Robust and Efficient Physics-Based Learning and Reasoning in Degraded Environments

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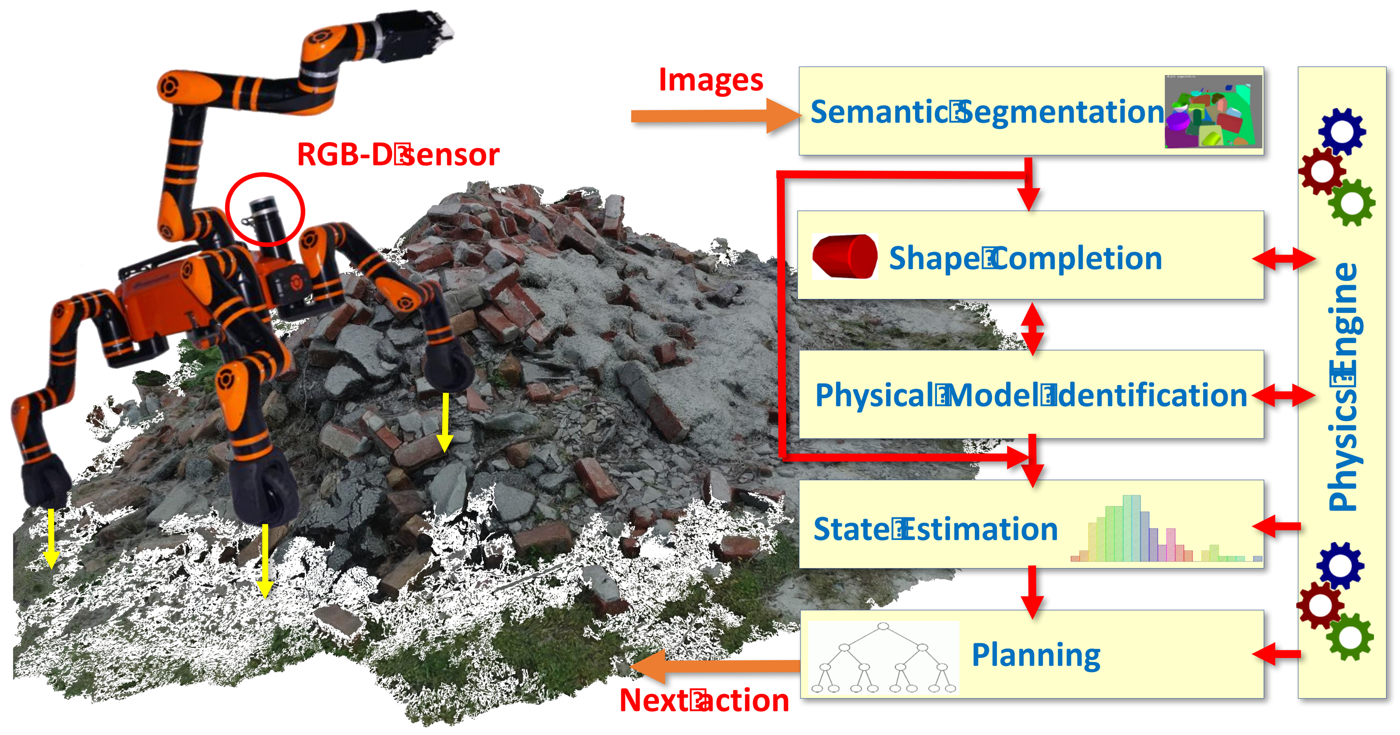
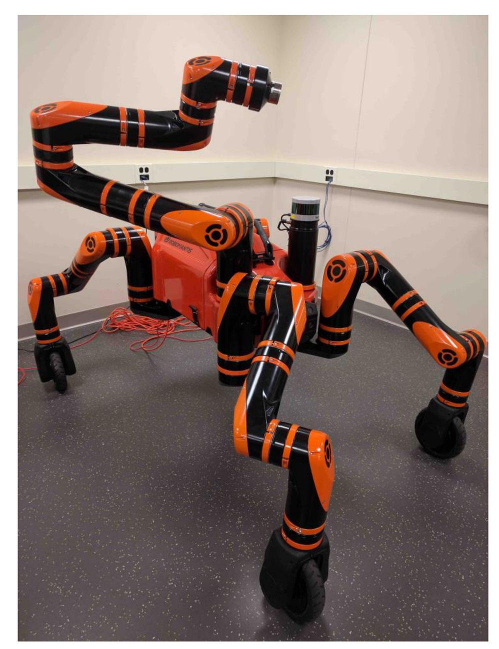
Challenge:





Robotic Platform: four-legged *RoboMantis*

Development and integration of model learning, simulation, and planning algorithms to enable the deployment of robots to unstructured and cluttered environments that occur around disaster sites.

Goals:

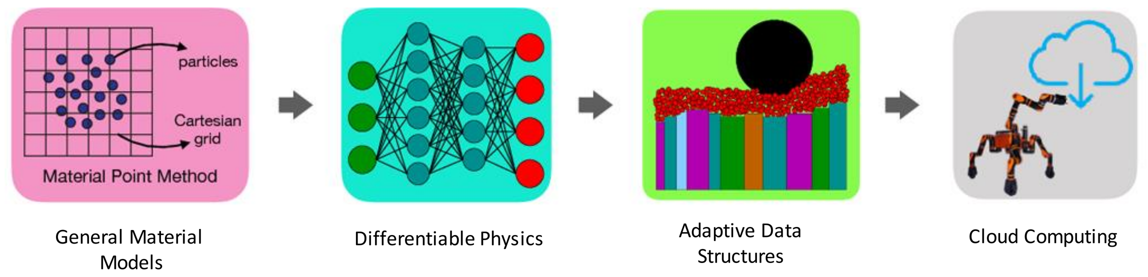
The proposed project will develop (1) **physics simulation tools** that can be used for efficiently inferring models of both rigid and non-rigid objects and for robust planning, (2) **optimization tools** for learning models of objects from limited vision and interaction data, and (3) **manipulation and navigation algorithms** that can leverage the learned models.

Intellectual Merits:

At the heart of the proposed methodology lies the design of a novel physics engine that can simulate rigid, non-rigid, elastic, plastic, and granular materials, all within a single unified framework.

The physics engine will be used to learn both the shapes and the mechanical properties of different objects in a clutter, which can then be used to predict the outcomes of new physical interactions.

Novel physics-aware task primitives for stepping, poking, pushing, and grasping will be integrated into a highly optimized task and motion planner.



