Robot-Assisted FBG-based Sensorized Needle Calibration

Project Checkpoint Presentation

Team 6: Kefan Song
Mentors: Iulian Iordachita, Jin Seob Kim, Dimitri Lezcano, Ge Sun
04/06/2021

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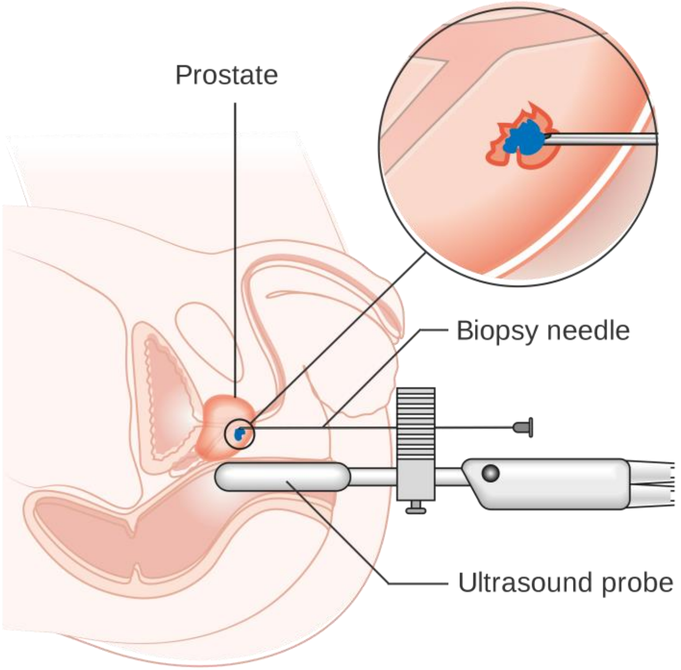
Project Objective

- **This project aims to build a robotic system for (semi)automatic calibration of flexible needles with FBG-based shape-sensing capabilities.** FBG-embedded needles require precise and consistent calibration which can take several hours and is prone to human errors. Robot-assisted needle calibration would optimize needle construction and improve shape-sensing accuracy.

Motivation

- **Problem setting:** Prostate biopsy & brachytherapy
- **Current approach:** Ultrasound guided manual needle insertion with stiff needle
- **Problems:** target displacement, poor repeatability
- **Updated approach:** MRI guided robot needle insertion with flexible needle



