JOHNS HOPKINS
WHITING SCHOOL of ENGINEERING

CortiTech

Motorized Fixation to Tubular Retractor in Brain Surgery

Group 1:
Robby Waxman, Mark Shifman, Caroline Hoerrner

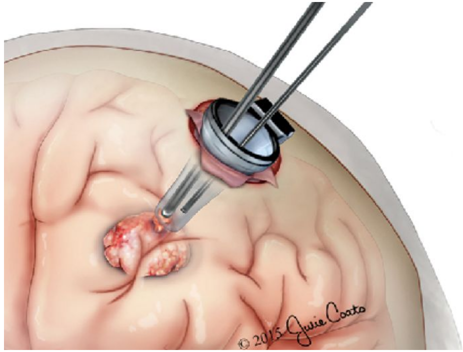
EN.601.456
Computer Integrated Surgery II

March 25, 2021
Checkpoint Presentation

Summary

- Problem

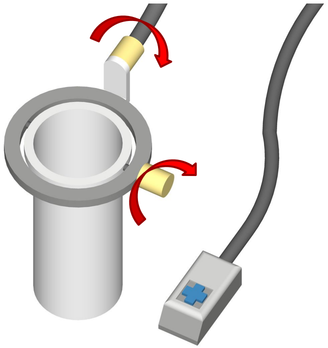
  Tubular retractors aid surgeons in viewing deep target brain lesions. However, they can be difficult to reposition, and the human hand can add excess noise to an area delicate to force.



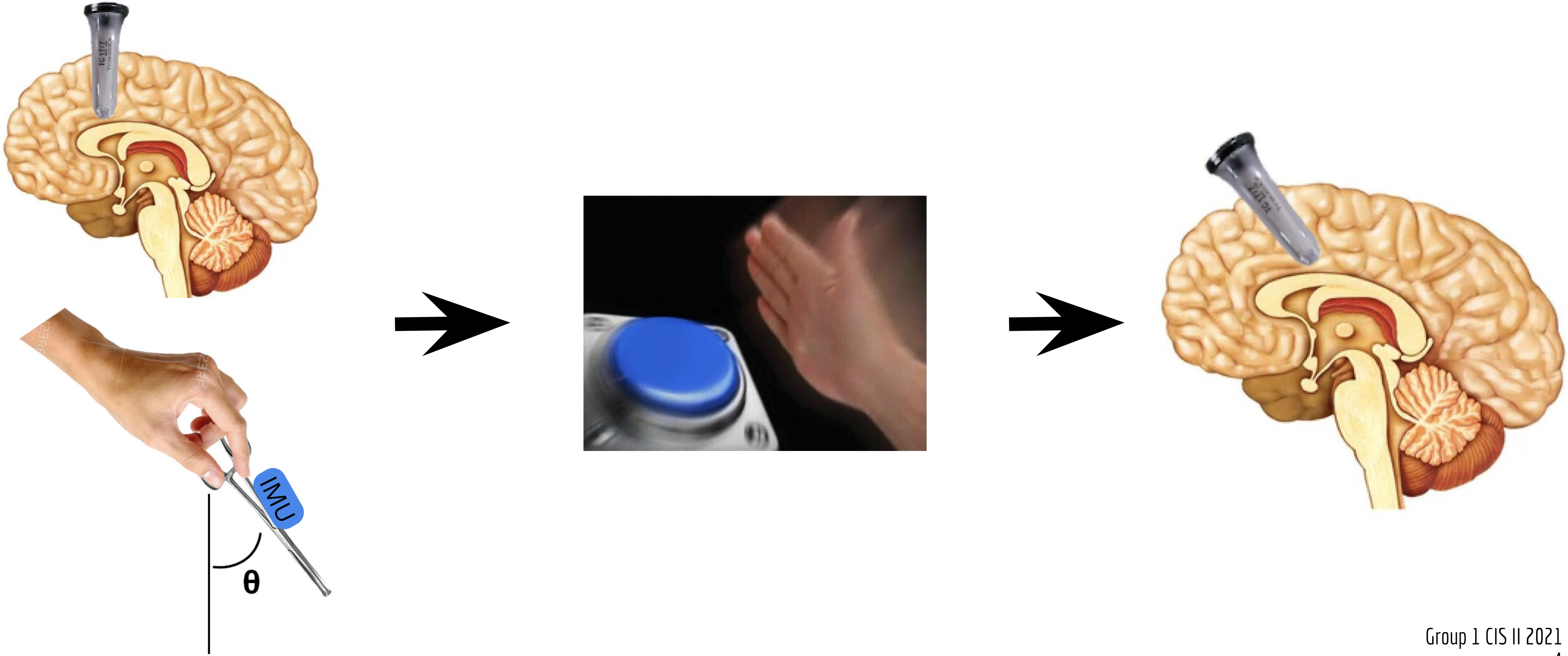
Summary

- Solution

  Add motorized fixation to retractor, allowing for smooth and precise movements. Create intuitive motion control system for surgeons.



