EN.530.721: Medical Robotic System Design

Automated Ultrasound using UR5e

Team 2:

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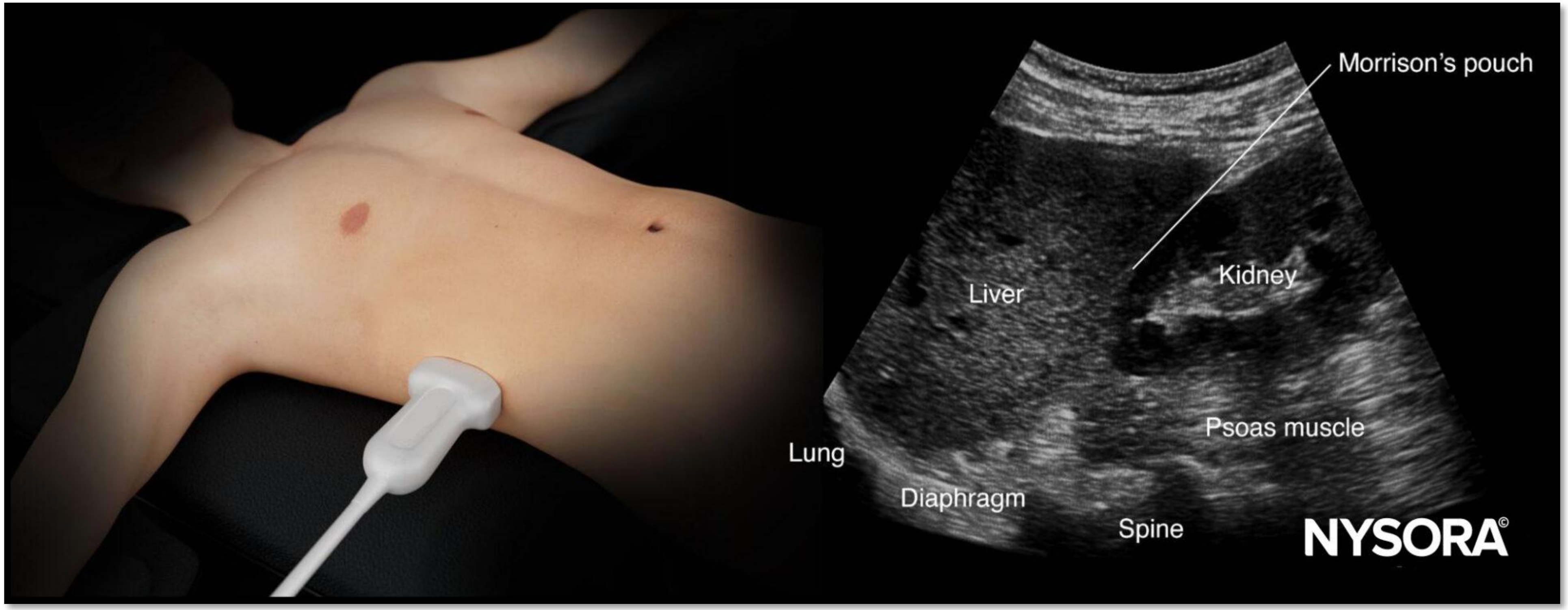
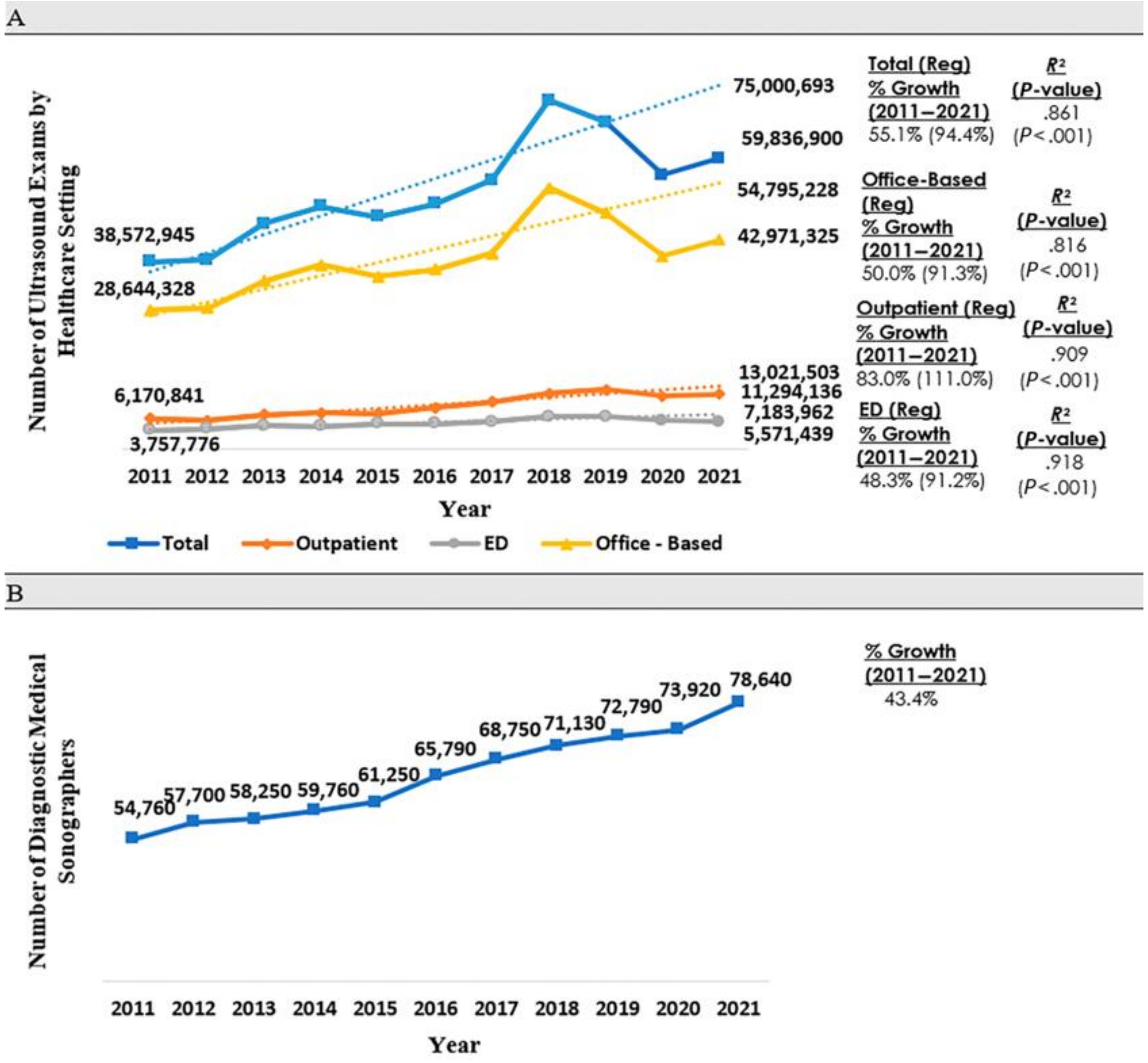
Brief Introduction to Ultrasound

