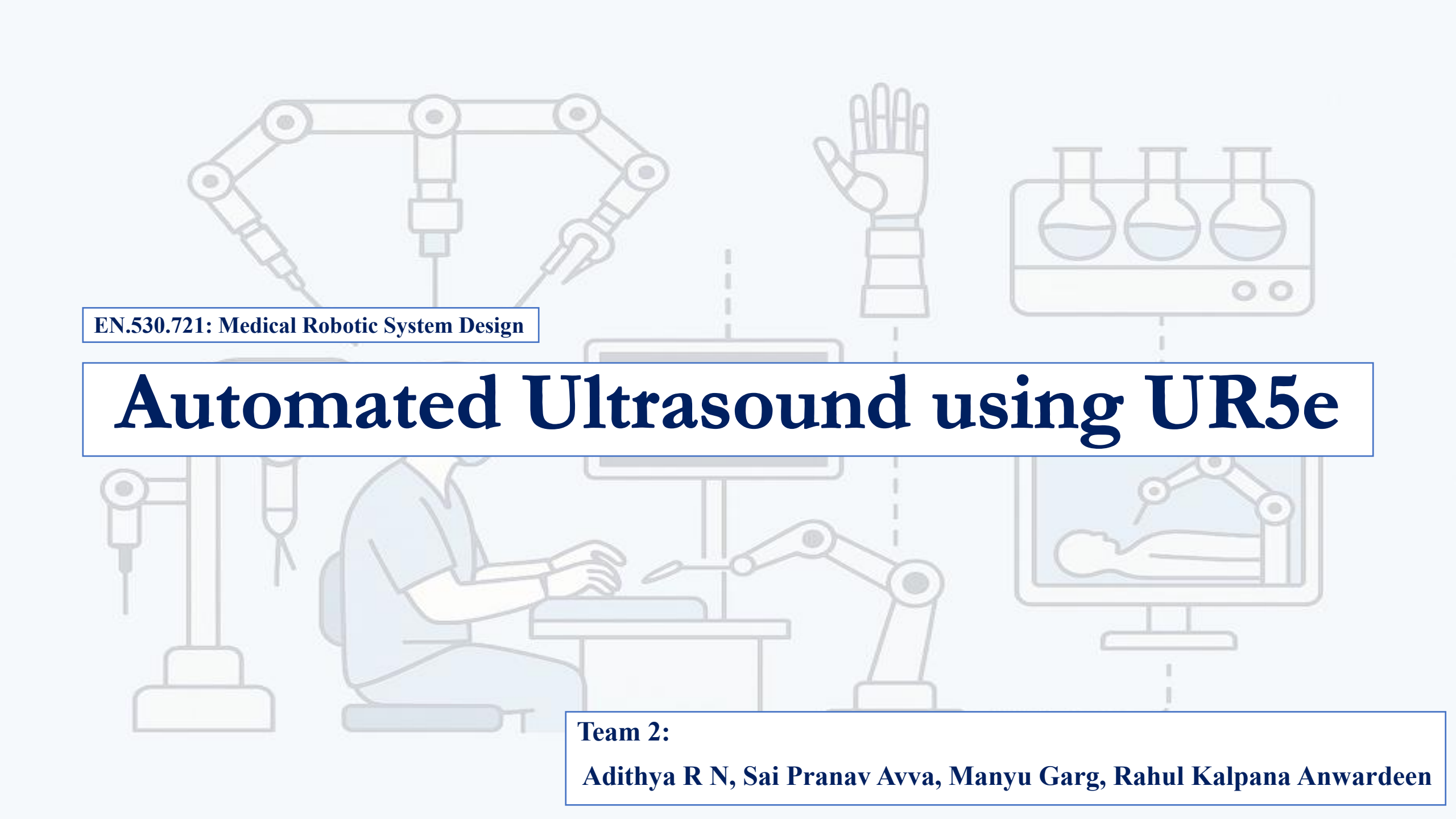


The background features a light blue line-art illustration of various medical robotic systems. At the top left is a multi-jointed robotic arm with a gripper. To its right is a prosthetic arm with a hand. Further right is a tray containing three Erlenmeyer flasks. Below these, a central monitor displays a robotic arm. To the left of the monitor, a person in medical scrubs is seated at a desk, interacting with a device. To the right of the monitor, another robotic arm is shown. On the far right, a monitor displays a patient lying down with a robotic arm positioned over them. Dashed vertical lines connect the top elements to the central monitor and the bottom elements to the patient monitor.