Summary: Surgical Workflow



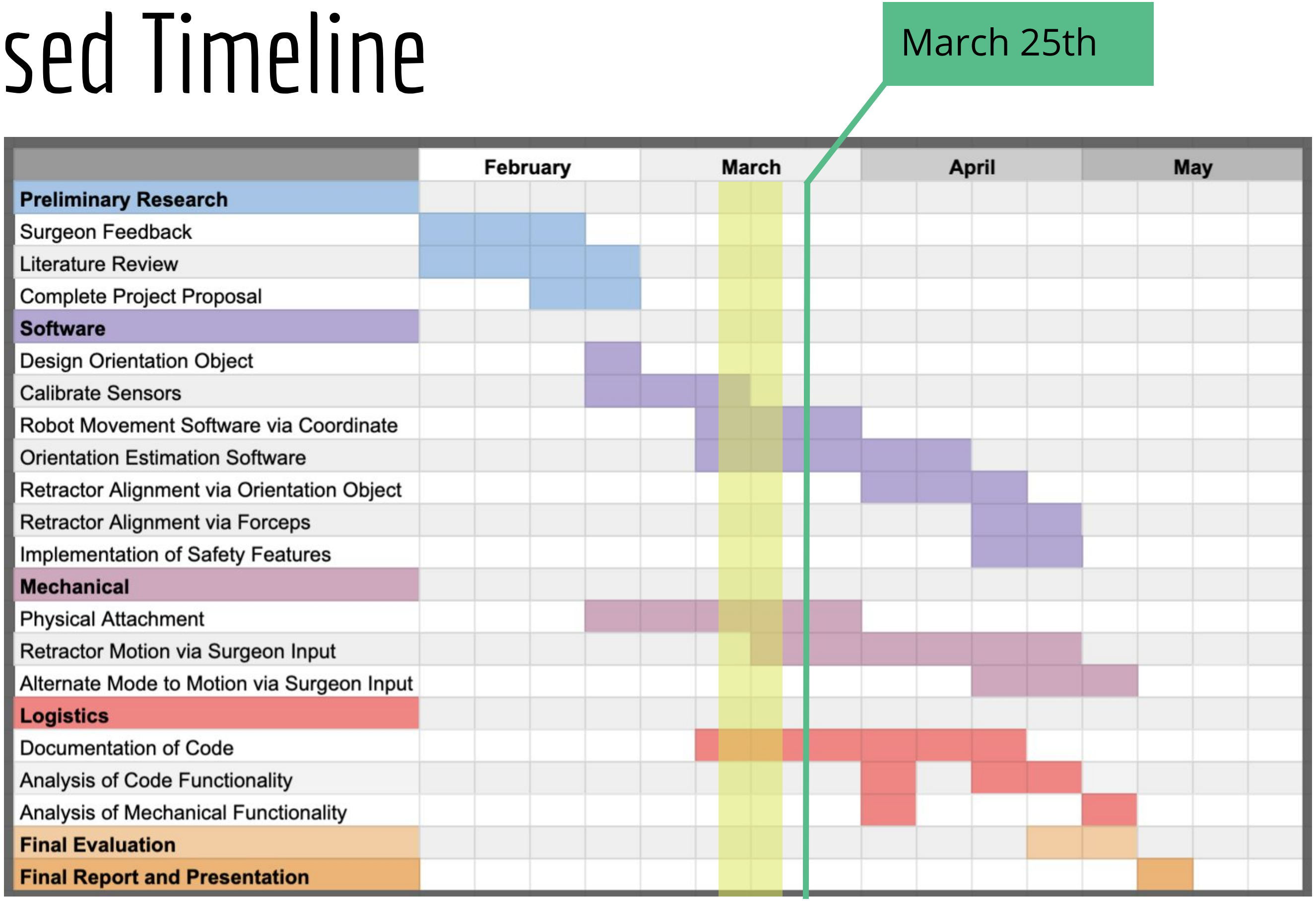
Summary

- Solution Development Stages
    - Rapidly prototype physical attachment
    - Calibrate motor movement based on keyboard input
    - Calibrate motor movement based on inputted angles
    - Integrate IMU orientation estimation with motor control
    - Retrofit IMU sensors onto surgical forcep

