

Evaluation of Computational Cost Reduction by Introducing a Monitoring Function into Combinatorial-Optimization-Based Trajectory Planning for Highway Merging Scenarios

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Highway merging is a challenging task for automated driving systems because safe merging requires prediction of surrounding vehicle behavior and selection of an appropriate merge gap. In our previous work, we developed a trajectory planning method based on combinatorial optimization, and demonstrated its effectiveness in highway merging scenarios using simulations based on real-world traffic data. To enable the ego vehicle to safely merge into the selected gap, merging plans for the ego vehicle (Fig. 1) with predictions of the other vehicles on the main road are generated by solving a large-scale combinatorial optimization problem using an Ising-machine-based optimization framework. Although the approach provides high-quality planning results, repeated trajectory replanning can increase computational cost, which may become a challenge for implementation on practical automotive computing platforms. The simulation setup is identical to that used in our previous presentation, and the highway traffic data collected around the Ohama entrance of the Hanshin Expressway (Fig. 2) are used.

To reduce this computational cost, we first introduce a monitoring-based planning framework. In this framework, full-scale planning is initially performed in the same manner as in the previous method, and the two vehicles adjacent to the selected merge gap (denoted as Vehicles A and B) are monitored. Instead of repeatedly performing full-scale planning, the proposed monitoring function continuously compares the actual motions of vehicles A and B with their predicted trajectories obtained from the latest planning result. Replanning is triggered only when a significant deviation is detected, thereby reducing unnecessary optimization calculations.

In addition, we propose an A/B-vehicle-based planning (AB merge plan) strategy for further computational cost reduction. When replanning becomes necessary, only Vehicles A and B are considered if the gap between them expands. Full-scale planning is performed only when the selected merge gap tends to shrink. By restricting the optimization problem to the vehicles most relevant to the selected merge gap, the search space can be significantly reduced.

The results show that the proposed monitoring framework decreases the number of replanning operations compared with conventional repeated planning (Fig.3). Furthermore, the AB planning strategy substantially reduces computational cost. The computational cost of AB

planning is approximately 8.2% of the computational cost of full-scale planning, and the total computational time is expected to be reduced to approximately one-quarter of the baseline approach (Fig.4). These results demonstrate that the proposed monitoring-based framework can improve computational efficiency while maintaining trajectory planning quality for combinatorial-optimization-based highway merging applications.

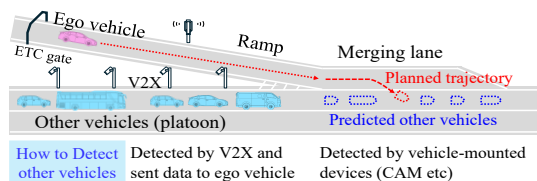


Fig.1 Highway merging scenarios

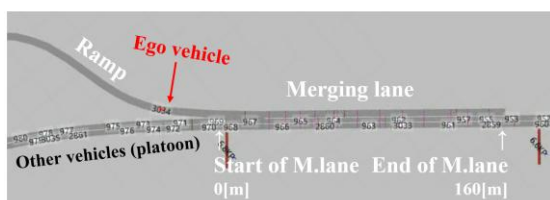


Fig. 3 schematic illustration of initial condition of SIM

	Repeat	Monitoring AB	AB Merge Plan	
	Normal plan	Normal plan	Normal plan	AB Merge plan
F001_3041	5	5	1	1
F002_2926	7	2	1	1
F003_3289	5	2	1	1
F003_3383	2	2	1	1

Table 1 Numbers of calculation times of merge plans.

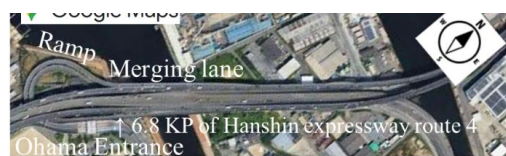


Fig.2 Target road for use case test

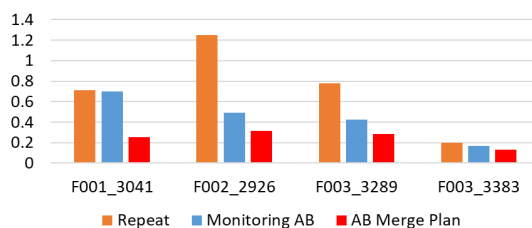


Fig. 4 Total computational cost [a.u.]