Ultrasound is an imaging technique that is used to view internal organs and soft tissue. It has been widely used as a diagnostic tool for various disorders. This widespread use in the medical field makes it a quintessential tool in hospitals and health centers.



What is the Clinical Need?



- Ultrasound exams have increased by 55.1% during the 2011-2021 period, outpacing the 43.6% growth in the sonographer workforce.
- Demand for sonographers has been(open positions: +36.3%) growing significantly faster than new supply (graduates: +23.0%).
- This critical shortage creates substantial strain on the healthcare system.
- 90% of sonographers experience work-related musculo-skeletal disorders (WRMSDs)

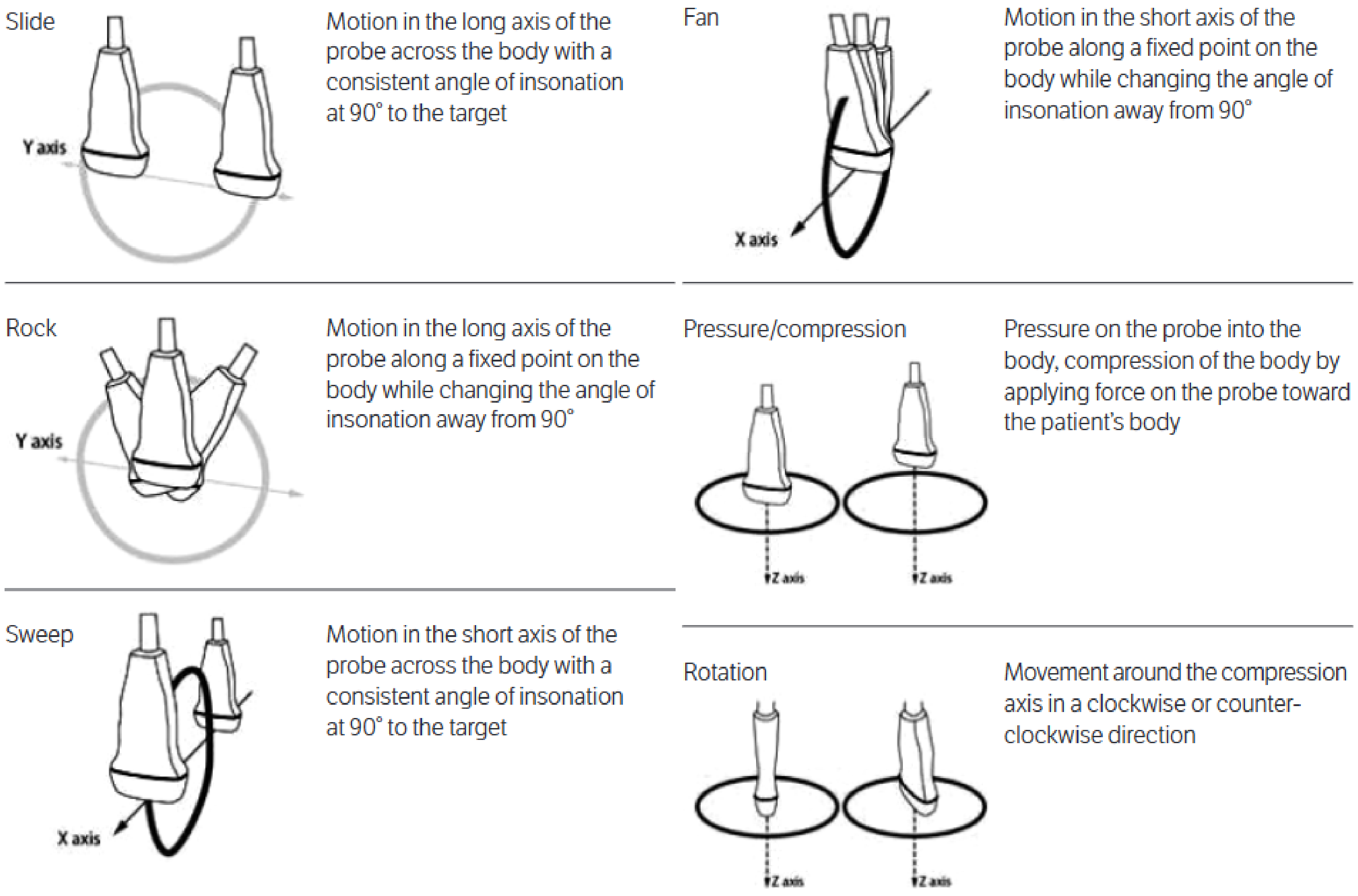
Specifications

High-Level:

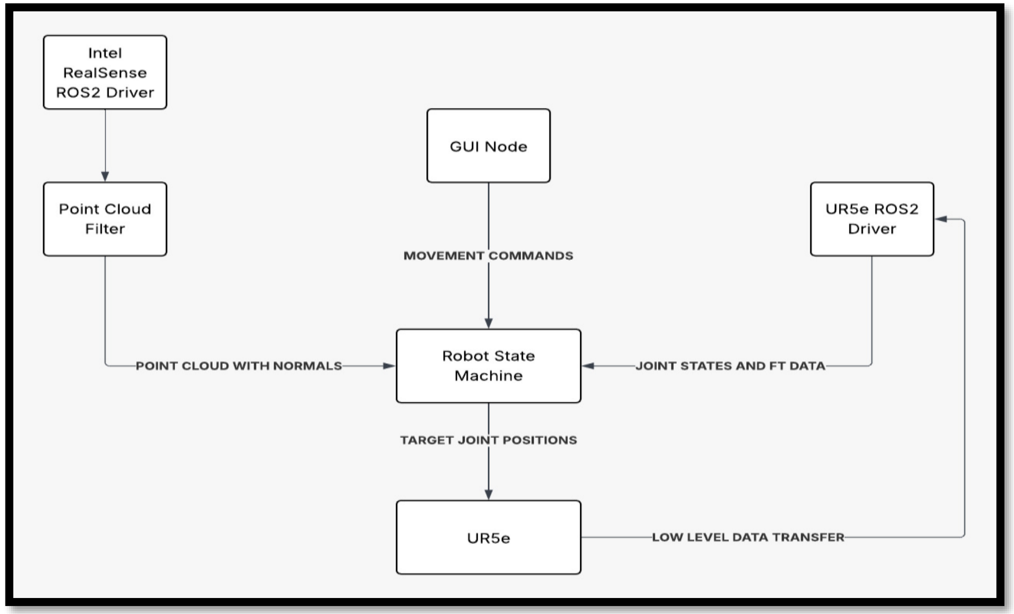
Carry out any of the six fundamental transducer motions on any anthropomorphic contour at the press of a button.

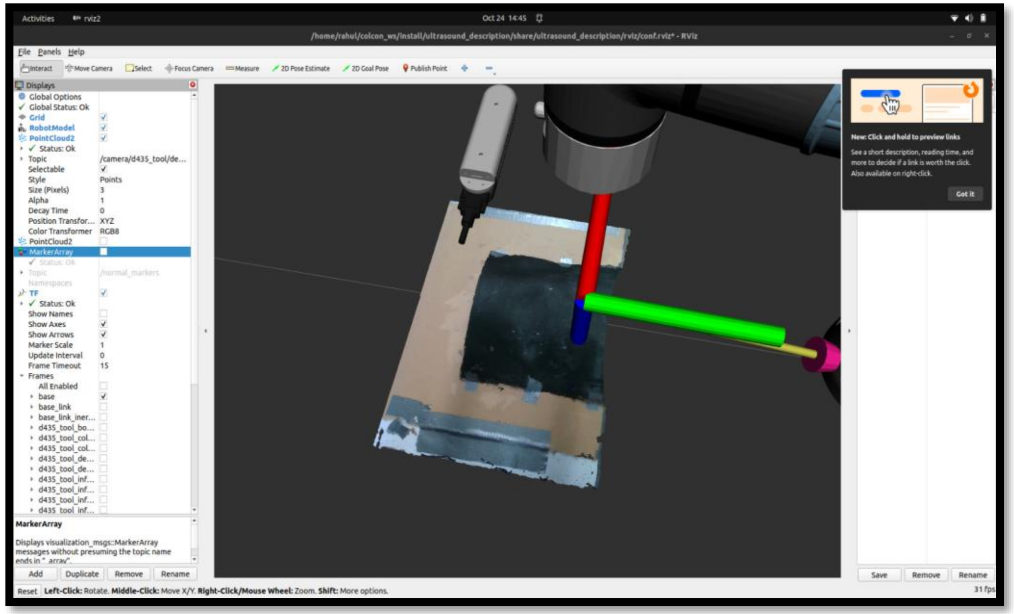
Low-Level:

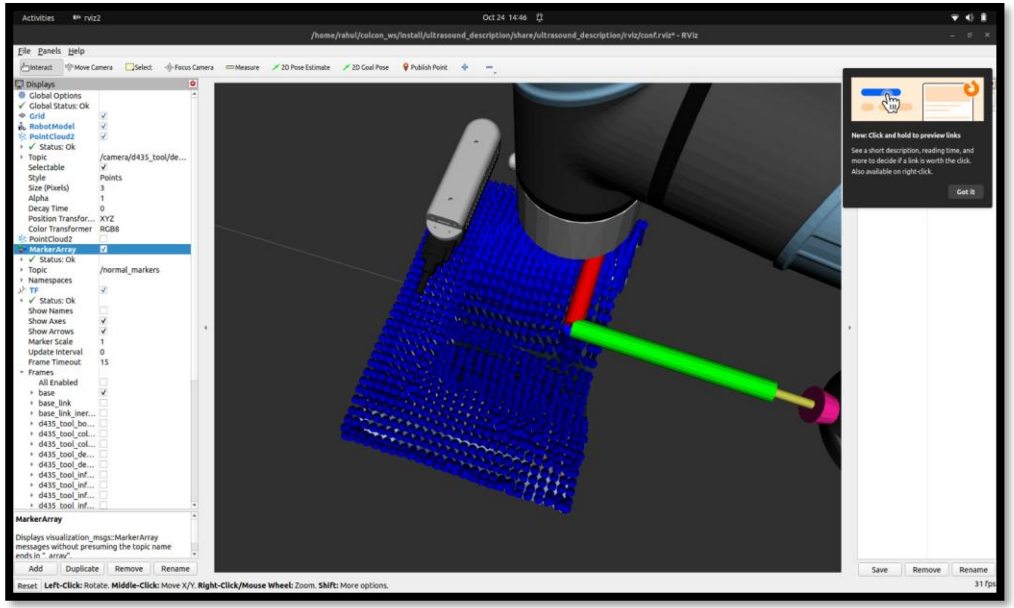
- Maintain orientation of the transducer to be normal to the contour at all times.
- Ensure contact with the contour at all times with reasonable force pressing down on the contour to simulate application of gentle pressure.

