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CIS II Spring 2019
Critical Review
Due: Thursday March 14, 2019

Vedula, Satyanarayana S et al. “Objective Assessment of Surgical Technical Skill and Competency in the Operating Room.” *Annual Review of Biomedical Engineering 19* (2017): 301-325.

Project Overview

The topic of this project is objective surgical skill assessment of computer-aided hysterectomy procedures. We will be using video footage from procedures at Johns Hopkins Hospital, as well as motion data from the da Vinci Surgical System. The goal of this project is to automatically assess skill in robot assisted hysterectomy procedures, particularly the colpotomy step. Hysterectomy is the process of the removal of the uterus. Colpotomy is a specific step in the hysterectomy procedure during which the uterus is separated from the vaginal opening through a circular incision.

Paper Summary

This is a paper from Johns Hopkins University, Malone Center for Engineering in Healthcare published in The Annual Review of Biomedical Engineering in 2017. It is an article that reviews the available literature from 45 publications representing recent research in the domain of objective computer-aided technical skill evaluation (OCASE-T) for "scalable, accurate assessment; individualized feedback; and automated coaching of surgeons".

Paper Selection

In a nutshell, the relevance of this paper to our project is that this paper puts into context why this project is necessary which I will be going into detail in the following sections. Moreover, the paper also gives an overview of:

- What has been done in the field
- Where the field is lacking in research - for example, there are only a handful of papers published that are specifically about hysterectomy procedures

- Technical/Algorithmic approaches taken which gives us an idea on how to approach our problem, kind of provides a selection of algorithms we can choose to apply
- Different types of data used

Background

"With increasing attention to the efficiency and effectiveness of health care, multiple factors are converging to make traditional methods of training combined with structured manual assessment untenable."[1] These factors are:

- Cost and safety implications of teaching in the operating room
- Desire for preventable technical error detection and minimization
- Limited work hours vs. completion of training in robotic, open, laparoscopic and endoscopic domains

All these factors combined with the fact that technological developments are enabling capture and analysis of large amounts of surgical data has led to the emergence of the field of surgical data science, and an increase in literature on objective computer-aided skill evaluation of surgical technical skill.

The paper contains the following table[2] which breaks down each of the 45 publications based on the surgical site in question and the surgical technique that was assessed. It also presents the data

[1] Vedula, Satyanarayana S et al. "Objective Assessment of Surgical Technical Skill and Competency in the Operating Room." *Annual Review of Biomedical Engineering 19* (2017): 302.

[2] Image from: Vedula, Satyanarayana S et al. pp 303.

sources used, the specific surgical tasks within the technique that were studied, and the sample size of the study conducted.

Table 1 Studies on algorithms for objective computer-aided technical skill evaluation (OCASE-T)

Surgical site	Surgical technique	Reference(s)	Data sources	Surgical tasks studied	Study sample size
Operating room	Open (freehand) surgery	(54)	Electromagnetic sensors attached to tools	Mucosal flap elevation task in nasal septoplasty	Unclear
	Laparoscopic surgery	(55)	Head-mounted eye tracker	Colon mobilization task in nephrectomy	11
Cadaver	Endoscopic surgery	(56–59)	Electromagnetic sensors attached to instruments	Reaching anatomical targets in paranasal sinuses	11–20
Pig	Laparoscopic surgery	(60, 61)	Force/torque sensors attached to instruments	Cholecystectomy, Nissen fundoplication	8–10
	Robotic surgery	(62)	Direct capture from robot	Intracorporeal knot-tying	30
Benchtop simulation	Open (freehand) surgery	(46, 63–67)	Video images, colored markers on gloves, accelerometers attached to instruments	Suturing, knot-tying	4–20
	Laparoscopic surgery	(68–75)	Video images, optical tracking of instruments, force sensors on platform holding benchtop models, sensors attached to instruments and placed on surgeon	Suturing, knot-tying, needle passing, peg transfer, intracorporeal suturing, shape cutting	4–52
	Robotic surgery	(76–85)	Direct capture from robot, accelerometers attached to instruments	Suturing, knot-tying, needle passing, peg transfer, intracorporeal suturing, shape cutting, dissection	8–18
	Endovascular surgery	(87, 88)	Motion and force sensors on platform holding model; magnetic tracker at tool tip	Aortic arch cannulation and other unspecified tasks	15–23
Virtual reality simulation	Open (freehand) surgery	(89–91)	Virtual reality: known environment	Mastoidectomy, tooth preparation for crown replacement	10–16
	Laparoscopic surgery	(69, 92–96)	Virtual reality: known environment	Needle passing, reaching objects, knot-tying, peg transfer	6–28
	Robotic surgery	(97)	Virtual reality: known environment	Ring walk and other unspecified tasks	17

