Force Sensing Drill for Skull Base Surgery

Computer Integrated Surgery II

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Introduction

- Galen Robotics created a hand-over-hand cooperatively controlled surgical robotic system for head and neck microsurgery.
- Our project adapted strain gauge force sensors to be used in surgical drilling applications. We designed an ergonomic force sensing drill sleeve to be used with a Midas surgical drill and the Galen robot.
- We collected force data from the drill sleeve force sensors and the Galen's ATI force sensor and fit a linear model relating the drill sleeve's force sensor readings to the Galen's ATI force sensor readings.
- We were able to find tooltip forces with the drill sleeve's force sensor data and demonstrated the limitations of using strain gauge force sensors for this application

The Problem

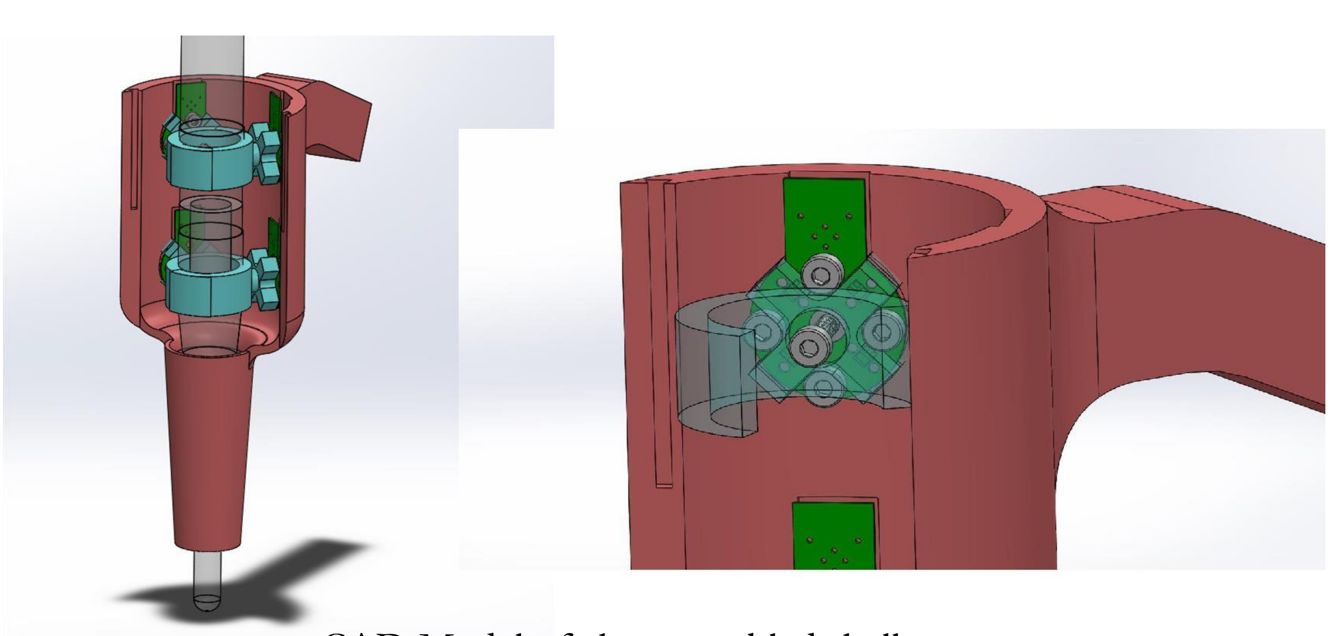
- Many complications can occur during skull base drilling due to the complex and critical anatomy.
- A physician's inadvertent motions, hand tremors, and lack of feedback or safety controls from their surgical tools hinder the physician's accuracy in procedures. The current methods of sensing the force/depth were subjective in nature and not quantifiable.
- **Project Goal:** During skull base drilling, we aim to sense these forces and integrate this data for better control of the Galen robot