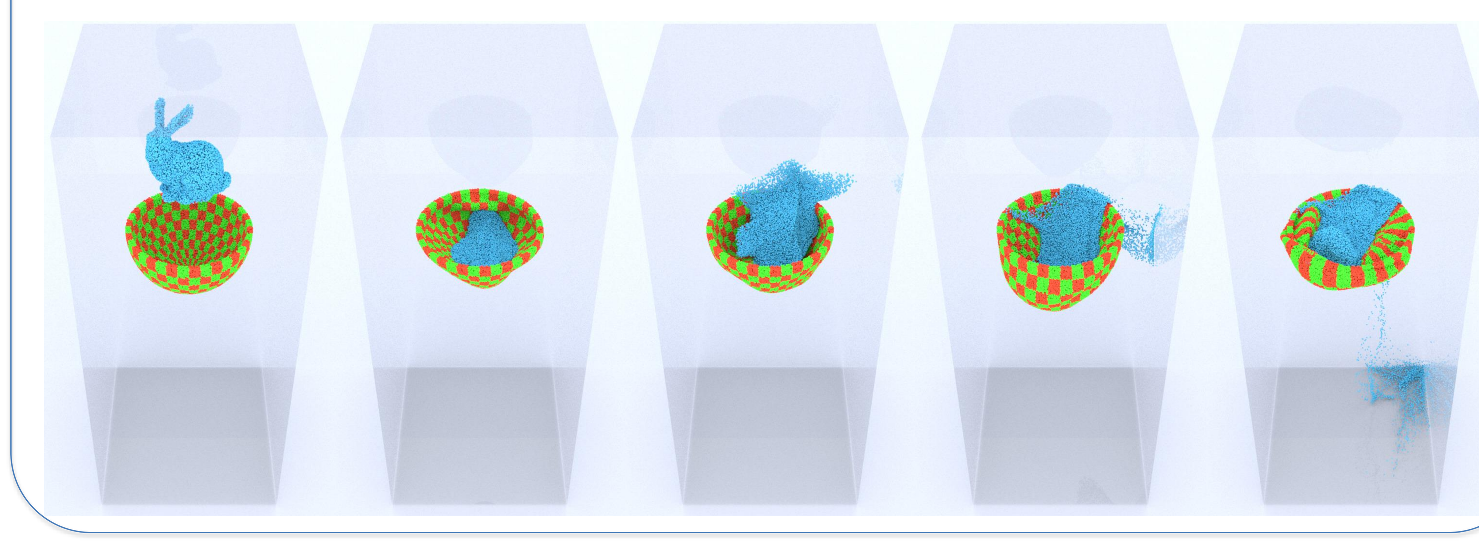
Broader Impact:

This work can promote the use of robots in a variety of domains, such as disaster response.

The PIs will provide to the research community implementations of their solutions and benchmark challenges in robotic manipulation where the objects are unknown a priori.

Multi-Material Simulation

This project uses the Material Point Method (MPM) for simulating different kinds of objects and their coupled interactions. MPM suffers from numerical fracture. To remedy this, we have develop adaptively updated Lagrangian MPM (A-ULMPM) which avoids numerical fracture with large deformations:

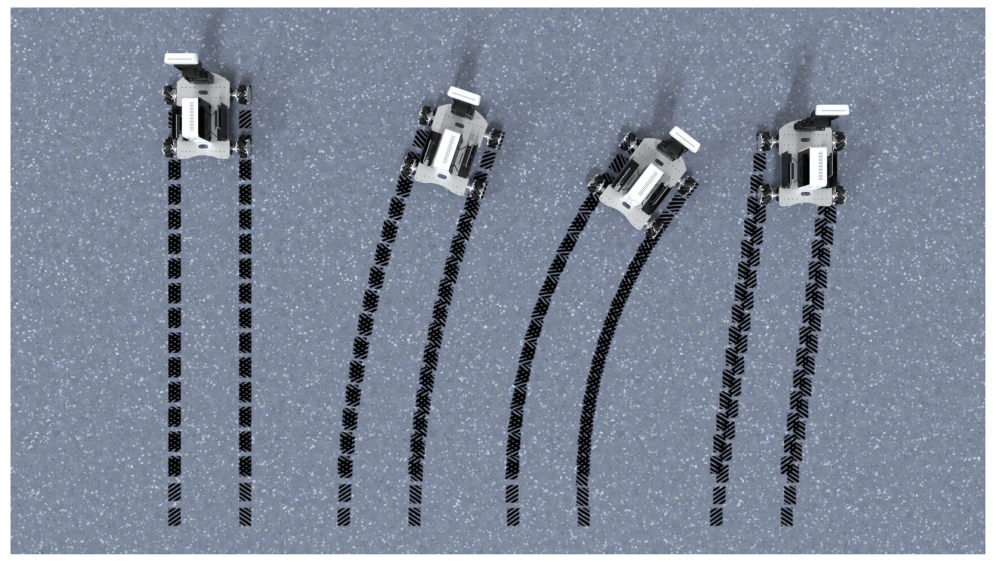


Destruction with Compressible Flow

This project aims to simulate scenarios with destruction and damage, where compressible flow and shock waves may arise. To efficiently simulate dynamic fracture and high-speed objects in such situations, we have extended MPM algorithm.

