Mechanical Systems Control Lab (MSC Lab)

CalDay - 04/2020

About us

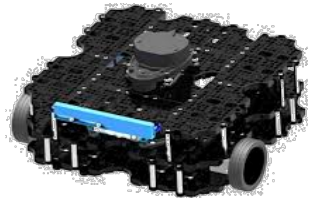
- Recent research of MSC Lab:
  - intelligent/autonomous mechanical systems:
    - industrial robots
    - autonomous driving

FANUC Green Robot

NuTonomy Automated Car

Intelligent/autonomous mechanical systems

- What does a robot do?



Observe

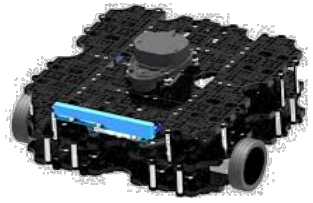
Reason

Plan

Act

Intelligent/autonomous mechanical systems

- What are in the system?



Perception module

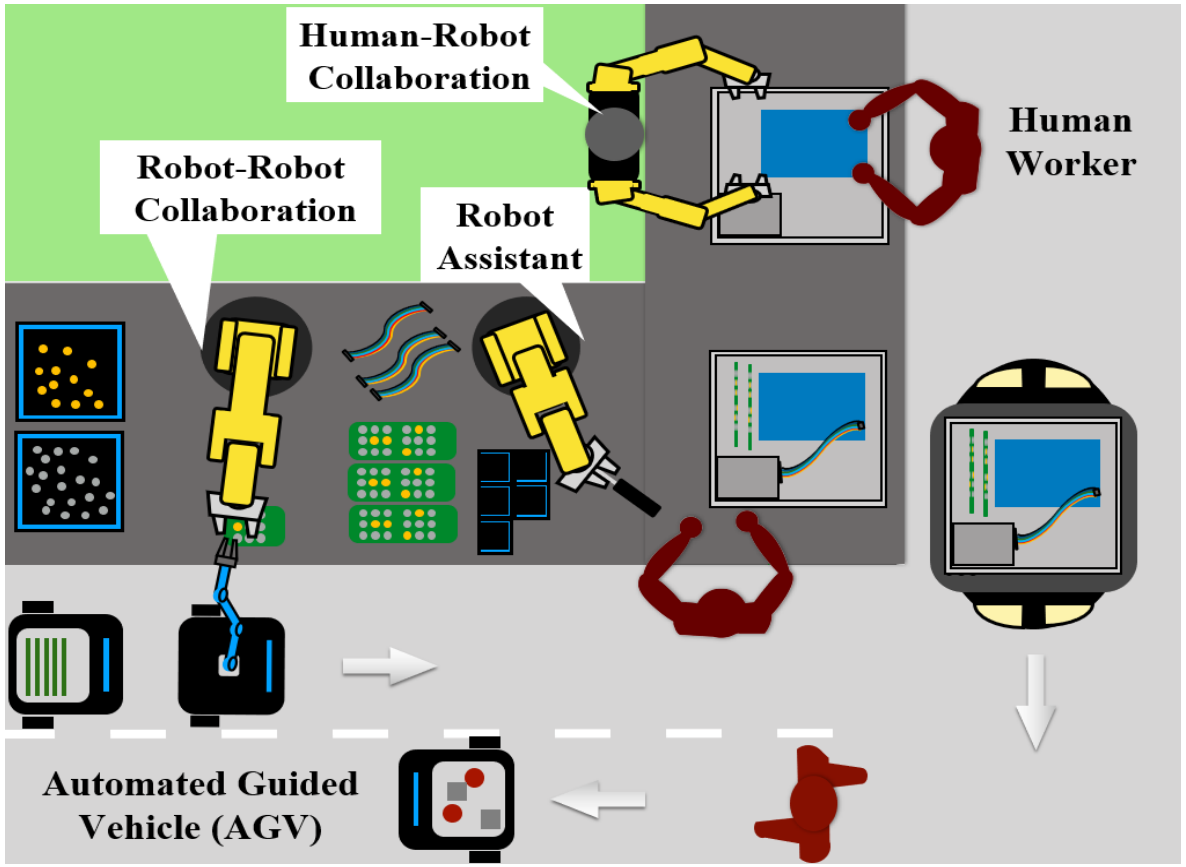
Prediction module

