KI WISSEN
Automotive AI Powered by Knowledge

2.7 Causality-Driven Checks of the Physical Conformity of Vehicle Trajectories

Himanshu Agarwal, Christian Brunner | e:fs TechHub GmbH

Trajectory Prediction and Motion Planning

Causal Model for Conformity Checks

Our concept (cf. Figure 1) has been designed for UC2: Complex Lane Change. The conformity check methods can be used to detect physically implausible vehicle trajectories.

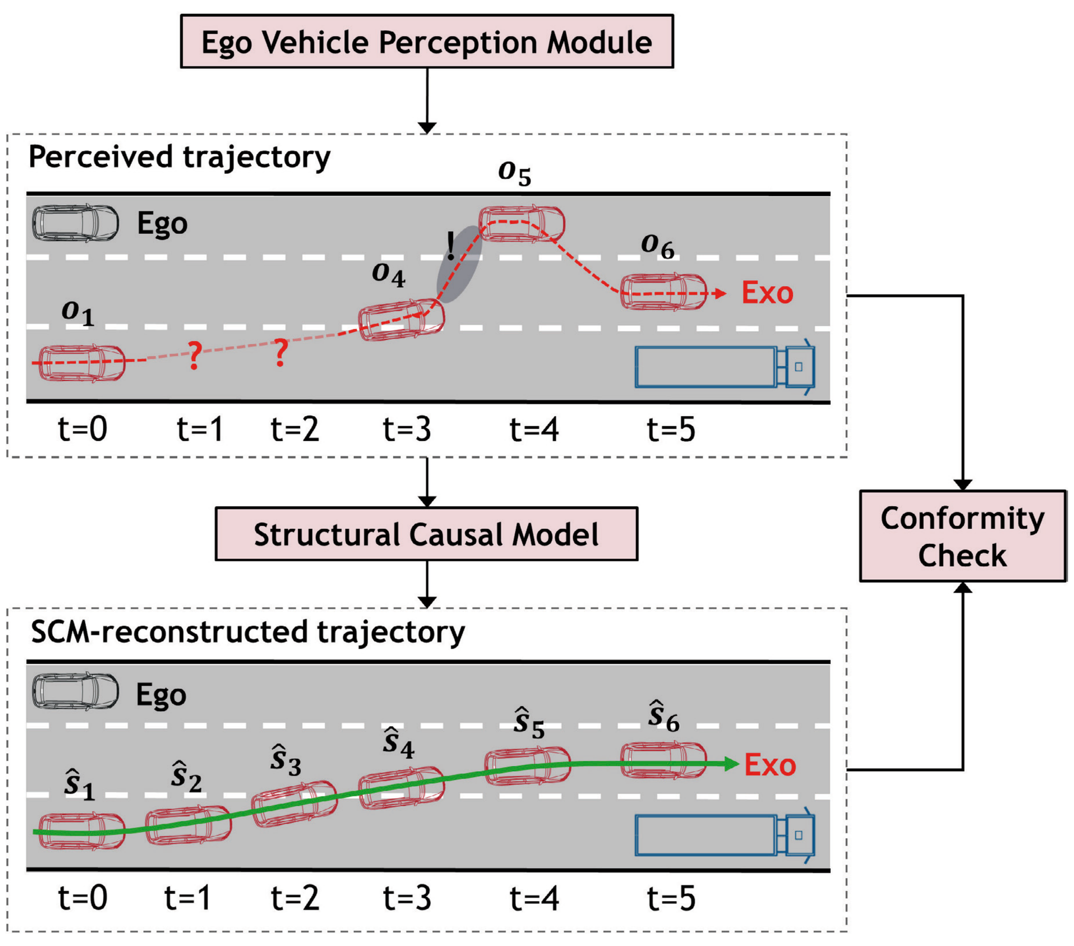

Figure 1: Conformity check concept to detect physically implausible vehicle trajectories. (© e:fs TechHub GmbH, adapted from [1])

Vehicle Dynamics as Structural Causal Model

Our structural causal model (SCM) for vehicle trajectories is illustrated in Figure 2. The vehicle dynamics model, i.e., Circle Model M is used to compute the next state, using the previous state and action, ensuring the laws of physics are obeyed. The guide provides posterior approximation of the state-action pairs $(\hat{s}_t, \hat{a}_t)$ at every time step conditioned on the entire sequence of observations.

