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Obstacle Avoidance Framework Based on Reach Sets

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Introduction

Problem statement: Given a UAV equipped with a LiDAR sensor, capable of following a low altitude sequence of waypoints over a previously mapped terrain derive a control strategy that will enable the UAV to follow the sequence of waypoints while avoiding obstacles not present in the given map

Challenges:

- How to design modules ?
- Any Control interface idea ?
- How to make decisions ?

Results:

- Simple scenario simulation

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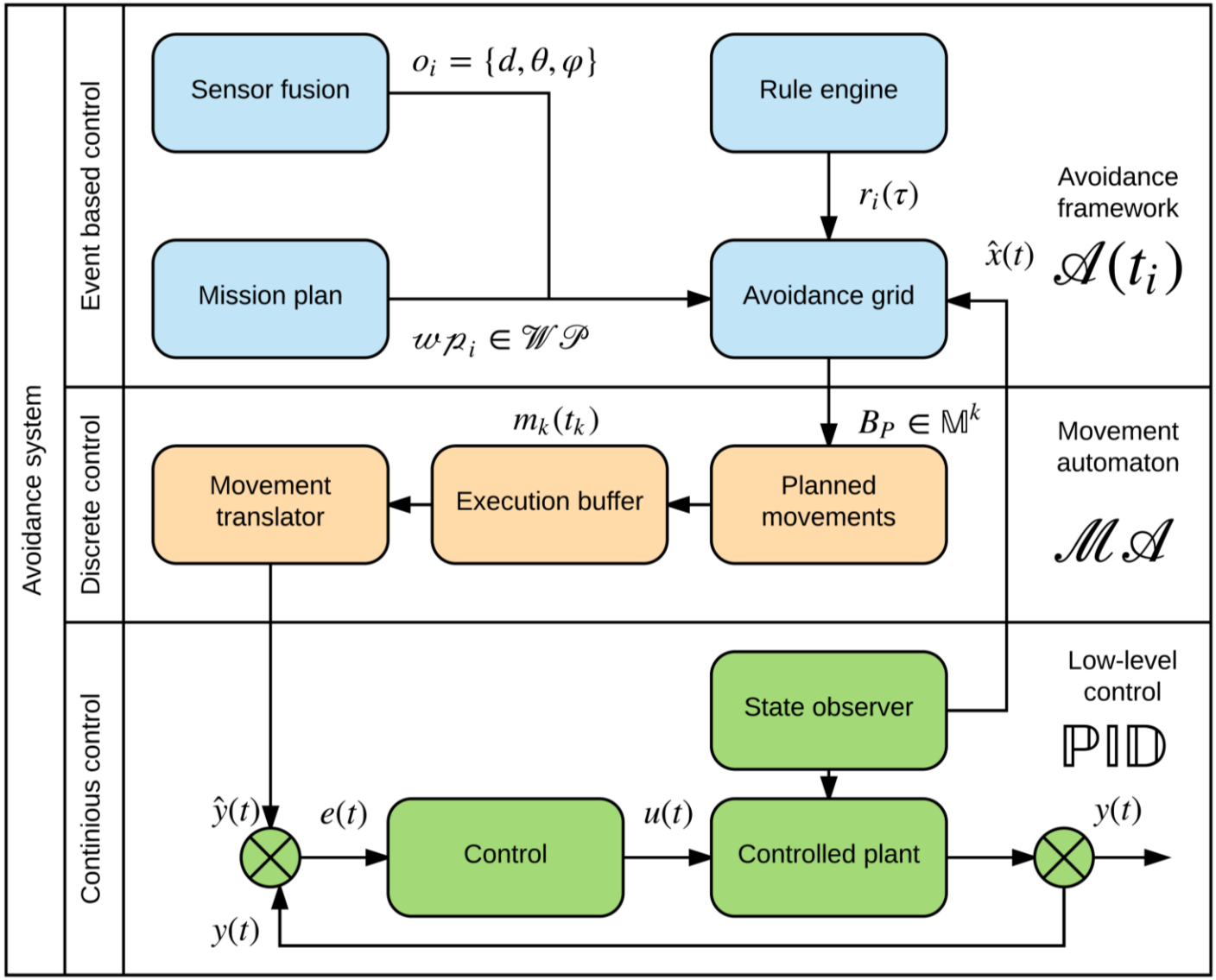
Avoidance Framework