Planning and control module

Tracking module

In robotics

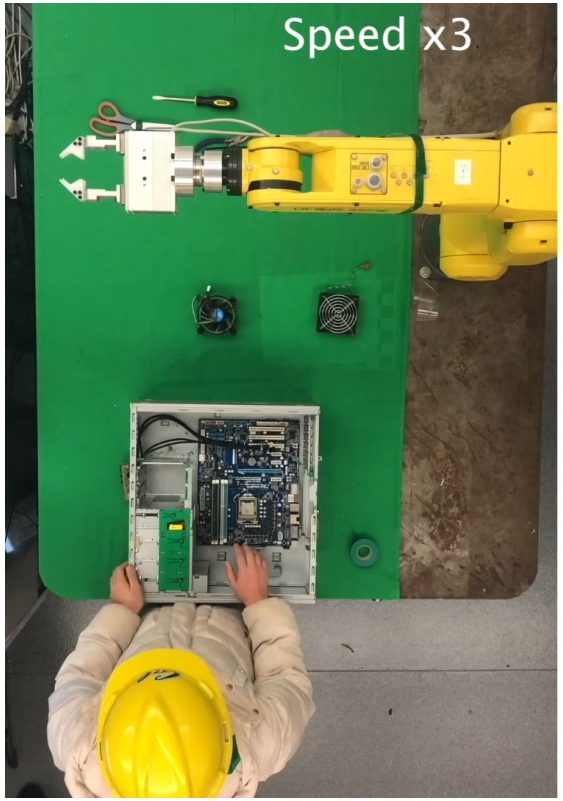
- When co-robots and human workers work together, the robots need to:
  - Monitor the environment and predict human motion
  - Have a Skill Library to complete tasks
  - Plan its motion safely and efficiently

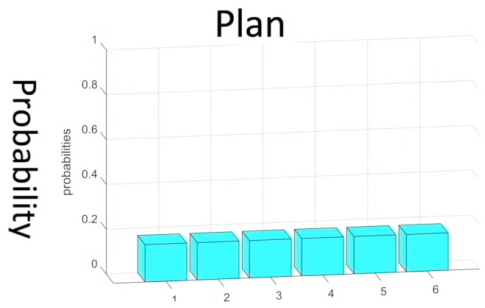


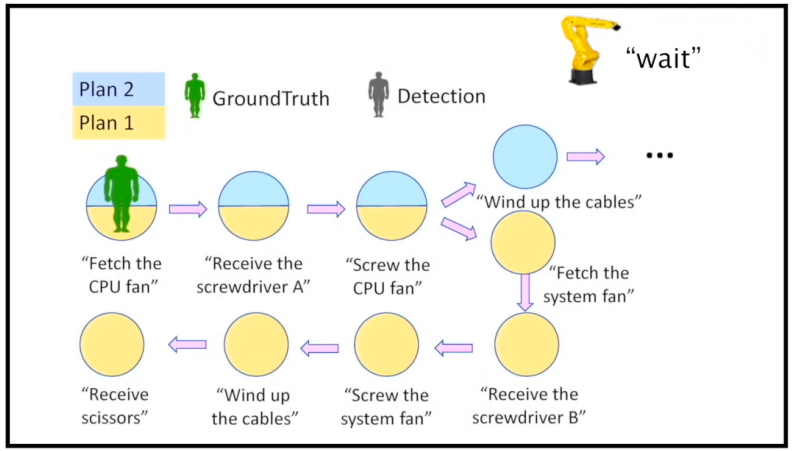
C. Liu, T. Tang, H-C. Lin, Y. Jiao, and M. Tomizuka. "SERoCS: Safe and Efficient Robot Collaborative Systems for Next Generation Intelligent Industrial Co-Robots." arXiv:1809.08215.

