Motion Planning – Mobile Robot Control 2020

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Motion Behaviour of Last Years

EMC 2019 – Group 5

- What are the motion requirements?
- When do they change?

Motion Behaviour of Last Years

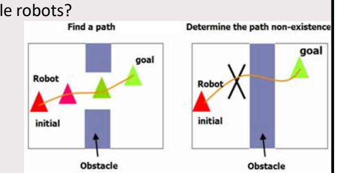
EMC 2019 – Group 9

- What went well?
- What can be improved? How?

Motion Planning Problem

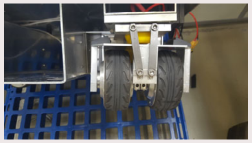
Given an initial pose, determine the control outputs such that, via a sequence of valid configurations, its desired final pose is reached

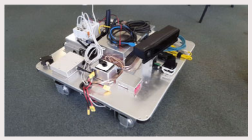
- Which motion constraints does the robot have?
  - Holonomic/non-holonomic?
  - Actuator & physical limits? Maximum jerk, acceleration, velocity?
  - Complient with environment-constraints? Multiple robots?
  - How strict is the “trajectory"?
- When is the final position achieved?
  - Constant or variable requirements?
  - Which requirements for MRC?
- Environment static? Dynamic?
- Measurement Uncertainty? E.g., localization uncertainty?

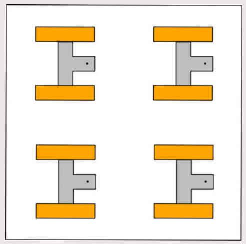


http://gamma.cs.unc.edu/NOPATH/

Motion Planning Problem: Example







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Motion Planning Problem: Example

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Specifications & Properties

- Completeness: finding a path if one exists
- Optimality: finding the optimal path
- Computational complexity
- Robustness against a dynamic environment
- Robustness against uncertainty
- Kinematic and dynamic constraints

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Motion Planning: Taxonomy

Global vs. Local

Bio Inspired
- Genetic Algorithms
- Particle Swarm Optimization

Graph Based:
- Topological
  - Semantics Based
  - Probabilistic Roadmap
    - Voronoi Graph
    - Visibility Graph
- Cell/grid based

Learning:
- Reinforcement Learning
- Deep Learning

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Hierarchical Planning: Global vs. Local

Reduction of complexity: divide the planning problem into global and local planner

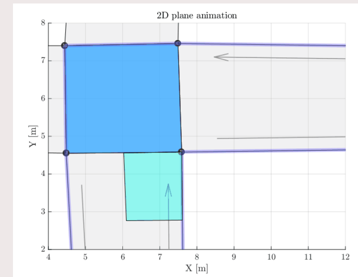
- Global planner: computes a path from start to goal
- Local planner: satisfy kinodynamic constraints

"What is the route from Eindhoven to Amsterdam" vs. "I need to pass the car in front of me"

Always explicitly describe what you mean with local & global, it might create a lot of confusion!

Representation

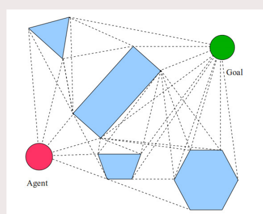
- Robot



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

Representation

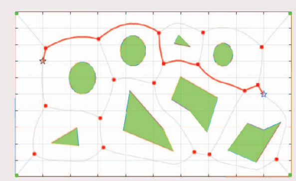
- Robot
- Exact: Roadmaps
  - Visibility Graph: traversable Routes



Niu, Hanlin & Lu, Yu & Savvaris, Al & Tsourdos, Antonios. (2018). An energy-efficient path planning algorithm for unmanned surface vehicles. Ocean Engineering. 161. 308-321. 10.1016/j.oceaneng.2018.01.025.

Representation

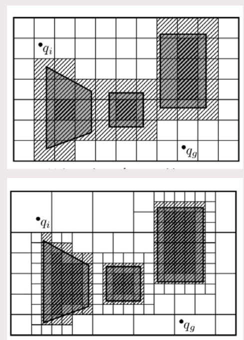
- Robot
- Exact: Roadmaps
  - Visibility Graph: traversable Routes
  - Voronoi Diagram



Magid, Evgeni et al. "Voronoi-based trajectory optimization for UGV path planning." 2017 International Conference on Mechanical, System and Control Engineering (ICMSC) (2017): 383-387.

Representation

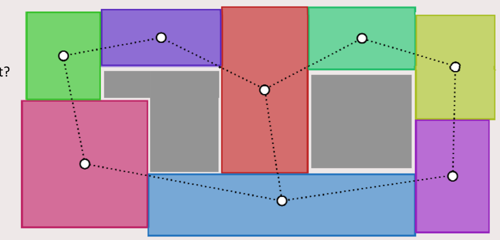
- Robot
- Exact: Roadmaps
  - Visibility Graph
  - Graph of traversable Routes, e.g. Topological Map
- Approximate: Cell decompositions
  - Occupied vs Free
  - Adaptive?
  - Semantics?



Coenen, S.A.M. (2012). Motion Planning for Mobile Robots - A Guide. Master's thesis

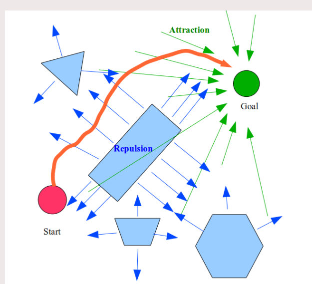
Topological Map

- Where to place the nodes?
- Which semantics might be relevant?
- Which semantics is missing?



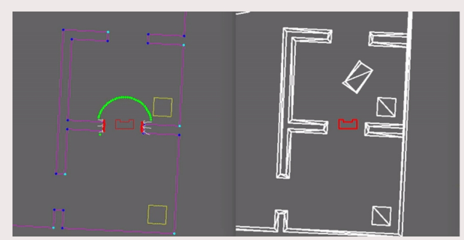
Blöchliger et al. (2017). Topomap: Topological Mapping and Navigation Based on Visual SLAM Maps. CoRR, http://arxiv.org/abs/1709.05533

Popular in EMC: Artificial Potential Field Algorithm



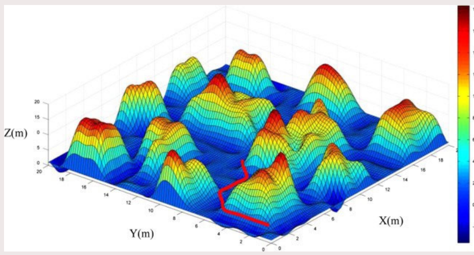
https://sudonull.com/post/62343-What-robotics-can-teach-gaming-AI

Artificial Potential Field Algorithm



Simulation - EMC 2019 – Group 2

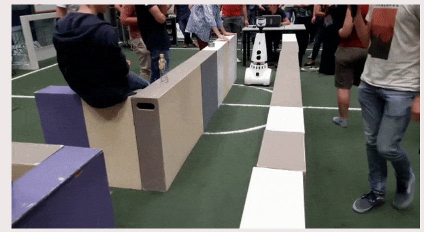
Artificial Potential Field Algorithm - Considerations



- Robustness? To What? What not?

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

Artificial Potential Field Algorithm – Typical Behavior

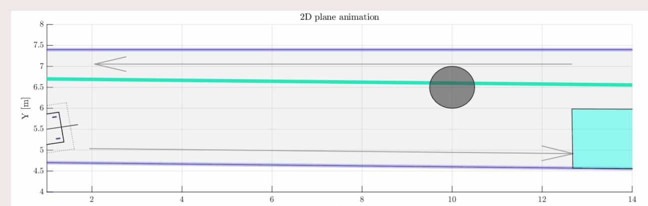


EMC 2017 – Group 10

Control Objectives – Abstraction Source

- **Setpoint:** only one single instantaneous value of the desired state of the plant is being used in the control computations. In other words, the control horizon is only one time instant "deep".
- **Trajectory**: instead of just one instantaneous desired value for the plant state as input to the control design process, a trajectory of desired plant state values at multiple sample times over a certain horizon is used. This gives the designer more freedom to spread the inevitable control error budget over a larger space.
- **Path**: another mechanism is to use a path instead of a trajectory. This is a less constraining input, because the time is not imposed. In other words, the state is constrained to follow the geometry of the path in state space, but not any timing along that path.
- **Tube**: this is the least constraining input, because the controller can now also deviate from a given path, as long as the resulting path keeps the plant state inside a "tube", or "region", in the state space

Control Objectives – Tube Example



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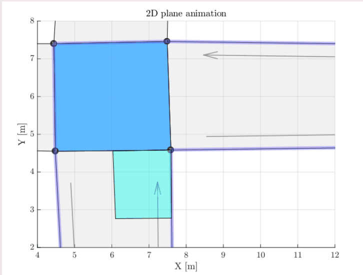
Control Objectives – Tube Example

- Guarded Motion

  "Keep on executing, till something happens"

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



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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?