Motorized Fixation to Tubular Retractor in Brain Surgery

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EN.601.456
Computer Integrated Surgery II

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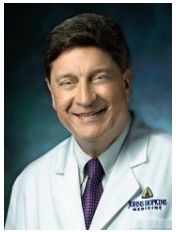
Project Plan Presentation

Team



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Background

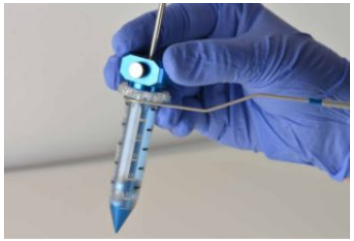
"Brain spatulas" can impart excessive pressure on the brain, leading to injury.

~ 63K cases/year cause retraction-induced injury.

$2,500/day increased hospital stay results in a **$3 billion burden** on US healthcare system.

- Modern brain surgery utilizes "tubular retractors" to access deep-seated lesions

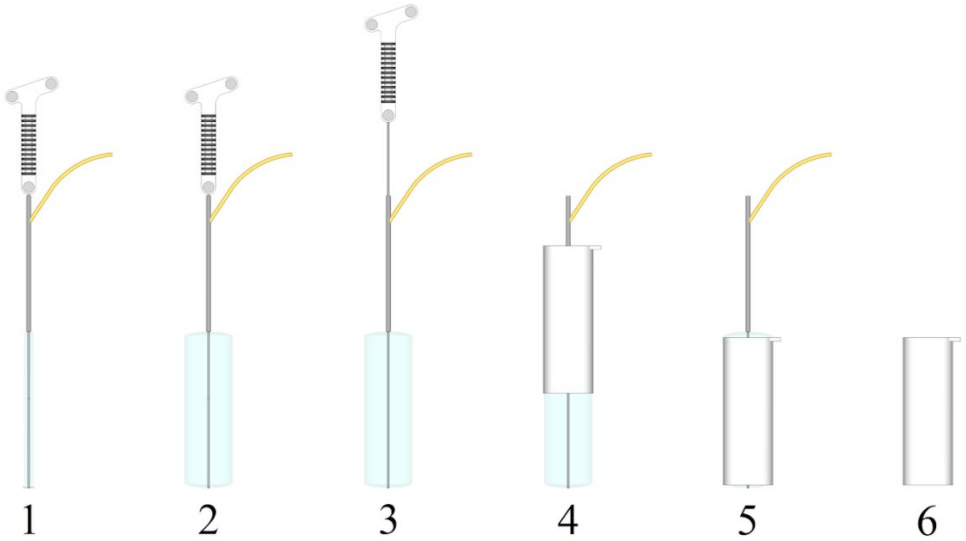
- Retractors are either unconstrained or attached to shaky manual devices

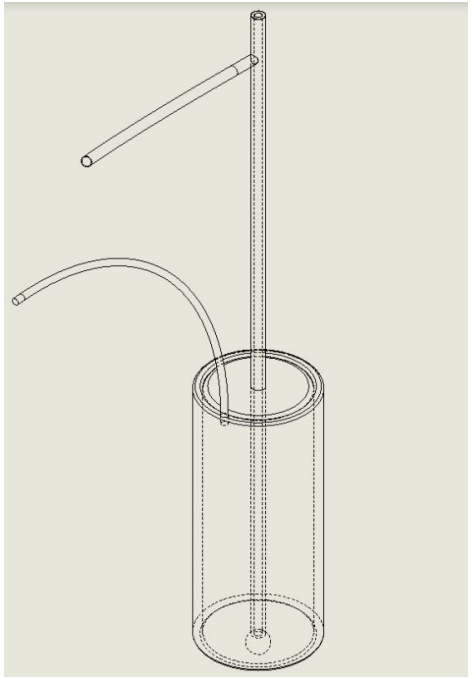


Prior Work

CortiTech

Minimally invasive retractor insertion through uniform balloon dilation





Latest invention: concentric inflating balloon

Our Goal this Semester

- Tubular retractors require repositioning during procedures
- Minimal white matter disruption is associated with fewer neurological symptoms post procedure (J. Zhong et al. (2004))
- Current tubular retractor designs have limited maneuverability (Shapiro et al. (2020))