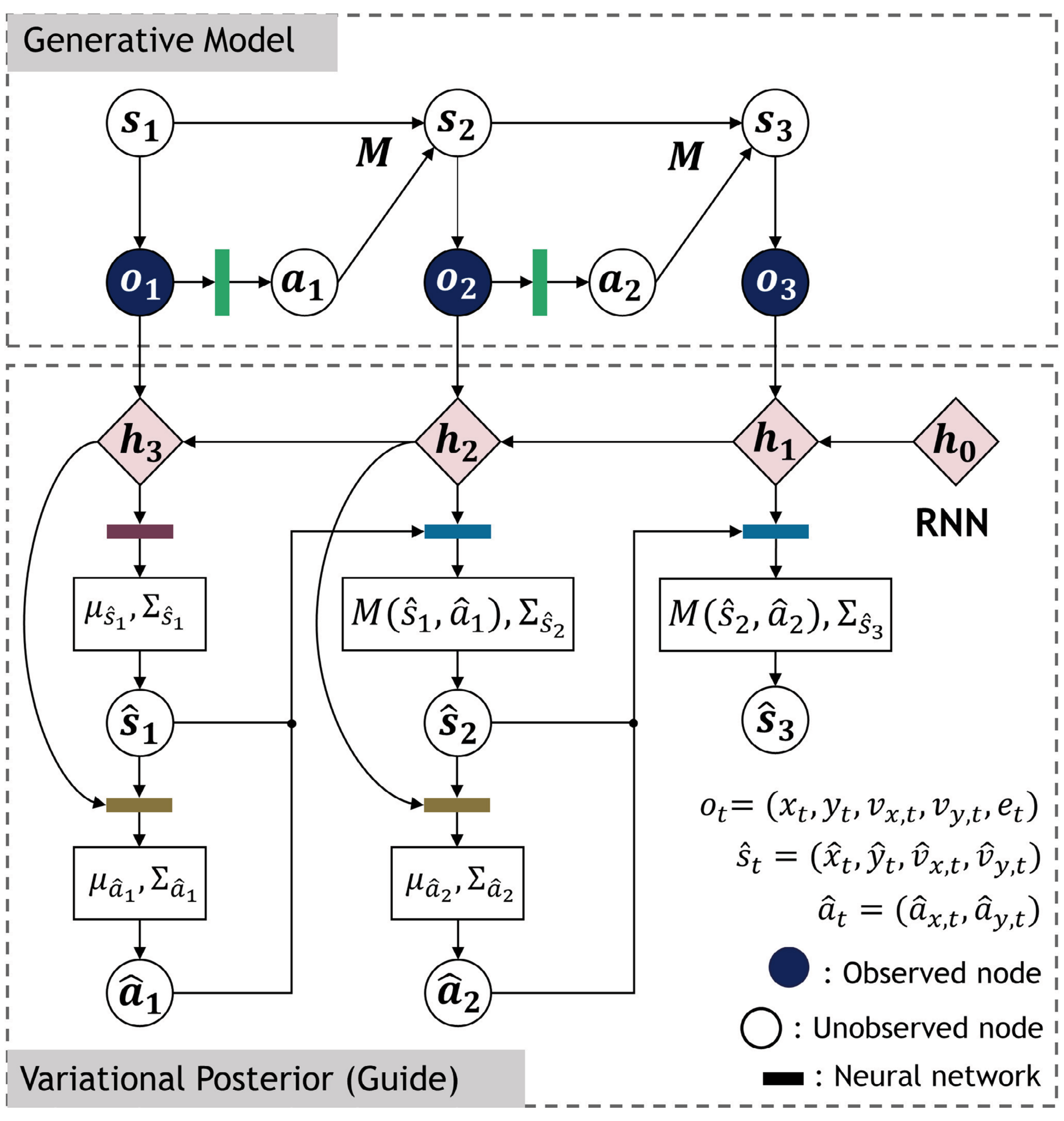

Figure 2: Schematic representation of the Vehicle-SCM for vehicle trajectories. (© e:fs TechHub GmbH, adapted from [1])

Conformity Check Methods

Our methods M1 and M2 (cf. Table 1) aim at reconstructing the perceived trajectory using the SCM. If the SCM is not able to reconstruct the trajectory, it will be reported as non-conform (cf. Figure 3). The method M3 checks the accelerations against realistic thresholds.

Table 1: Overview of the conformity check methods

M1	Measures the Euclidean distance between poitions from the input and the reconstructed trajectory.
M2	Measures the Mahalanobis distance between the observed state s_t and the SCM-estimated posterior distribution $q(s_t)$.
M3	Checks if longitudinal and lateral acceleration computed via *Circle Model* conform to realistic thresholds (obtained via expert survey).

