Deploying Mobile Robots (Autonomous Cars) amongst Human (Crowds): Challenges and Opportunities

Arun Kumar Singh

Overview of the Talk

1. Opportunities with mobile robots.

2. Challenges

3. Our works

4. Conclusions

Mobile Robots among Humans

1.https://www.hurriyetdailynews.com/photo-istanbul-restaurant-debuts-robot-waiters-148505
2.https://www.forbes.com/sites/stevebanker/2019/03/11/the-autonomous-mobile-robot-market-is-taking-off-like-a-rocket-ship/?sh=5b6f03341603
3.https://www.cargo-partner.com/trendletter/issue-4/drones-in-warehouse-logistics
4.https://cleveron.com/cleveron-mobility/cleveron-701

What it takes to bring Mobile Robots into your Workspace

1. **Regular Stuffs: Good starting point is ROS libraries**

   Perception Stack: Mapping, Localization, Obstacle Detection etc.

   Motion Planning and Control Stack: Motion planning in static maps, mildly changing environments.

1. **Niche Stuffs: Open Research Problems**

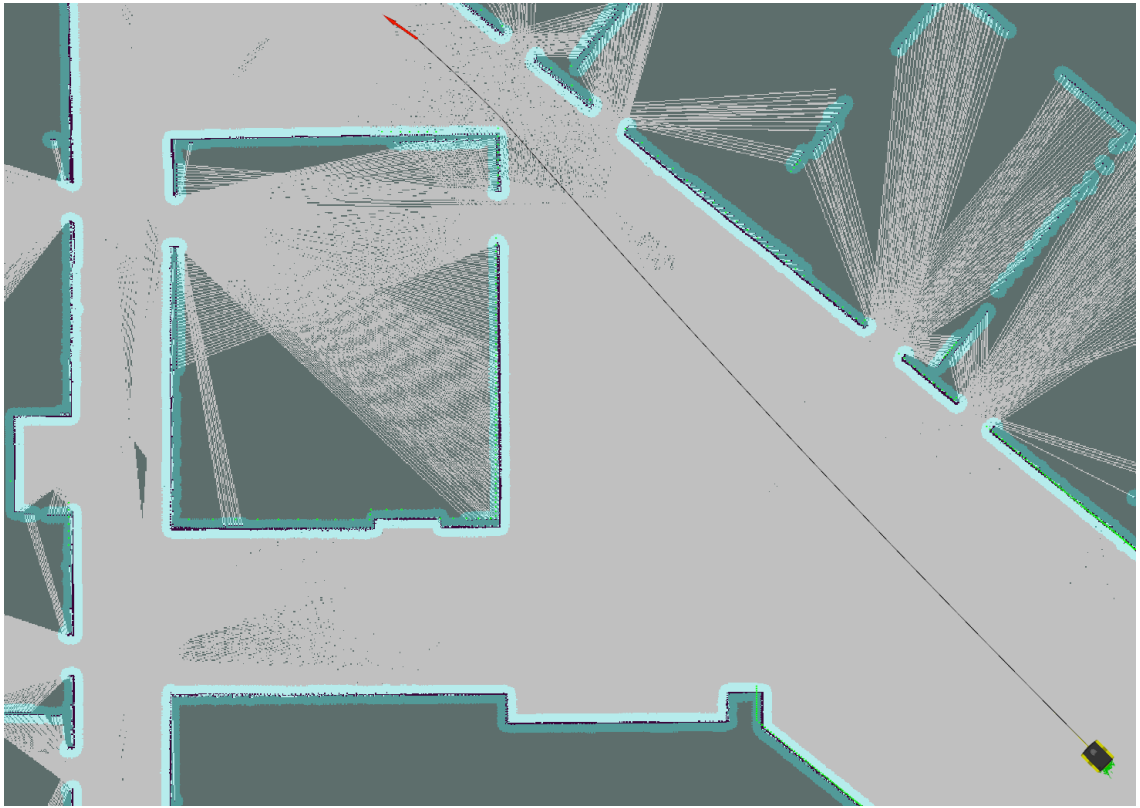
   Trajectory Prediction: How humans will move in the environment and how they will react to your robot.

