Seminar Presentation:
A Holistic Data Acquisition Framework for Robotic Surgical Skill Assessment

Student: Giacomo Taylor
Mentors: Dr. Jeremy Brown,
Dr. Anand Malpani

"ASSESSING SYSTEM OPERATION SKILLS IN ROBOTIC SURGERY TRAINEES"

R. Kumar, A. Jog, et al

Laboratory for Computational Sensing + Robotics

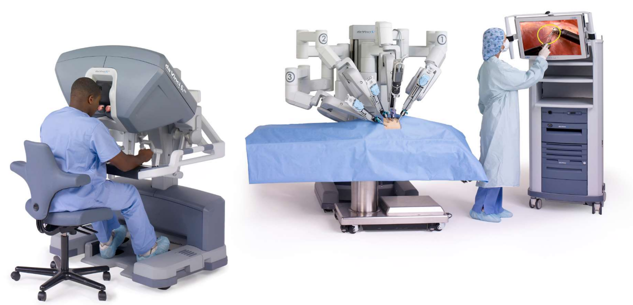
STATEMENT OF NEED

- Robotic minimally invasive surgery has become the standard of care in many specialties including cardiothoracic surgery, urology, gynecology, etc.
- Robotic surgical training still mostly follows the Halstedean apprenticeship model: subjective assessment of recorded training videos, direct observations, discussion… time and labor intensive -> costly, slow

Laboratory for Computational Sensing + Robotics

PROJECT RECAP

- The goal of our project is to develop an intelligent system that can objectively assess robotic surgical skill using performance data about how surgeons move their hands, connected instruments, and how the instruments interact with the surgical workspace.
- Develop a hardware + software platform that collects motion data from da Vinci and physical interaction data (forces on task board and accelerations of tool). This will combine two previously developed surgical skill assessment platforms.
- Collect pilot data from users of various robotic surgical skill levels
- Search for patterns in data to prepare for machine learning applications



PAPER SELECTION

R. Kumar, A. Jog, A. Malpani, B. Vagvolgyi, D. Yuh, H. Nguyen, G. Hager, C. Chen, "Assessing system operation skills in robotic surgery trainees," in *The International Journal of Medical Robotics and Computer Assisted Surgery,* 2012

BACKGROUND

- Collected and used kinematic data to classify surgeons as “skilled” or not
- Lays groundwork for long term training evaluation, judging efficacy of training

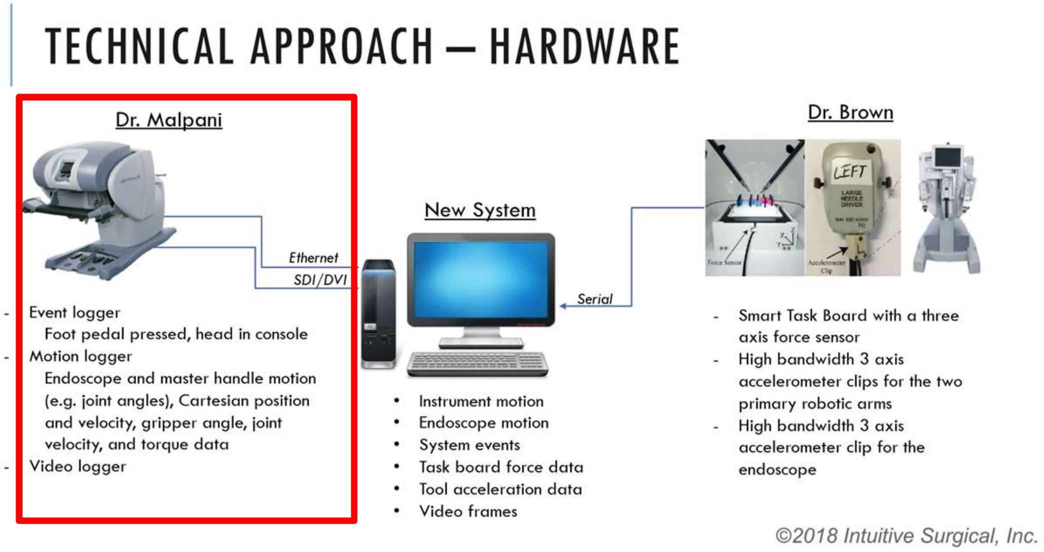
- Kinematics based methods are self-contained to the surgical system, no need for additional sensors
- Position and velocity data allows for larger, more in-depth feature set
  - Can allow for contextualization or more intuitive results

