

Study on High-Precision Estimation Methods for Vehicle Trajectory Using Drive Recorder Video and 3D-LiDAR Data

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KEY WORDS: Safety, Drive recorder/Event data recorder, Accident reconstruction, Driving trajectory [C1]

Reliable vehicle trajectories are important for objective accident reconstruction. A previous EDR method estimated trajectory from vehicle speed and yaw rate, but absolute placement required two manually selected reference points, introducing analyst subjectivity. This study therefore estimates vehicle position and attitude by matching drive recorder images with an absolute-scale 3D-LiDAR point cloud, with the aim of improving accuracy and reproducibility and enabling parameter reuse across repeated drives on the same route.

COLMAP-PCD combines the relative-scale 3D reconstruction from drive recorder images with an absolute-scale LiDAR point cloud, allowing vehicle pose to be estimated in real scale. Because 236 calculation parameters are involved and are affected by surrounding landmarks, the study determined section-wise parameters from a repeated reference drive and then applied them to other drives on the same route. This approach assumes that repeated drives share similar roadside structures.

Five straight-through drives were performed at an urban intersection using a test vehicle with a vehicle-mounted monocular camera. Roadside 3D point clouds were measured with a 3D-LiDAR, and vehicle trajectories were measured independently by RTK-GPS. The route was divided into five partially overlapping sections (A–E); Drive ①, which showed the smallest error, was selected as the reference drive and its section-wise parameters were applied to Drives ②–⑤.

Figure 1 shows close agreement between the estimated and RTK-GPS trajectories for Drive ①. Table 1 gives the error statistics by section. Section C had the largest Mean Absolute Error (MAE) and standard Deviation (SD), 0.15 m and 0.12 m, with a maximum error of 0.34 m; the minimum error was 0.01 m.

Using Drive ① parameters for Drives ②–⑤, the largest MAE was 0.57 m in Section D of Drive ②, with an SD of 0.28 m. Among the 25 MAE values in Tables 1 and 2, about 92% were 0.5 m or less, indicating potential reuse of representative parameters on the same route when the required accuracy is appropriate.

The results demonstrate that appropriate parameter selection enables more accurate trajectory estimation than the previously reported level of about 1 m. The estimated trajectory can complement EDR- trajectory. Future work should address turning right or left at intersections, areas with few landmarks (rural region), semantic segmentation accuracy, and further parameter optimization.

Table1 Error Evaluation of the Estimated Trajectory (Drive①)

Section	Mean Error [m]	Standard Deviation [m]	Maximum [m]	Minimum [m]
A	0.10	0.06	0.18	0.01
B	0.15	0.06	0.31	0.08
C	0.15	0.12	0.34	0.01
D	0.07	0.06	0.17	0.01
E	0.05	0.03	0.08	0.01

Table2 Error Evaluation for Drive ②–⑤ using the parameters of Drive ①

Sec	Drive②		Drive③		Drive④		Drive⑤	
	MAE	SD	MAE	SD	MAE	SD	MAE	SD
A	0.18	0.09	0.36	0.11	0.28	0.09	0.18	0.10
B	0.43	0.11	0.22	0.06	0.06	0.04	0.06	0.04
C	0.18	0.10	0.21	0.14	0.13	0.09	0.20	0.12
D	0.57	0.28	0.56	0.37	0.28	0.19	0.14	0.08
E	0.14	0.11	0.22	0.06	0.27	0.09	0.14	0.09

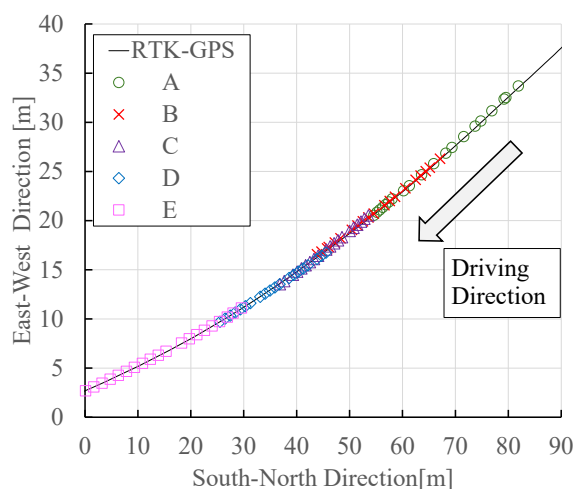


Fig.1 Estimated and RTK-GPS Trajectories (Drive①)