

# Model Predictive Robustness of Signal Temporal Logic Predicates

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## I. Robustness of Signal Temporal Logic

Signal temporal logic (STL) allows one to specify safety properties and unambiguous tasks for a system over time:

- **Boolean Evaluation:** determining whether a signal of the system meets a given temporal specification ( $> 0$ : satisfaction;  $< 0$ : violation)
- **Robustness Degree:** offering a continuous measure of how much a signal fulfills or violates the specification

## II. Model-Free Robustness [1]

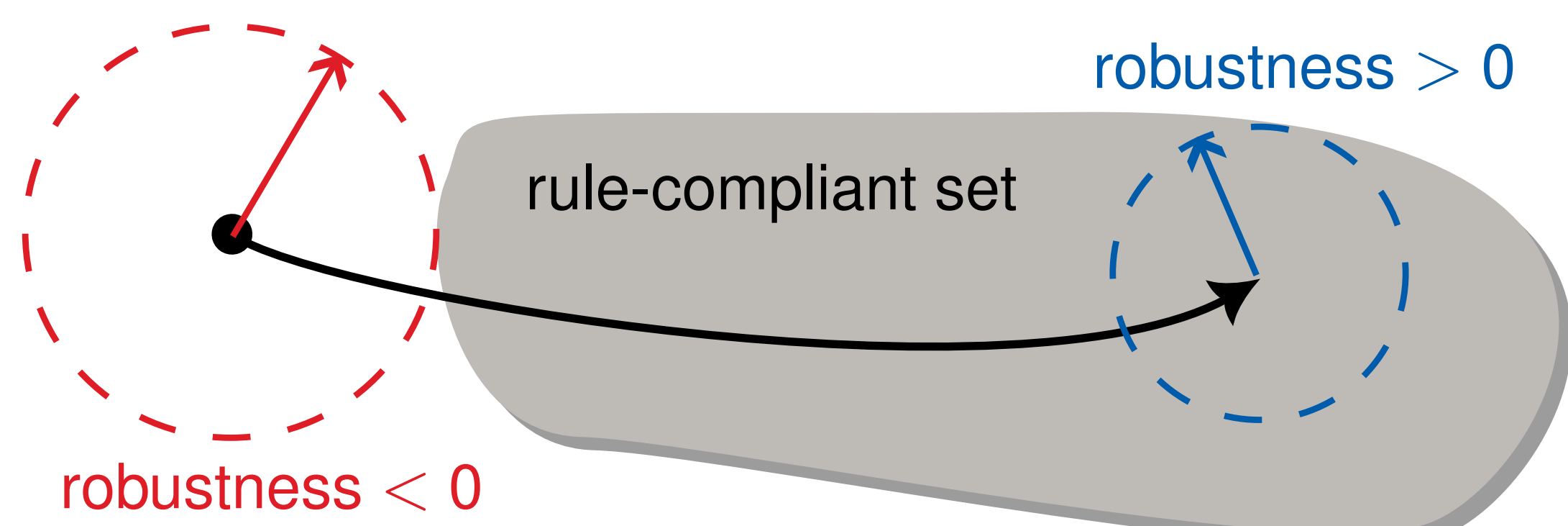
- closest distance to the satisfaction or violation boundaries
- without considering the underlying system dynamics

