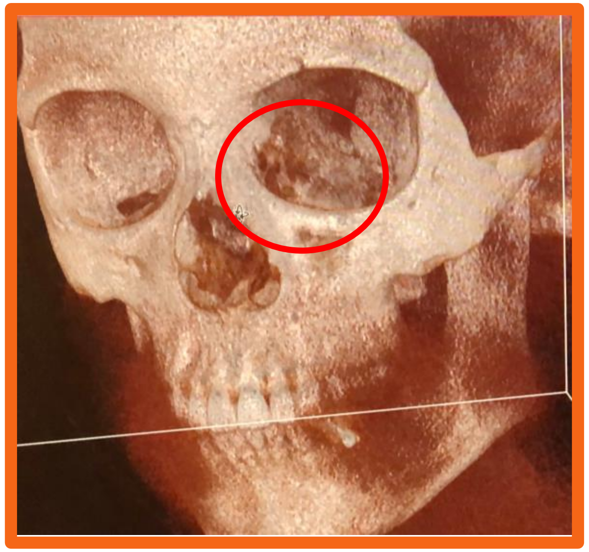
AUGMENTED REALITY AIDED CRANIOFACIAL SURGERY – MODIFIED PLAN

CIS2 PROJECT PROPOSAL

Team Members: Nikhil Dave & Yihao Liu

Mentors: Dr. Peter Kazanzides, Ehsan Azimi, Dr. Cecil Qiu, Dr. Shashank Reddy

Background



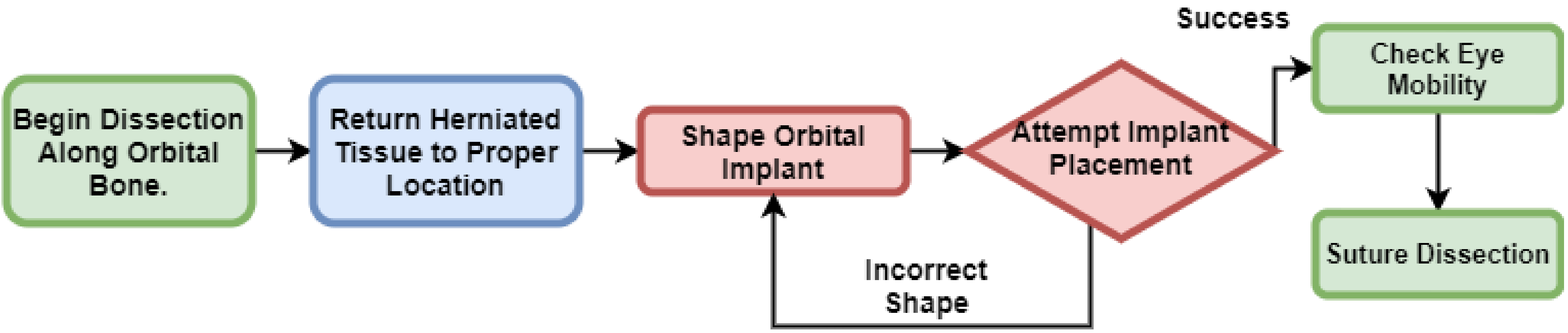
Orbital Floor Fracture:

- Due to pressure on the eye from blunt trauma, the medial wall and orbital floor can fracture.
- Fracture repair requires manipulation of delicate and complex structures in a tight, compact space.
- Surgeons struggle with visibility in the confined region.

Reconstruction:

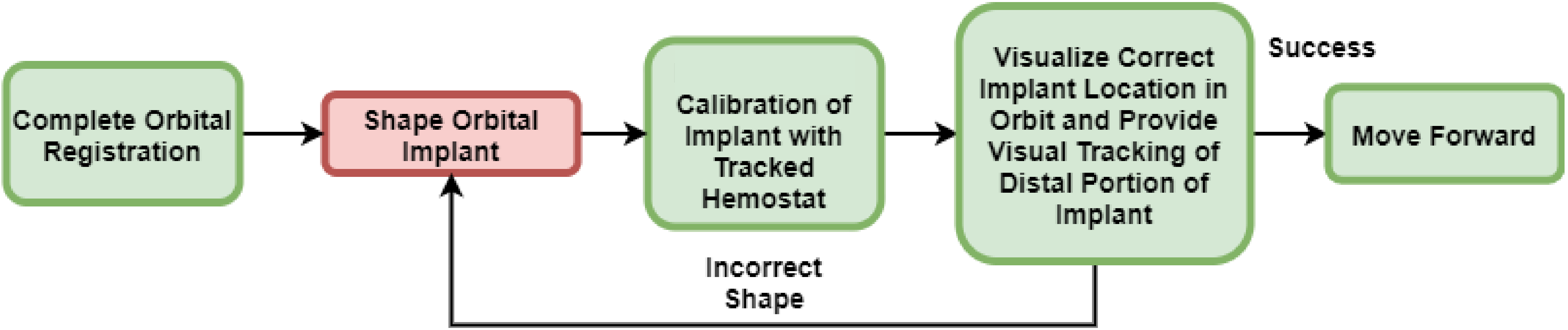
- A concave plate is placed along the wall of the eye socket to prevent tissue from entering fracture cavity.
- Hard to place.
  - Low visibility
- Misplacement can result in injury to sensitive tissue.
- Long operating time.

