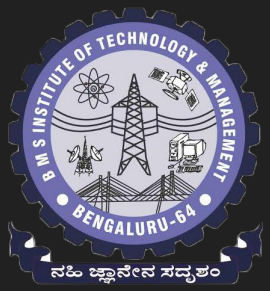

BMS Institute of Technology and Management

Department of Computer Science and Engineering

Investigation and Design of Swarm Intelligence Methodologies Applying Machine Learning for Terrain Mapping

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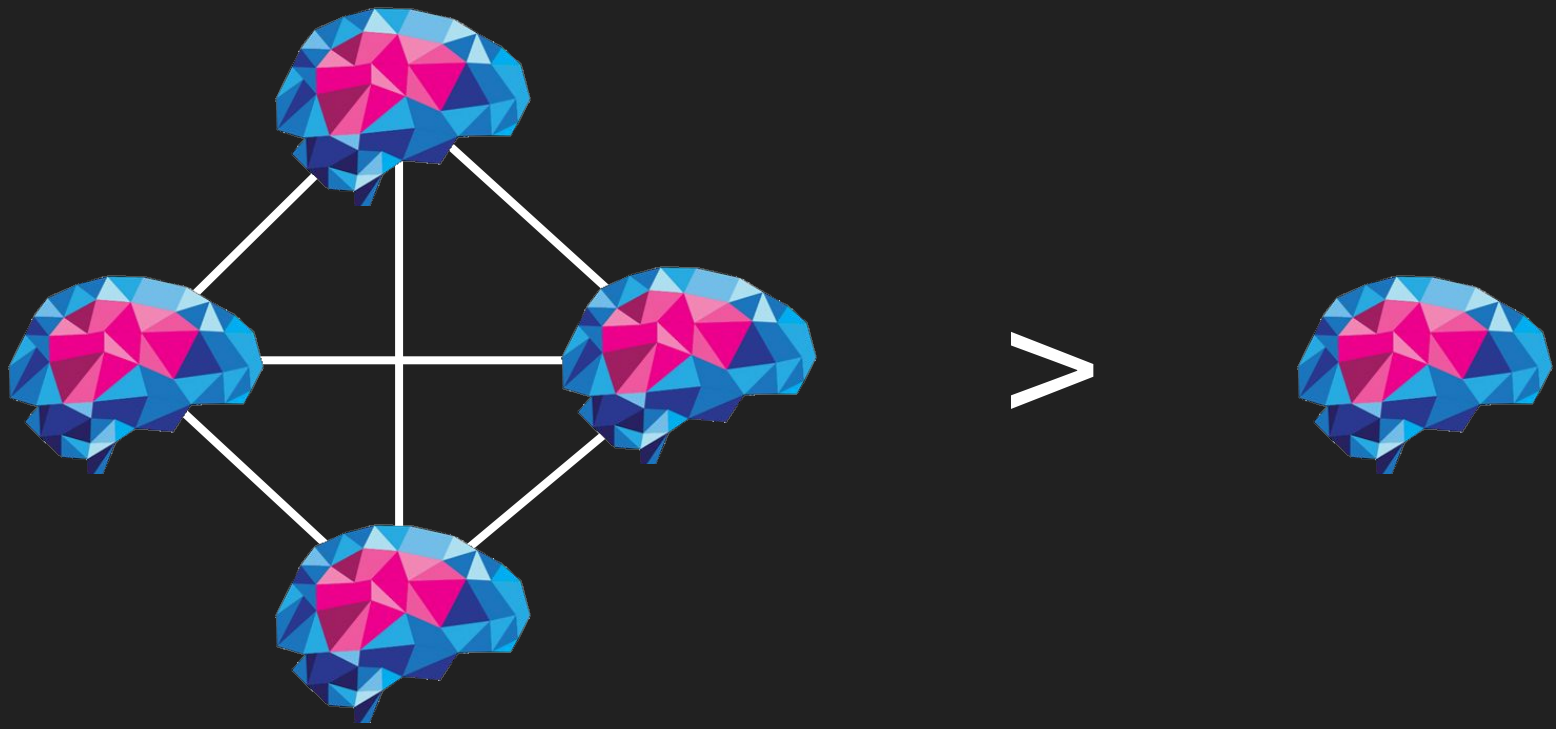
Agenda

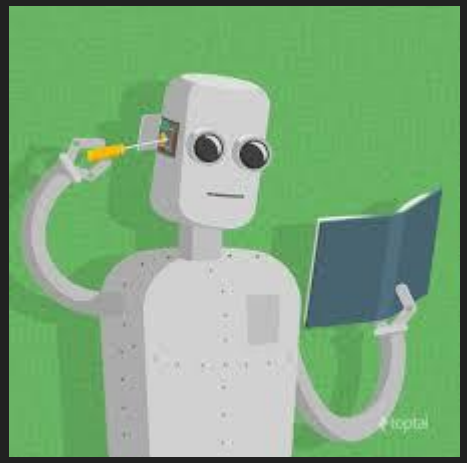
- Introduction
- Literature Survey
- Problem Statement
- Implementation
- Results
- Conclusion
- References

What is Swarm Intelligence?



