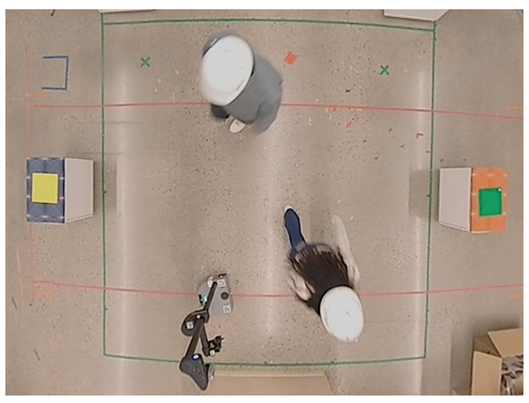
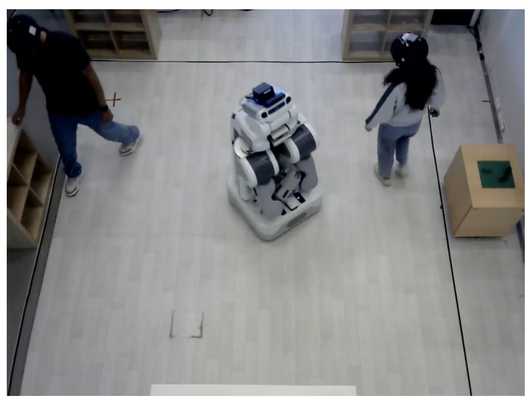
Effects of Human Motion Prediction Quality on Robot Navigation and Human Impressions in Teamwork Scenarios

Andrew Stratton[1], Phani Teja Singamaneni[2], Rachid Alami[2], and Christoforos Mavrogiannis[1]
[1]Department of Robotics, University of Michigan
[2]LAAS-CNRS, Universite de Toulouse

Summary



UMich

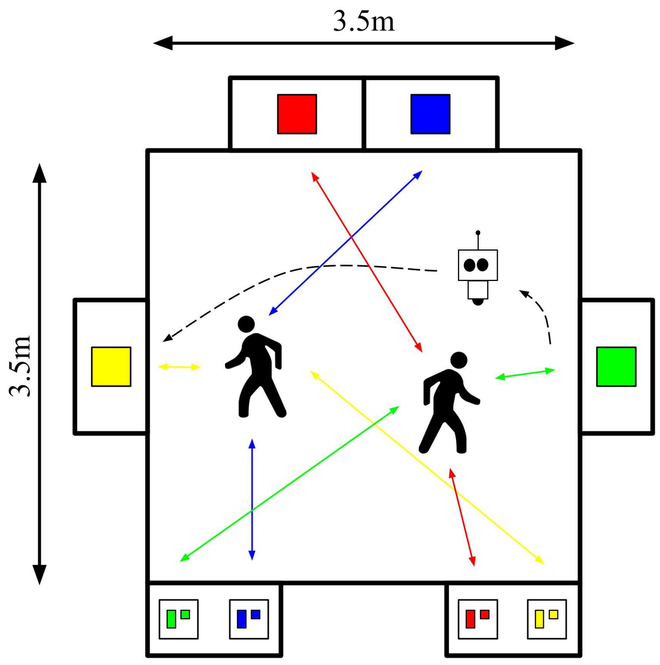


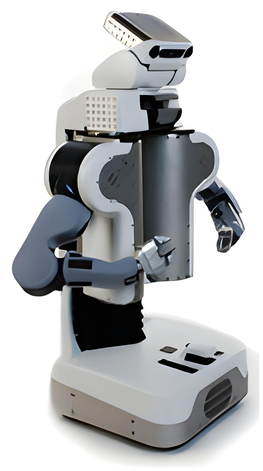
LAAS-CNRS

- The implications of using existing **human motion prediction** strategies **in mobile robot navigation** are **not well-studied**
- We created a **teamwork scenario** in which two humans and a robot navigate a shared workspace, **mirrored at two sites**
- We integrated **motion prediction models** into a social robot navigation MPC to **evaluate their effects** on robot navigation performance, human productivity, and human perceptions
- Through a **large-scale user study**, we expect to uncover insights for **embodying human motion prediction models on mobile robots**

Experimental Design

- Two participants must traverse between workstations on the perimeter of a shared workspace
- Each participant must pick up blocks from stations and stack them into towers at corresponding assembly stations
- Participants are each responsible for two of four block colors, ensuring they cross each others' paths
- The robot moves between workstations on opposite sides of the workspace