Environment Monitoring with Human Motion Prediction

- By observing the motion of the human worker, the robot will try to figure out what “plan” the human worker has.
- With the identified plan, the robot can assist “actively” to increase efficiency.



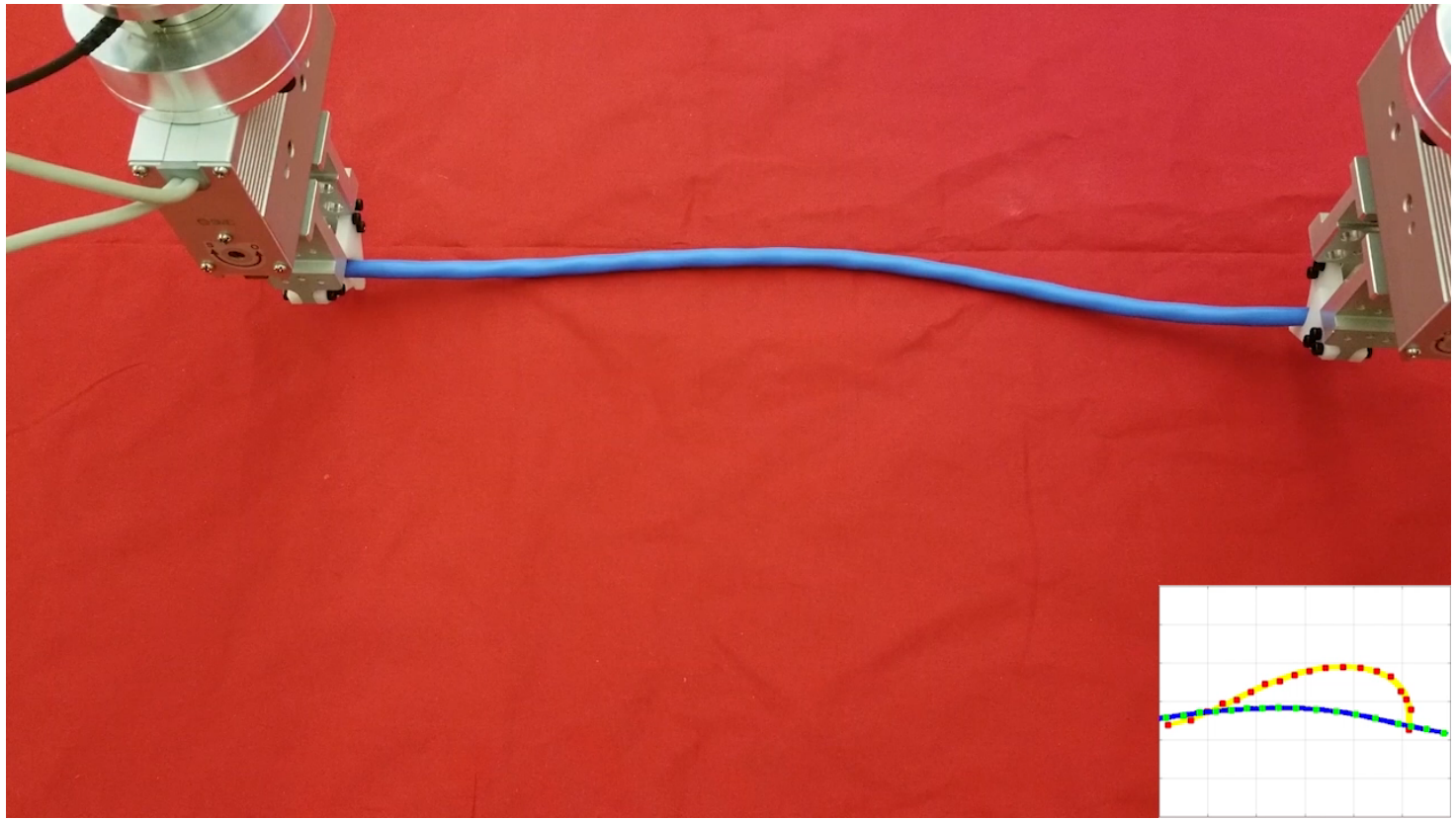




Y. Cheng, et al. "Towards Efficient Human Robot Collaboration with Robust Plan Recognition and Trajectory Prediction.” in IEEE Robotics and Automation Letters, 2020.

