Towards context-aware mobile robot navigation

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Who am I?

Someone who likes academia and industry

- 2015-present. Industry jobs in Mechatronics & Robotics
- 2017-2019. Postdoc CST Robotics Lab - ROPOD project
- 2020-present. Part-time Assistant Professor CST Robotics Lab
- 2023-present. Starnus Technology - Modular Mobile Robotics for Logistics

Agenda

- Motivation
- Classical Navigation Approach
- Context-aware Navigation Approach
- Conclusion

Robots in spaces shared with humans

Hospitals, schools, public buildings, etc

Poor performance around people and highly dynamic environments

- Robots lack context knowledge of their environment
- Results in people “not understanding” robot’s actions

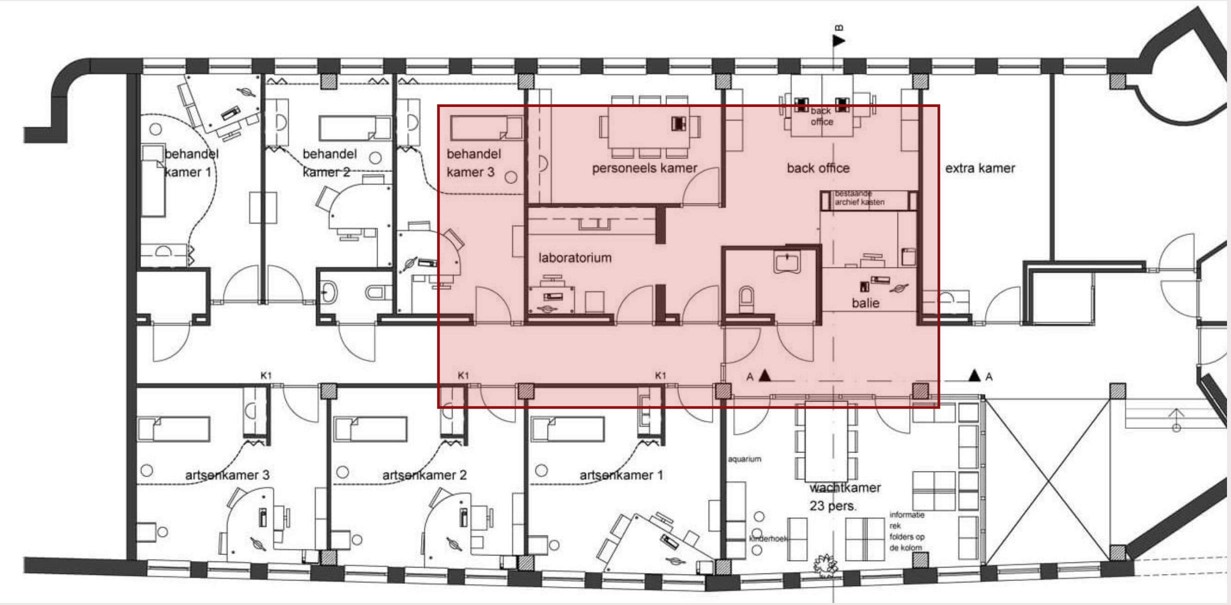
TUG [2]

BOIKON-FOSKE [1]

Spencer [3]

Motivation

We consider indoor environments:



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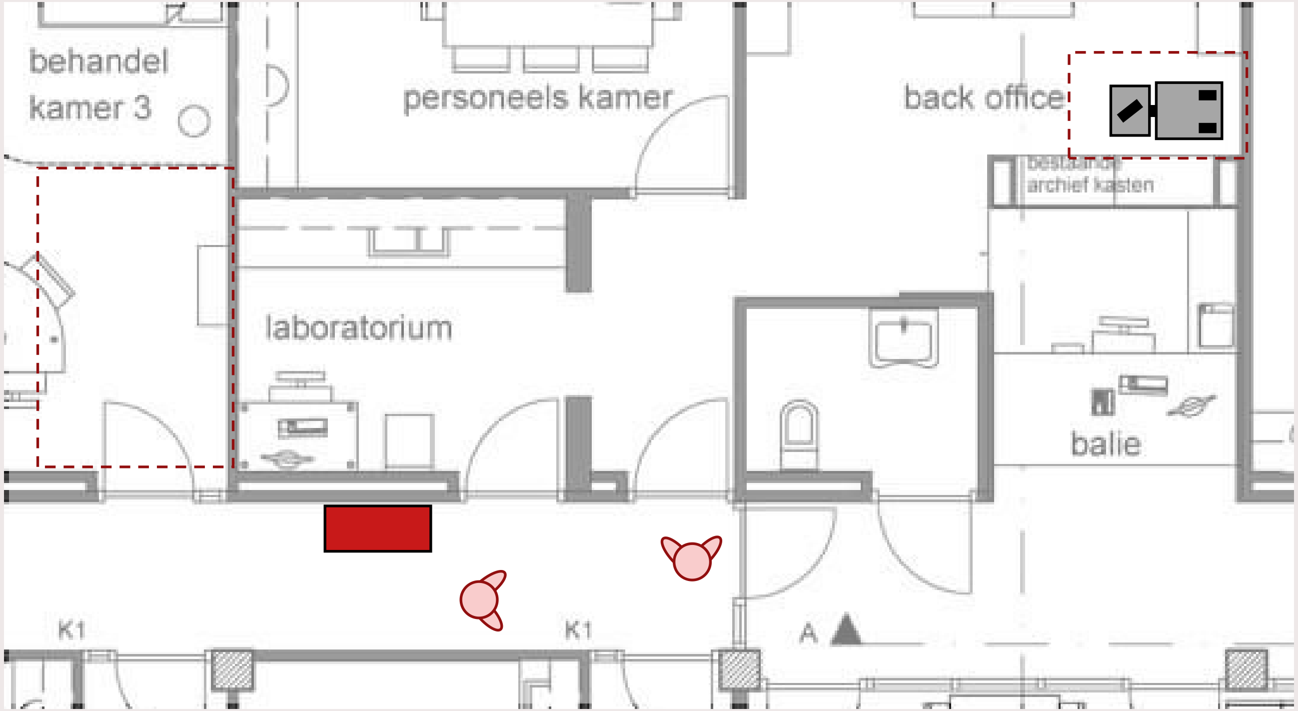
Motivation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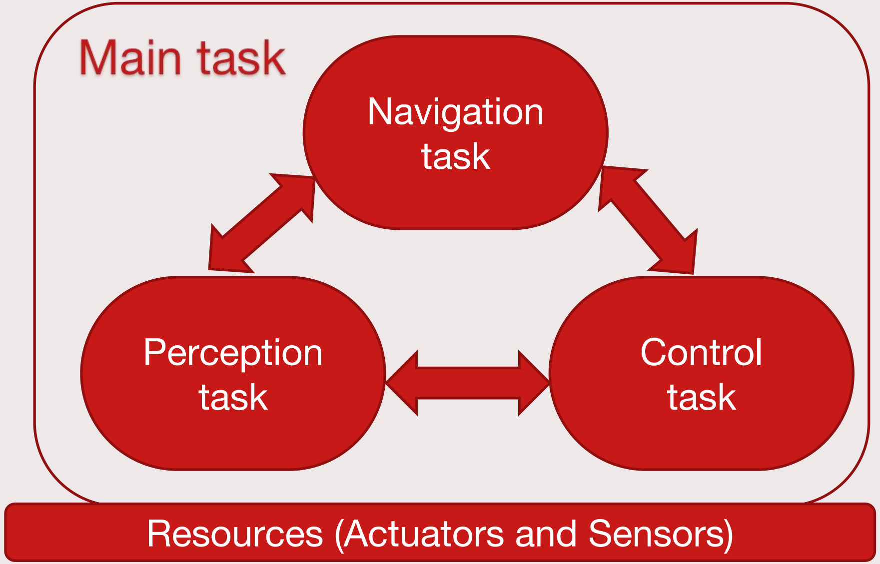
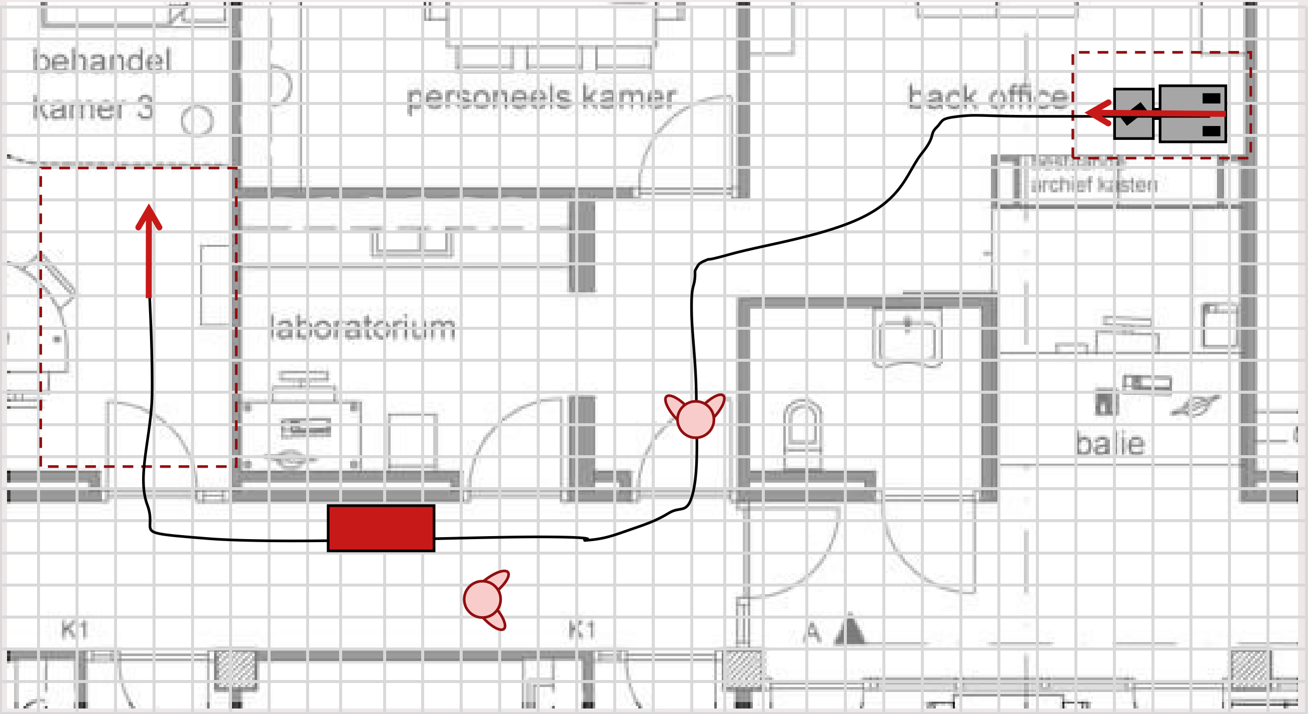
Main components of a mobile robot software



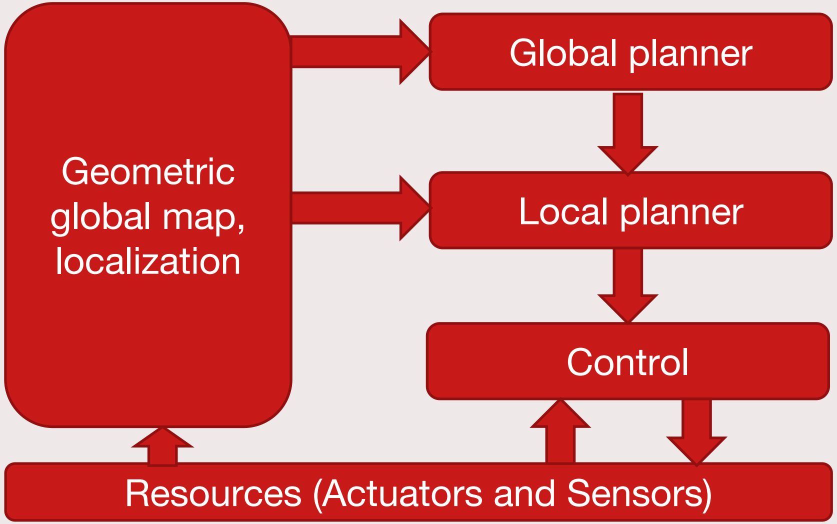
Navigation Task

Classical approach



Classical approach

The literature in robot navigation is vast: Most fit in this classical approach:



- Global planners: commonly use grids [6] to find geometric paths
- Local planners: track global plan while avoiding obstacles via numerical optimization techniques [8-9-10].

Classical approach

Semantics of the environment is usually ignored!, which can lead to frequently hindering the traffic flow

Most pure numerical optimization techniques suffer from:

- Local-minima and numerical issues (especially around tight spaces)
- which can lead to undesirable and incosistent results

Tracking a global path impose tight requirements on localization accuracy

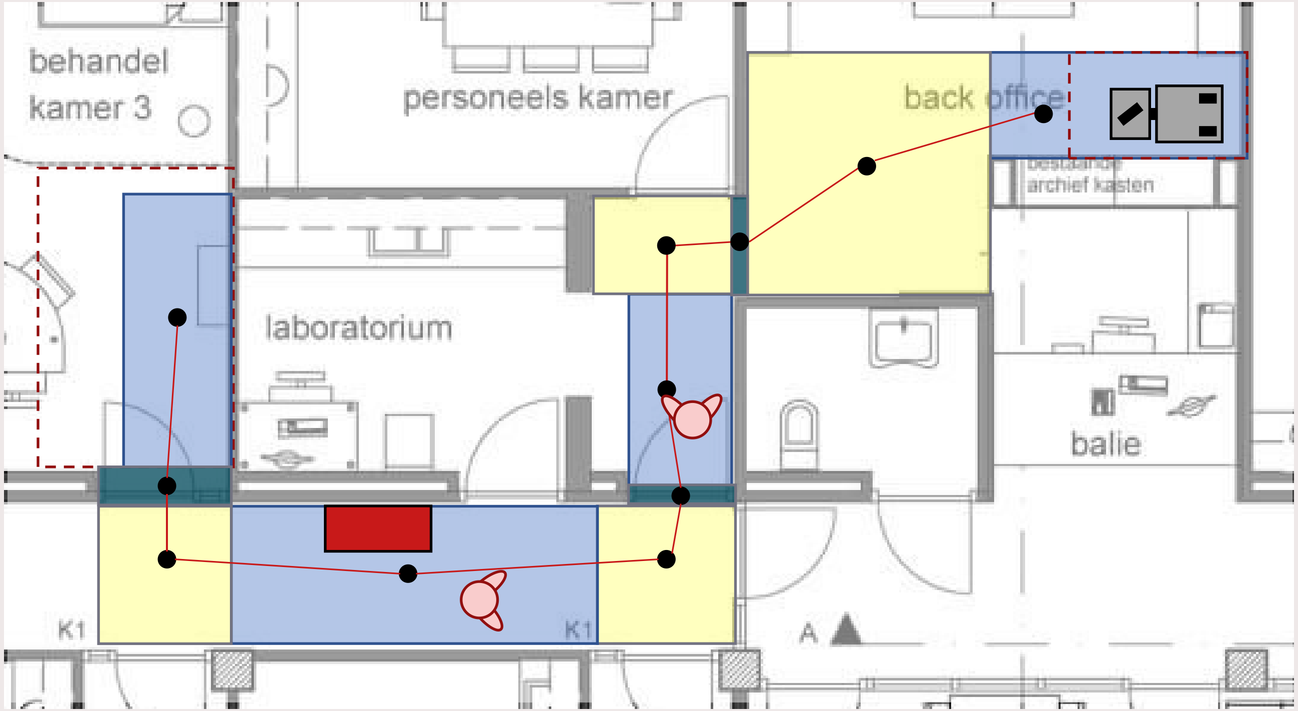
Context-aware Navigation Approach

These issues can be reduced/avoided by taking semantics of the task and the environment into account

Make explicit robot’s decisions and actions with respect to the environment context and geometry, and its associated semantics

context-aware navigation

Semantics in indoor environments



- Corridors

  Intersections

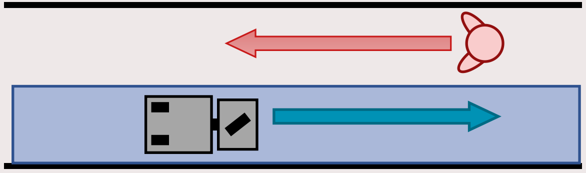
  Doorways

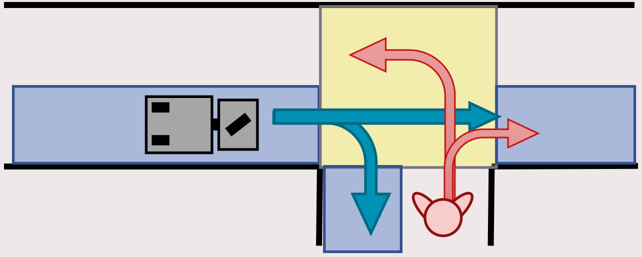
- Topological plan

Traffic “rules”

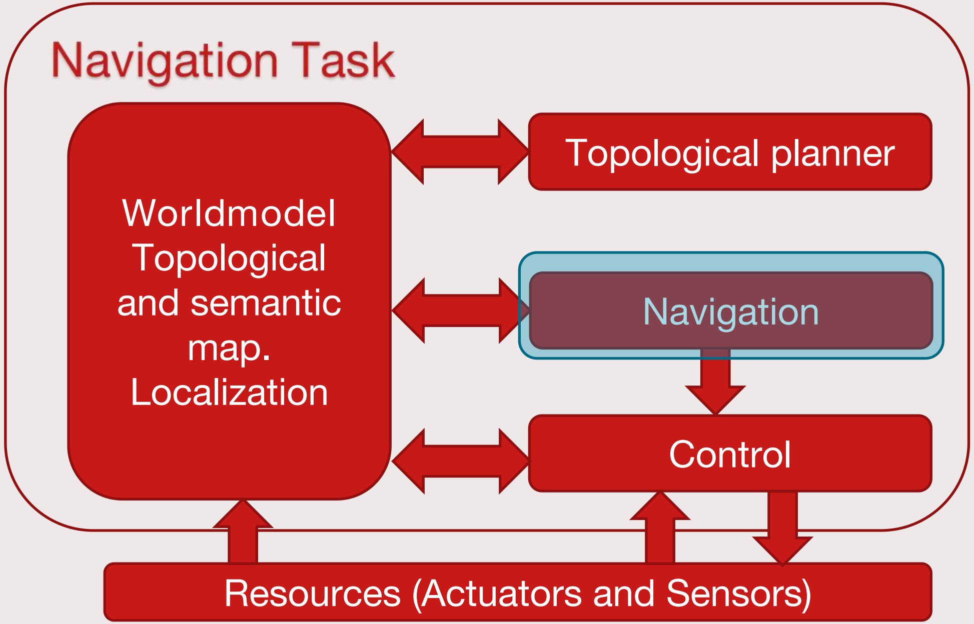
Use traffic rules, which people are aqcuinted to (from social conventions):

- limits the potential actions taken by other actors of the environment,
- but also limits the set of possible actions the robot can take





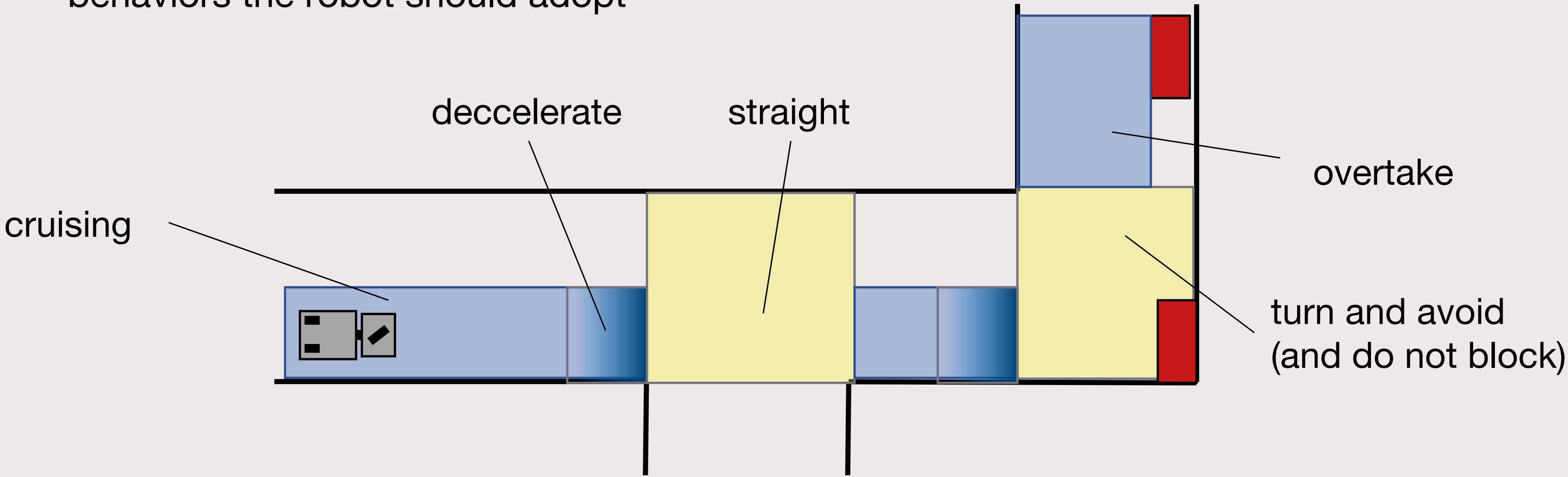
Proposed Approach



- Worldmodel is the central element
- Plan consists of sequence corridors, intersections, doorways...
- Navigation uses semantic information (which imposes explicit navigation constraints) from the worldmodel

Semantics in indoor environments

The environment context and its semantics provides explicit behaviors the robot should adopt

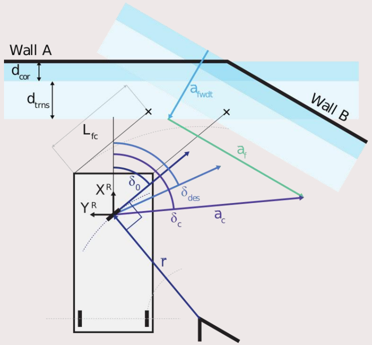


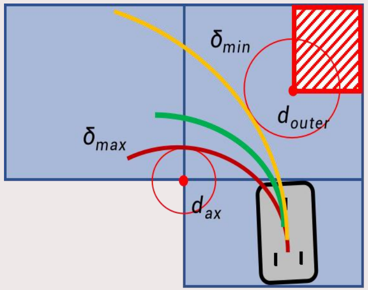
How to generate velocity commands?

Environment geometry (partially derived from semantics) provides information on how to steer

Two main methods explored:

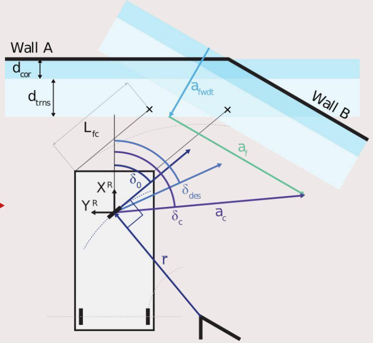
- Navigation via reactive steering using tubes (ROPOD project) [12]
- Navigation via open space steering [13]

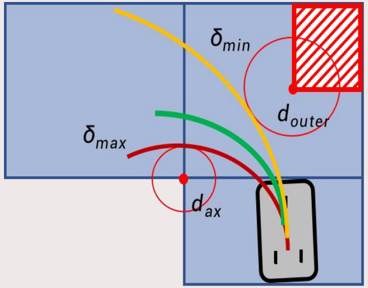


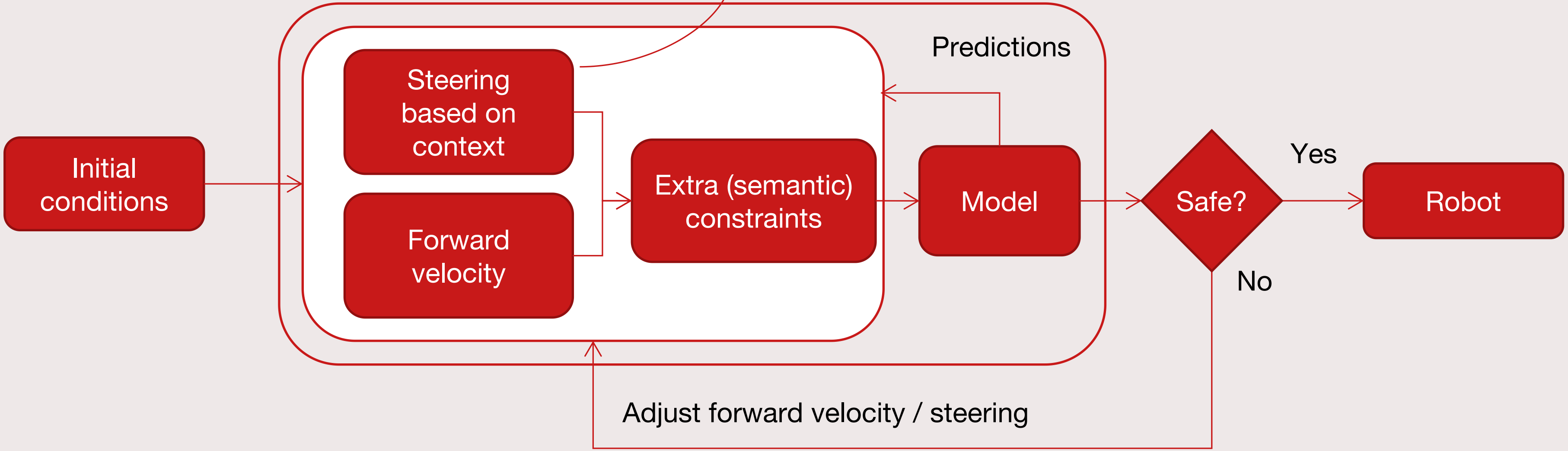


Predictions

Robots should anticipate the scene



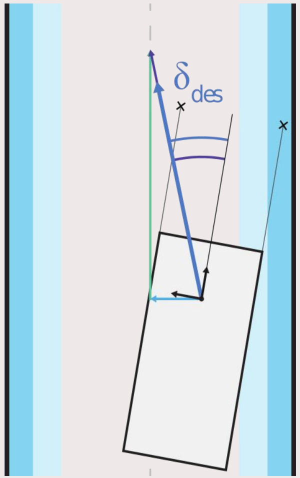




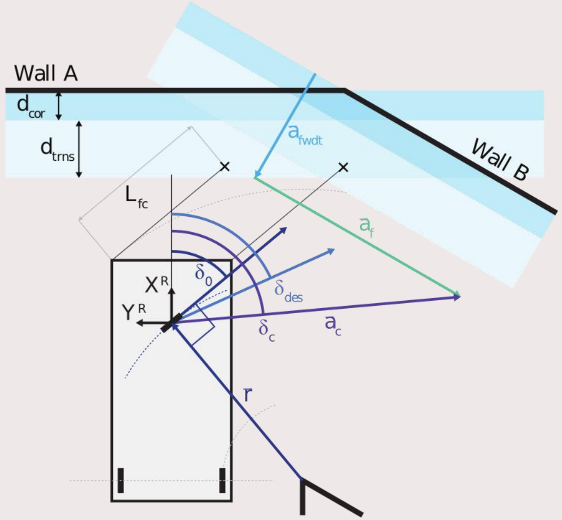
Reactive steering method

Virtual feelers in front of the robot determine steering values based on features like walls and corners

cruising

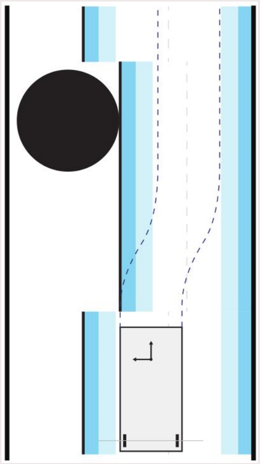


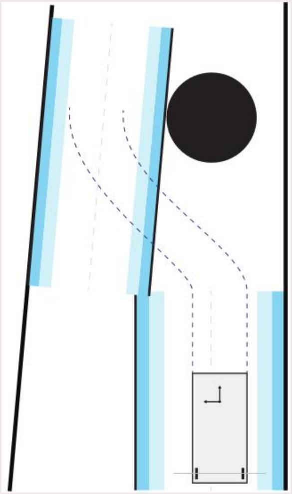
turn

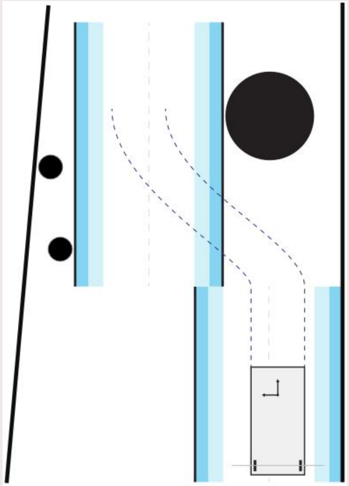


Reactive steering method

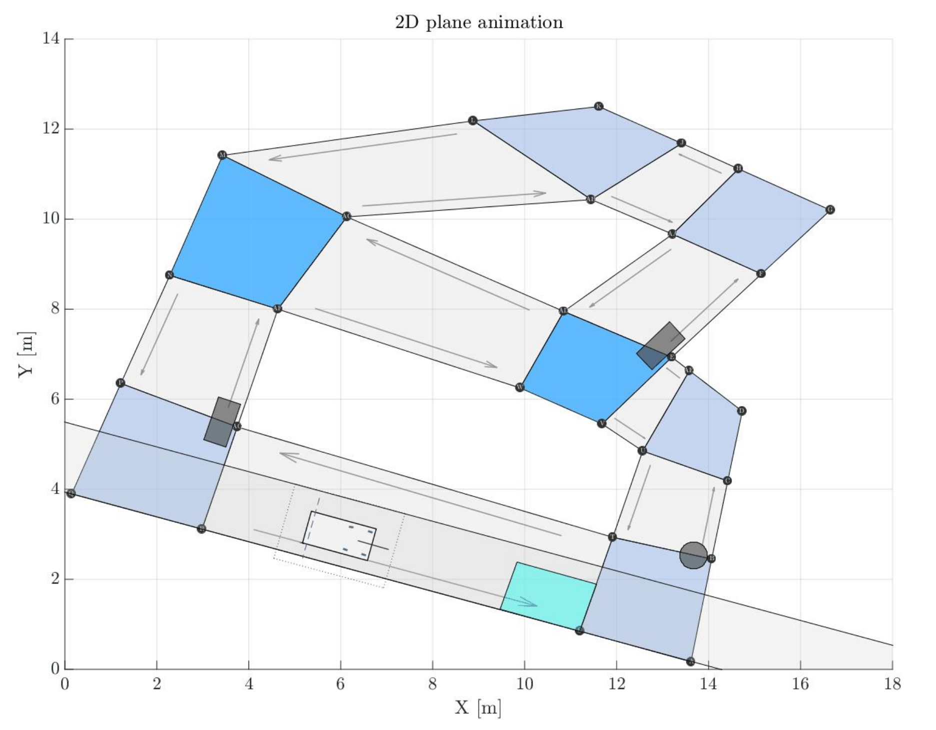
Obstacles avoided by moving virtual tubes:





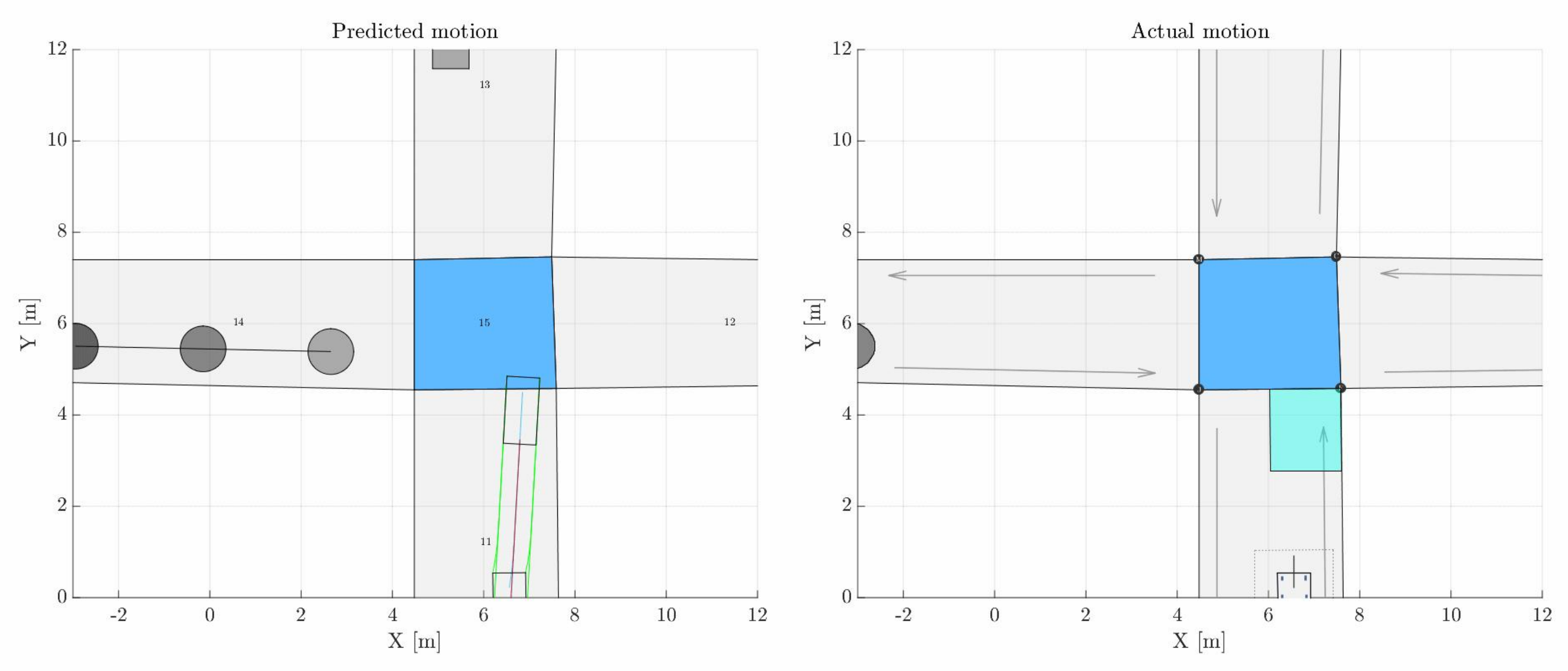


Reactive steering method



TU/e

Reactive steering method

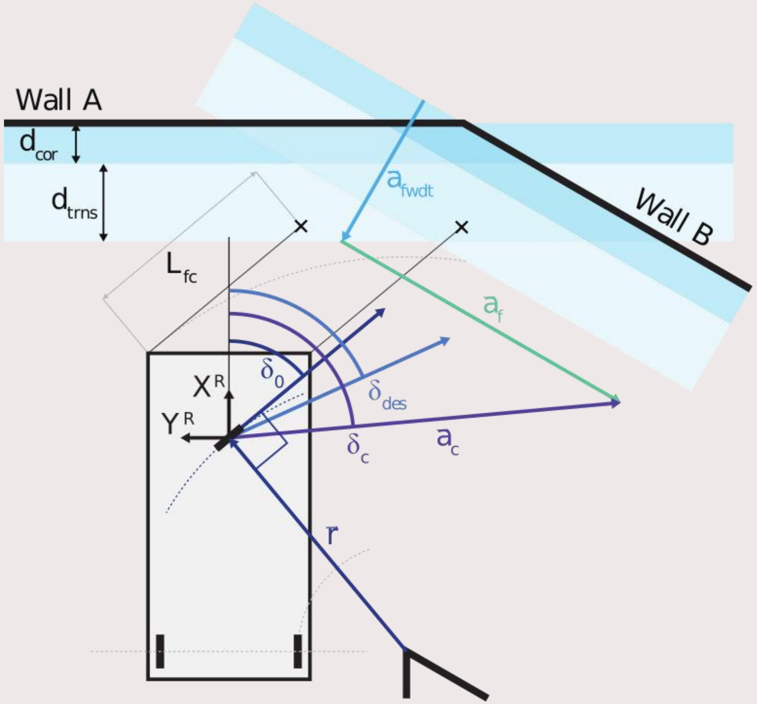


Reactive steering method

https://youtu.be/AhBgBI59yEA

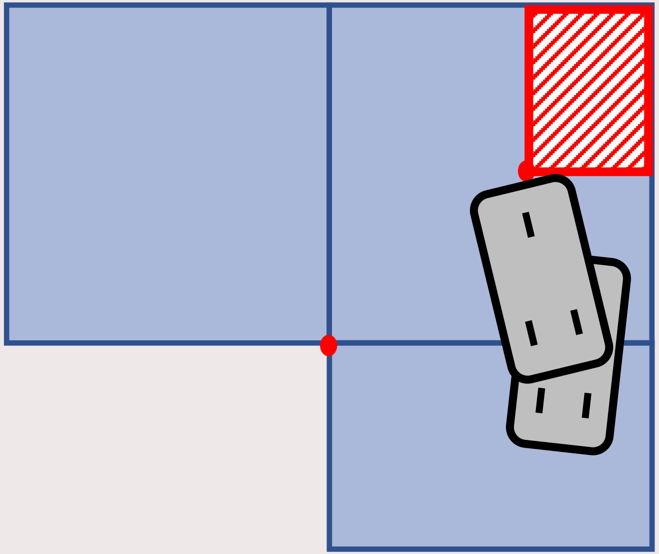
Issues

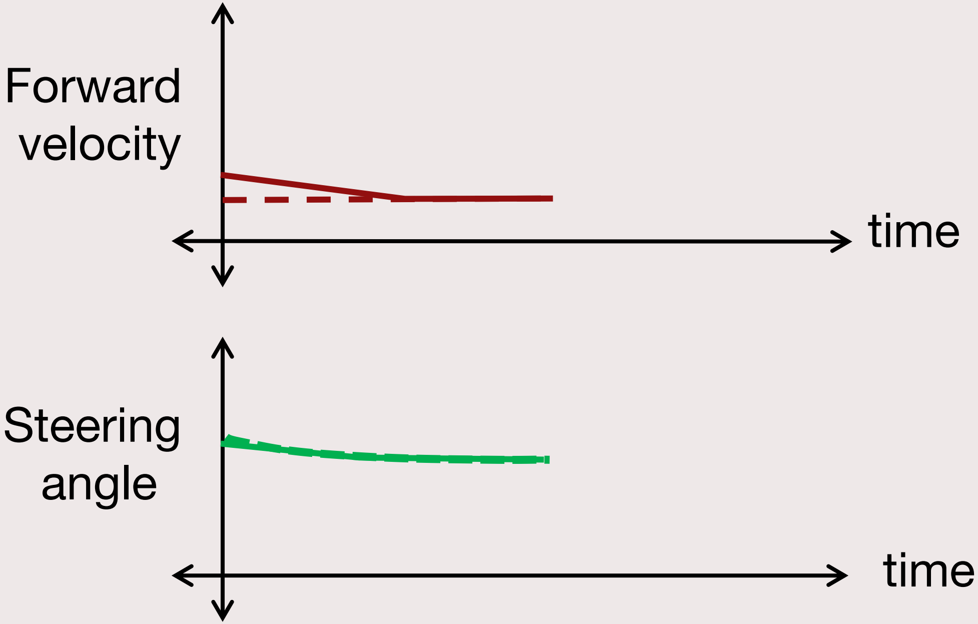
Too many parameters!



Issues

Insufficient steering

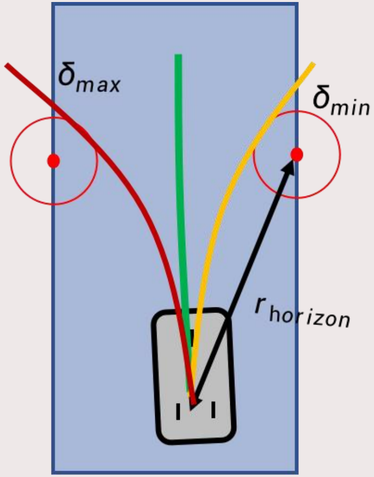




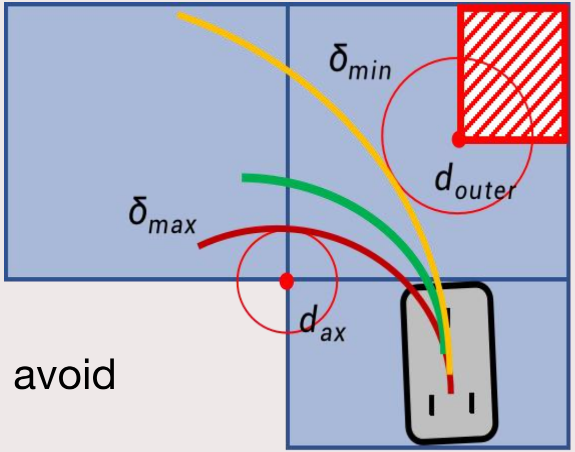
Open space steering method

Based on semantic and geomtery of measured objects, find a steering range that ideally drives the robot to open space

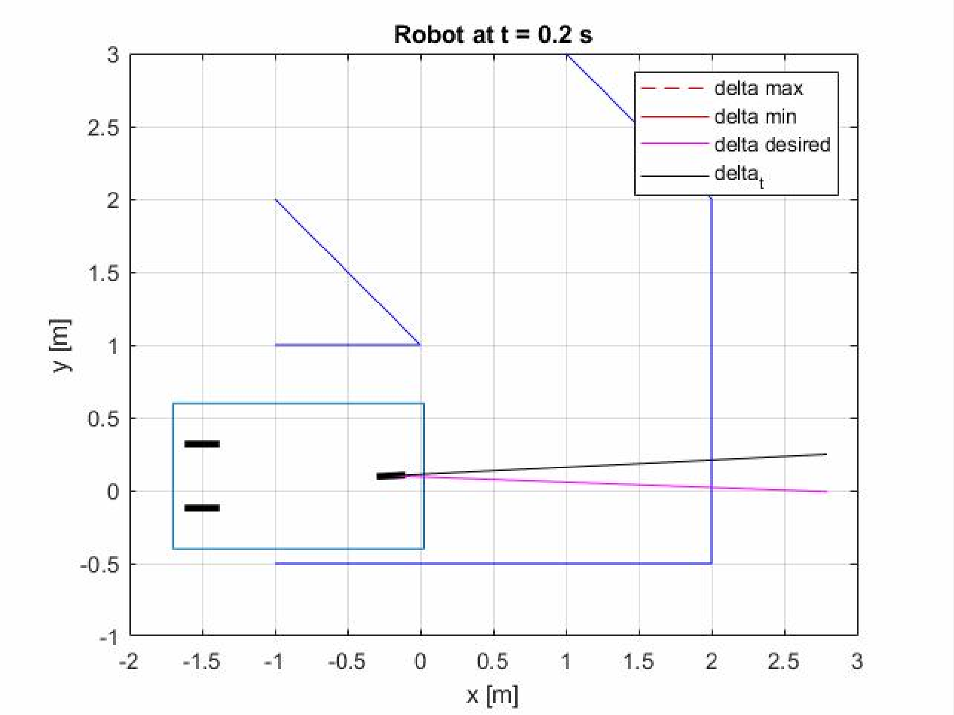
cruising



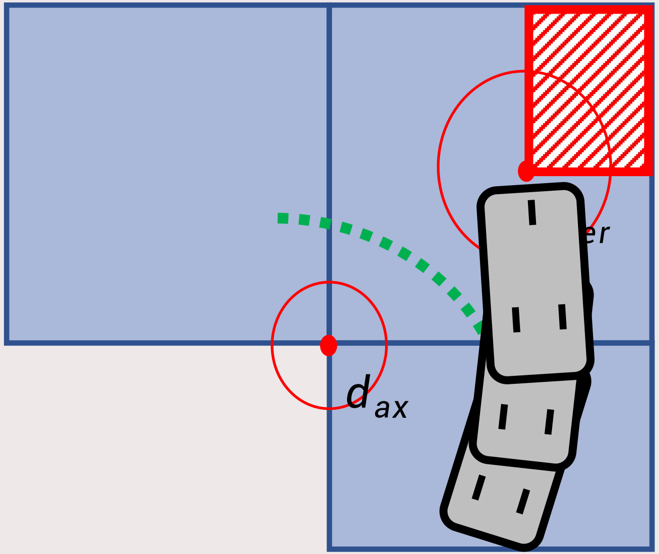
turn and avoid

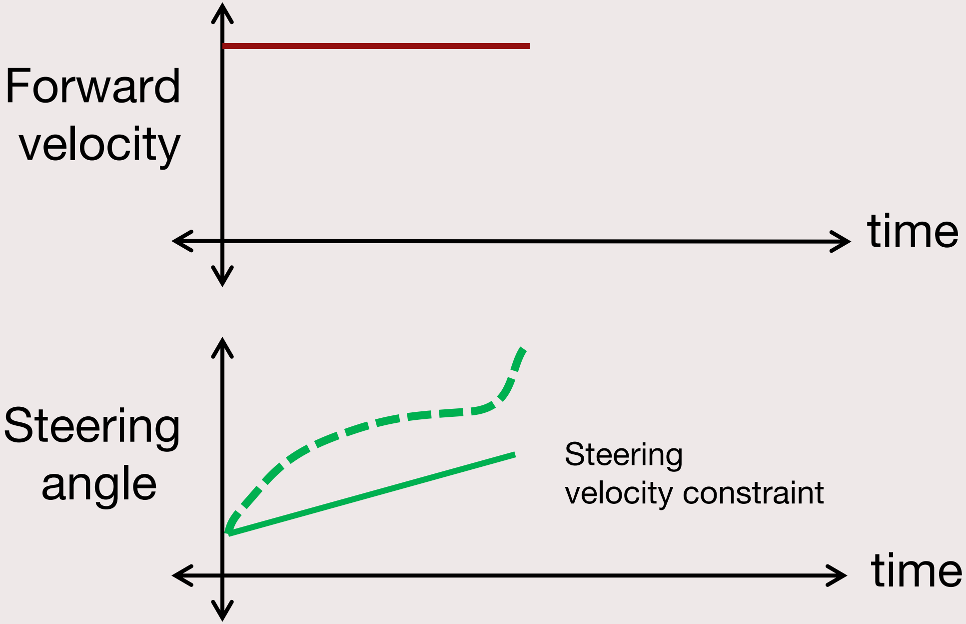


Open space steering method

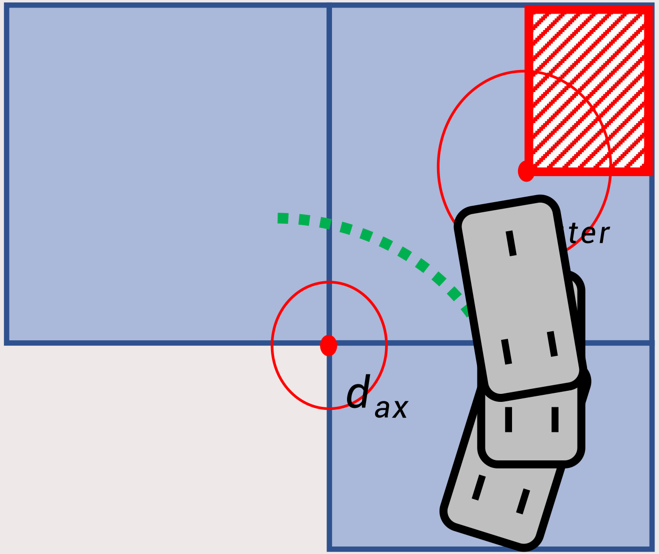


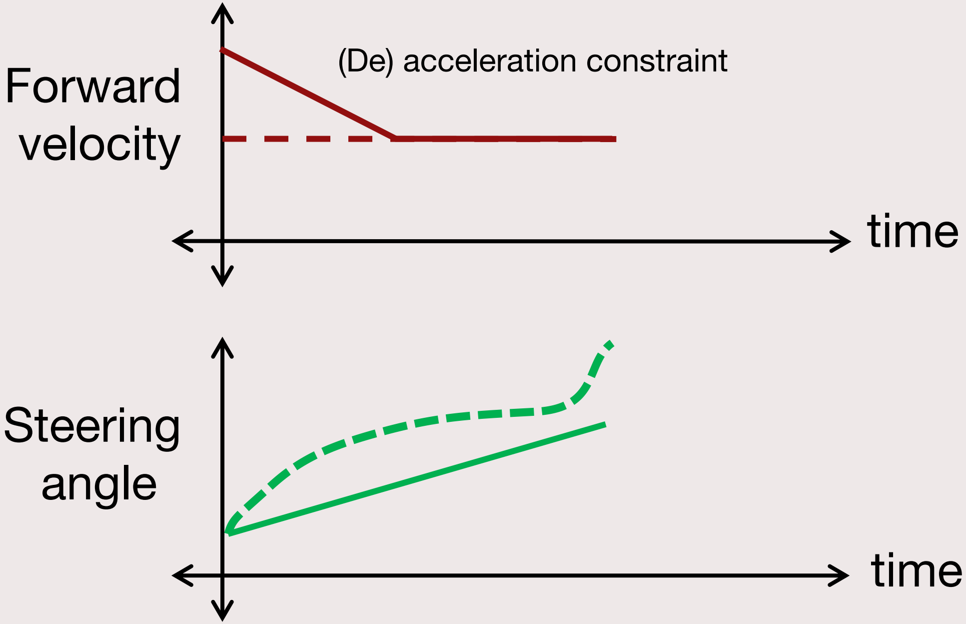
Predictions



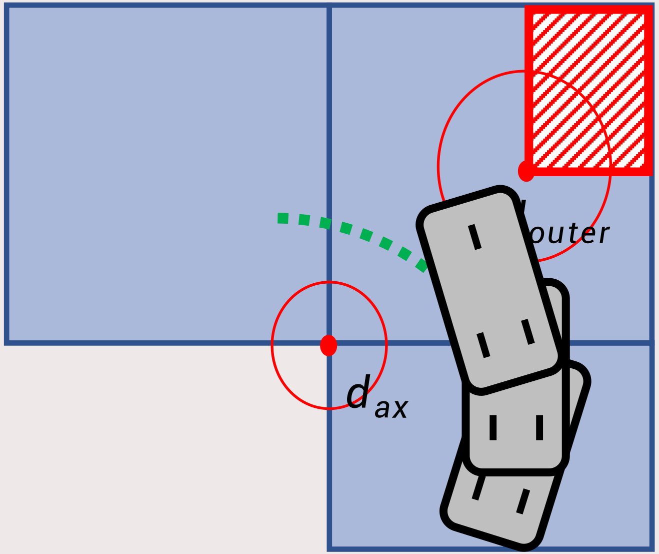


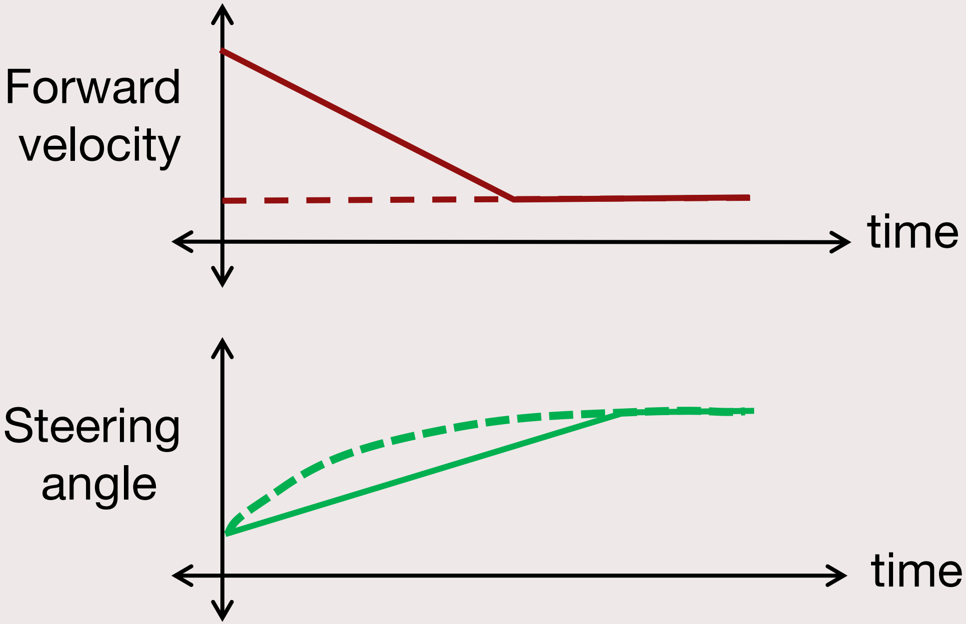
Predictions



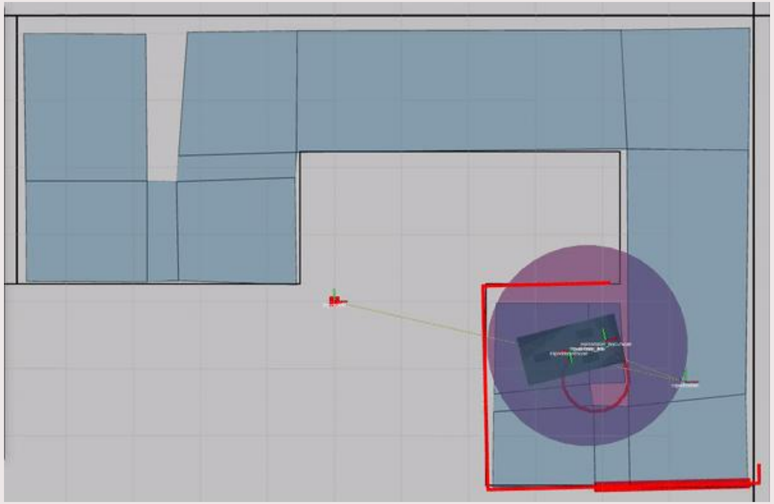


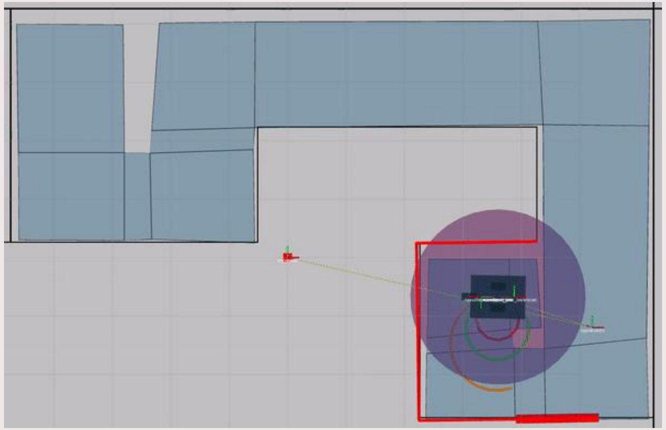
Predictions

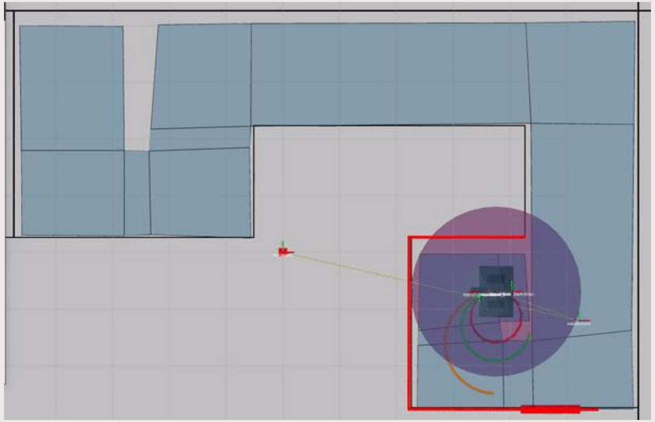




Simulation results







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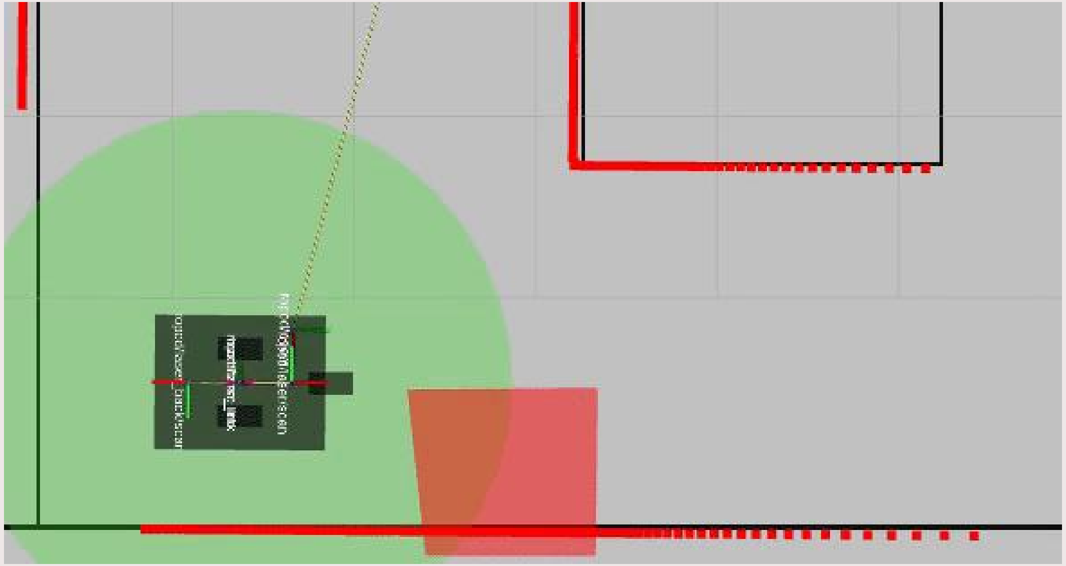

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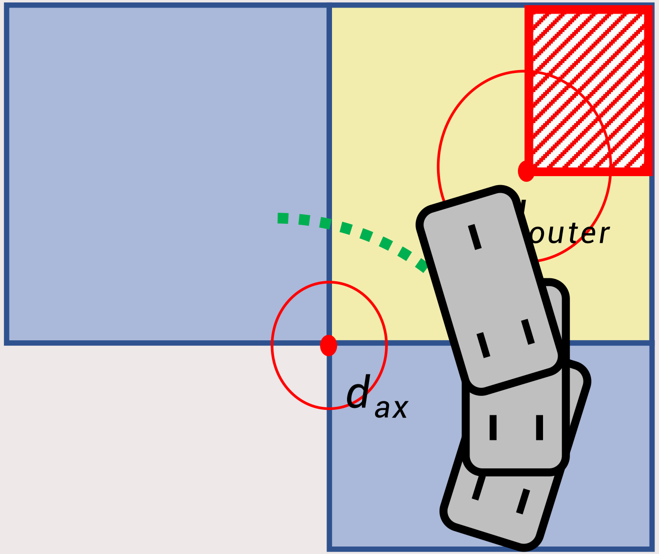
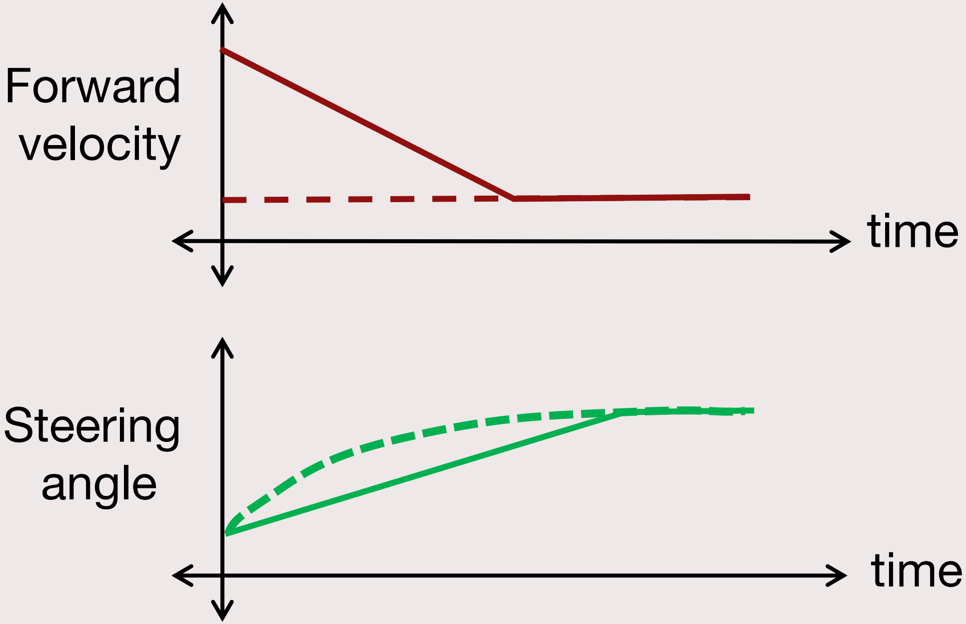
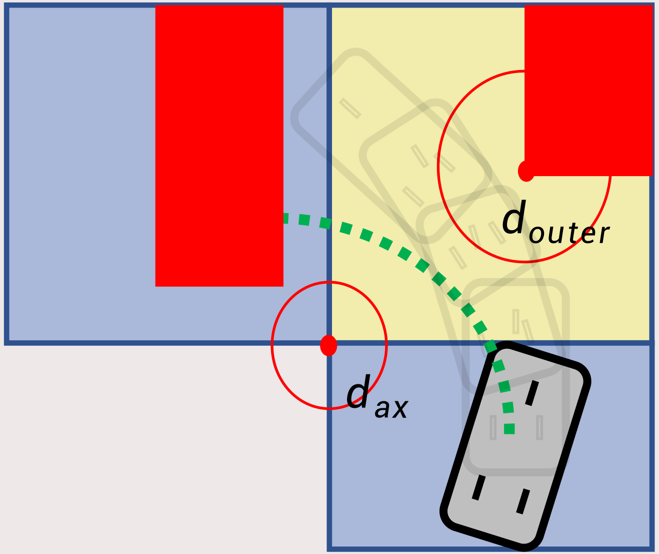
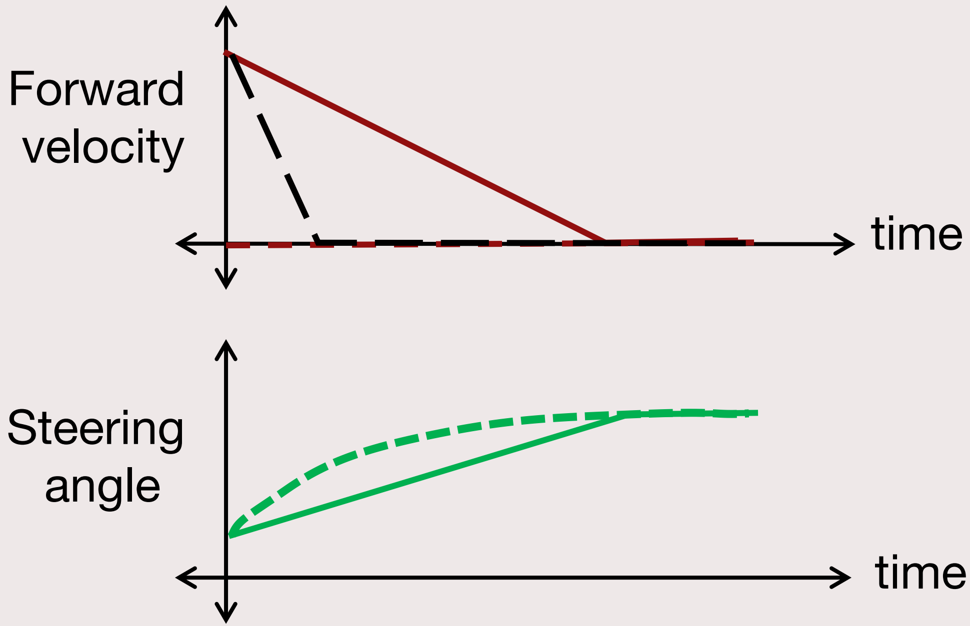
Semantic constraints



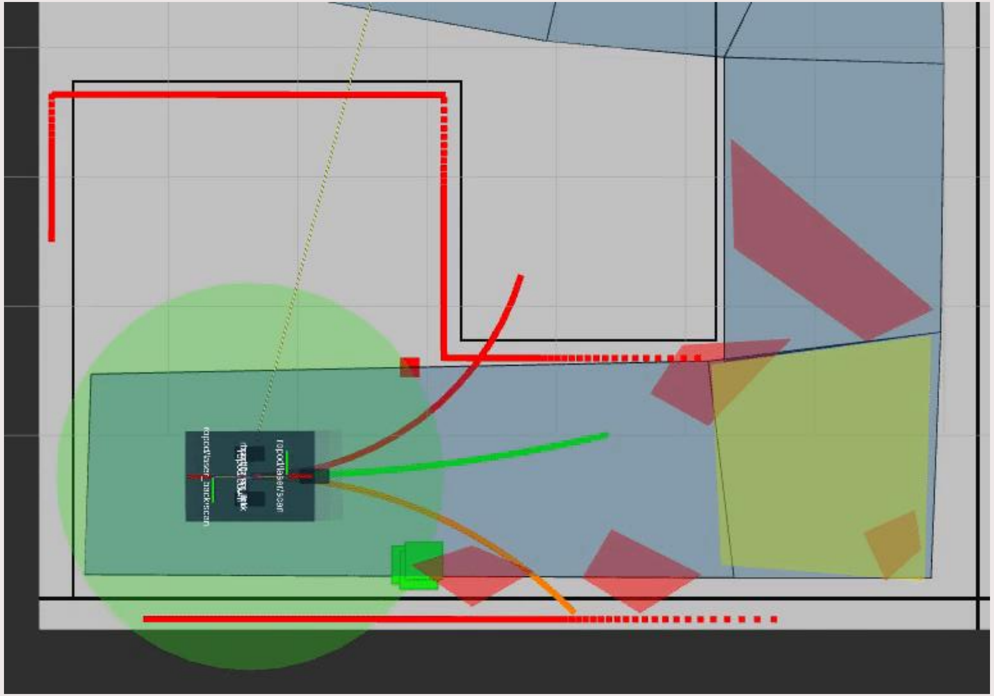


Semantic constraints





Simulation results



Conclusion

- The environment's geometry and semantics already provide cues on desired robot behavior and motions

- In practice multiple footprint and obstacle geometries can be handled without the numerical issues in non-linear optimization methods

- Actions can be linked to the specific parts of the environment and its context, making the algorithm explainable (also when it fails)

Future Research

- For now the center of the steering range is selected, which does not work well in too tight spaces. How to choose a better steering value?
- Expansion to multi-robot case. Can robots impose each other constraints to coordinate their actions?
- Failure prediction and efficient recover by using the context information

Thanks

Special thanks to all people that have contributed to these concepts:

Rinse Hobma

Melvin de Wildt

Hao Chen

Koen de Vos

Herman Bruyninckx

René van de Molengraft

Multiple Internship / Master's projects assignments

STARNUS TECH

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Interested?
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