Project Title: NRI: FND: Efficient algorithms for safety guiding mobile robots through spaces populated by humans and mobile intelligent machines and robots

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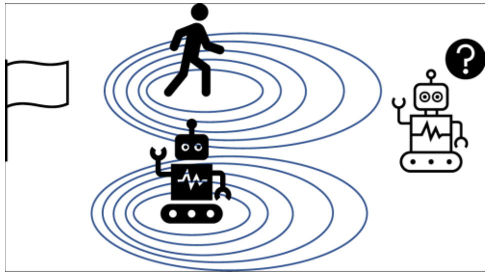
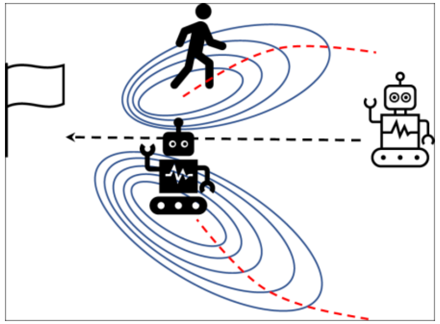
- **Goal**: Solve “unfreezing the robot” type path / motion planning problems in the presence of other agents(e.g., humans and intelligent machines) which move unpredictably
- **Impact**: Promote integration of intelligent machines in different aspects of our everyday life (e.g., Amazon fulfillment centers, busy crossroads on campus)



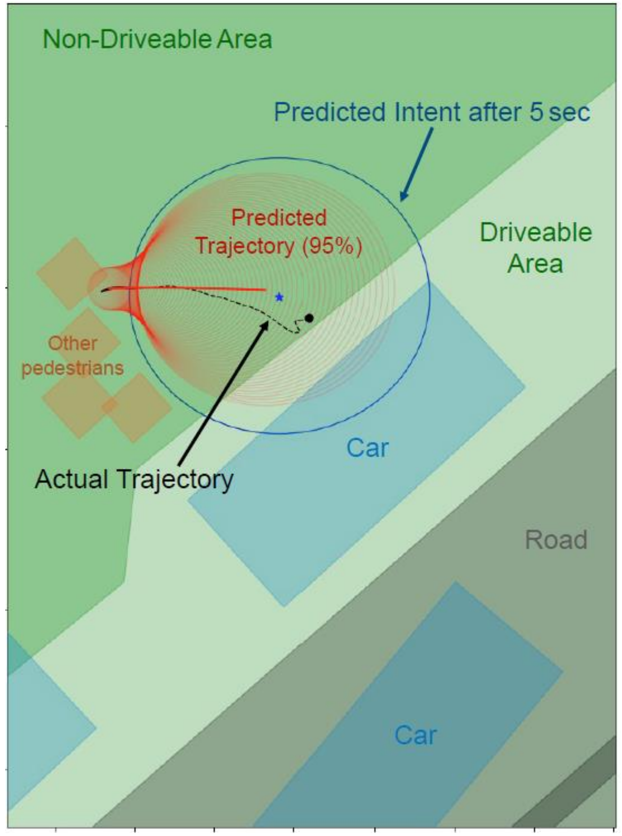




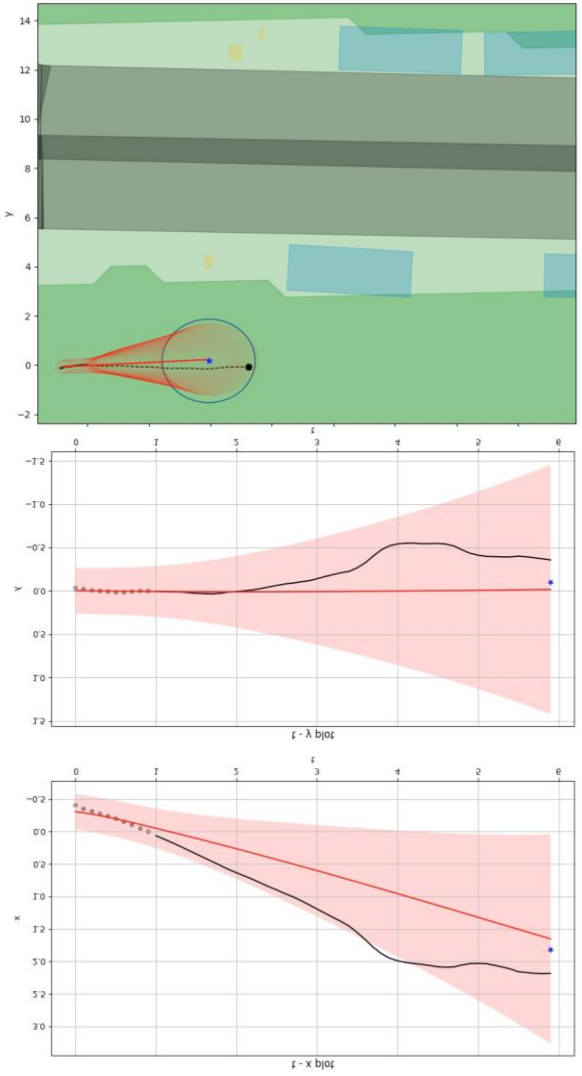
Local motion planners that account for the intentions and future trajectories of nearby agents can find solutions to problem where worst-case / robust path planners may fail

Technical Approach:

- **Prediction problem:** Use non-parametric regression / estimation methods (e.g., Gaussian processes) to predict in real time the intent and future trajectories of nearby mobile agents/obstacles and construct “probabilistic” obstacles
- **Local motion planning problem:** Compute safe trajectories that keep mobile robots away from probabilistic obstacles (abstractions of nearby mobile agents) using stochastic optimal control

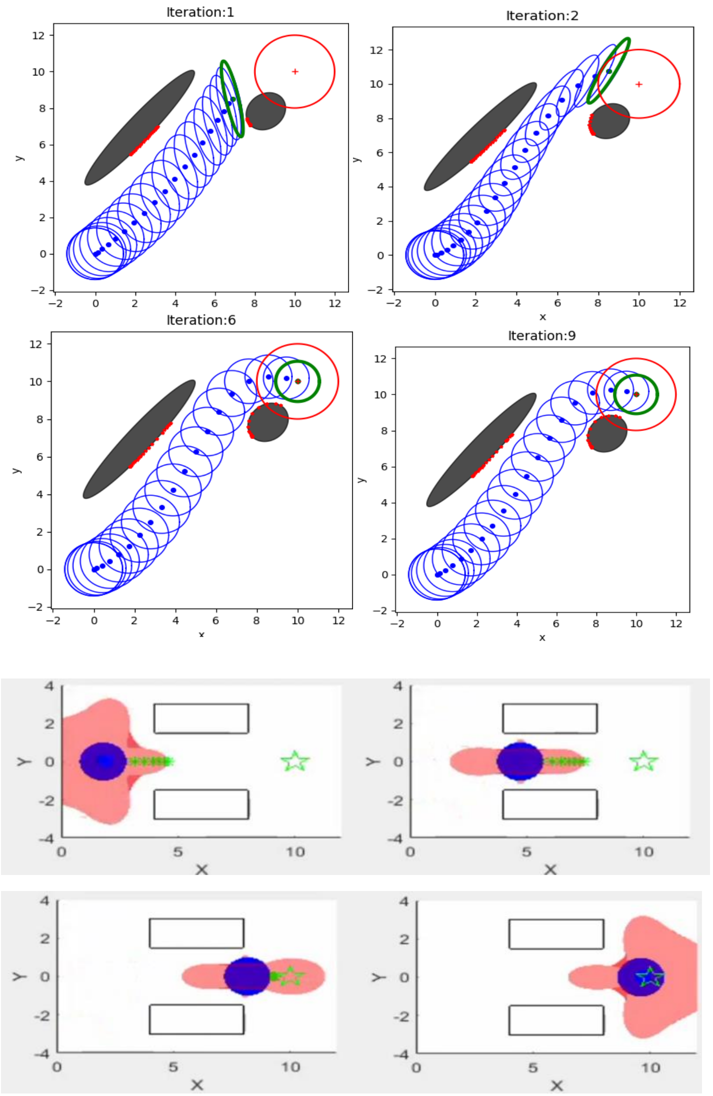
Real-time Prediction of Intent and Future Trajectories of Mobile Agents based on GP Regression





- Given: **Observed trajectory** of a mobile agents/obstacles (last 1 sec) Information about **environment** (roads, obstacles, etc)
- Predict: **Intent**: where the mobile agent/obstacle will be after 5 sec (goal). **Trajectory**: cubic spline from current to goal position
- Intent Prediction: **Stochastic Variational GP (GP: Gaussian Processes)** with last 10 (x,y) as input and (x,y) after 5 sec as output. Future steps: incorporate environment info (e.g. obstacles, lanes from HD maps, etc)
- Trajectory Prediction: **Multi-Output GP** with **cubic spline kernel**. The GP fits a cubic spline on the observed (x,y) and the goal distribution

Distribution Steering for Local Motion Planning Among Uncertain/Dynamic Obstacles



- Covariance / distribution steering algorithms to steer the uncertain state of the ego-robot to its goal destination (random vector drawn from a target distribution) while remaining away from (probabilistic) obstacles (abstractions of nearby agents)
- Distance between probabilistic obstacles and agent measured in terms of squared Wasserstein distance (or other similar metrics)
- Standard approaches to represent probabilistic obstacles (e.g., ellipsoid approximations) give conservative results (unnecessary reduction of the probabilistically safe space around ego-robot)
- Develop more accurate descriptions of probabilistic obstacles by using *spherical harmonics* which give less conservative approximations and thus allow for more efficient motion planning

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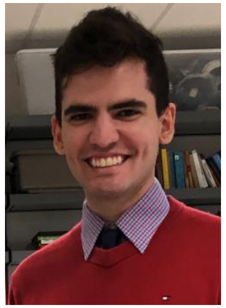

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