Skill Library For intelligent co-robots

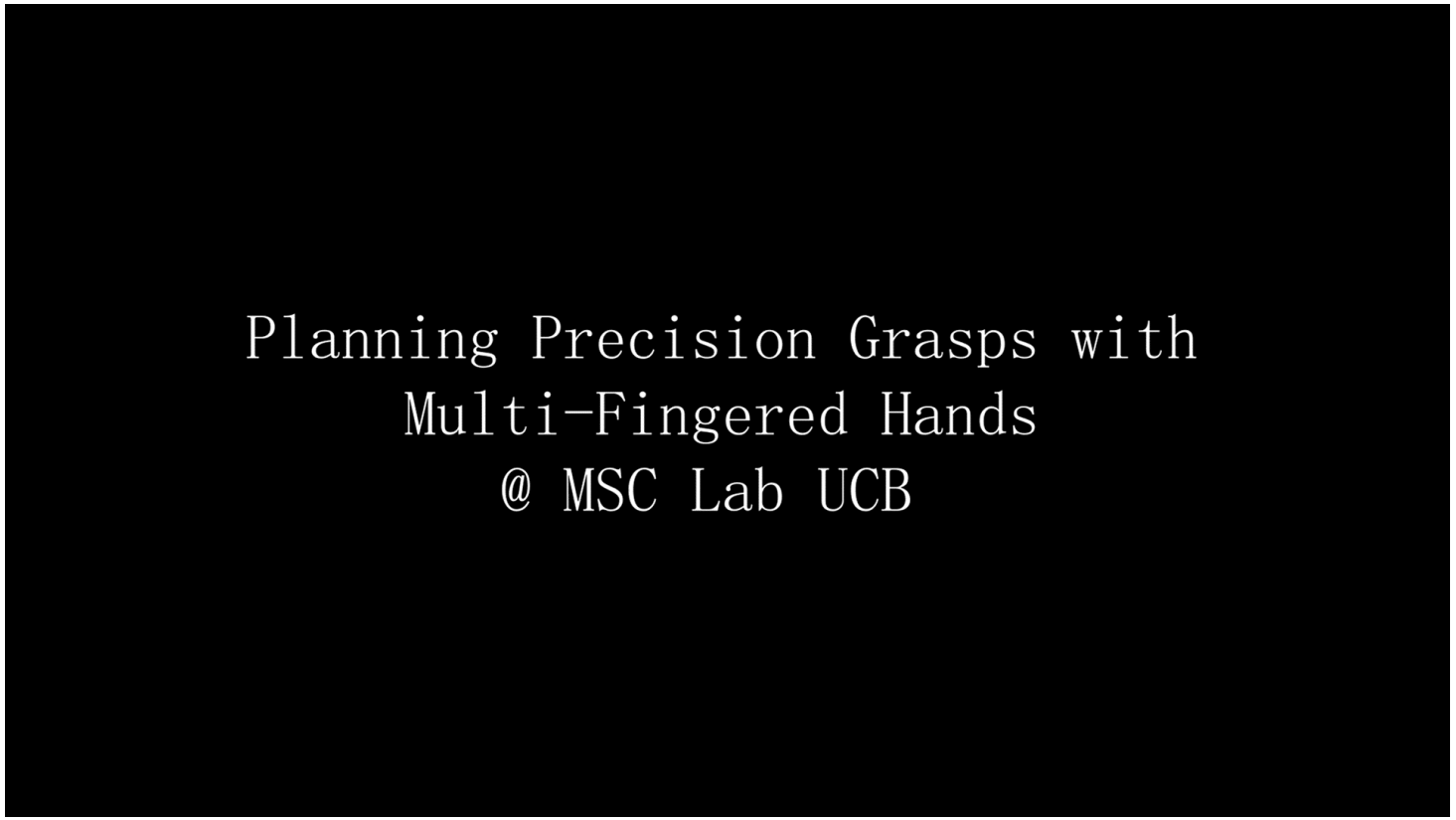
- Cable Manipulation
  - Our method can deal robustly with noisy sensor measurement of the cable shape.
  - The robot can manipulate the cable to a desired shape



S. Jin, C. Wang, and M. Tomizuka. "Robust Deformation Model Approximation for Robotic Cable Manipulation." *2019 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. IEEE, 2019.