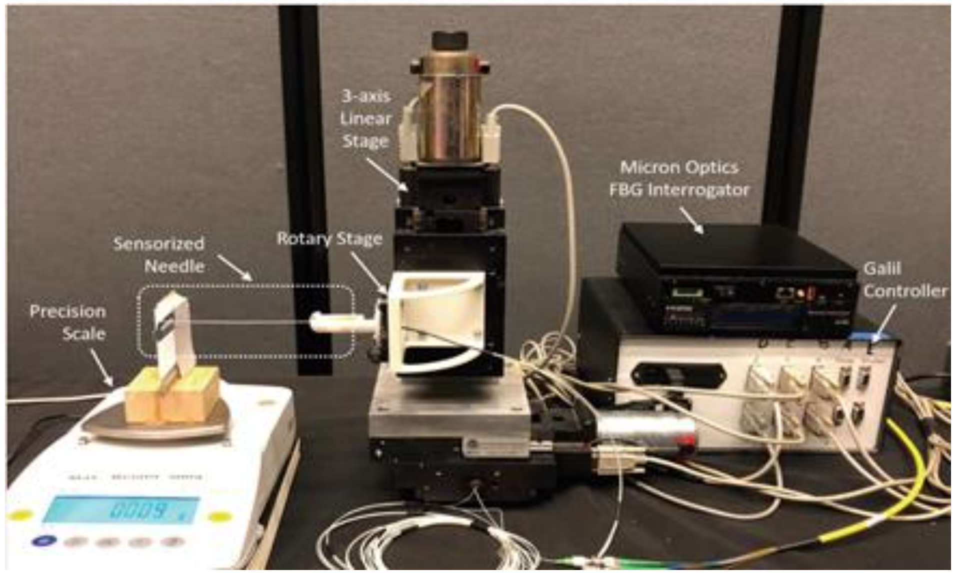
Picture credit: Cancer Research UK

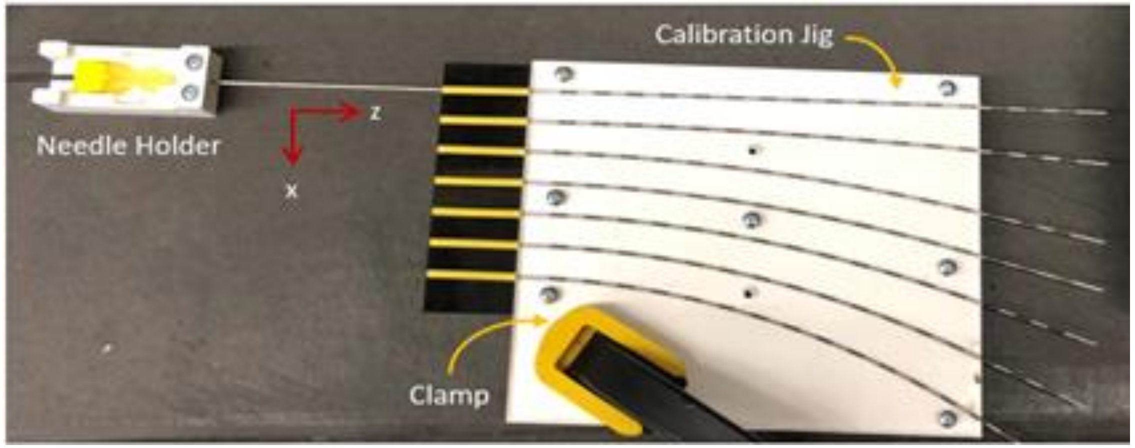
Project Summary

- **Current problem:** FBG-sensorized needles, which are chosen to monitor curvature of the needle, needs to be calibrated individually. Current manual calibration is time consuming and prone to human error.
- **Objective:** to design a (semi)automatic FBG-based needle calibration system to perform both characterization and calibration of the needle.

Current Progress - Hardware

- Goal: to perform both needle characterization and calibration





Left: current manual characterization process
Right: current manual calibration process

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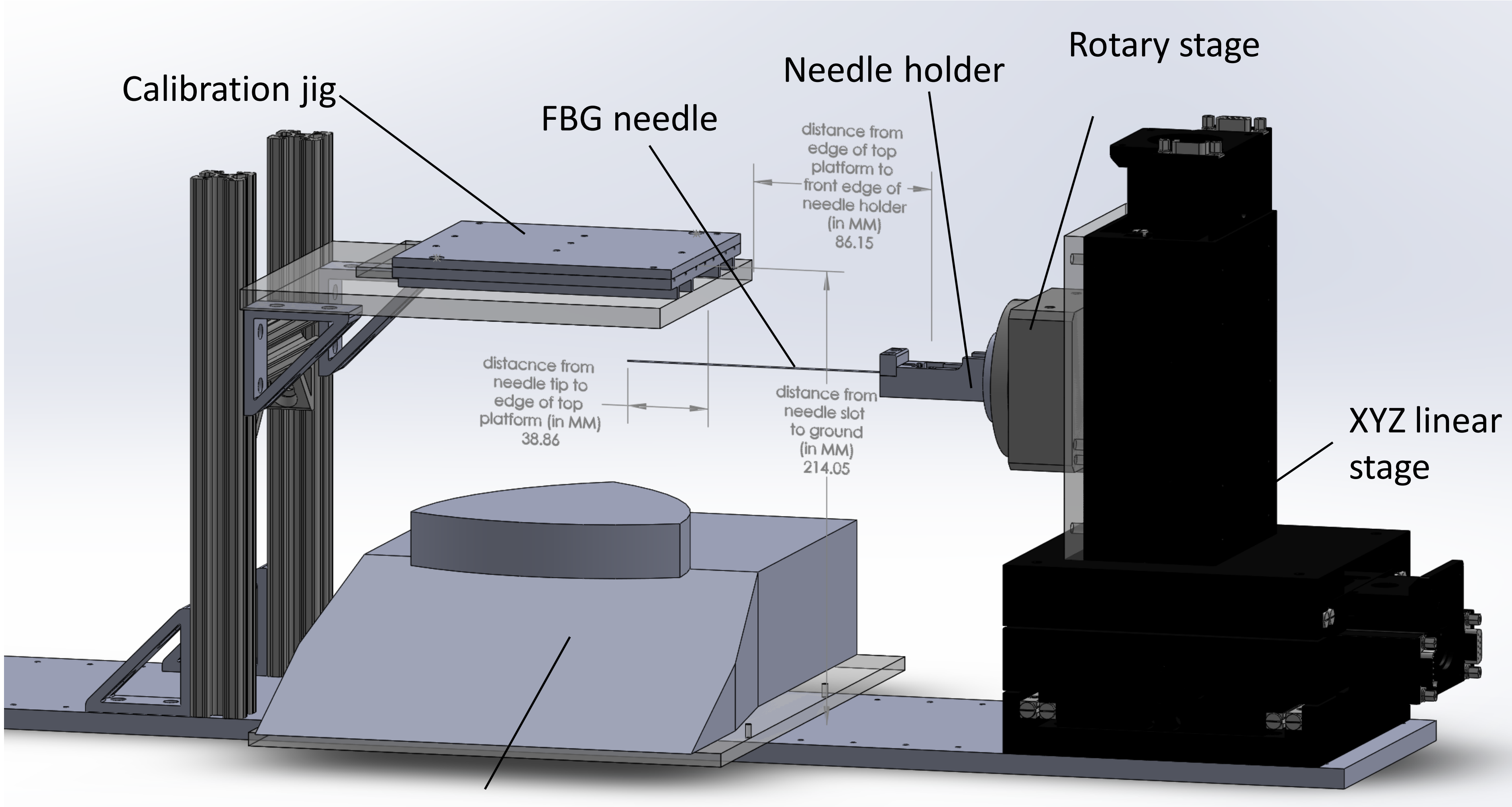
Current Progress - Hardware