Many autonomous agents co-operating to achieve a global objective.

Machine Learning



Machine Learning explores the study and construction of algorithms that can learn from and make predictions on data.

What is Terrain Mapping?

Terrain

The vertical and horizontal dimension of the land surface.

Terrain Mapping

Generating a software representation of a terrain.

What is Terrain Mapping?

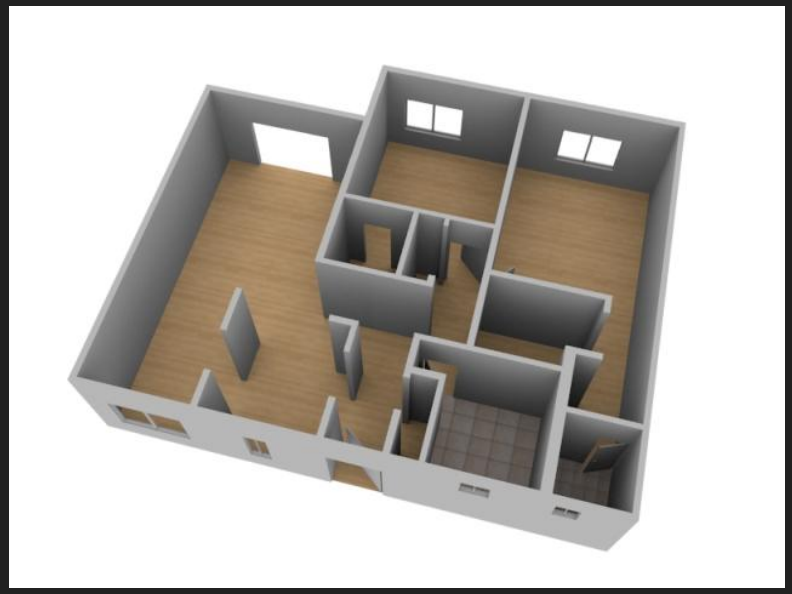


Fig: Mapping of the interior of a house

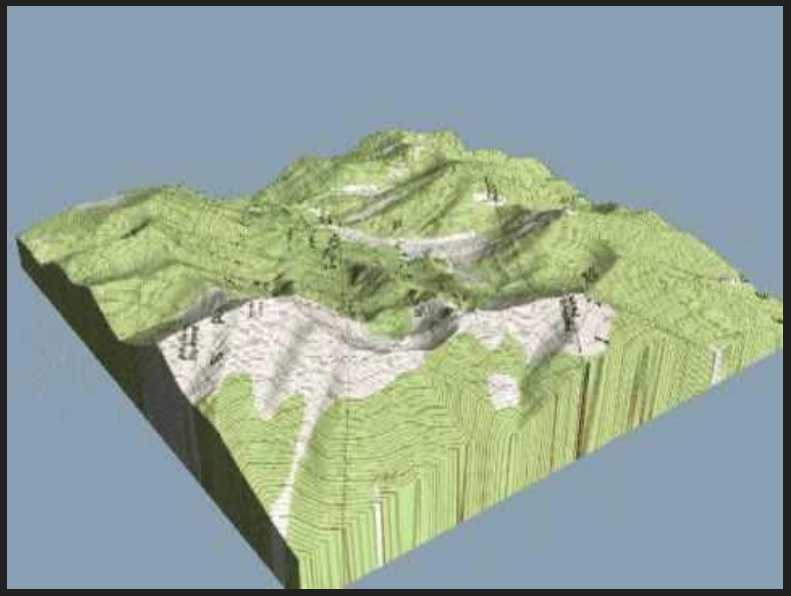


Fig: Mapping of an outdoor terrain

Relevance in Present Context

Swarm Intelligence and Robotics

Multiple agents working together to achieve a global objective has been employed in multiple situations:

- Agriculture - seed distribution, precision farming
- Defence and Security
- Search and Rescue (in hazardous environments such as underground mines and nuclear plants)

Relevance in Present Context

Machine Learning

- Machine learning has several very practical applications that drive the kind of real business results – such as time and money savings.
- Having a robot learn from its environment results in a robust system

Relevance in Present Context

Terrain Mapping

- Modeling water flow
- 3D flight planning
- GIS
- Precision Farming

Literature Survey - Terrain Mapping

- **Forward looking InSAR based field terrain mapping for unmanned ground vehicle**
  - Interferometric Synthetic Aperture Radar (InSAR Sensor)
- **Towards LIDAR-RADAR based terrain mapping**
  - combine an optical sensor and an electromagnetic sensor to build a richer map of the environment
- **Straightforward reconstruction of 3D surfaces and topography with a camera: Accuracy and geoscience application**
  - Uses computer vision software on field photographs

Literature Survey - Swarm Intelligence

- **Information Sharing in Swarm Intelligence Techniques: A Perspective Application for Natural Terrain Feature Elicitation**
  - Basic overview of swarm algorithms
- **A Robot System Design for Low-Cost Multi-Robot Manipulation**
  - The architecture of the Rice University Swarm Robot, the R-one
- **Kilobot: A Low Cost Scalable Robot System for Collective Behaviors**
  - The architecture of the Harvard University Swarm Robot, the kilobot

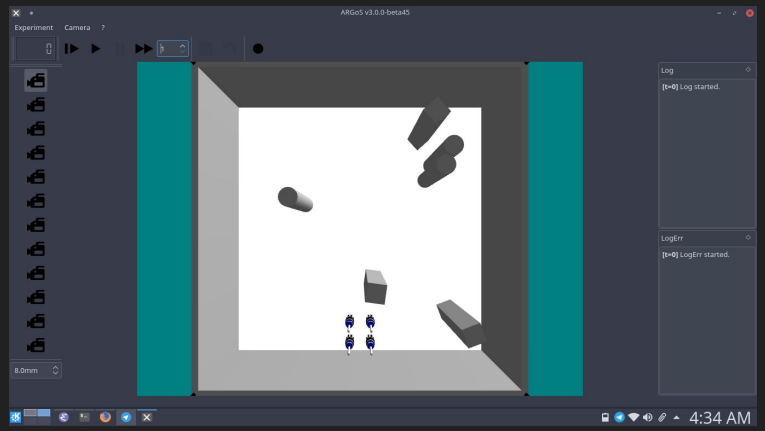
Literature Survey - Machine Learning

- **Playing Atari with Deep Reinforcement Learning**
  - Deep Q Network - an AI that can learn to play games just by observing the screen

Problem Statement

Generating a 3D surface model for a surface posing a traversability challenge.

Implementation - Theoretical Modeling



- ARGoS is a multi-physics robot simulator. It can simulate large-scale swarms of robots of any kind efficiently.
- A **swarm dispersion/exploration** algorithm was implemented on the footbot using just the proximity sensors

Implementation - Hardware

Three robots were built. Each robot has:

- **A differential drive mechanism** : motors run via the L293D H-bridge
- 4 **HC-SR04** sensors arranged facing different directions
- A microcontroller **Arduino Uno/Mega** running the same swarm dispersion algorithm as in the simulation

Implementation - ORB SLAM

Computer vision was chosen to implement mapping (in specific, the **ORB-SLAM** algorithm)

- An **android smartphone** is mounted on it with the browser open and running the web application
- The web application captures a video sequence when commanded and sends the video sequence to the server
- The video sequence is processed to generate a map of the area and the trajectory of the robot.

Implementation - Machine Learning

Machine Learning is simulated using OpenAI gym (the Mountain Car problem)

- The solution uses a kernel function and a linear classifier to implement **Reinforcement Learning**
- Written in Python with the scikit-learn library

