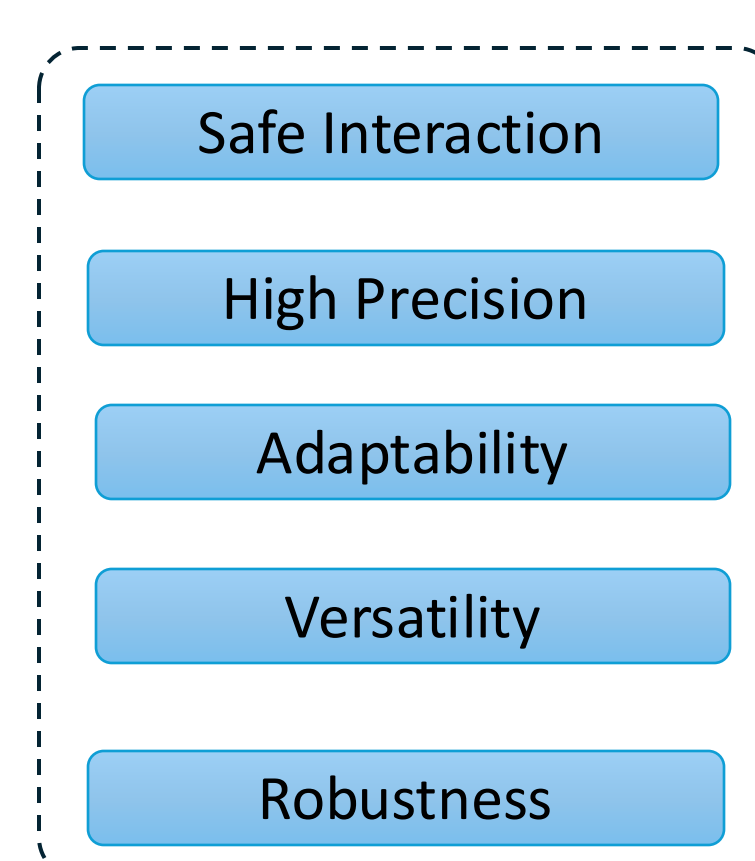


Soft Manipulation on A Vision Powered Quadruped Robot

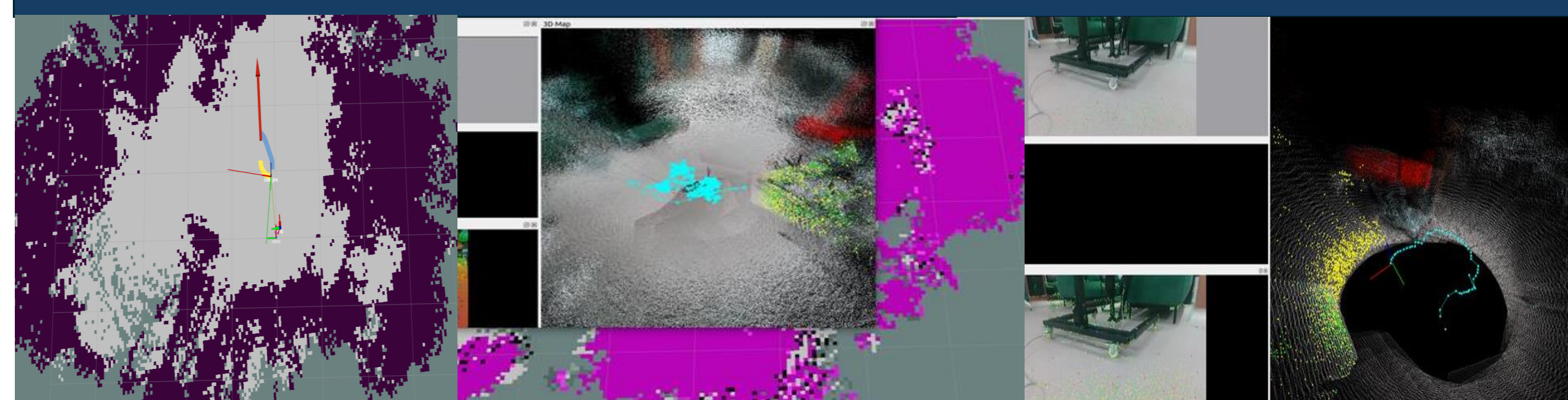
Nakul Nibe, Ramy Kachwaa, Ibrahim Sarraj, Ke Wu

Introduction

- **Research Problem:** We present continuum soft robotic manipulator mounted on the Deeprobotics Lite-3 quadruped robot to safely grip fragile objects like glass, eggshells, and ceramics tasks where rigid manipulators typically fail.
- **Proposed Solution:** The system uses RTABMAP SLAM for 2D mapping and 3D point clouds, enabling autonomous navigation via path planning. RGB-D data supports object detection for tasks like gripping, door opening, and trolley handling.