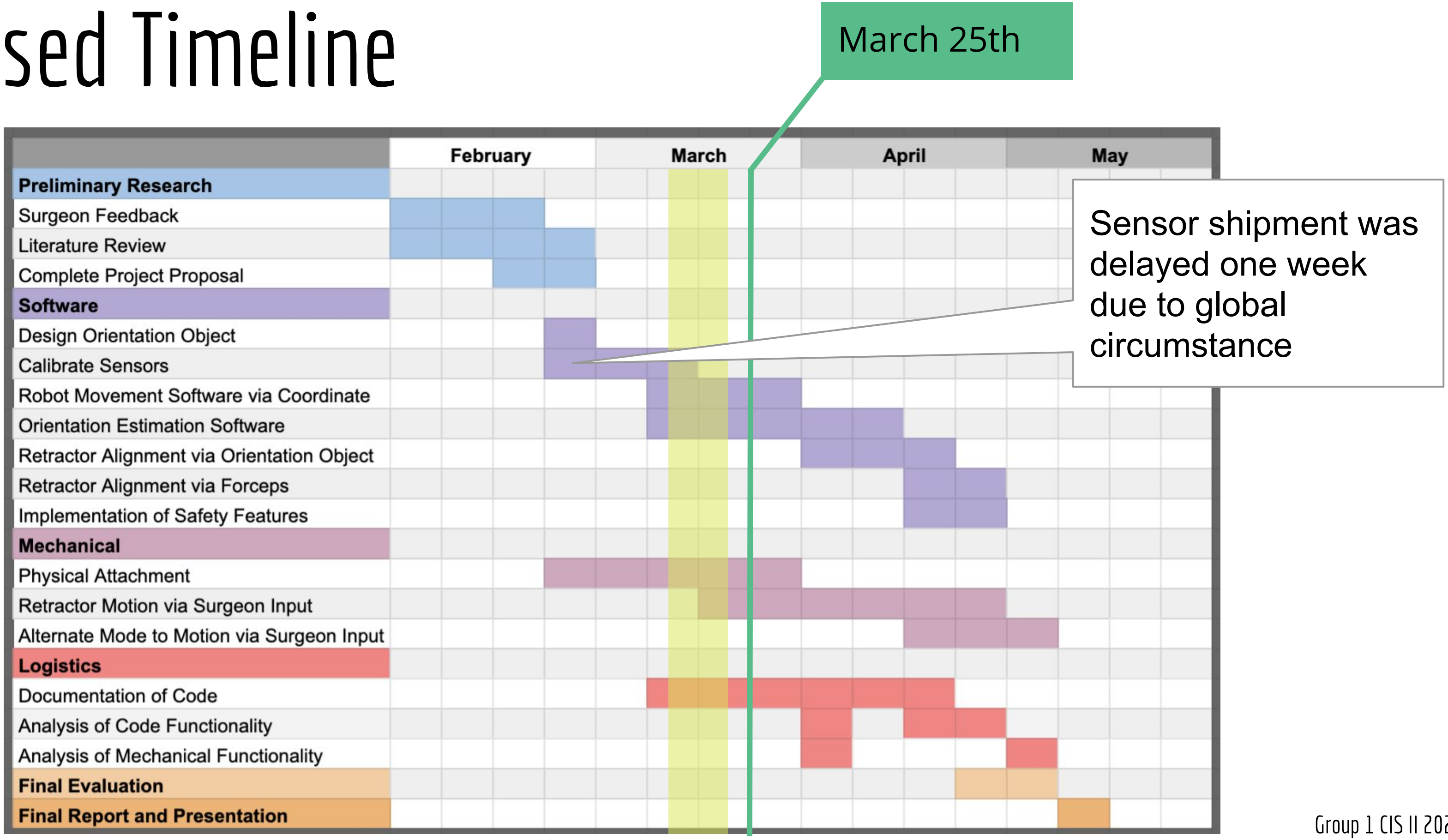
Project Status

Checkpoint	Deadline	Status
Hardware determination and budgeting creation. Orders placed.	3/5	Complete 3/5
Electrical system assembly.	3/12	Complete 3/18
IMU calibration and static orientation trials.	3/12	Complete 3/22
Analysis of Madgwick orientation estimation algorithms.	3/25	Complete 3/22
Physical attachment prototype. (Min Deliverable)	3/31	Prototype Complete 3/25
Motor movement, including keypad input.	4/30	Prototype Complete 3/25
Motor movement on inputted Euler Angles.	4/9	On Track
Orientation Estimation Software (Min Deliverable)	4/14	On Track

