Safe Navigation in Dynamic, Unknown, Continuous, and Cluttered Environments

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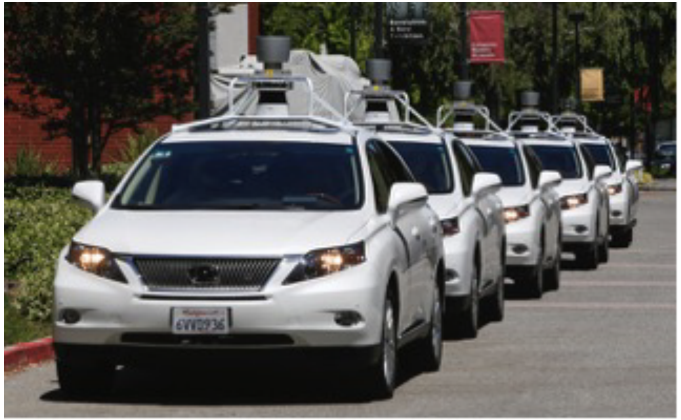
Introduction

- Safe Navigation through Dynamic , Unknown, Continuous, and Cluttered environments is a crucial ability for autonomous robots

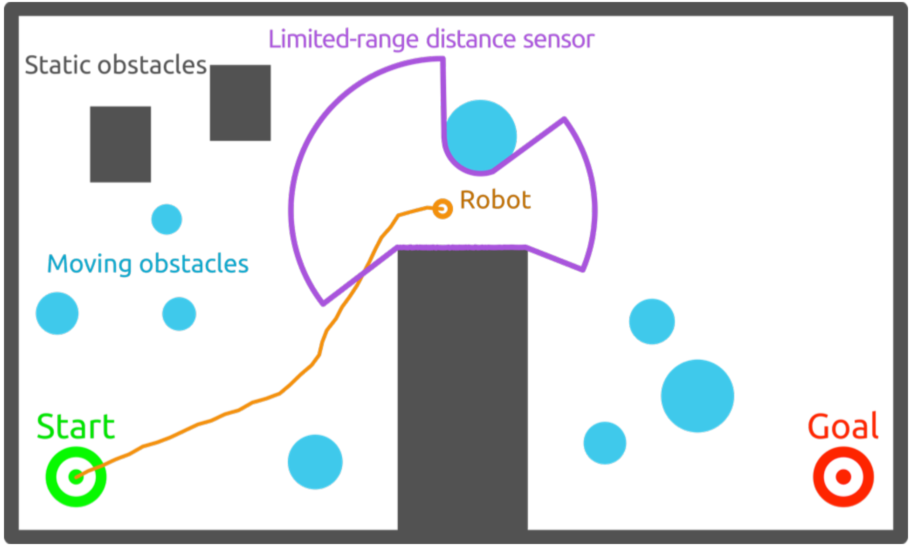


Google Autonomous Cars

Amazon, Kiva Systems Robots

Problem Definition

- 2D unknown configuration space
- Static and moving obstacles
- Point-sized holonomic robot
- Limited-range distance sensor (e.g. lidar)
- Knows its own position and goal position



Objective: To navigate from an initial point to the goal without colliding with any of the dynamic or static obstacles

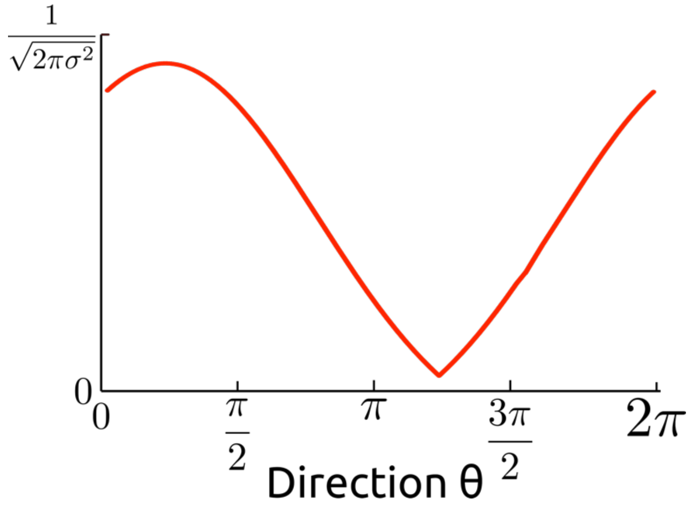
Probabilistic Local Planner (ProbLP)

- ProbLP is a local planner
- Based on trajectory sampling, but…
- We construct a probability distribution of promising directions
- Sampling from this distribution finds safe and efficient trajectories faster

Constructing the Probability Distribution

Target distribution

- Gaussian centered on the direction to the goal



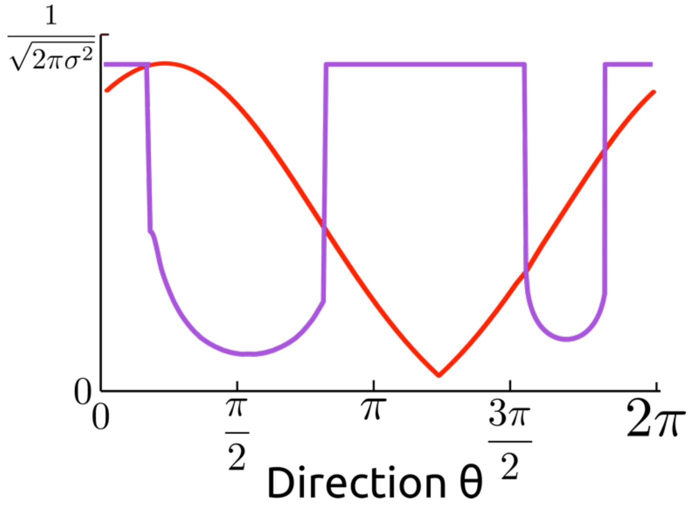
Constructing the Probability Distribution

Target distribution

- Gaussian centered on the direction to the goal

Obstacle distribution

- The range sensor data



Constructing the Probability Distribution

Target distribution

- Gaussian centered on the direction to the goal

Obstacle distribution

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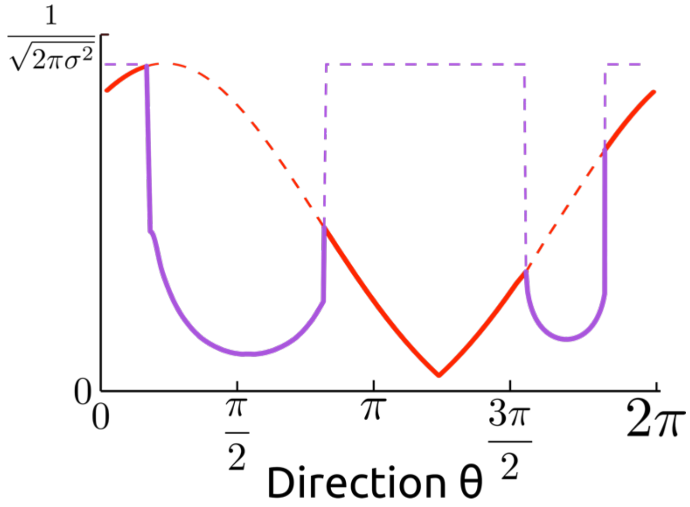
Final distribution

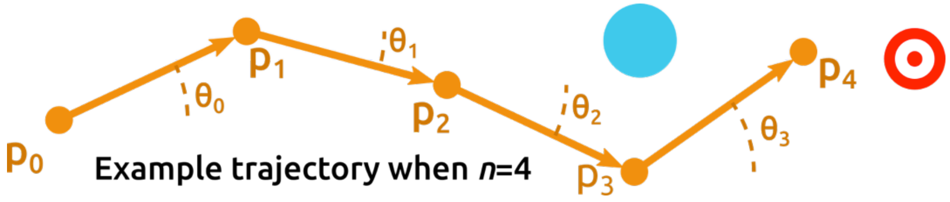
- Minimum of the target and obstacle distributions
- Area normalized to 1



Selecting the Candidate Trajectories

Starting at the current location p_0:

- Pick a direction θ from the distribution
- Put p_{i+1} a small distance from p_i in the direction of θ
- Repeat up to p_n



Scoring Trajectories

- Distance score
  - Distribution value at the angle between p_0 and p_n, multiplied by the ratio of trajectory length to straight-line distance from p_0 to p_n
- Safety score
  - Use obstacle predictor to get the probability of a collision if *p* is followed
- Take a weighted sum of distance and safety scores

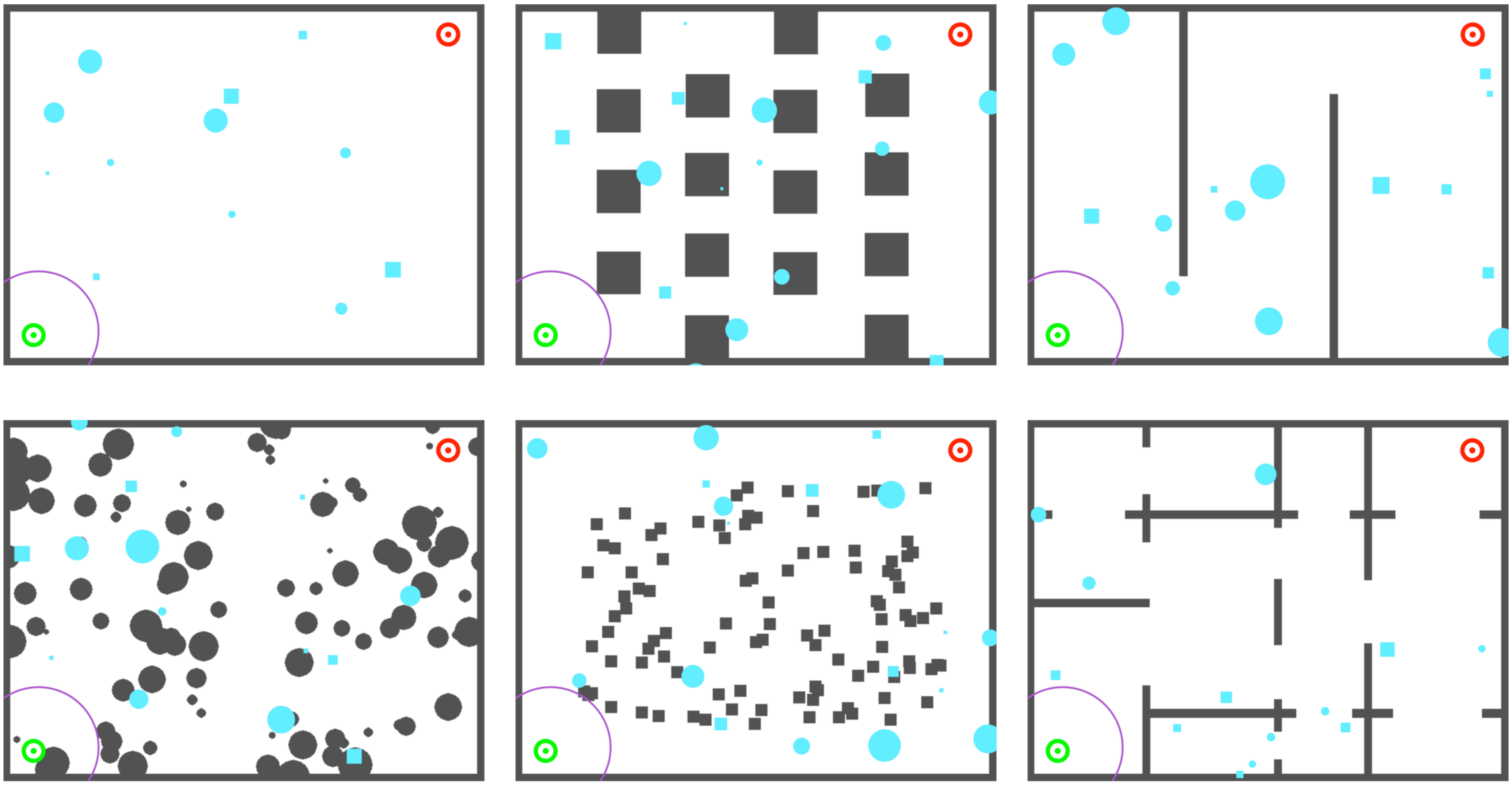
Adding a Global Planner

- ProbLP alone has no memory, so it gets stuck in dead ends
- Global planner plans a sequence of subgoals for ProbLP to follow
- We use Dynamic Rapidly-exploring Random Trees (DRRT)
- The environment is still unknown: DRRT builds a map as it goes

Experiments

- Four speed modes
  - **SP-1:** All obstacles move 0.5 m/s (slower than the robot)
  - **SP-2:** All obstacles move 1.0 m/s (same as the robot)
  - **SP-3:** All obstacles move 1.5 m/s (faster than the robot)
  - **SP-4:** Each obstacle moves randomly between 0.5-1.5 m/s

- Compared DRRT+ProbLP vs DRRT+Straight-Line Local Planner (DRRT-SLLP)



Results

- DRRT-ProbLP averaged 0.27 collisions vs 1.20 for DRRT-SLLP
- Only 10% longer paths to achieve the safety benefit

Conclusion and Future Work

- ProbLP is a reactive planner for navigating in dynamic, unknown, continuous, and cluttered environments
- In the future, we would like to
  - Work in 3D environments
  - Better handle kinematic constraints
  - Optimize algorithm parameters automatically