

DECISION MAKING IN AUTONOMOUS DRIVING

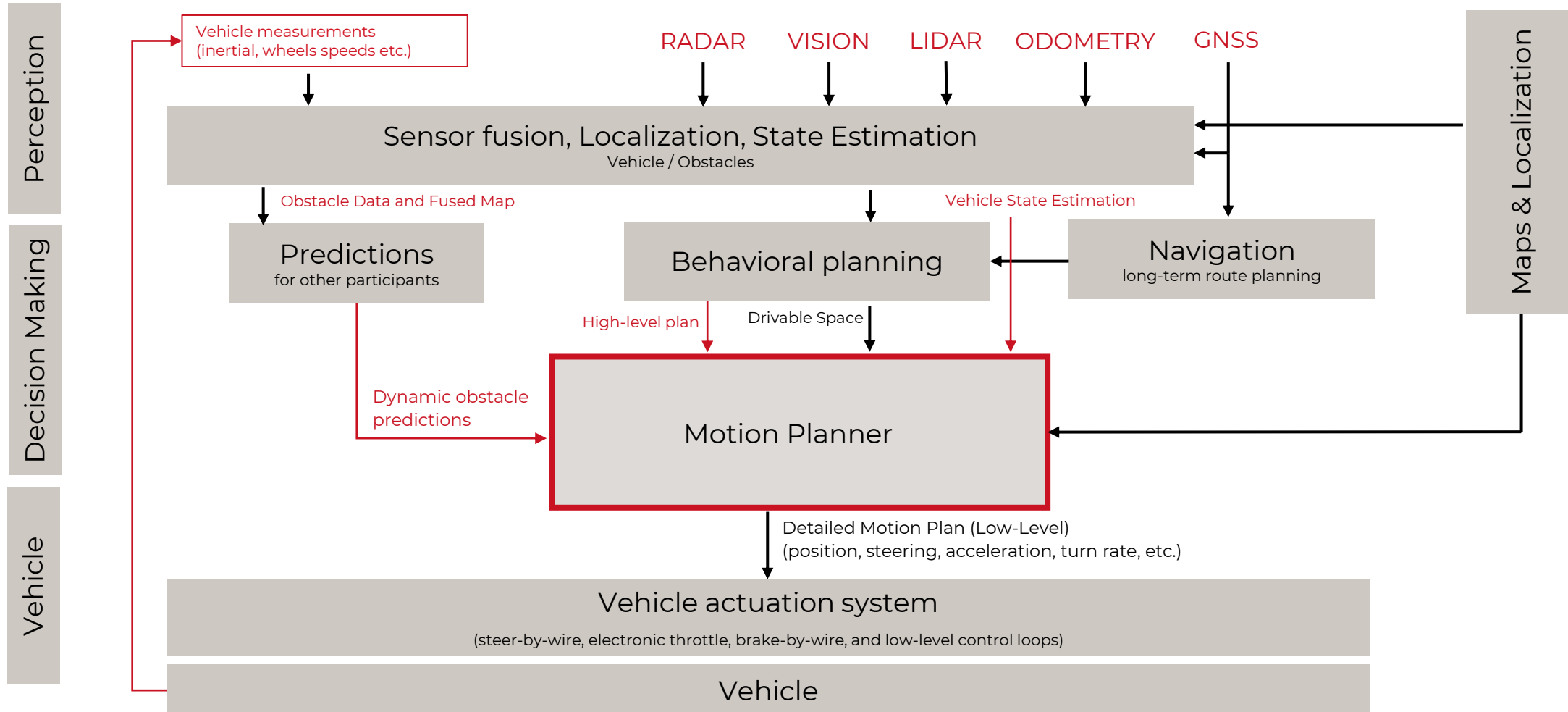
Uros Markovic
Optimization Specialist

2022 American Control Conference
Atlanta, GA, USA / June 2022

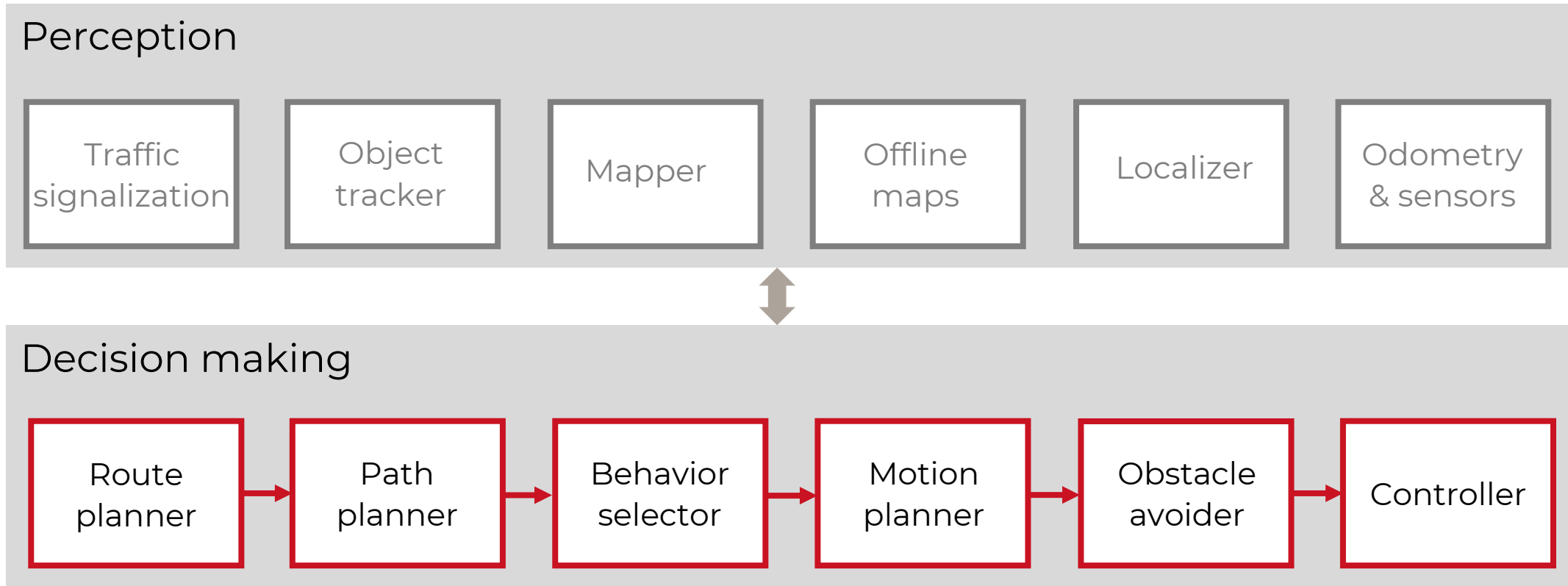
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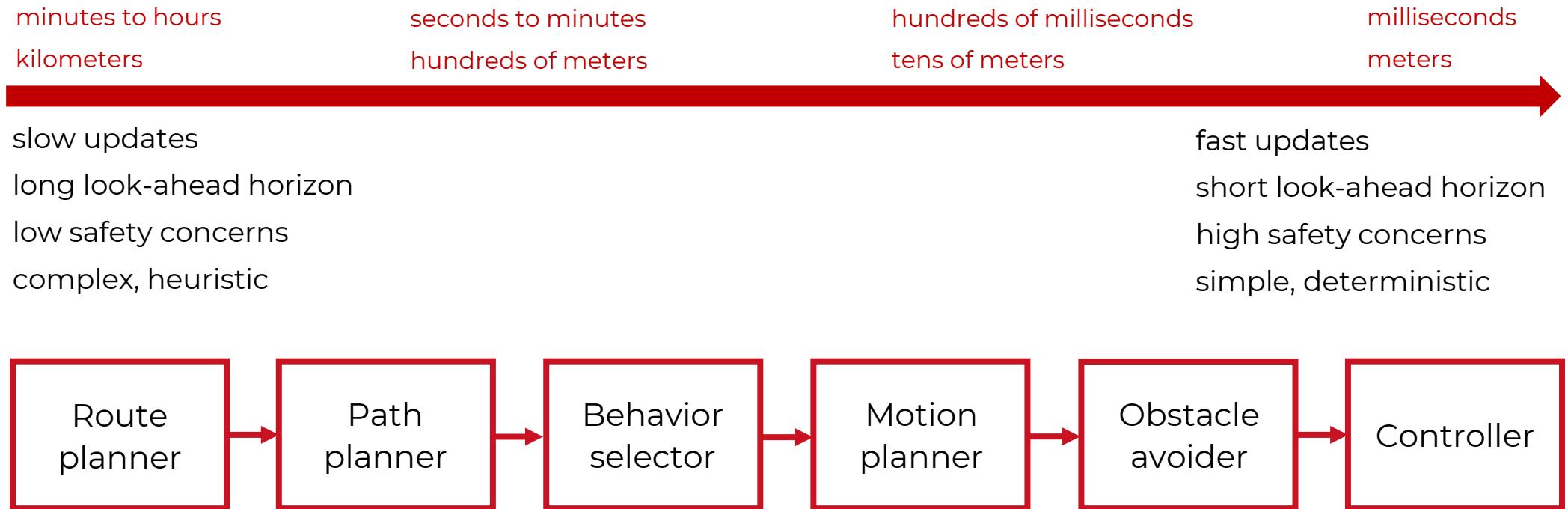
HIERARCHICAL CONTROL ARCHITECTURE