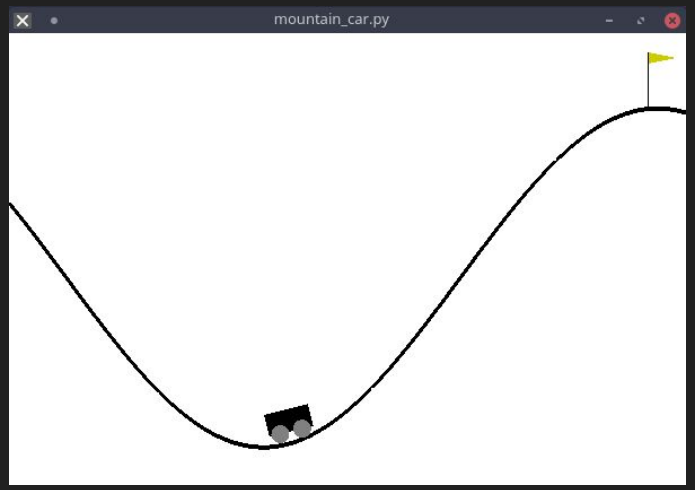


Fig: Mountain Car Problem

Results - Swarm Dispersion

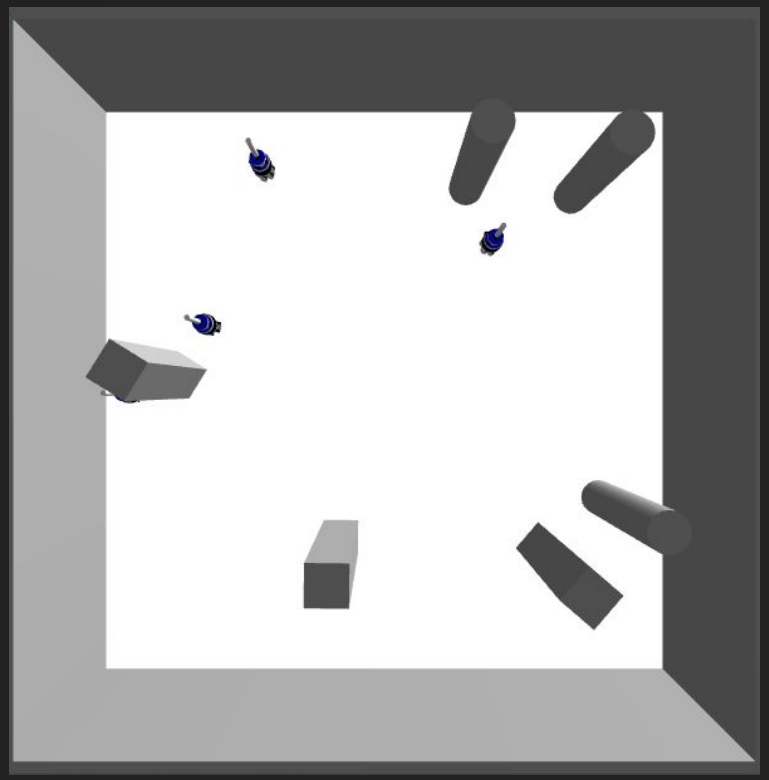
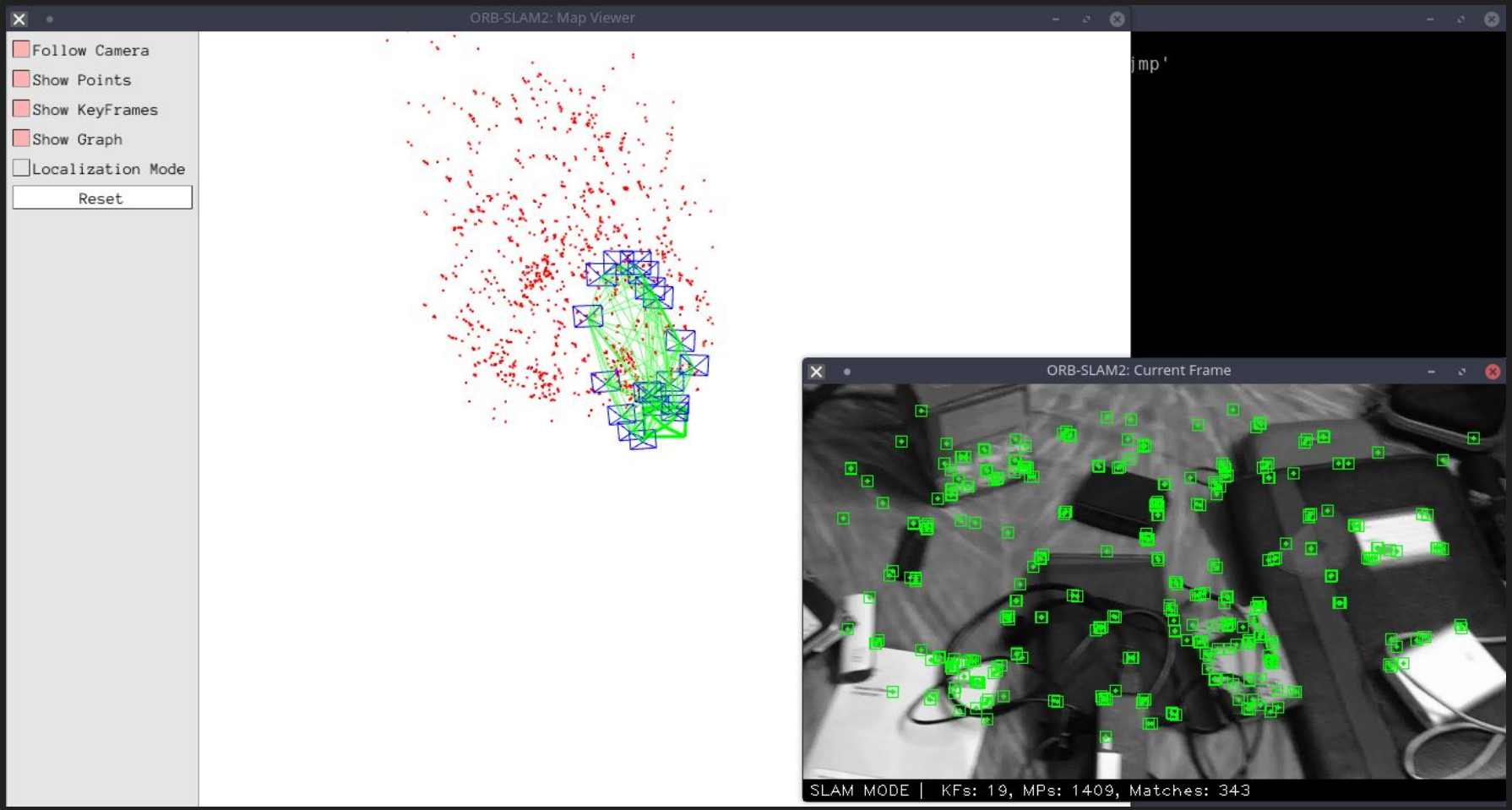
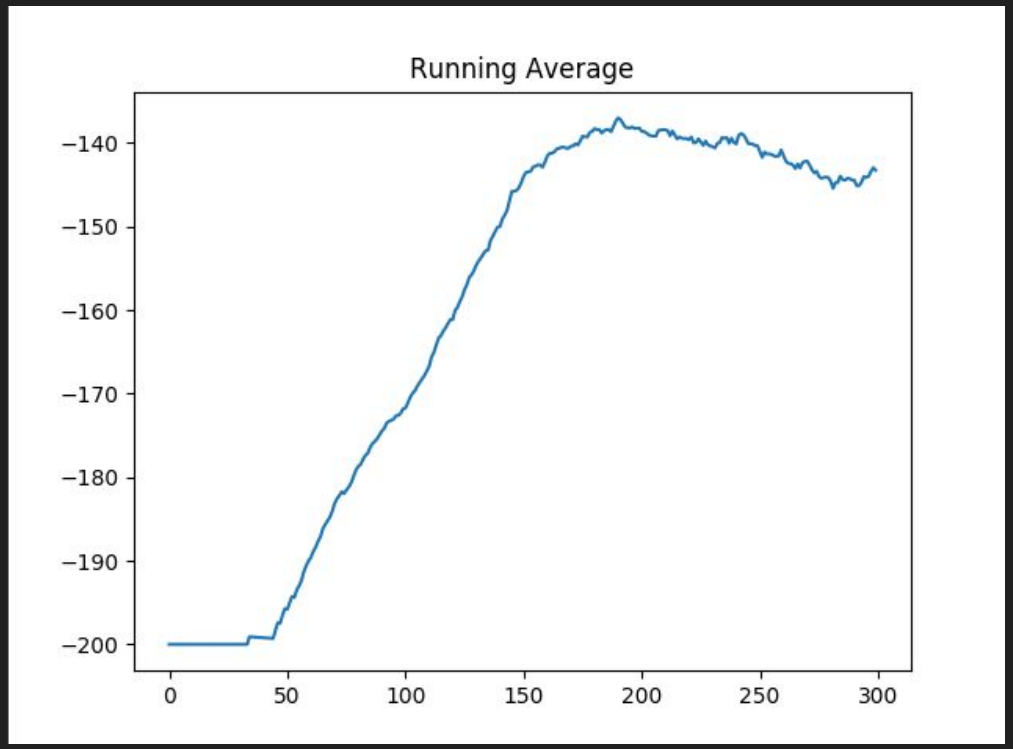


Fig: Swarm Dispersion

Results - ORB SLAM



Results - Machine Learning



Conclusion and Future Work

- Synchronizing the data feed from different robots and fusing them to generate one terrain map of the entire region.
- The feature to mark a region and command the swarm to map/explore that region only.
- Using industry-grade sensors such as a LIDAR scanner.
- The reinforcement learning algorithm could be implemented on the hardware. This could open new means to traverse unknown environments.
- Using other approaches to implement the reinforcement learning agent, such as Deep Q-Learning, as described in one of the papers surveyed or Policy Gradients.