Current Intraoperative Surgical Workflow



Length of Time for Completion Gradient:
GREEN ~ Standard
BLUE ~ Slow Step
RED ~ Time Limiting Step

Simplifying Implant Placement



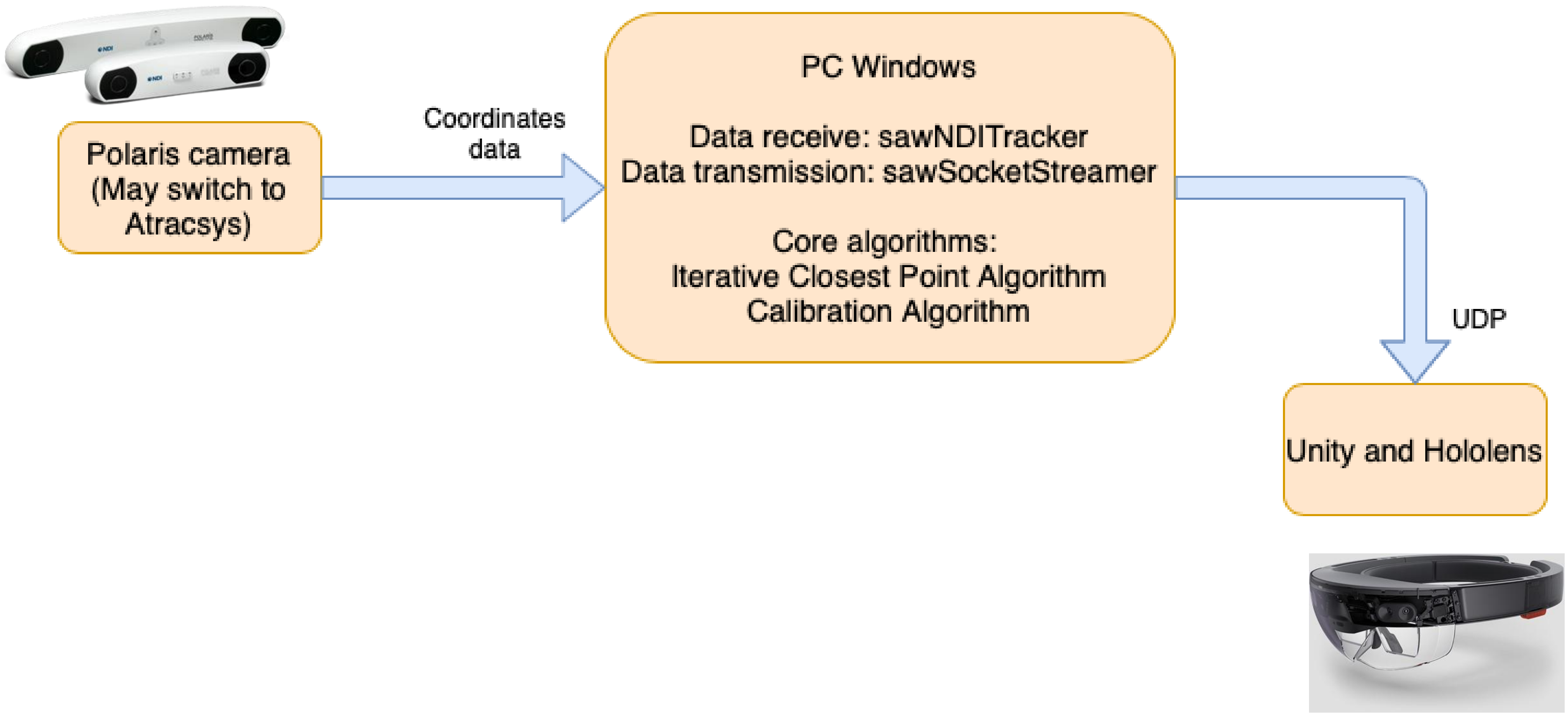
Length of Time for Completion Gradient:

GREEN ~ Standard

BLUE ~ Slow Step

RED ~ Time Limiting Step

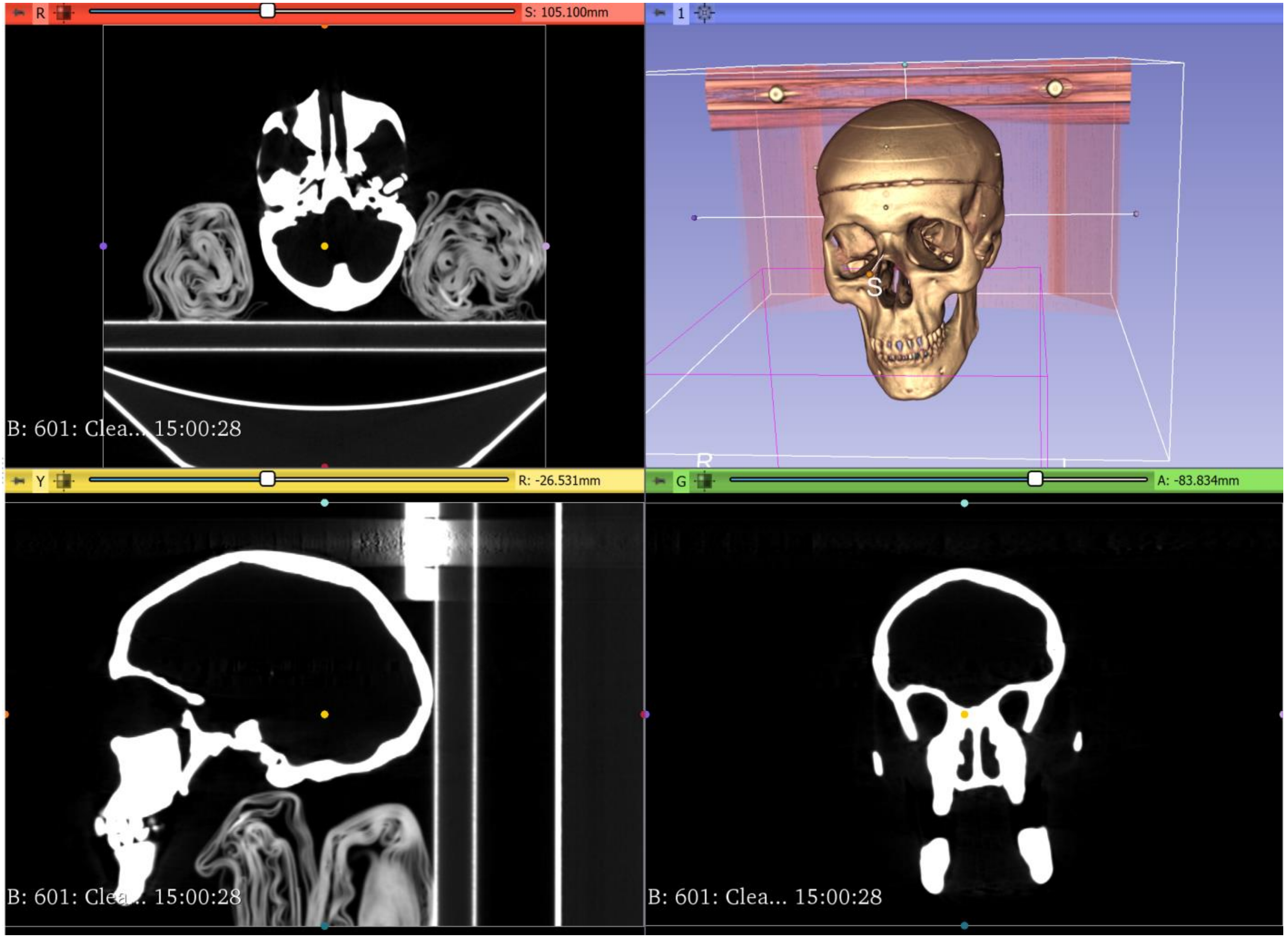
Preliminary System Components Diagram



Progress: Visualization in 3D-Slicer

Unable to retrieve CT's from clinical partners for skull slices.

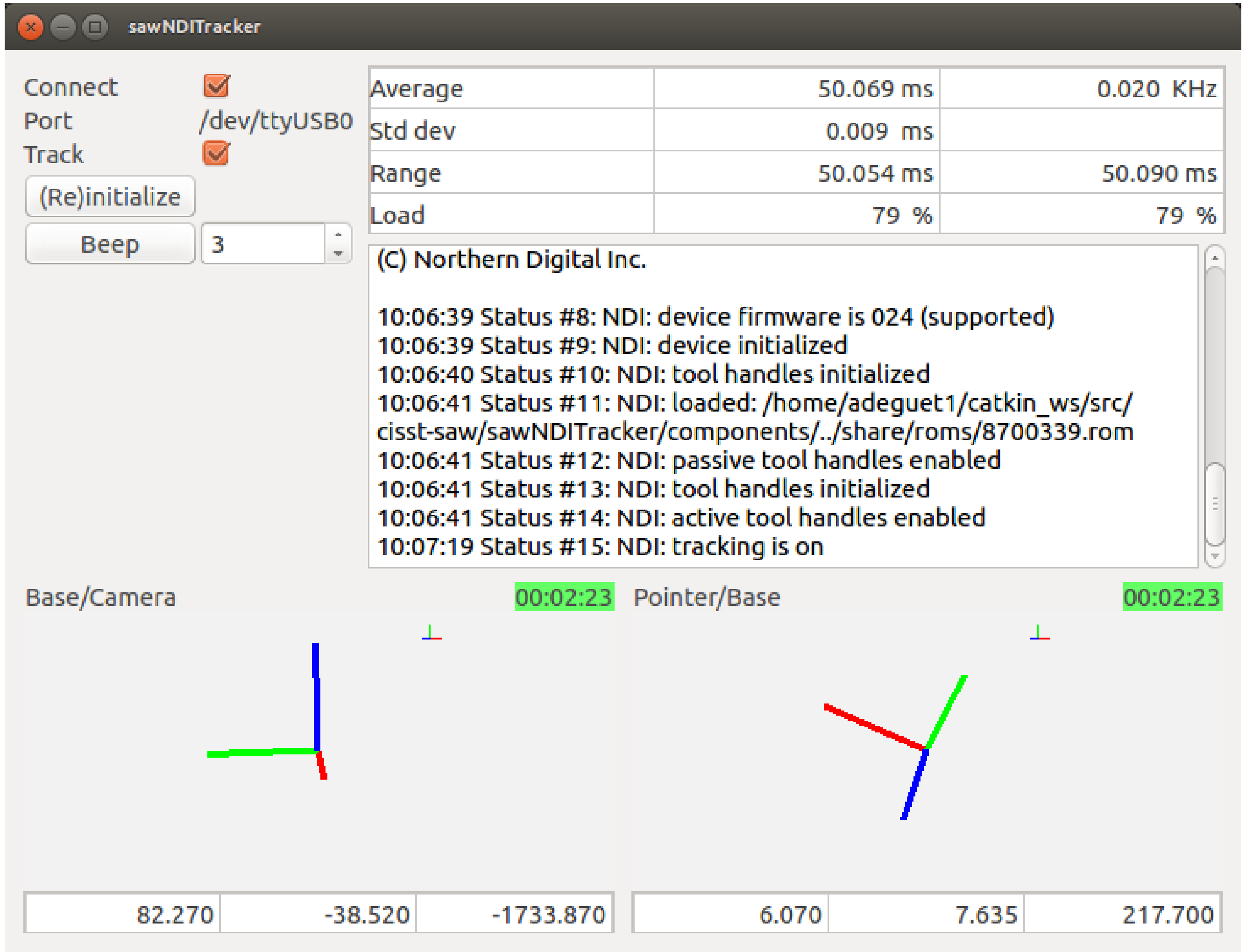
- Using alternative Skull.
- Able to generate STL's
- Working to integrate Open IGT link for updating the visualization.
- Allows for navigation without HoloLens, though we wish to develop both methods.



