A HOLISTIC DATA ACQUISITION FRAMEWORK FOR ROBOTIC SURGICAL SKILL ASSESSMENT

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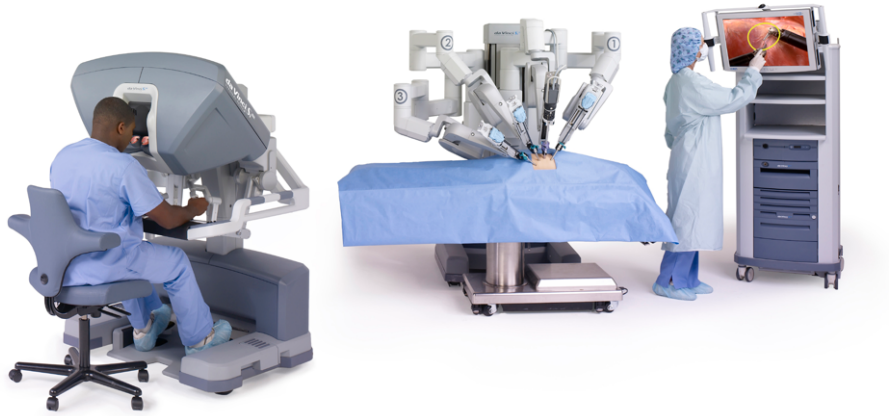
CLINICAL MOTIVATION

Robot-assisted minimally invasive surgery (RAMIS) is quickly becoming the prescribed method of treatment for many different routine and non-routine surgical procedures.

- There is a need to ensure that all robotic surgeons have a minimal level of skill proficiency before they operate on patients. (Pradarelli, et al.)
- Current methods of skill assessment rely almost exclusively on structured human grading which can be subjective, tedious, time consuming, cost ineffective (raters are practicing physicians). (Curry M, Malpani A, Li R, et al.)



GOAL

The goal of this project is to develop an intelligent system that can objectively assess surgical skill using performance data about how surgeons move their hands and connected instruments, as well as how the instruments interact with the surgical workspace.

PROPOSED SOLUTION

1. Develop a hardware + software platform using ROS (Python) that collects synchronous streams of motion and physical interaction data (forces and vibrations). This will combine two previously developed surgical skill assessment platforms.
2. Collect pilot data from students and members of the LCSR group
3. Analyze pilot data using standard statistical approaches to determine best approaches for finding patterns in data.
4. Develop experimental protocol for a large-scale data collection
5. Collect data from clinicians of various skill level on a da Vinci surgical robot at JHU Minimally Invasive Surgical Teaching Innovation Center (MISTIC)

TECHNICAL APPROACH – HARDWARE

Dr. Malpani

- Event logger
  Foot pedal pressed, head in console
- Motion logger
  Endoscope and master handle motion (e.g. joint angles), Cartesian position and velocity, gripper angle, joint velocity, and torque data
- Video logger

Ethernet

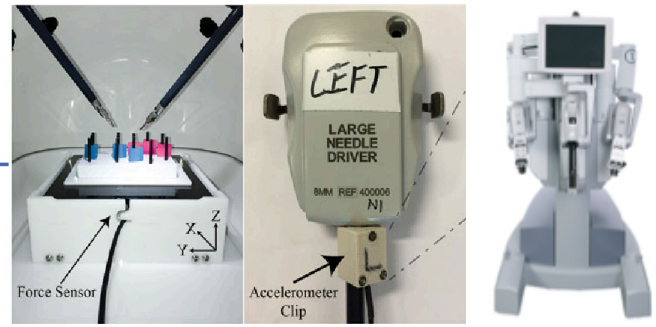
SDI/DVI

New System

- Instrument motion
- Endoscope motion
- System events
- Task board force data
- Tool acceleration data
- Video frames

Serial

Dr. Brown



- Smart Task Board with a three axis force sensor
- High bandwidth 3 axis accelerometer clips for the two primary robotic arms
- High bandwidth 3 axis accelerometer clip for the endoscope