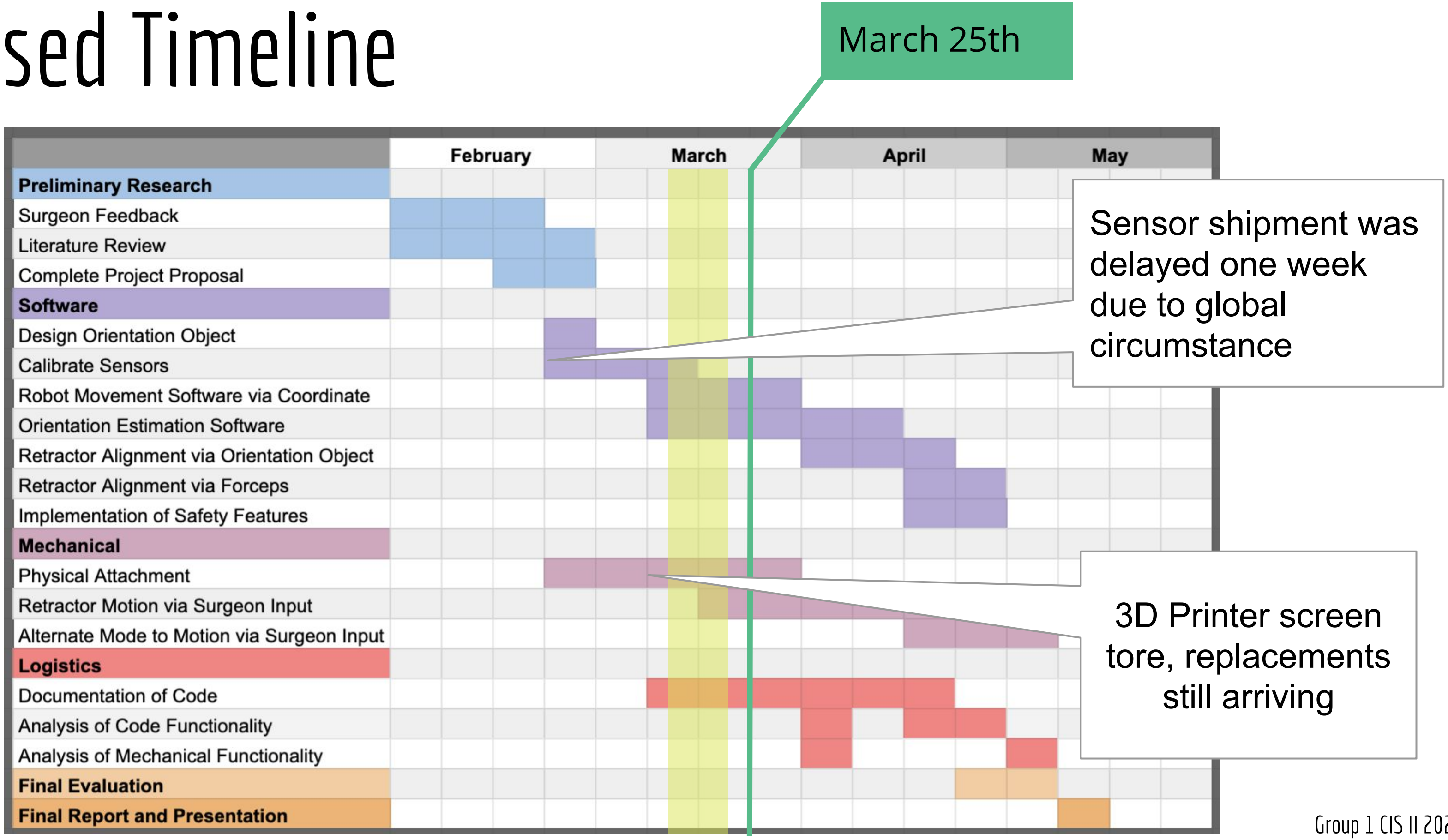
Proposed Timeline



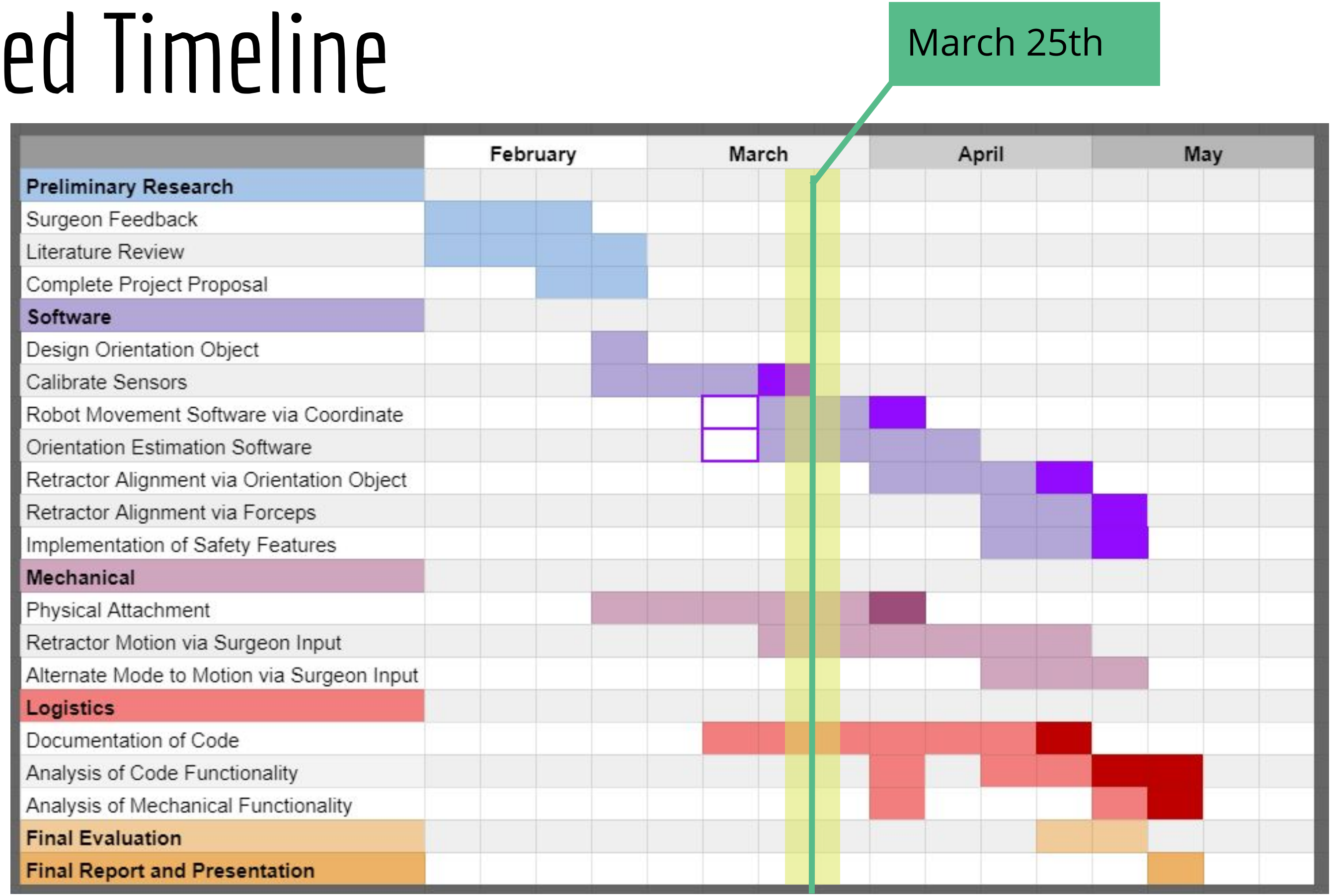
Proposed Timeline



Proposed Timeline



Updated Timeline



Dependencies

Dependency	Need	Status	Followup	Contingency Plan	Deadline
Leyla Retractor	Base for robot	Acquired	Put in Request through Dr. Cohen	Have a partially functional Leyla	2/28 Complete
3D Printer	Manufacturing	Acquired	N/A	If broken, look to use one owned by school	2/1 Complete
Arduinos and Motors	Robot Design and Data Collection	Acquired	Purchase ASAP, CortiTech budget	If breaks, need to purchase more ASAP (Also have extras)	2/24 - Ordered 3/15 - Complete
9 DoF IMUs, wires, breadboard, and USB port	Robot Design and Data Collection	Acquired	Purchase ASAP, CortiTech budget	If breaks, need to purchase more ASAP (Also have extras)	2/24 - Ordered 3/15 - Complete
Space Benchtop models	Testing	Preliminary models acquired	Request from CortiTech later if need better models	Will test for movement without brain model	4/5
3D Printer Films	Robot Design	Need to Request ASAP, but using a different printer	Request from CortiTech later if need more film	Right now we are going to be using a friend's 3D printer while we wait for more film	3/31
Surgical Tools	Retrofitting forceps and Testing	Need to Request ASAP	Request from Dr. Cohen or Dr. Fouda	Request from Cortitech	4/20