Preliminary Work



PATH-PLANNING

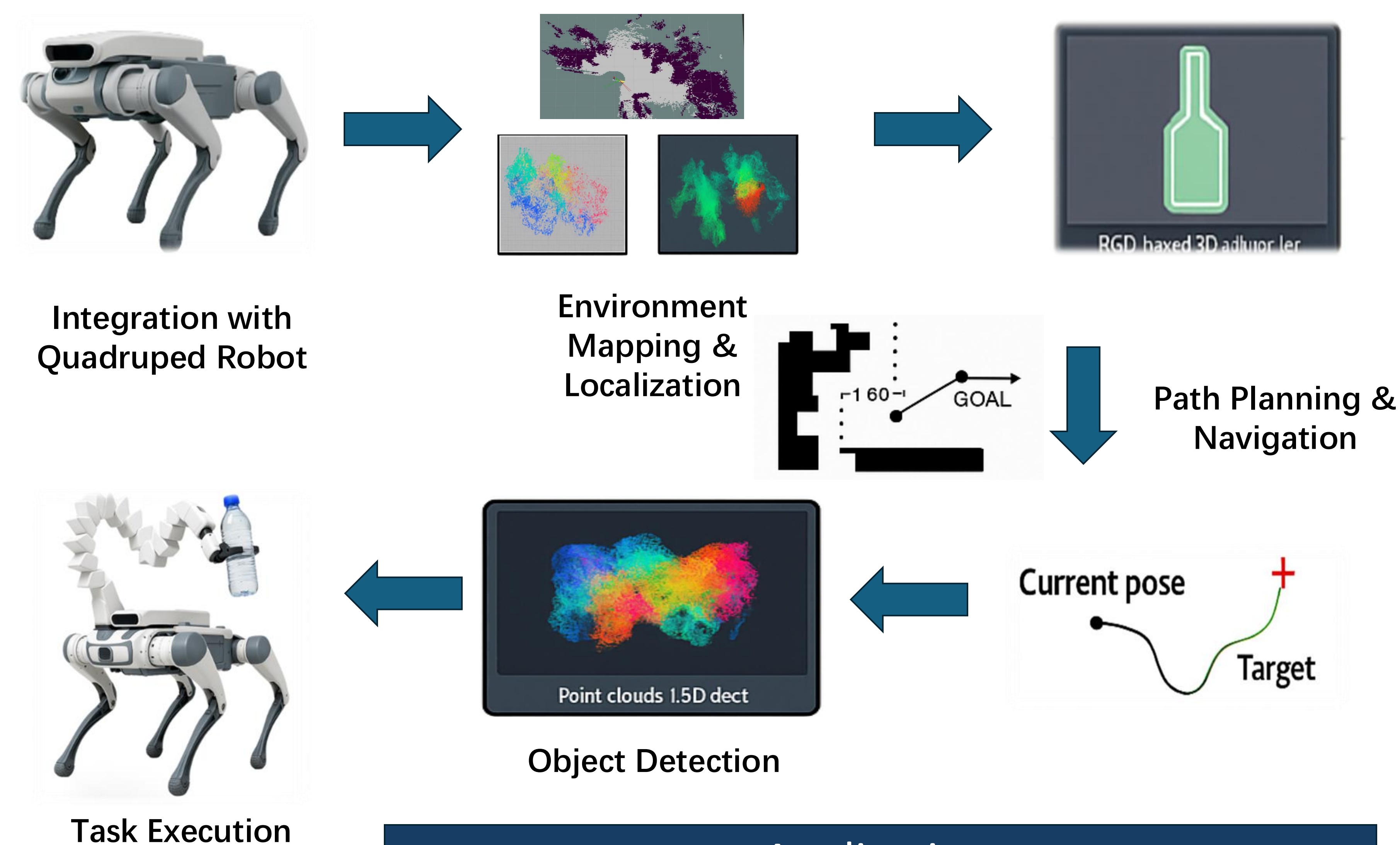
RTABMAP

POINT CLOUDS

- **Soft Manipulator Grasp Testing:**
The 3D-printed TPU soft manipulator was evaluated across multiple grasping scenarios (apple, rock, plant, etc.), confirming safe interaction with fragile and irregular objects.
- **Manipulator-Robot Integration:**
Successfully mounted the soft manipulator on the Deep robotics Lite-3 robot and validated motor controls and actuation for directional bending.
- **Real-Time SLAM Mapping (RTABMAP):**
Implemented and visualized real-time 3D mapping and loop closure using RTABMAP. Screenshots confirm trajectory tracking and feature-rich point cloud generation.
- **2D Occupancy Grid with RViz:**
SLAM outputs were processed in RViz to generate a 2D occupancy grid. Local and global path planning was enabled with visible robot trajectory and goal path overlays.
- **Navigation & Localization Verification:**
Initial trials showed successful navigation across mapped environments. Local path curves and robot pose alignment validate the pipeline.
- **Perception Pipeline – Object Detection:**
Captured RGB-D data and 3D visual cues for object identification. Early-stage feature tracking and odometry validation were tested with loop rejection visualization.