TECHNICAL APPROACH – DATA PROCESSING

- Machine learning:
  - Previously - Time signal -> discrete features (mean, standard deviation, minimum, maximum, range, RMS, TSS, and time integral) (J. D. Brown et al.)
  - More research to be conducted on best pattern recognition approach
- "Skill" labels:
  - Experience (# of robotic surgeries performed)
  - Surgical Appointment (engineering, medical student, resident, fellow, attending)
  - G.E.A.R.S. Rating
    - Most clinically relevant
    - Evaluate using recorded video

DELIVERABLES

4/5/18

- Minimum:
  - Hardware + software platform for surgical skill assessment based on robot motion and physical interactions

4/26/18

- Expected:
  - Collect pilot data from students and members of the LCSR group
  - Analysis of pilot data and recommendations for best pattern recognition approaches to understand the data.

5/11/18

- Maximum:
  - Experimental protocol for large scale data collection
  - Collect data from clinicians of various skill level at MISTIC

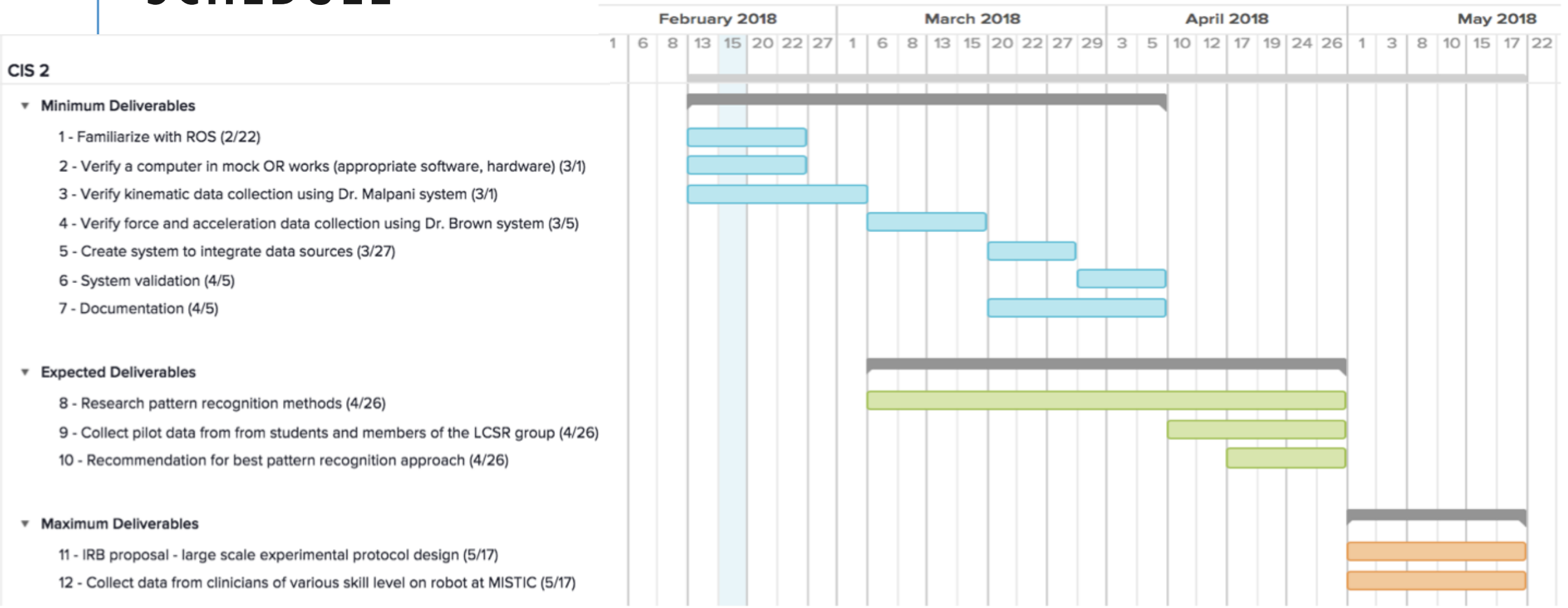
DEPENDENCIES

Dependency	Proposed Solution	Status
Access to mock OR	Appropriate forms submitted to LCSR office	Pending
da Vinci training	Training session with Dr. Malpani	Scheduled (2/22)
Access to existing code repositories	Access to Dr. Brown's code given, access to Dr. Malpani's code given after signing of NDA (API from Intuitive Surgical)	Awaiting code
Smart task board/ Accelerometer	Malfunctioning motherboard, new board is ordered	Waiting for delivery
PC to handle data acquisition	Test system on PC in mock OR, if not operational obtain new PC	In progress
ROS for interfacing with da Vinci API	Download required software, consult with Anton on usage	Software downloaded
Video frame grabber	Dr. Malpani has grabbers from previous project – need to test with ROS	Awaiting code
Schedules of clinicians	Need to accommodate busy schedules of clinicians for pilot data	Will pursue when system is created

MANAGEMENT PLAN

- Weekly meetings with Dr. Brown and Dr. Malpani
- Source control via git.lcsr.jhu.edu

SCHEDULE


February 2018
March 2018
April 2018
May 2018
