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

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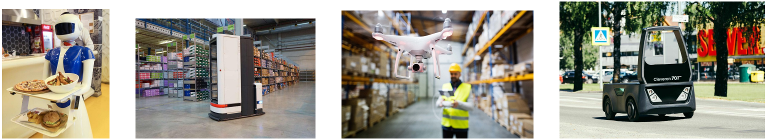
Overview

Mobile Robots Among Humans



(a) (b) (c) (d)

Figure: Modern Mobile Robot Applications working alongside humans

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

What does it take to bring Mobile Robots into your workspace

The Regular Stuff

- Perception Stack: Mapping, Localization, obstacle detection
- Motion Planning and Control Stack

The Niche Stuff because of Humans in the Envionment

- Trajectory Prediction: How humans will move in the environment and how they will react to your robot.
- Mapping and Localization in Dynamic Environments
- Human-Aware motion planning and control.

Mapping and Localization: Off-the-Shelf Solution

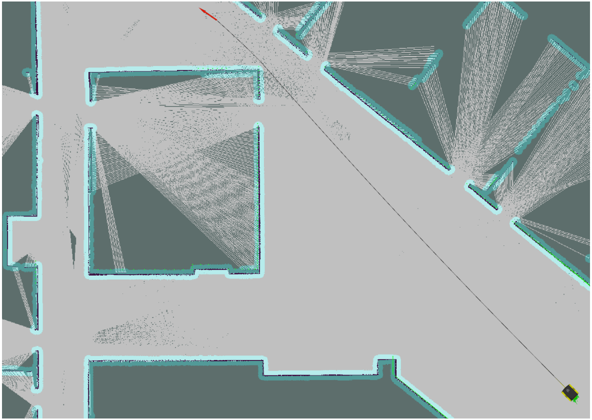

Figure: Map of 3rd floor of Delta Building built with ROS SLAM Package

When can off-the-shelf stack break down

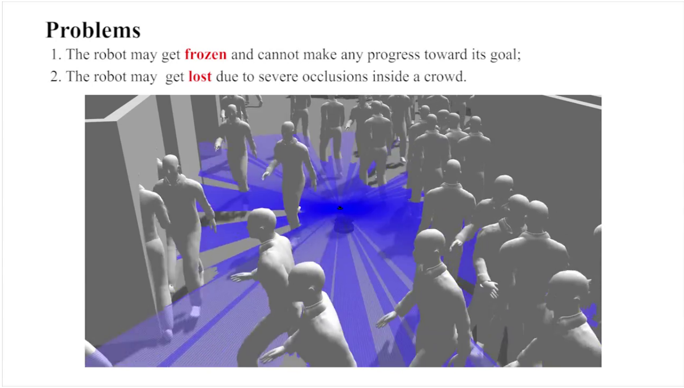

Figure: Localization Loss in Dynamic Environments

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[2] 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.

Possible Solution: Active Perception

Active perception means the robot moves in a way to improve its localization.

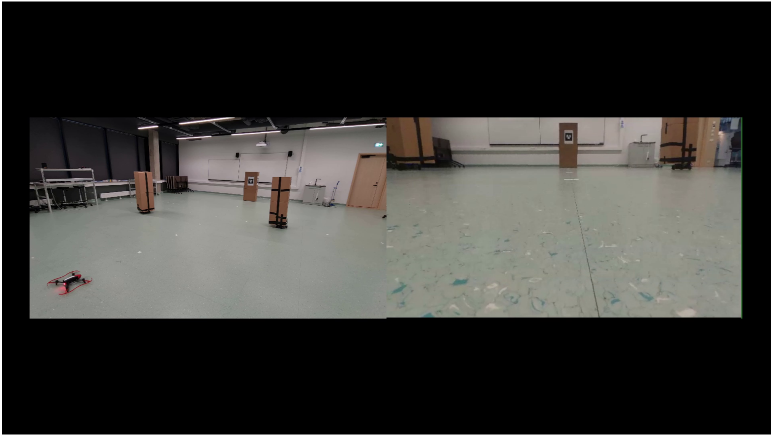
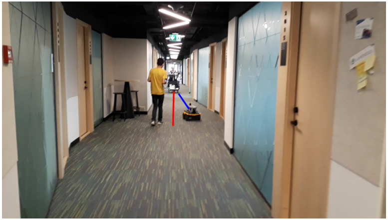


Figure: Active Perception with Quadrotors and Fiducial Markers

Human-Trajectory Prediction



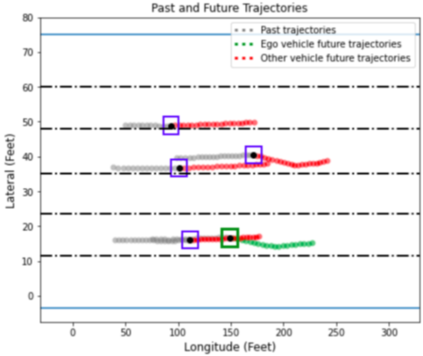
(a)

