Politechnika Śląska
Wydział Automatyki, Elektroniki i Informatyki
Kierunek Informatyka

Rozprawa doktorska
Doktorat wdrożeniowy

Wykorzystanie symulacji komputerowej w systemach autonomii pojazdów lądowych

Autor: mgr inż. Łukasz Sobczak
Promotor: dr hab. inż. Adam Domański, Prof. PŚ

Gliwice, grudzień 2022

Abstract

The aim of the thesis was to prepare a series of methods and a simulation environment that would allow the evaluation of selected autonomous driving algorithms designed for Unmanned Land Platforms (BPLs) and other robotic vehicles. The developed tools and solutions refer to issues in the implementation of simulation systems for both autonomous vehicles and sensors used in autonomous driving systems, and made it possible to create a comprehensive simulator for autonomous vehicles WST (Virtual Testing System).

Realization of the thesis required the author to conduct an extensive literature review of the algorithms used by many types of self-driving vehicles. Localization and mapping of the environment, perception of the surroundings or routing and navigation to a destination are the main issues of autonomous driving, which require access to a driving platform, many types of sensors and time-consuming tests performed in real conditions. In contrast, the author's thesis presented as part of his PhD thesis is that it is possible to prepare a simulation system for a vehicle and its sensors in a way that allows verification and evaluation of autonomy algorithms without access to a physical vehicle. Thus, the developed simulator can be used to prepare, test and evaluate driving automation methods, and provides a simulation environment for BPL vehicles of almost any size, purpose or drive configuration. The system also offers high performance by providing high quality of generated sensors data while maintaining real-time operation. Moreover, it allows data exchange between real and simulated sensors thanks to the use of a common data representation and its format compatible with real devices. In addition, the prepared simulator makes it possible to collect data allowing the evaluation of the reasonableness of the use of specific sensors and their selection with their physical location on a given vehicle. The developed solution allows direct communication between the robot operating system (ROS) and the simulation environment with high data bandwidth, which was confirmed by the performed tests and comparison with the existing solution.

The author spent a large part of the research using the developed simulator to evaluate the performance of the SLAM localization and mapping algorithm, which is a crucial component of almost every autonomous driving system. In order to properly evaluate and compare the efficiency of position determination and the quality of the generated map of the environment using simulation data, it is necessary to verify the accuracy of the synthetic data against those provided by the physical device. The conducted tests showed that the data generated using the simulator significantly corresponds to reality, especially thanks to the simulation of characteristic errors and sensor data noise. The localization error values of the selected SLAM algorithm using real and synthetic data have been compared next. The prepared test track and its equivalent modeled in the simulation environment made it possible to study the impact of using data generated in the simulator on the quality of vehicle localization. The obtained results confirmed

that the value of the vehicle positioning error using simulation data is similar to that in real conditions thus confirming the validity of using the simulator.

Thanks to the performed research and demonstration of the effectiveness of the simulation in the context of localization and mapping, the author also decided to evaluate the possibility of using the simulator in the process of selecting LiDAR, IMU and odometry sensors for the selected SLAM algorithm. Using the developed environment, a test procedure was proposed to find a suitable sensor configuration, and the advantages and disadvantages of such a solution were also presented.

In addition, the prepared simulator and its capabilities were analyzed for application in the process of research and development of other algorithms used during autonomous driving. Thus, the issue of using the designed environment to test methods for preprocessing sensory data was discussed. Also presented is the developed mechanism for creating a dataset that can provide test and training data for learning deep neural network models used, for example, for semantic segmentation of images coming from cameras placed on an autonomous vehicle. A practical application of the simulator for developing and testing algorithms for autonomous navigation, including creating an obstacle occupancy grid based on lidar data, determining a driving path, and generating control commands to follow a defined plan, was also presented. Finally, an architecture was also presented to enable testing of the autonomy system, in which real sensor data is replaced by simulation data, while functionalities remain unchanged from the system operator's perspective. The presented results of the work concluded with the implementation of a simulation environment for the development of vehicles equipped with an autonomous driving system, the components of which were designed, evaluated and adapted in the presented WST simulator. It allowed to prepare several Unmanned Land Platforms that meet the objectives in the context of autonomous driving.

The results obtained by the author from the research and work performed in connection with the thesis made it possible to expand the state of knowledge beyond that available in the literature and presented, in several aspects, a novel approach to the application of simulation methods for the work on autonomous vehicles, which is an important discipline in modern computer science. In addition, the results obtained, as well as the proposed methods and potential applications in practice, have been published by the author in a number of articles in international journals.