KU LEUVEN

Path planning algorithm for semi-autonomous mobile robots with fast and accurate collision checking

Final Master's Thesis Presentation

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Introduction

Design of a Local Path Planner

Evaluation of the Developed Local Path Planner

Extension for Dynamic Obstacles

Socially Compliant Path Planning

Future Work and Conclusion

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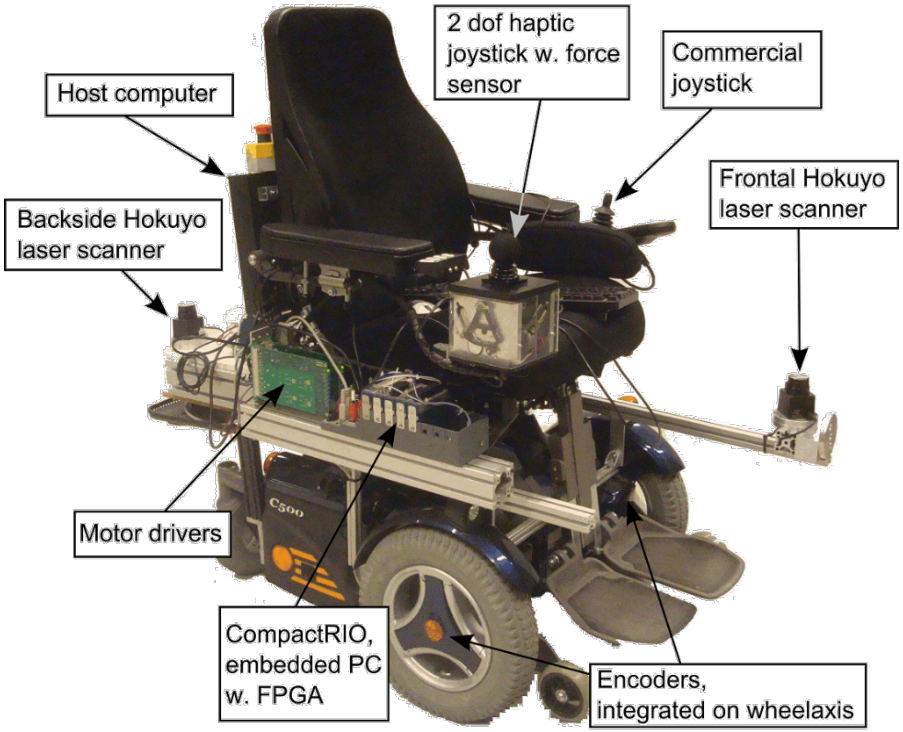
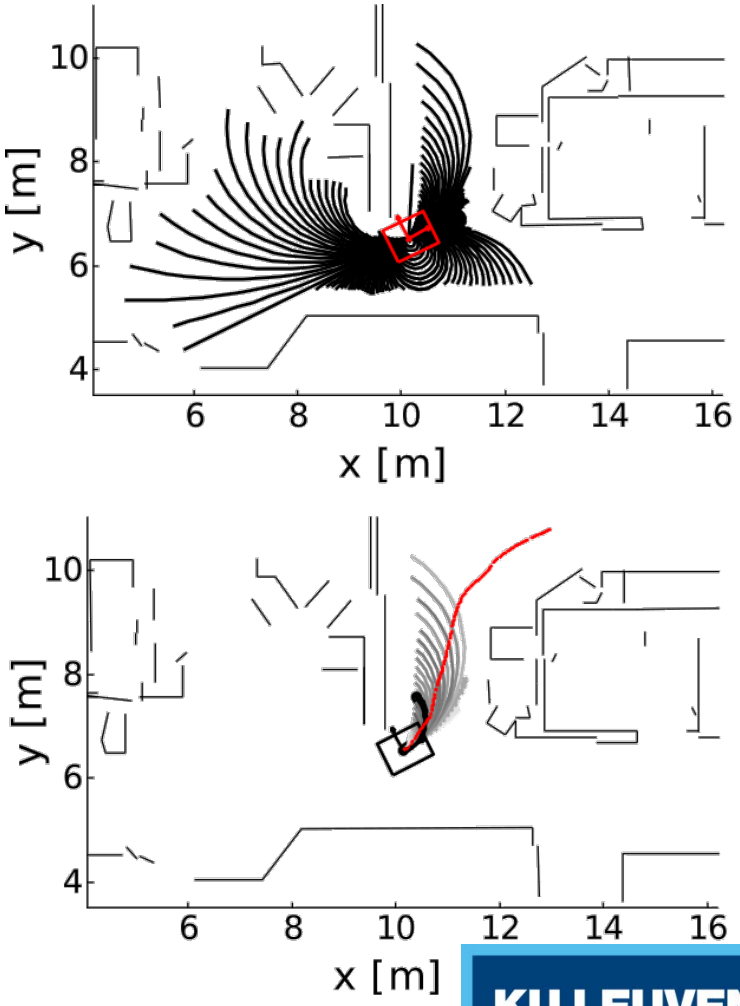
Introduction

Semi Autonomous Mobile Robot



(Local) Path Planning Algorithm



Circular Local Path Template

Currently used local path planner

Fixed set of feasible **paths**, from the **current pose** of the robot.

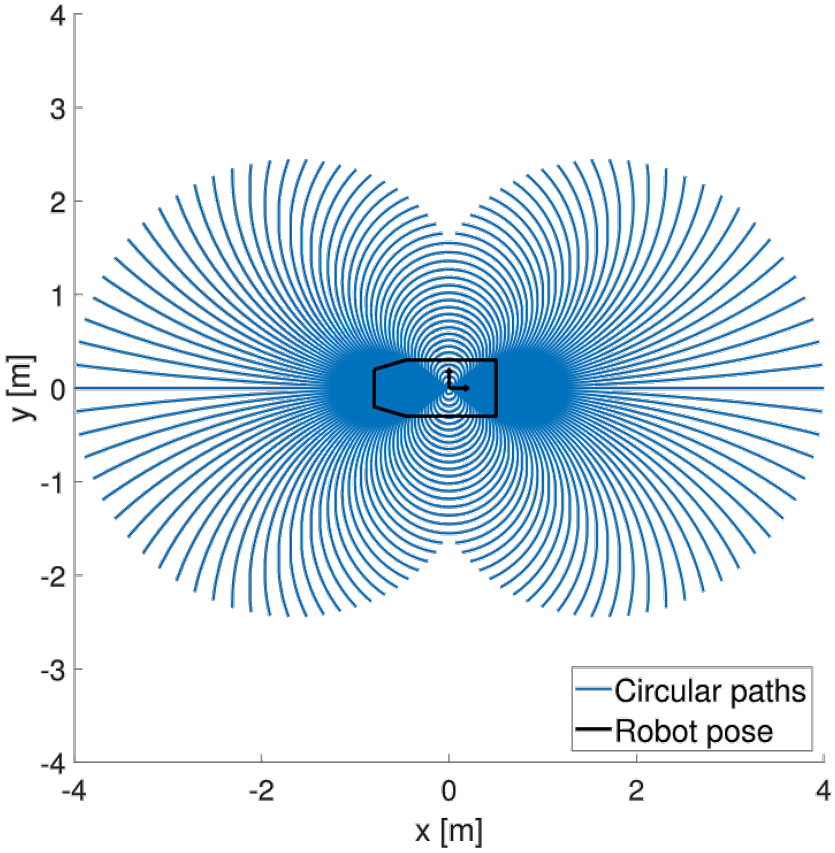
Integrating achievable v, ω pairs, resulting in **circular trajectories**.

Advantage

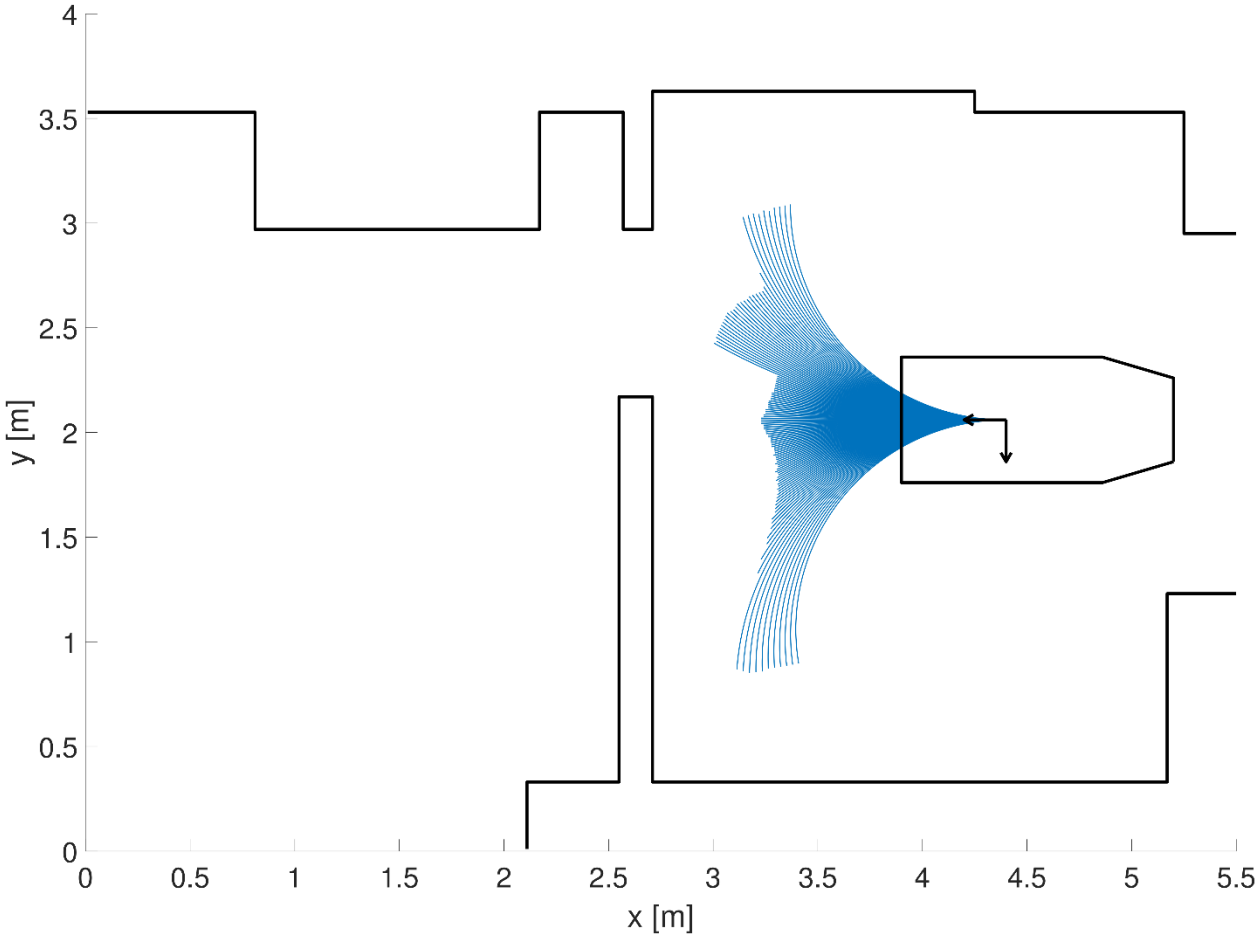
- Space the robot will take is known
- **Lookup table** for path length adjustment
- Obtain quickly **collision-free paths**

