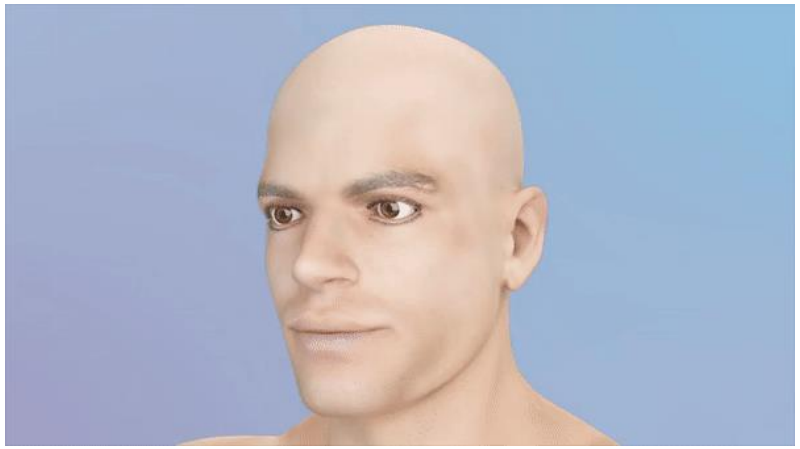
Group 9: Checkpoint Presentation

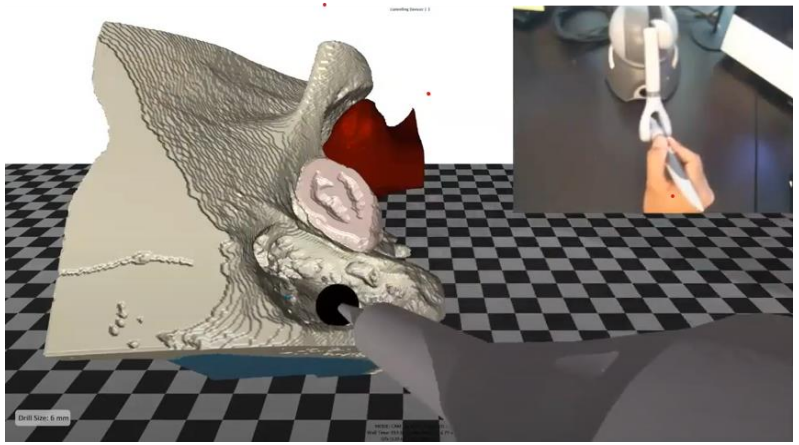
Team Members: Tommy Liang, Jintan Zhang, HongYi Fan

Mentors: Max Li, Dr. Adnan Munawar, Dr. Francis Creighton, Prof. Mathias Unberath, Prof. Russ Taylor

Project Background



Context Situation Awareness



Actual Surgical State

Simulated Surgical State

Video credit:

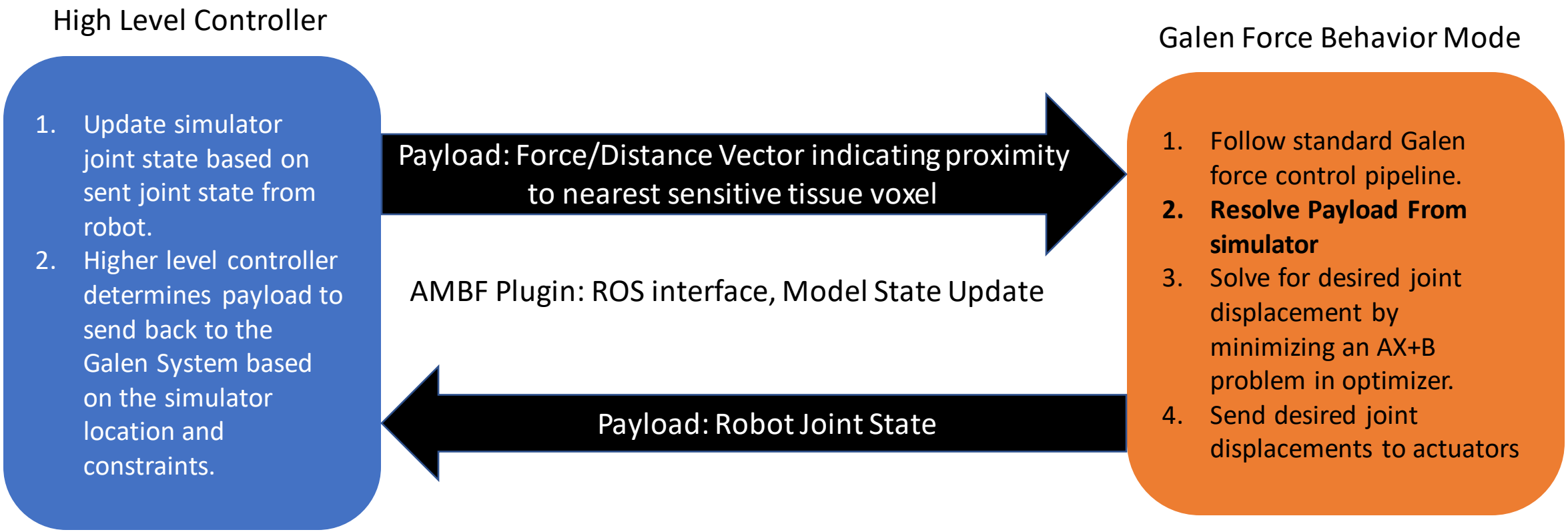
[1] https://www.youtube.com/watch?v=jnonLwxW2Cg

[2] Munawar, A., Li, Z., Kunjam, P., Nagururu, N., Ding, A.S., Kazanzides, P., Looi, T., Creighton, F.X., Taylor, R.H. and Unberath, M., 2021. Virtual reality for synergistic surgical training and data generation.

Project Goals

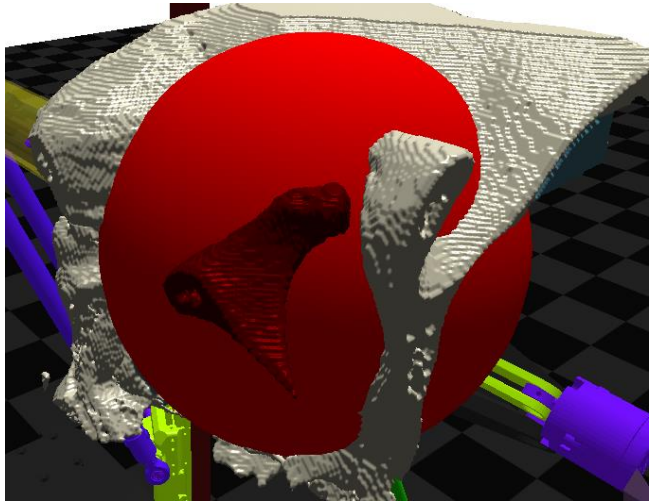
- Create virtual environment in AMBF for skull-base surgery with the following components:
  - Galen Robot
  - Skull-base Model
- Sync Galen robot in VR space with physical Galen robot.
  - Establish mode of communication between robot and AMBF simulation
  - Develop control scheme to keep both in sync:
    - Movement in physical robot is mapped to the virtual space.
    - Constraints in virtual space reflected in physical robot.