Progress: Polaris Interface Method

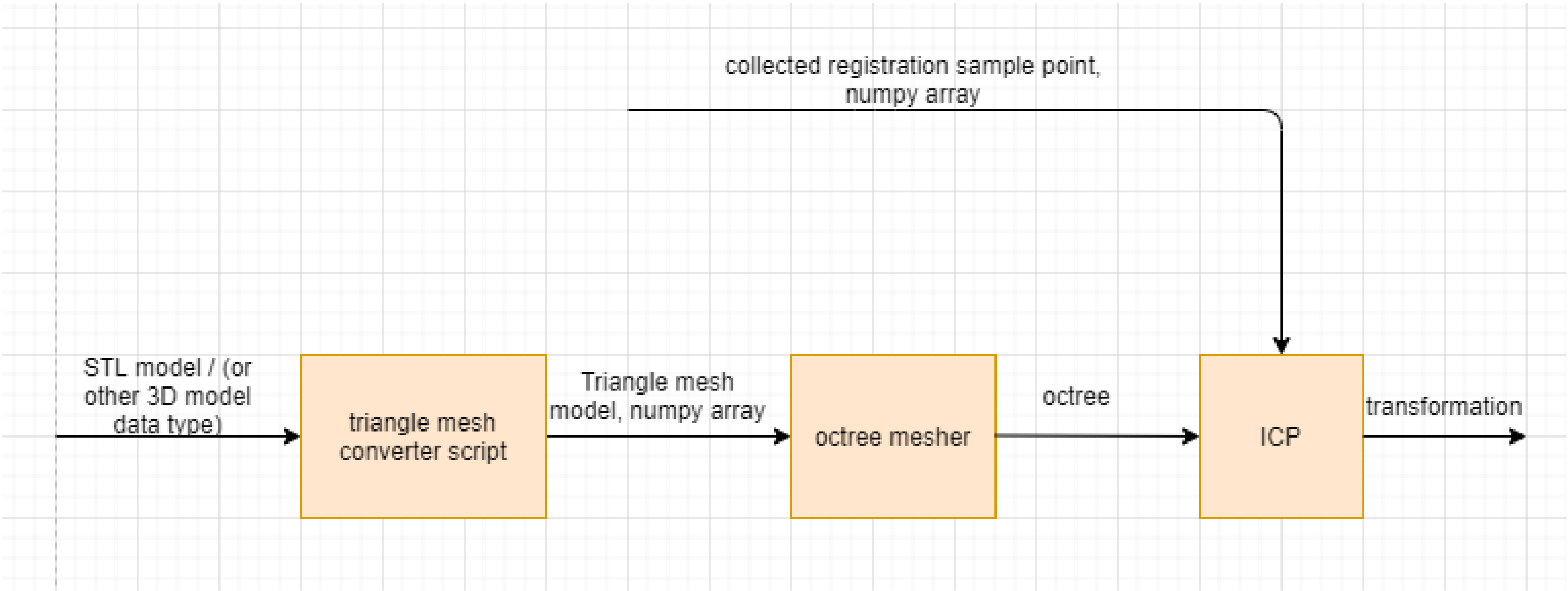
Built sawNDITracker software.

- Able to track Polaris active trackers. (Working on Passive)
- Through communication with ROS, we can extract 6 DOF data of collected points.
- Data acquisition process is simple.
  - Data is parsed and usable directly after point collection. (No time delay)



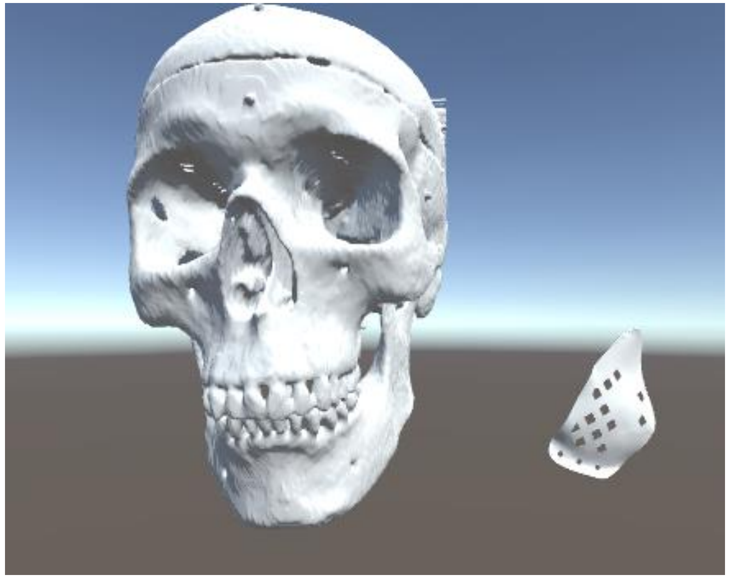
Picture Courtesy of : sawNDITracker Github (Anton Deguet)

Progress: ICP Algorithm

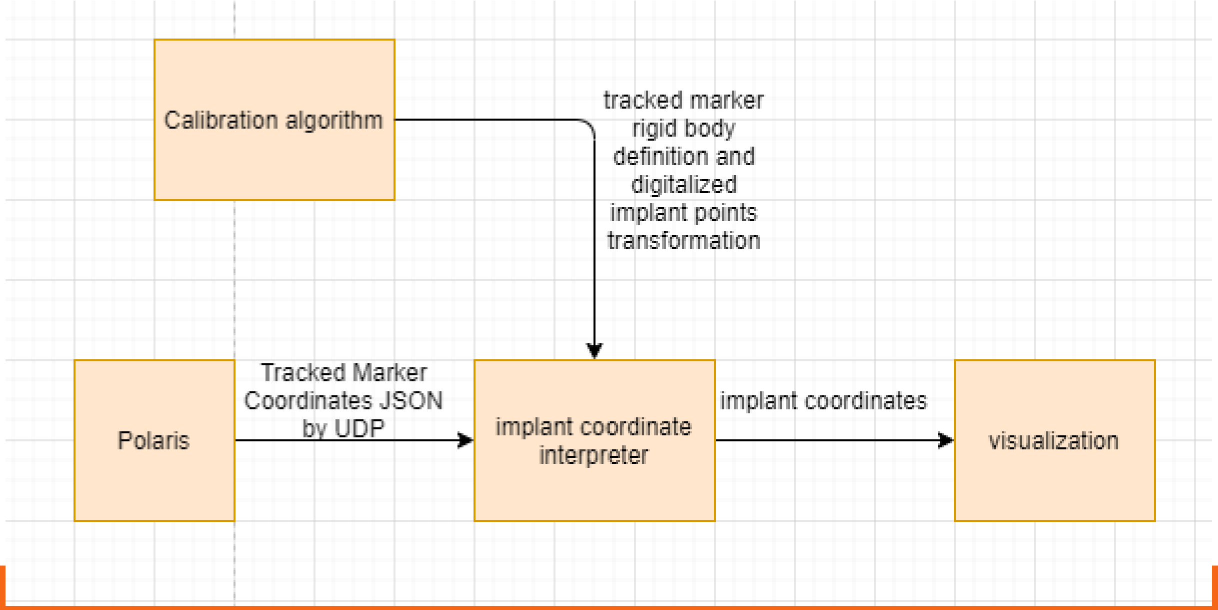


Progress: Unity Development

- Model visualization



- Start C# scripts



COVID-19 Polaris Replacement

- Tracker replacement:
  - Option 1. Camera-based tracker
    - Use checkerboard marker + a webcam
    - HoloLens library
    - Calibrate the intrinsic of a webcam (camera calibration in OpenCV) -> get world reference -> track a checkerboard marker (pose estimation in OpenCV)
    - Need a ground truth to have an accuracy analysis
  - Option 2. Micron
    - https://www.claronav.com/microntracker/

COVID-19 Adjusted Deliverables

The following deliverables are all expected before the end of the semester (final presentation).

Point/surface registration method for orbital socket

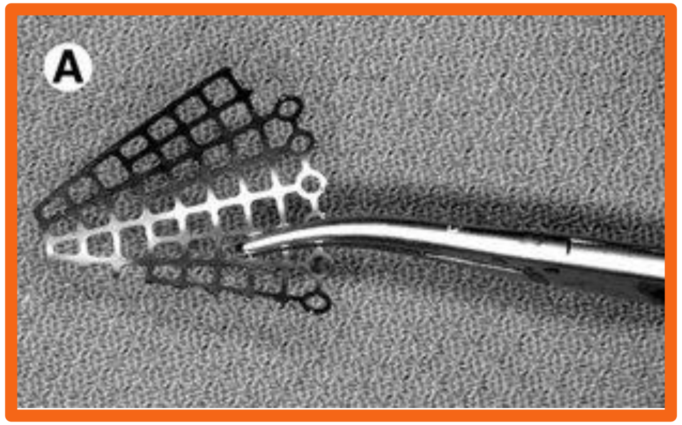
- Min: Target registration error (TRE) <4mm – camera-based tracker accuracy
- Expected: TRE <3mm - camera-based tracker accuracy
- Max: TRE <2mm - camera-based tracker accuracy

Calibration of implant with respect to tracked hemostat

- Min: Pivot Calibration of the distal edge of the implant (only model the distal edge)
- Expected: Use calibrated pointer to model the implant distal edge
- Max: Use calibrated pointer to model the entire implant

Visualize position of tracked implant respect to CT

- Min: Visualization on 3D slicer (Open IGT link on client to update model)
- Expected: Visualization in AR system (Hololens)
- Max: A comparison between 3D slicer implementation and Hololens implementation

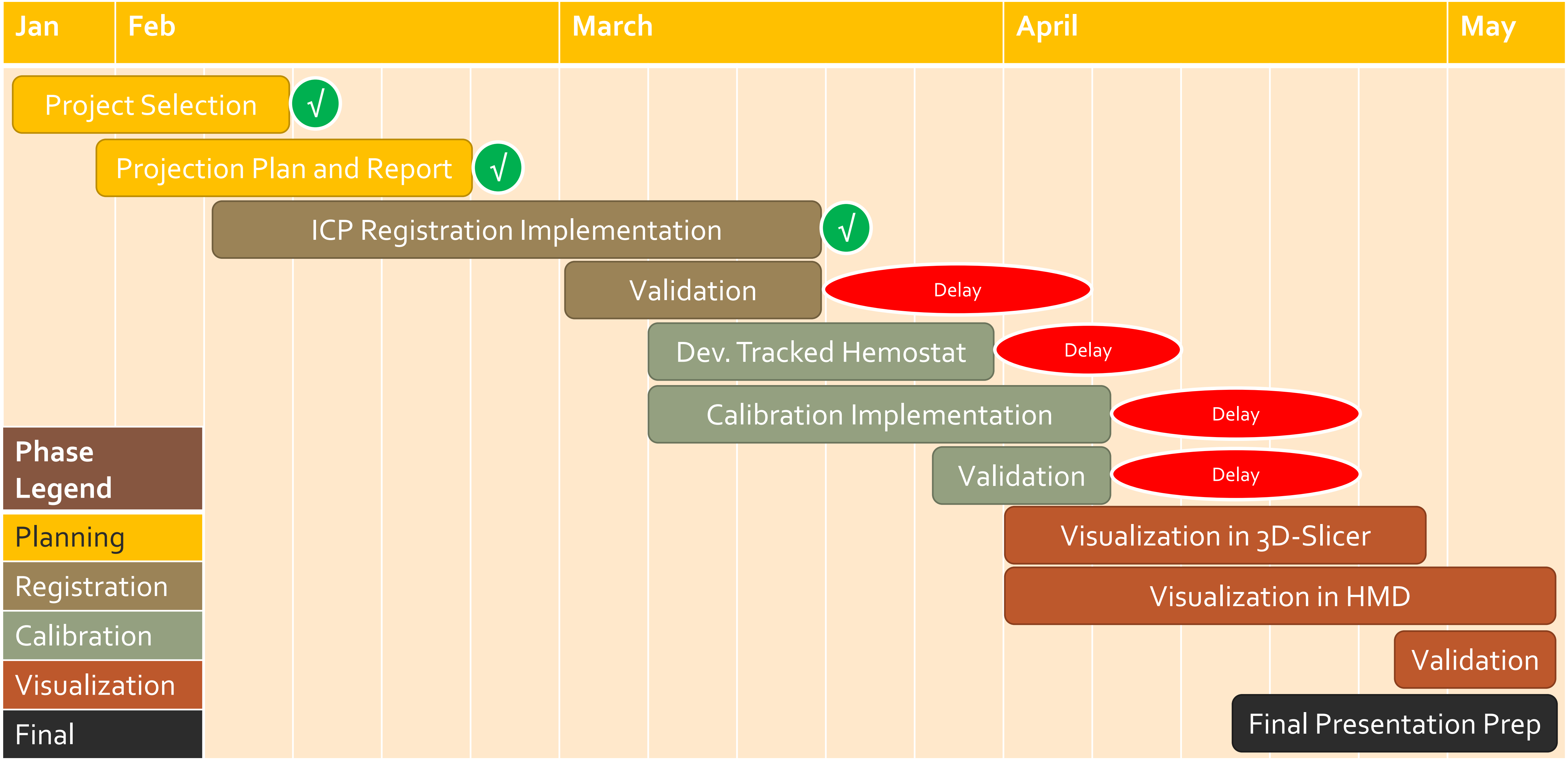


Pictures Courtesy of :
Dr. Peter Kazanzides

[1] Kazanzides, P. (2020). Navigation for Orbital Floor Fracture Repair. [PowerPoint Slides]

