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Robustness Evaluation of Vehicle Localization in 3D Map Using Convergence of Scan Matching

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In this study, we propose a robustness evaluation method for vehicle localization using convergence of scan matching with the help of game engine based simulator for autonomous driving. Fig. 1 shows an overview of the proposed method. The proposed method first constructs a simulation environment from a 3D point cloud map and generates virtual sensor data by driving a vehicle in the simulation environment. Using the virtual sensor data, the robustness of the system is verified by performing localization that accounts for dead reckoning errors.

The method for creating a 3D model first classifies the 3D point cloud map into road surfaces and other buildings. Next, each point in the 3D point cloud map is replaced with a plane for road surfaces and a triangular prism for other surfaces, and each is transformed into a 3D model. By changing the shapes to be converted for road surfaces and other areas, it is possible to reduce the file size of the 3D model.

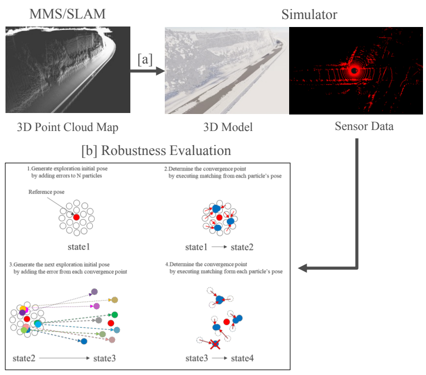
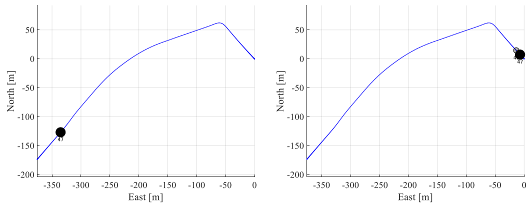


Fig.1 Overview of the proposed method

In robustness evaluation step, N particles are first created based on the reference pose. Next, NDT scan matching is performed on each particle in parallel with LiDAR data and a 3D point cloud map to estimate its position and orientation. In continuous scan matching, each particle is intentionally assigned an error based on a random normal distribution for its initial position and orientation, assuming that the initial position and orientation are not given correctly due to dead reckoning errors caused by road surface irregularities, friction, and wheel diameter changes. In the process of successive scan matching of each particle, if the error between the ground truth and the convergent position exceeds a threshold, the particle is considered to have failed in localization and the particle is deleted. The robustness of the localization at a point is quantified by determining the ratio of the remaining particles to the number N of particles in the previous step at each point in the series of runs.



a) longitudinal　　b) lateral

Fig.2 Vehicle trajectory and locations of particle disappearance

We confirmed that the proposed method of creating 3D models can generate 3D models with smaller file sizes than the usual method. It was also confirmed that sensor data generated using the 3D model was comparable to actual sensor data.

Fig. 2 shows the results of the longitudinal and lateral localization evaluation using this method. The trajectory is shown by a blue line, and the areas where the number of particles decreased are indicated by black circles. As shown in this figure, by checking where particles disappear along the trajectory, it is possible to identify where localization may fail.

In this study, we proposed a method to evaluate the robustness of localization using the initial pose error of scan matching. In the evaluation test, we confirmed the possibility of evaluating the robustness of localization. Our future work involves enabling the simulator to accommodate changes in the LiDAR model and mounting position to make the localization evaluation more realistic. Furthermore, we will use these evaluations to quantify the 3D features necessary for vehicle localization.