Current Approach: Mechanical Design (2-axis gimbal)

- Manufacturing in progress

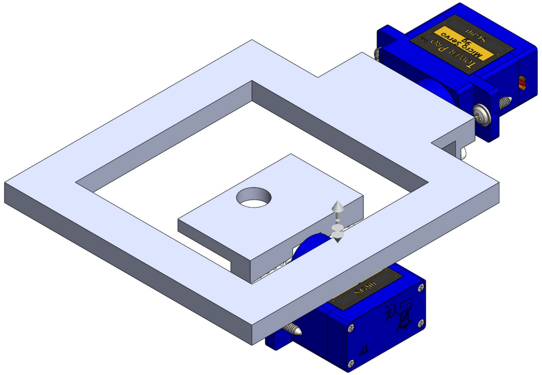
  (3D printing delays due to printer film replacing)
  - Upscaled design - motion validation
  - Leyla attachment useful in actual size

- Mock retractor

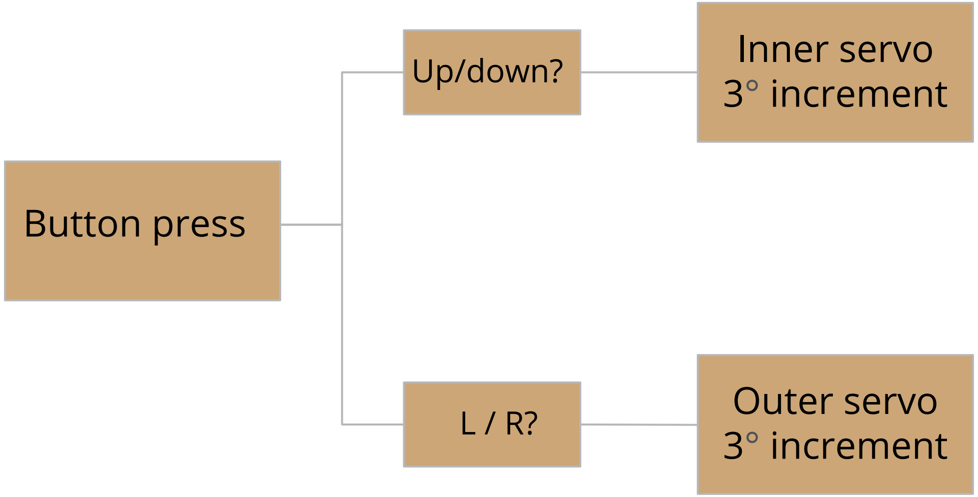
  (useful for accuracy of motion validation)

- Temporary replacement of stepper motors with servo

  (temporary 3D printer's resolution is coarse)



Current Approach: Actuator Control Design



Current Approach: Software Design - Calibration

- Orientation estimation requires accurate magnetometer readings so we had to calibrate our sensors prior to use.
- Tried MotionCal to automatically calibrate our sensors
    - However, after using software and performing trials, it could not upload to the Arduino (memory)
- Instead, we had to calibrate using the Adafruit SensorLab Arduino library
    - Ran 20 trials with their calibration example “mag_hardiron_simplecal.ino” to collect magnetic hard offset values
    - We then averaged our results, and wrote them back to the Arduino