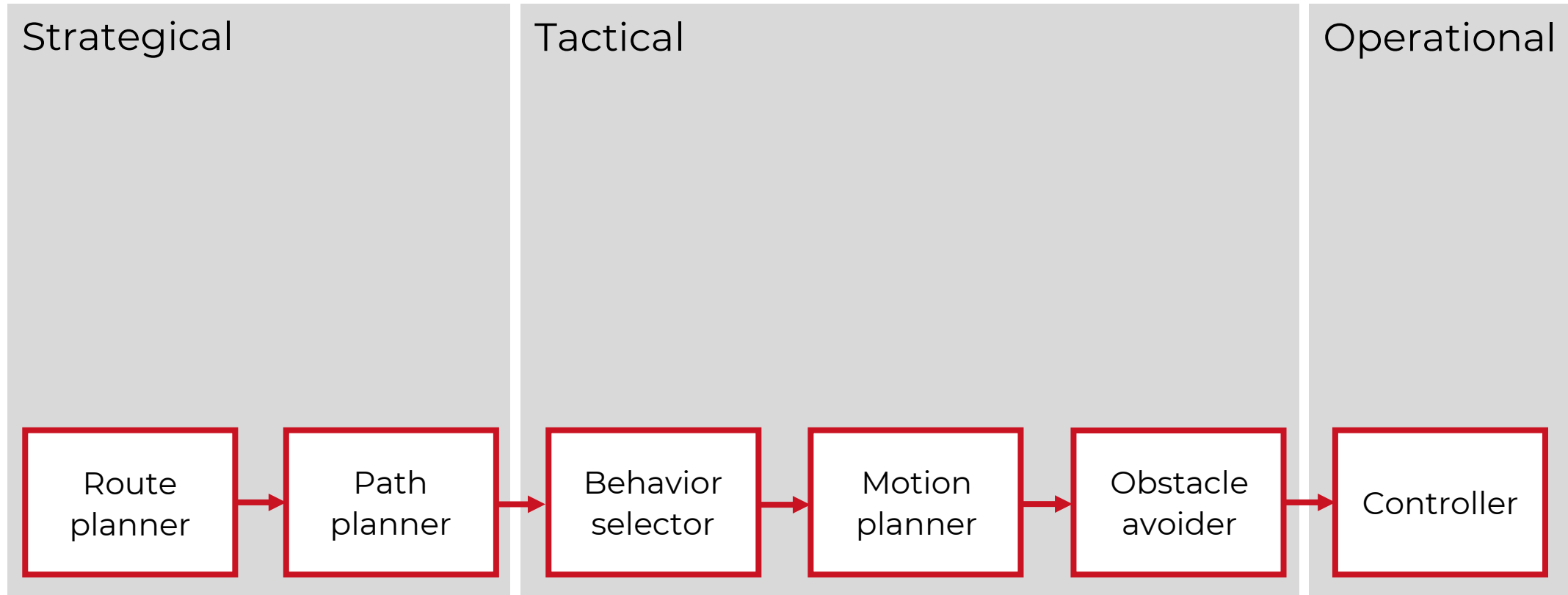
HIERARCHICAL CONTROL ARCHITECTURE



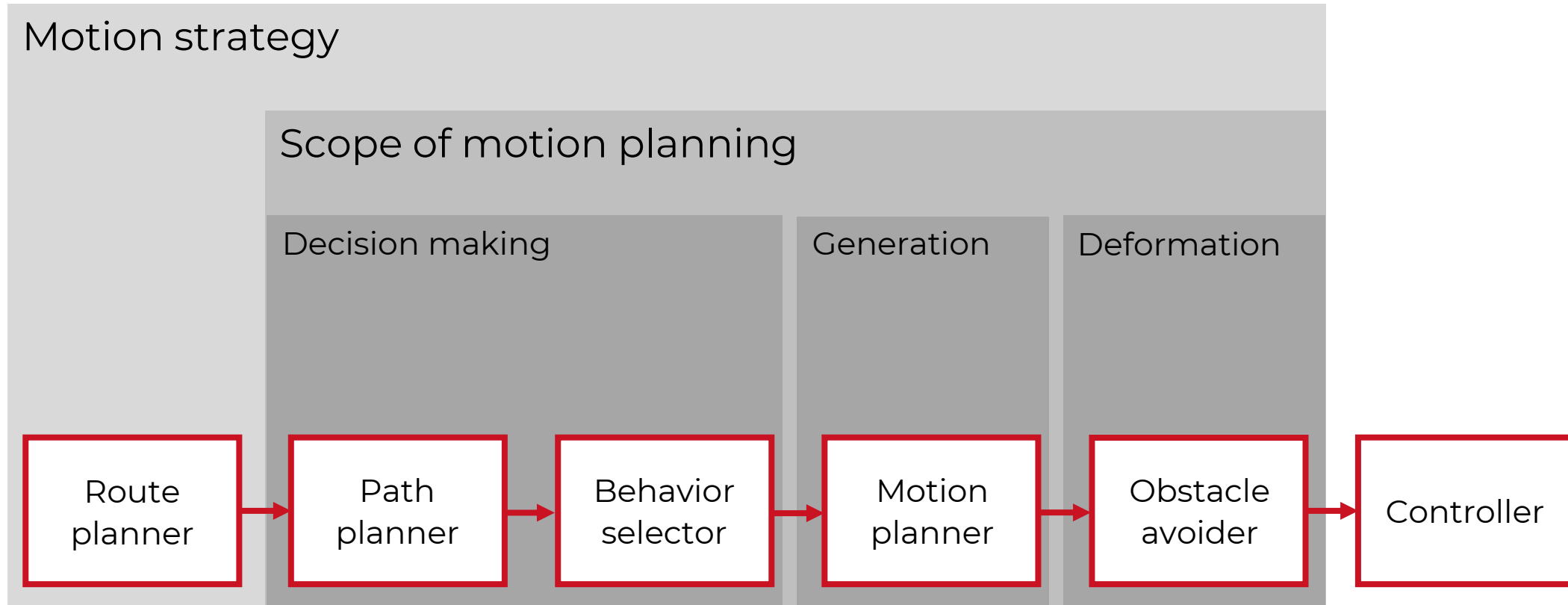
CASCADE AD CONTROL STACK



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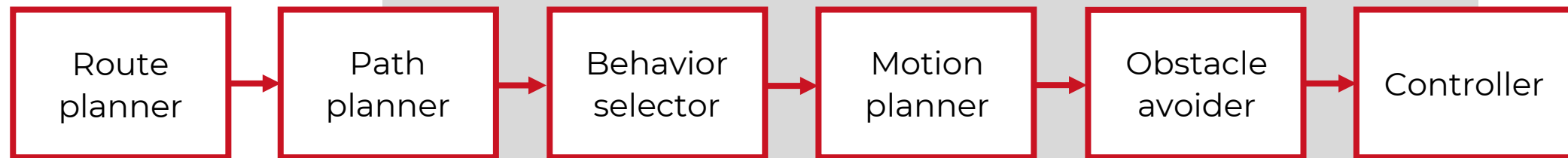


CASCADE AD CONTROL STACK

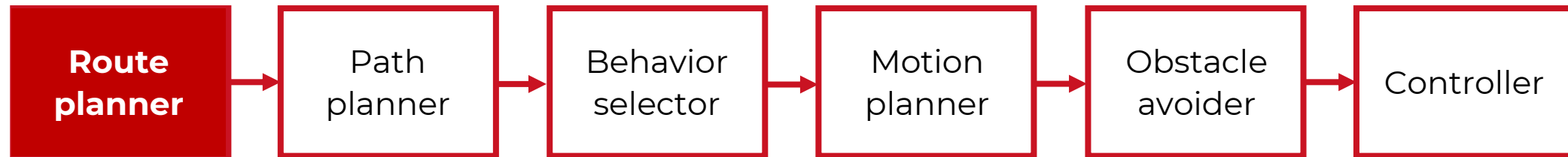


CASCADE AD CONTROL STACK

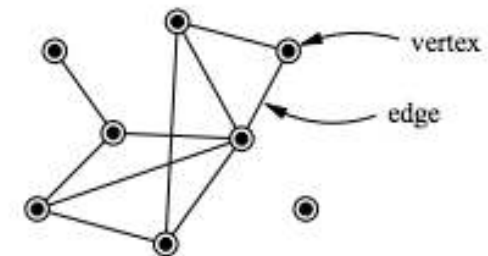
Motion planner
(as a single problem)



ROUTE PLANNER

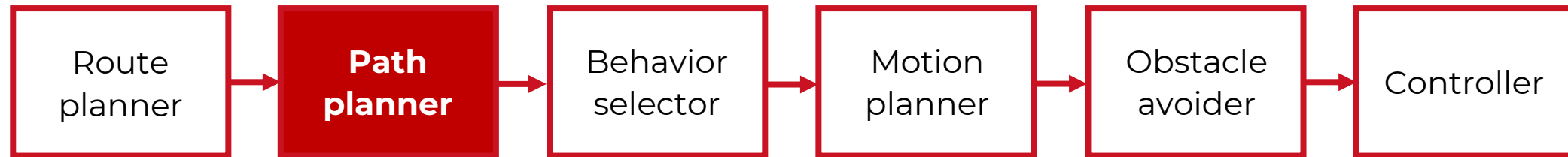


- **Computes the route** (sequence of x-y **waypoints**), like a SatNav
- For a **road network defined as a graph**
 - vertices are waypoints
 - edges are costs of traversing that segment
- **Algorithms:**
 - goal-directed
 - separator-based
 - hierarchical
 - bounded hop