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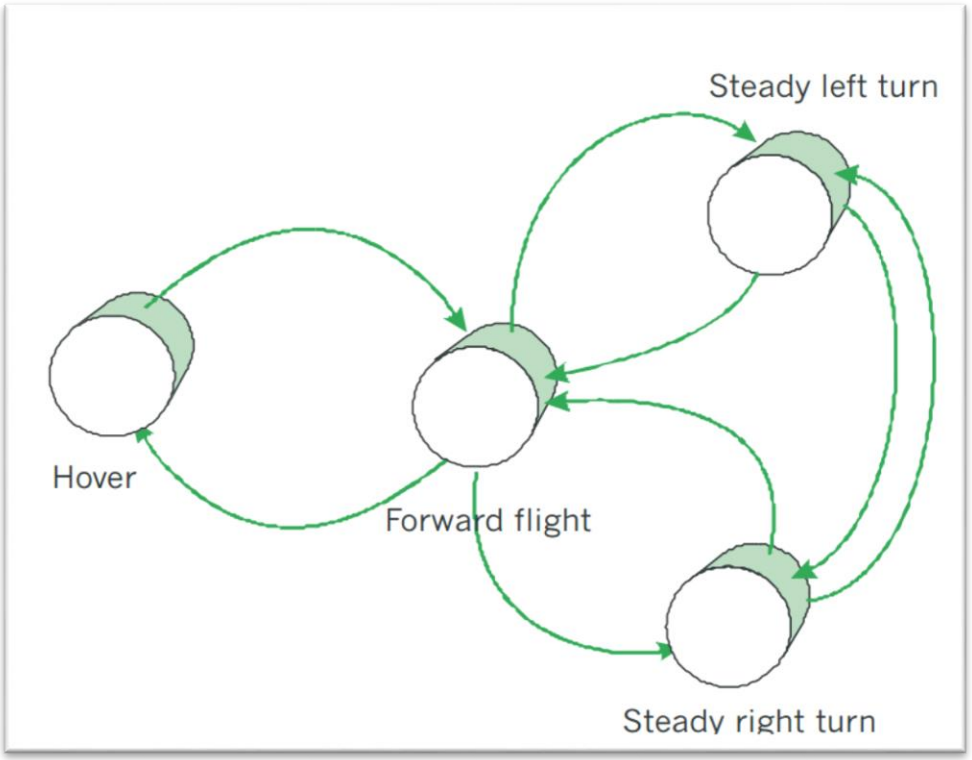
Movement Automaton - Control Interface

Decouple:

- Optimal control problem
- Navigation problem

Movement automaton:

- Open hybrid automaton
- Finite set of movements
- For Simulation/control



Discrete chain of commands: hover(20s), left(10s),fly(12s)

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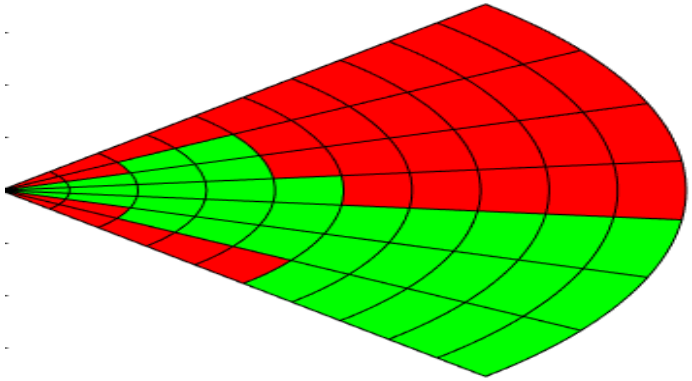
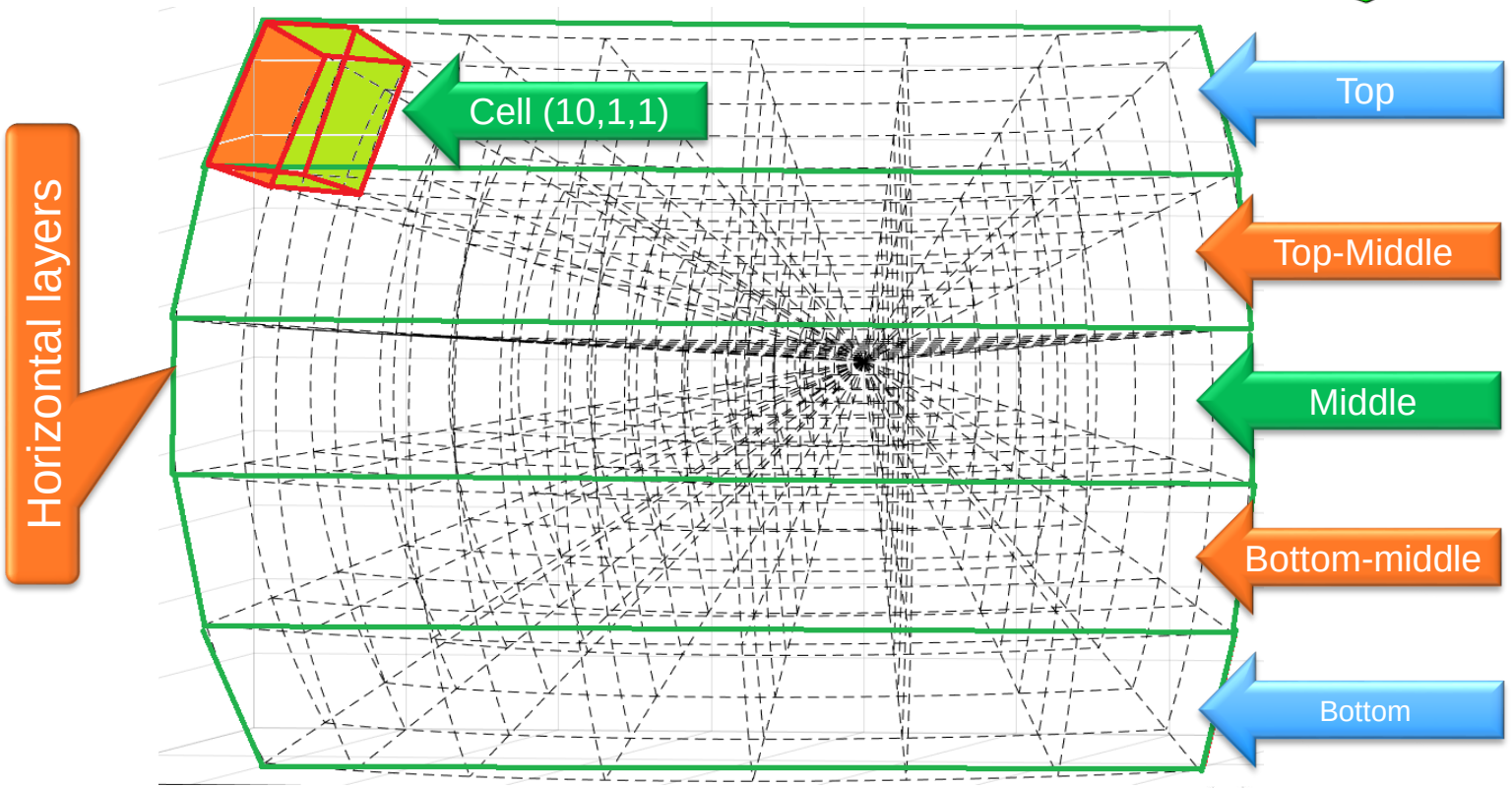
Avoidance Grid – Space Segmentation