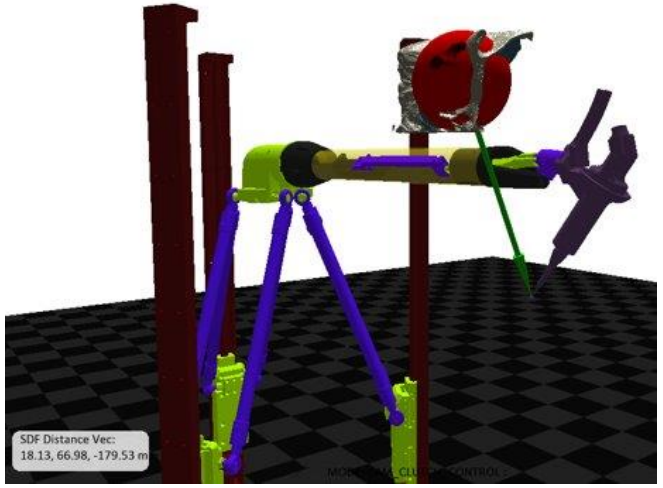
Technical Approach



Simulator Progress - Accomplished

- Galen model in simulator
- Pseudo-SDF using a red sphere
  - Approximate distance vector to sensitive tissue
- Simulator – Robot information pipeline
  - Simulator follows robot
  - Robot receives pseudo-SDF vector from simulator
- Volumetric drilling integration
- Some usability improvements





Simulator Progress - Continuing

- Finetune Galen model
  - Joint position calibration
  - Size scaling
- Finetune controller of simulated robot
  - PID gains of the simulated robot
- Software documentation
- Usability improvements
- Integration with other VR-Guided Skull Surgery teams

Galen Side Controls

Payload: Distance vector d from TOOL TIP to closest voxel on virtual surface

This distance vector can be replaced by a gradient term from the SDF team, the math should still be largely the same

1. Force applied to tool tip

$d = (x, y, z, 0\ 0\ 0)$

If $||d|| > \alpha$, $d = (0, 0, 0, 0, 0, 0)$ where α is a maximum distance threshold

$F_{s\_tip} = (1/||d||)*kp*(\text{normalized}(d)) + kd$ term <- this is in robot frame

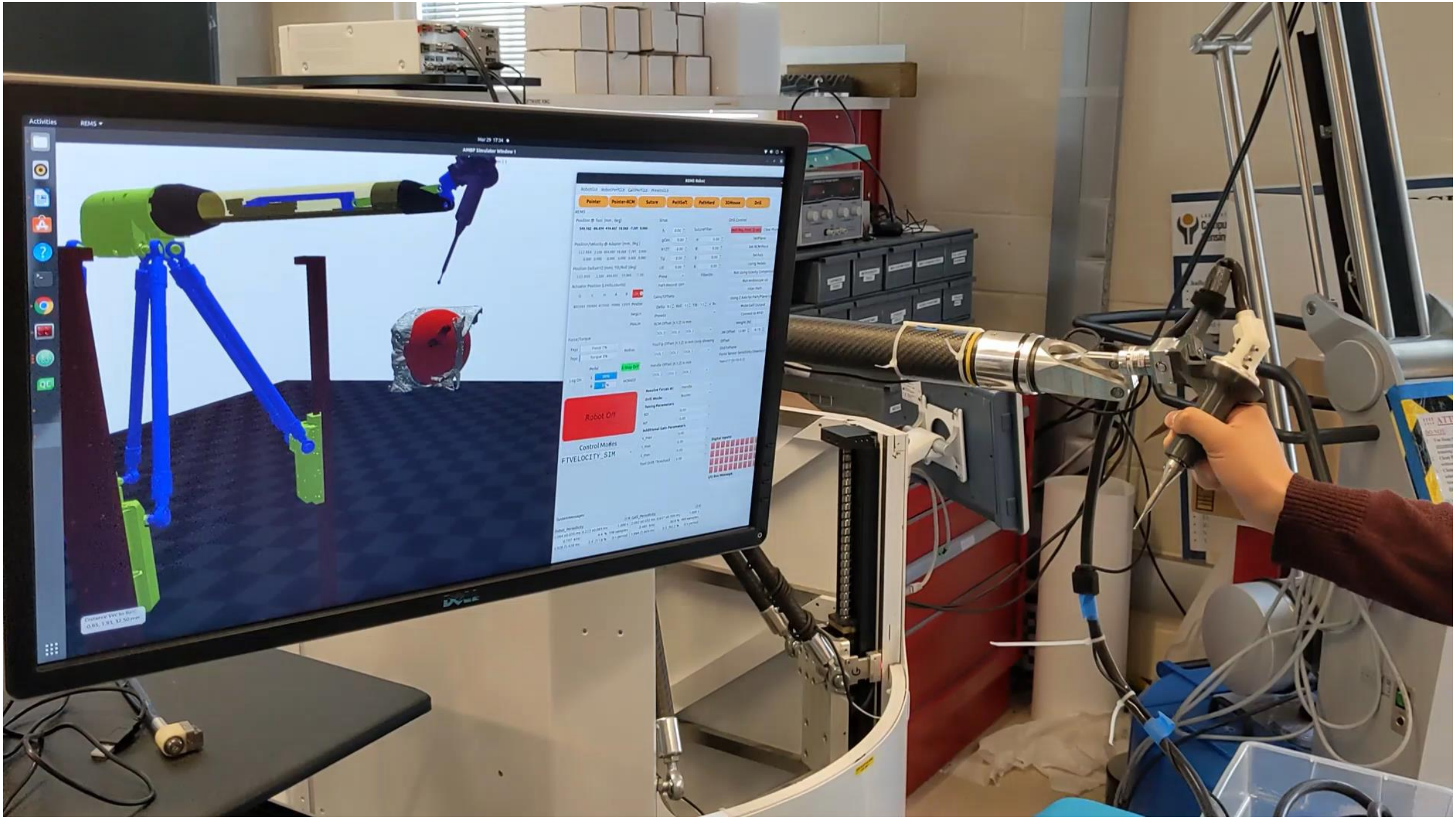
$F_{s\_ee} = Ad^{T}_{tip\_ee} * F_{s\_tip}$