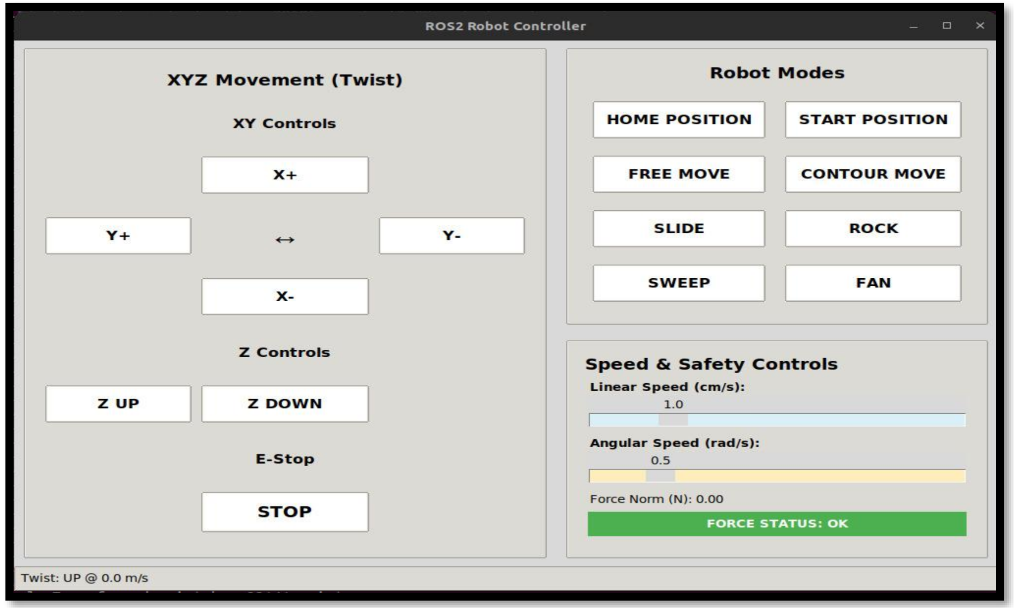


Experimental Plan

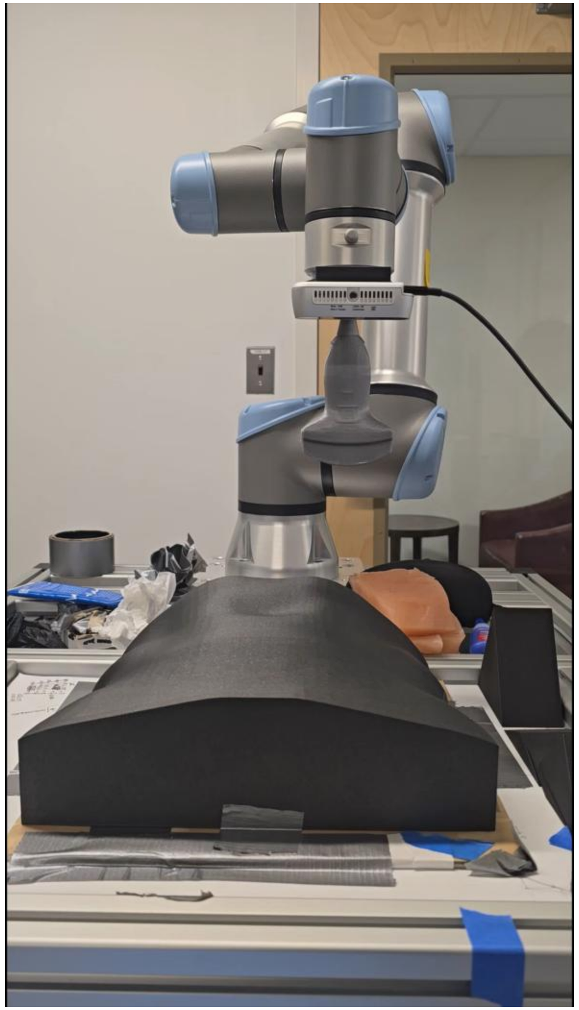








Experiments



Error Analysis

Degree of Slope	Expected Tool Tip Angle						
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Mean	Standard Deviation
0°	0.26	1	0.64	0.45	0.15	0.5	0.3
30°	26.15	25.91	25.51	26.16	25.81	25.9	0.24
45°	39.84	40.00	43.53	39.69	39.19	40.45	1.5

- Acceptable Flat Surface Performance: Mean error on a flat surface (0° slope) was 0.5; within acceptable limits
- Challenges with Sloped Contours: Testing on sloped surfaces (30° and 45°) revealed mean tool tip angle was accurate, but required significant tuning
- Sources of Error: Noisy Point Clouds; Down sampling Issues; Normal Distribution
- Successful Resolution: Despite the issues, system proved capable of following smooth, anthropomorphic surfaces