Planar grid segmentation:

- Cone reflecting effective decision range
- Cell range defined by movement set
- Cells increasing size with distance



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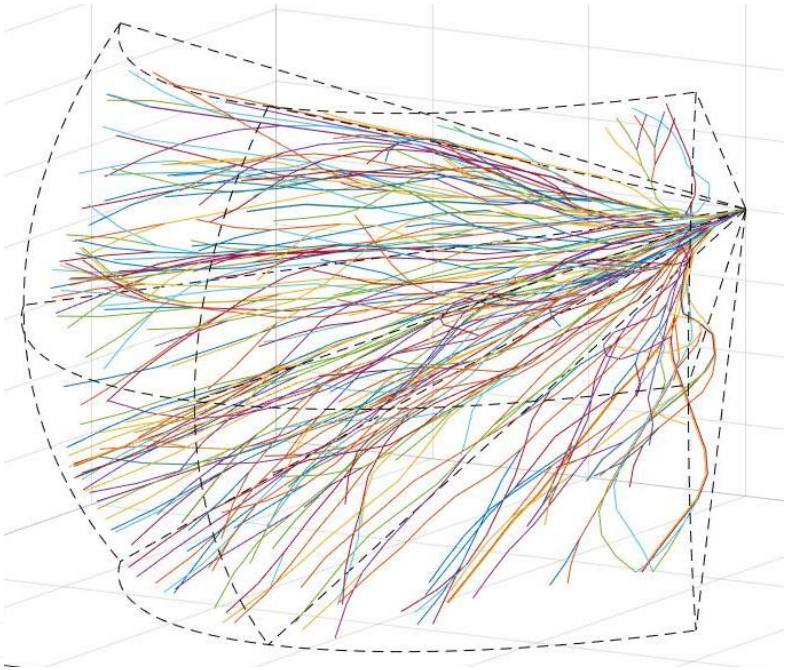
Reach Set Estimation

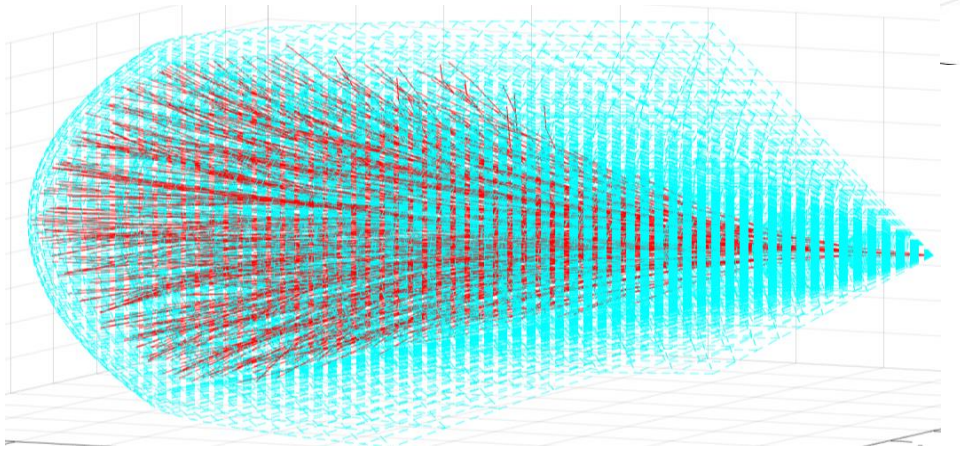
Representation:

- Tree of movement chains
- Bounded by FOV

Estimation process:

- Load full reach set by given state
- Prune Reach set according obstacle set





Issues:

- Global vs Local state disparity
  - Proportional state space distribution
  - Calculate many proto reach sets
- Approximation accuracy
  - Pick apropretiate movement set

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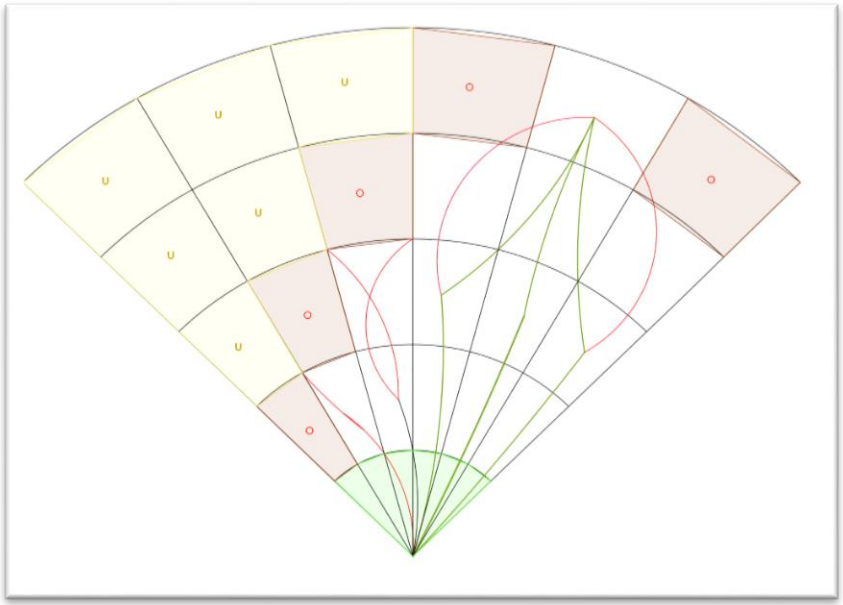
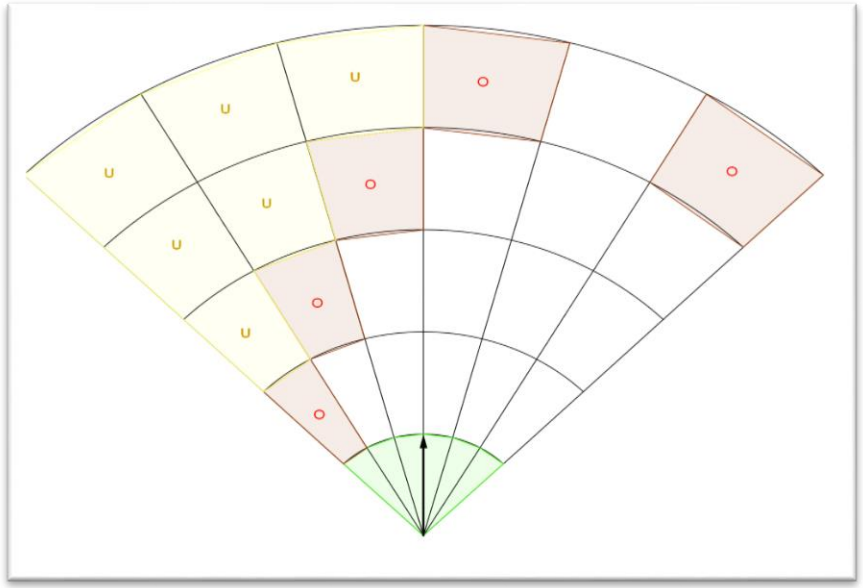
Space Assessment – Avoidance Grid

1. Space segmentation:

- Determine *Obstacle* cells
- Select *Uncertain* cells
- Load proto-reach set:
  - state of vehicle x
  - dynamic constraints





2. Reach set pruning:

- Remove unfeasible trajectories from proto-reach set
  - Green – feasible
  - Red - unfeasible