   Long horizon Motion Planning and Control in Dynamic and uncertain environments

   Mapping and Localization in Dynamic Environments

   Human-Aware motion planning and control.

Mapping and Localization (Indoors): Off-the-shelf Solution

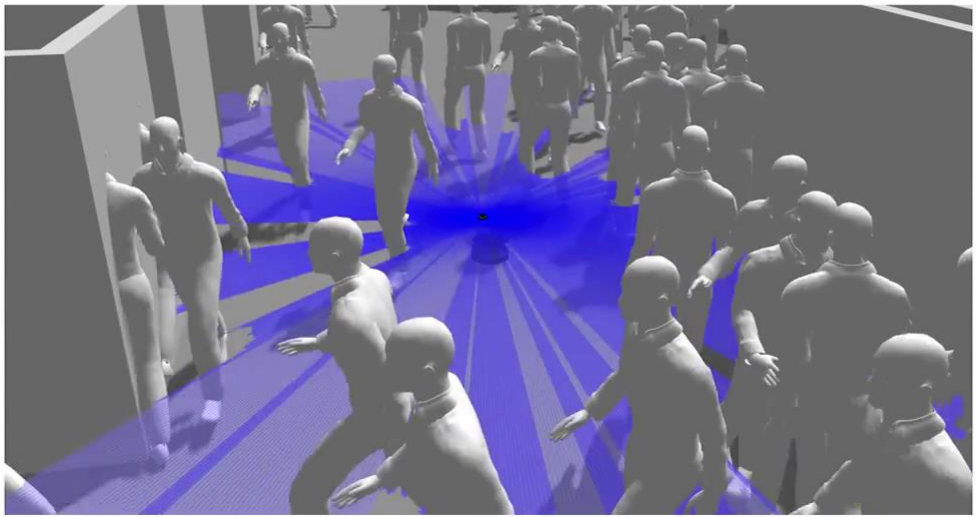


A Lidar Based Map of the Delta 3rd floor building

When can off-the-shelf mapping stack fail.

Problems

1. The robot may get **frozen** and cannot make any progress toward its goal;
2. The robot may get **lost** due to severe occlusions inside a crowd.



1. Human crowd can block lidar view.
2. Localization failure can make the robot stop/freeze

Fan, T., Cheng, X., Pan, J., Long, P., Liu, W., Yang, R. and Manocha, D., 2019. Getting robots unfrozen and unlost in dense pedestrian crowds. IEEE Robotics and Automation Letters, 4(2), pp.1178-1185.

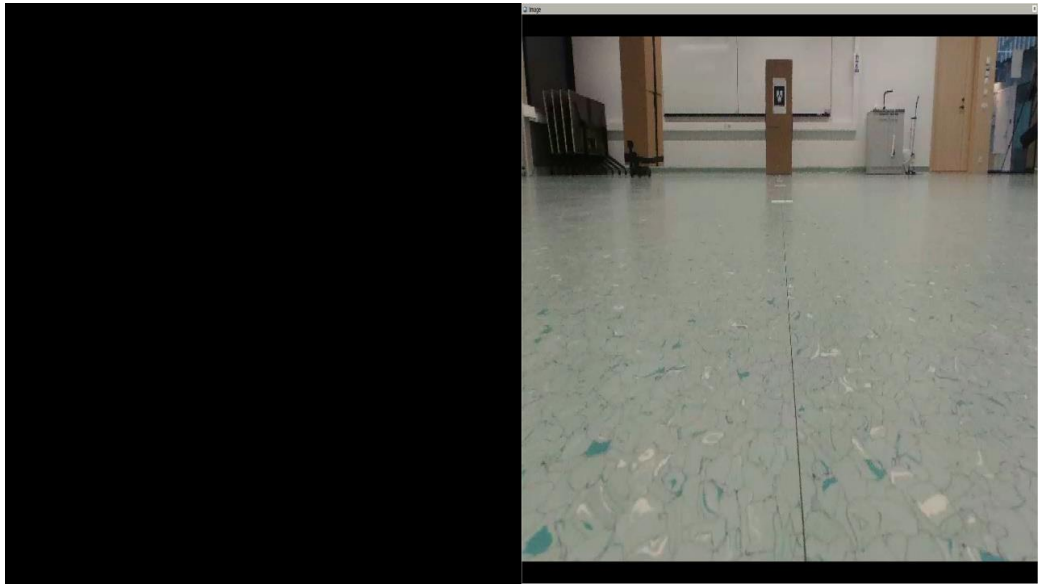
Vision Based Localization Failure in Dynamic Environments

1.A drone uses its front camera for localization.