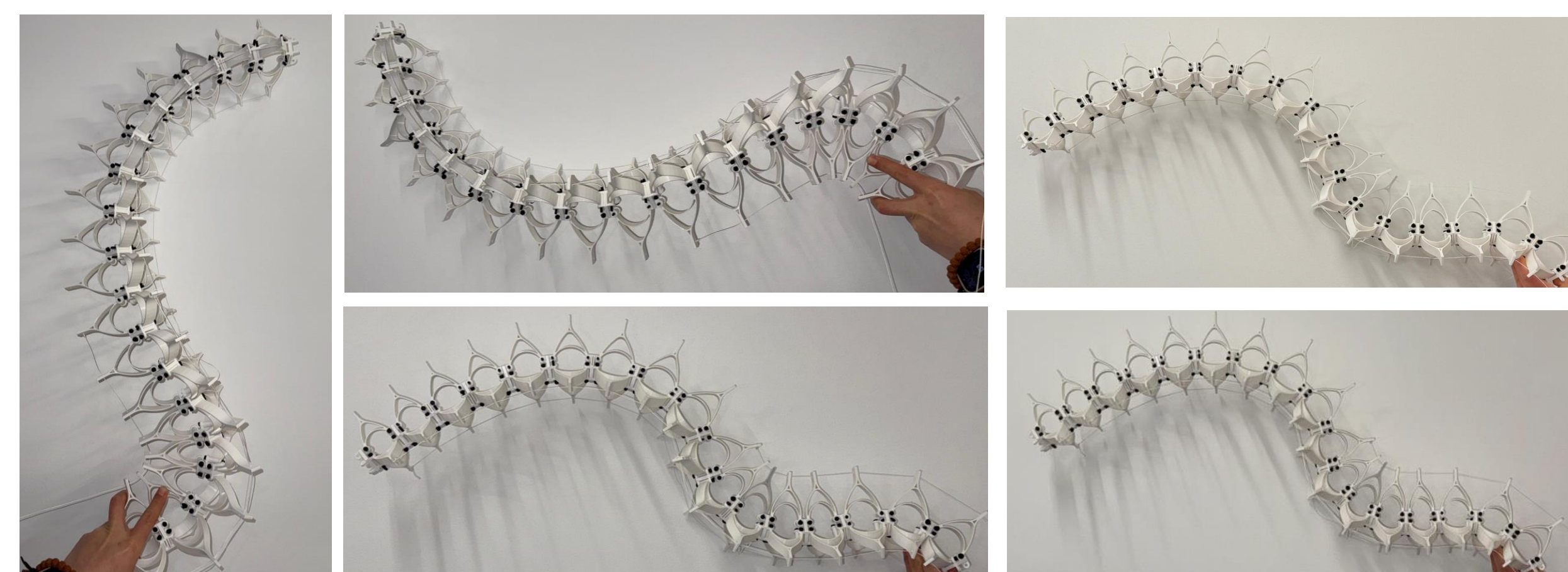
Methodology

- **Design & Fabrication:** A 3D-printed soft manipulator made of TPU material is developed for delicate object handling.
- **Integration with Quadruped Robot:** The soft manipulator is mounted on the Deeprobotics Lite-3 quadruped robot for mobile manipulation
- **Environment Mapping & Localization:** RTABMAP SLAM is used to generate a 2D occupancy grid and 3D point clouds for real-time localization and environment understanding.
- **Path Planning & Navigation:** A shortest path planning algorithm determines a safe route from the current robot pose to the target, followed by velocity command execution.
- **Object Detection:** RGB and depth data are extracted point clouds and used for 3D object detection.
- **Task Execution:** The robot autonomously navigates to the object and performs tasks like gripping, door opening, window cleaning, and trolley manipulation.



Anticipated Outcomes

- **Safe and Adaptive Grasping:**
Successful manipulation of fragile objects (glass, eggshells, ceramics) without damage using a compliant TPU-based soft arm.
- **Integrated Mobile Manipulation System:**
A fully functional quadruped robot equipped with a soft manipulator for autonomous, task-oriented operation.
- **Efficient Autonomous Navigation:**
Smooth and optimized motion planning enabling the robot to reach goal poses precisely with dynamic path replanning.
- **Real-Time Object Detection & Gripping:**
Successful detection of objects from RGB-D data and execution of tasks like gripping, door opening, and object handling.
- **Application-Ready Prototype:**
A versatile robotic system deployable for real-world scenarios like search-and-rescue, elderly assistance, or automated inspection.



ACTUAL PROTOTYPE

Applications

- **Search and Rescue Operations;**
Navigate disaster zones and gently retrieve fragile or irregular objects (e.g., evidence, debris samples) from rubble or tight spaces.
- **Medical and Elderly Assistance:**
Assist patients or the elderly by safely handling delicate items like medications, water bottles, or glassware without risk of damage.
- **Domestic and Service Robotics:**
Perform household tasks such as picking up delicate items, cleaning windows, or opening doors-safely and autonomously.
- **Industrial Inspection & Handling:**
Transport and manipulate fragile components or tools in unstructured factory environments with reduced risk of product damage.
- **Agricultural Robotics:**
Harvest soft crops like fruits or vegetables with minimal bruising using compliant gripping and terrain-aware navigation.