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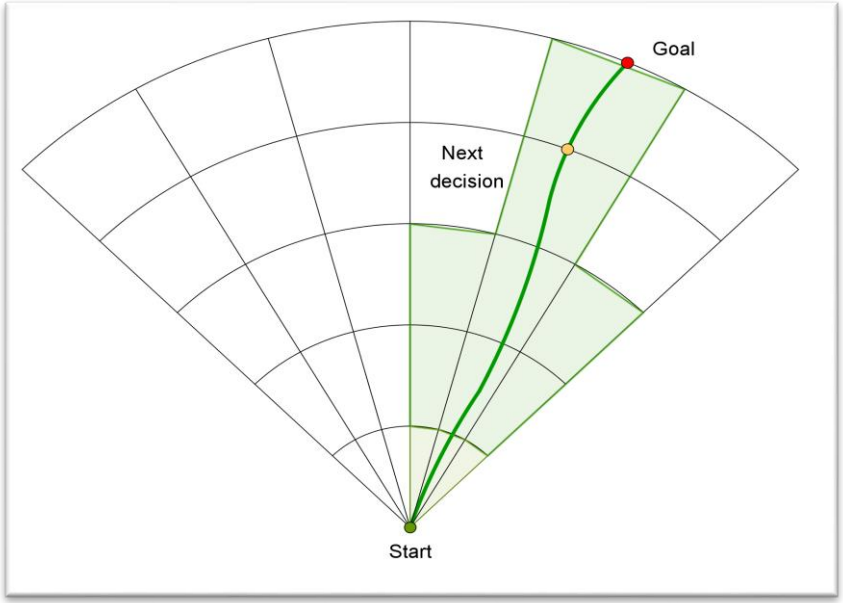
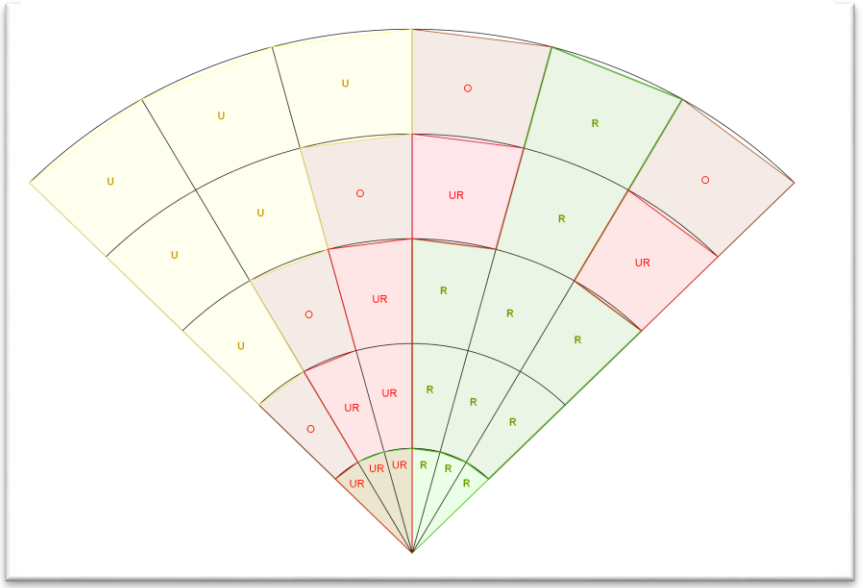
Avoidance Phase – Avoidance Grid

3. Reachable Space assessment:

- For *free cells assess:*
- Reachable:
  - At least one passing trajectory exists
- Unreachable:
  - Otherwise





4. Trajectory selection

- Select trajectory based on distance to waypoint criterion
- Next decision point is planned

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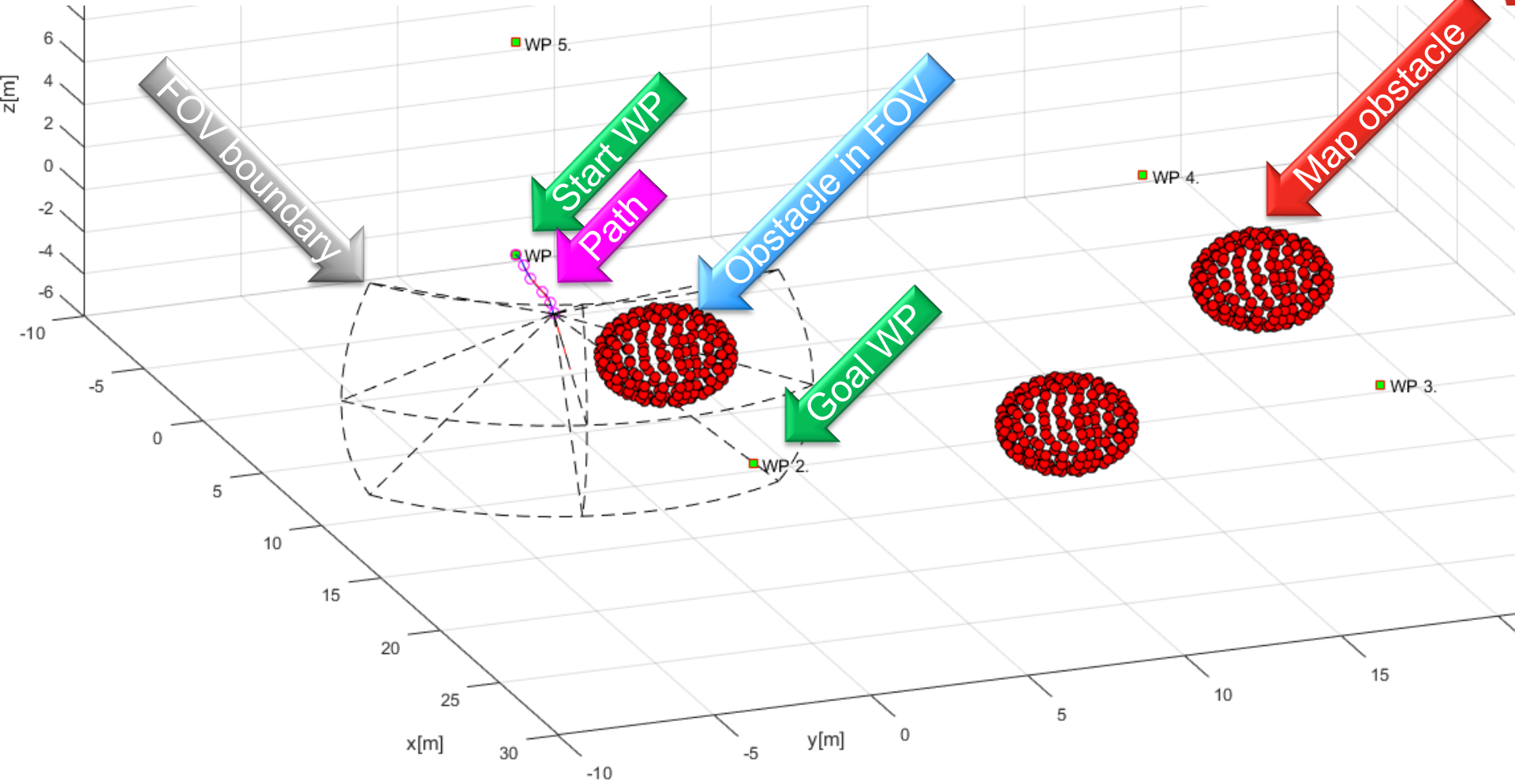
Simulation