2. Dynamic Obstacle blocks the drone view of the fiducial marker

IEEE Access, 2021

Active Perception to Prevent Localization Failures



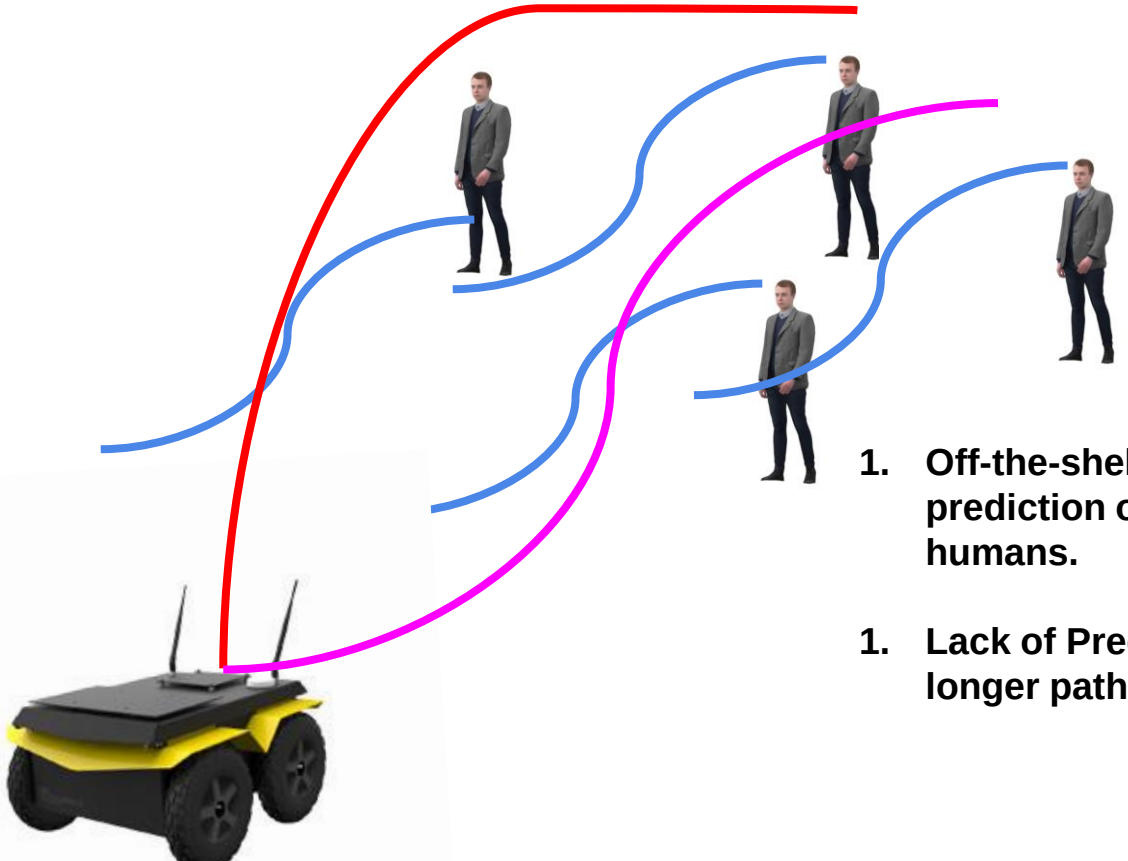
1.A drone uses its front camera for localization.