Skill Library For intelligent co-robots

- Grasping
  - We propose an optimization model to solve the grasp planning problem.
  - The proposed method considered palm pose and joint position optimization.



Y. Fan, X. Zhu and M. Tomizuka *"*Optimization Model for Planning Precision Grasps with Multi-Fingered Hands*"*, *2019 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. IEEE, 2019.

Real Time Safe and Efficient Motion Planning and Control

- Planning for mobile manipulators

  we developed optimization-based motion planning algorithm for the robot to avoid both static obstacles and moving obstacles in the factories.

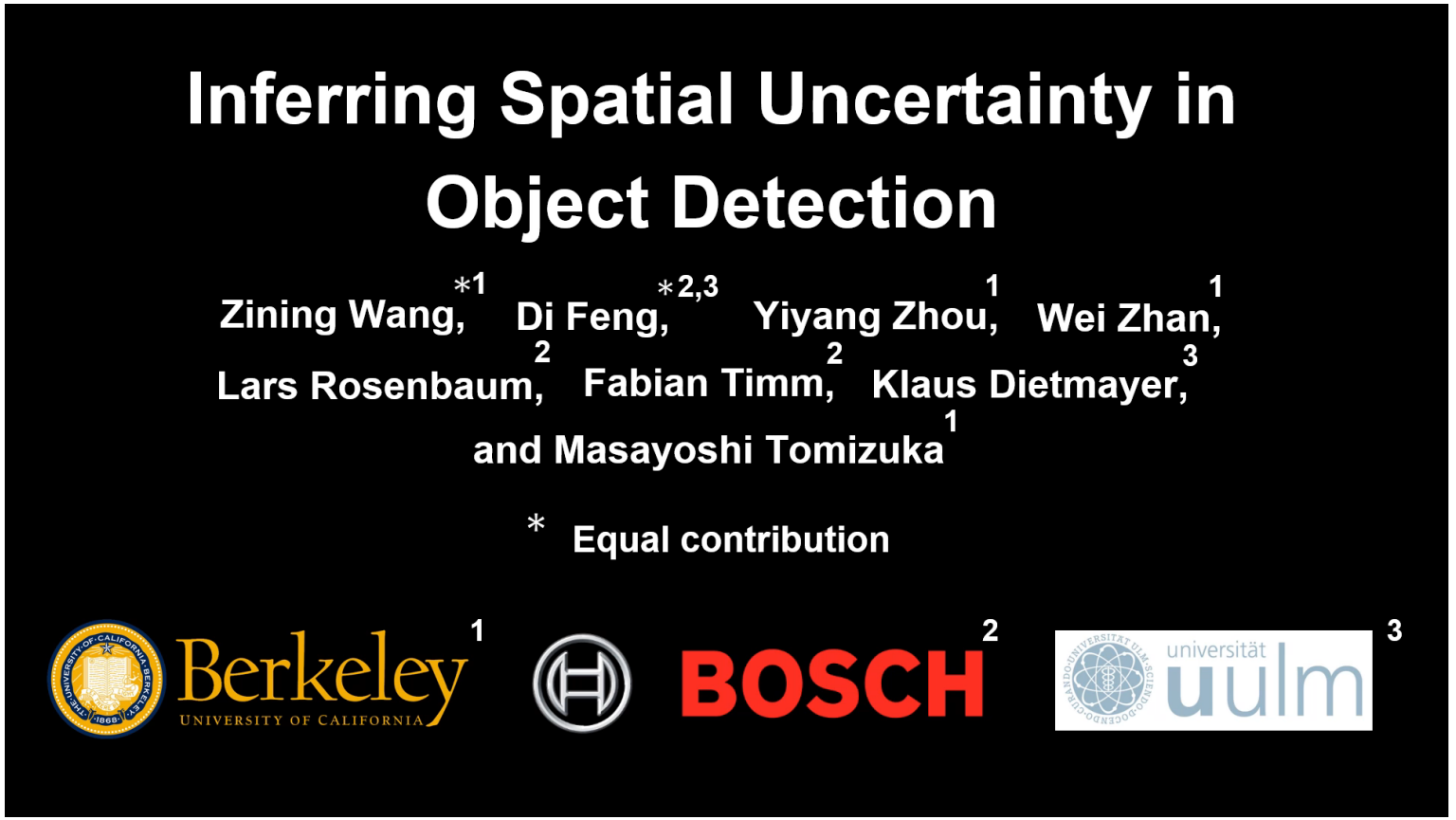
J. Leu, R. Lim, and M. Tomizuka, “Safe and coordinated hierarchical receding horizon control for mobile manipulators,” in Proc. American Control Conference (ACC 2020), Accepted, Jun. 2020