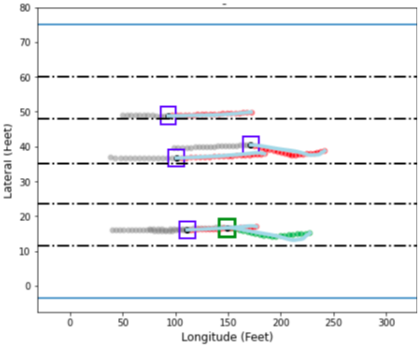
(b)

Figure: Importance of trajectory prediction for navigation in tight-corridors alongside humans

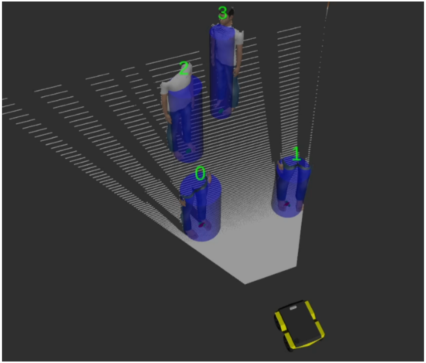
Trajectory Prediction: Challenges

- Hardly any off-the-shelf solutions exist for trajectory prediction: There are neural-network models but you need to re-train it on your data set.
- Inherently an unsolved problem, especially if you consider prediction in multi-agent setting: TRL level 1 or 2.
- We are working on developing solutions that require minimal re-training.

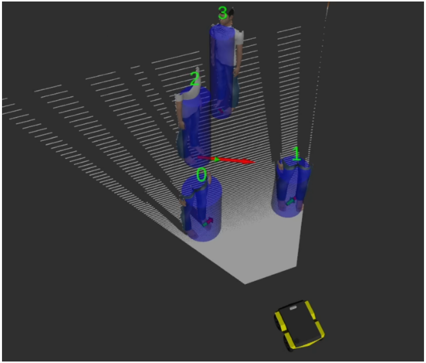




Human Detection and Tracking



(a)



(b)

Figure: 3D bounding box detection of Humans from RGBD Images

Motion Planning and Control: Off-the-shelf Solutions

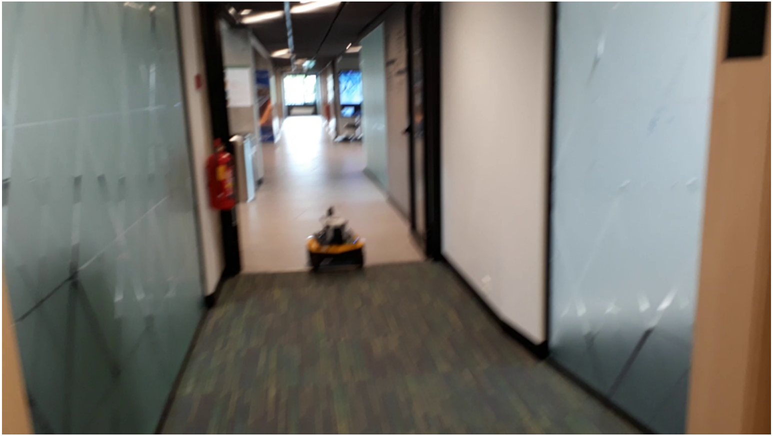


Figure: Navigation in Delta Building Corridors

Where off-the-shelf motion-planning stack breaks down

- Off-the-shelf software stack represents static and dynamic obstacles in the same form that is unsuitable for navigation among crowds.
- Navigation at moderate to high speeds is a challenge: even at 1 m/s speeds off-the-shelf navigation stack starts showing problems
  - More sophisticated algorithms like Model Predictive control are computationally intensive and thus difficult to attain real-time responsiveness.
- Navigation in crowded environments: off-the-shelf solutions aren't great.
- Coordination of fleet of robots: Almost complete lack of the off-the-shelf solution

This is our core expertise lies. We develop advanced real-time motion planning and control algorithms for a large range of applications.

Our Core Expertise

- We develop advanced real-time motion planning and control algorithms for a large range of applications:
  - autonomous driving, indoor navigation, object transportation, aerial navigation, objec
  - We are focusing mostly of improving the computation speed and reliability of approaches like Model Predictive Control
    - At the nuts and bolts level, this involve coming with faster and reliable optimization algorithms
  - Our algorithms run fast on both conventional Laptops and Embedded Hardware like Jetson TX2.