Disadvantage

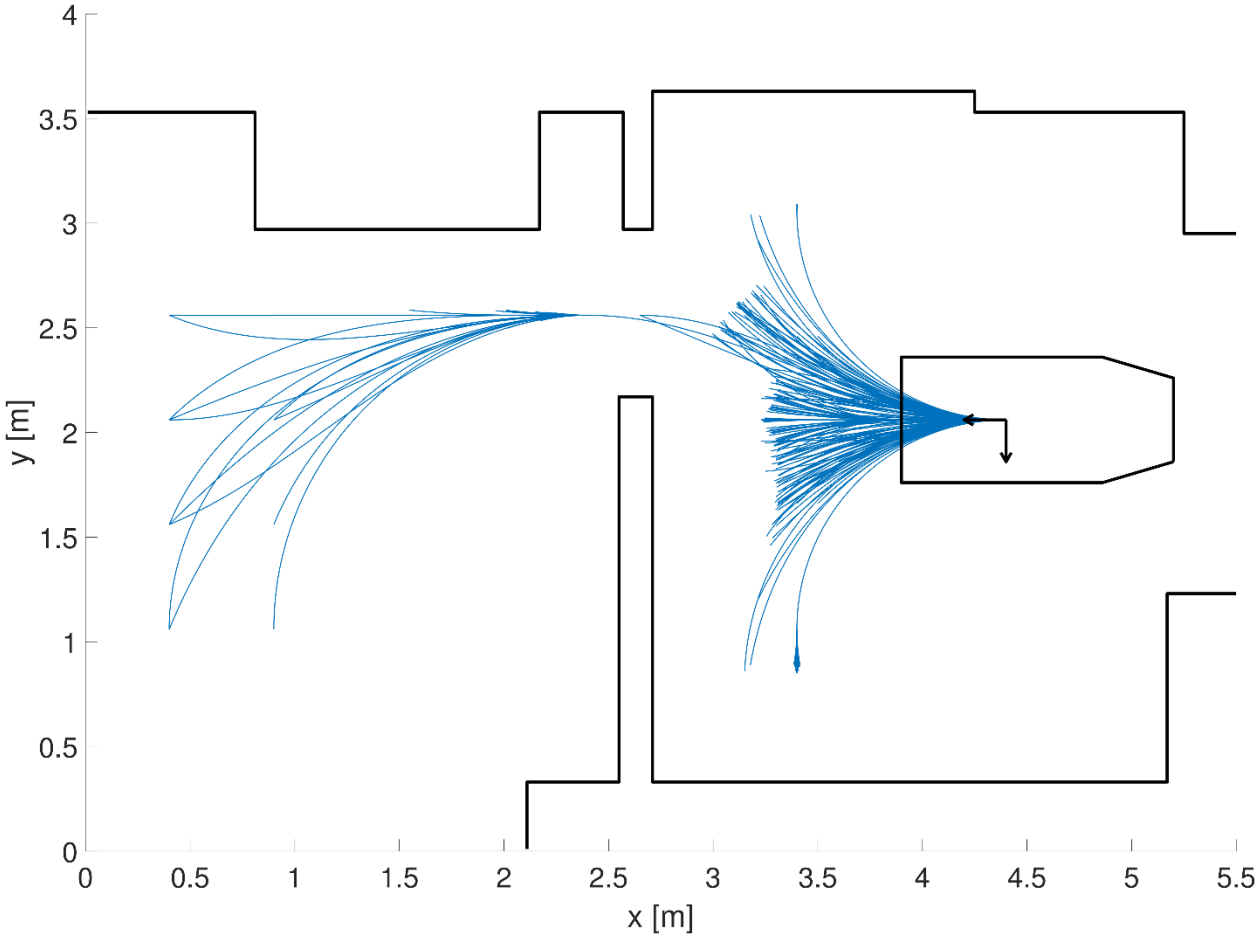
- Only **subset** of achievable trajectories



Circular Local Path Template



Clothoidal Local Path Template



Scope and Contribution

Expand the set of feasible motions by using a **more complex curve geometry**, offering better assistance to the user.

Conceptual solution taking **dynamic obstacles** into account, by finding an optimal speed profile for each path.

Guidelines to obtain a **socially compliant path planner** and explicitly takes into account **the cooperation of surrounding persons**.

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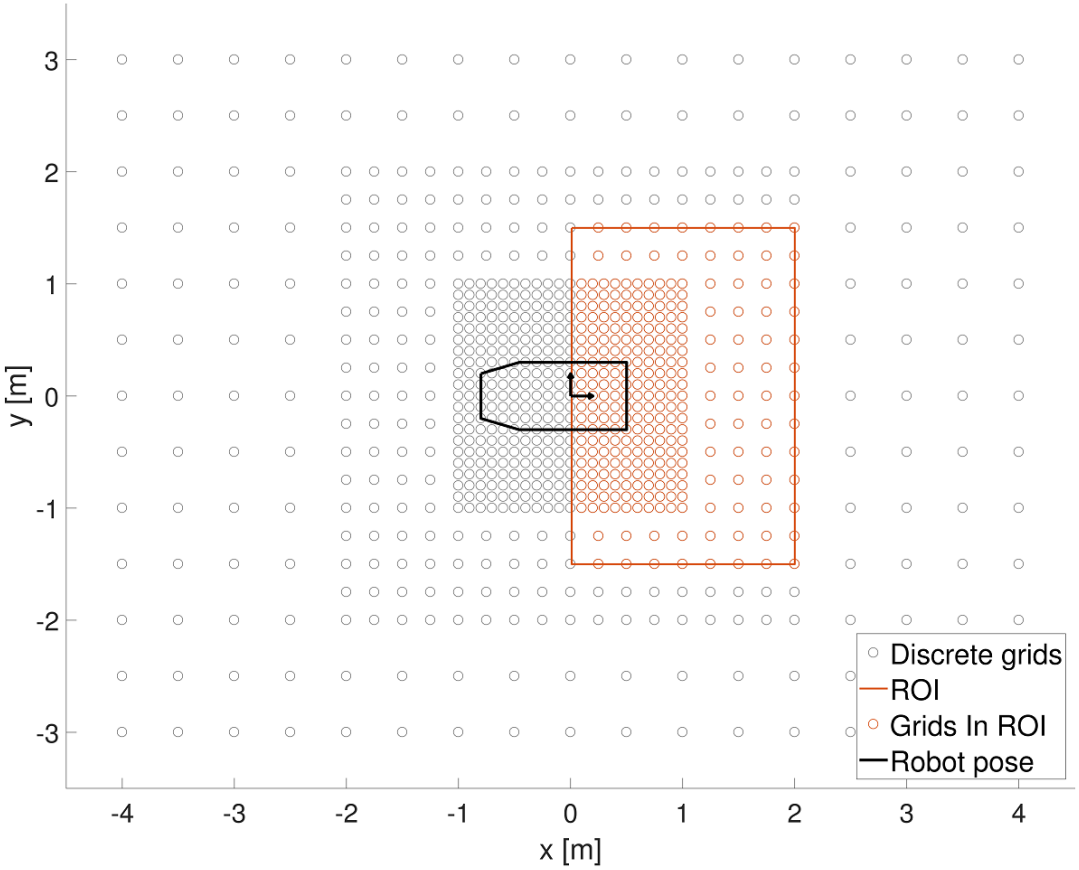
Multi-Size Grid and Region Of Interest

Sampling the reachable space surrounding the robot.

3 different sample **sizes**, dependent on the **distance to the origin**.

Goal: **limit the numbers of paths** leading to a relatively similar end pose.

Region Of Interest defines the **grid cells which will be connected** with the selected geometrical curve.

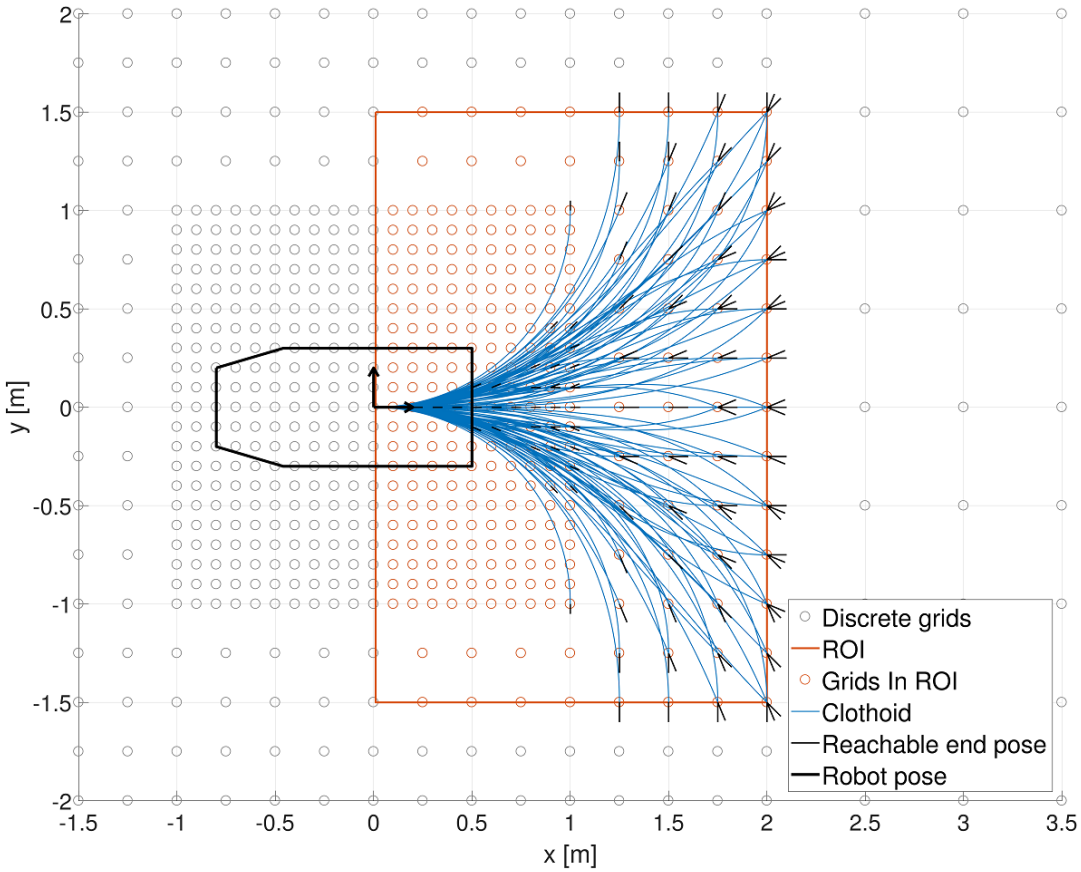


Selected curve geometry: clothoid

Each grid in ROI is connected with the origin with a certain end-pose using a **kinematically feasible clothoid** (non-holonomic constraints and $\kappa < \kappa_{max}$).