STL formula

predicates

temporal operators

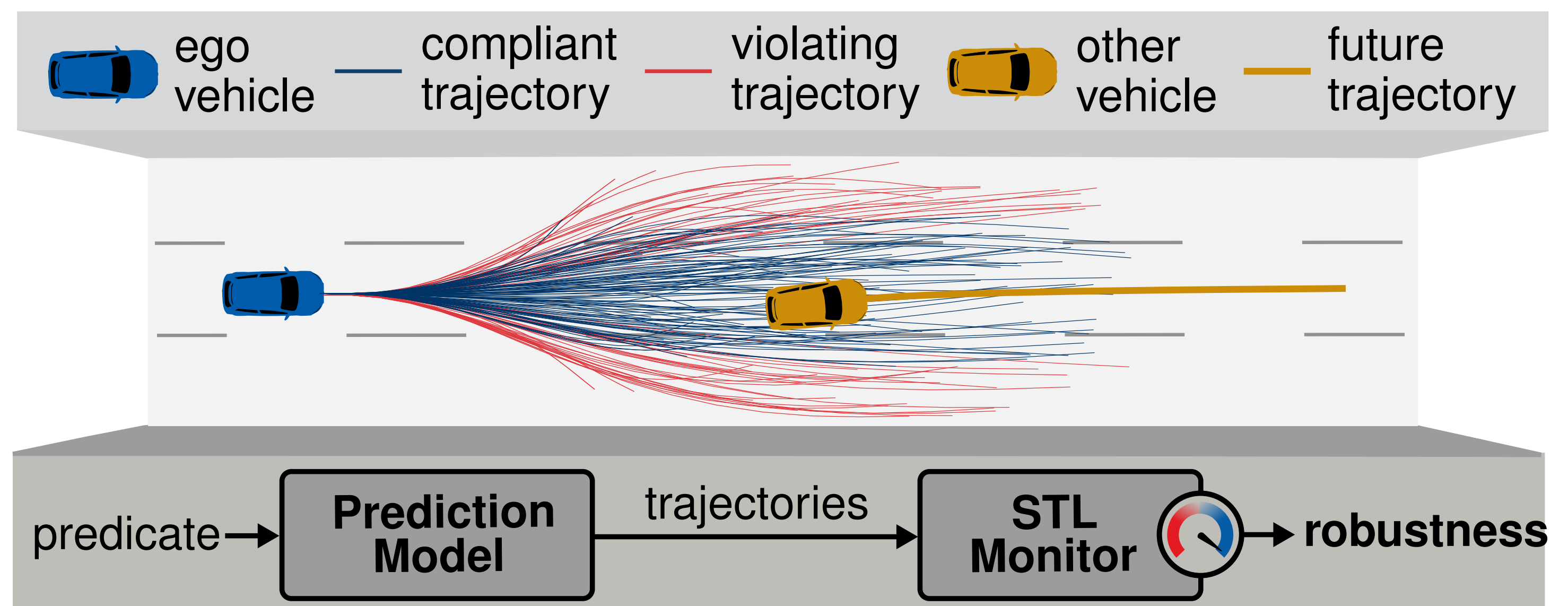
logical connectives



→ formulating a precise robustness definition in a unified way is challenging

## III. Model Predictive Robustness

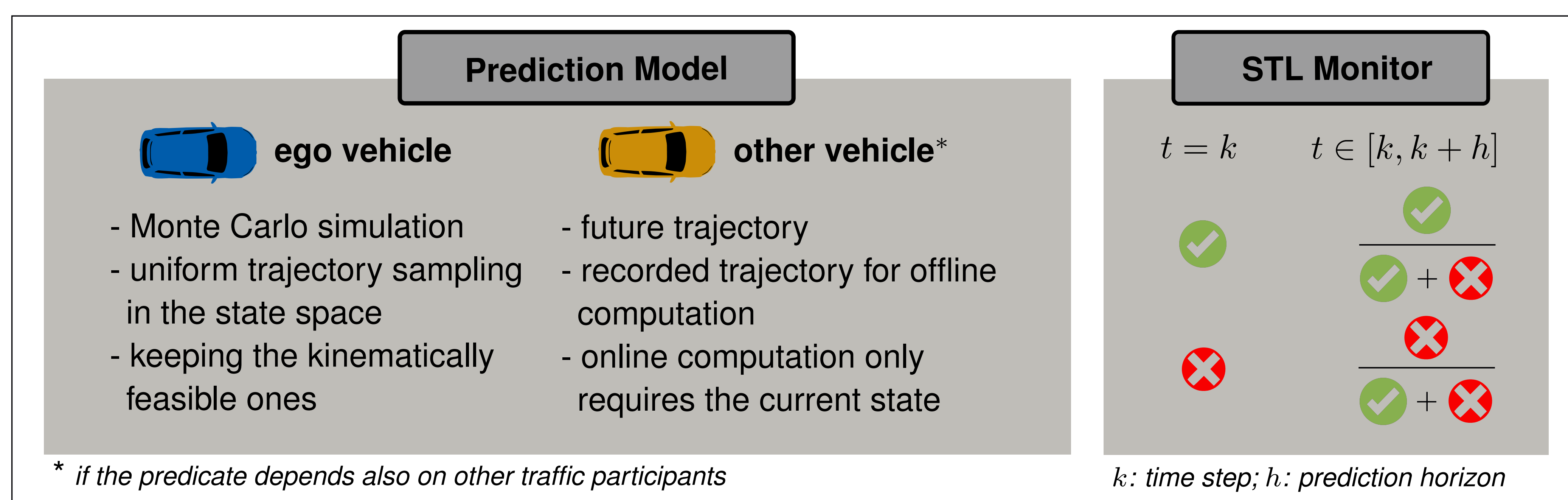
- considers the probability that the compliance is unchanged over a finite prediction horizon