EN.530.721: Medical Robotic System Design

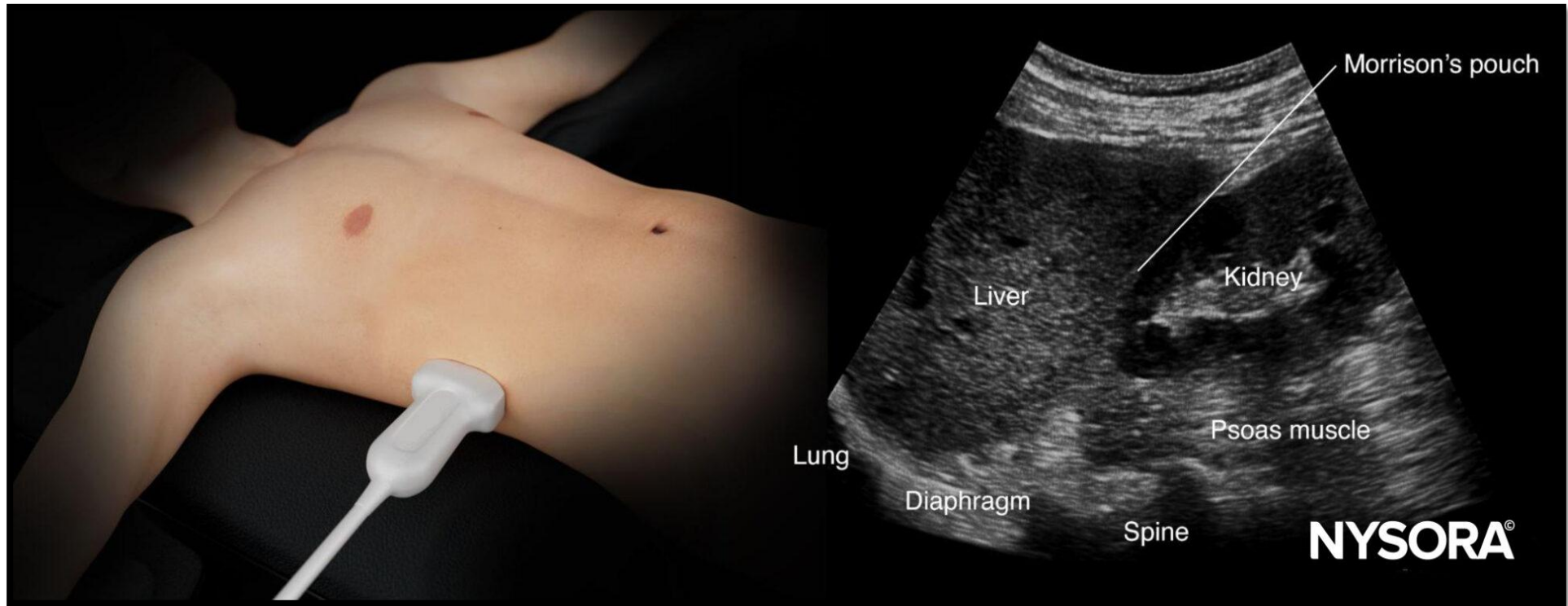
Automated Ultrasound using UR5e

Team 2:

Adithya R N, Sai Pranav Avva, Manyu Garg, Rahul Kalpana Anwardeen

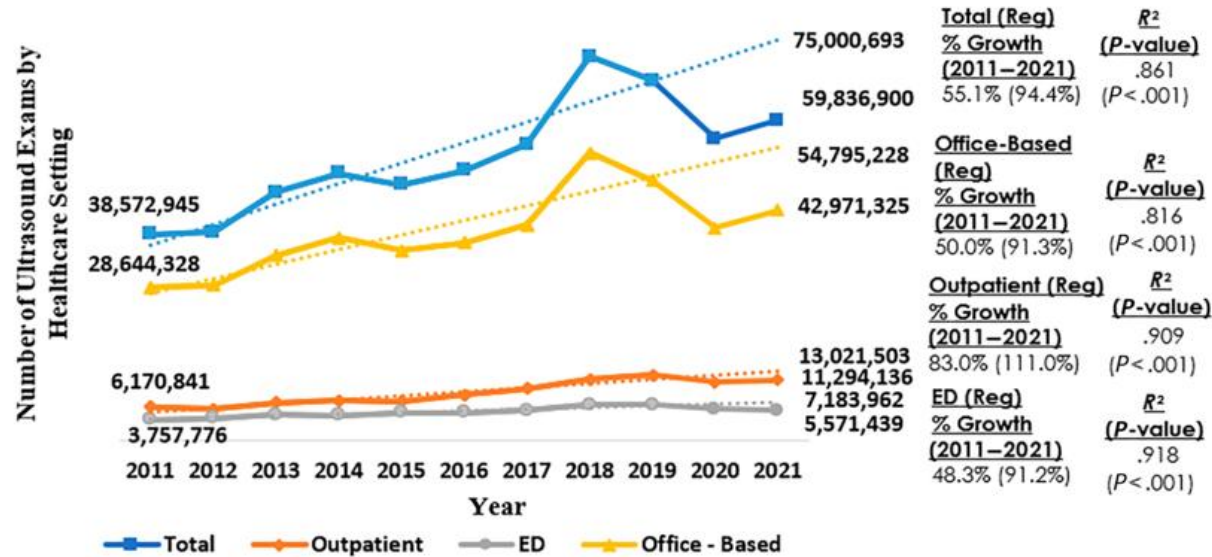
Brief Introduction to Ultrasound

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.

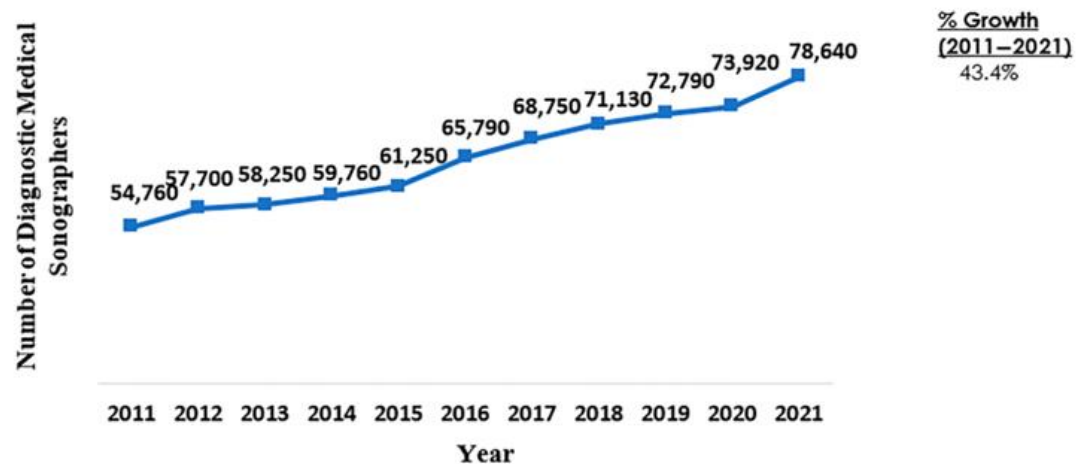


What is the Clinical Need?