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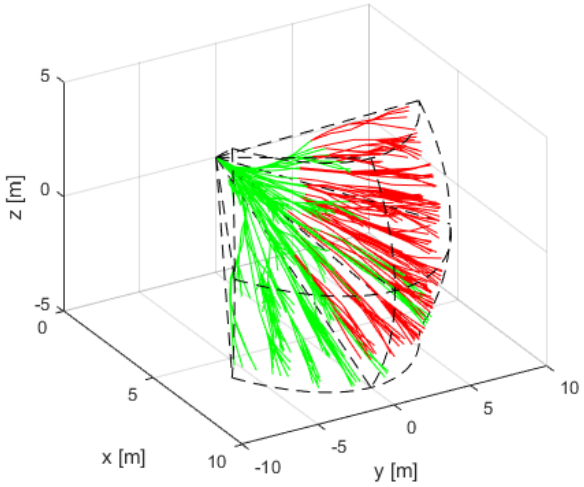
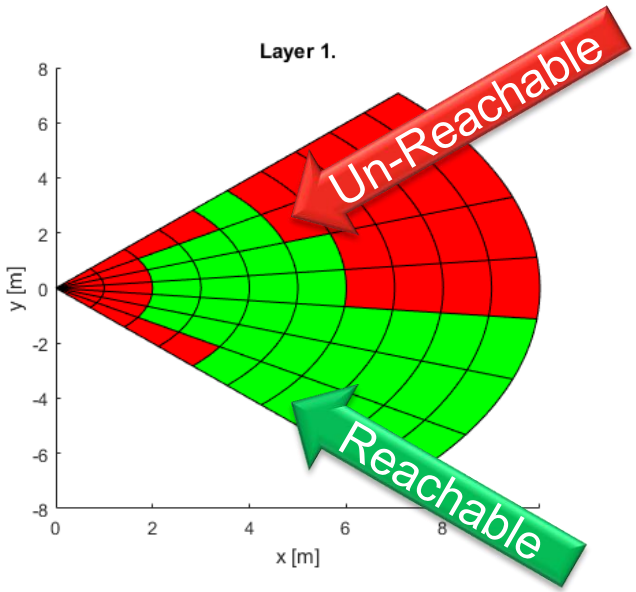
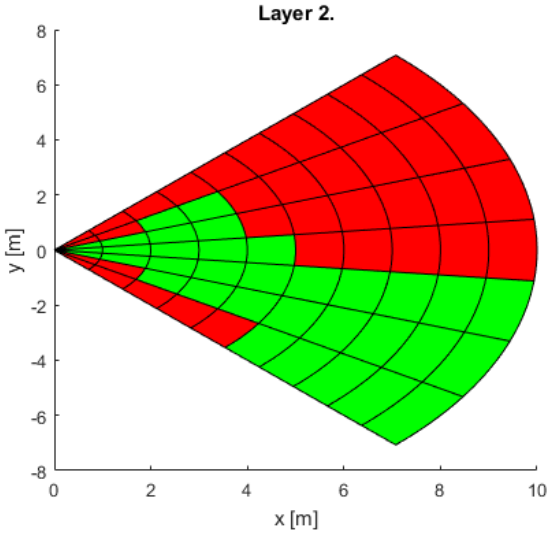
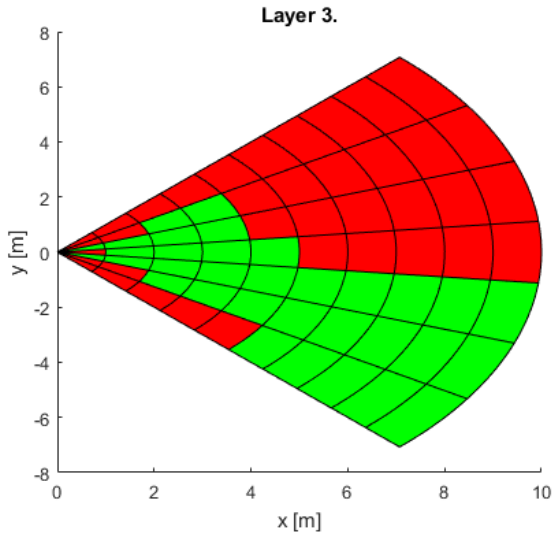
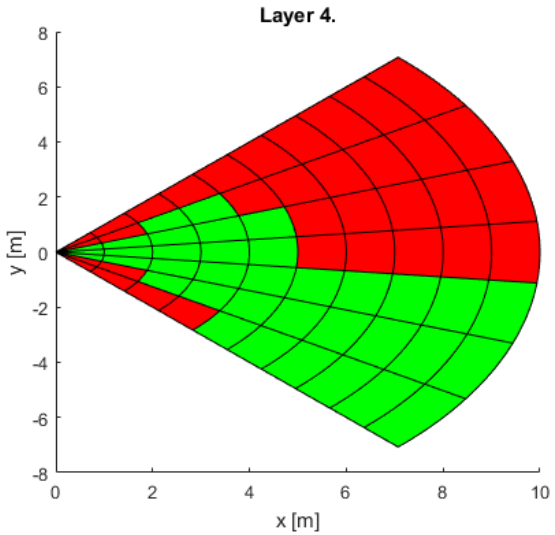
Avoidance Grid State

