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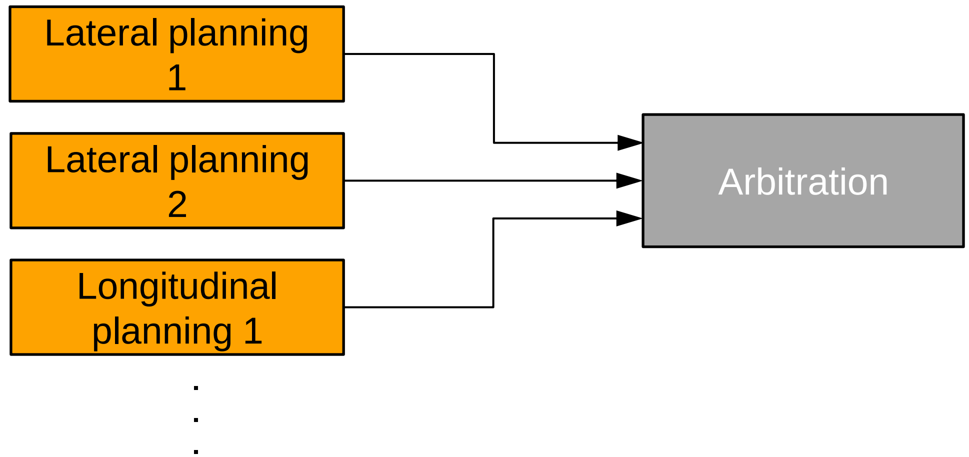
Eric Bauer

Trajectory Planning

Integrated Trajectory Planning Approach

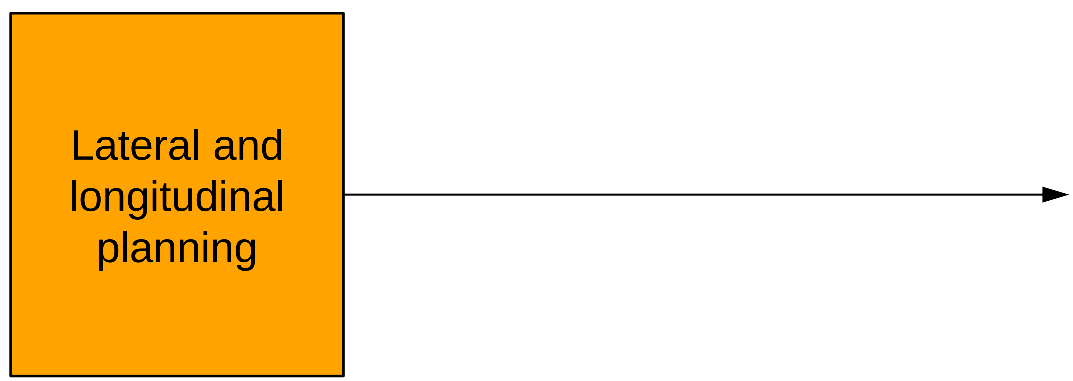
So far:

Distributive approach



Goal:

Integrated approach



Trajectory Planning PRORETA 3 – Potential Field

- Mapping the world model to a hazard map (potential field)

  → Function of the relative distance to lane markers, freespace border and obstacles
- No limitation of number of obstacles in general
- Intuitive and describtive
- Many degrees of freedom for problem-orientated modeling of the potential field