A



B



- 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

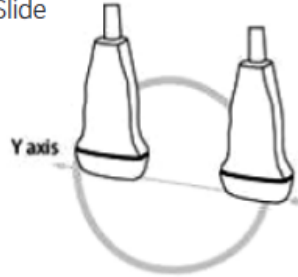
High-Level:

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.

Slide



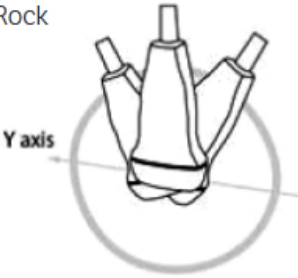
Motion in the long axis of the probe across the body with a consistent angle of insonation at 90° to the target

Fan



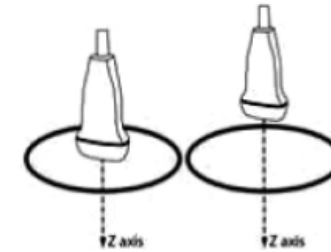
Motion in the short axis of the probe along a fixed point on the body while changing the angle of insonation away from 90°

Rock



Motion in the long axis of the probe along a fixed point on the body while changing the angle of insonation away from 90°

Pressure/compression



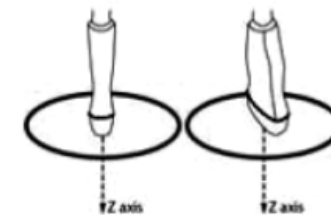
Pressure on the probe into the body, compression of the body by applying force on the probe toward the patient's body

