Improving The Transparency of the Galen Robot

Computer Integrated Surgery II

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Introduction

- The Galen Surgical Robot is a prototype delta platform based robotic manipulator designed to be cooperatively controlled by an experienced surgeon in a hand-over-hand control mode.
- However this hand-over-hand control mode is not as responsive and transparent as it can be, and there is room for improvement.
- Multiple approaches were used to improve the responsiveness and transparency of the robot including admittance gain tuning and adaptive gains.
- As a result of these improvements, the robot's transparency improved and it became more responsive to operator input.

Fig-1: Galen Surgical Robot

The Problem

- The Galen Surgical Robot uses a 6-axis F/T sensor in between the robot and the end effector (wrist sensor) to measure the amount of force the surgeon exerts on the tool. This force is used as input to an admittance controller.
- Using this admittance controller, the surgeon is able to cooperatively control the tool path while the robot provide a steady platform by eliminating hand tremors and enforcing virtual barriers.
- However, when the tool is being controlled in the hand-over-hand control mode, it does not 'feel' very responsive and it's motion is a little sluggish. This is highly undesirable for a surgical robot and could potentially affect it's commercial adoption.

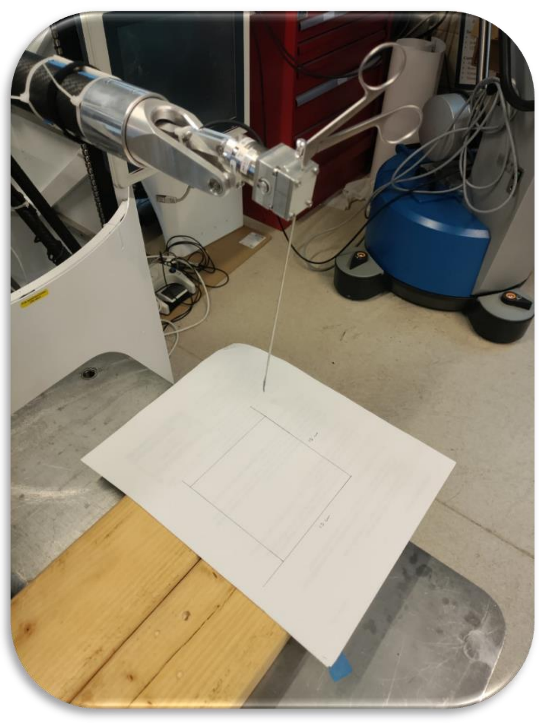

Fig-5: Test Setup

The Solution

- Multiple approaches were used to improve the responsiveness

❖ Corrected Control Loop Timing: commands from mid level controller now being sent at regular intervals to low level controller.

❖ Adaptive Gains: admittance control gains are being changed on the fly depending on the operator force input.

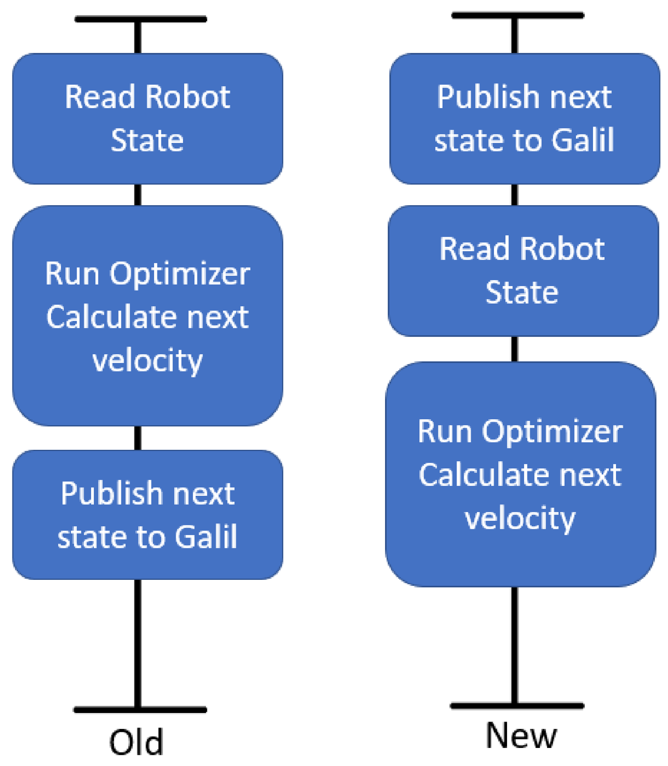

Fig-2: Control Loop Timing, Old vs New

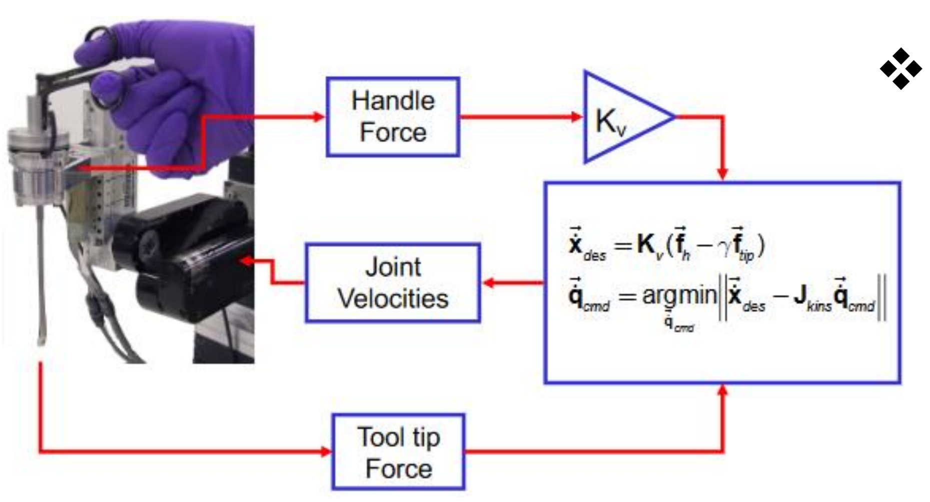

Fig-3: Admittance controller with Gain

❖ Sensor Data Filtering: the input from the wrist force sensor is now being filtered to remove jitters and smoothen input.

