

Detection of Driver's Unusual Latent Awareness Based on Dynamic Estimation of Preview Point

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Recently, driver monitoring systems (DMS) estimating driver conditions from explicit behaviors, such as smartphone use, have gained attention for accident prevention⁽¹⁾. Additionally, methods like Real-time Steering Entropy (RSE) and Risk Feeling (RF) quantify lateral and longitudinal driving loads based on vehicle behavior⁽²⁻³⁾. However, relying entirely on observable physical quantities, RSE and RF only evaluate behaviors after they manifest, struggling to capture the underlying "latent awareness." Early detection of this latent awareness—the pre-disease stage before dangerous driving occurs—is essential. Thus, we propose a methodology using entropy to evaluate both longitudinal and lateral behaviors to detect unusual latent states.

Experiments utilized a 10-car cooperative driving simulator to measure multi-vehicle interactions. The scenario forced a right lane change due to a blockage in the first lane. Ten male participants in their 20s (ID 0–9) performed multiple trials in congested and non-congested scenarios. This experiment was approved by the Research Ethics Committee of the Faculty of Science and Engineering and the Graduate School of Science and Engineering, Toyo University, and was conducted after obtaining written informed consent from the participants.

This study adopts the Preview Driver Model (PDM)⁽⁴⁾, which performs target tracking based on the deviation between a preview point and a target trajectory. The front wheel steering angle δ is defined using vehicle speed, yaw rate, and five parameters representing latent awareness, including preview time T and target point lateral position y_r . Since DMS cannot directly measure these, we formulated a state-space model and utilized a Dual Particle Filter (DPF)⁽⁵⁾ for dynamic online estimation. Results showed that across all trials, errors between reproduced and measured steering angles fell within 1.0×10^{-4} rad in 97.03% of cases, validating estimation accuracy.

We introduce Real-time Awareness Entropy (RAE) to quantify potential cognitive load by replacing the steering angle input in the conventional RSE method with DPF-estimated parameters (T and y_r). RAE is calculated by extracting prediction errors, updating probability density distributions, and computing relative entropy when cognitive load occurs simultaneously in both directions. Figure 1 shows the validation results, taking participant ID 7 as an example. During normal driving where RSE remains below its threshold, RAE successfully detects unusual fluctuations in latent awareness. Notably, RAE's reaction timing precedes RF peaks, demonstrating its ability to capture unusual latent awareness before risk behaviors become explicit.

In contrast to conventional monitoring methods that depend heavily on physical indicators, the approach proposed in this study successfully quantifies a driver's latent awareness by estimating unobservable cognitive parameters. Our experimental validations clearly indicate that the RAE method can detect unusual latent awareness prior to any unsafe physical actions—a critical capability that cannot be adequately achieved by existing RSE and RF techniques. Future work requires detailed verification to determine whether the detected latent awareness can be genuinely classified as true unsafe awareness.

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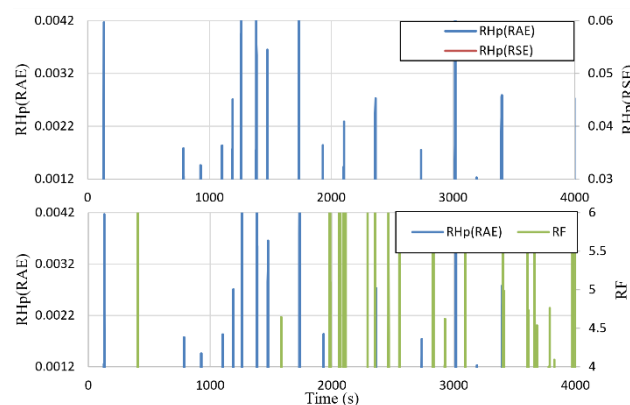


Fig. 1 Comparison of RAE with RSE and RF