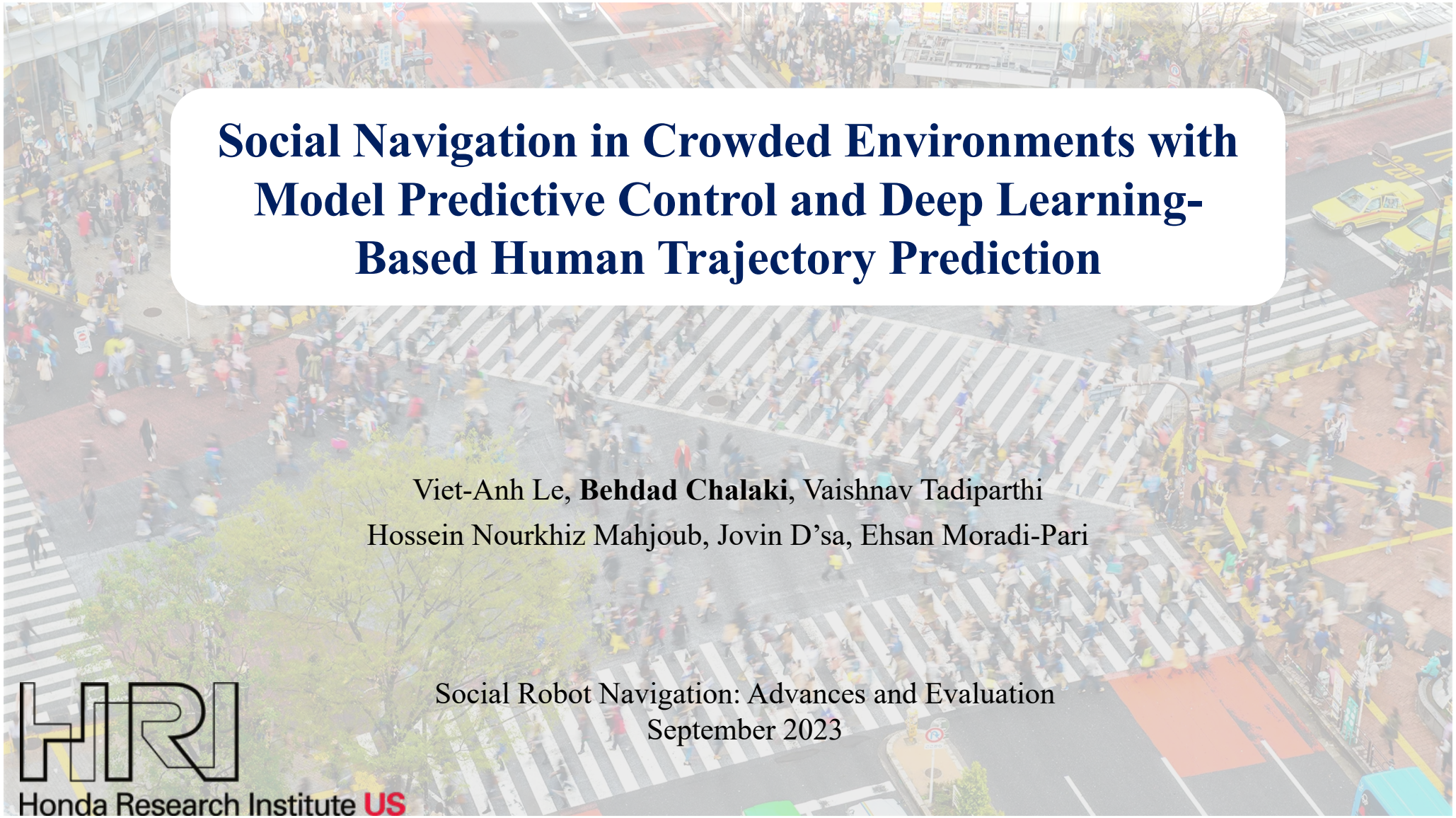

Social Navigation in Crowded Environments with Model Predictive Control and Deep Learning-Based Human Trajectory Prediction