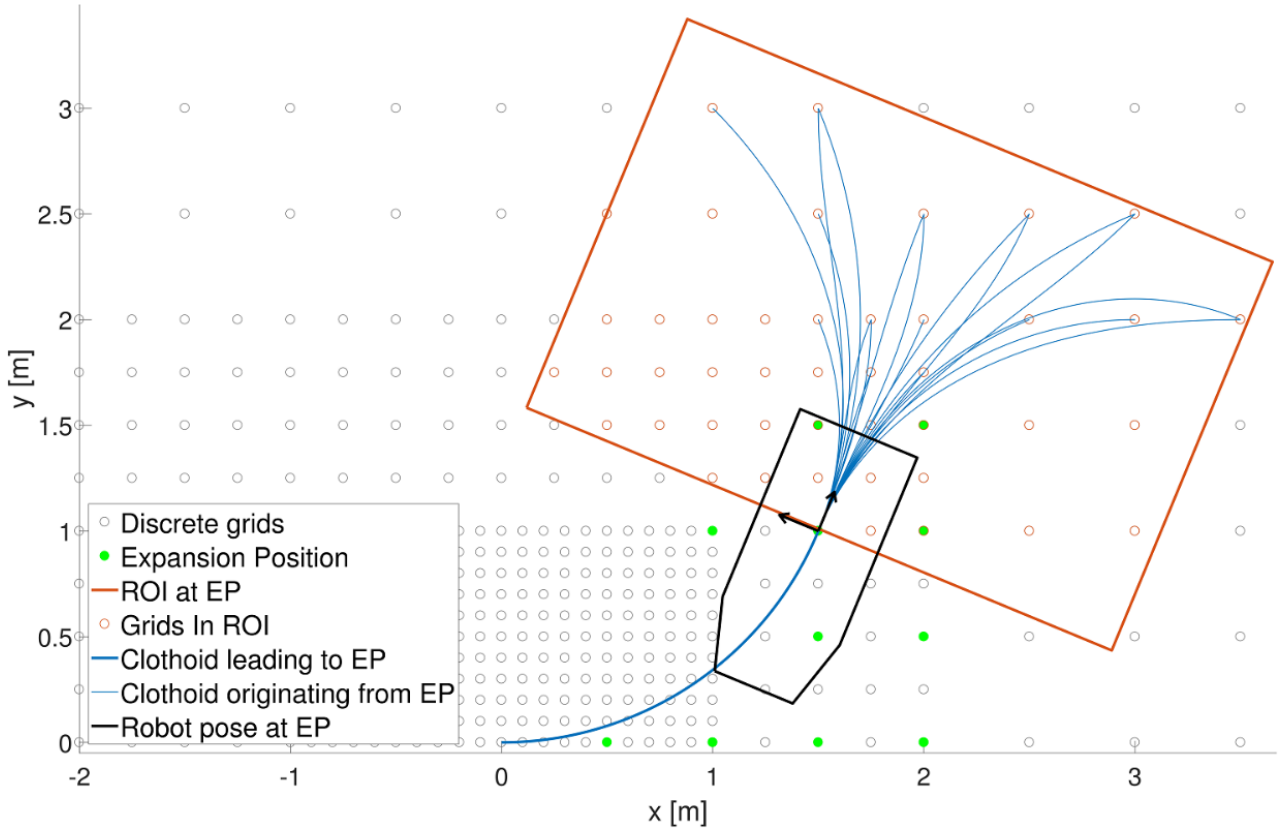
Why the clothoid?

- **Curvature changes linearly** w.r.t. the arc length
- More **flexible formulation** compared to circular arc
- "Ideal" characteristic, when driving at constant speed, the **wheel velocity** (=actuator) only has to **change linearly**.

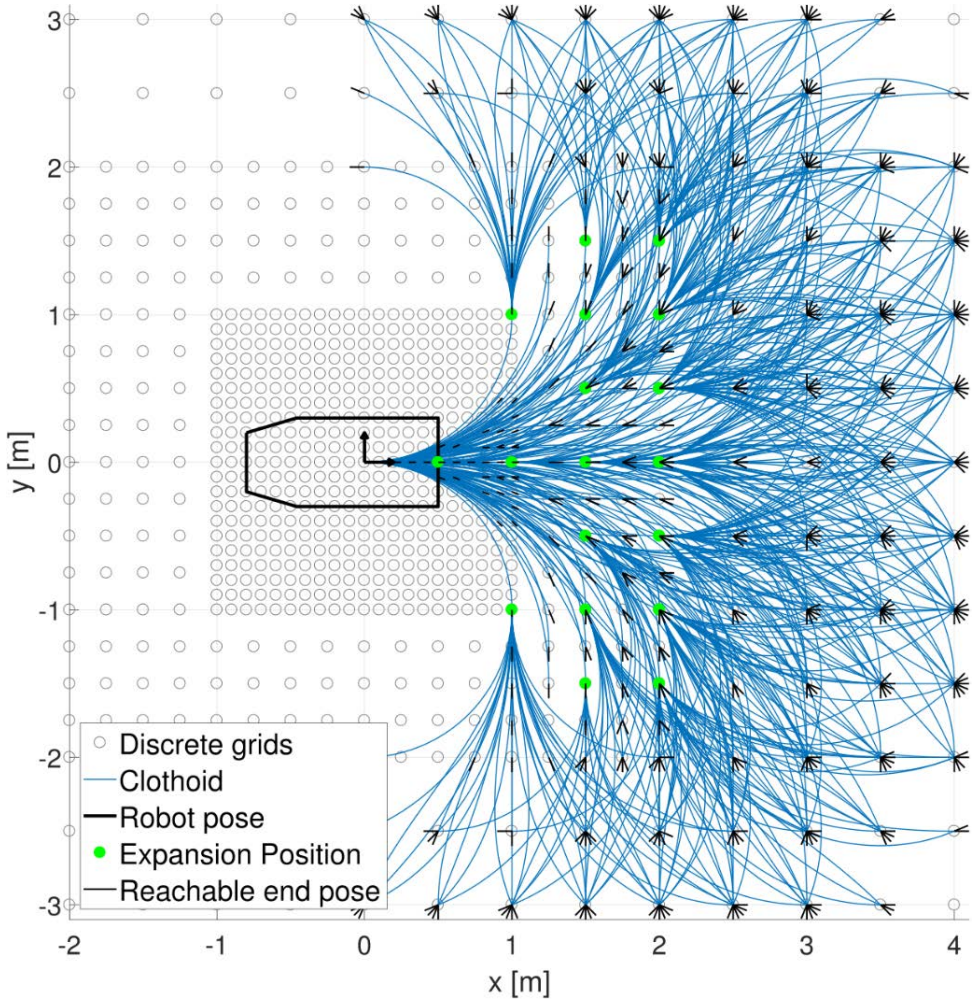


Expansion Positions

Larger variety of local paths obtained by repeating previous steps at different Expansion Positions.



Fixed set of trajectories based on Clothoids



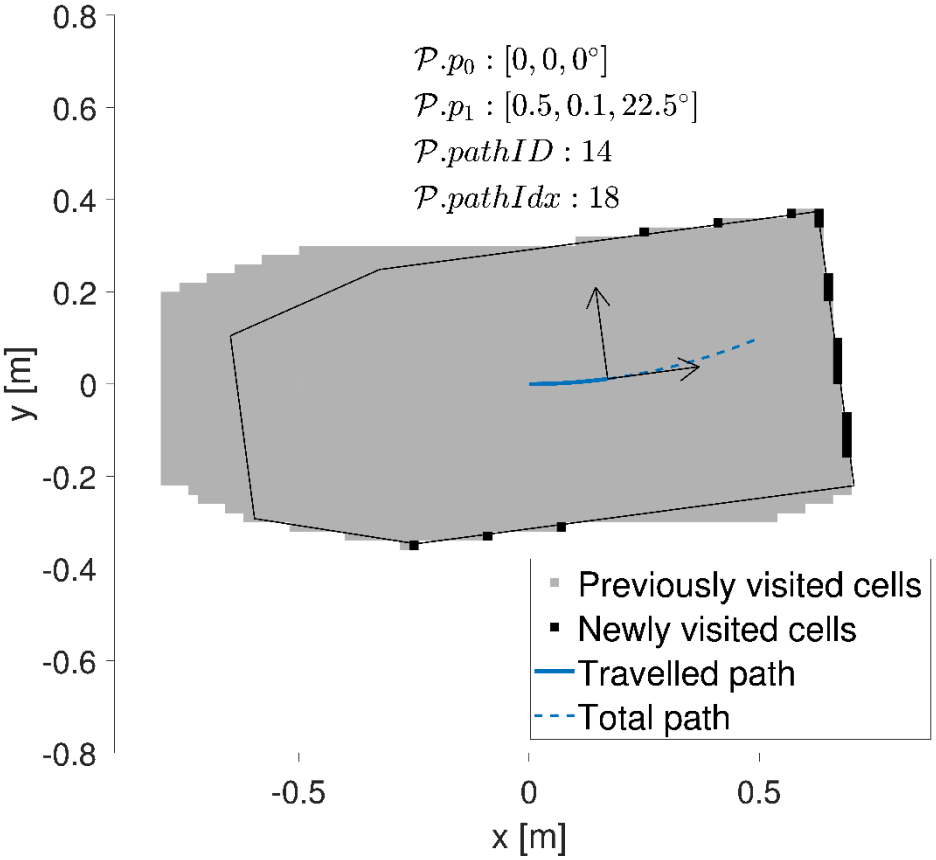
Precomputed lookup table for fast collision checking

Precompute space the wheelchair occupies when taking each path.