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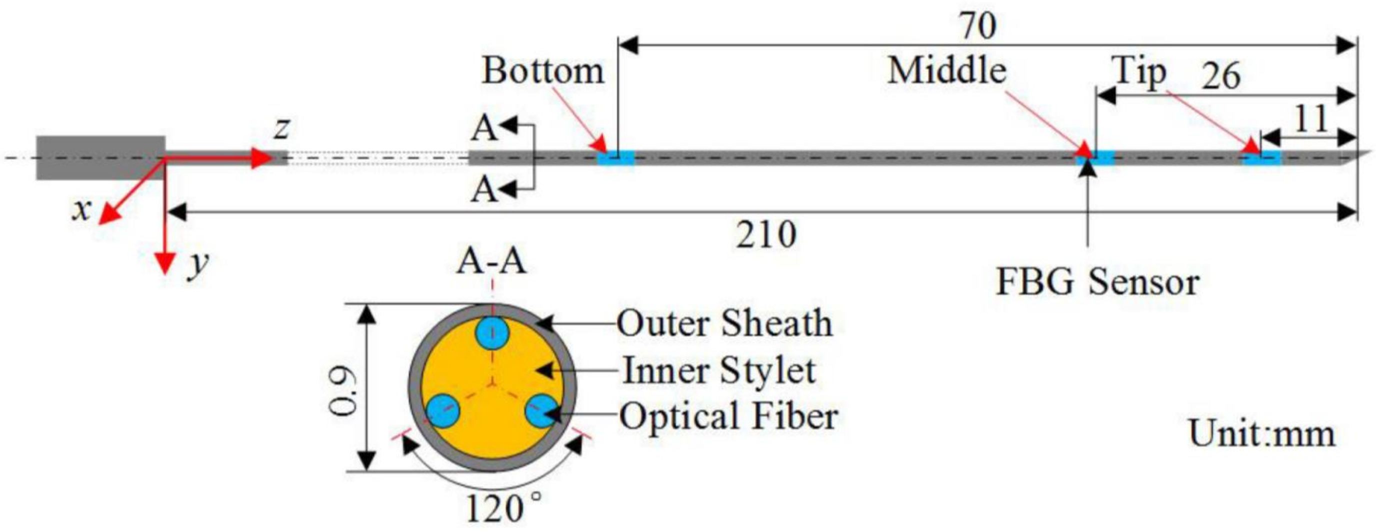
Current Progress - Software

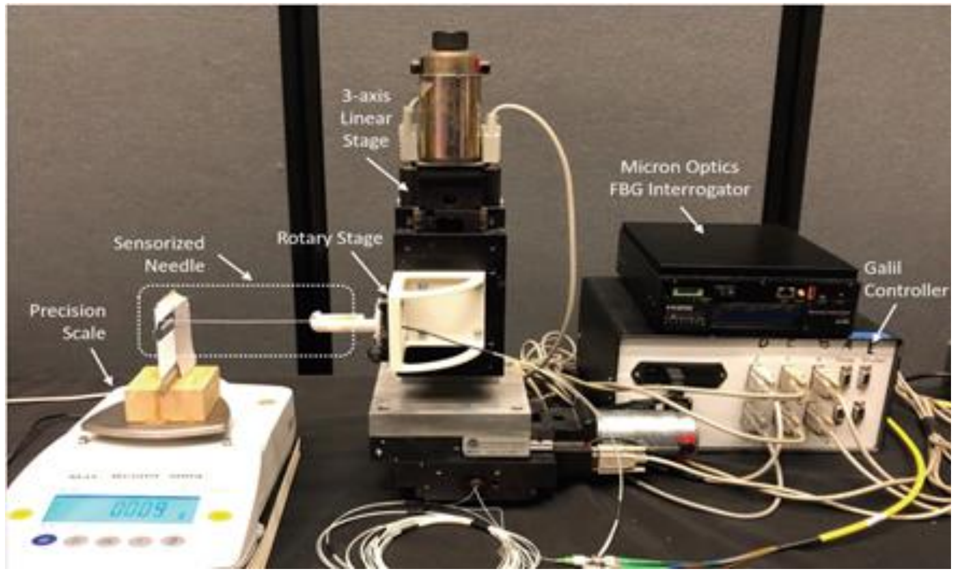
- Goal: to perform both needle characterization and calibration automatically for a 3-channel 3-active area FBG needle



Current Progress - Software

- **Characterization:** check whether the FBG readings are proportional to the bending distance
- **Current manual procedure:**

1. With channel 1 on bottom, touch the horizontal bar on the scale with the needle tip.
2. Move up the needle till it's barely touching the bar and the scale reads zero.
3. press needle down for 10 steps of 1.5 mm each and then reverse the motion, collecting data after each step.
4. Repeat the steps 1~3 for 5 trials for each FBG channel facing down.



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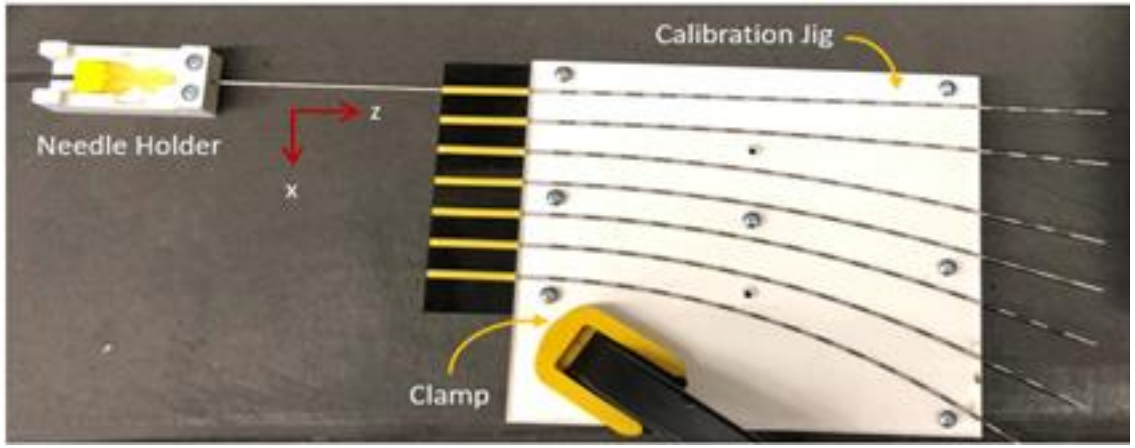
Current Progress - Software

- **Calibration:** Calculate the relationship between FBG readings and the bending curvature
- **Current manual procedure:**

1. Insert the needle into all the slots on the calibration jig sequentially, collecting data for each slot.
2. Repeat step 1 for 10 trials.
3. Rotate the needle by +90, -90, and 180 degrees, respectively. After each rotation, repeat steps 1~2.



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Current Progress - Software

- Developed a Matlab algorithm to control the robotic arm, collect experiment data, and perform data analysis
- Achieved objectives:
  - Collect data from all inputs including the precision scale and the FBG needle
  - Control both linear stage and rotary stage to move according to the workflow
  - Perform data analysis on the needle characterization
  - Automated movement with manual checkpoints during the process
- Expected objectives:
  - Perform data analysis to obtain the calibration matrix