As noted in the paper, the publications referred to “various surgical techniques and platforms such as traditional open surgery and minimally invasive techniques such as laparoscopy, robotic surgery, endoscopy, natural orifice transluminal endoscopic surgery, and endovascular

interventions". It is also important to note that most of the studies are from benchtop simulation (26), and virtual reality simulation (10).

Key Results Identified	Significance
Technological developments are enabling capture and analysis of large amounts of complex surgical data	The availability of data and the need for efficient surgical training provide a unique opportunity to augment surgical education
Identified a need to develop/improve: • Technology for data capture in the surgical environment • Techniques for transforming the data • Algorithms for data analysis	This will allow for the assessment of skill and enable automated coaching/feedback through diagnosis of skill deficits, targeted assessments, or both.
Algorithms for OCASE-T have been developed mostly for **benchtop** and **virtual reality simulation** settings; research in the **operating room** has been limited to only two studies.	Future work in data based on the operating room data is necessary for a more in depth, realistic assessment approach
Existing methods for OCASE-T have produced promising results, but the approaches are highly varied.	A consensus being established on what the best approaches and benchmarks are is necessary for a more
Algorithms for OCASE-T have focused only on **technical skill** and not on **competency**. [3]	Measuring competency would be the next step after technical skill evaluation algorithms are well established

Assessment

Pros

- Comprehensive research of papers regarding OCASE-T from Inspec, Pubmed, Google Scholar and Proquest
- Long list of references
- Many tables that summarize information from 45 cases
- Many shortcomings of the field put forward

Cons

- No detail into the various "ground truths"
- Lack of explanation of validation methods in some cases
- Discussion was limited to instances in which the surgical tasks and metrics for validation were directly comparable

[3] A **skill** is the learned capacity to carry out pre-determined results, it is proficiency one has at a task. A **competency** is more than just knowledge and skills and involves the ability to work independently without supervision.

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Most Important Relevance for Project

This paper emphasizes how OR based data and research is very important and is extremely lacking as there are only 2 studies that have done this in this 45-case study. Since this paper has been published, there has only been 2 papers that are based on OR data:

1. Azari DP, Frasier LL, Quamme SRP, Greenberg CC, Pugh CM, Greenberg JA, Radwin RG. **Modeling Surgical Technical Skill Using Expert Assessment for Automated Computer Rating**. Ann Surg. 2017 Sep 6; PMID: 28885509

2. Law H, Ghani K, Deng J. **Surgeon Technical Skill Assessment using Computer Vision based Analysis**. Proceedings of Machine Learning for Healthcare 2017 [Internet]. Boston, Massachuesetts; 2017.

This puts into perspective the critical need for more research on data collected directly from the OR as well as the need for more data in this domain.

Conclusions

Overall, I found this paper to be very informative, especially for a novice person in the field such as myself. It gave me access to a lengthy list of new references to incorporate into my reading list, as well as referring to some papers I already had on my reading list. It also was helpful in deciding the direction we wanted to go with the project regarding which data/metrics to use.

Future Steps

- In addition to technical skill assessment, future research can focus on technical competency assessment.
- Larger dataset collections that preferably are from OR data are needed to be accumulated.
- Establishment of a consistent evaluation metric for systematic assessment of validity of approaches is necessary.

- Incorporating the concept of a learning curve to the automated skill assessment algorithms.

References

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