MT Robot Reading Group

Planning and Control in Unstructured Terrain

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Agenda

1. Introduction
2. Related Work
3. Methodology
    - Map Representation
    - Global Planning
    - Local Planning / Control
4. Performance
5. Discussion

Introduction

- Autonomous navigation in **unstructured outdoor** environment
- DARPA Learning Applied to Ground Robotics (LAGR) program
- Description of the **planning** and **control** aspects

Related Work

Global planning

- Gradient technique
    - 2D grid map → cost map → global navigation function
    - Computes a global navigation function over the cost map
- Wavefront planning
- Level sets

Related Work

Local planning

- Dynamic Window Approach (DWA)
  - Works in position or velocity space
  - Converts trajectory to velocity commands
- Stanley controller (DARPA 2005 Grand Challenge winner)
- Howard et al.
  - Sampling directly in the vehicle's state space

Approach

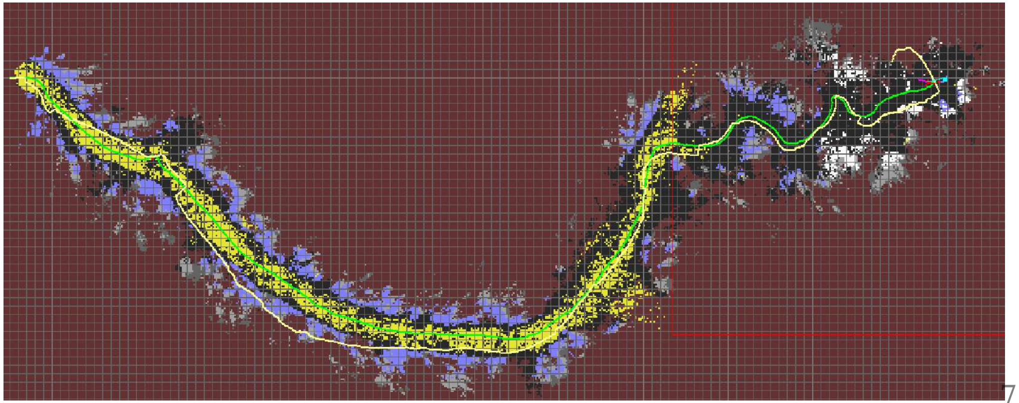
Map Representation

2D occupancy grid (20cm x 20cm)

- Abstract **characteristics of terrain** into set of **categories**
    - obstacle, ground plane free space, sight line free space, and path free space
- **Fuse information** form categories into **scalar map**

Approach

Map Representation



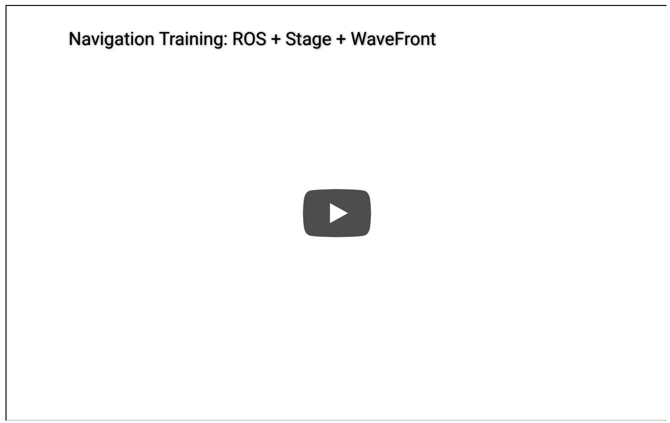
Approach

Global Planning

- Re-implemented **gradient planner**
  - A wavefront planner
  - Given a cost map
  - Computes optimal paths from the goal to the robot

Approach

Global Planning



Approach

Gradient Map

Approach

Global Planning

- Optimistic planner: Assuming the **robot** to be **circular**, **holonomic**
- Global planner **typically** run within a **subregion** of the **map**
  - On 80m x 80m area **30ms**
  - On 100m x 200m area **100ms**

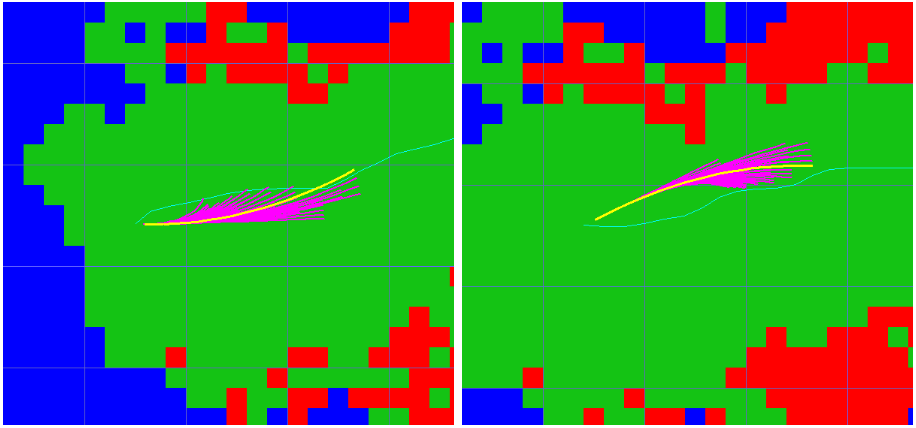
Approach

Local Planning / Control - Trajectory Generation

- Searching in the space of **feasible controls**
  - **Instead** of in the space of **feasible trajectories**
- **2D space** of possible commands $(\dot{x}, \dot{\theta})$
- Sample in the region of **allowed velocities**
- For each sample **simulate** over **short time horizon**
  - Predicts robot's trajectory

Approach

Local Planning / Control - Trajectory Generation



Approach

Local Planning / Control - Trajectory Evaluation

Each simulated trajectory es evaluated with:

$$C(t) = \alpha \mathrm{Obs} + \beta \mathrm{Gdist} + \gamma \mathrm{Pdist} + \delta \frac{1}{\dot{x}^2}$$

where:

- Obs: Sum of grid cell costs
- Gdist: Estimated shortest distances (endpoint ↔ goal)
- Pdist: Estimated shortest distances (endpoint ↔ optimal path)
- $\dot{x}$: Translational velocity

Approach

Local Planning / Control - Trajectory Evaluation

Choose **trajectories** with **minimal cost**:

- Remain **far** from **obstacles**
- Go **toward** the **goal**
- Remain **near** the **optimal path**
- Drive **fast**

Approach

Local Planning / Control - Supervisory control

Add **supervisory logic** to **direct** the order of trajectories:

1. **Forward** velocities $\dot{x} > 0$:
2. In-place **rotations** $\dot{x} = 0$
3. **Backward** velocities $\dot{x} < 0$

If any **legal** trajectory **found**, the best is **selected**

Encourages **forward progress** whenever possible

Performance

- "Best in class" among 10 teamin in DARPA LAGR program
- Average speed over 1.1 m/s
- Top speed limited to 1.3 m/s

Discussion

- Designed for **unstructured outdoor** environment
- Seems to have problems in in **structured indoor** environment
  - **Symmetric** topology
- No **backwards** movement in our "Navigatior" when stuck