Mobile Robot Control – Navigation (2/2)

MAY 10, 2023

Mobile Robot Control 2023

Mechanical Engineering, Control Systems Technology, Robotics Lab

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Outline

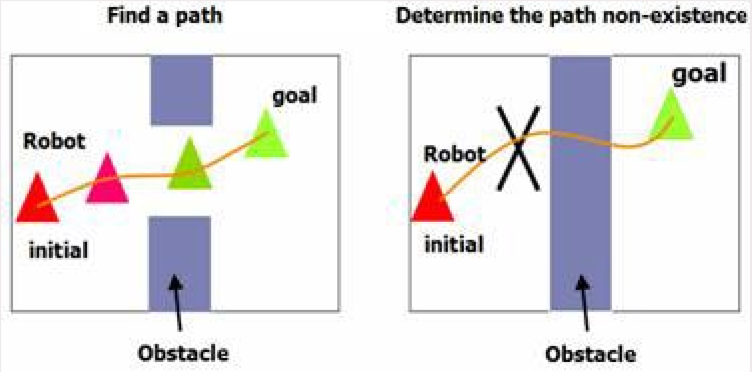
- Motion planning problem
  - Motion constraints
- Motion planning algorithms
  - Specifications & properties
  - Taxonomy
  - World representation
  - Graph-based solutions
  - Local motion planning algorithms
- Control objectives

Last week

Recap

- Motion planning problem:

Given an initial pose, determine the control outputs such that, via a sequence of valid configurations, its desired final pose is reached



Source: http://gamma.cs.unc.edu/NOPATH/

Recap

- Motion planning problem:

  Given an initial pose, determine the control outputs such that, via a sequence of valid configurations, its desired final pose is reached

- Specifications and properties:
  - Completeness
  - Optimality
  - Computational complexity
  - Robustness against dynamic environment
  - Robustness against uncertainty
  - Kinematic and dynamic constraints
- Global vs local planner
- Graph-based representations and (global) solutions

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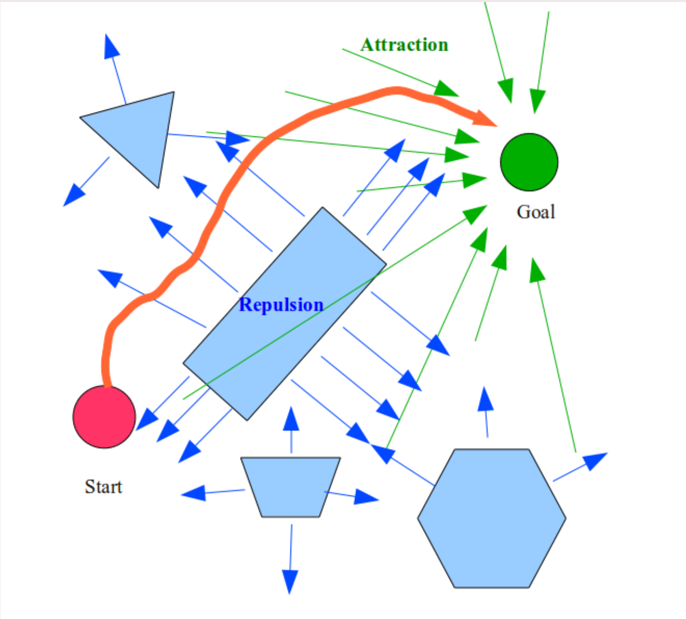
Local Motion Planning

- Global planning algorithms (in general) not appropriate for fast obstacle avoidance
- Global world model often incomplete or unavailable

- Goal of local planning:
  - Execute a (local) part of the global plan while avoiding collisions
- Example algorithms:
  - Artificial potential fields
  - Pure pursuit
  - Dynamic window approach
  - Open space approach

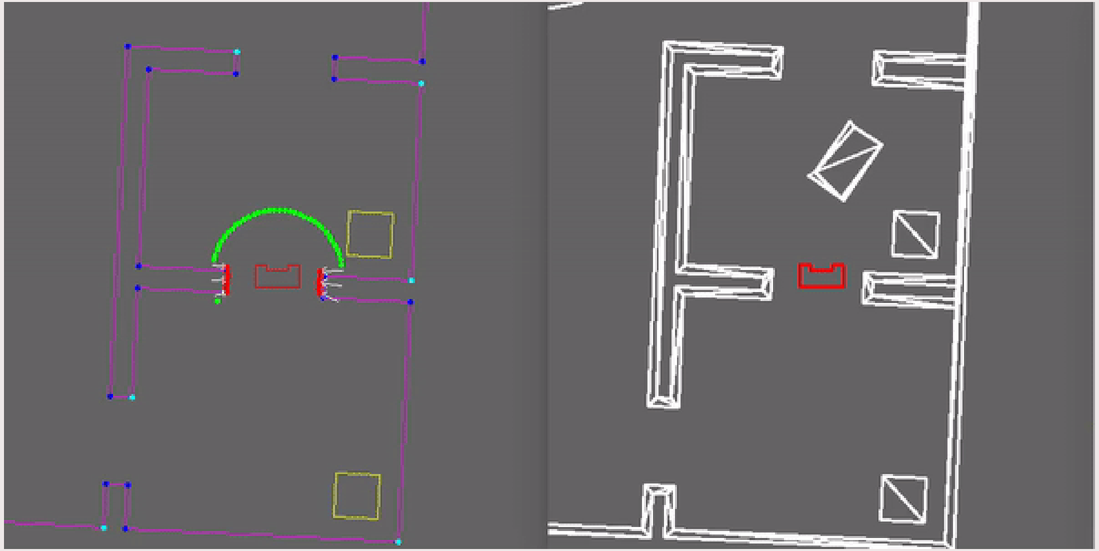
Popular in MRC: Artificial Potential Field Algorithm

- Artificial repulsion and attraction
  - Repulsion from obstacles
  - Attraction towards goal
- Global and local planning



Source: https://sudonull.com/post/62343-What-robotics-can-teach-gaming-AI

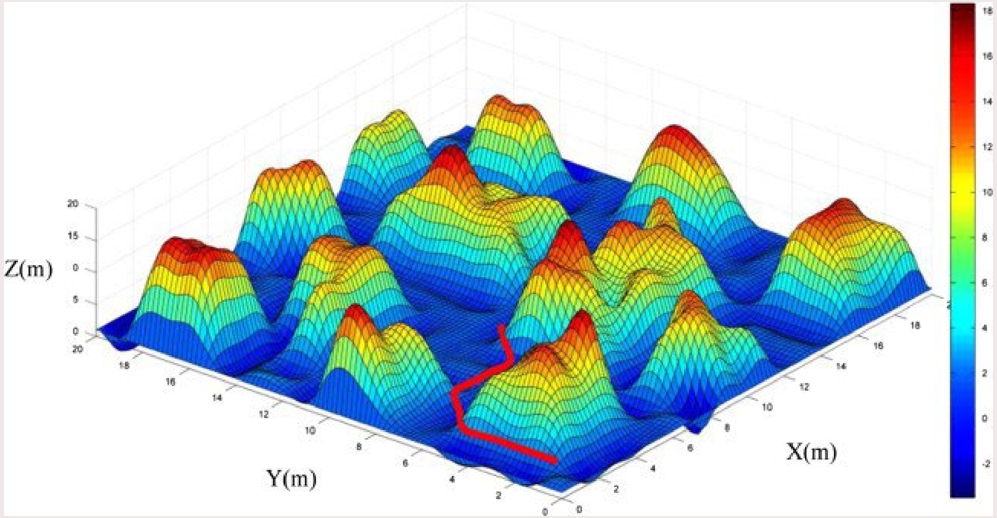
Artificial Potential Field Algorithm



Simulation - EMC 2019 – Group 2

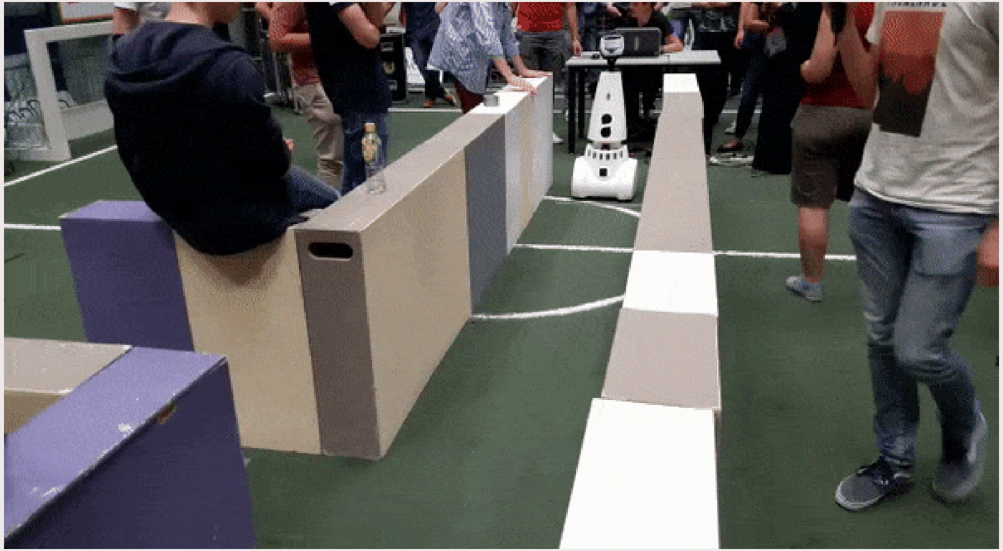
Artificial Potential Field Algorithm – Considerations

- Robustness?
  - To What? What not?



Source: https://medium.com/@rymshasiddiqui/path-planning-using-potential-field-algorithm-a30ad12bdb08

Artificial Potential Field Algorithm – Typical Behavior

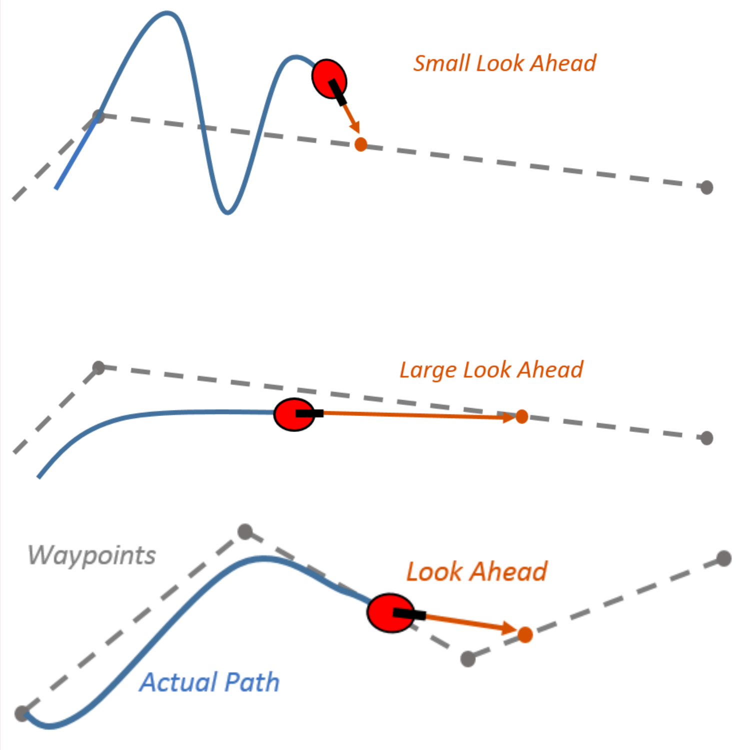


EMC 2017 – Group 10

Pure Pursuit (Carrot Planner)

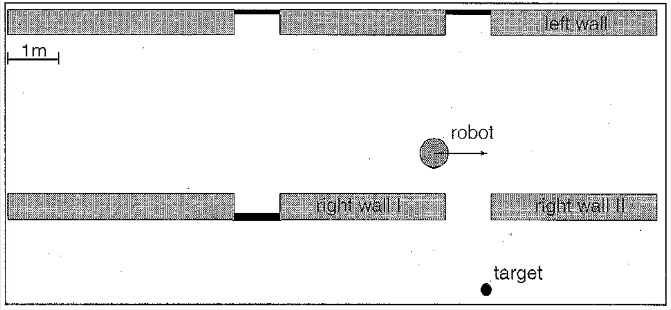
- Carrot planner
- Look ahead distance
  - Smoothness vs strict tracking

Source: https://www.shutterstock.com/

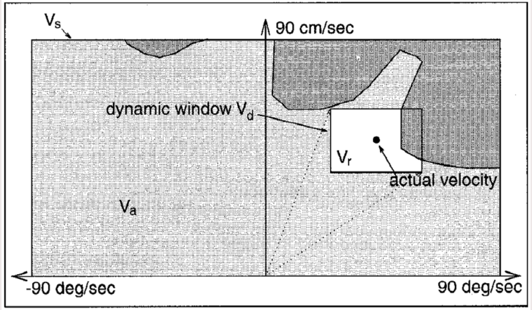


Source: https://nl.mathworks.com/help/nav/ug/pure-pursuit-controller.html

Dynamic Window Approach

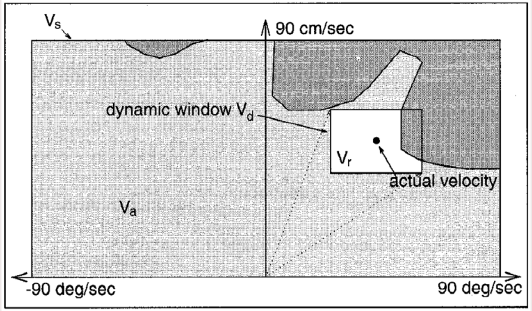


- Reactive avoidance of collisions with obstacles
- Assume piecewise constant velocities (v,ω) to approximate the trajectory by circular and straight line arcs over a short time interval
- Consider only admissible and reachable velocities within the interval
  - Admissible: robot can stop before reaching closest obstacle
  - Reachable: velocity and acceleration constraints (dynamic model)



D. Fox, W. Burgard and S. Thrun, "The dynamic window approach to collision avoidance," in *IEEE Robotics & Automation Magazine*, vol. 4, no. 1, pp. 23-33, March 1997, doi: 10.1109/100.580977.

Dynamic Window Approach



- Reactive avoidance of collisions with obstacles
- Assume piecewise constant velocities (v,ω) to approximate the trajectory by circular and straight line arcs over a short time interval
- Consider only admissible and reachable velocities within the interval

- Maximizing objective function for remaining set
  - Target heading towards goal
  - Forward velocity of the robot
  - Distance to closest obstacle on trajectory

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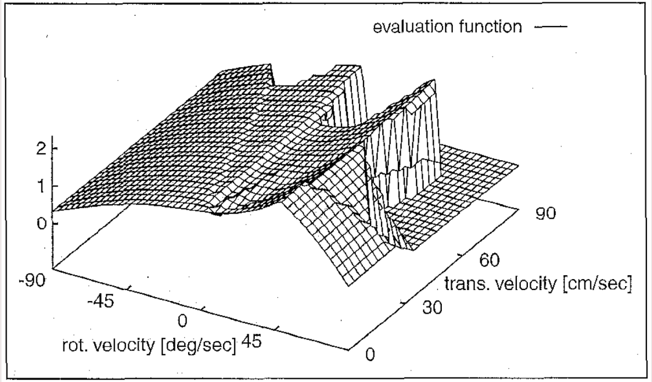
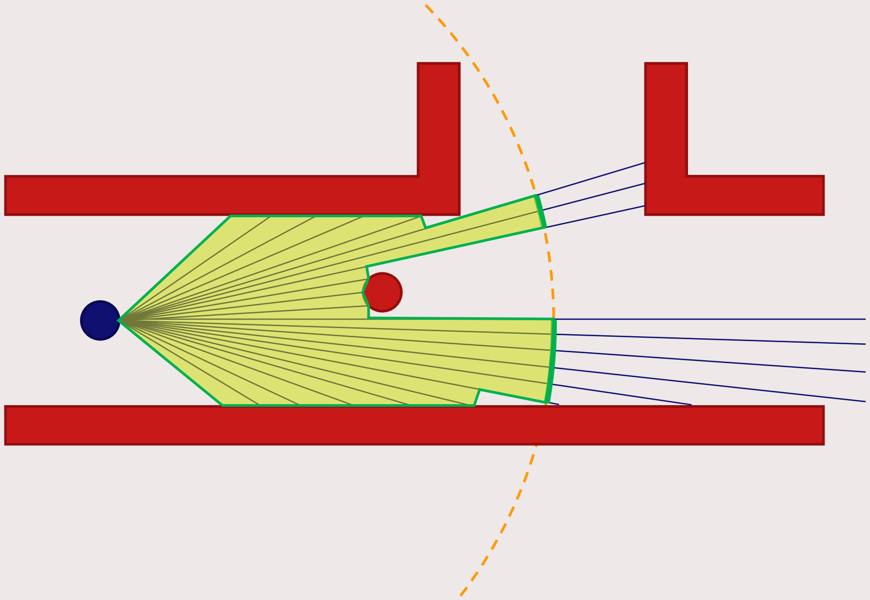


Open Space Approach

- Instead of focusing on obstacles, focus on open space
- Horizon parameter
- Ongoing research



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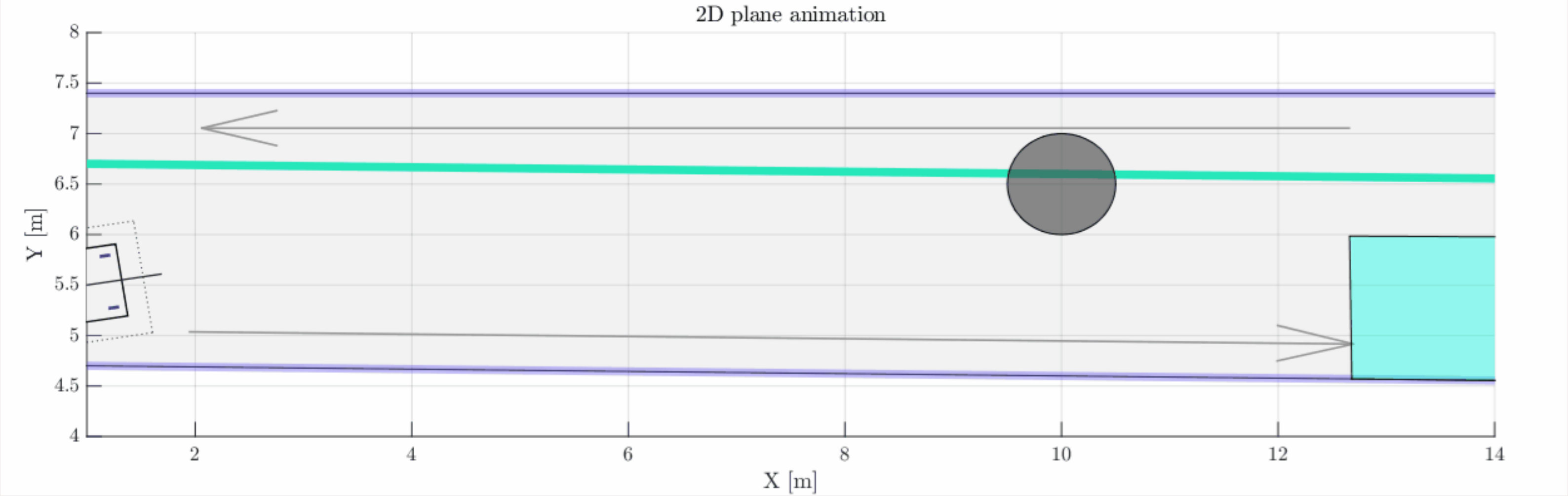
Control Objectives – Abstraction

- Setpoint:
  - One instantaneous value of the desired state
- Trajectory:
  - Desired state values at multiple sample times over a certain horizon
  - Gives the designer more freedom
- Path:
  - Desired states along the geometry of the path in state space, without timing
  - Less constraining than trajectory
- Tube:
  - Allow deviation from path, state should remain inside a ‘tube’ or ‘region’
  - Least constraining

Source: Building blocks for complicated and situational aware robotic and cyber-physical systems by Herman Bruyninckx

Control Objectives – Tube Example



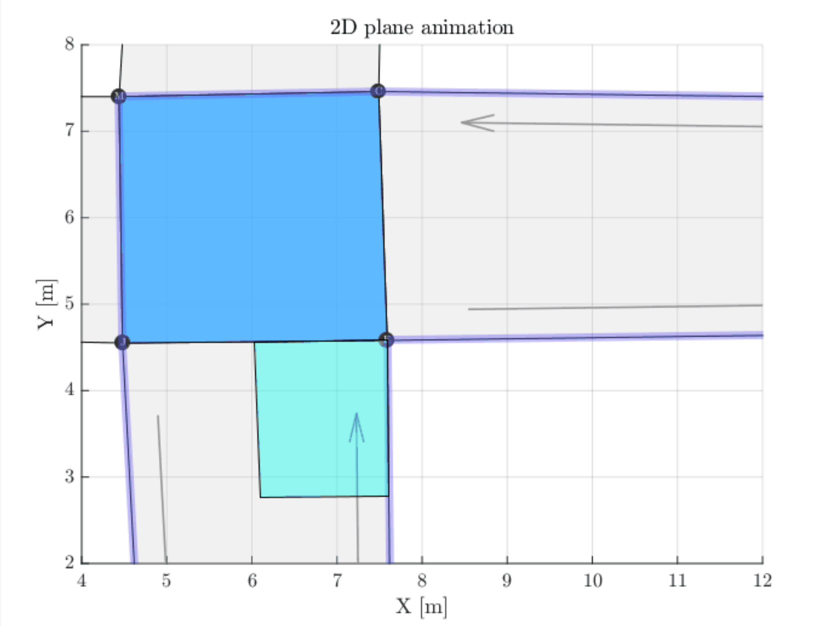
M.S. de Wildt, C.A. Lopez Martinez, M.J.G. van de Molengraft and H.P.J. Bruyninckx. (2018). Tube Driving Mobile Robot Navigation Using Semantic Features. Master's Thesis

Control Objectives – Tube Example

- Guarded Motion

  "Keep on executing, till something happens"

  - What is "something"?
  - What to recompute?



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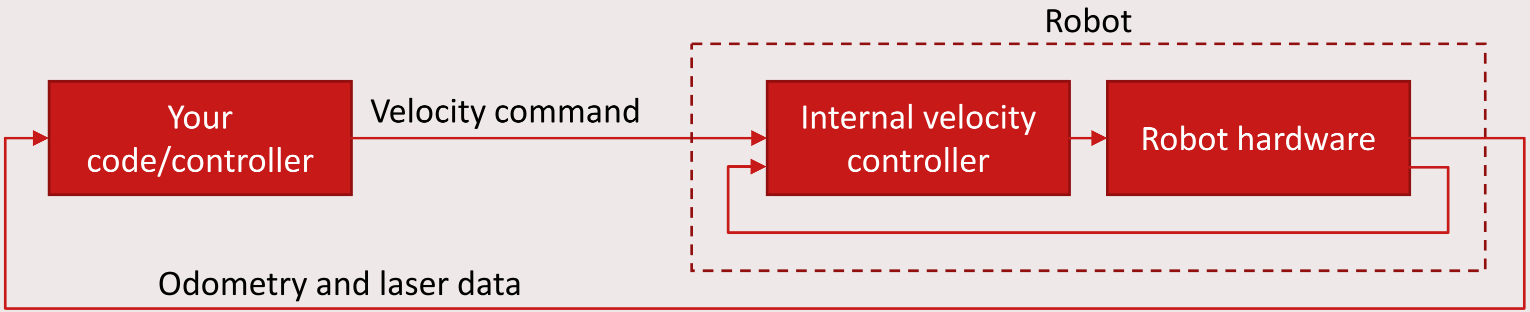
Control Objectives – MRC

- MRC Robots' Interfaces:
  - Send velocity command in local (robot) frame
- Your approach can contain other objectives
  - Use cascaded control loops to achieve this
    - Bandwidth
  - Use your knowledge from other control courses!



Some conclusive considerations

- Many planning concepts exist
- How to obtain robustness?
- How to spend your computational resources?
  - Trial and error?
  - Compute a path at each sample? Or, recomputation when required?
- How to take (which) semantics into account?
- How to take physical constraints into account?
- What level of discretization or abstraction is required?

Assignment 2 – Obstacle Avoidance in a Corridor

- Let the robot move 5 meters through a corridor without collisions with (unknown) obstacles
- Open assignment, select/develop your own algorithm