2. Drone predicts future occlusions and adapt its positions to keep the marker in its field of view.

IEEE Access 2021

Motion Planning and Control : Off the shelf Solution

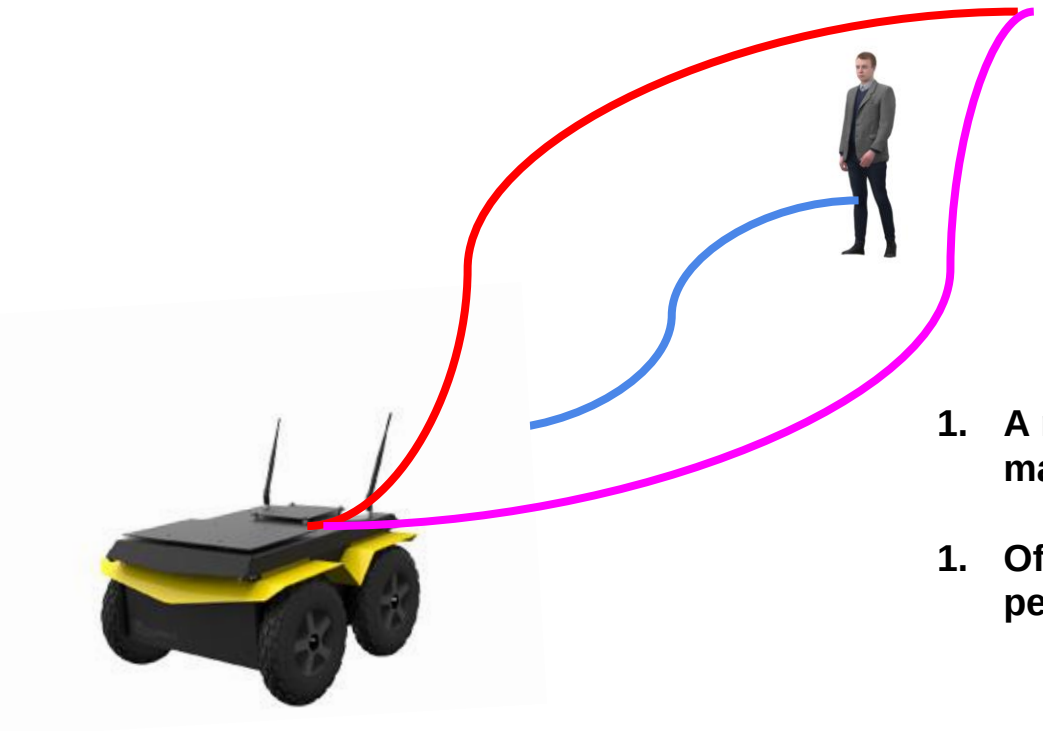
When can off-the-shelf motion planning stack can break



1. **Off-the-shelf motion planners in ROS can leverage prediction of trajectories and interaction with humans.**

1. **Lack of Prediction means robot stops or takes a longer path**

When can off-the-shelf motion planning stack can break



1. **A robot can avoid obstacles in multiple-ways (red, magenta)**

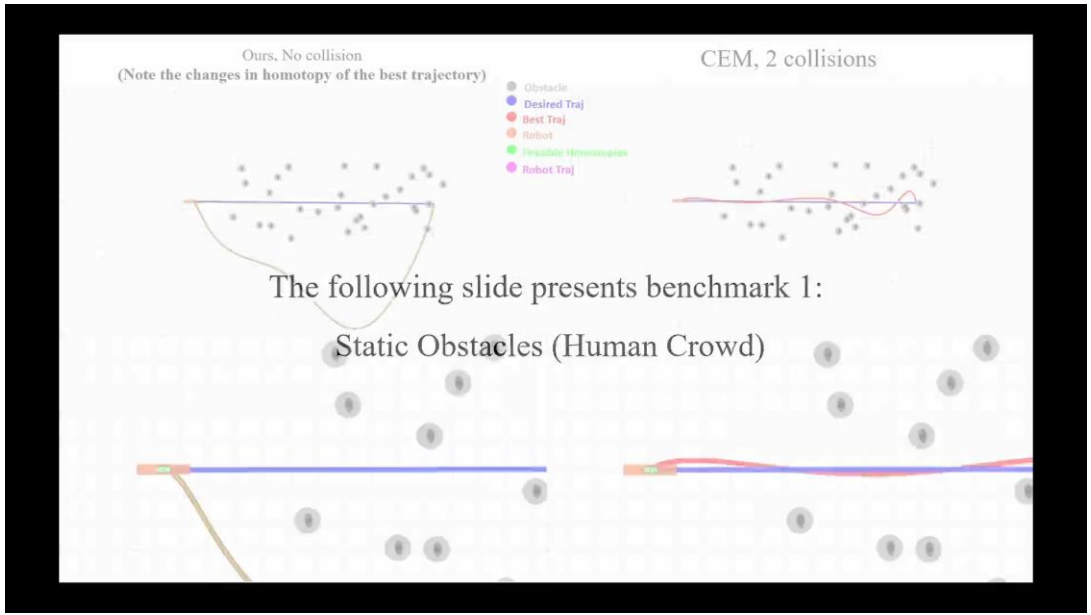
1. **Off-the-shelf motion planners in ROS cannot perform long-horizon multi-modal planning.**