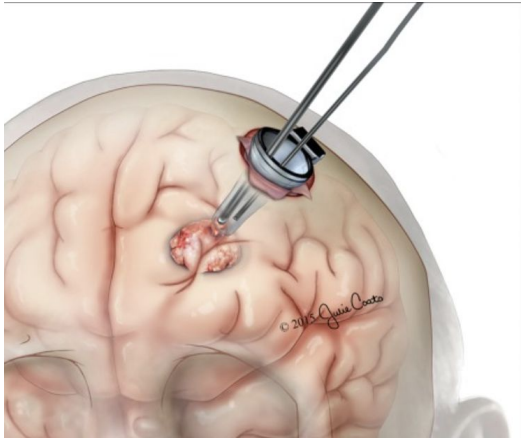
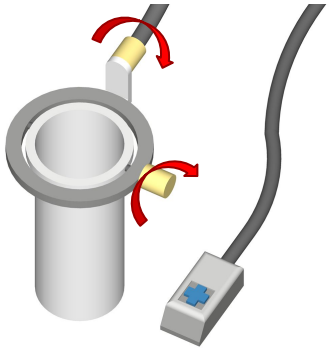


Image sourced from White et al. (2017)

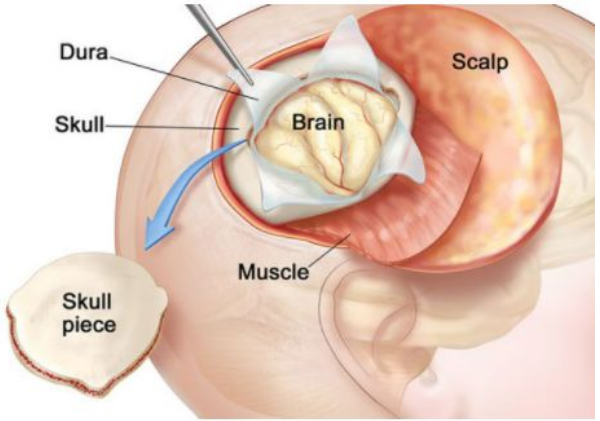
Our Goal this Semester

- Automate retractor positioning to maximize stability and minimize unnecessary disruption of cerebral tissue
- Create intuitive control system for seamless surgeon interfacing



Technical Approach (stabilization)

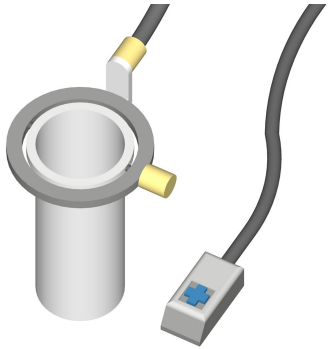
Theme: make the solution harmless.



Basically, we want to *stay out of the surgeon's way*.

Technical Approach (control)

Initial proof of concept: directional pad control

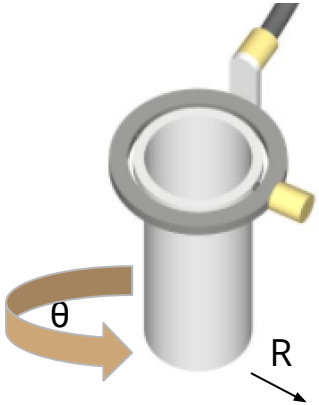


Alternate control method, contingent upon clinical opinion

Rotation about 2 axes:

Rotation about X

Rotation about Y



Technical Approach (instrumental synchronization)

- Sensors will be placed onto the orientation object and then later directly onto the forceps
  - Plan to use IMUs to capture gyroscope and accelerometer data
- Will follow similar procedure from Contreras-Rodriguez et al. (2017) to estimate the orientation of the tool in 3D space by combining the different data from the IMU and using a Direct Cosine Matrix
  - This is only initial plan, need to do more literature review before finalizing procedure
- When a doctor wants to realign the tubular retractor, they will hold their forceps at the desired angle and then press a button
  - We will use the estimated orientation calculated above and slowly move the retractor to that desired orientation using the motors