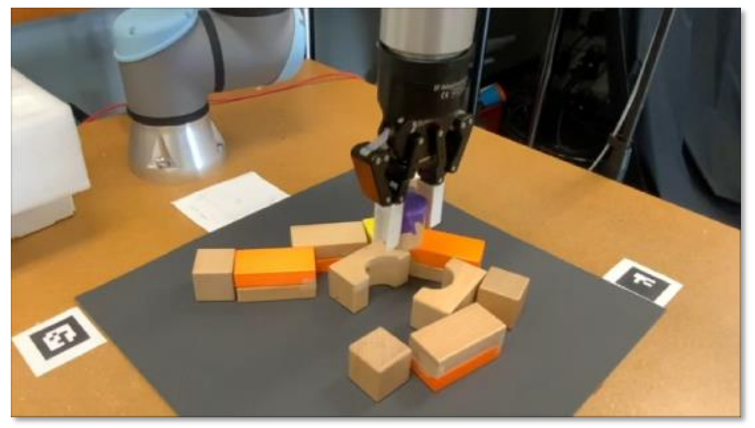
Differentiable Physics for Control

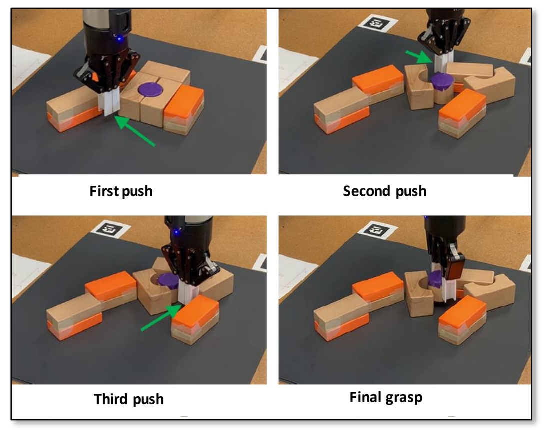
A crucial component of this project is the use of differentiable physics for automatically learning material properties of objects in the environment for efficiently designing control policies. To this end, we have designed a new algorithm for model identification and path planning of a mobile robot that is data-efficient.