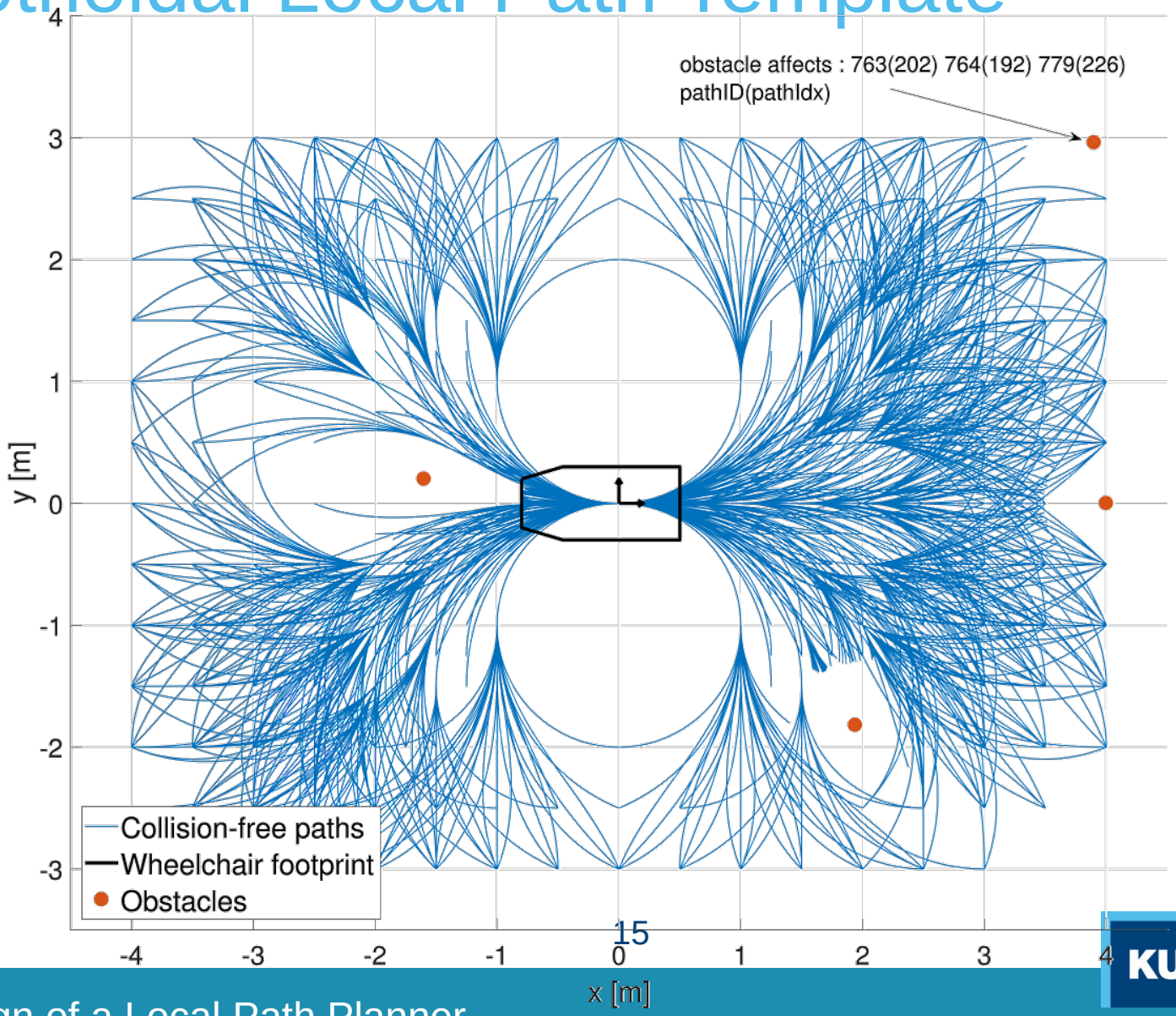
Structure **lookup table optimized**, each occupied cell contains:

- Which path the robot took when going trough it
- Its corresponding path length

Online phase:
Matching the occupied grid cells in the environment with cells from the **lookup table**



Clothoidal Local Path Template



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Path Planning Performance

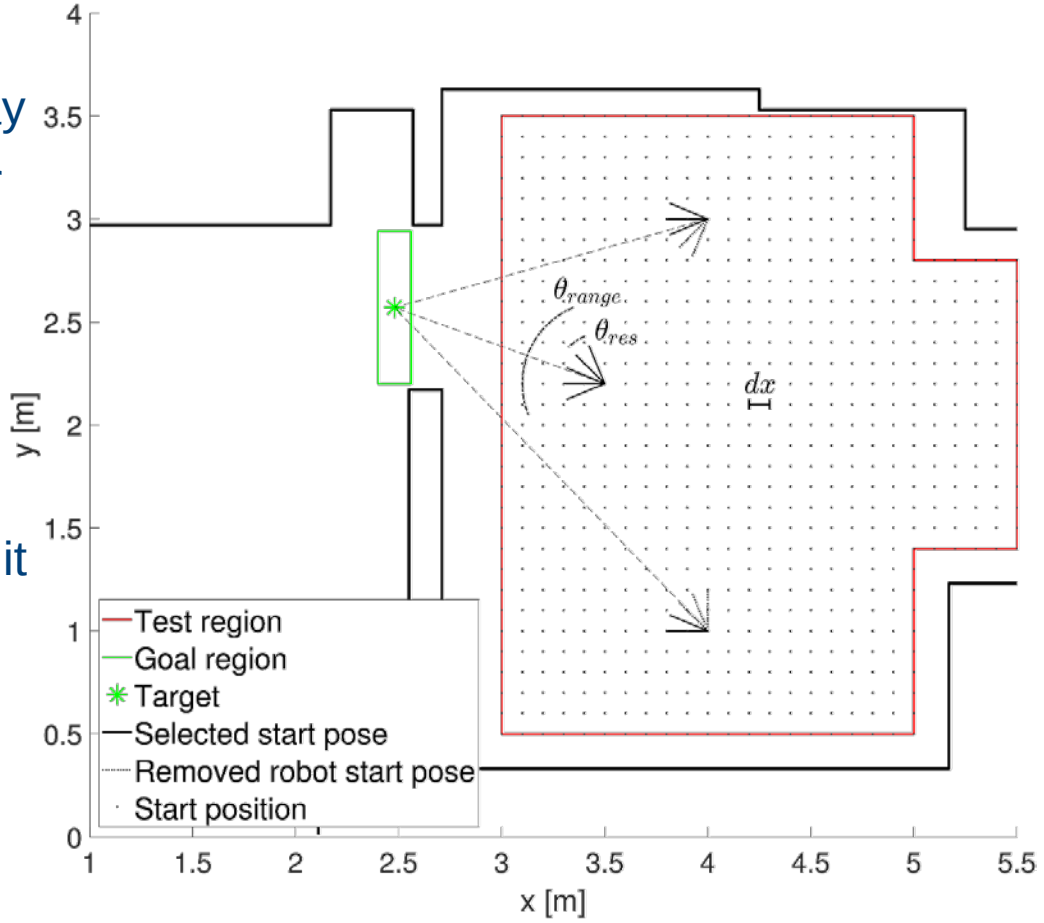
Two scenario's :

- Forward driving trough a doorway
- Backwards driving in an elevator

A uniformly distributed set of start poses is created.

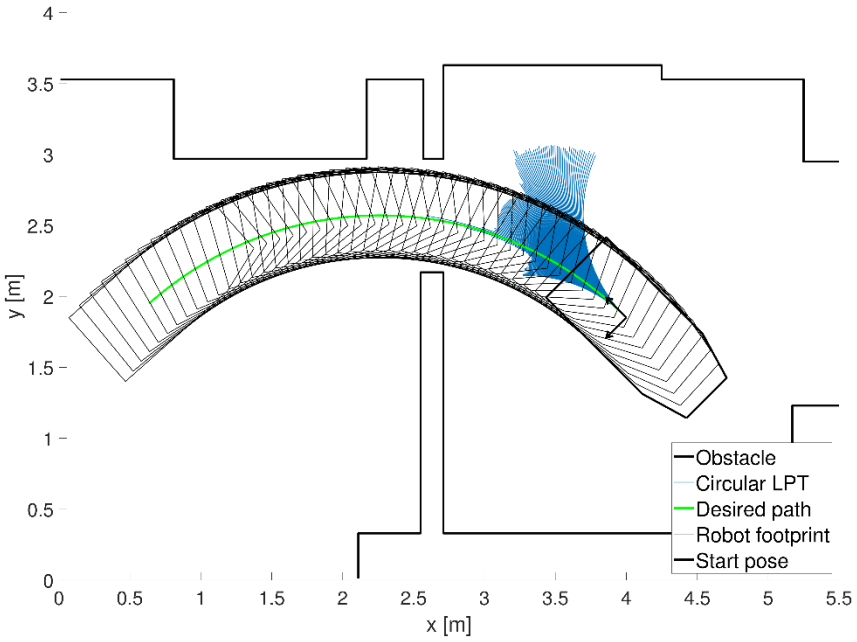
Each LPT is positioned on the different start poses. **Successful** if it achieves to plan a path trough the **goal region**.