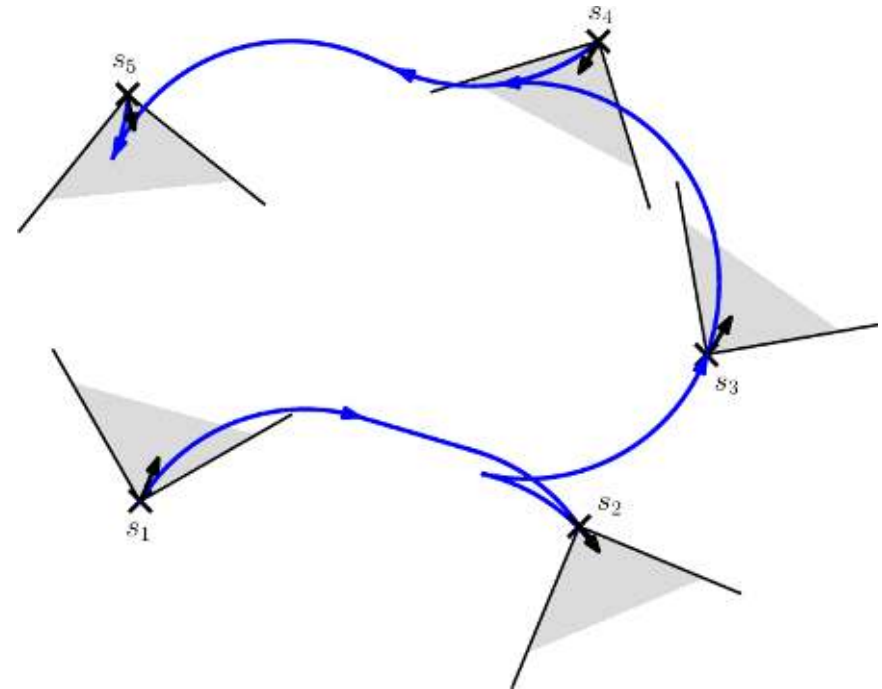


[https://en.wikipedia.org/wiki/Vertex_\(graph_theory\)](https://en.wikipedia.org/wiki/Vertex_(graph_theory))

PATH PLANNER

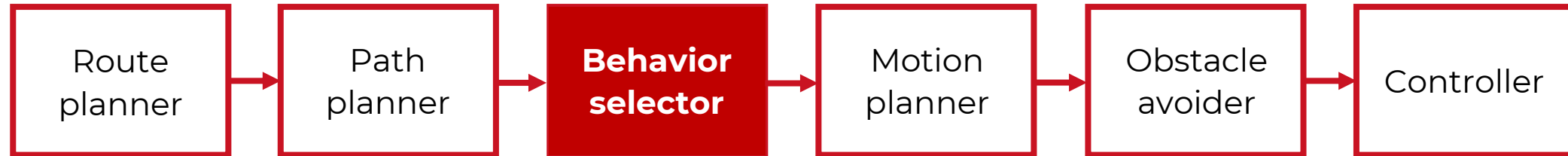


- Computes **paths (sequence of poses)** comprising the route
- A pose is an **x-y position plus orientation** bounded hop
- **Algorithms:**
 - graph search
 - curve interpolation

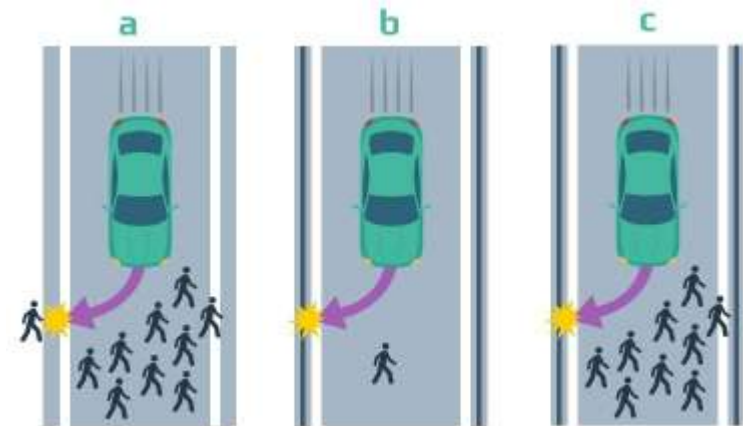


Rathinam, Sivakumar et al. "Path Planning Algorithms for a Car-Like Robot visiting a set of Waypoints with Field of View Constraints."

BEHAVIOR SELECTOR

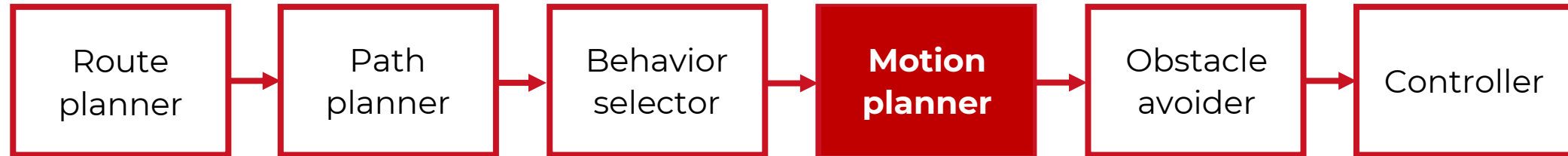


- Decides on **driving behavior** (lane keeping, intersection handling, traffic lights) **by selecting a path**
- Usually a **combination of heuristics and finite state machines**
- **Algorithms:**
 - finite state machines
 - ontology-based
 - Markov decision processes