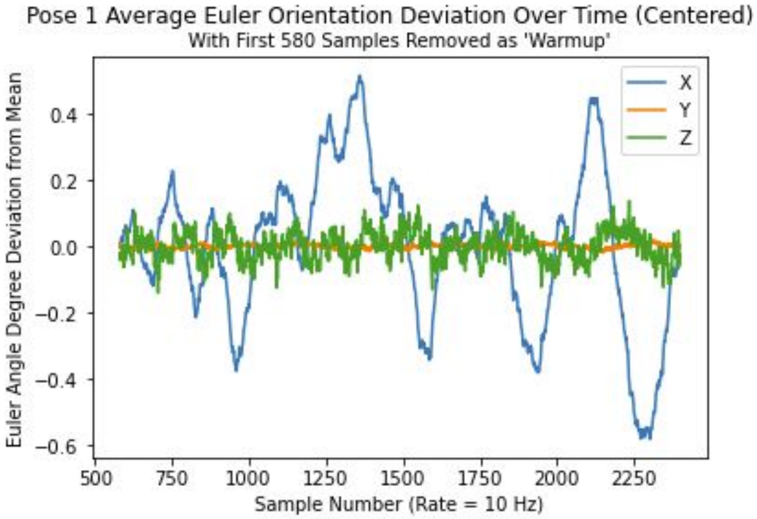
TrialNum	xHardOffset	yHardOffset	zHardOffset
1	-14.55	-45.85	-82.5
2	-17.35	-47.65	-86.2
3	-16.4	-49.75	-81.75
4	-16.55	-48.6	-82.2
5	-16.1	-47.95	-82.45
6	-15.4	-47.1	-81.3
7	-16.5	-46.75	-80.15
8	-15.75	-50.65	-82.25
9	-15.95	-47.5	-87.15
10	-16.65	-48.2	-83.2
11	-15.3	-45.65	-85.25
12	-15.65	-48.75	-85.5
13	-15.95	-48.35	-84.35
14	-16.05	-48.55	-81.25
15	-15.65	-45	-85.3
16	-15.05	-44.9	-85.95
17	-16.55	-47.95	-85.4
18	-15.6	-45.9	-81.25
19	-15.5	-47.8	-82.35
20	-15.55	-45.55	-82.8
Average	-15.9025	-47.42	-83.4275

Current Approach: Software Design - Orientation

- To estimate orientation, we are fusing data from the IMU
- The Madgwick Filter and Mahony Filter are 2 very popular filters for orientation estimation with IMUs
- Using the Arduino library Adafruit AHRS, we can estimate the orientation of the IMU for both the Madgwick and Mahony filters
- Right now we are conducting static trials (and soon dynamic trials) to compare the performance of the two filters, as well as determine the best positioning of our sensor.
- Created library of functions to analyze the data efficiently with documentation and unit tests (Available on private Github)

<u>Note</u>: We measure orientation with Euler angles (deg)

```
Average Absolute Euler Degree Deviation in X: 0.1801
Average Absolute Euler Degree Deviation in Y: 0.0050
Average Absolute Euler Degree Deviation in Z: 0.0353
```



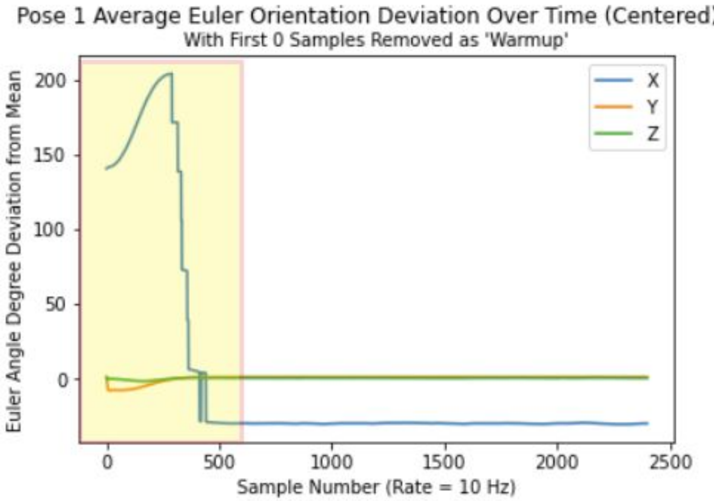
Note: This is the results of our best pose, we tested all poses 10 times for 5 min per run

Issues with Orientation

Two issues arose during testing:

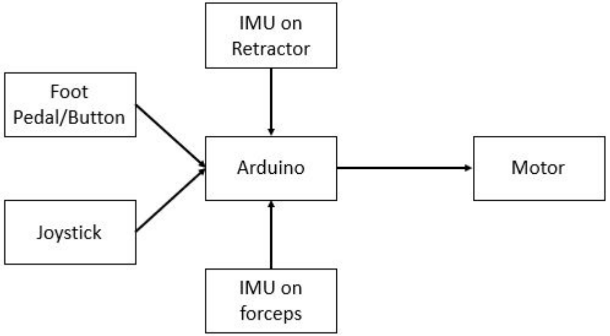
1. Orientation estimates fluctuate wildly during first minute of every experiment.
    a. Current fix: Just wait one minute before analysis (possibly warm up?)
2. When the IMU is in certain poses, the orientation readings change periodically when IMU is still.
    a. Fix: We will place the IMUs at the optimal orientation at the start of the procedure. Procedure only moves 15 degrees at most so should not become an issue.