In autonomous driving

- To build an autonomous car, we must have:
  - Perception of humans, vehicles, and cities
  - Prediction, representation, and emulation of interactive behaviors
  - Planning, dynamics, and control for autonomous systems

Perception of the surroundings

- In perception, we include the information of how reliable the perception itself is.



Wang, Z., Feng, D., Zhou, Y., Zhan, W., Rosenbaum, L., Timm, F., ... & Tomizuka, M. (2020). Inferring Spatial Uncertainty in Object Detection. *arXiv preprint arXiv:2003.03644*.

Prediction and representation of Interactive Behavior

- We make our robot car be aware of courtesy in the interaction with other cars.
- Such a courtesy term enables the robot car to be aware of possible irrationality of the human driver behavior, and plan accordingly.

Berkeley UNIVERSITY OF CALIFORNIA

MSC mechanical systems control laboratory

InterACT Laboratory

Courteous Autonomous Cars

Liting Sun, Wei Zhan,
Masayoshi Tomizuka, and Anca D. Dragan

Sun, L., Zhan, W., Tomizuka, M., & Dragan, A. D. (2018, October). Courteous autonomous cars. In *2018 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)* (pp. 663-670). IEEE.

Planning, dynamics, and control for autonomous systems

- With the perception and prediction results, combining with planning and control, the car can plan safely for parking and overtaking.

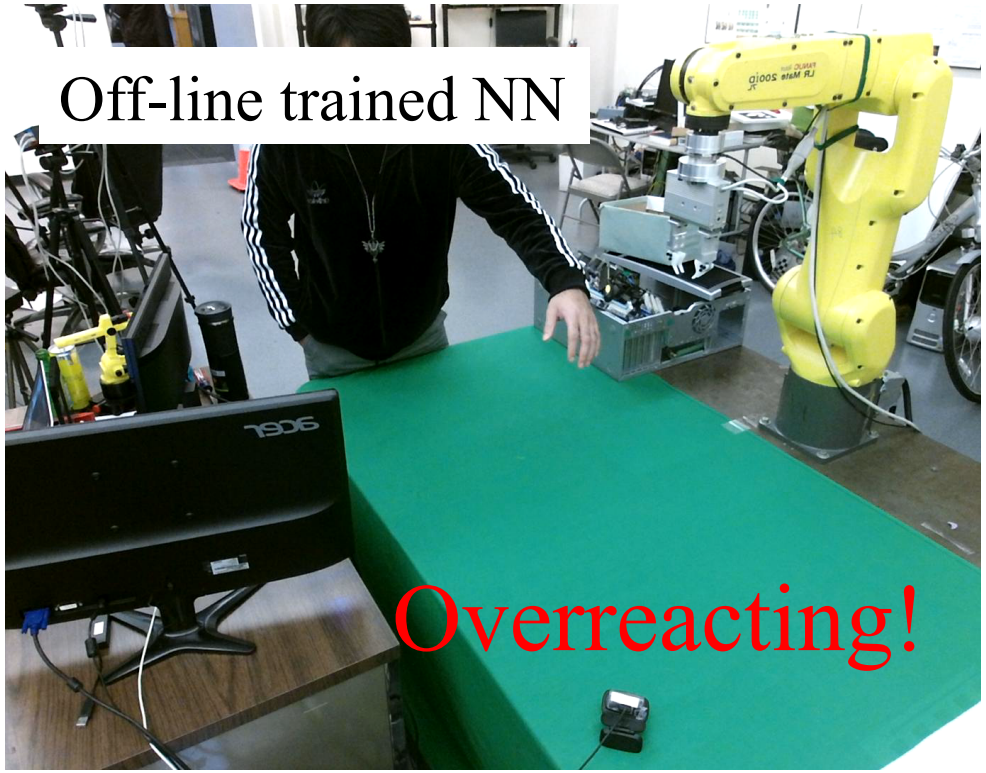
https://msc.berkeley.edu/research/autonomous-vehicle.html