Outcomes and Results

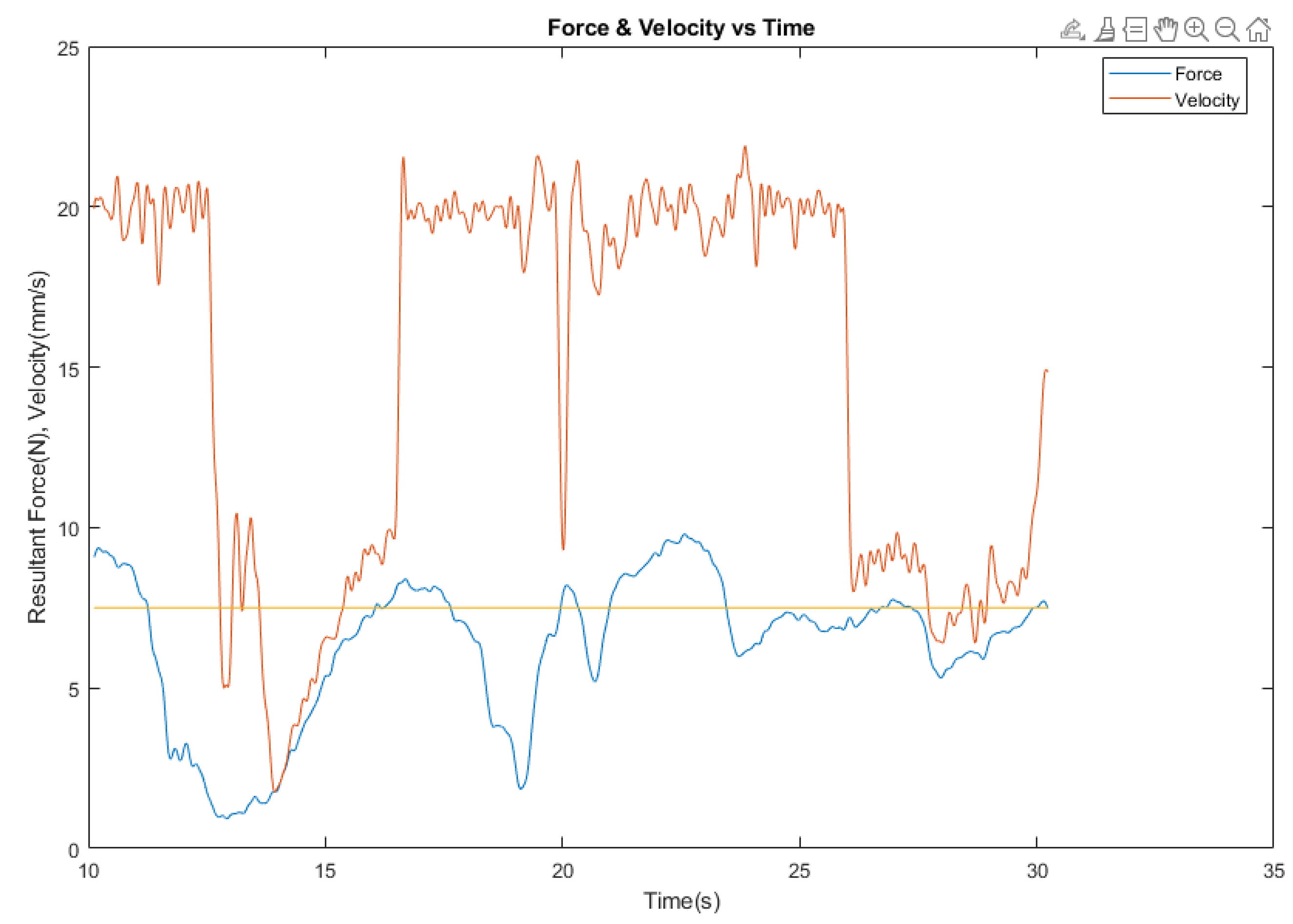

Fig-4: Adaptive Gains changing based on Force Threshold

- The responsiveness and transparency of the robot improved.
- Adaptive gains allowing for surgeons to quickly perform large motions and precisely perform small motions
- Sensor data filtering increasing stability in transitory phases.

Future Work

- Since this is a control systems project, there remain a wide array of potential solutions that could further improve the transparency of the robot.
- A dynamic model to better estimate the effect of input commands on state of the robot and correct for errors
- Extensive user testing and data analysis.
- Operator feedback and surgical trials

Lessons Learned

- Internal workings of a cutting edge surgical robot.
- Experience with control systems tuning and analysis of responses.
- Contingency planning and effective execution without the ability to test.

Credits

- Vishnu Kolal is responsible for all the work done
- Tommy Liang graciously provided assistance with the code base.

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