The Solution

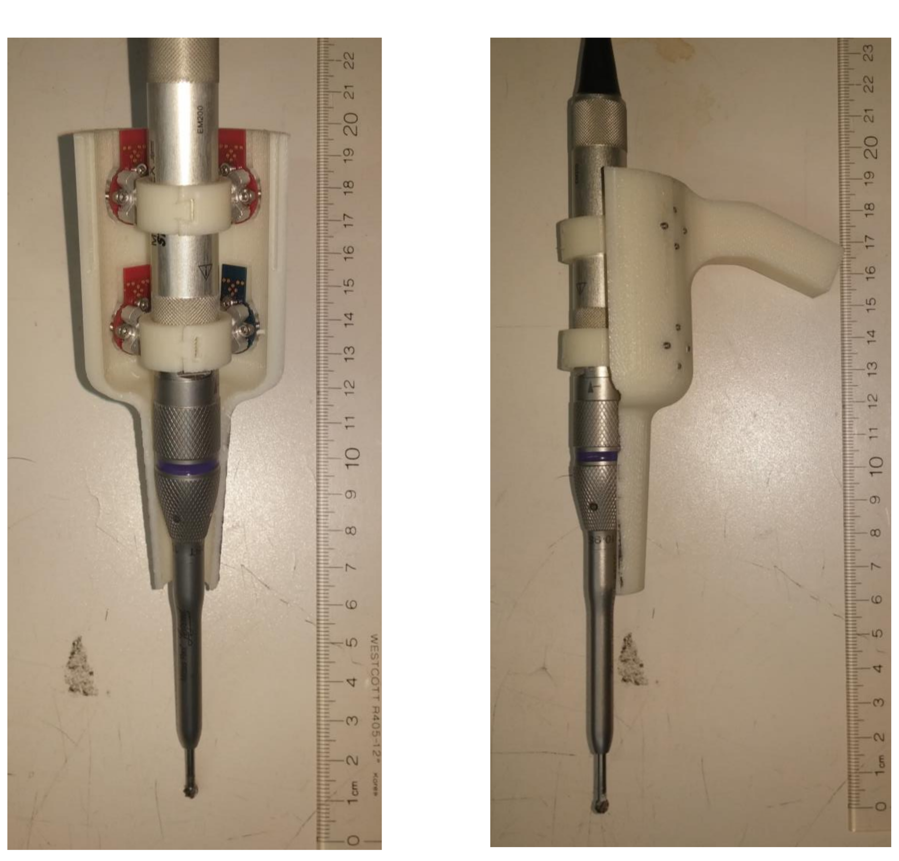
- We designed a tool holder attachment capable of measuring the force exerted by the tooltip on the tissue. This was tested using the drill for now, and in future work can be extended to hold other instruments as well.
- For this purpose, we used force sensors based on strain gauges available from BLAM lab, JHMI. Using these sensors, we came up with the design and calibration.

Mechanical Drill Sleeve Design

- The drill holder design consists of three major components:
  - 4 force sensors placed perpendicular to the axis of the drill, with forces transmitted using a rigid metal pivot.
  - A 3D printed ABS sleeve holding these sensors, wiring and a quick release tool attachment to the Galen surgical robot.
  - A 3D printed cover to ensure that no forces apart from the ones from drill tool tip are exerted on the sensors.



CAD Model of the assembled shell



3D printed and assembled drill holder

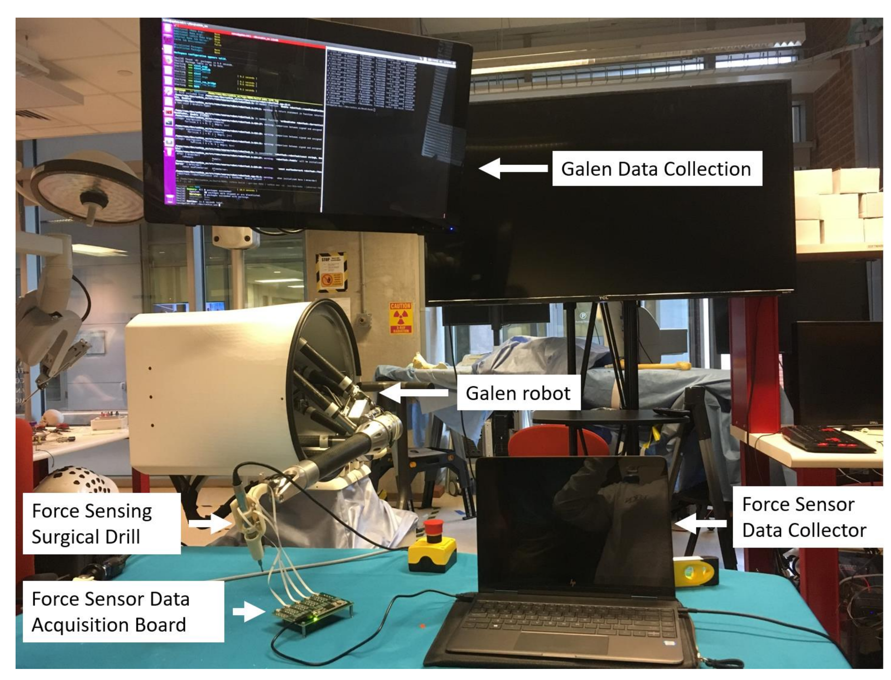
Calibration:

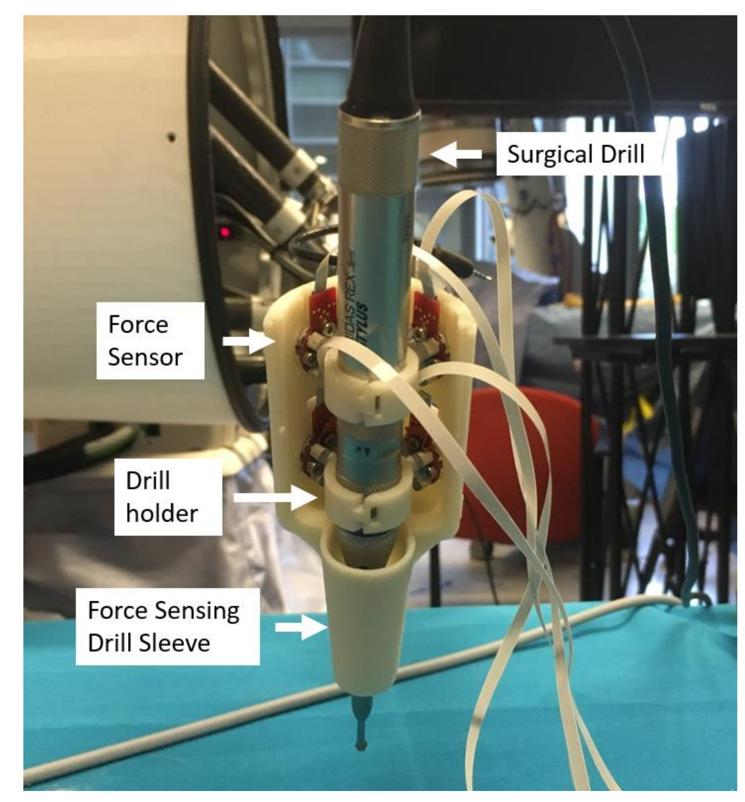
Data Collection

- Use DAQ and Plotosaurus for obtaining uncalibrated drill sleeve forces
- Collect force readings from ATI sensor on Galen robot, resolved at tooltip
- Push on tooltip in multiple directions to simulate range of tool motion
- Output time stamped data files for both the drill sensor and ATI sensor

Data Processing:

- ATI samples at 200 Hz, drill sleeve sensors at 1 kHz,
- Offset determined using mechanical trigger to line up Galen and drill sensor timestamps.
- Least-Squares Calibration using 12 force readings from force sensors and 6 readings from ATI sensor on Galen, resolved at drill tip

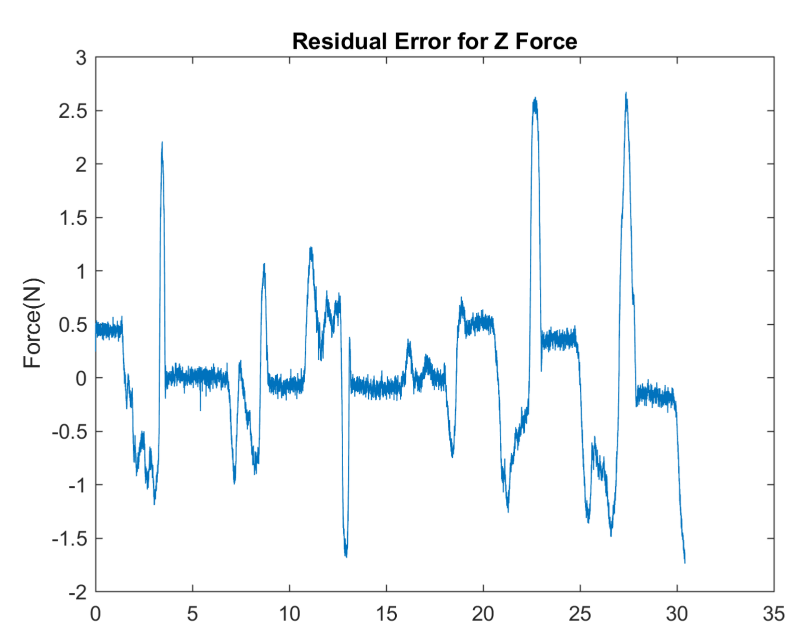




Results

- Using a linear least squares model we obtained a matrix X that transforms the readings from the drill sensors to tip force readings.
- The linear model could not fit for the x and y linear forces at the drill tip.
- We evaluated fit by determining an R-squared value for the Z force, X torque, Y torque, and Z torque.

Component	Z Force	X Torque	Y Torque	Z Torque
R-Squared	0.7100	0.6064	0.7226	0.4761



Future Work

- Future directions for this project would include designing a tool holder capable of holding a variety of surgical tools.
- A better model of the system needs to be developed including nonlinear relations between forces, for a better fit.
- Hall effect sensors can be used for a smaller drill profile and accurate sensing.

Lessons Learned

- The design iterations take time for printing and review. This part could have been completed faster.
- The calibration model could be improved on further.
- Better Hall effect sensors can also be used for a smaller profile and probably more accurate sensing.

Acknowledgements

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