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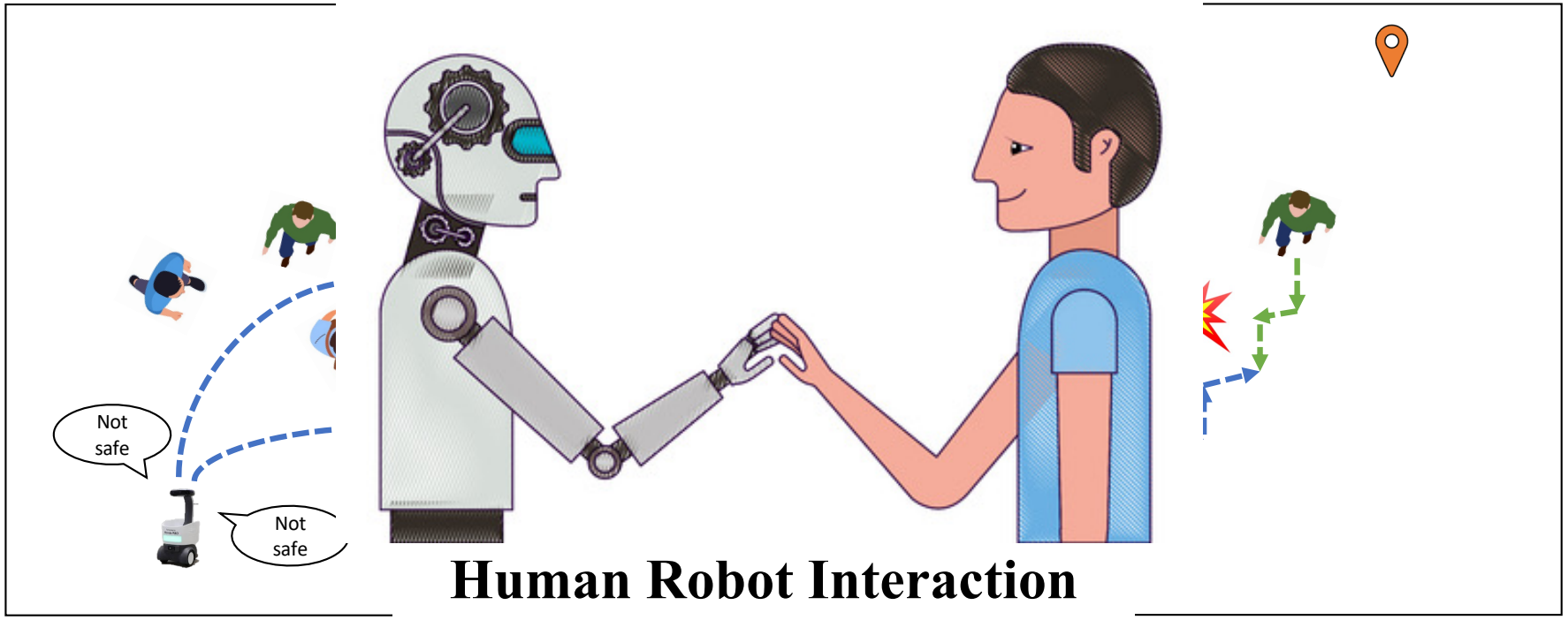
Social Robot Navigation: Advances and Evaluation
September 2023

Honda Research Institute US

Motivation

Interaction-Aware Navigation



Freezing robot problem

Reciprocal dance problem

1, Mavrogiannis, Christoforos, et al. "Core challenges of social robot navigation: A survey." ACM Transactions on Human-Robot Interaction 12.3 (2023): 1-39.

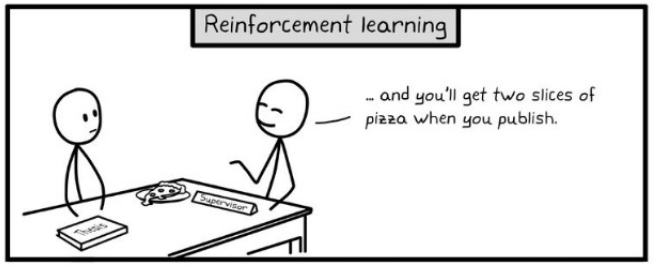
Literature Review

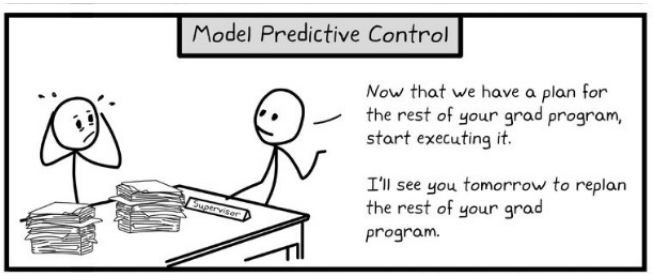
Reinforcement Learning (RL)