2. Resolve Force Vector at End Effector and Sum

$F_{total} = w_1 * F_{s\_ee} + w_2 * F_{handle}$

W1 and w2 are adjustable weights

3. F_{total} get shipped to the optimizer


Activities
REMS
Pointer
Pointer-RCM
Suture
PalmSoft
PalmHard
3DMouse
Drill
Robot Off
Control Modes
FTVELOCITY_SIM

Update Deliverables

- **Minimum:** Working Software and Documentation for VR - robot communication, including:
  - Controls to keep physical Galen in sync with simulated Galen
  - AMBF simulated environment with all relevant components. Registration assumed to be provided/fixed.
- **Expected:**
  - Environment constraints fed back to robot.
  - Interfaces developed for ease of integration with registration and SDF teams.
  - Any additional UI components or scripts for updating settings/modes to improve usability.
  - Documentation of system architecture.
- ~~**Maximum:** Conduct Internal User Study~~
  - Unlikely to achieve due to operational delays from the Galen system.

Updated Dependencies

Dependencies	Who to contact	Status/Date	Failure Consequences	Resolution
Mentor Availability	Mentors	Meetings Schedule Set	Insufficient feedback may impact quality of project	Weekly meetings set up with mentors
Linux System	LCSR	Acquired	Available in MockOR. Availability issues may set timeline back.	Schedule ahead of time on shared calendar for shared use
Galen Surgical System	Galen Robotics, Inc	Not Functional	Availability issues may set timeline back.	Schedule ahead of time on shared calendar for shared use
Desktop and monitors for running software	LCSR	Acquired	Available in MockOR. Availability issues may set timeline back.	Schedule ahead of time on shared calendar for shared use
Surgical Drill	LCSR	Acquired	Testing Synchronization could be impacted.	Reach out to LCSR for acquiring tool if unavailable.
C++, Python, OpenGL, ROS	Open Source	Acquired	Publicly available	N/A

Updated Timeline

#Week 1-3	4	5	6	7	8	9	10	11	12	13	14	15-16
Preparation	Presentation											
	Simulation follows robot											
		Robot gets feedback from simulation										
			Add “Volumetric Drilling” to Galen World		Testing synced Robot and simulation *(Dependency Failed)*							
				Assemble and test combined virtual environment				Interface for combining other groups' work				
							Usability improvement					
								Software documentation				Presentation

QUESTIONS?