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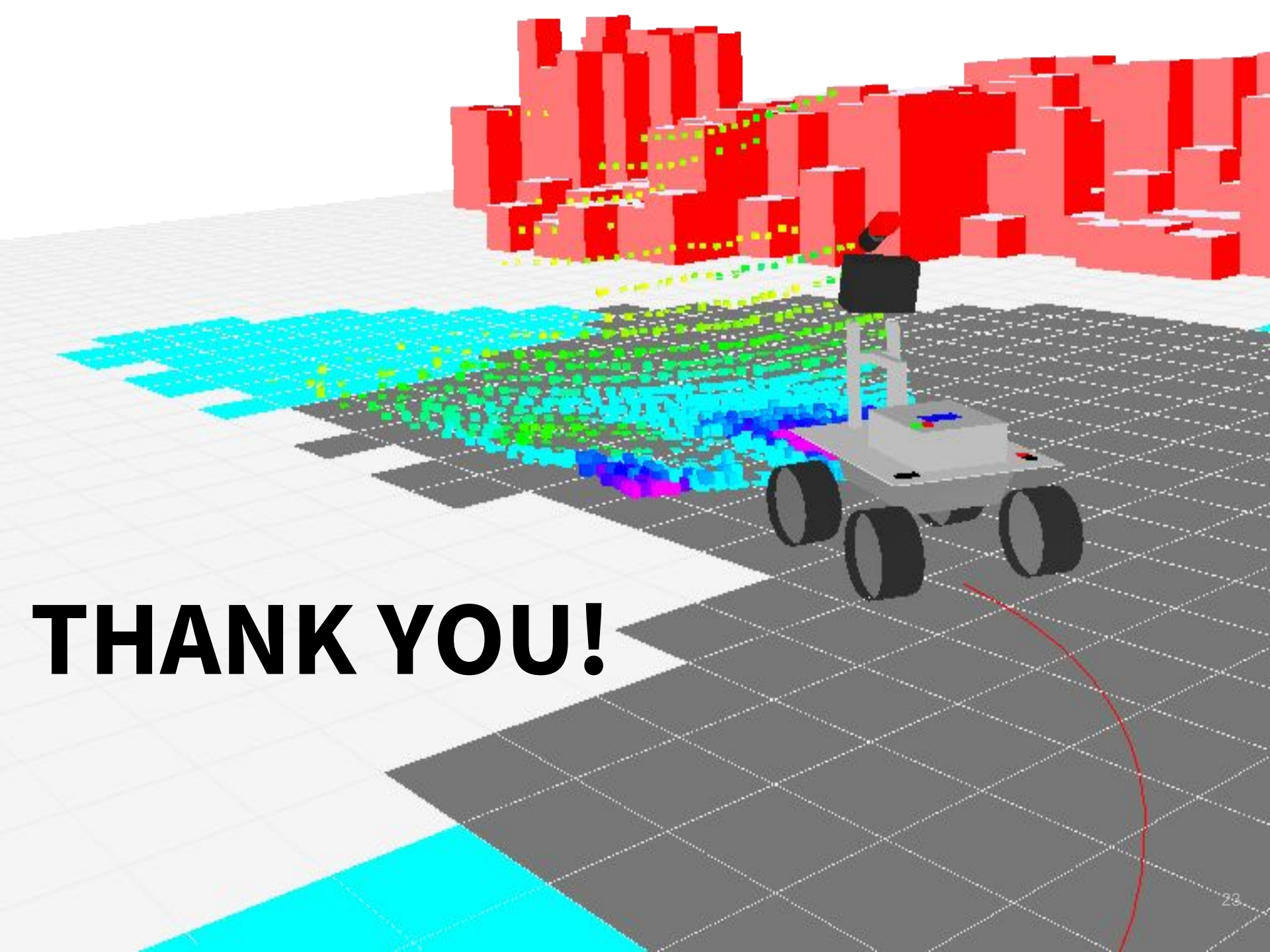
THANK YOU!