- CADRL [Chen et. al., 2017]
- LSTM-RL [Everett et. al., 2018]
- SARL [Chen et. al., 2019]
- Social-NCE [Li et. al., 2021]
- Recurrent graph NN [Liu et. al., 2023]

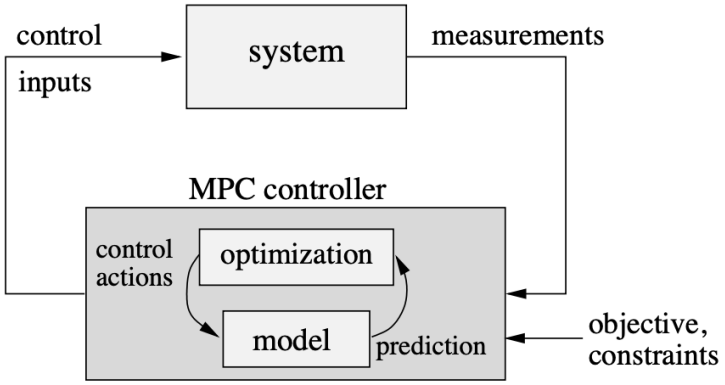
Model Predictive Control (MPC)

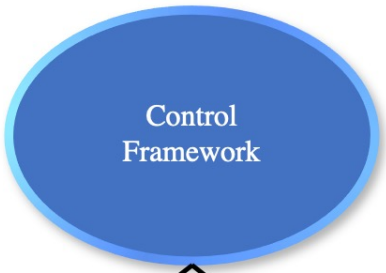
- MPC – constant velocity model [Brito et. al., 2021]
- MPC – Kalman filter [Vulcano et. al., 2022]
- MPC – iORCA [Chen et. al., 2021]
- MPC – Social GAN [Poddar et. al., 2023]
- MPC – LSTM [Lindemann et. al., 2023]

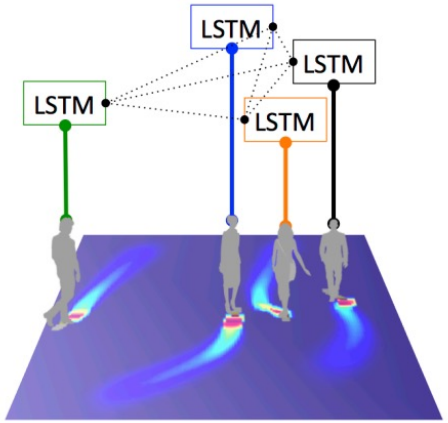




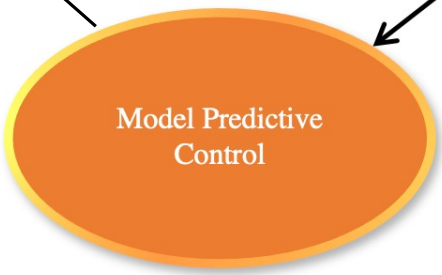
Overview







Social LSTM[1]



1, Alahi, Alexandre, et al. "Social lstm: Human trajectory prediction in crowded spaces." Proceedings of the IEEE conference on computer vision and pattern recognition. 2016.

MPC Formulation

Objective = Reaching goal + Minimization of acceleration and jerk + Penalty for collision with humans

MPC Formulation

$$\underset{\mathbf{u}_0}{\text{minimize}} \;\; J_0(\mathbf{u}_0, \mathbf{x}_0, \mathbf{s}_{\mathcal{H}}),$$

subject to

$\mathbf{u}_{0,k} \in \mathcal{U}_0, \mathbf{x}_{0,k+1} \in \mathcal{X}_0, \; \forall k \in \mathcal{I}_t,$

Robot dynamics,

Human prediction model.

Iterative Best Response

How to solve the MPC problem?

MPC Problem

$$\underset{\mathbf{u}_0}{\text{minimize}} \; J_0(\mathbf{u}_0, \mathbf{x}_0, \mathbf{s}_{\mathcal{H}})v,$$