RELEVANCE

- Reduces need for human raters to assess basic psychomotor skill development (save time, money, objectivity)
- Improved trainee learning due to real-time feedback on skill
- Complementary to Dr. Brown's work analyzing relation of surgical workspace interaction forces to surgical skill

RELEVANCE (CONT.)

- Describes a Da Vinci kinematic data acquisition system similar to what we will use *(minimum deliverable)*
- Implements ML features and techniques we may draw from as suggestions *(maximum deliverable)*



COLLECTION METHODOLOGY

- Surgery residents & fellows of varying training levels
- Used the Da Vinci SI system/API with no workflow modification
- Collected motion data for benchmark tasks
- OSATS scores from clinical collaborators for ground truth
- ~30min/trial; 2 “experts,” 6 “trainees”

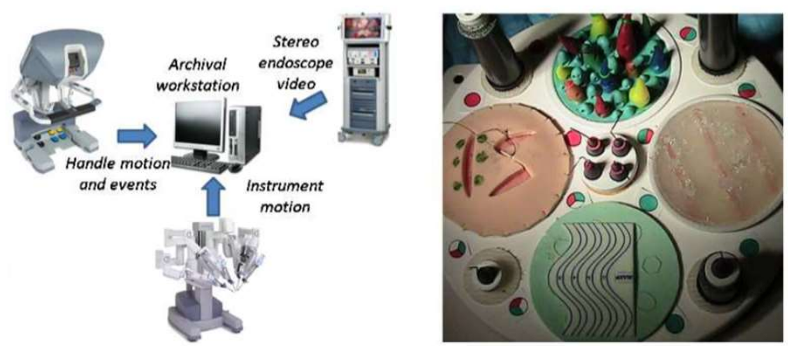


Figure 1. Information flow for the JHU/VISR archival system for the da Vinci system (left), and the benchmarking task pod (right). A demonstration pod (not used for benchmarking), the dissection pod, transection pod and the suturing pod (clockwise, respectively). The posts for the manipulation task are in the center and on the periphery

OSATS

"Objective Structured Assessment of Technical Skill"

Six skill-related variables, each graded on a 5 point Likert-like scale

GLOBAL RATING SCALE OF OPERATIVE PERFORMANCE

Please circle the number corresponding to the candidate's performance in each category, irrespective of training level

Category	1	2	3	4	5
Respect for Tissue :	Frequently used unnecessary force on tissue or caused damage by inappropriate use of instruments		Careful handling of tissue but occasionally caused inadvertent damage		Consistently handled tissue appropriately with minimal damage
Time and Motion :	Many unnecessary moves		Efficient time/motion but some unneccessary moves		Clear economy of movement and maximum efficiency
Instrument Handling :	Repeatedly makes tentative or awkward moves with instruments by inappropriate use of instruments		Competent use of instruments but occasionally appeard stiff or awkward		Fluid moves with instruments and no awkwardness
Knowledge of Instruments :	Frequently asked for wrong instrument or used inappropriate instrument		Knew names of most instruments and used appropriate instrument		Obviously familiar with the instruments and their names
Flow of Operation :	Frequently stopped operating and seemed unsure of next move		Demonstrated some forward planning with reasonable progression of procedure		Obviously planned course of operation with effortless flow from one move to the next
Use of Assistants :	Consistently placed assistants poorly or failed to use assistants		Appropriate use of assistants most of time		Strategically used assistants to the best advantage at all time
Knowledge of Specific Procedure :	Deficient knowledge. Needed specific instruction at most steps		Knew all important steps of operation		Demonstrated familiarity with all aspects of operation