3 Cases : only circular, both and only clothoidal.

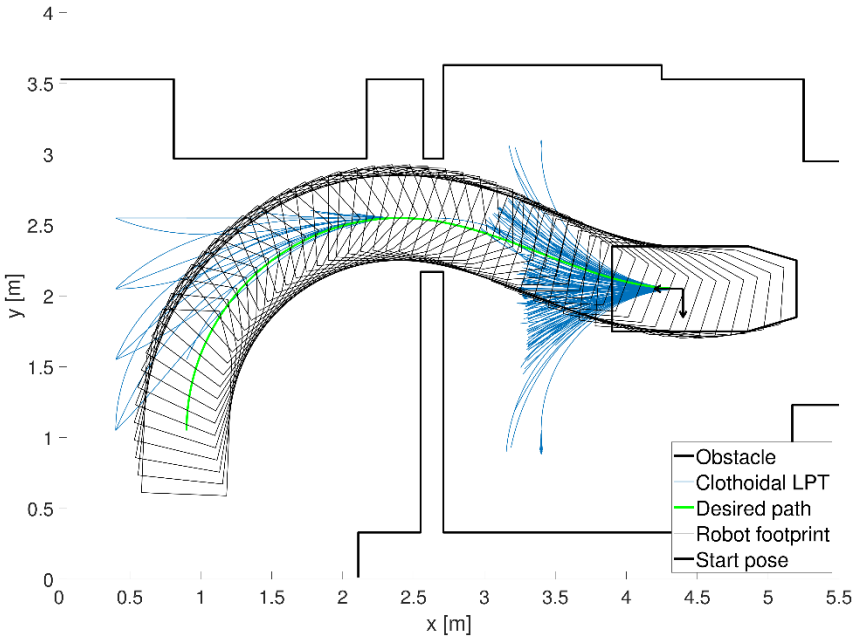


Path Planning Performance

Successful circular LPT



Successful clothoidal LPT



Path Planning Performances

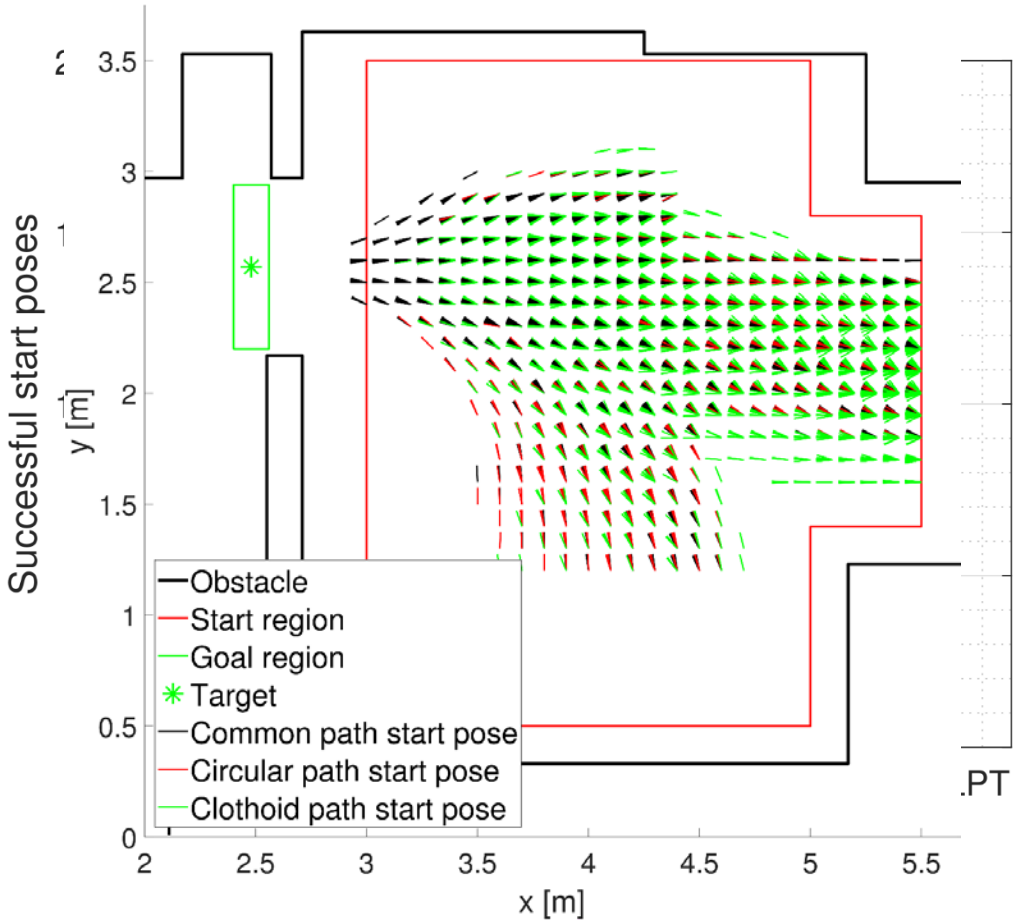
Common start poses in front of the goal

Lower end favours the circular LPT

From the moment a more complex path is needed, only the clothoidal LPT is successful

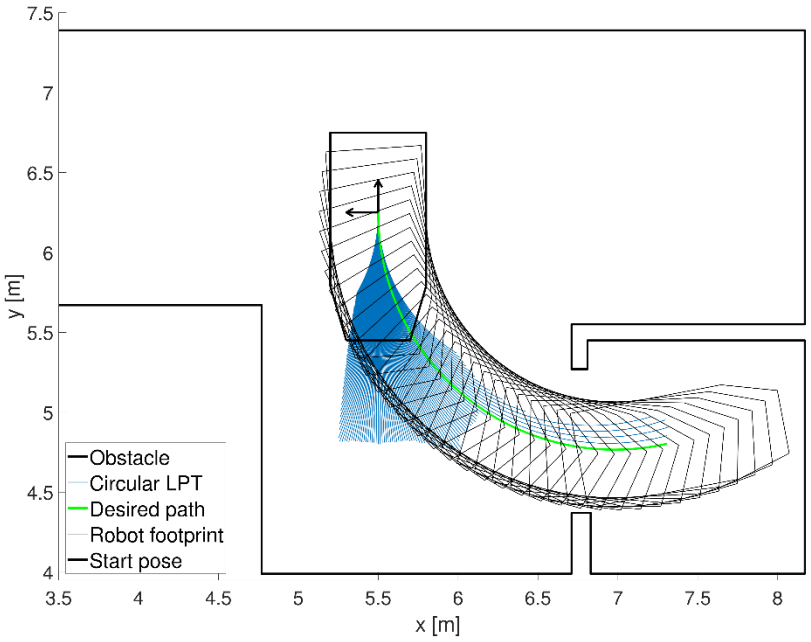
Clothoidal LPT: 87% successful

Circular LPT: 60% successful

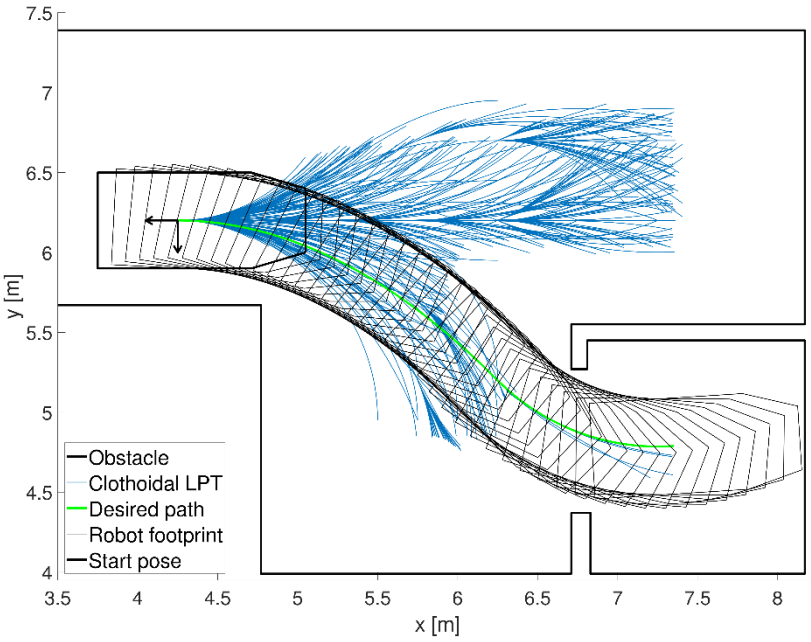


Path Planning Performances

Successful circular LPT



Successful clothoidal LPT



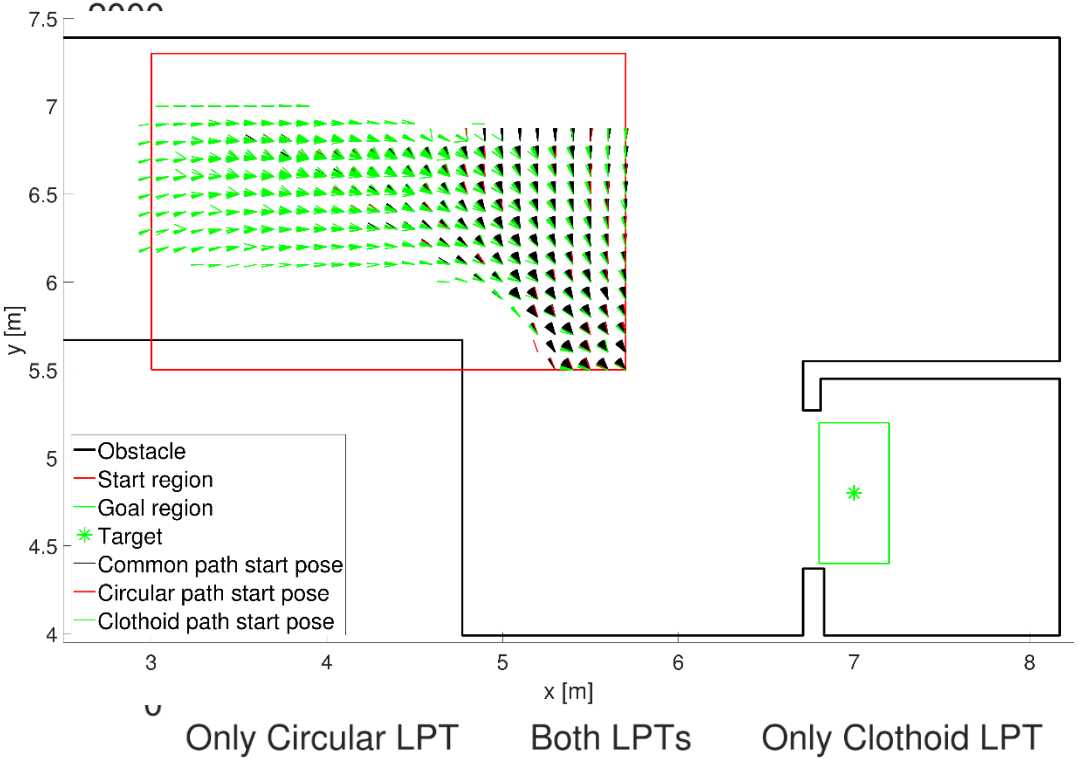
Path Planning Performances

The only LPT able to plan a path from the corridor is the clothoidal LPT.

Clothoidal LPT: 98% successful

Circular LPT: 44% successful

Better assistance to the wheelchair user



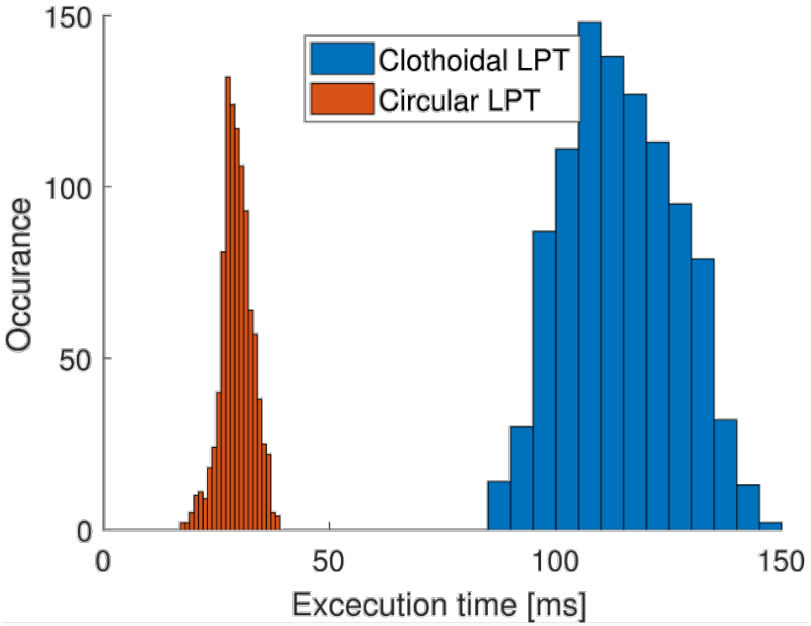
Time Performances

The clothoidal LPT has **6x more paths** compared to the circular LPT.

Executing time to adjust each path of the LPT in an environment as shown in the planning performances.

Price: **4x longer execution time** (30ms vs 120ms)

Simulations performed in MATLAB, faster execution times are expected.