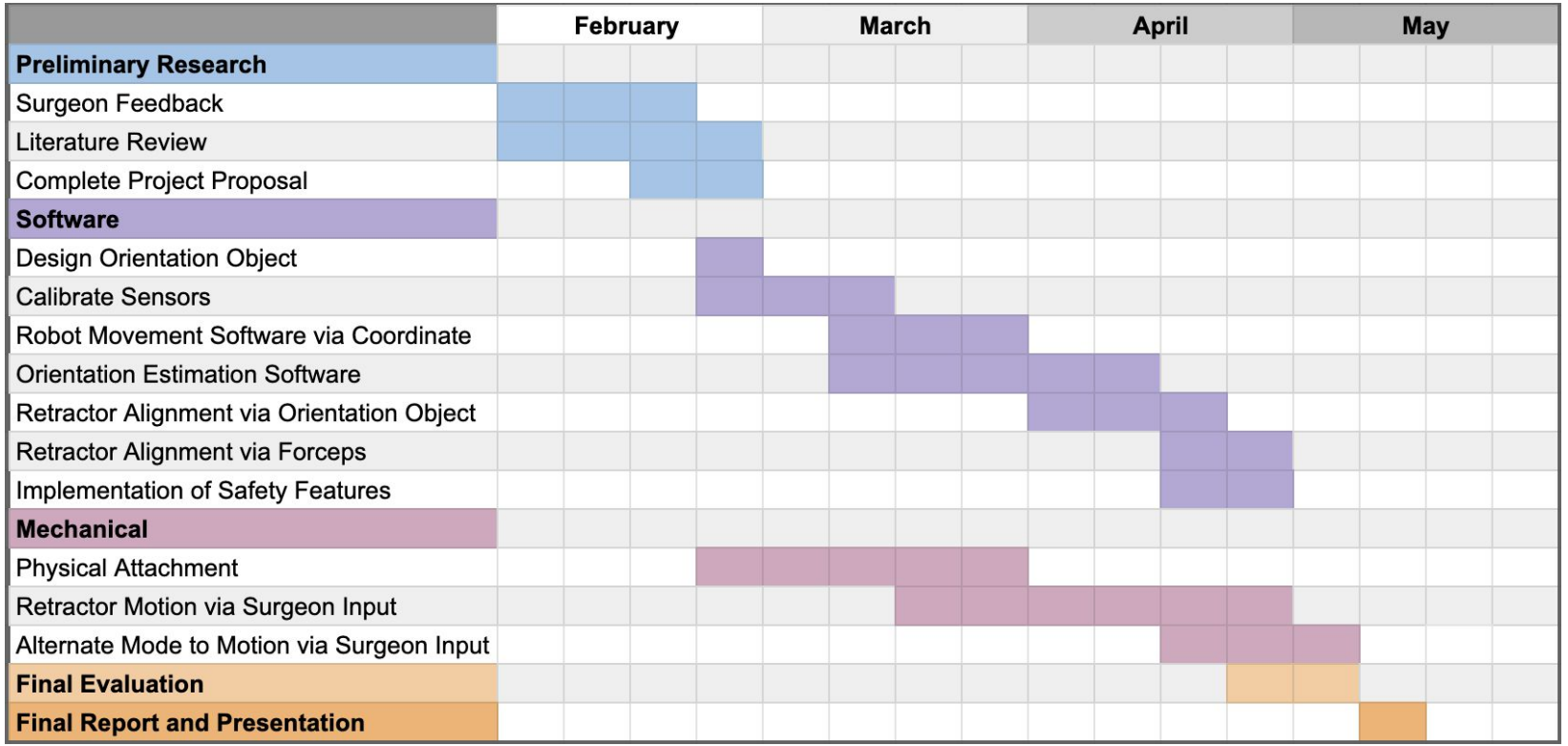
Deliverables

- Minimum:
  - Develop hardware to allow for 2 DOF movement of the tubular retractor
  - Design and implement rudimentary software to align a tubular retractor using motors, based on computer inputs such as a desired coordinate, set of angles, or a control pad/joystick
- Expected:
  - Design an “orientation object” for collecting orientation/movement data using IMUs
  - Design and implement software that filters and analyzes data collected from the “orientation object” and determines the relative orientation of the object and moves the retractor to a matching orientation when a button or foot pedal is pressed
- Maximum:
  - Retrofit surgical forceps with IMUs (without hindering their functionality)
  - Adjust software so that will it filter and analyze the data collected from the forceps and move in the same was as it did with the calibration object (New constraints in this system)
  - Implement safety features to limit velocity, maximum angle, and prevent shaky movements from surgeons
  - Design and implement software that allows for retractor to change re-align based on the view of a surgical microscope

Dependencies

Dependency	Need	Status	Followup	Contingency Plan	Deadline
Leyla Retractor	Base for robot	Unacquired	Put in Request through Dr. Cohen	Have a partially functional Leyla	2/28
3D Printer	Manufacturing	Acquired	N/A	If broken, look to use one owned by school	2/1
Microcontroller, Actuators, Sensors, misc.	Robot Design and Data Collection	Unacquired	Purchase ASAP, CortiTech budget	If breaks, need to purchase more ASAP	2/24
Testing	Space Benchtop models	Preliminary models acquired	Request from CortiTech later if need better models	Will test for movement without brain model	4/5

Timeline


February
March
April
May
Preliminary Research
Surgeon Feedback
Literature Review
Complete Project Proposal
Software
Design Orientation Object
Calibrate Sensors
Robot Movement Software via Coordinate
Orientation Estimation Software
Retractor Alignment via Orientation Object
Retractor Alignment via Forceps
Implementation of Safety Features
Mechanical
Physical Attachment
Retractor Motion via Surgeon Input
Alternate Mode to Motion via Surgeon Input
Final Evaluation
Final Report and Presentation

