
A Modular, Real-Time Framework for Interpretable Scene-Level Reliability in Autonomous Vehicle Perception

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Abstract

Autonomous driving perception degrades under adverse conditions such as fog, rain, snow, and glare, where failures often co-occur and are difficult to diagnose at the system level. We introduce a modular framework for estimating scene-level reliability that aggregates perception outputs and environmental signals into a global reliability score, along with attribution to likely degradation factors. Unlike per-prediction uncertainty methods, the proposed approach represents reliability as a decomposition over semantically interpretable components at the scene level. The architecture separates perception, environmental inference, and aggregation modules through a fixed interface, allowing components to be replaced without redesigning the aggregation logic. We implement the framework in a real-time system that produces structured outputs and visualizations to support failure analysis, safety monitoring, and debugging.