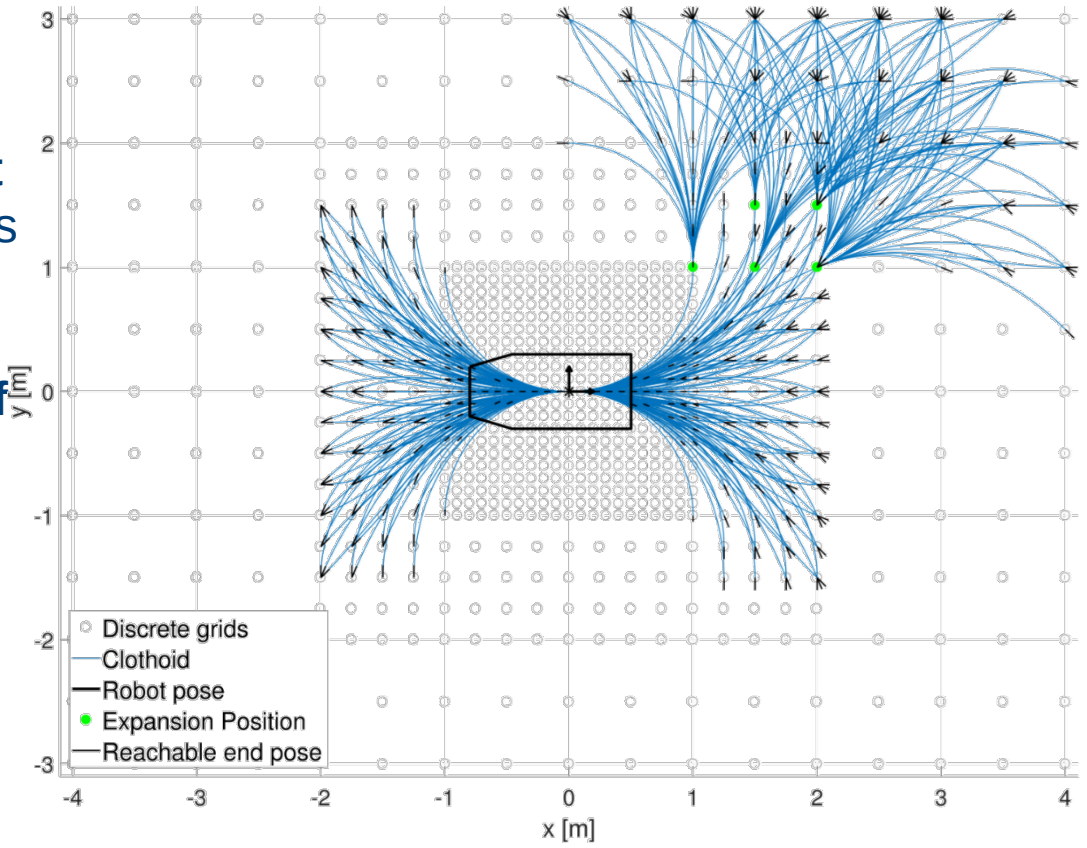
Improvements reducing execution time

Using an **asymmetrical LPT**:

Location of the Expansion Positions could be **dependant** on the **direction** the **user** wants to take.

This will **reduce the amount of paths** by 2/3.

Other possible improvement, **decide online** where to put the Expansion Positions



Previous user intention: going **straight** while **turning to the left**

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Extension for Dynamic Obstacles

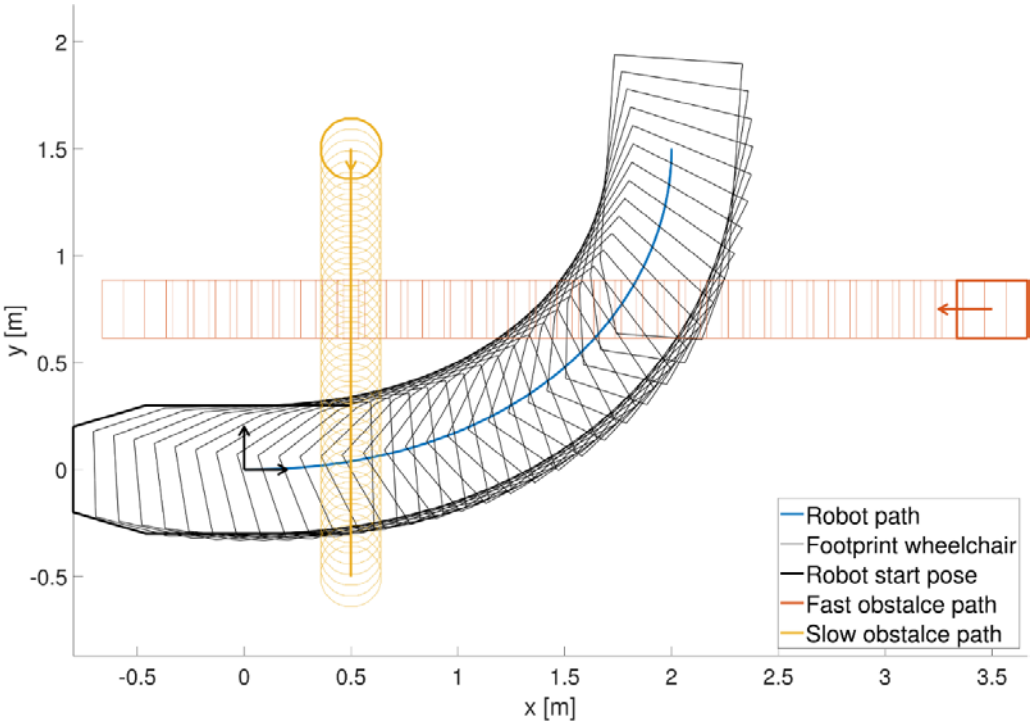
Requirements:

- **Shape** obstacle
- **Motion model** obstacle

While using a **fixed path** from the LPT, an **optimal velocity profile** is calculated for a **collision-free motion for the robot**

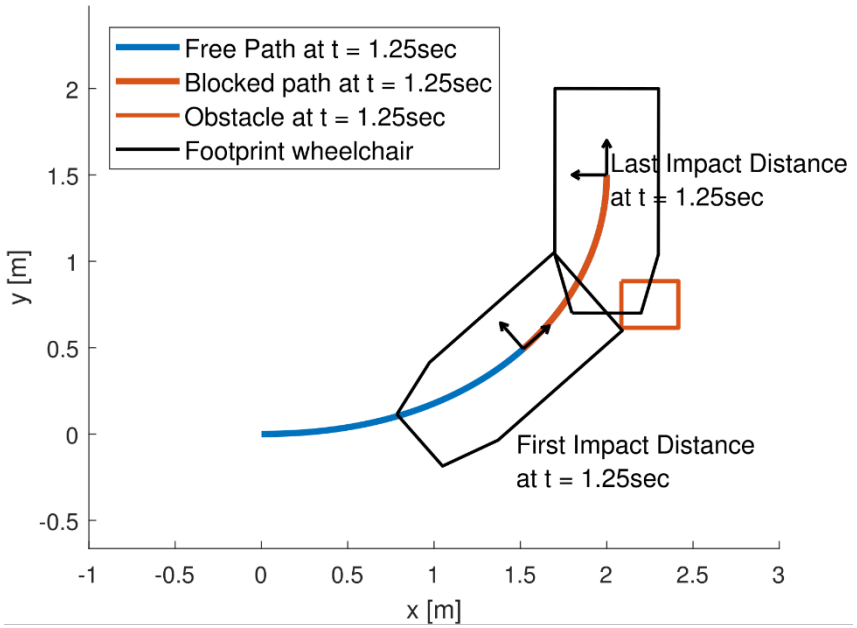
Takes both **kinematic** and **dynamic constraints** into account.

Search is performed in an efficient search space, the **distance-time collision space**.

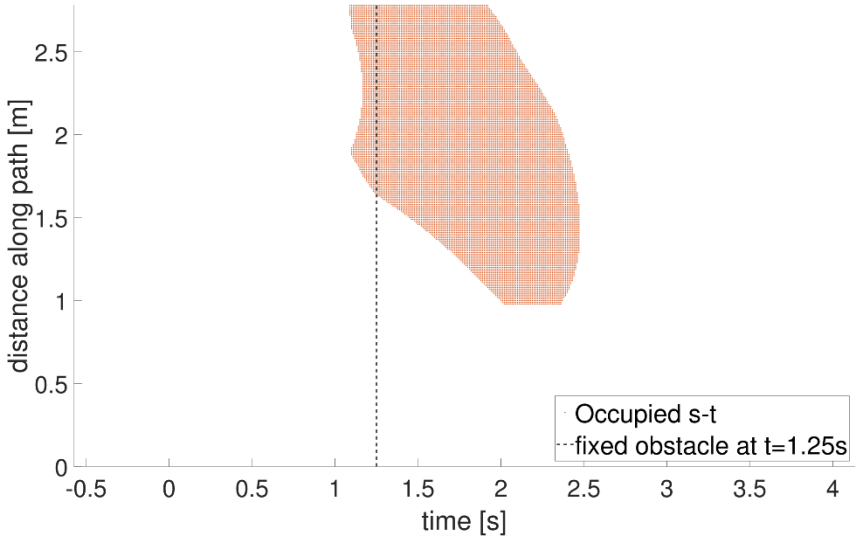


Distance-time collision space

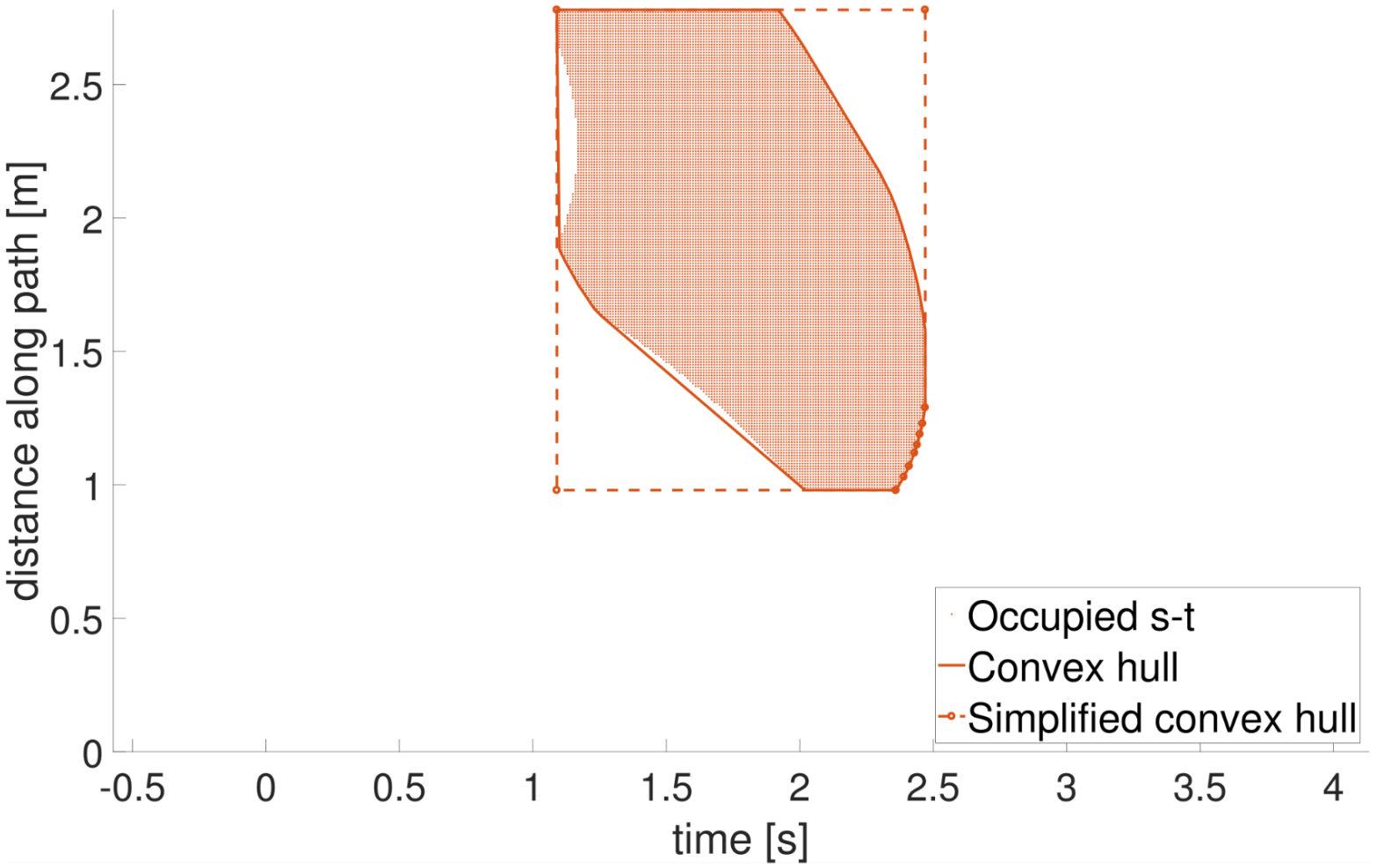
Situation at 1.25 sec



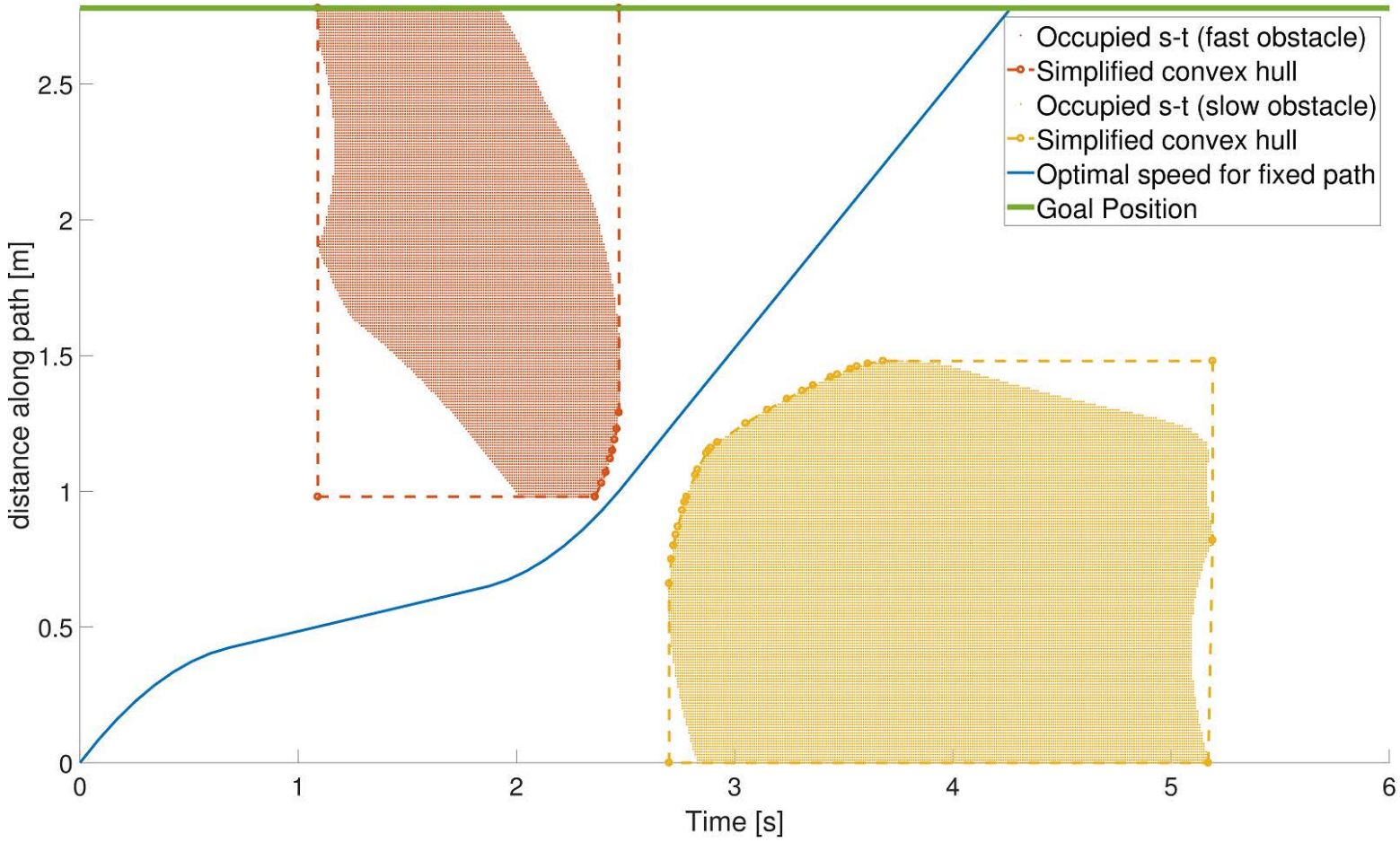
s-t collision grid space



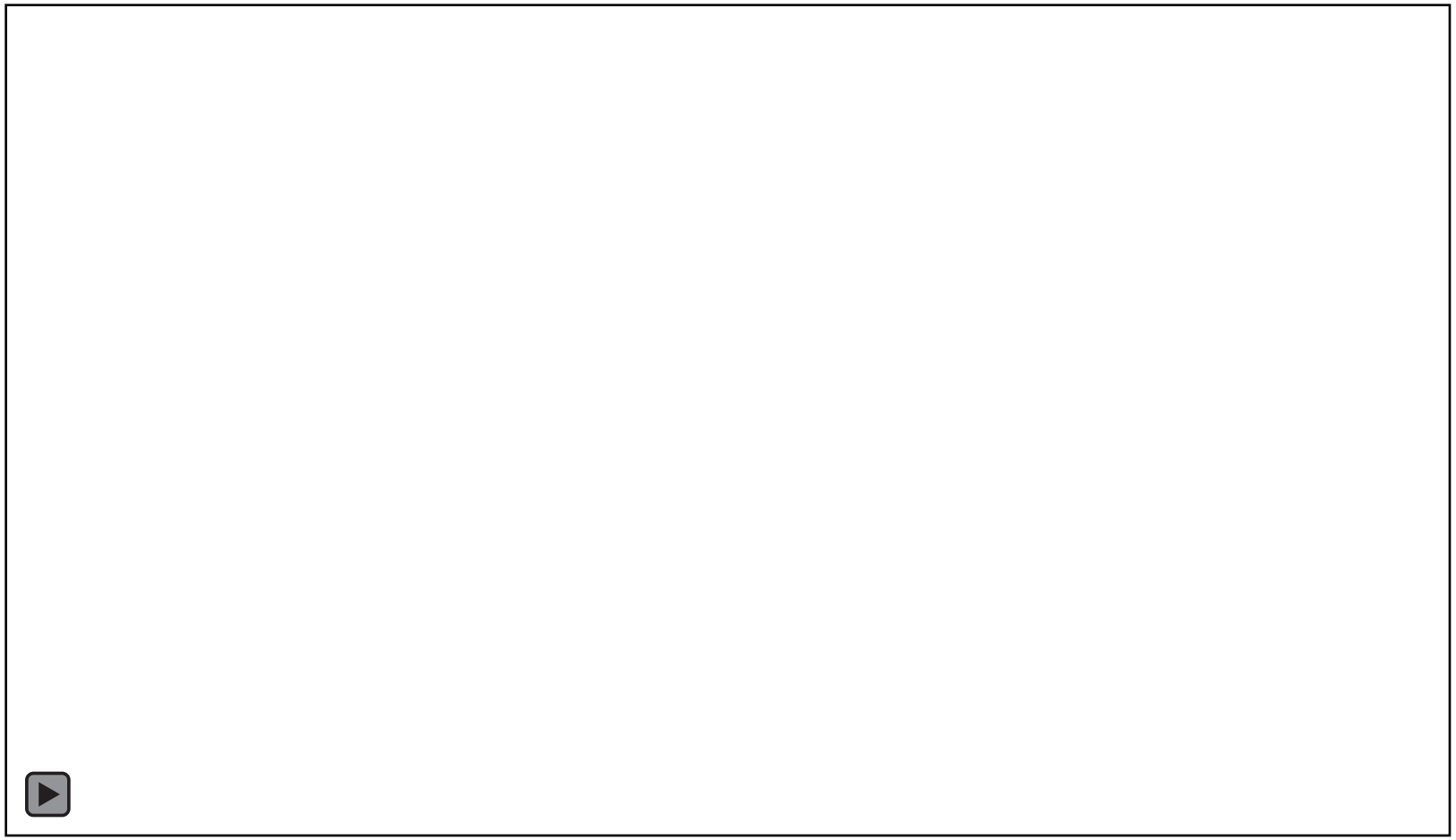
Distance-time collision space



Optimal Velocity Profile for fixed path

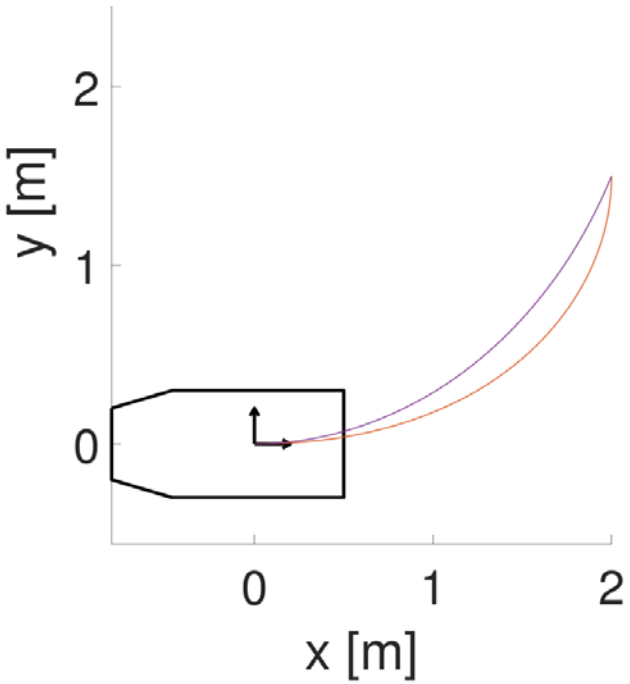


Optimal Velocity Profile for fixed path

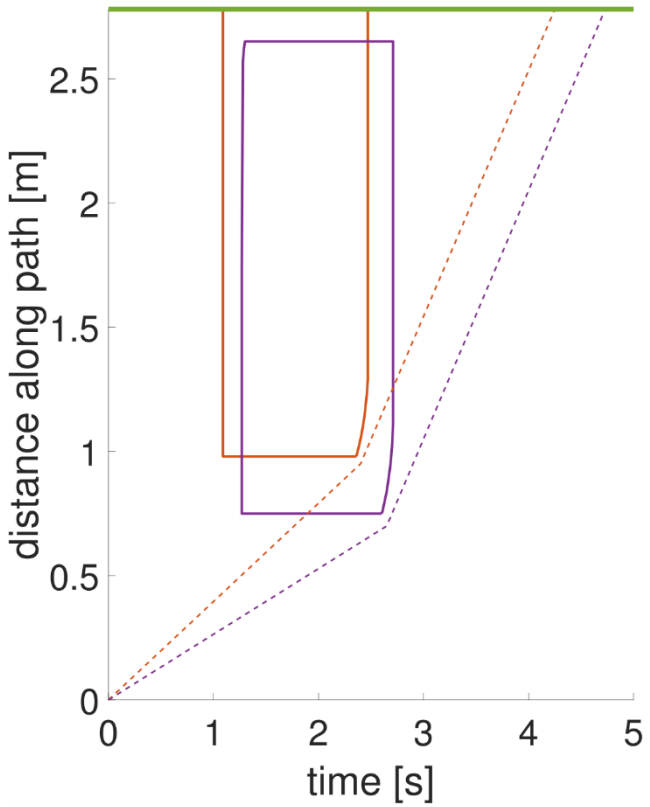


Improve calculation time

Relatively similar paths



Relatively similar solution



Grid search function with replanning capability : D* or Incremental Phi*

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Human-Aware Robot Navigation

Combines the field of human-robot interaction and robot motion planning.