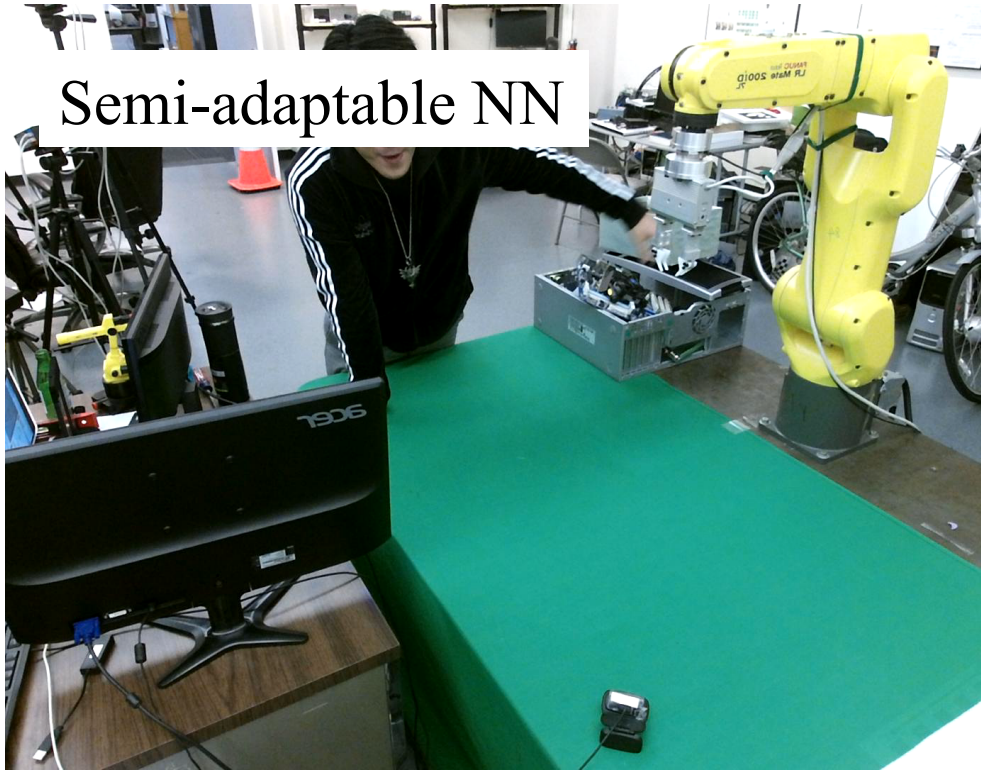
System evaluation

- How do we know if our system is working well?
  - Evaluation experiments for robots
  - Validation and simulation for autonomy and environments

Evaluation experiments for robots

- We evaluate the robot system with different human motion predictors.