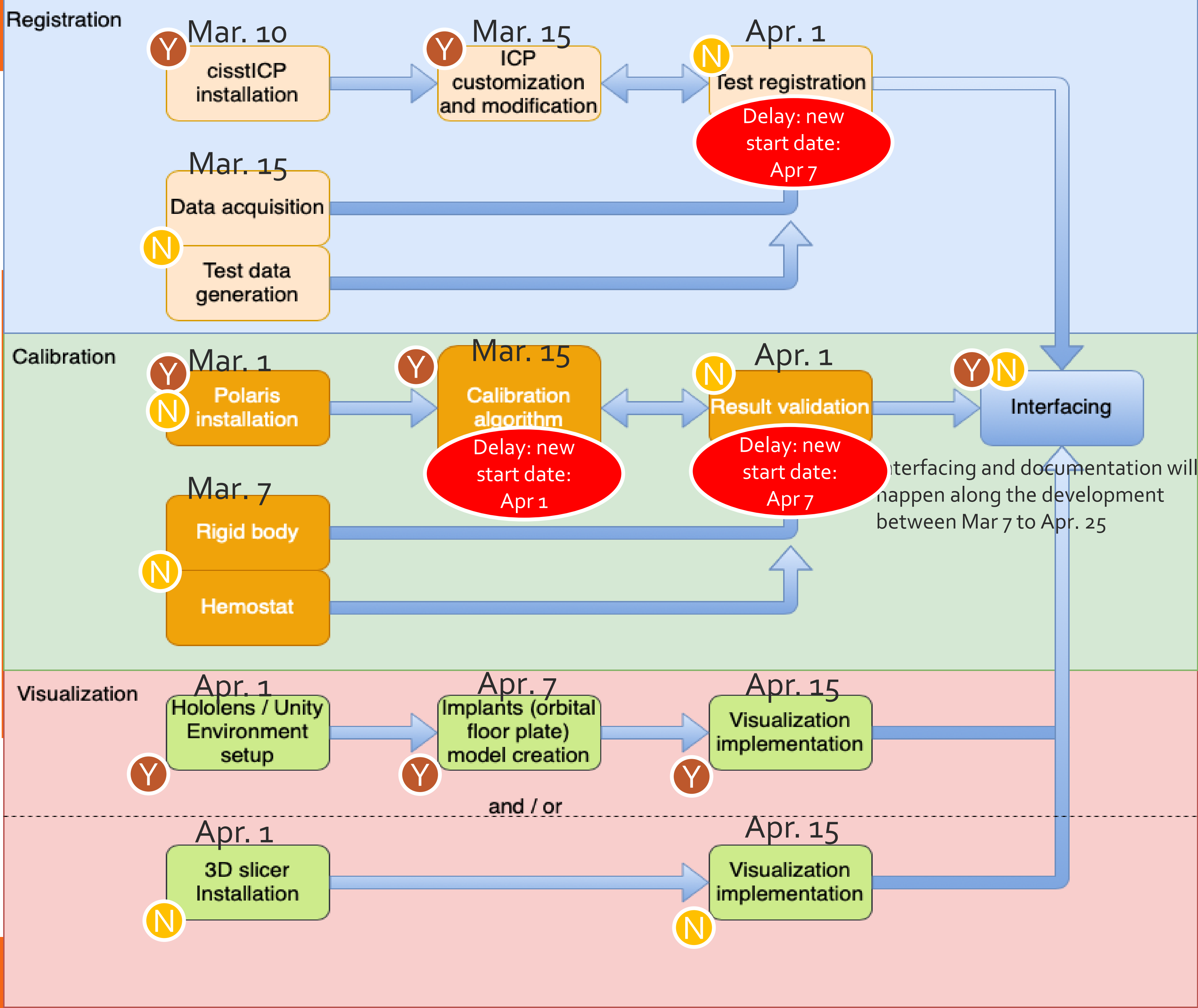
Dependencies	Solution	Alternatives	Status or expected resolve date
Computer with Linux	Use personal computers	Use LCSR cab computer	Resolved
Computer with Windows PC1	Use personal desktop	Seek for borrowing a laptop	Resolved
Computer with Windows PC2 (HMD development)	Use personal computers	Request lab computer	Resolved
Data Back-ups	Use Microsoft OneDrive	Use personal hardrive	Resolved
Learn Workflow from Surgeons	Shadow surgery in OR	Meet with surgeons	Resolved
STL Files for Implants	Coordinate with clinical partners	Find potential online source	Resolved
CT Scans of Skulls for Corresponding STL Files	Coordinate with clinical partners	Obtain other model from Dr. Kazanzides	Resolved (Found Alternative)
Polaris Camera	Coordinate with Anton	Coordinate with Dr. Kazanzides	Resolved
Learn CISST Library ICP	Refer to online material	Work with Anton	Resolved (Went in other direction)
Passive Rigid Body Pointer	Coordinate with Ehsan & Dr. Kazanzides	Make a rigid body pointer and calibrate it	Resolved
Installation of SAWSocketStreamer	Discuss with Anton	Discuss with Long	Resolved