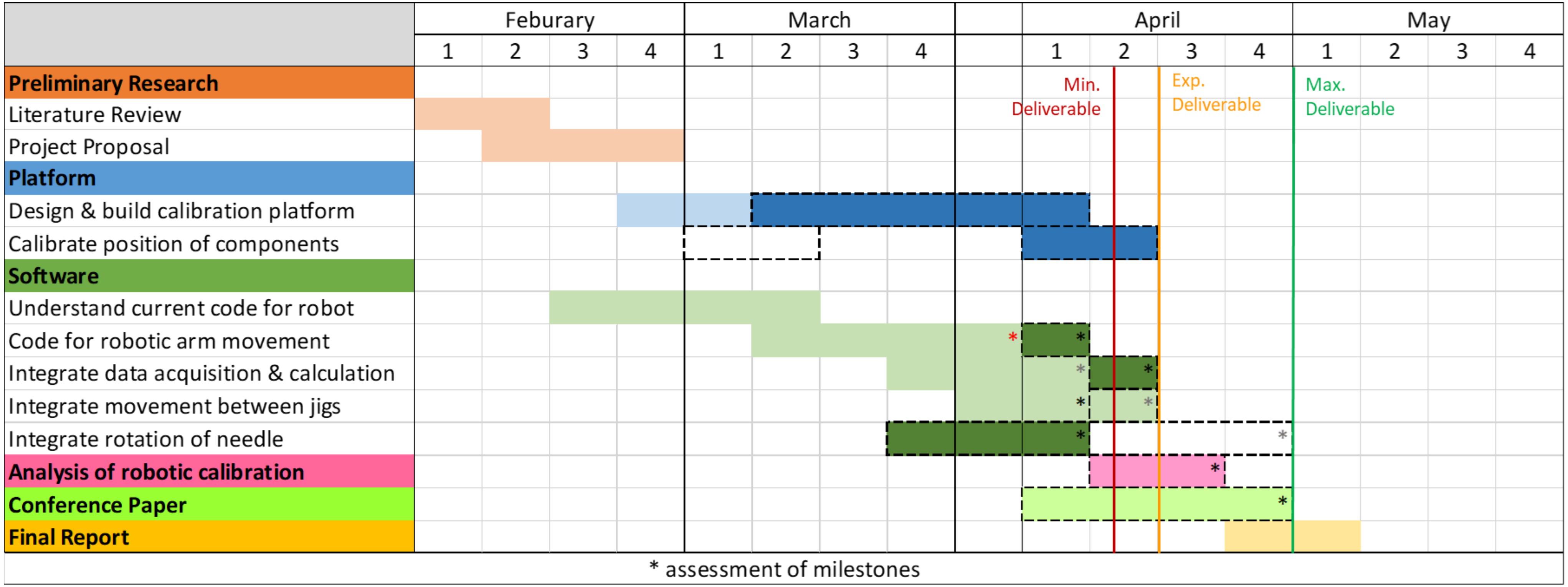
Deliverables

	Hardware	Algorithm	Experiment data	Documentation
Minimum	Calibration platform	Semi-automatic code (manual movement between jigs + manual needle rotation) with comments	Calibration matrices for one needle	User manual for the system
Expected	~~Updated platform~~	Mostly automatic code ~~(manual needle rotation)~~ with comments		Updated user manual and example calibration video
Maximum		~~Fully automatic code with comments~~	~~Calibration results using other calibration jigs~~ Comparison of robotic calibration and manual calibration	~~Updated user manual and example calibration video~~ A conference paper based on this project

Deliverables

	Hardware	Algorithm	Experiment data	Documentation
Minimum	Calibration platform	Semi-automatic code (manual movement between jigs + manual needle rotation) with comments	Calibration matrices for one needle	User manual for the system
Expected		Automatic code with comments		Updated user manual and example calibration video
Maximum			Comparison of robotic calibration and manual calibration	A conference paper based on this project

Timeline



- Platform design delayed due to oversimplified thought during project proposal and shipping delay
- Rotation of needle finished early due to the need to validate the rotary stage

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Dependencies

Dependency	Status	Contingency plan	Planned DDL	Hard DDL
Acquire robotic arm and data acquisition unit	Acquired	Both robot and the data acquisition unit have a backup model	Feb 19	Feb 19
Several needles for testing	Acquired	Currently the lab has multiple needles	Feb 19	Feb 19
Curvature jig model	Acquired	More models can be 3D printed fairly quickly	Feb 19	Feb 19
Lab access	Acquired	N/A	Feb 12	Feb 12
Aluminum breadboard	Acquired	Multiple backup choices including acrylic base and aluminum profiles	Feb 25	March 12
Substitute force sensing mechanism for precision scale	Not acquired	Continue using the scale	March 29	N/A
Aluminum profiles & accessories	Acquired	Buy from other vendors	March 26	Apr 6
Acrylic sheet	Acquired	Use scraps from lab	March 26	Apr 6
DB-9 cables	Acquired	Use existing cables from another robot	March 26	Apr 6

Newly added

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Team Management

- Weekly meeting on Fridays with Prof. Iordachita, Dimitri and Ge
- Code and 3D model files stored on JHU OneDrive and computer in lab
- Reports stored on CIS II website

Thank you!

- Questions?