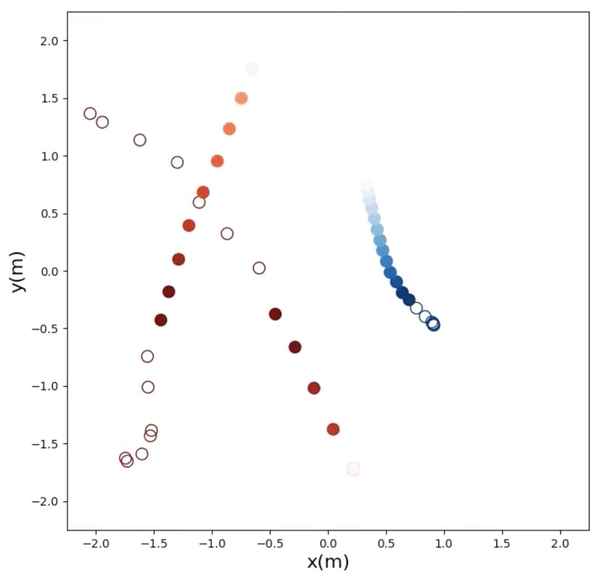




Willow Garage PR2 [5] (LAAS-CNRS)

Hello Robot Stretch [6] (UMich)

Prediction Models



History *Prediction*

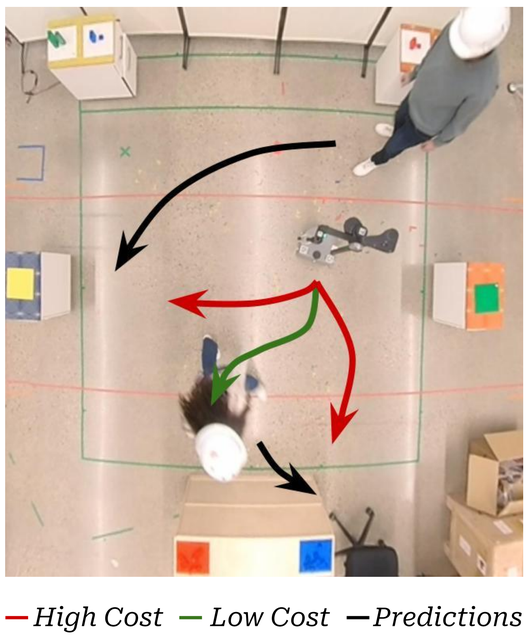
We consider five prediction methods:

- *No Model* Prediction
- *Static* Prediction
- *Constant Velocity* Prediction
- Optimization Based Prediction (*CoHAN* [1])
- Deep-Learning Based Prediction (*Human Scene Transformer* [2])

Hypotheses

- ***H1.*** Using socially aware navigation algorithms results in improved working conditions and outcomes*
- **H2.** Using prediction models with lower ADE results in improved working conditions and outcomes*
- **H3.** A larger robot embodiment is associated with decreased perceptions of user comfort
- *Metrics include users' RoSAS discomfort [7], NASA TLX [8] answers, path smoothness, and **team goals per second**

Social Navigation MPC



High Cost *Low Cost* *Predictions*

- We integrate the above prediction models into a model predictive path integral (MPPI) controller [3]
- Cost function, (based on Mavrogiannis et al. [4]) penalizes collisions with predicted trajectories, distance to goal, and penetration of obstacles

Early Insights

- *No Model Predictions* often causes uncomfortable interactions, while *Static Predictions* lead to overly conservative behavior
- *CoHAN, CV,* and *HST Predictions* have efficiency closer to *No Model* but still take actions to avoid disrupting participants
- Participants that interact with the larger robot report higher discomfort on average

References

[1] P. T. Singamaneni and R. Alami. Hateb-2: Reactive planning and decision making in human-robot co-navigation. Pages 179–186, 08 2020. doi: 10.1109/RO-MAN47096.2020.9223463.
[2] T. Salzmann, L. Chiang, M. Ryll, D. Sadigh, C. Parada, and A. Bewley. Robots that can see: Leveraging human pose for trajectory prediction. IEEE Robotics and Automation Letters, 8(11):7090–7097, 2023.
[3] G. Williams, A. Aldrich, and E. Theodorou. Model predictive path integral control: From theory to parallel computation. Journal of Guidance, Control, and Dynamics, 40:1–14, 01 2017. doi: 10.2514/1.G001921.
[4] C. Mavrogiannis, K. Balasubramanian, S. Poddar, A. Gandra, and S. S. Srinivasa. Winding through: Crowd navigation via topological invariance. IEEE Robotics and Automation Letters, 8(1):121–128, 2023.
[5] http://wiki.ros.org/Robots/PR2.
[6] https://hello-robot.com/stretch-3-product.
[7] S. G. Hart and L. E. Staveland. Development of Nasa-TLX (Task Load Index): Results of empirical and theoretical research. Human Mental Workload, 1(3):139–183, 1988.
[8] C. M. Carpinella, A. B. Wyman, M. A. Perez, and S. J. Stroessner. The robotic social attributes scale (RoSAS): Development and validation. In Proceedings of the 2017 ACM/IEEE International Conference on Human-Robot Interaction, HRI '17, page 254–262, New York, NY, USA, 2017. Association for Computing Machinery. ISBN 9781450343367.