Dependencies	Solution	Alternatives	Status
Learning Python Wrapper Check ICP	Refer to Online Material	Seek mentorship from Anton and Ehsan	Resolved (Found alternatives)
Hemostat (or clamp)	Coordinate with Dr. Kazanzides and Ehsan	Seek from Clinical Mentors	Resolved
Attachable Rigid Body for Polaris and Hemostat	Seek from Ehsan or Dr. Kazanzides	Coordinate with LCSR, Potentially make our own.	Resolved
HoloLens	Coordinate with Ehsan	Coordinate with Dr. Kazanzides	Resolved
Unity Installation and Hololens Set-up	Utilization of Online Resources	Help from Ehsan	Resolved
3D-Slicer Installation and Set-up	Utilization of Online Resources	Coordinate with Dr. Kazanzides and Ehsan	Resolved



Jan
Feb
March
April
May
Project Selection
√
Projection Plan and Report
√
ICP Registration Implementation
√
Validation
Delay
Dev. Tracked Hemostat
Delay
Calibration Implementation
Delay
Validation
Delay
Visualization in 3D-Slicer
Visualization in HMD
Validation
Final Presentation Prep
Phase Legend
Planning
Registration
Calibration
Visualization
Final

Management Plan – Development Flow Chart



Y Yihao Liu

N Nikhil Davé

Meeting Management

- Biweekly mentor meeting (Friday 3 pm.)
  - Weekly progress report
- Scheduled surgeon meetings
- Scheduled technician engineer meetings
- Daily sprint group meeting (3 or 4 meetings / week) (Zoom Adjusted)
  - M: 12.00-15.00
  - TTh: 18.00-21.00
  - F: 15.00 - 18.00
- Weekend technical meeting (Zoom Adjusted)
  - Saturday 15.30 - 19.30

Reading List

Hussain, R., Lalande, A., Guigou, C., and Bozorg Grayeli, A. (2019). Contribution of Augmented Reality to Minimally Invasive Computer-Assisted Cranial Base Surgery, *IEEE Journal of Biomedical and Health Informatics*.

Gsaxner C., Pepe, A., Wallner, J., Schmalstieg, D., and Egger, J. (2019). Markerless Image-to-Face Registration for Untethered Augmented Reality in Head and Neck Surgery, MICCAI 2019.

Li, Y., Chen, X., Wang, N., Zhang, W., Li, D., Zhang, L., Qu, X., Cheng, W., Xu, Y., Chen, W., and Yang, Q. (2018). A wearable mixed-reality holographic computer for guiding external ventricular drain insertion at the bedside, Journal of Neurosurgery JNS, 131(5), 1599-1606.

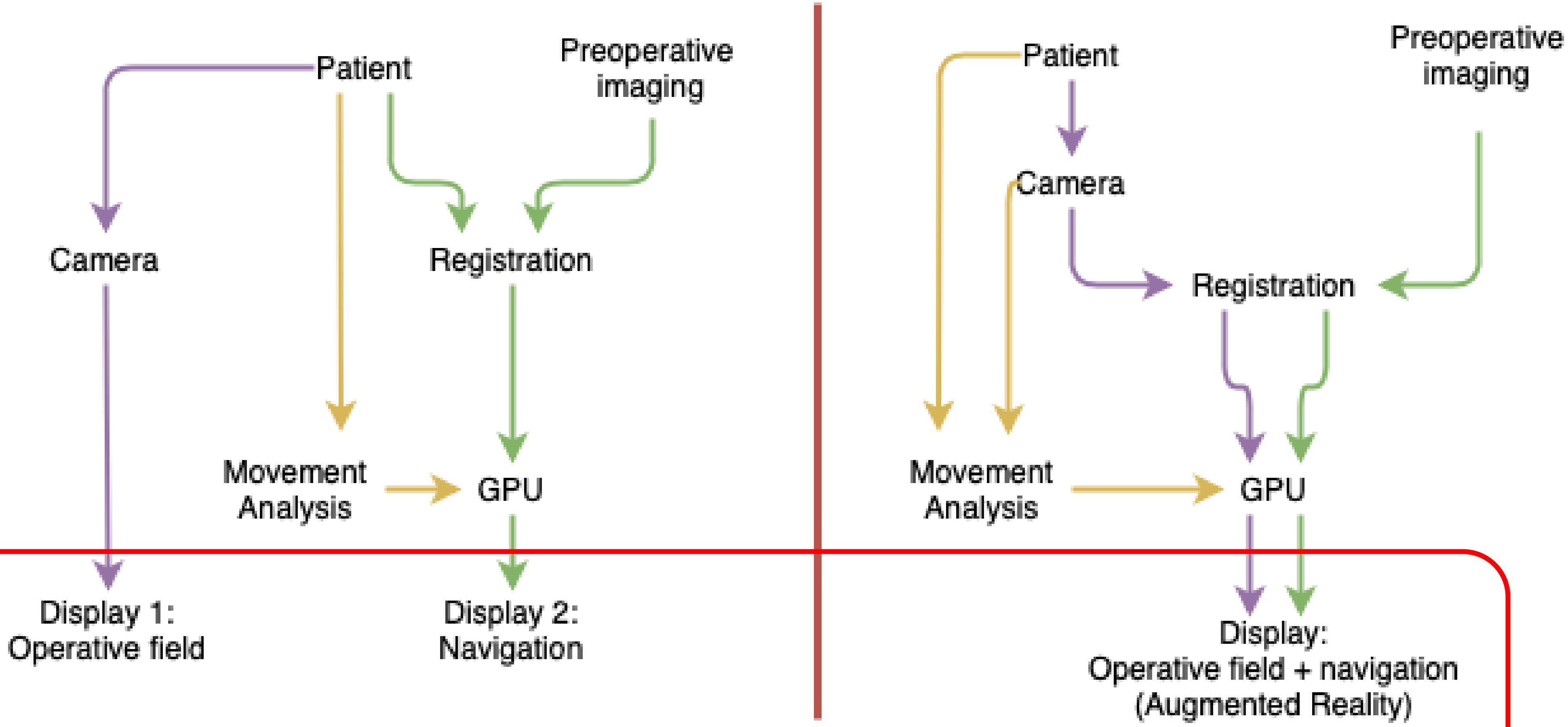
Chen, X., Xu, L., Wang, Y., Wang, H., Wang, F., Zeng, X., Wang, Q., and Egger, J. (2015). Development of a surgical navigation system based on augmented reality using an optical see-through head-mounted display, Journal of Biomedical Informatics, Volume 55, 2015, Pages 124-131

