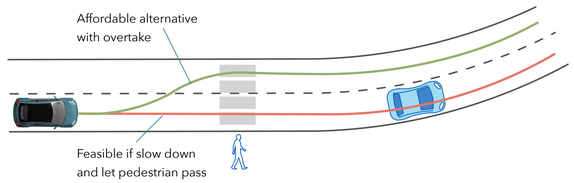
# MPTree: Motion Primitive Tree Exploration for Trajectory Planning with Dynamic Obstacle Avoidance

**Mattia Piazza, Mattia Piccinini**
Supervisors: **Prof. Francesco Biral, Prof. Mauro Da Lio**
Department of Industrial Engineering, University of Trento, Italy

## MOTIVATION

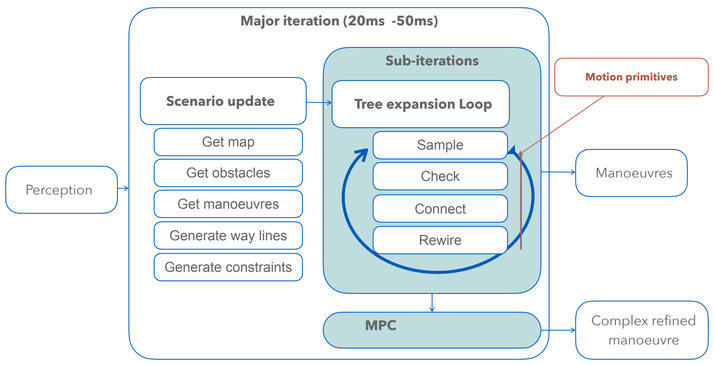
- Trajectory planning for **autonomous vehicles** with dynamic obstacle avoidance

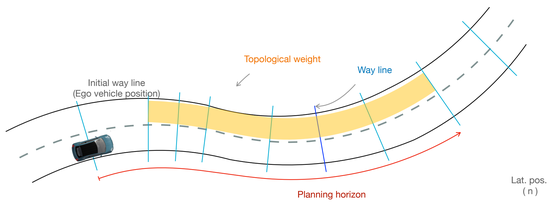


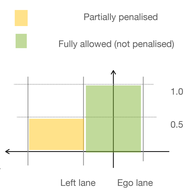

- Existing optimization methods (MPC) have a high computational time and find sub-optimal solutions
- Existing sampling-based methods (RRT*) waste computational time to randomly explore the entire domain

## PLANNING FRAMEWORK

- **Sampling-based** exploration in a **structured** grid of waylines, to create a tree of optimal **motion primitives**
- **Refine** the solution with an **MPC** problem in the computed collision-free **corridor**

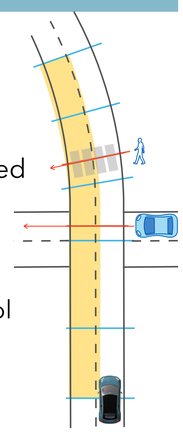



## URBAN SCENARIO

- Trajectory planning to deal with dynamic **pedestrians** and **vehicles** (cooperative or not)
- Combining multiple planning **goals**: minimize jerk, minimize time, keep a reference speed
- Motion primitives to connect pairs of waypoints:
  1. **Path**: G2 clothoids (curvature continuity ensured)
  2. **Velocity** trajectory: semi-analytical optimal control problem