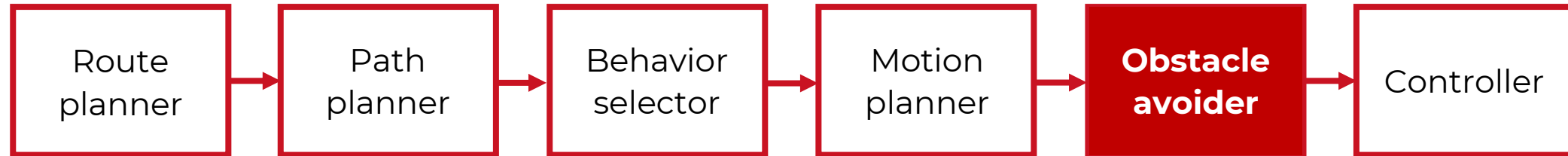
<https://www.intellias.com/it-s-time-to-give-autonomous-cars-an-ethics-lesson/>

MOTION PLANNER



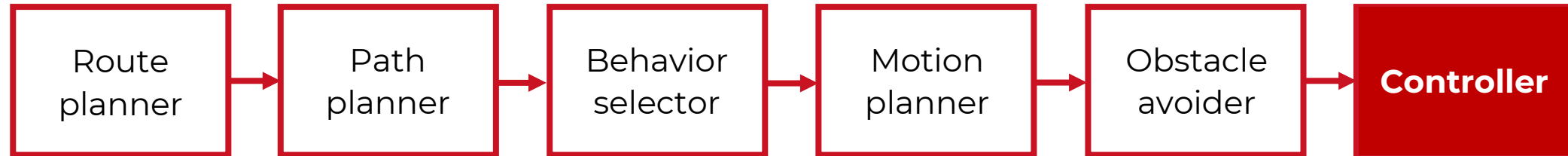
- Computes **trajectory (sequence of states or actuator commands)** from current state to current goal which **follows a given path**
 - satisfies actuation, kinematic and dynamics constraints
 - meets safety, comfort and eco-driving requirements
 - distinguishes between structured and unstructured space
- **Algorithms:**
 - graph search
 - sampling-based
 - curve interpolation
 - **numerical optimization**

OBSTACLE AVOIDER



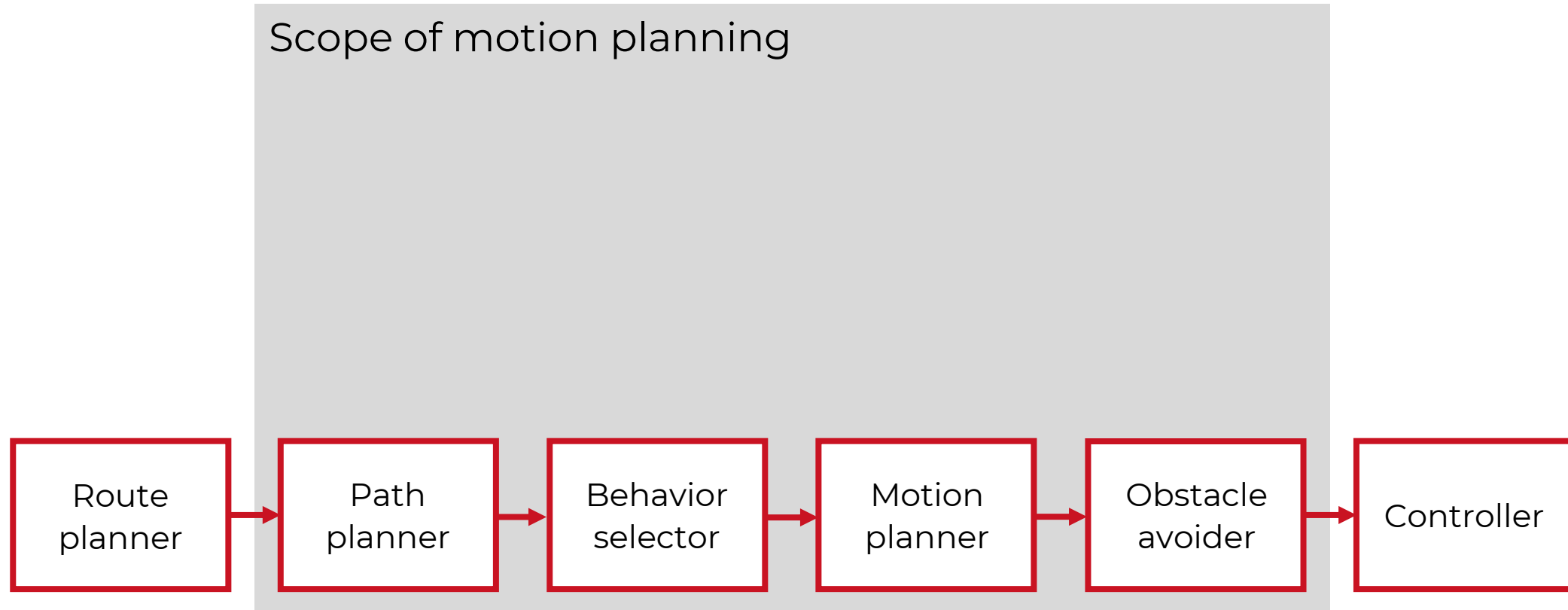
- **Tweaks trajectory** to avoid collisions (often simply reduces speed)
- Uses **information directly from the perception** to assess risk
- **Safety-critical** component: the simpler, the better