Bong, J. H., Song, H. J., Oh, Y. , Park, N., Kim, H., and Park, S.. (2018). Endoscopic navigation system with extended field of view using augmented reality technology, Int. J. Med. Robot., vol. 14, no. 2, pp. e1886

Inoue, D., Cho, B., Mori, M., Kikkawa, Y., Amano, T., Nakamizo, A., Yoshimoto, K., Mizoguchi, M., Tomikawa, M., Hong, J., and Hashizume, M.. (2013). Preliminary study on the clinical application of augmented reality neuronavigation, J. Neurol. Surg. Part A, vol. 74, no. 02, pp. 71-76

Lapeer, R. J., Jeffrey, S. J., Dao, J. T., García, G. G., Chen, M., Shickell, S. M., Rowland, R. S., and Philpott, C. M.. (2014). Using a passive coordinate measurement arm for motion tracking of a rigid endoscope for augmented-reality image-guided surgery, Int. J. Med. Robot., vol. 10, no. 1, pp. 65-77

Importance



Surgeons have direct visualization by using AR.

Flow chart from: R. Hussain, A. Lalande, C. Guigou and A. Bozorg Grayeli. (2019) Contribution of Augmented Reality to Minimally Invasive Computer-Assisted Cranial Base Surgery, *IEEE Journal of Biomedical and Health Informatics*.

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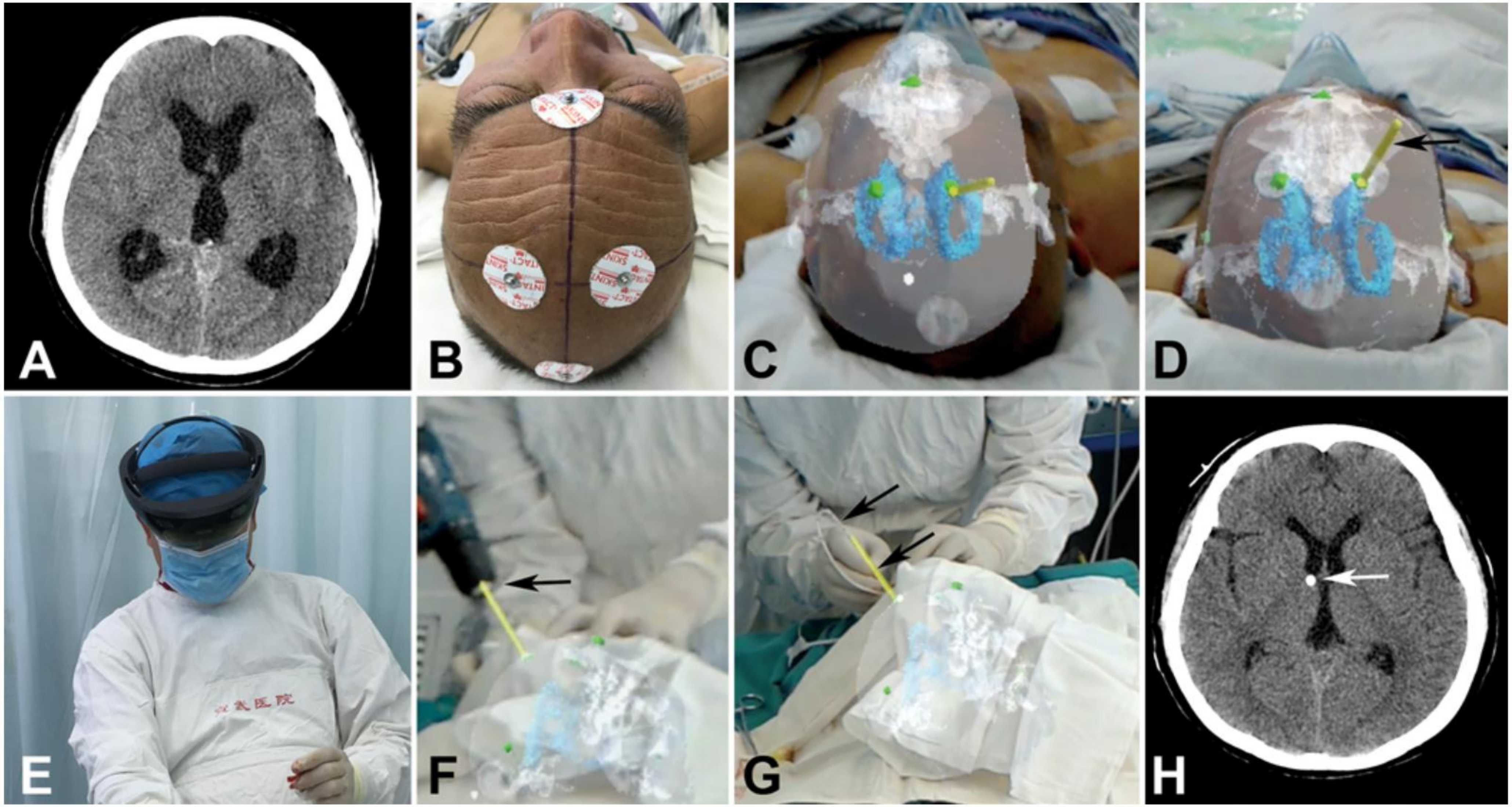

FIG. 2. Hologram-guided operation procedures. **A:** Preoperative CT image of a patient. **B:** Electrocorticography gel electrodes attached to the head of the patient as registration markers. **C and D:** Before (C) and after (D) manual rigid coregistration between the holograms and the patient's head. *Arrow* denotes hologram of the insertion trajectory. **E:** The neurosurgeon wore the headset during the whole procedure. **F:** A burr hole was performed guided by the holographic orientation of the trajectory (*arrow*). **G:** The stylet-loaded catheter (*upper arrow*) insertion was intuitively guided by keeping it aligned with the holographic trajectory (*lower arrow*). **H:** Postoperative CT scan verified the accuracy of EVD placement. *Arrow* denotes the tip of the catheter. Figure is available in color online only.