Our Core Expertise

1. Our group works at the intersection of classical control theoretic and deep learning approaches to develop sophisticated motion planning and control algorithms.

1. **Our core focus is on developing real-time algorithms for fast-changing environments.**

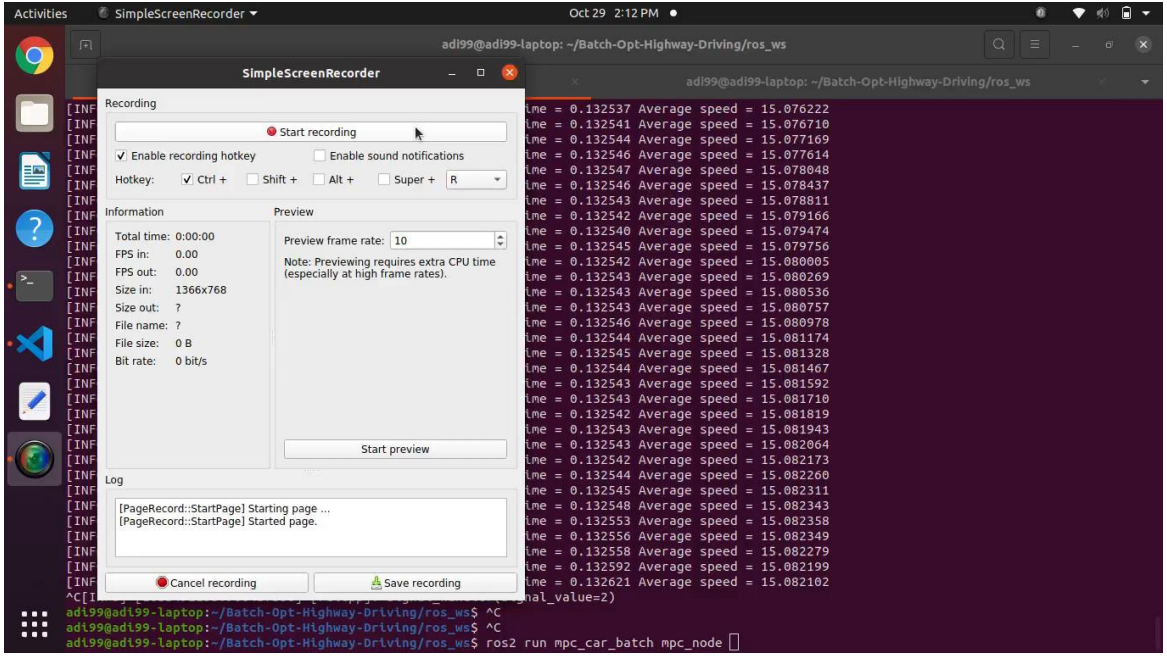
Some Glimpses of our Solutions in Multi-Modal Motion Planning



IEEE ICRA 2020, 2021 IROS 2020, 2021, Robotics and Automation letters 2021

Under review ICRA 2022

Some Glimpses of our Solutions in Multi-Modal Motion Planning



IEEE ICRA 2020, 2021 IROS 2020, 2021

Under review ICRA 2022

Off-The-Shelf Motion Planning Solutions are Limited for Multi-Robot Deployment

GPU Accelerated Convex Approximation for Fast Multi-Agent Trajectory Optimization