Management Plan

- Weekly meeting with Dr. Axel Krieger at 4 pm on Fridays
- Weekly meeting with full Cortitech team at 9:30 pm on Thursdays
- Team meeting 1-2 times a week
  - Currently, looks like Monday nights at 8 pm onward
  - Meet later throughout the week if required
- Biweekly meeting with Dr. Mohammed Fouda
  - Time still needs to be worked out
- Meetings with Dr. Cohen as and when required

Responsibility Distribution

- Mark
  - Mainly responsible for the mechanical design of our project, including:
    - Design, construction, and actuation of motorized fixation device
    - Design and construction of “orientation object”
    - Time permitting: Retrofitting of sensors onto surgical forceps, joystick control
- Caroline and Robby
  - Mainly responsible for the design and development of software, including:
    - Initial coordinate based movement software
    - Sensor calibration
    - Filtering and analysis of sensor data
    - Orientation based motor movement
  - Will also assist Mark with mechanical development and prototyping as needed

Reading List

Bander, Evan D., et al. “Utility of Tubular Retractors to Minimize Surgical Brain Injury in the Removal of Deep Intraparenchymal Lesions: a Quantitative Analysis of FLAIR Hyperintensity and Apparent Diffusion Coefficient Maps.” Jns, American Association of Neurological Surgeons, 1 Apr. 2016, thejns.org/view/journals/j-neurosurg/124/4/article-p1053.xml?body=pdf-16286.

L. A. **Contreras-Rodriguez**, R. Muñoz-Guerrero and J. A. Barraza-Madrigal, "Algorithm for estimating the orientation of an object in 3D space, through the optimal fusion of gyroscope and accelerometer information," 2017 14th International Conference on Electrical Engineering, Computing Science and Automatic Control (CCE), Mexico City, 2017, pp. 1-5, doi: 10.1109/ICEEE.2017.8108879.

Doulgeris JJ, Gonzalez-Blohm SA, Filis AK, Shea TM, Aghayev K, Vrionis FD. “Robotics in Neurosurgery: Evolution, Current Challenges, and Compromises. Cancer Control.” 2015 Jul;22(3):352-9. doi: 10.1177/107327481502200314. PMID: 26351892.

Echeverry, Nikolas et al.” Intracranial Tubular Retractor Systems: A Comparison and Review of the Literature of the BrainPath, Vycor, and METRx Tubular Retractors in the Management of Deep Brain Lesions,” World Neurosurgery, Volume 143, 2020, Pages 134-146, ISSN 1878-8750, https://doi.org/10.1016/j.wneu.2020.07.131. (https://www.sciencedirect.com/science/article/pii/S1878875020316521)

Manon **Kok**, Jeroen D. Hol and Thomas B. Sch¨on (2017), ”Using Inertial Sensors for Position and Orientation Estimation”, Foundations and Trends in Signal Processing: Vol. 11: No. 1-2, pp 1-153. http://dx.doi.org/10.1561/2000000094

Yi C, Ma J, Guo H, Han J, Gao H, Jiang F, Yang C. Estimating Three-Dimensional Body Orientation Based on an Improved Complementary Filter for Human Motion Tracking. Sensors (Basel). 2018 Nov 4;18(11):3765. doi: 10.3390/s18113765. PMID: 30400359; PMCID: PMC6263778.

References

[1] White, Tim et al. “Frameless Stereotactic Insertion of Viewsite Brain Access System with Microscope-Mounted Tracking Device for Resection of Deep Brain Lesions: Technical Report.” *Cureus* vol. 9,2 e1012. 4 Feb. 2017, doi:10.7759/cureus.1012

[2] Shapiro, Stephen et al. “Use of Vycor Tubular Retractors in the Management of Deep Brain Lesions: A Review of Current Studies.” World Neurosurgery, Volume 133, 2020, Pages 283-290, ISSN 1878-8750, https://doi.org/10.1016/j.wneu.2019.08.217.

[3] Zhong, Jun & Dujovny, Manuel & Perlin, Alfred & Perez-Arjona, Eimir & Park, Hun & Diaz, Fernando. (2004). Brain retraction injury. Neurological research. 25. 831-8. 10.1179/016164103771953925.

[4] L. A. Contreras-Rodriguez, R. Muñoz-Guerrero and J. A. Barraza-Madrigal, "Algorithm for estimating the orientation of an object in 3D space, through the optimal fusion of gyroscope and accelerometer information," 2017 14th International Conference on Electrical Engineering, Computing Science and Automatic Control (CCE), Mexico City, 2017, pp. 1-5, doi: 10.1109/ICEEE.2017.8108879.