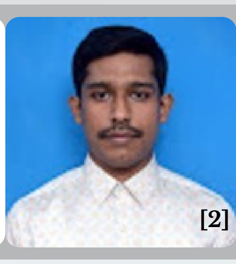
Advancing Intelligent Robot Motion Planning and Learning in Dynamic Environments

KID: 20240406



Motion planning in dynamic and unstructured environments remains a critical challenge in deploying intelligent robots for real-world applications. At the Robotics and AI Lab at the Indian Institute of Technology Hyderabad (IITH), we focus on developing advanced motion planning algorithms that enable robots to operate autonomously in environments characterized by a mixture of movable and immovable obstacles. Our research targets both indoor and outdoor settings, ranging from assistive indoor robotics that rearrange furniture to enable navigation, to agricultural robots that interact with natural elements like leaves and branches to harvest fruits efficiently.

Our group, comprising one PhD and three master's students, investigates hybrid strategies that combine classical motion planning algorithms with machine learning and reinforcement learning (RL) techniques. These strategies aim to enhance the robot's adaptability, decision-making, and long-term autonomy in complex tasks.

At the core of our research is the integration of semantic understanding and physical interaction in motion planning. Unlike traditional planning approaches that treat the environment as static or binary (free vs. occupied), our algorithms distinguish between static obstacles and dynamic or manipulable objects. For example, in indoor scenarios, a mobile robot may push chairs out of its path to reach a desired location. In agricultural environments, our robots must plan efficient trajectories while dynamically repositioning foliage to access fruit-bearing branches. To tackle these challenges, our lab explores three key research directions:
We build upon traditional planners such as Rapidly-exploring Random Trees (RRT) and A* algorithm by embedding scene semantics and manipulability information.

This allows the planner to reason about potential object interactions and make informed trade-offs between path optimality and manipulation effort. Our use of deep reinforcement learning (DRL) facilitates the development of policies that learn from environment interactions and improve over time. Robots trained using DRL can explore the action space involving pushing, pulling, or avoiding objects based on rewards tied to goal achievement and energy efficiency.

To enhance situational awareness in occluded or cluttered environments, we integrate NBV planning to guide robot sensors (e.g., RGB-D or stereo cameras) towards the most informative viewpoints. This is particularly useful in agricultural settings where visual occlusion from leaves can hinder object detection and manipulation.

Our experimental platform consists of simulated and physical testbeds equipped with mobile manipulators and 3D vision systems shown in 1. We benchmark our algorithms using indoor navigation challenges and outdoor harvesting scenarios, demonstrating improvements in success rate, task completion time, and robustness to environmental uncertainty.

Our ultimate goal is to enable robots to intelligently interact with their environment rather than merely navigating around it. By pushing the boundaries of motion planning, learning, and perception, we strive to bring robot autonomy closer to deployment in real-world, human-centric, nature-integrated settings.

As we look ahead, our focus will continue on developing generalizable frameworks that combine model-based reasoning with data-driven adaptability. We also aim to contribute to open-source simulation tools and datasets that encourage collaboration and innovation in the robotics community.

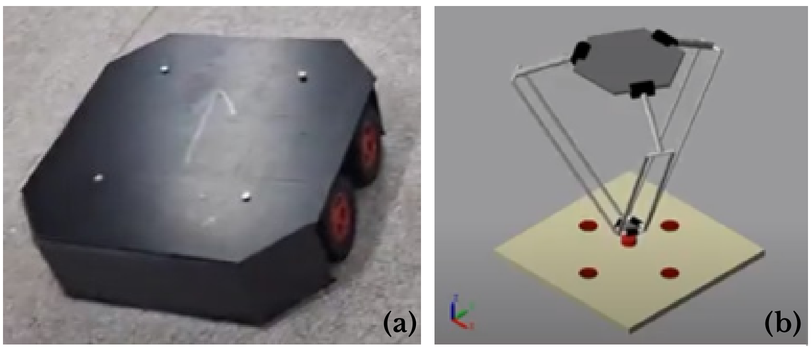


Figure 1. Robots are built at the Robot Learning Lab, IITH.
(a) Mobile robot,
(b) Delta robot

[1] **Dr Rekha Raja**, Assistant Professor
[2] **Mr Shibajyoti Das**
Research Scholar
[3] **Mr YawalkarPratik Yuvraj** (Masters Student)
[4] **Mr Amma Kartikeya** (Masters Student)
Dept of Artificial Intelligence