Some glimpses of our works: Quadrotor Navigation

Figure: Quadrotor Navigation in Cluttered Environments

Some glimpses of our works: Quadrotor Navigation

Figure: Quadrotor Navigation Amongst Humans

Some glimpses of our works: Multi-Robot Fleet Coordination

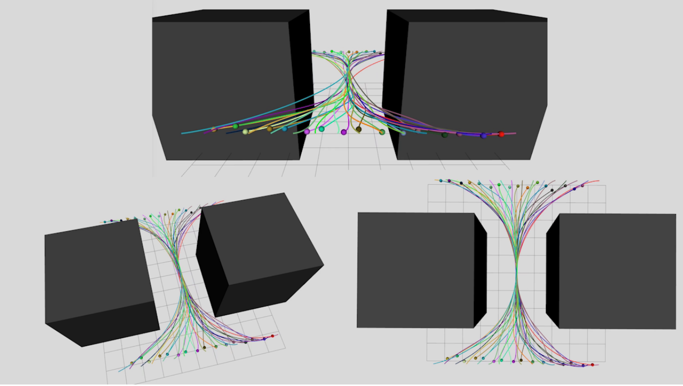


Figure: Multi-Robot Trajectory Optimization

Trajectory Optimization/MPC for Autonomous Driving

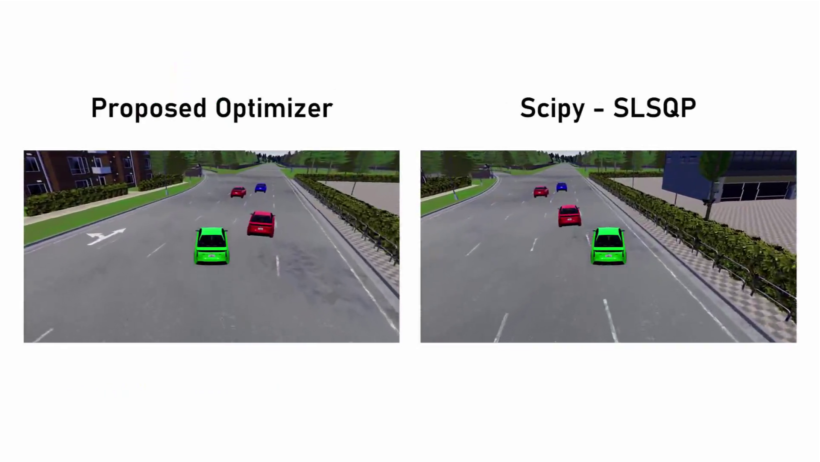
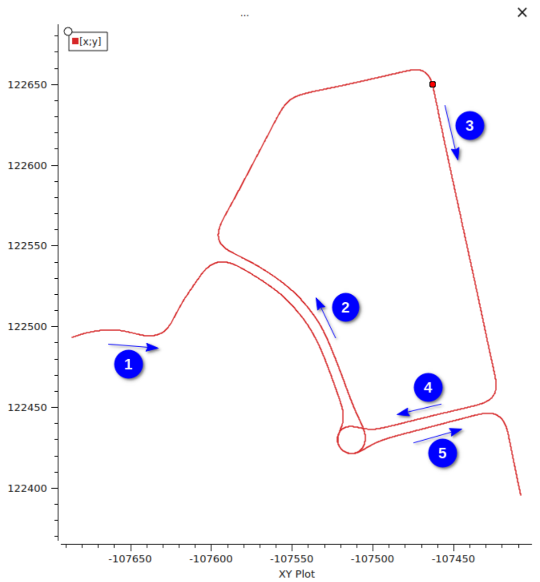


Figure: Trajectory Optimization for Lane Change and Overtaking

Results on MPC based Waypoint Navigation



Results on MPC based Waypoint Navigation for Autonomous Driving

Methods (Max/Mean)	Lat.Error	Jerk (m/s^3)	Steering Velocity (rad/s)
Ours	0.59/0.25	1.60/1.90	0.20/0.03
AutoWare MPC	0.57/0.125	8020/59	0.72/0.04

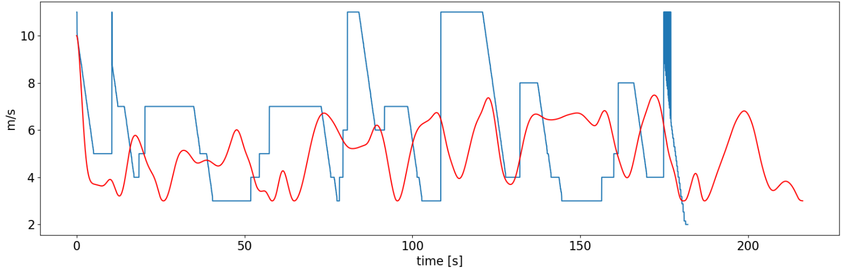


Figure: Comparing Forward Velocity for Ours (red) and Autoware MPC (blue)

Conclusions

- The entry barrier of introducing mobile robots into workspaces is reducing, both in terms of technical know-how and initial investment.
- Existing off-the-shelf solutions for navigation and perception provide good baselines but a economically and industrially competitive solutions will require solving research problems.