subject to

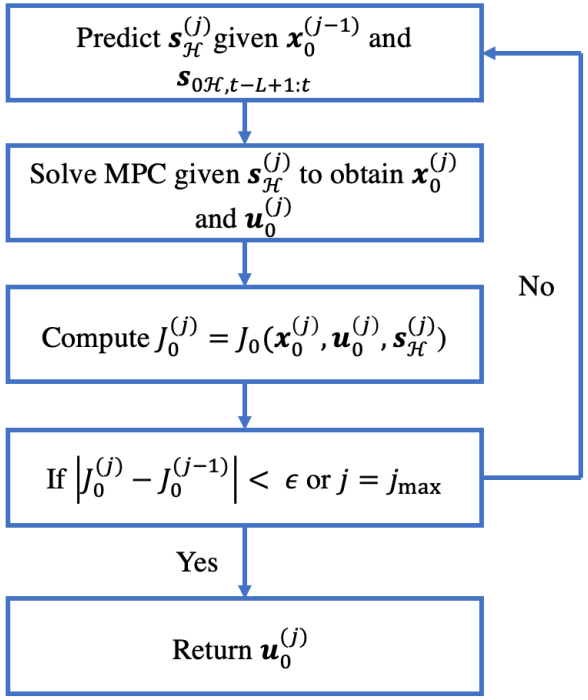
$\mathbf{u}_{0,k} \in \mathcal{U}_0, \mathbf{x}_{0,k+1} \in \mathcal{X}_0, \forall k \in \mathcal{I}_t,$

Robot dynamics,

Human prediction model.

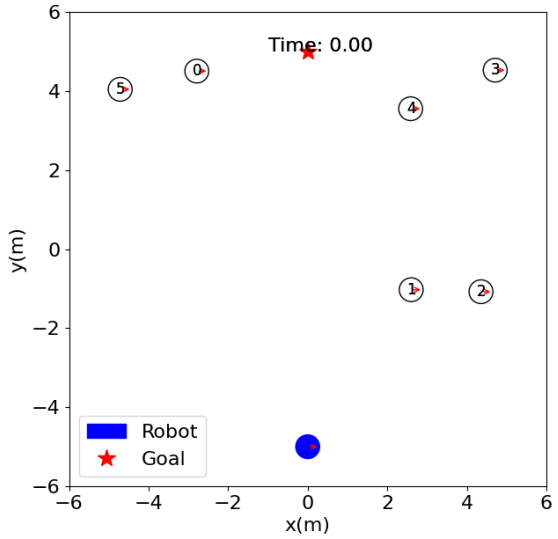
🤔 The optimization is nonconvex and highly complex!

➡ Iterative best response

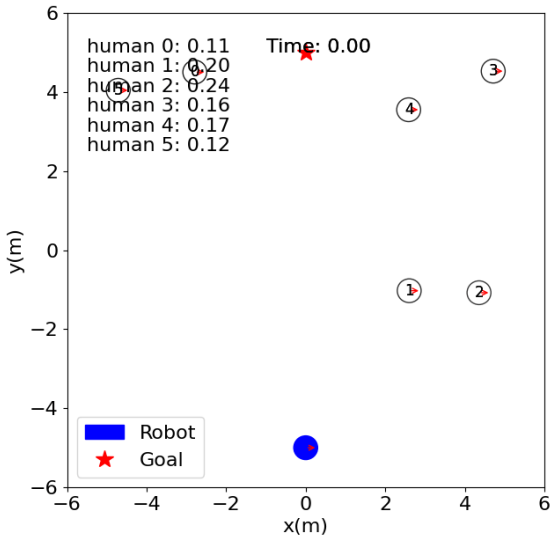


Simulation Results

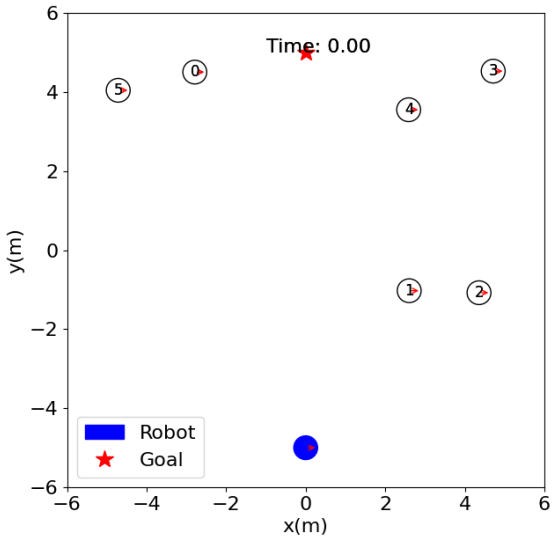
Perpendicular crossing scenario



MPC



SARL



CADRL

Conclusions

Summary:

- Robot navigation in crowds can be addressed by combining MPC with deep learning-based human prediction model.

Limitation:

- There is no convergence guarantee for iterative best response approach.