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HYBRID FUZZY INFERENCE SYSTEMS AND INTERACTING MULTIPLE-MODEL EXTENDED KALMAN FILTER FOR LONGITUDINAL-LATERAL CONTROL OF AUTONOMOUS VEHICLES IN DIVERSE DRIVING SCENARIOS

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Abstract:
This paper proposes a hybrid control framework that integrates an interacting multiple-model extended Kalman filter (IMM–EKF) with four mode-specific fuzzy inference systems (FIS) for longitudinal and lateral control of autonomous vehicles. The objective is to improve safety, efficiency, and comfort across unsignalized intersections, road curves, vehicle-following, and overtaking scenarios. The system fuses camera, radar, and lidar measurements at 20 Hz, generating 1–3 s trajectory predictions using an IMM–EKF. A scenario manager classifies the driving context and activates one of four FIS modules that issue throttle, brake, and steering commands. We evaluated the approach in Webots using 200 Monte Carlo trials per scenario and compared it to FIS-only, PID with pure-pursuit, and model-predictive control baselines. The hybrid controller reduced aggregate collision events by approximately 25% and improved travel efficiency by approximately 30% versus the FIS-only baseline. The hybrid approach also reduced RMS lateral error and longitudinal jerk, achieving higher safe-overtaking success rates. Statistical tests confirmed that travel-time and lateral-error improvements were significant ($p < 0.01$) after correction for multiple comparisons. IMM–EKF model confidences improved decision timing and reduced unsafe lane-change intents under moderate uncertainty. The proposed architecture is scalable and interpretable. However, it merits further real-world validation.

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Keywords: Autonomous vehicles, hybrid control framework, interacting multi-model kalman filter, fuzzy inference system, longitudinal-lateral control

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