Sweep



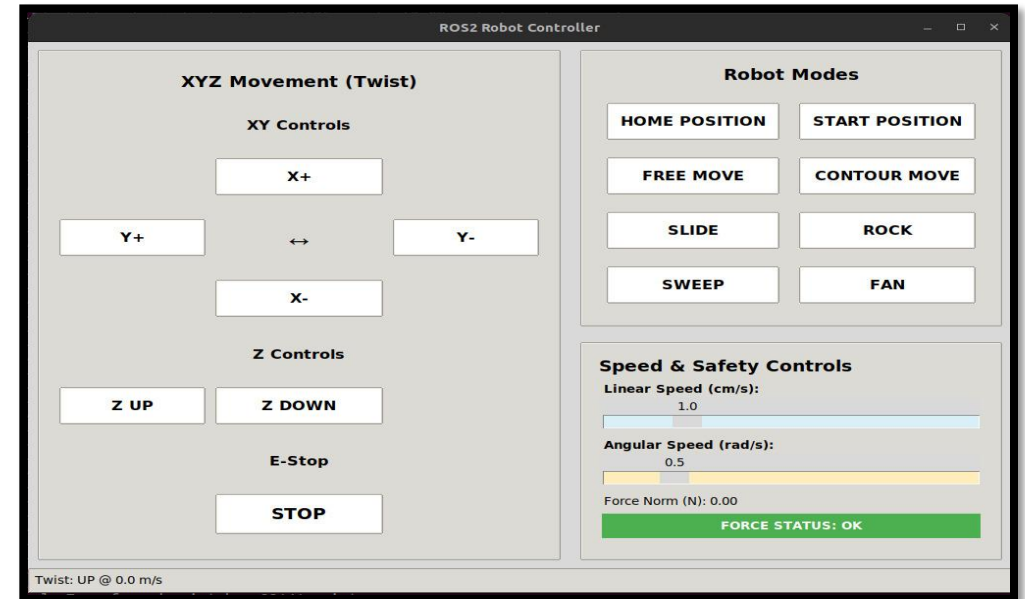
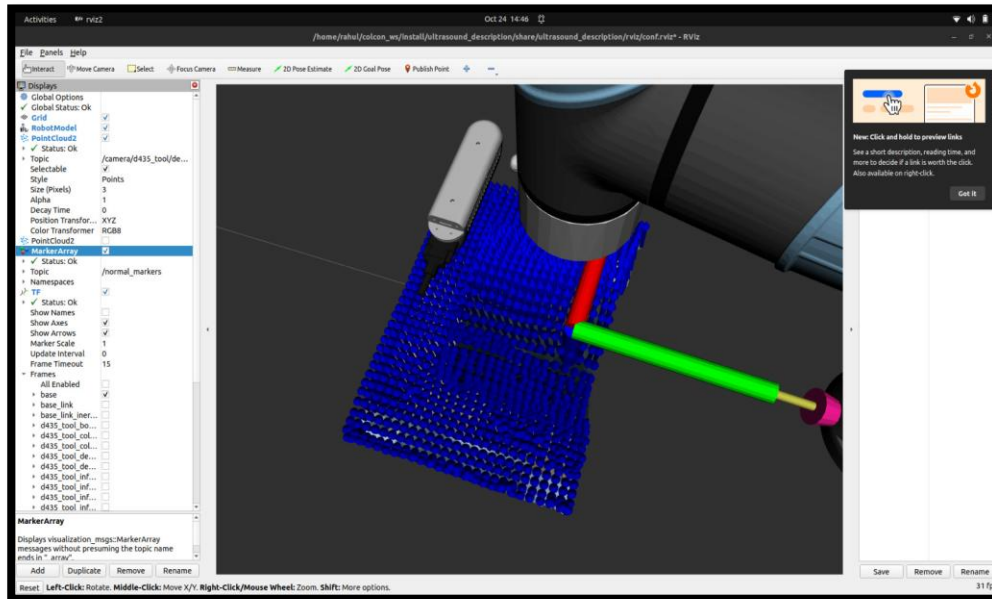
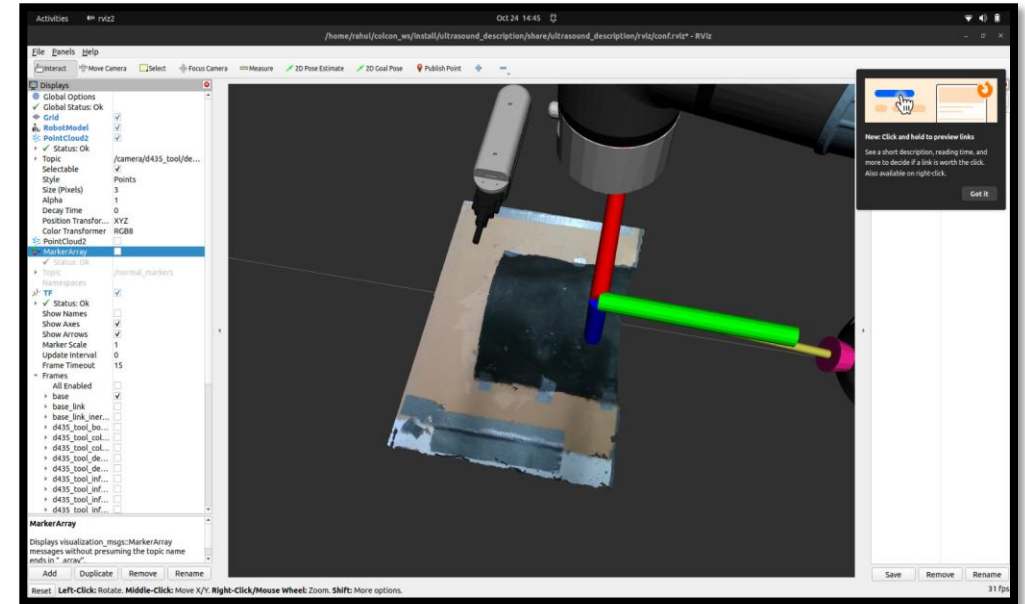
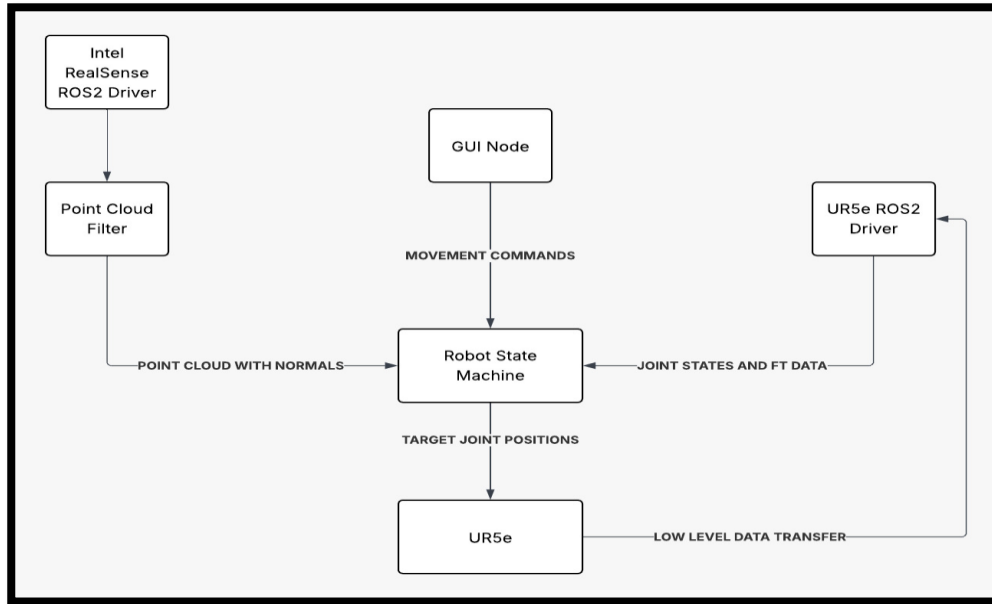
Motion in the short axis of the probe across the body with a consistent angle of insonation at 90° to the target