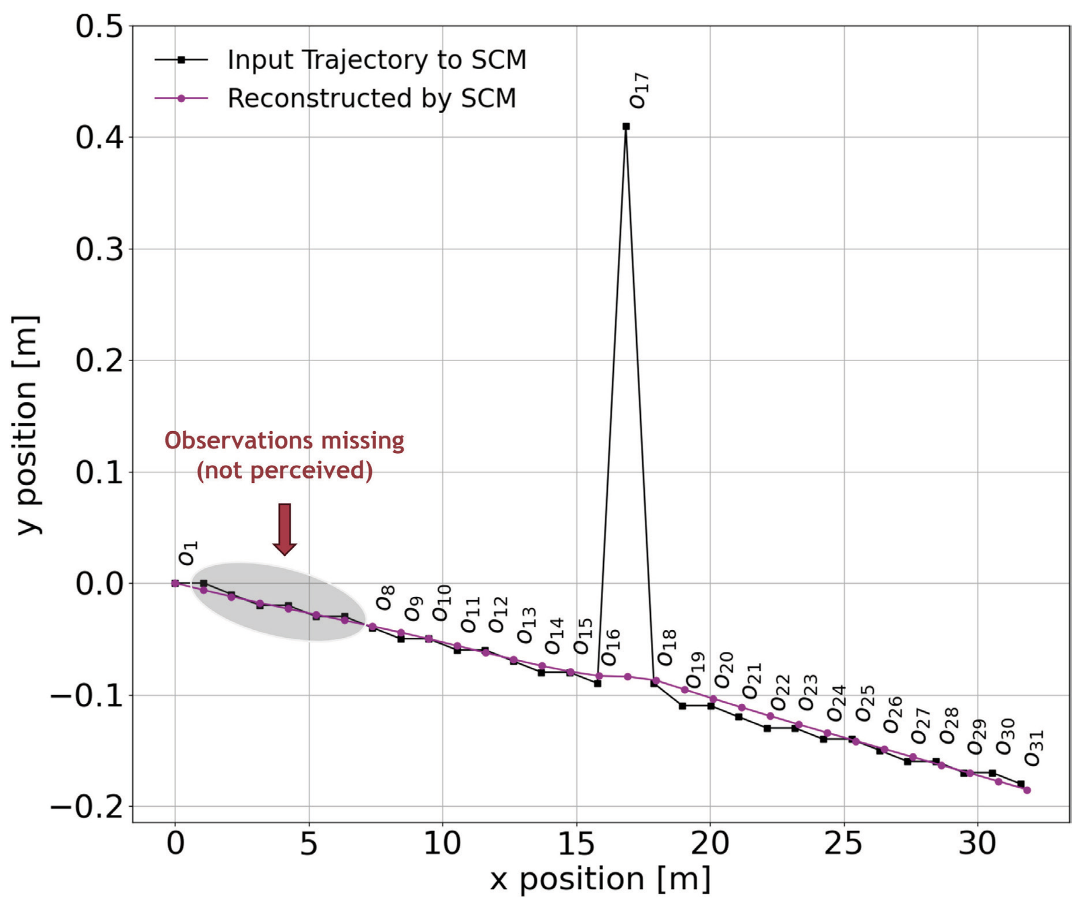

Figure 3: SCM reconstruction of a physically non-conform vehicle trajectory with missing observations o_2 to o_7. (© e:fs TechHub GmbH)

Evaluation

We evaluate our methods on non-conform trajectories obtained by adding artificial perturbations to the real-world observations. The results are summarized in Figure 4 and 5.