CONTROLLER

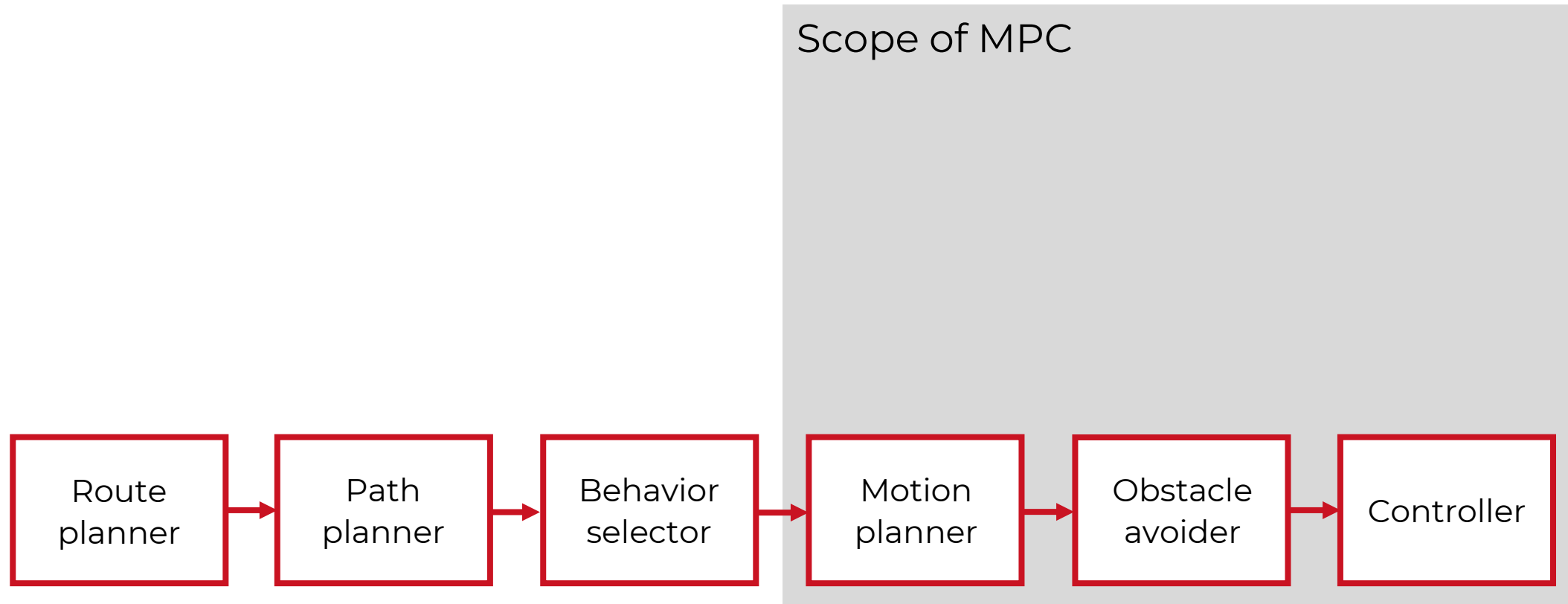


- Uses the **trajectory as set point**, and calculates and **sends commands to actuators** (steering, acceleration, braking)
- Can be a **simple PID loop**, but also a **nonlinear MPC**
- **Direct actuation** (sequence of commands) or **path tracking** (sequence of states)