Rotation

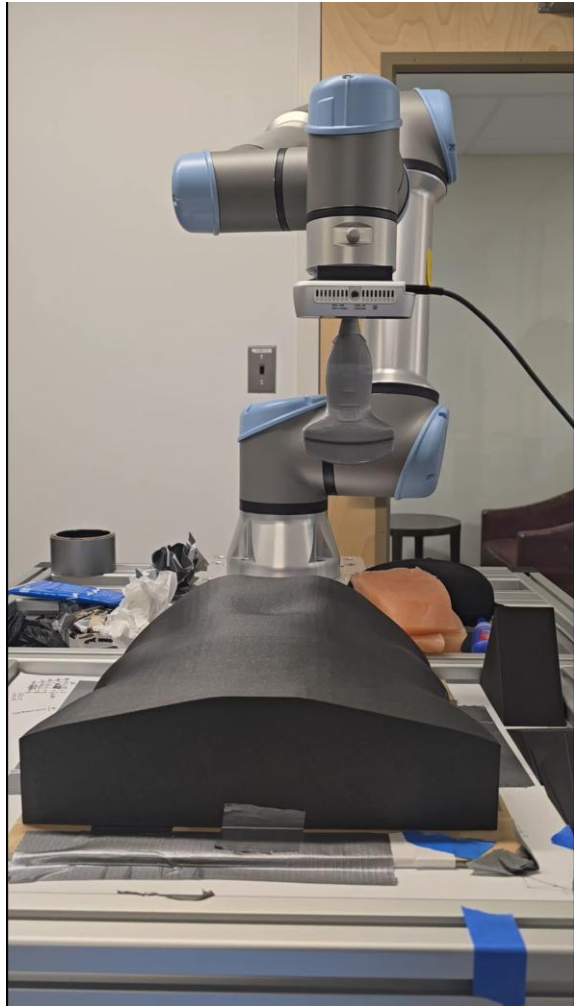


Movement around the compression axis in a clockwise or counter-clockwise direction