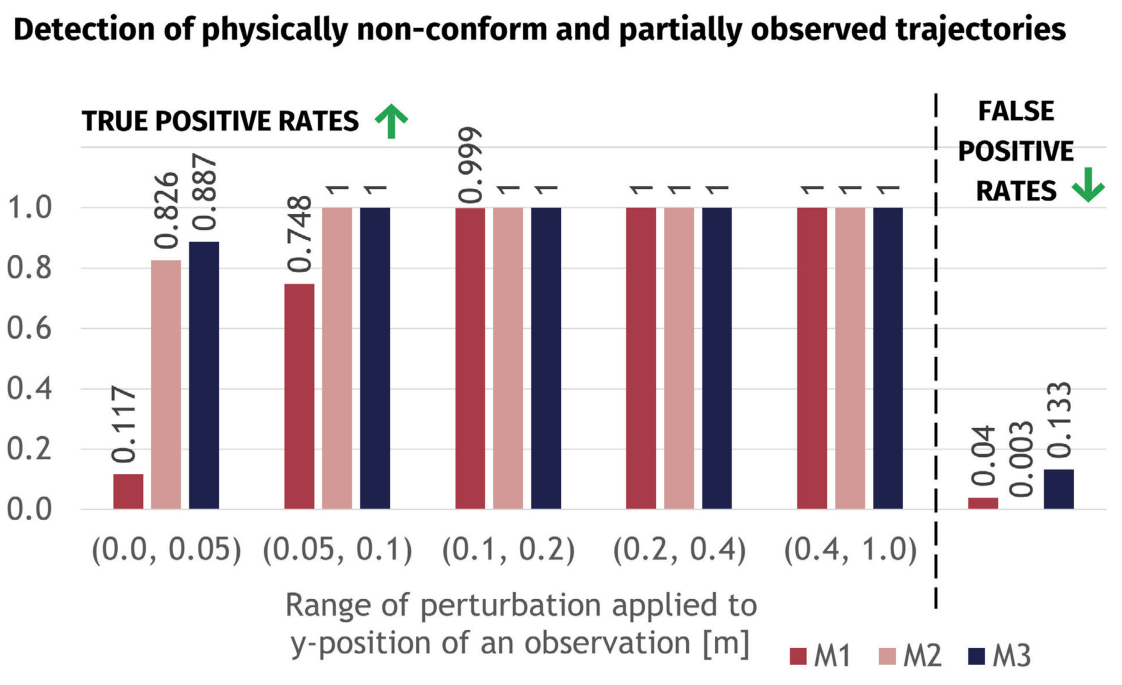

Figure 4: Conformity checks on trajectories with 50% missing observations. SCM parameters: trajectory length = 31 and sampling time = 40 ms. (© e:fs TechHub GmbH)

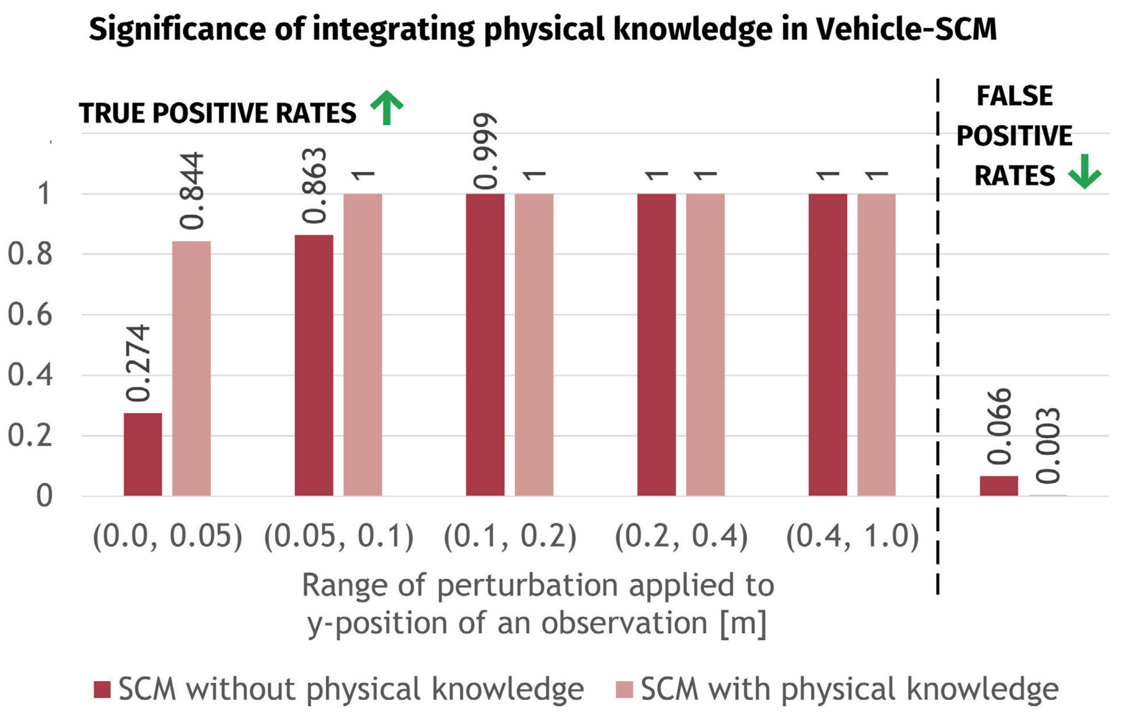

Figure 5: Comparison of SCM with and without integrating physical knowledge. Experiment setup: conformity checks on complete vehicle trajectories using method M2. (© e:fs TechHub GmbH)

Reference:

[1] Agarwal, Brunner, Latka, Rudolph: A Causal Model for Physics-Conform Vehicle Trajectories. In IEEE ITSC, 2023.

Partners

External partners

For more information contact:

himanshu.agarwal@efs-techhub.com
christian.brunner@efs-techhub.com

KI Wissen is a project of the KI Familie. It was initiated and developed by the VDA Leitinitiative autonomous and connected driving and is funded by the Federal Ministry for Economic Affairs and Climate Action.

Funded by the European Union NextGenerationEU

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag