Tool Gravity Compensation for Galen Microsurgical Robot

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Background

- The Galen is a general purpose, hand-over-hand, admittance control robot developed mainly for otolaryngology.
- Initial developed as a PhD project in the LCSR but is currently being commercialized by Galen Robotics inc.

The Problem

- The weight of the tool is also read by the force sensor
- There is no way for the force sensor to distinguish between force from the tool and force from the surgeon

Objective

- Develop static model of tool gravity for multiple tools in various configurations
- Integrate tool gravity model into the control loop of the Galen robot
- If time permits, develop and integrate model of tool torques during dynamic motion

Technical Approach: Model

$$L = KE - PE$$

$$f_T/\tau = \frac{\partial}{\partial t}(\frac{\partial L}{\partial \dot{x}}) + (\frac{\partial L}{\partial x})$$

$$f_T/\tau = M(x) + C(x, \dot{x}) + G(x)$$

$$\begin{bmatrix} f_S \\ \tau_S \end{bmatrix} = \begin{bmatrix} R_{ST} & 0 \\ -R_{ST}\hat{p_T} & R_{ST} \end{bmatrix} \begin{bmatrix} f_T \\ \tau_T \end{bmatrix}$$

$$\begin{bmatrix} f_S \\ \tau_S \end{bmatrix} = \mathbf{A}\vec{b}$$

Technical Approach: Method

- Develop an analytical model of the tool in static/dynamic cases
- Move tool to different positions, velocities, and angular velocities
- Take measurements from force sensor
- Regress unknown parameters (such as tool offset and inertial components)
- Use model to predict force sensor readings based upon tool position, velocity, and angular velocity
- Subtract predicted sensor reading from actual sensor reading

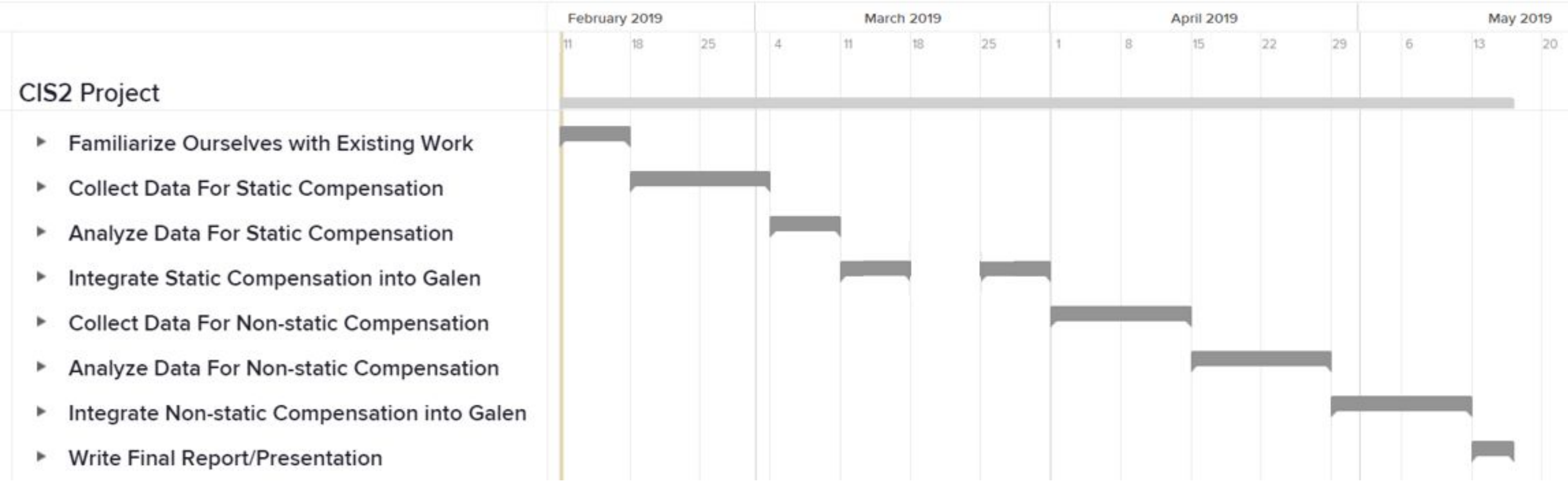
Deliverables

- Minimum:
    - Report with data and analysis demonstrating a model capable of predicting 6 DoF forces and torque given a tool and tool holder pose due to gravity, along with code and documentation
- Expected:
    - Video and data demonstrating successful integration of gravity compensation into robot control software, along with code and documentation
- Maximum:
    - Report demonstrating a model capable of predicting 6 DoF forces and torque given a tool and tool holder pose due to dynamic motion, along with code and documentation
    - Video and data demonstrating successful integration of dynamic model compensation into robot control software,
      along with code and documentation

Dependencies

Dependencies	Solution	Alternative	Date
Access to MockOR	resolved	N/A	N/A
Access to Galen Mark 2	Speak with Galen Commercial team about scheduling	Use Galen Mark 1.	2/14
Access to Galen Bitbucket Repository	Email Barry Voorhees	Speak to Galen Team/Dr. Taylor. Worst Case, use old LCSR repo and mark 1	2/14
Get access or knowledge about previously used data collection on the Galen	Email Paul Wilkening	Read through code and write our own script.	2/14
Discuss tool exchange	Speak with Dave Levi	Use Galen Mark 1	2/14
Login Access to Galen Computers	resolved	N/A	N/A

Schedule


February 2019
March 2019
April 2019
May 2019
11
18
25
4
11
18
25
1
8
15
22
29
6
13
20
CIS2 Project
Familiarize Ourselves with Existing Work
Collect Data For Static Compensation
Analyze Data For Static Compensation
Integrate Static Compensation into Galen
Collect Data For Non-static Compensation
Analyze Data For Non-static Compensation
Integrate Non-static Compensation into Galen
Write Final Report/Presentation

Milestones

Milestone	Data Achieved
Project Proposal submitted	Feb 21st
Collect all data for static compensation	March 4th
Create working model for static compensation	March 11th
Integrate static compensation model into Galen	April 1st
Collect all data for non-static compensation	April 15th
Create working Model for non-static compensation	April 29th
Integrate non-static compensation model into Galen	May 13th

Management Plan

- Work Together: Tues/Thurs/Fri 8:45-11:45 am
- Mentor Meetings: Fri 10:00-10:30 am
- Code updates will be pushed a branch of the bitbucket repository
- Data and Reports will be stored in jhBox

Reading List

Beer, Randall F., et al. "Development and evaluation of a gravity compensated training environment for robotic rehabilitation of post-stroke reaching." *Proc. 2nd IEEE RAS & EMBS International Conference on Biomedical Robotics and Biomechatronics (BioRob)*. 2008.

Dimeas, Fotios & Aspragathos, Nikos. (2015). Learning optimal variable admittance control for rotational motion in human-robot co-manipulation. IFAC-PapersOnLine. 48. 10.1016/j.ifacol.2015.12.021.

Feng, Allen L., et al. "The robotic ENT microsurgery system: A novel robotic platform for microvascular surgery." *The Laryngoscope* 127.11 (2017): 2495-2500.

Kim, Woo Young & Han, Sanghoon & Park, Sukho & Park, Jong-Oh & Ko, Seong Young. (2013). Tool Gravity Compensation for Maneuverability Enhancement of Interactive Robot Control for Bone Fracture Reduction System.

Luo, Ren C., Y. Yi Chun, and Yi W. Perng. "Gravity compensation and compliance based force control for auxiliarily easiness in manipulating robot arm." *Control Conference (ASCC), 2011 8th Asian*. IEEE, 2011.

Olds, Kevin. *Robotic Assistant Systems for Otolaryngology-Head and Neck Surgery*. Diss. 2015.