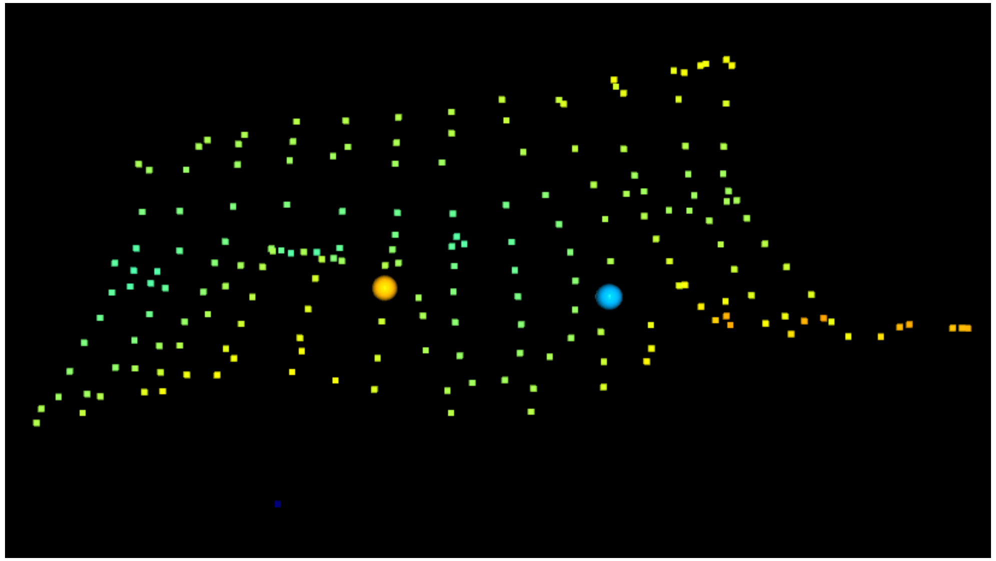
Contour	Mean (N)	Median (N)	Std Dev (N)
1	1.144371	0.982003	1.891779
2	1.784494	1.392440	2.611447
3	-11.490597	0.456875	29.438409
4	1.316986	1.214646	1.846161
5	-6.400815	0.453778	17.018572

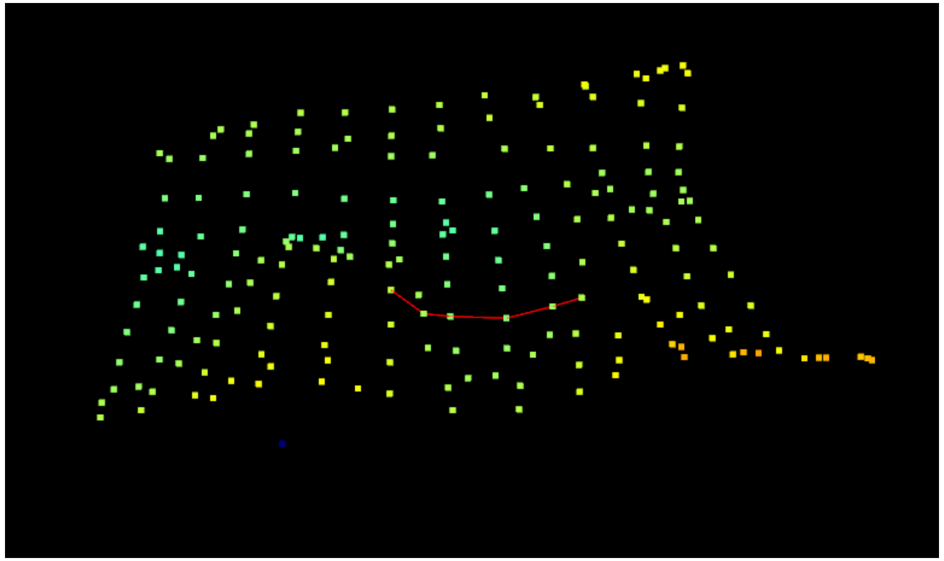
- Baseline Force registered by the tool head was 6 N; Acceptable Force Range: -1 N to 2 N
- Contour Testing Results: Contours 3 & 5 showed excessive force application
- Sources of Error: Straight Line Path Assumption and High Rate of Movement
- Solutions Implemented: Refining the density of the point cloud; Reducing the robot's rate of movement.

Future Scope

Looking at the limitations and observations, we believe these would be the following next set of steps for implementation of the robot:

- The robot takes a single snapshot of the workspace and then navigates. Active tracking and capturing would provide greater point cloud resolution.
- Implementation of the camera at a fixed position, in the form of an enclosure, to have a fixed transformation for camera calibration.
- Integrating the Clarius ultrasound probes' output to ROS.
- The robot control is done by using a node and its overall performance can be made real-time and improved.
- Using velocity control over position control would allow overcoming of the limitation of moving over large contour slopes.
- Currently, sweep and slide are semi autonomous. For complete autonomy, we would require an algorithm to generate a straight-line path between two points. We were able to implement it but were unable to integrate due to time constraints.





Thank You