1 6 8 13 15 20 22 27 1 6 8 13 15 20 22 27 29 3 5 10 12 17 19 24 26 1 3 8 10 15 17 22
CIS 2
Minimum Deliverables
1 - Familiarize with ROS (2/22)
2 - Verify a computer in mock OR works (appropriate software, hardware) (3/1)
3 - Verify kinematic data collection using Dr. Malpani system (3/1)
4 - Verify force and acceleration data collection using Dr. Brown system (3/5)
5 - Create system to integrate data sources (3/27)
6 - System validation (4/5)
7 - Documentation (4/5)
Expected Deliverables
8 - Research pattern recognition methods (4/26)
9 - Collect pilot data from from students and members of the LCSR group (4/26)
10 - Recommendation for best pattern recognition approach (4/26)
Maximum Deliverables
11 - IRB proposal - large scale experimental protocol design (5/17)
12 - Collect data from clinicians of various skill level on robot at MISTIC (5/17)

READING LIST

E. D. Gomez et al., "Objective assessment of robotic surgical skill using instrument contact vibrations", *Surgical Endoscopy Interventional Techn.*, vol. 30, pp. 1419-1431, 2015.

J. D. Brown, C. E. O'Brien, S. C. Leung, K. R. Dumon, D. I. Lee and K. J. Kuchenbecker, "Using Contact Forces and Robot Arm Accelerations to Automatically Rate Surgeon Skill at Peg Transfer," in *IEEE Transactions on Biomedical Engineering*, vol. 64, no. 9, pp. 2263-2275, Sept. 2017.

K. Bark et al., "Surgical instrument vibrations are a construct-valid measure of technical skill in robotic peg transfer and suturing tasks", *Proc. Hamlyn Symp. Med. Robot.*, pp. 50-51, 2012.

Pradarelli, Jason C., Darrell A. Campbell, and Justin B. Dimick. "Hospital Credentialing and Privileging of Surgeons: A Potential Safety Blind Spot." JAMA 313, no. 13 (April 7, 2015): 1313–14.

Rajesh Kumar, Amod Jog, Balazs Vagvolgyi, Hiep Nguyen, Gregory Hager, Chi Chiung Grace Chen, David Yuh, "Objective measures for longitudinal assessment of robotic surgery training," The Journal of Thoracic and Cardiovascular Surgery, Volume 143, Issue 3, 2012, Pages 528-534, ISSN 0022-5223

Shackelford, Stacy, Mark Bowyer. "Modern Metrics for Evaluating Surgical Technical Skills." *Current Surgery Reports*, vol. 5, no. 10, 2017, doi:10.1007/s40137-017-0187-0.