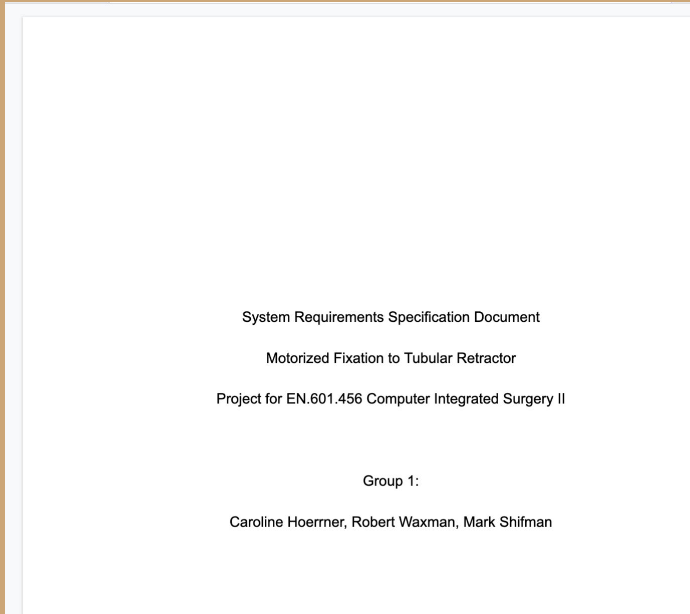
```
Average Absolute Euler Degree Deviation in X: 49.5905
Average Absolute Euler Degree Deviation in Y: 1.3236
Average Absolute Euler Degree Deviation in Z: 0.2939
```



Documentation: Software Requirements Specification

- Product Features: realign tubular retractor
    - Via control pad / joystick
    - Via orientation object
    - Via surgical forcep
- Operating Environment




System Requirements Specification Document

Motorized Fixation to Tubular Retractor

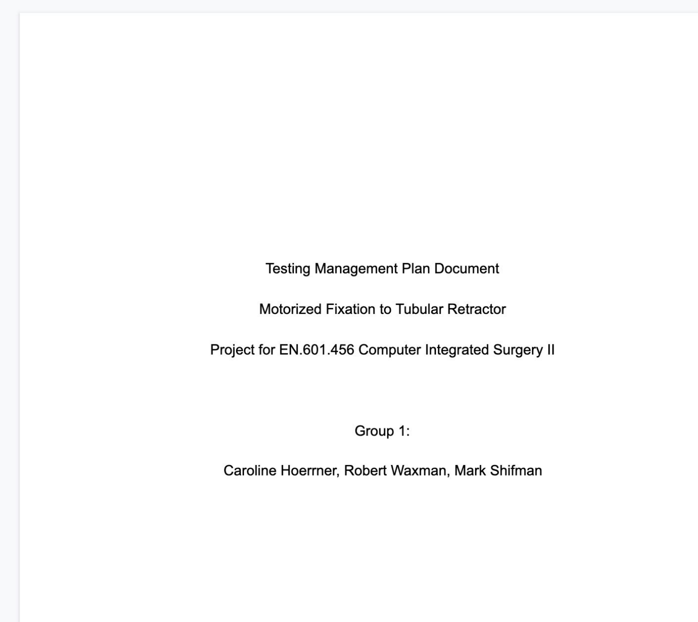
Project for EN.601.456 Computer Integrated Surgery II

Group 1:

Caroline Hoerrner, Robert Waxman, Mark Shifman

Documentation: Testing Management Plan

- Unit testing software
- Benchtop system tests
  - Force testing for max retractor angle (quantitative)
  - Clinical usability evaluation (qualitative)
- More concrete testing schedule to come...



Testing Management Plan Document

Motorized Fixation to Tubular Retractor

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Group 1:

Caroline Hoerrner, Robert Waxman, Mark Shifman

Management Plan

- Weekly Team Meetings (Robby, Caroline, Mark)
    - Supplemental messenger communication daily
- Bi-weekly update meetings with Dr. Krieger
- Bi-weekly update meetings with CortiTech
- Messaging questions to Dr. Fouda as needed

Responsibility Distribution

Mark	Primarily responsible for mechanical design including: ● Design (CAD) and manufacturing of the physical attachment ● Design and circuit construction of the motor system ● Tactile input based motor movement
Caroline	Responsible for software along with Robby, but focused on: ● Sensor calibration ● Tuning motor control ● Coordinate based motor movement
Robby	Responsible for software along with Caroline, but focused on: ● Sensor calibration ● Orientation estimation algorithm ● Orientation based motor movement

Thanks :) Questions?