Trajectory Planning PRORETA 3 – Potential Field Modeling

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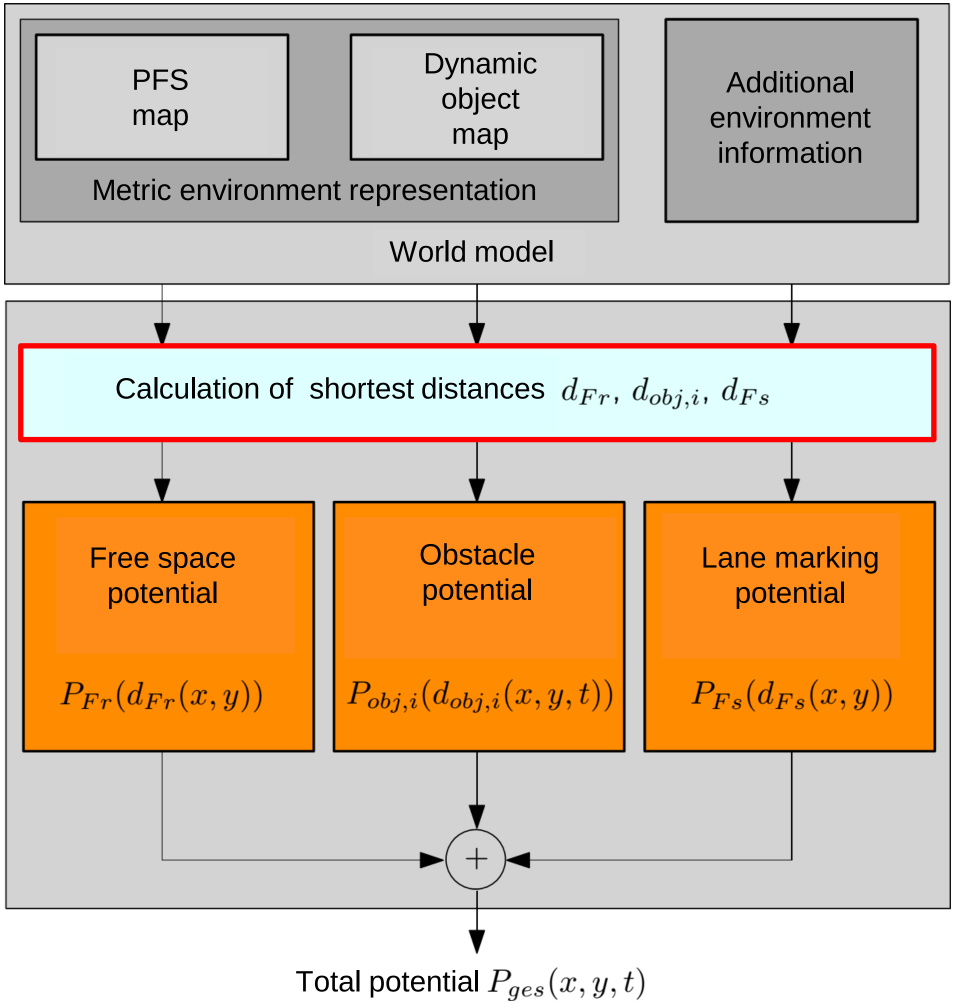
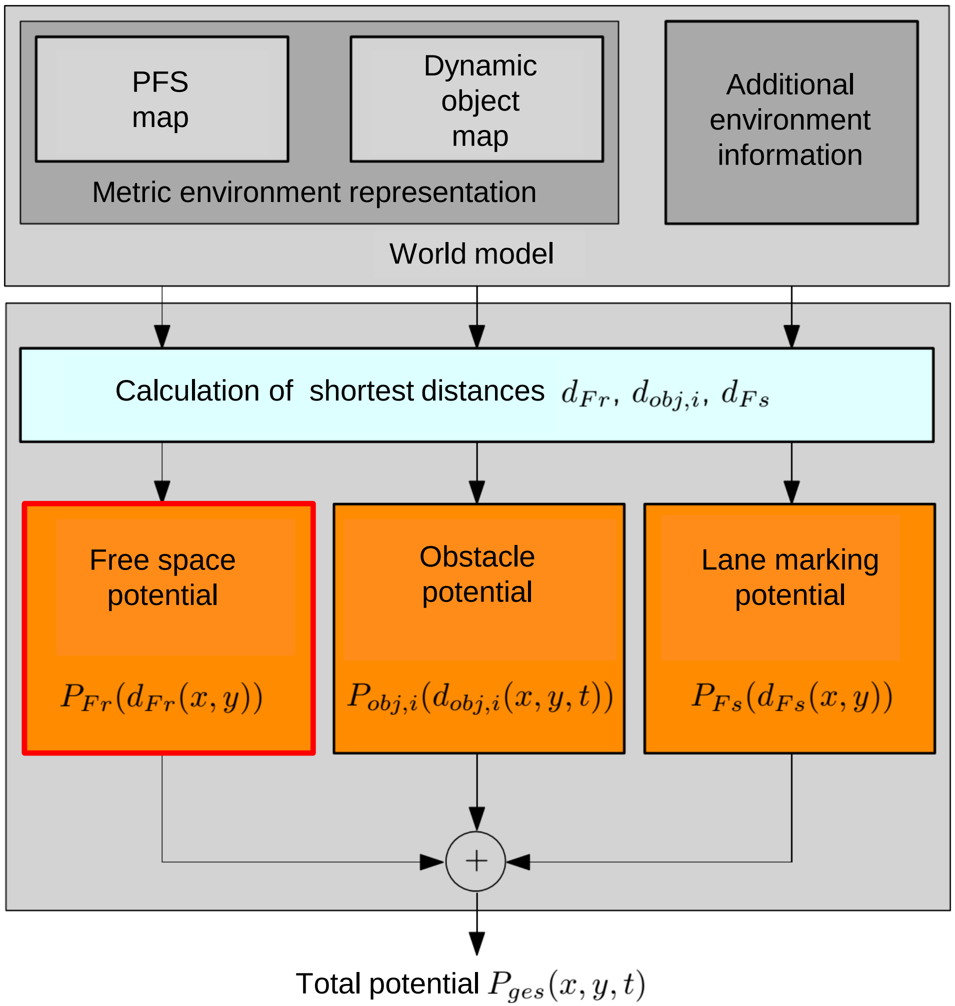
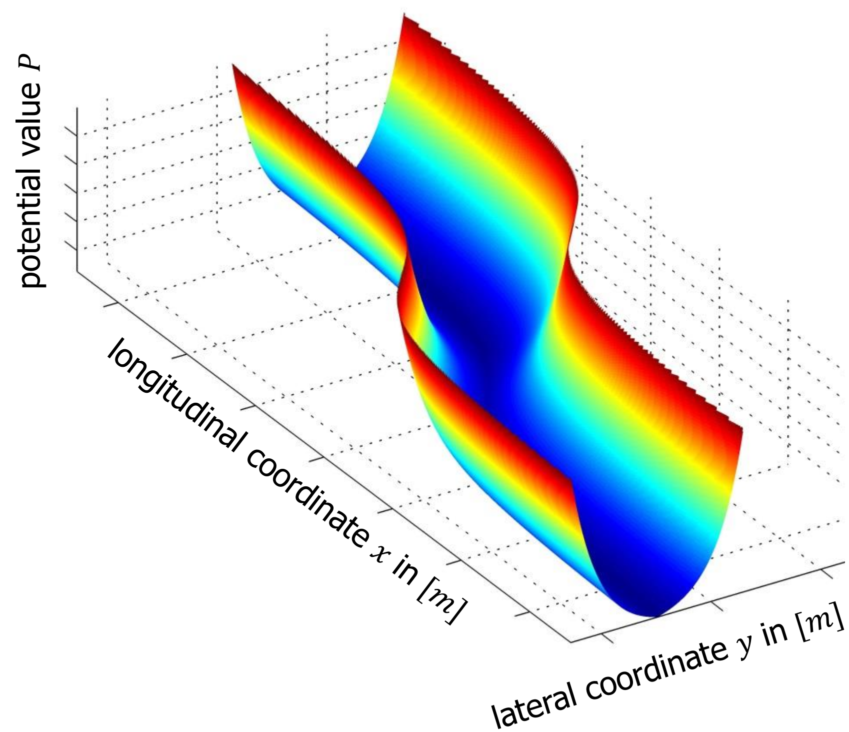