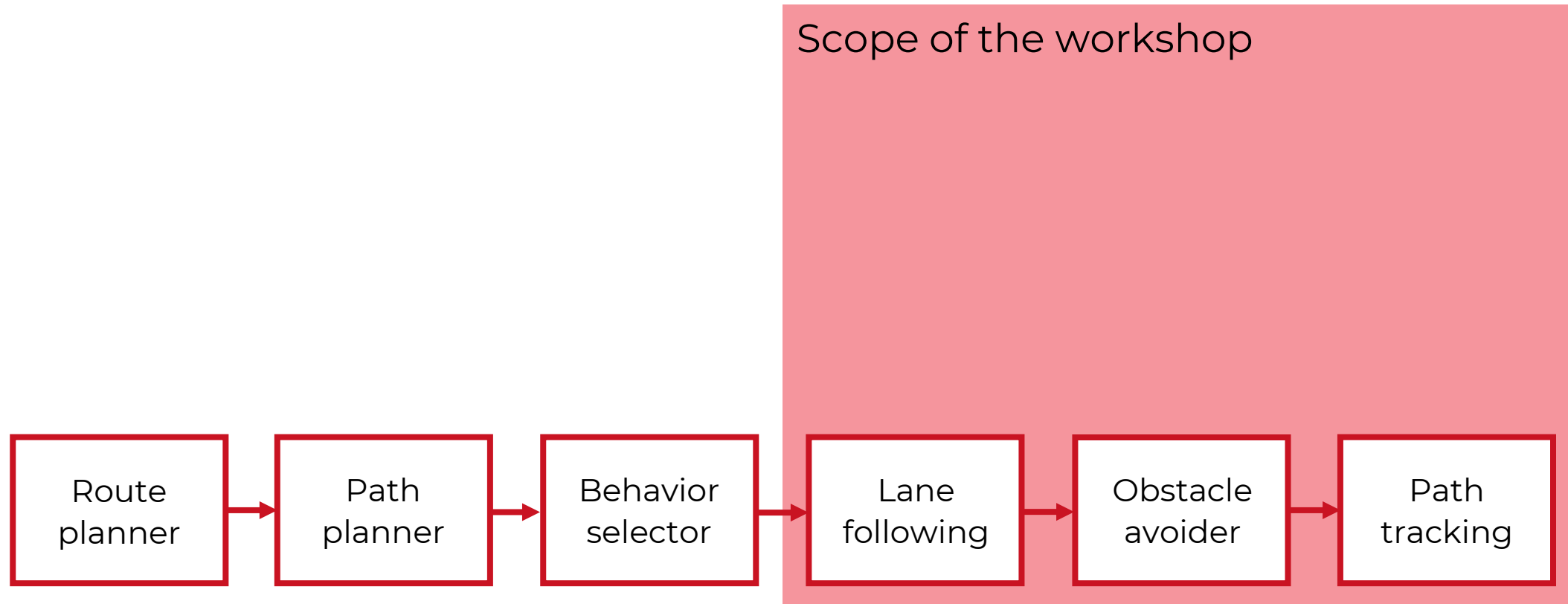
MPC IN MOTION PLANNING & TRACKING



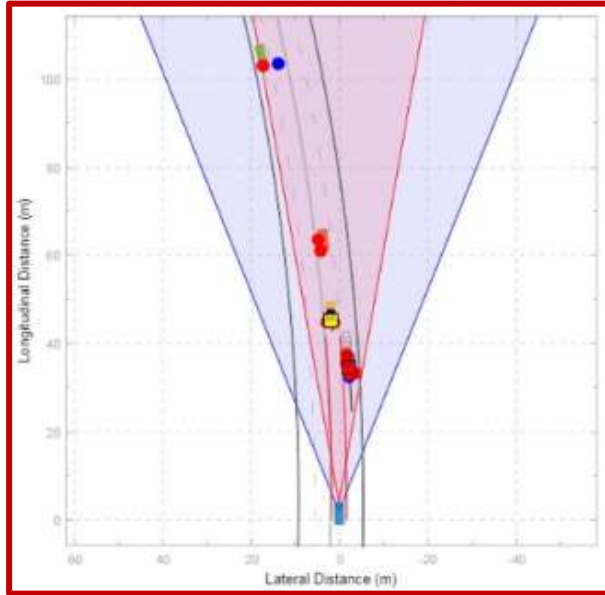
MPC IN MOTION PLANNING & TRACKING



MPC IN MOTION PLANNING & TRACKING



MPC IN MOTION PLANNING & TRACKING

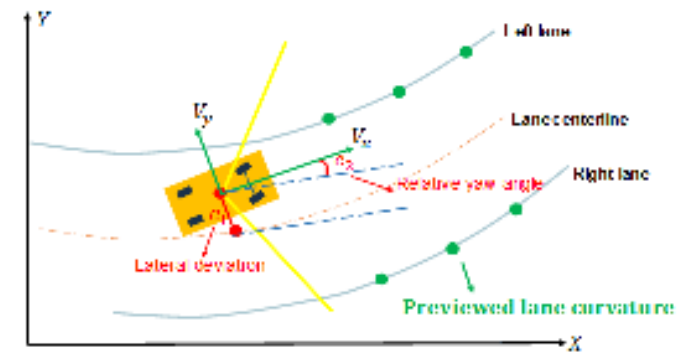


Lane following

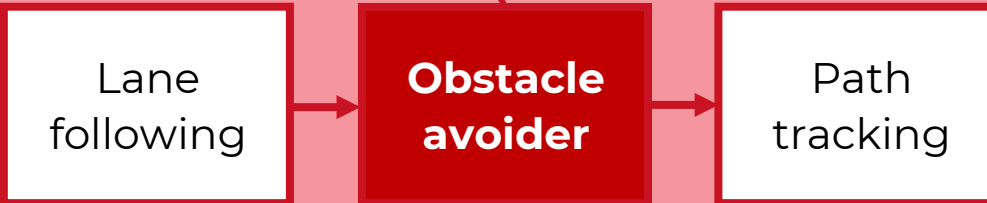
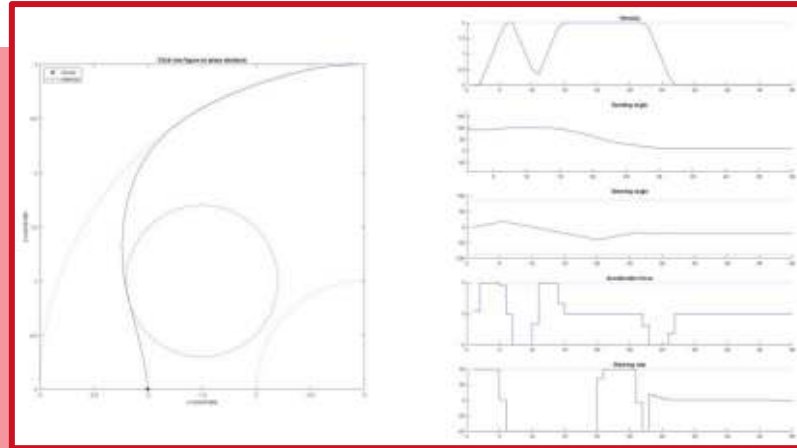
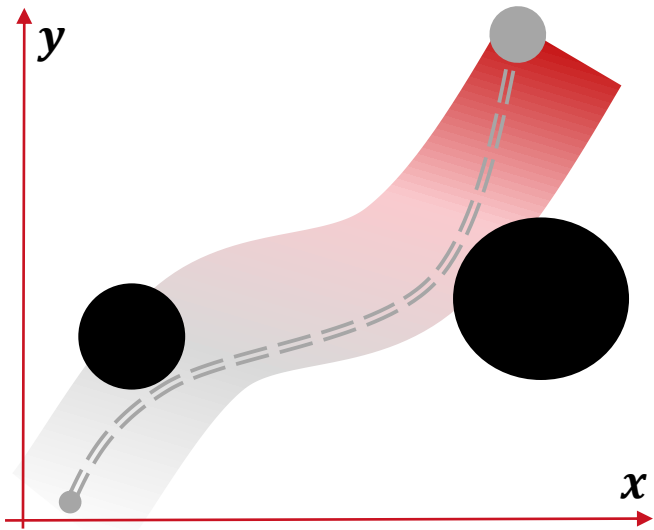
Obstacle avoider