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

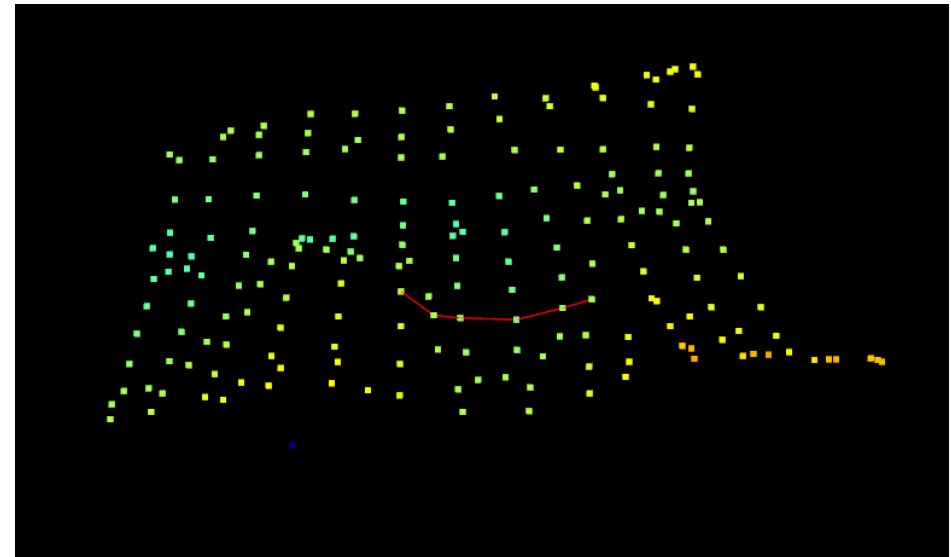
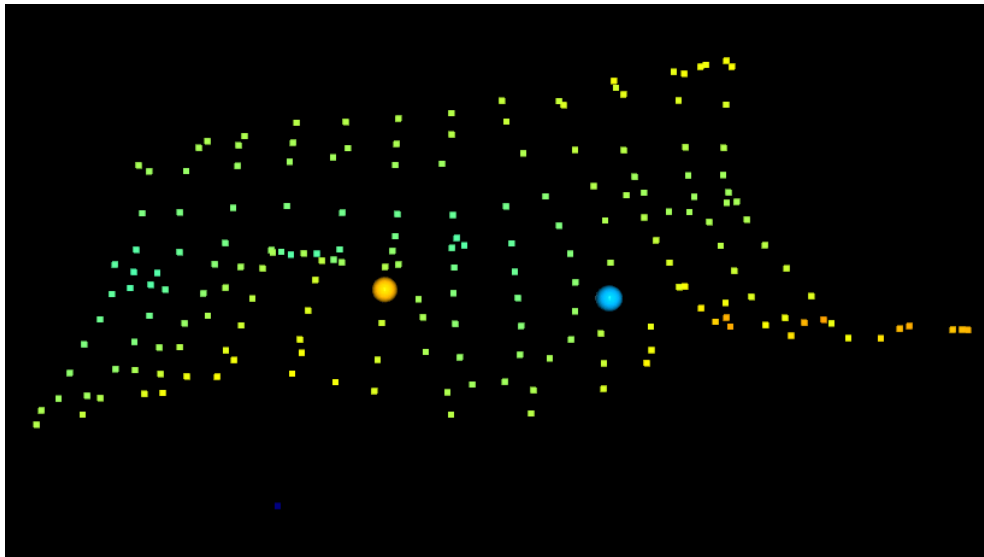
Contour	Mean (N)	Median (N)	Std Dev (N)
1	1.144371	0.982003	1.891779
2	1.784494	1.392440	2.611447
3	-11.490597	0.456875	29.438409
4	1.316986	1.214646	1.846161
5	-6.400815	0.453778	17.018572

- 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