

Right-Turn Decision Support Based on Stochastic Prediction of Traffic Scenarios at Multi-Lane Intersections

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When making a right turn across oncoming traffic, drivers need to select an appropriate turning opportunity while considering the trade-off between safety margin and waiting time. However, in multi-lane traffic environments, future gaps cannot be uniquely determined because the route intentions of oncoming vehicles are uncertain. Therefore, this study proposes a right-turn decision support method that performs stochastic prediction of the states and route intentions of oncoming vehicles, generates multiple future traffic scenarios, and determines whether to turn at the current opportunity or wait for a better future opportunity.

The target environment is a signalized intersection with two general-purpose lanes and one dedicated right-turn lane for oncoming traffic. A roadside sensor measures the position, velocity, and traveling lane of each oncoming vehicle. Longitudinal vehicle behavior is modeled using the Intelligent Driver Model, and vehicle position, velocity, and desired velocity are sequentially estimated using a particle filter. In addition, each oncoming vehicle is assigned either a through or right-turn route mode, and its route intention is sampled according to conditional route-choice probabilities based on the current lane and observed lane-change information. This enables the generation of multiple future traffic scenarios that account for uncertainties in both vehicle states and route intentions.

In each scenario, the time intervals during which oncoming vehicles occupy the conflict area with the host vehicle are predicted, and the unoccupied time intervals are extracted as gaps. The value of each gap is evaluated using a driver utility function based on the Post-Encroachment Time (PET), which represents the safety margin, and the waiting time:

$$J(q) = U_{\text{safe}}(\text{PET}_q) - \alpha T_{\text{wait},q}$$

For the current right-turn opportunity, the expected utility R_{current} is calculated over all scenarios. Since future gap configurations differ among scenarios, individual future gaps cannot be directly matched across scenarios. When the driver waits, the right-turn opportunity can be selected according to the traffic situation that is subsequently realized. Therefore, for the waiting option, the maximum utility among future gaps is obtained in each scenario, and its expected value is defined as R_{future} . A right turn is recommended when the current gap satisfies the required safety probability and $R_{\text{current}} \geq R_{\text{future}}$; otherwise, waiting is recommended.

Numerical simulations were conducted with 1,000 trials for each condition, and the proposed method was compared with a fixed-threshold method that evaluates only the current gap. The results showed that the proposed method tended to achieve shorter average waiting times while maintaining larger average PET values than the fixed-threshold method, indicating an improved trade-off between safety margin and waiting time. In addition, considering route-intention uncertainty in the stochastic prediction improved driver utility compared with assuming that all oncoming vehicles travel straight. These results demonstrate that evaluating future right-turn opportunities under multiple possible traffic scenarios can improve the trade-off between safety margin and waiting time.

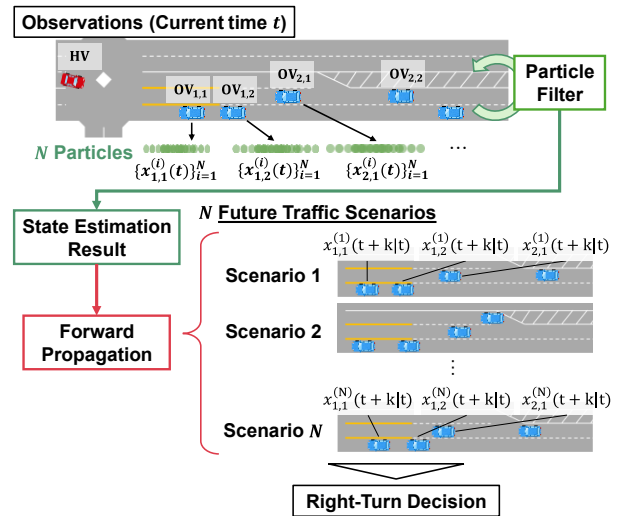


Fig.1 Overview of the Right-Turn Decision Support Framework

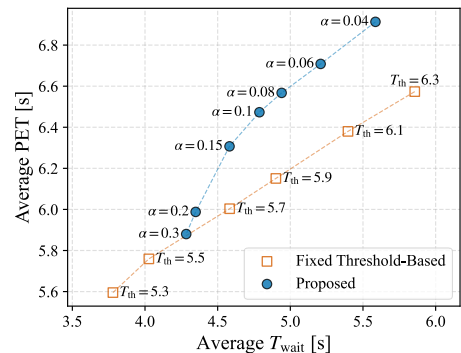


Fig.2 Trade-off between Average Waiting Time and Average PET