Path tracking

Scope of the workshop

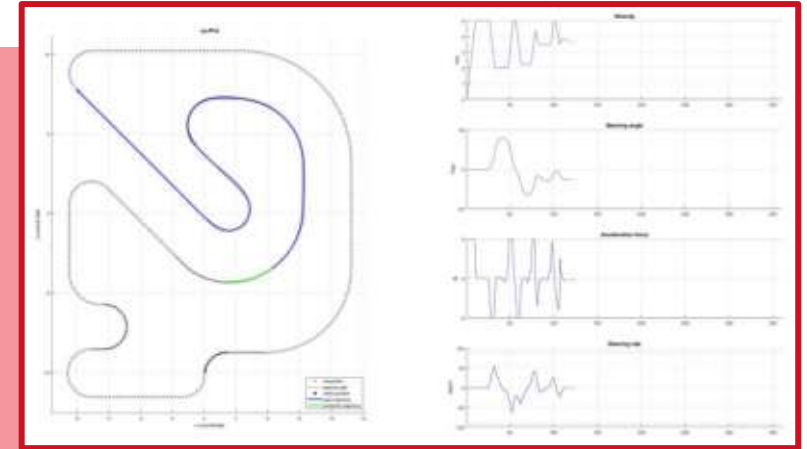
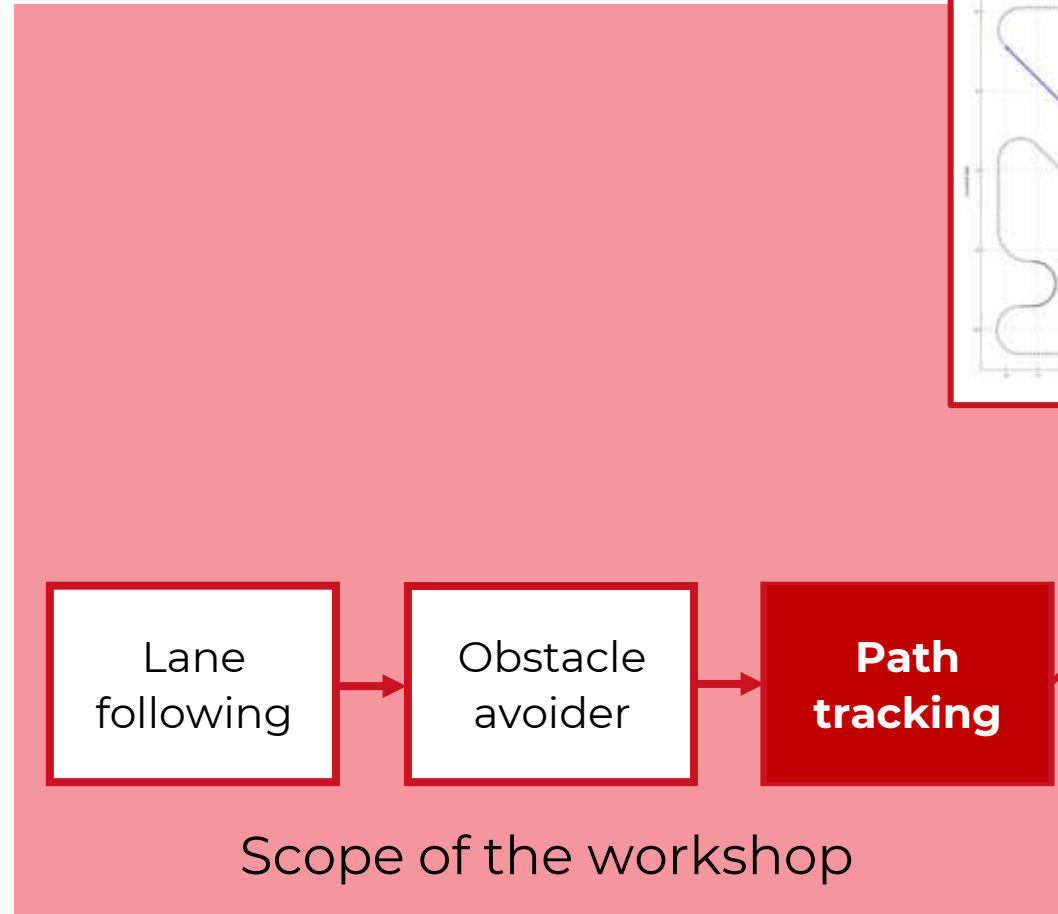


MPC IN MOTION PLANNING & TRACKING

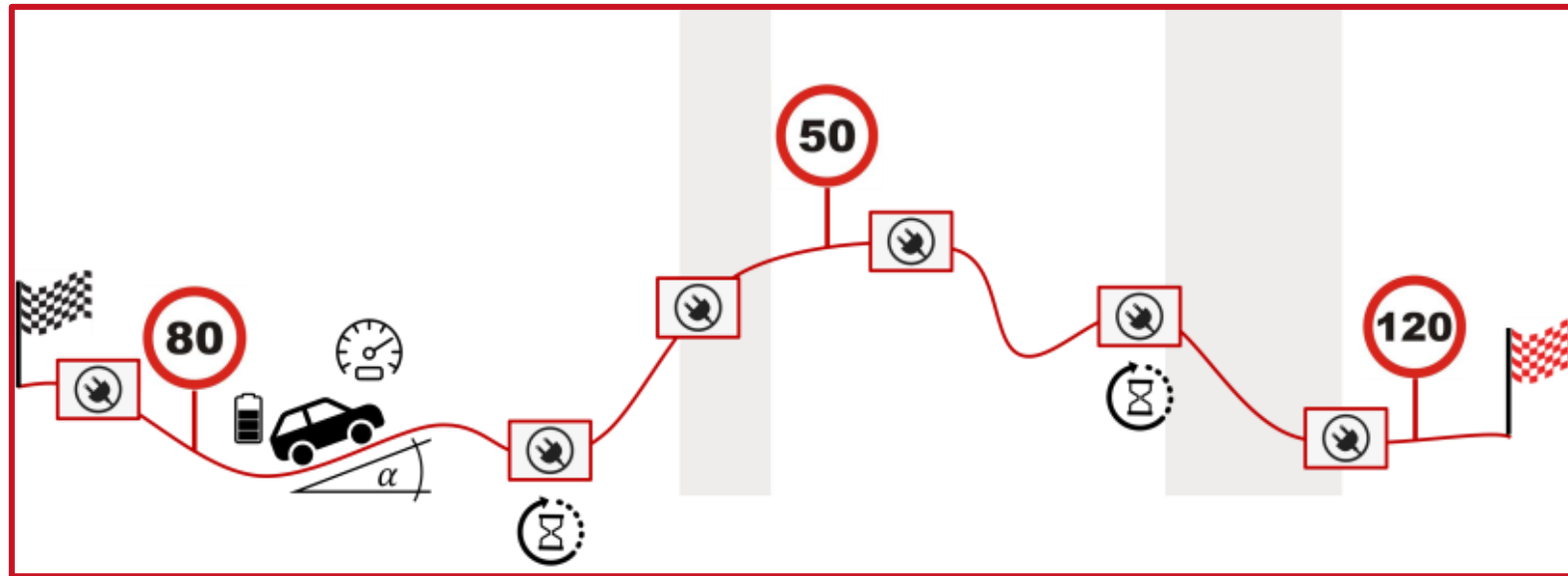


Scope of the workshop

MPC IN MOTION PLANNING & TRACKING



MPC IN MOTION PLANNING & TRACKING



**Energy-efficient EV
path planning & tracking**

Scope of the workshop

TAKE AWAY POINTS

- Decision making in AD is a **cascade** of functions
- **Boundaries** between such functionalities are **quite arbitrary**
- Choice of the **algorithm** is a **compromise** between
 - computational speed
 - accuracy
 - required safety levels



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