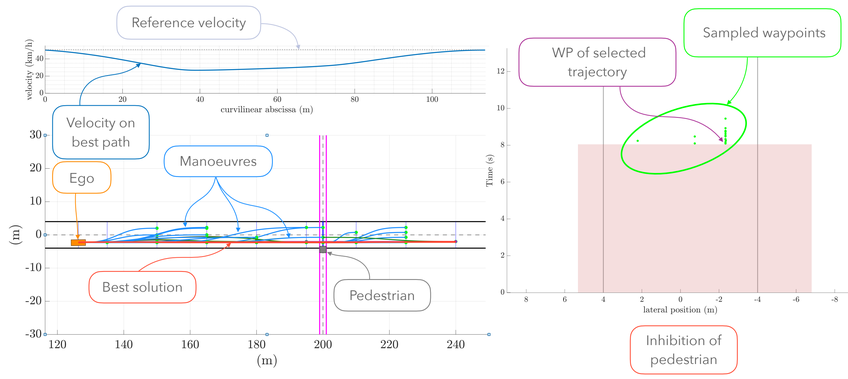


## RACING SCENARIO

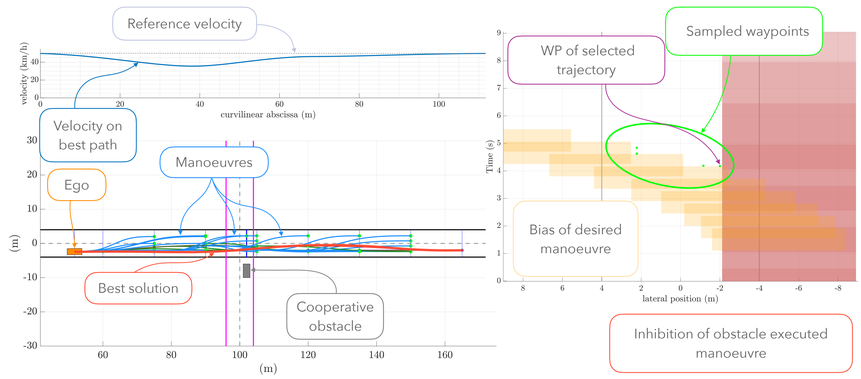
- **Minimum-time on-line** motion planning with **dynamic** non-cooperative opponents
- Explore a **structured grid** of waylines and waypoints
- **Spatio-temporal** prediction of the obstacle motion
- Motion primitives to connect pairs of waypoints:
  1. **Path**: Polynomial Neural Network (**NN-Poly**), approximating the minimum-time nonlinear MPC solutions
  2. **Velocity** trajectory: semi-analytical min-time optimal control problem with acceleration constraints

## RESULTS

- Pedestrian crossing considering occupancy

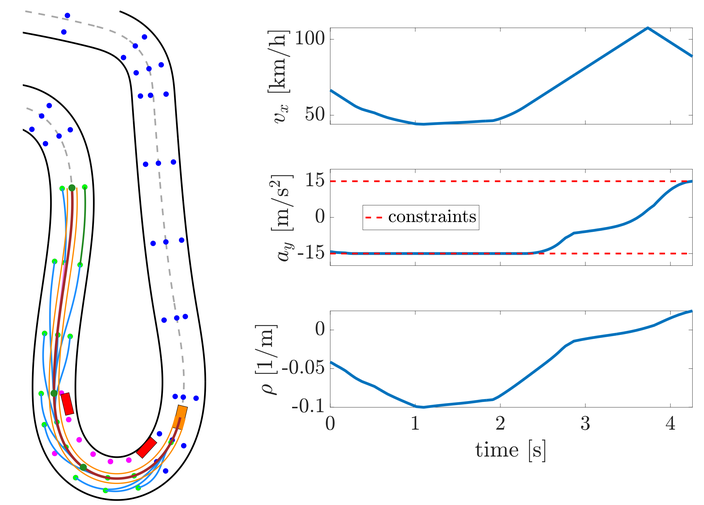



- Road intersection with manoeuvres exchange (cooperative)




## RESULTS

- **Real-time** motion planning, horizon length approx. 100 m
- MPTree outperforms a benchmark obstacle avoidance MPC
- NN-Poly outperforms a benchmark generic NN, and it guarantees the path curvature continuity




| | Mean cpu time |
|---|---|
| MPTree | 33 ms |
| Benchmark MPC | > 200 ms |

| | NN accuracy (test set) |
|---|---|
| NN-Poly | 0.0059 m |
| Benchmark NN | 0.0506 m |