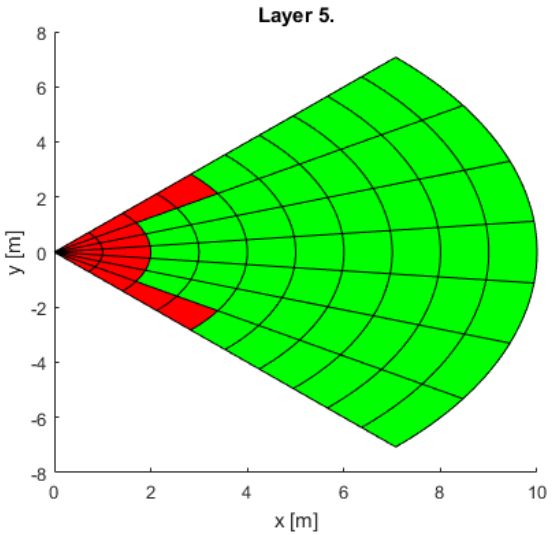












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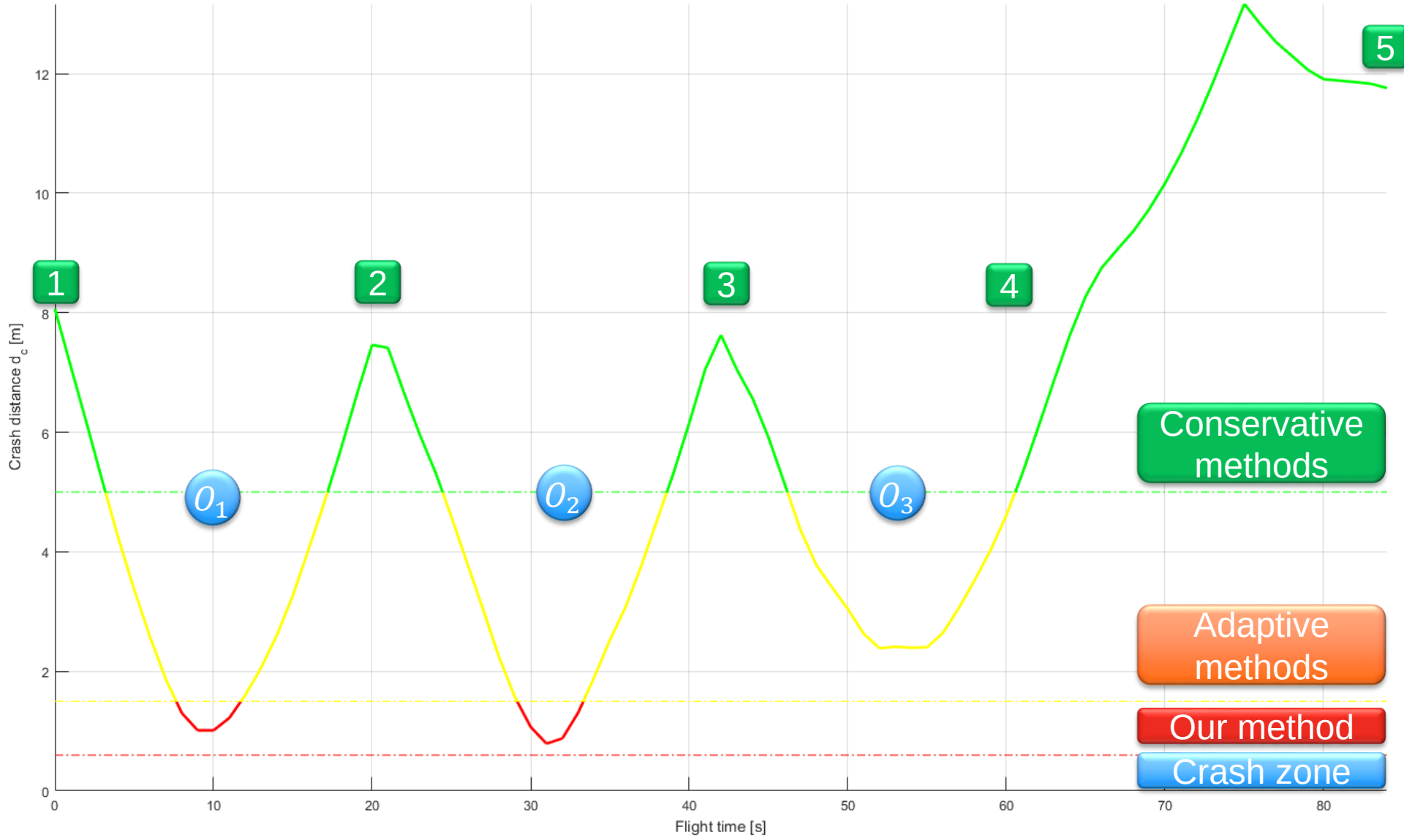
Static Obstacles – Crash Distance Performance



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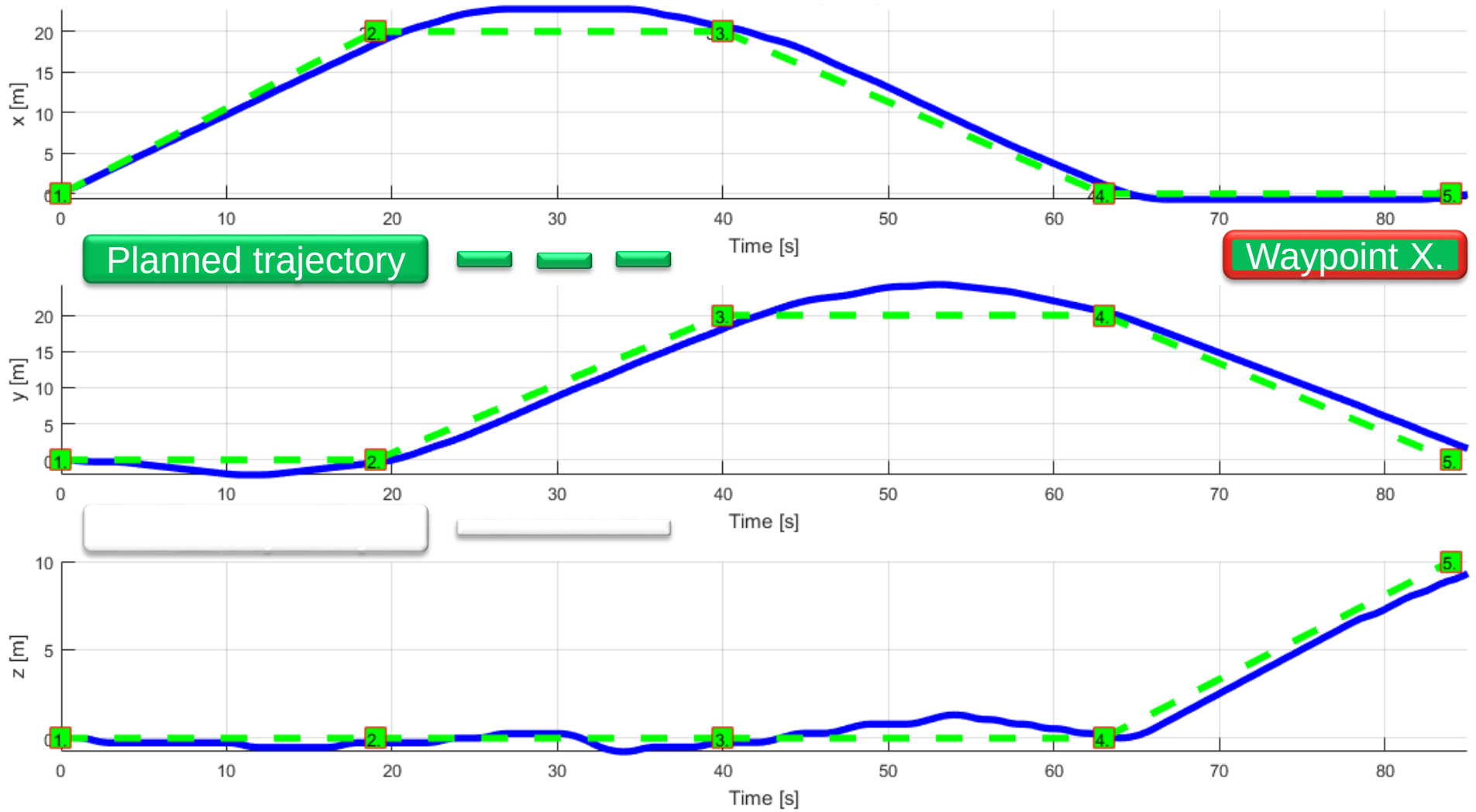
Static Obstacles – Trajectory Tracking Performance



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Conclusion

What we have:

- *Framework concept* proven on open space environment
- *Movement automaton* acts as interface to Control
- *Reach set estimation* method with finite calculation time
- Navigation algorithm considering *static obstacles*

Future research heading:

- *Data fusion* considering multiple information sources
- *Map obstacles,* from multiple sources
- *Intruders,* from ADS-B sensor

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