Efficient Object Retrieval from Clutter

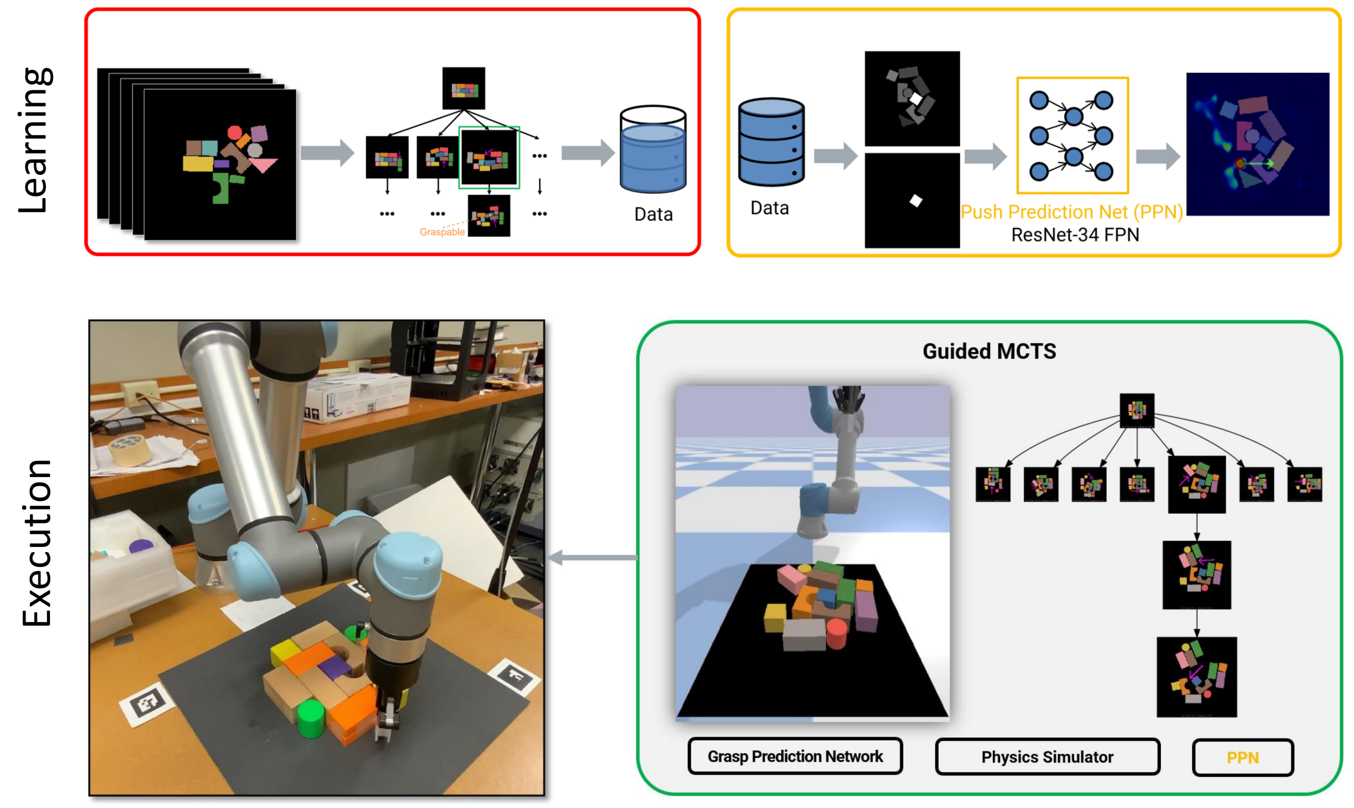
An integral element of the project is to enable robots to autonomously and effectively search and retrieve objects from rubbles/clutter. This often also must be done within a confined workspace.





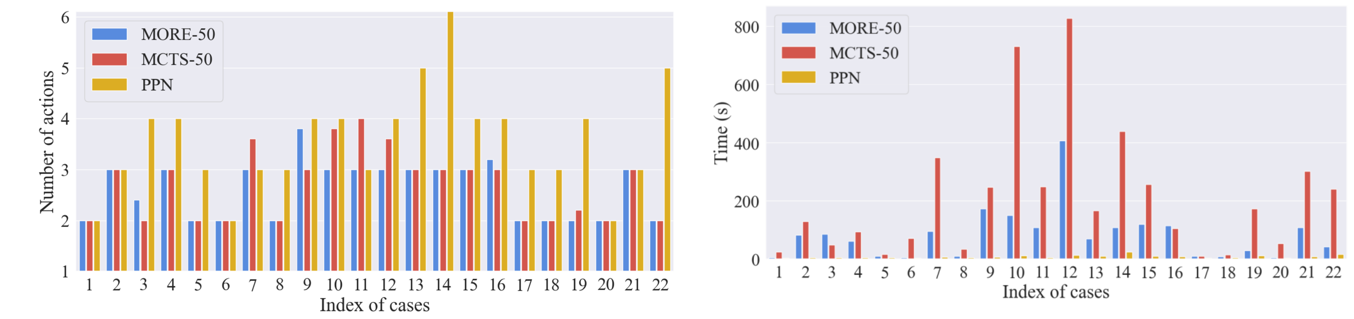
Algorithm: Guided Monte Carlo Tree Search

We develop a novel approach that first use Monte Carlo tree search (MCTS) to solve many problems by working with a digital twin of the problem at hand. The data is then used to train a DNN for guiding the MCTS to speed up the search process.



Result

Our method, while highly optimal, significantly speeds up the plan search process



Interleaving Monte Carlo Tree Search and Self-Supervised Learning for Object Retrieval in Clutter. B. Huang, T. Guo, A. Boularias and J. Yu. ICRA 2022

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