and will be actively looking for either.

4. Publications, Presentations, and Other Outputs.

A. Malpani, C. Lea, C. C. G. Chen, and G. D. Hager, "System events: readily accessible features for surgical phase detection," *Int J CARS*, vol. 11, no. 6, pp. 1201–1209, May 2016.

The above work was presented at the conference on Information Processing in Computer Assisted Interventions (IPCAI) 2016 held at Heidelberg, Germany in June 2016.

There will be a couple of future conference/journal submissions. We will send the correct citations and an updated report to Link Foundation as the time comes.