Martin JA, Regehr G, Reznick R, et al. Objective structured assessment of technical skill (OSATS) for surgical residents. Br J Surg 1997; 84(2): 273–278

DATA PROCESSING

- Ground truth ratings binarily separated as expert (OSATS 13) vs trainee (OSATS <10)
- Focused on three main categories of interaction:
  - Master workspace management
  - Camera field of view adjustment
  - Instrument safety (FOV considerations)
- 2 seconds of data (Cartesion pose, velocity, gripper angle) for each clutch event
- 0.5 seconds for each camera event
- Binary SVM classifier, polynomial kernel (with no dimensionality reduction)

RESULTS

- Both master workspace & camera manipulation classification experienced good results:
  - Accuracy of about 87-95%
  - Precision of 87%
  - Recall up to 100%
- Unsafe motion and collision data analysis is “ongoing”

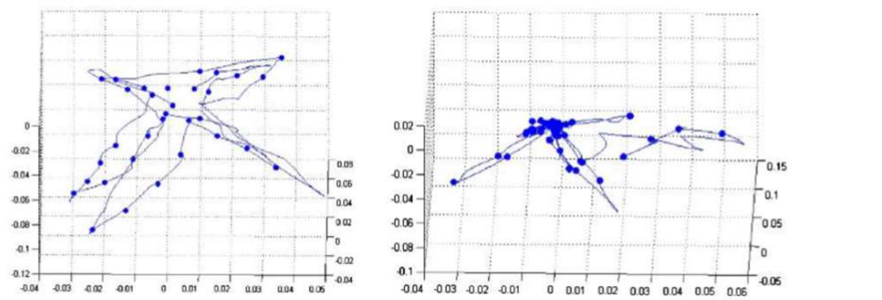


Figure 3. Expert (left) and trainee (right) endoscopic camera Cartesian trajectories during the manipulation task. Expert manipulates the field of view to keep the instruments visible at all times, while novices camera use is less structured. The points represent start of a camera motion

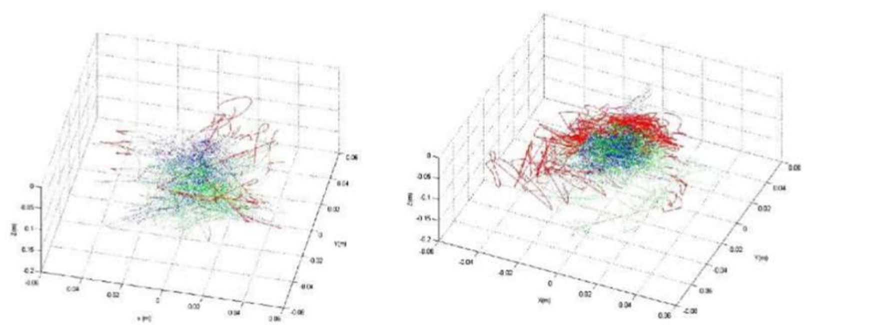


Figure 4. Expert (left) and trainee (right) instrument Cartesian trajectories for left (blue) and right (green) instruments during a training task. The red portions represent where an instrument was manipulated unsafely outside the field of view of the endoscopic camera

THE GOOD AND THE BAD

- PROS:
  - Da Vinci SI model is actuated by lead screws, interfering with interaction force measurements
  - Getting kinematic data through software does not require workspace modification; allows for larger scale data collection
  - Paper provides nice visuals that helps describe the data
  - Experimental setup mimics actual surgical task
- CONS:
  - Only extracted data around "events," i.e. pedal pressed/released
  - Could've explained OSATS specifications more
  - No mention of subtractive balancing or other method of evening data
  - Discussion of "unsafe motions" section is lacking

OVERALL

- Paper was very helpful to our project
  - Describes similar system
  - Provides suggestions of ML features, techniques to look into
- This paper will continue to be a valuable resource to us as we continue, especially the next phase of our project