Scheme of model predictive robustness computation for IN\_SAME\_LANE.

## IV. Offline and Online Computation

Offline



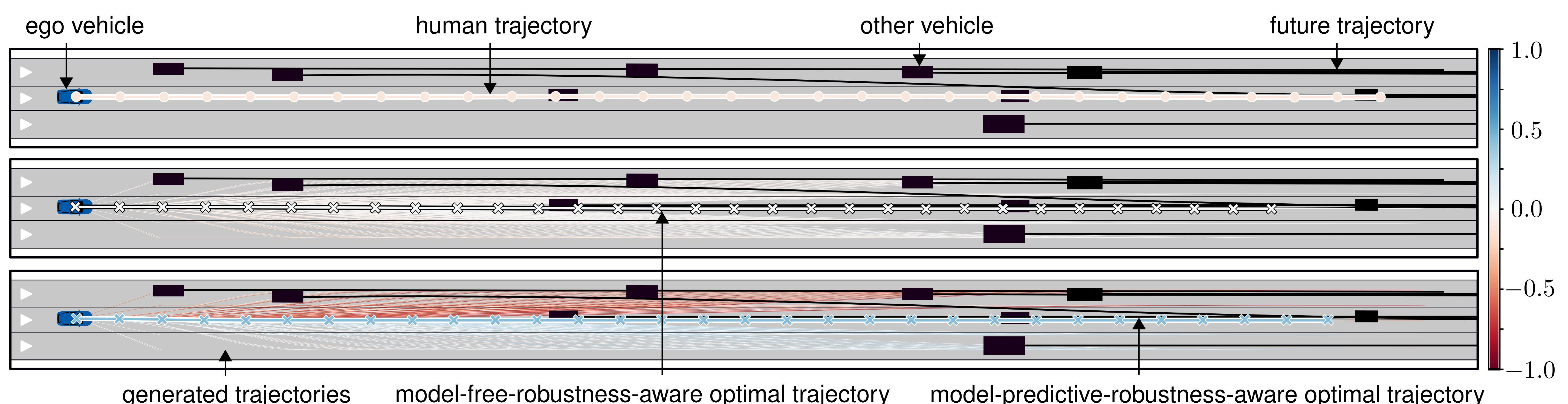
\* if the predicate depends also on other traffic participants

$k$ : time step;  $h$ : prediction horizon

Online

## V. Numerical Experiments

**Property:** Soundness ✓ Smoothness ✓ Monotonicity ✓  
⇒ facilitates the robustness awareness of trajectory planning using a sampling-based planner (integrating the robustness of rules into the cost function)



**Rules [1]:** Safe distance to preceding vehicle; Unnecessary braking; Maximum speed limit.

**References:**

- [1] L. Gressenbuch and M. Althoff, "Predictive monitoring of traffic rules," in Proc. IEEE Int. Conf. Intell. Transp. Syst., 2021, pp. 915–922.
- [2] C. E. Rasmussen and C. K. Williams, Gaussian Processes for Machine Learning. Cambridge, MA, USA: MIT Press, 2006.