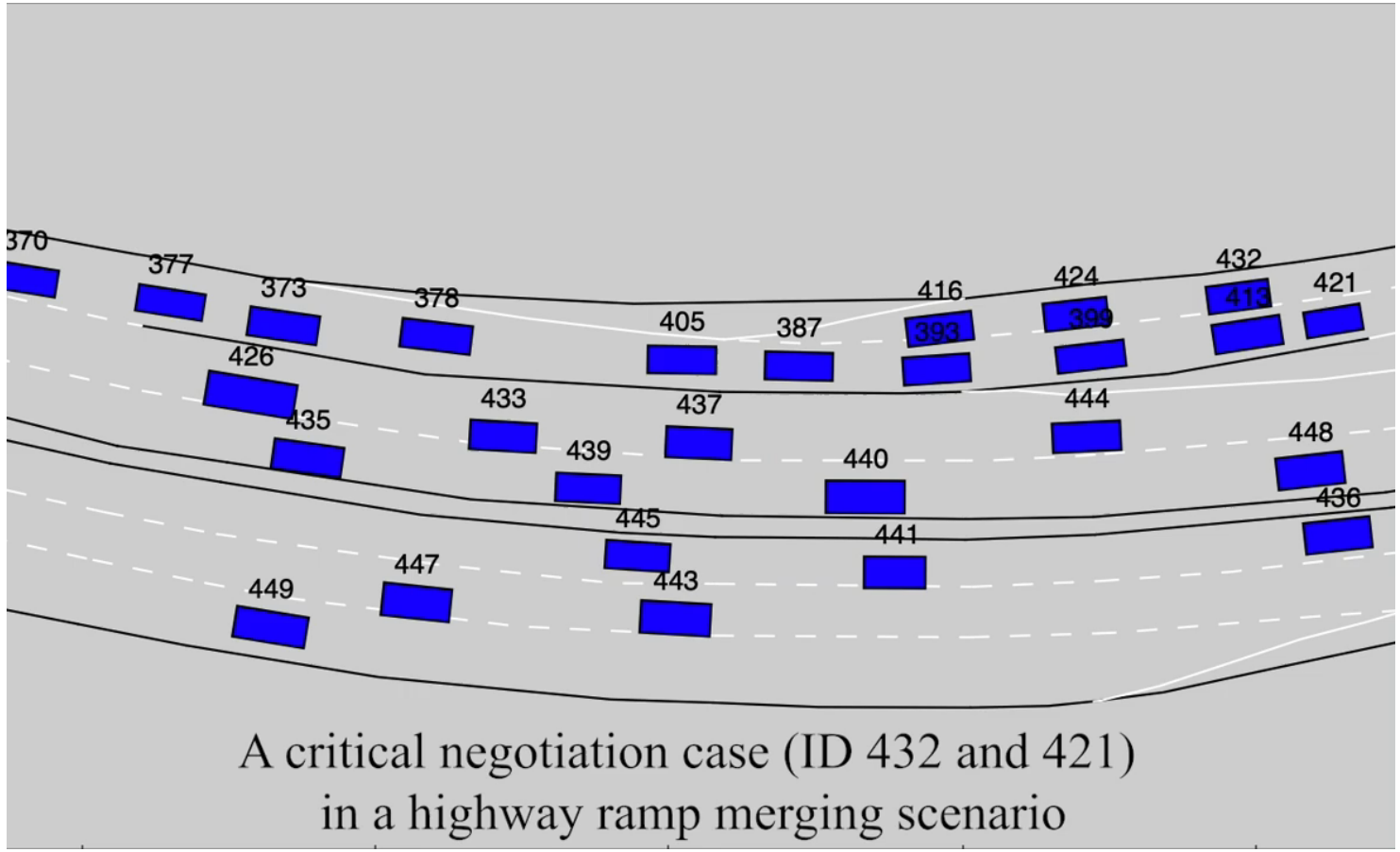




W. Zhao, et al. "Experimental Evaluation of Human Motion Prediction: Toward Safe and Efficient Human Robot Collaboration." in Proc. American Control Conference (ACC 2020).

Validation and simulation for autonomy and environments

- Prediction benchmark and challenge
  - We constructed a data set, INTERACTION Dataset for researches to test the algorithm of the autonomous vehicles.
  - We are also preparing to launch a competition, INTERPRET, using this dataset.



A critical negotiation case (ID 432 and 421)
in a highway ramp merging scenario

http://challenge.interaction-dataset.com/prediction-challenge/intro

Thank you!