Fields of research according to the survey by Kruse et Al. :

Comfort: safety, avoiding stress, annoyance

Naturalness: jerkless motion, legible

Sociability: cultural conventions, other social protocols

Dynamic Personal Space

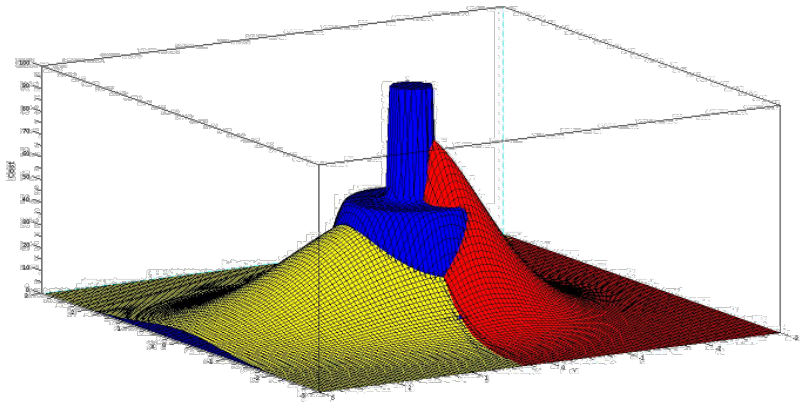
Path planner can inherently take into account the "social cost" of a particular path.

Similar to the user's intention ⇔ caused discomfort

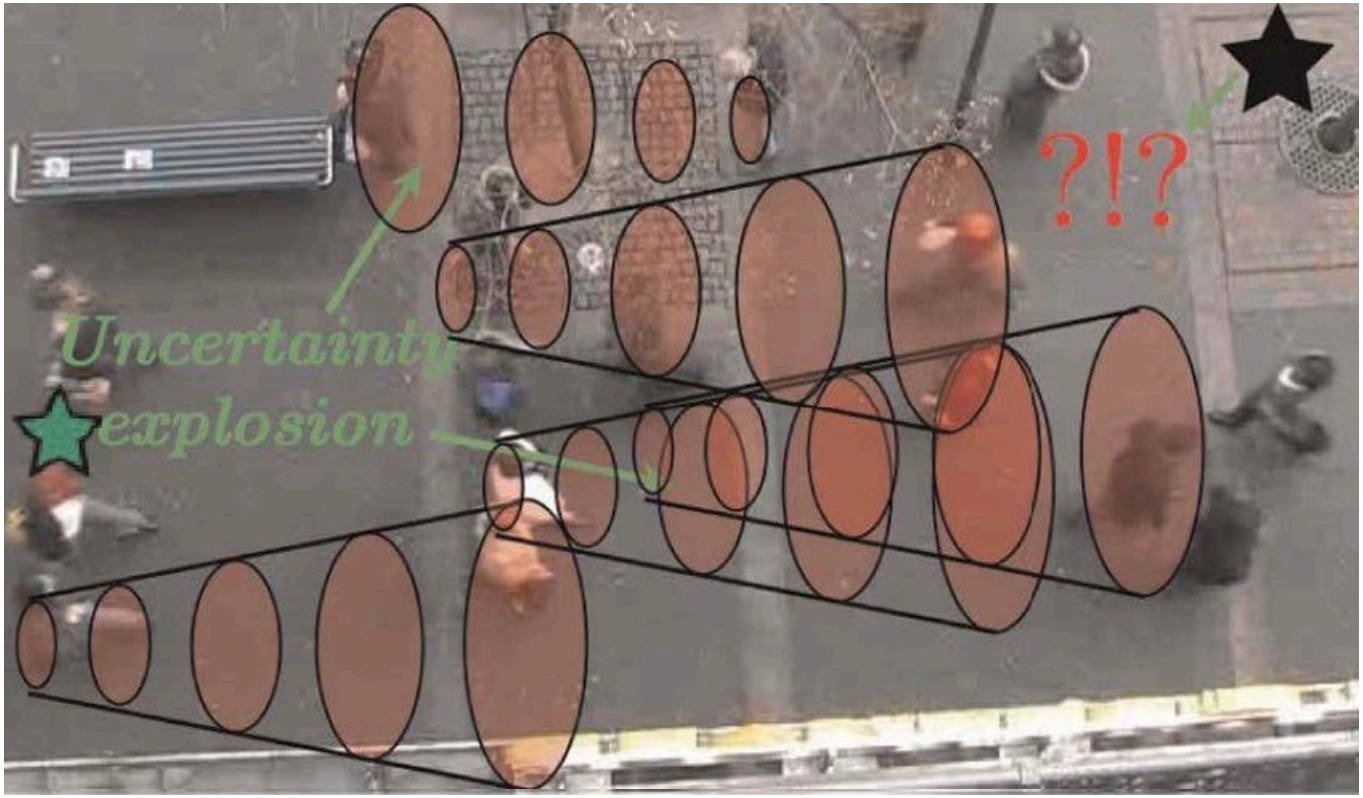
Cost map reflecting **dynamic personal space** developed by Scandolo and Fraichard.

Starting point of this model: the **proxemics** rules studied by Edward T. Hall (1966) → blue area

Additions to reflect the influence of movement:
Red area (orientation dependent, "**back space**")
Yellow area (speed and orientation dependent, "**Personal Space during Motion**")



Human-Robot Cooperation Model



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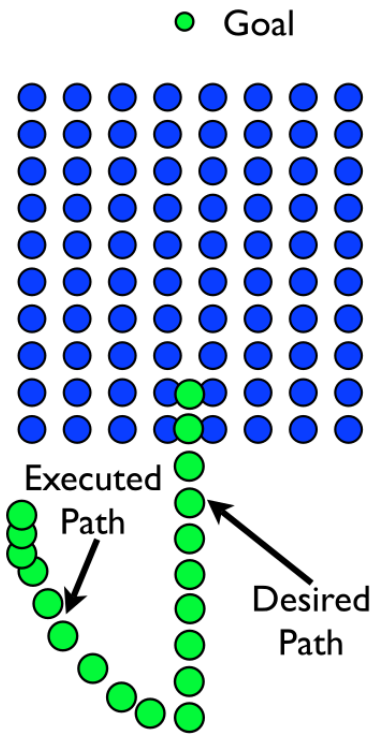

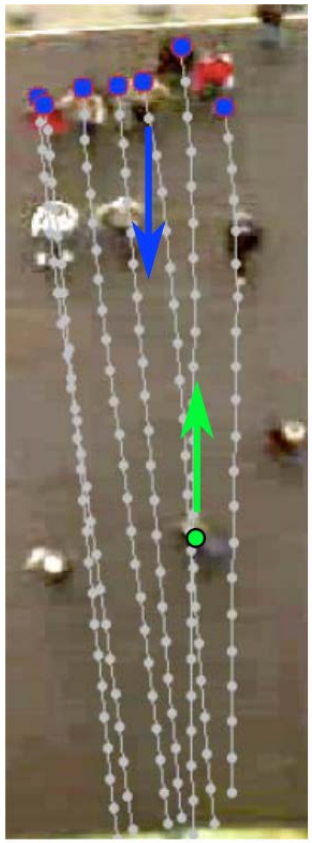

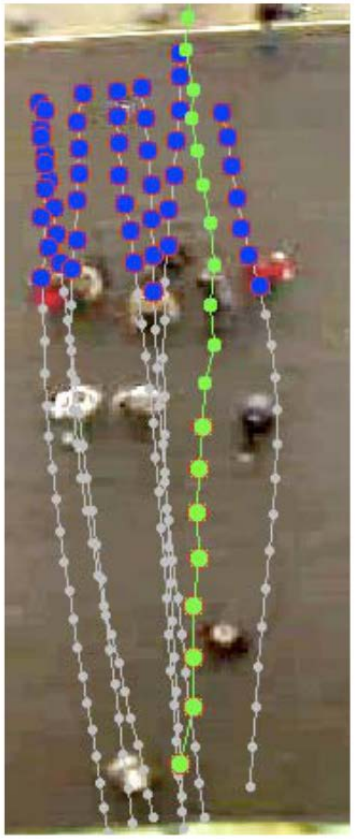

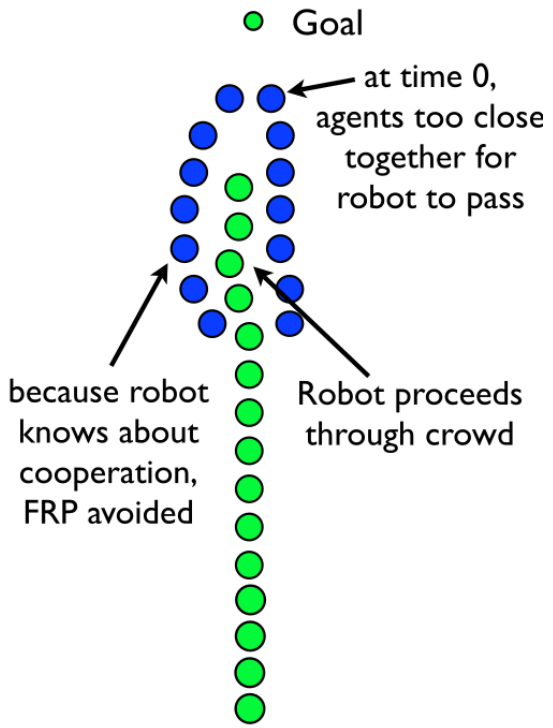

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Future Work

Better placement of the Expansion Position will reduce the computational time needed to adjust each path length.

Faster dynamic motion planner by using a grid search planner.

Implementation of human-aware navigation.

Conclusion

Expanded the current planner based on circular arcs with a **more flexible curve** geometry based on clothoids.

This improvement on path **planning performance** comes with a **cost**, the **time** needed to adapt each path length.

Conceptual solution **taking into account moving obstacle** by calculating a **collision-free speed profile** for a fixed path.

End of the presentation

Thank you for your kind attention