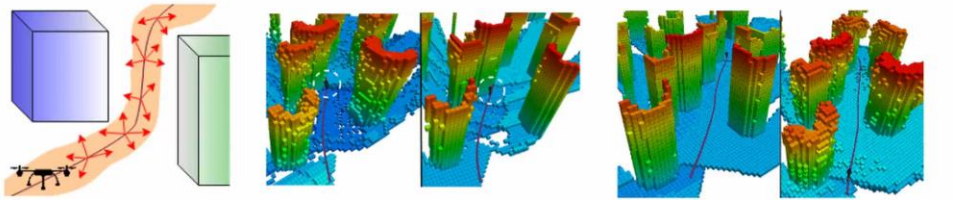
- Fatemeh Rastgar
- Houman Masnavi
- Jatan Shrestha
- Karl Kruusamäe
- Alvo Aabloo
- Arun Kumar Singh

IEEE Robotics and Automation letters (RAL) 2021

Off-The-Shelf Motion Planning Solutions cant handle uncertainty in perception and motion.

CCO-VOXEL: Chance Constrained Optimization over Uncertain Voxel-Grid Representation for Safe Trajectory Planning

Sudarshan S Harithas[1], Rishabh Dev Yadav[1], Deepak Singh[1], Arun Kumar Singh[2], Madhava Krishna[1]

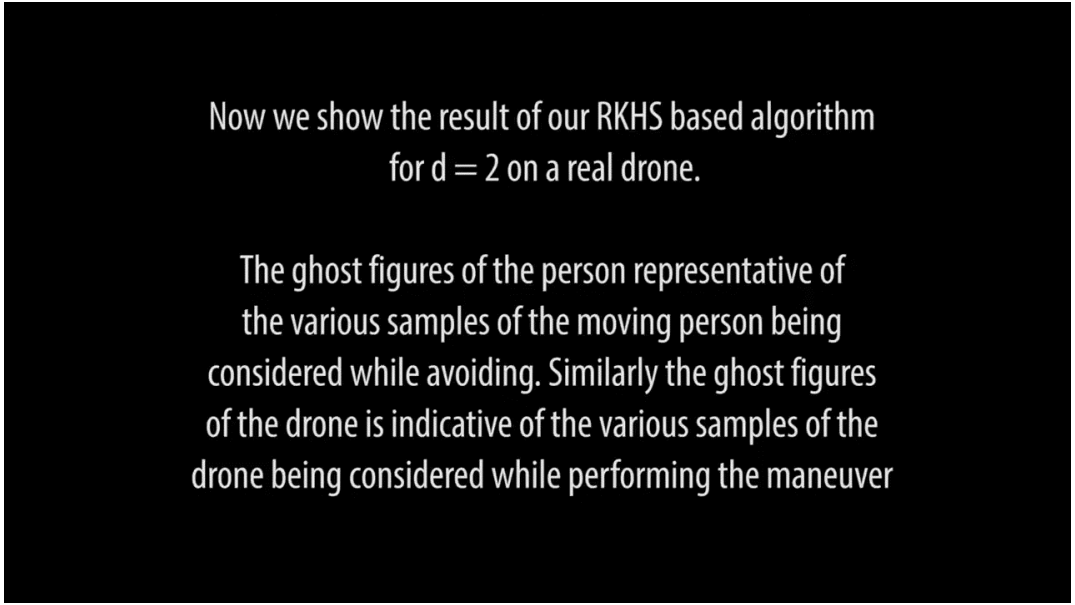


[1]Robotics Research Center, IIIT Hyderabad
[2]University of Tartu, Estonia

IEEE Robotics and Automation letters 2021

IEEE Transactions on Control Systems, 2021
Under review at ICRA 22

Off-The-Shelf Motion Planning Solutions cant handle uncertainty in perception and motion.



IEEE Robotics and Automation letters 2021

IEEE Transactions on Control Systems, 2022

Conclusions

1. The entry barrier of introducing mobile robots into workspaces is reducing, both in terms of technical know-how and initial investment.

2. Existing off-the-shelf solutions for navigation and perception provide good baselines but a economically and industrially competitive solutions will require solving difficult research problems.

3. Our group can be a potential partner to companies looking to venture into robotics