KI WISSEN
Automotive AI Powered by Knowledge

3.11 Monitoring Traffic Rule Conformance and Integrated Knowledge Impact

Esra Acar-Celik, Stefan Matthes, Xiangzhong Liu | fortiss GmbH

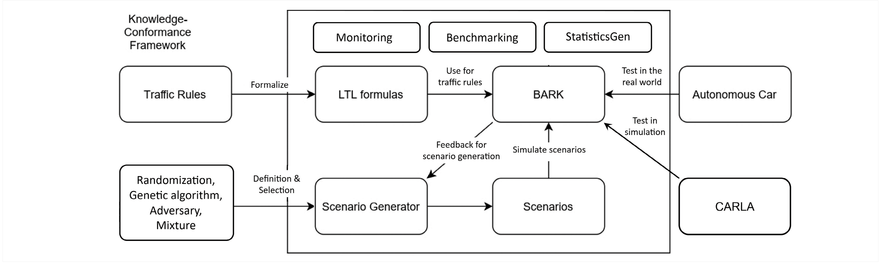

Figure 1: An overview of the "Knowledge Conformance Framework" (©fortiss GmbH)

Motivation

- Simplify the integration of diverse knowledge sources (e.g., traffic rules and map information) for machine learning-based motion planning.
- Automate the runtime verification of knowledge conformity during both training and evaluation.
- Demonstrate the effect of knowledge integration for machine learning models more clearly.

Solution

We have developed a "Knowledge Conformance Framework", as illustrated in Figure 1, which facilitates the development and testing of trajectory/behavior planning algorithms in three dimensions:

- Pre-defined system metrics ensuring knowledge conformance
- Achievable scenario complexity and data efficiency
- Generalization capability in both photorealistic simulator and real world

Traffic rules are formalized as knowledge into two types of temporal logic: Linear Temporal Logic (LTL) and Signal Temporal Logic (STL), with STL quantifying the probability of rule violations by evaluating formula robustness.

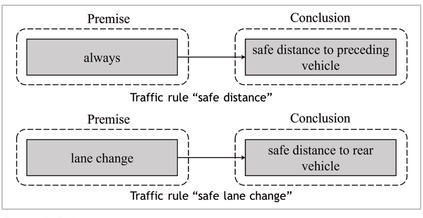

Figure 2: Safe distance and safe lane change rules in the format of premise-conclusion (©fortiss GmbH)

Scenario generation:

- Domain randomization
- Mixture with real-world recording
- Genetic algorithms and adversarial optimization for critical cases

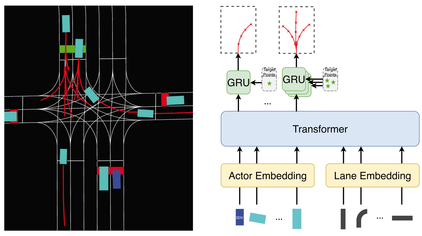

Figure 3: Integration of map knowledge (©fortiss GmbH)

Motion planning with knowledge-enhanced machine learning methods:

- Deep Reinforcement Learning (DRL) for behavior planning
  - Learn a behavior policy by maximizing rewards
  - TL integrated as a sparse reward
- Map-enhanced Imitation Learning
  - Feed lane embeddings into the model
  - Extract reachable target points to condition trajectory prediction

Results

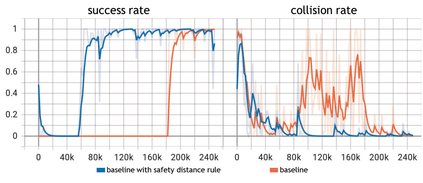

Figure 4: Evaluation results of RL agents with and without integration of traffic rules (©fortiss GmbH)

- The integration of traffic rules significantly accelerates DRL training and stabilizes model performance.
- Combining synthetic scenarios with real-world records enhances the robustness of DRL in both simulation and real world.
- The framework enables real-time monitoring of the conformance of multiple traffic rules.
- Integrated map knowledge significantly improves driving score on CARLA benchmark.

Formal Methods and Knowledge Representation

Partners

External partners

For more information contact:
acarcelik@fortiss.org
matthes@fortiss.org
xliu@fortiss.org

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