PRORETA

Trajectory Planning PRORETA 3 – Potential Field Modeling





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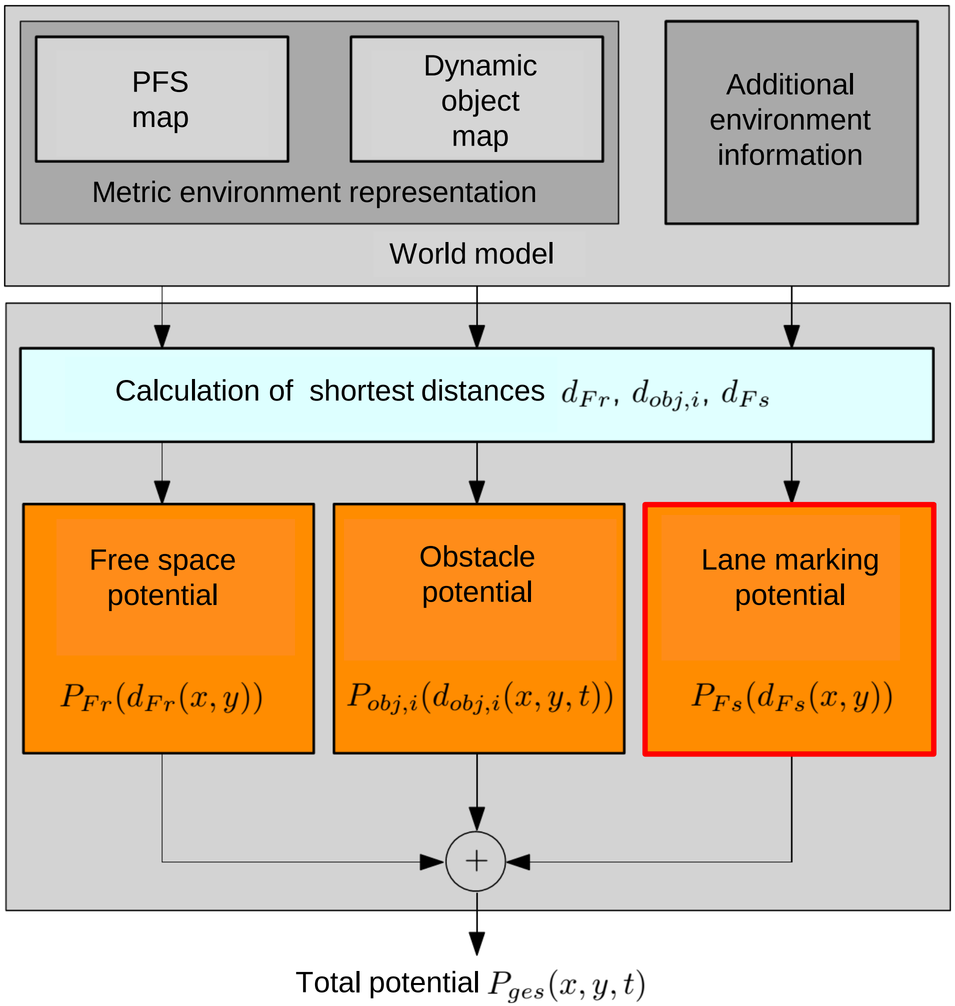

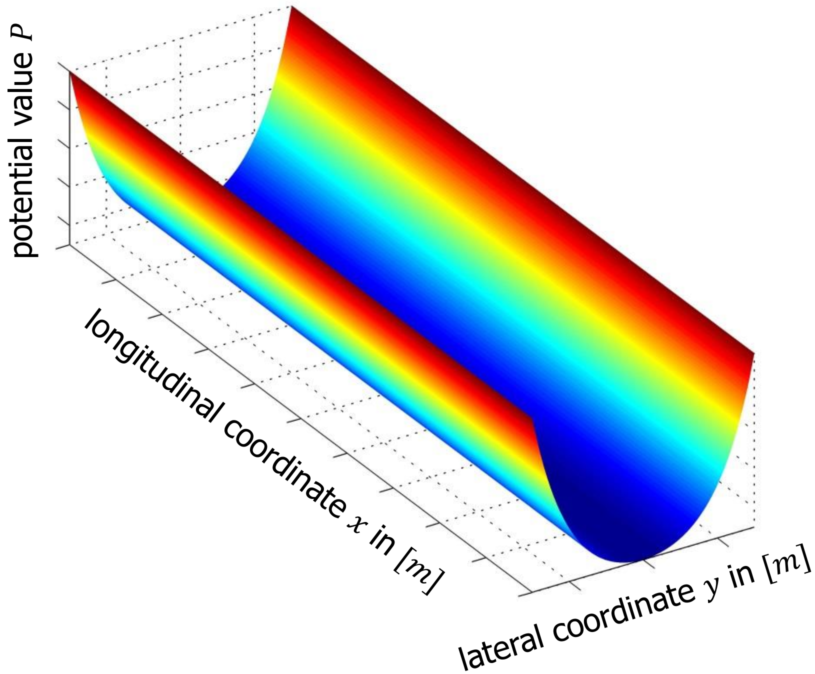

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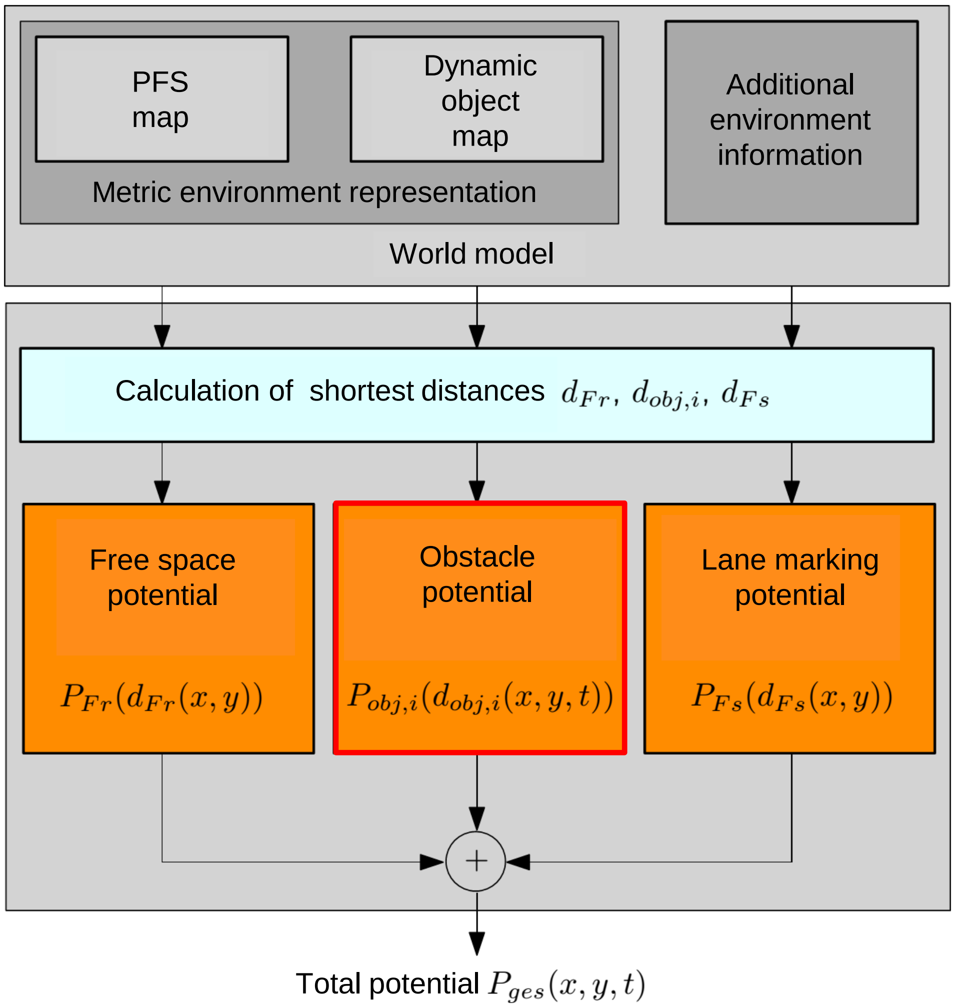

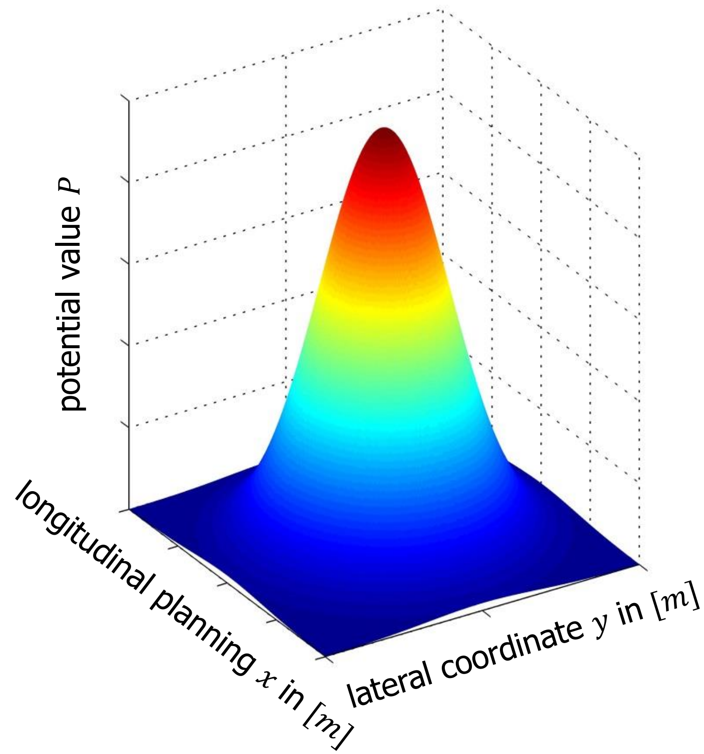

PRORETA

Trajectory Planning PRORETA 3 – Mathematical Formulation of the Lateral Problem

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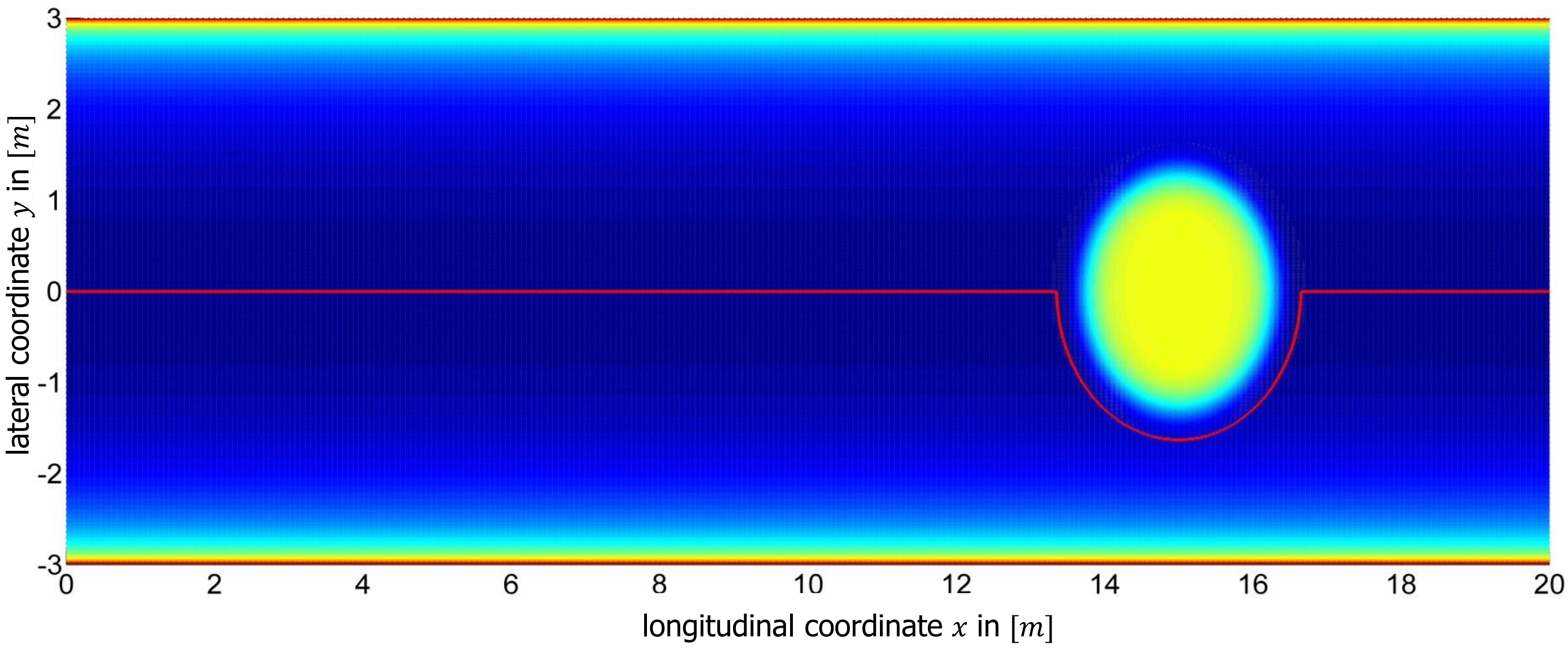
- Looking for the safest trajectory through the potential field for a finite, future horizon

Looking for:
→ Valley (minimum) of the potential field



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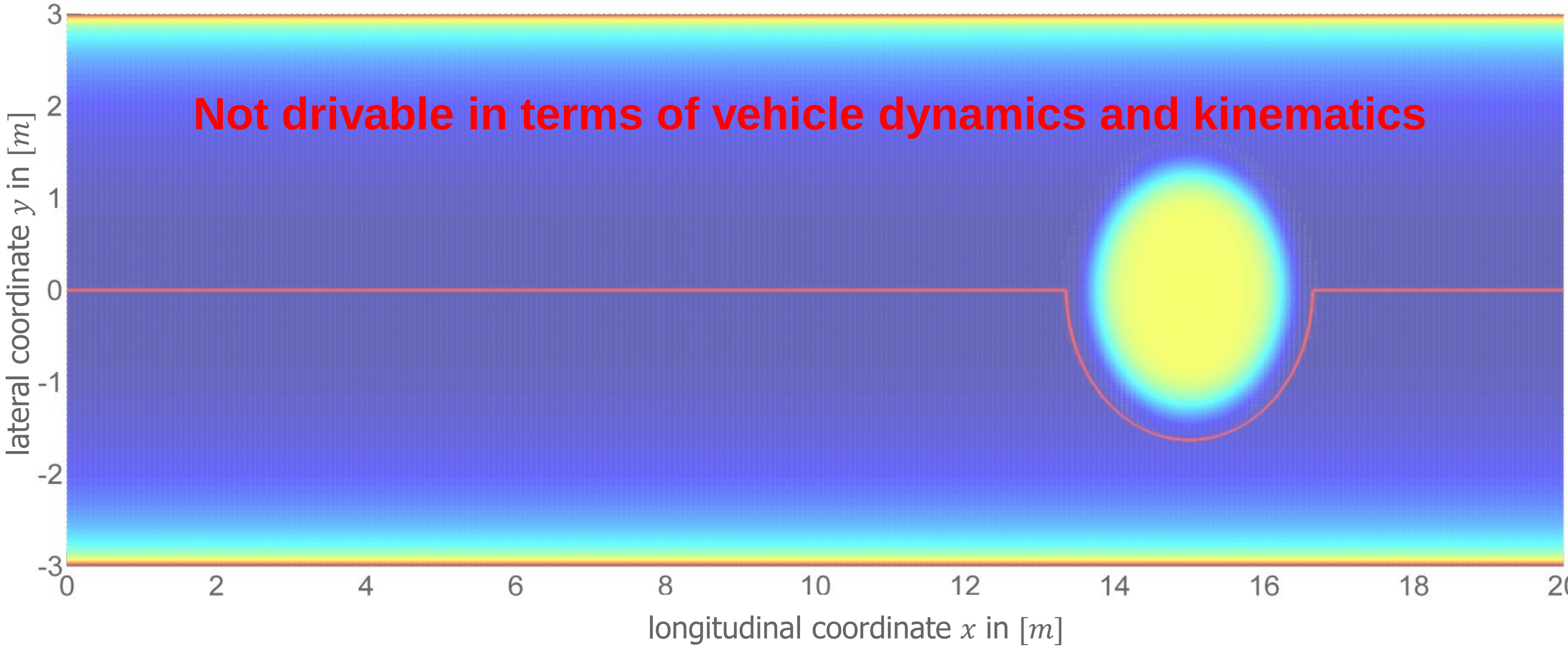

PRORETA

Trajectory Planning PRORETA 3 – Mathematical Formulation of the Lateral Problem

- Looking for the safest trajectory through the potential field for a finite, future horizon

subject to:

- kinematics and dynamics of the vehicle
- constraints of steering wheel angle and steering wheel angle rate

Looking for:

→ Valley (minimum) of the potential field

subject to:

→ dynamic vehicle model

→ input and state constraints

Semantic description of an optimal control problem

Trajectory Planning PRORETA 3 – Mathematical Formulation of the Lateral Problem

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$$\min J = \int_{t_0}^{t_0+T} \left(P_{\text{ges}}(\boldsymbol{x}_{\mathbf{F}}, \zeta) + \frac{1}{2} r \cdot u(\zeta)^2 \right) d\zeta$$

subject to:

$$\dot{\boldsymbol{x}}_{\boldsymbol{F}} = f(\boldsymbol{x}_{\boldsymbol{F}}, u)$$

$$\boldsymbol{g}(\boldsymbol{x}_{\mathbf{F}}, u) = \begin{pmatrix} |u(t)| \\ |\dot{\delta}_{\text{L}}(t)| \end{pmatrix} \leq \begin{pmatrix} \delta_{\text{L,max}} \\ \dot{\delta}_{\text{L,max}} \end{pmatrix}$$

$$\Downarrow$$

$$u_{\text{opt}}(\tau; t_0, \boldsymbol{x}_{\mathbf{F}}(t_0));$$
$$\boldsymbol{x}_{\mathbf{F,opt}}(\tau; t_0, \boldsymbol{x}_{\mathbf{F}}(t_0))$$

τ: time variable within time horizon $[t_0 \ \dots t_0 + T]$

Looking for:

→ Valley (minimum) of the potential field

subject to:

→ dynamic vehicle model

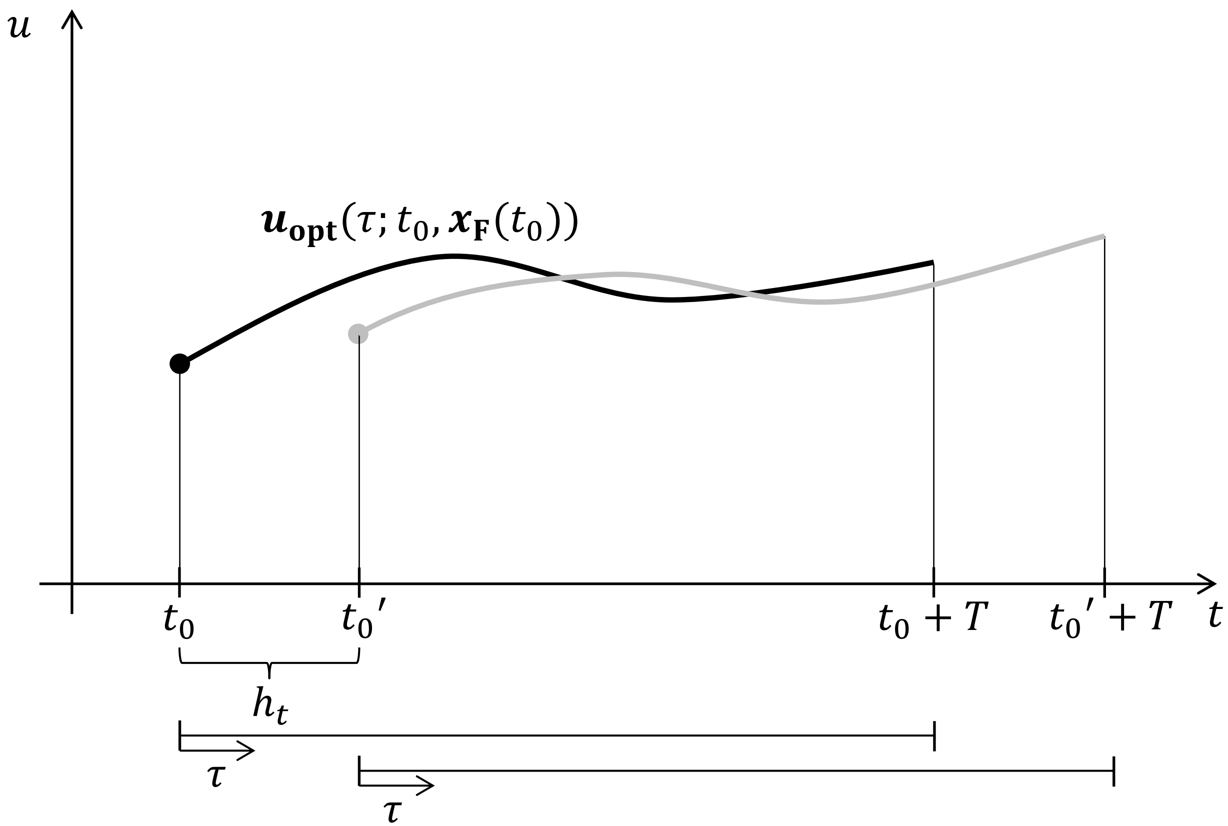
→ input and state constraints

Semantic description of an optimal control problem

PRORETA

Trajectory Planning PRORETA 3 – Formulation as a NMPC Problem

The optimal control problem is circularly solved with a variable $t_0 = t$, for example to regard prediction errors of dynamic obstacles



Trajectory Planning PRORETA 3 – Formulation as a NMPC Problem

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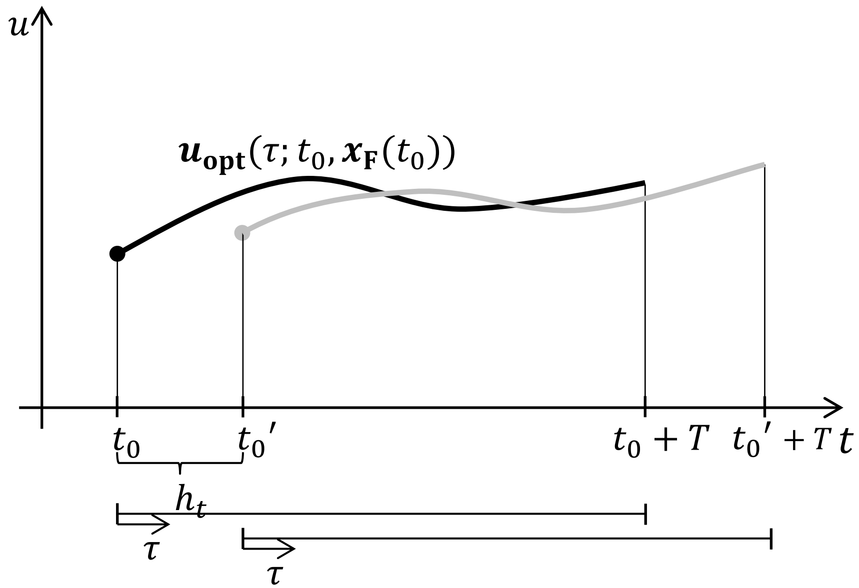
The optimal control problem is circularly solved with a variable $t_0 = t$, for example to regard prediction errors of dynamic obstacles

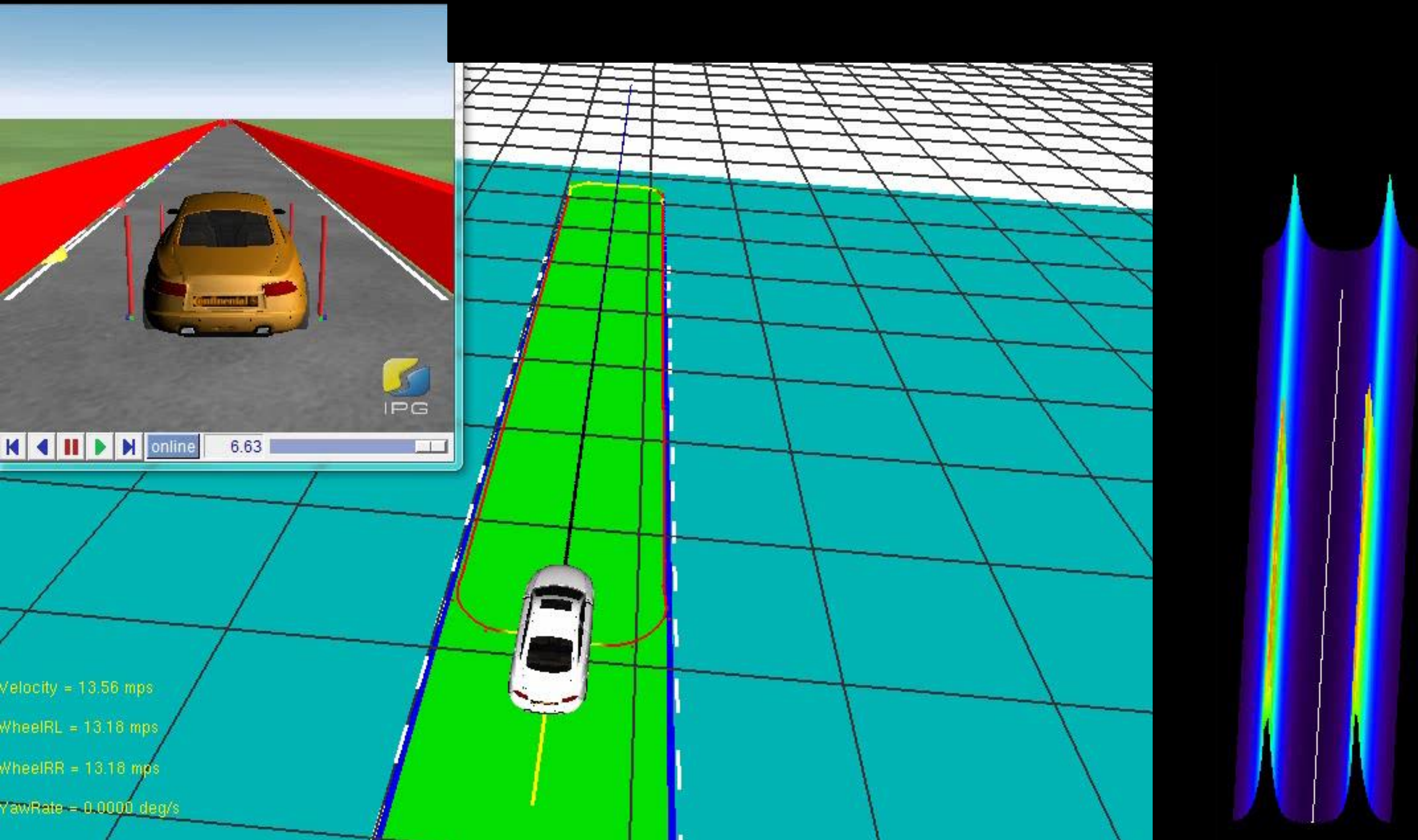


Nonlinear model predictive control problem:

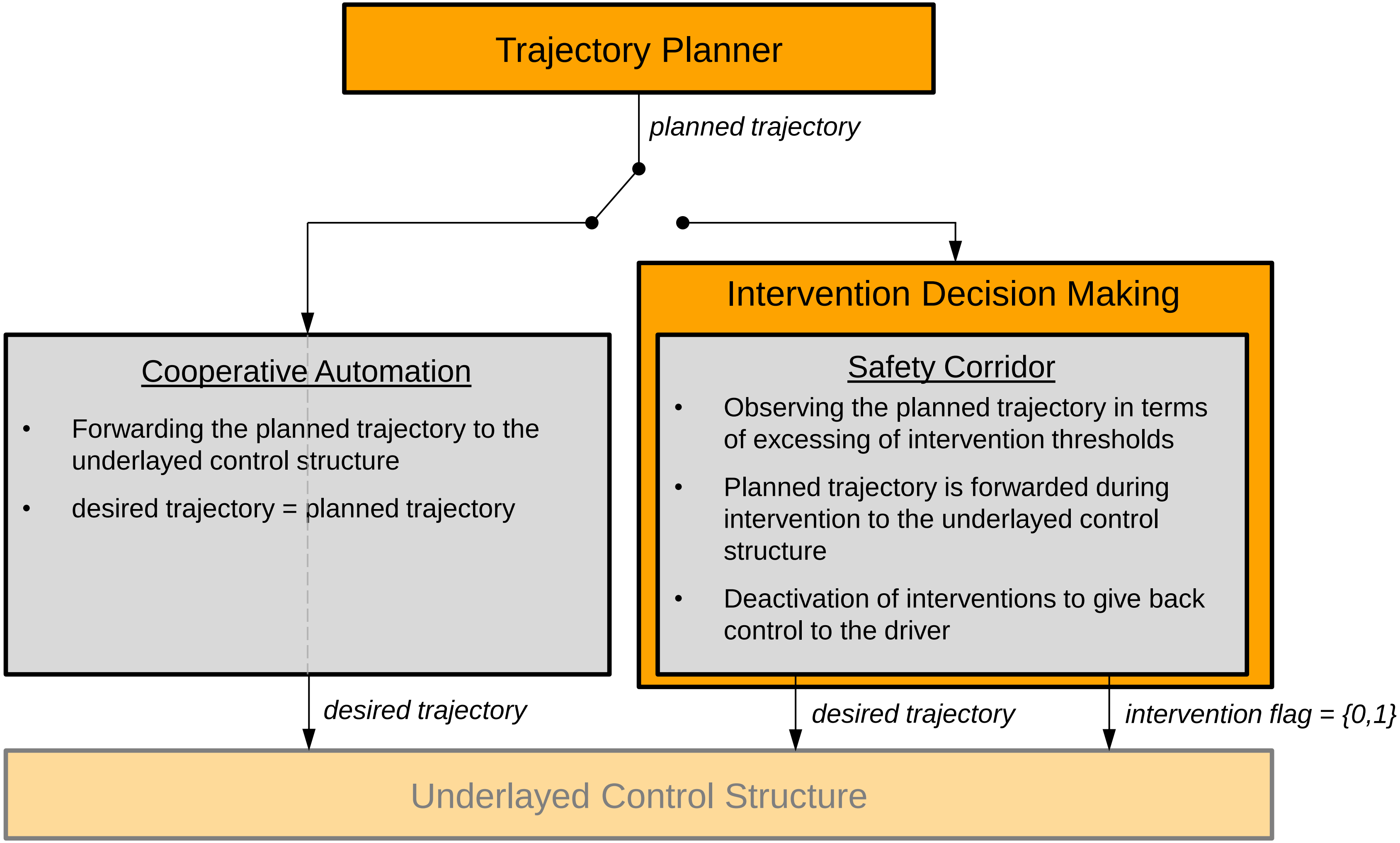
- Nonlinear cost functional
- Nonlinear dynamic model
- Linear constraints
- No terminal state constraints and no terminal costs

Used solver:

C/GMRES method [*Ohtsuka04*]


IPG
online
6.63
Velocity = 13.56 mps
WheelRL = 13.18 mps
WheelRR = 13.18 mps
YawRate = 0.0000 deg/s

Trajectory Planning PRORETA 3 – Decision Making for Interventions



Trajectory Planning PRORETA 3 – Conclusion

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- Modular generation of potential fields based on the proposed world model
- Presentation of a real-time capable, model predictive trajectory planning approach by using potential fields
- Planned trajectory can be used for Cooperative Automation and Safety Corridor
- Cooperative Automation: Regarding driver-selected desired maneuvers, e.g. a lane change maneuver
- Safety Corridor: Presentation of an intervention decision making by using the planned trajectory