Sensors and Sensor Fusion in Self-Driving Vehicles

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Abstract

Autonomous vehicle navigation has been at the forefront of numerous significant advancements, both in civilian and defense applications. New technologies such as multimodal data fusion, big data processing, and deep learning are transforming the quality of applications through upgrading sensors and systems. New concepts such as 3D radar, 3D sonar, LiDAR, and others are based on the revolutionary development of autonomous vehicles.

Introduction

Clothoid-a single framework for completely autonomous cars—was suggested as autonomous vehicles have been evolving rapidly. There are several options for autonomous driving frameworks in the literature. However, it should be noted that developing a safe and effective system remains a difficulty. Unfortunately, even huge businesses that specialize in constructing self-driving cars cannot prevent accidents. Examples include the Tesla and Volvo XC90, both of which have resulted in catastrophic injuries and even deaths. This is a result of growing urbanization and the increased desire for mobility. Nowadays, an autonomous car is intended to improve road safety and hence minimize accidents. Every car manufacturer strives for the best level of autonomy. To do this, it is vital to provide precise detection of the surroundings as well as safe driving in a variety of conditions. The authors developed a new unified architecture for fully autonomous cars that include several elements. Clothoid was installed on a Hyundai I-30 car, together with a unique sensory and control system. The system architecture includes a detailed description of the modules employed. The suggested approach contains safety-related modules such as HD mapping, localization, environment sensing, path planning, and control modules. In addition, comfort and scalability in a real-world traffic scenario were taken into account.

The given framework allows for obstacle avoidance, pedestrian safety of road users, object identification, roadblock avoidance, and path planning for single- and multi-lane roads. The authors proposed a system that would allow self-driving cars to travel securely during their voyage. During the testing, the performance of each module in K-City was evaluated and confirmed in a variety of scenarios. The suggested Clothoid was securely driven from the starting point to the goal position during these testing. It should be noted that the suggested car was one of the top five vehicles to successfully finish the Hyundai AVC (autono-oums vehicle challenge).The suggested framework is capable of dealing with difficult situations in real-world contexts such as metropolitan areas and highways. The capacity to deal with challenging conditions is one of Clothoid's distinctive features. These include identifying and avoiding pedestrians, avoiding construction sites and other barriers, yielding to ambulances or other services, and finding a vehicle in areas where GPS is not available.A one-of-a-kind mix of bathymetric data from an unmanned surface vessel, photogrammetric data from unmanned aerial vehicles and ground laser scanning, and geodetic data from precise measurements, combined with global satellite navigation system receivers The article discusses photogrammetric measurements taken by unmanned aerial vehicles during measurement sessions in detail. Several measurement campaigns were conducted in the Sopot littoral zone in response to the tombolo phenomenon's intense uplift of the seabed and beach. These phenomena generate continual and complex changes in the morphology of the bottom and the Earth's surface, and when they occur in a densely populated region, they must be constantly monitored. The paper examines the accuracy of several photogrammetric measuring techniques, provides a statistical method of data filtration and displays the changes that happened inside the study region. The investigation concludes with an analysis of the reasons for changes in the littoral zone's land section and a summary of the acquired data. A multi-sensor integrated navigation system that includes a global navigation satellite system inertial measurement unit, an odometer, and light detection and ranging for simultaneous localization and mapping. The front-end IMU/ODO was used to acquire the dead reckoning results. To acquire the final navigation results in the back end, the graph optimization was utilized to fuse the GNSS position, IMU/ODO pre-integration results, and the relative location and relative attitude from LiDAR-SLAM. The odometer information is used in the pre-integration process to reduce the IMU's high drift rate. The sliding window approach was also used to avoid the graph optimization's growing parameter counts. Furthermore, land vehicle testing was carried out in both open-sky and tunnel scenarios. According to the results of the experiments, the suggested navigation system can significantly increase navigation accuracy and resilience. During the navigation drift evaluation of the mimic two-minute GNSS outages, the proposed navigation system reduced the Root Mean Square (RMS) roots of the maximum position drift errors during outages by 62.8 percent, 72.3 percent, and 52.1 percent, respectively, along the north, east, and height, compared to the conventional GNSS/INS (inertial navigation system)/ODO integration. Furthermore, yaw error was decreased by 62.1 percent. When compared to the GNSS/IMU/LiDAR-SLAM integrated navigation system, the odometer and non-holonomic restriction reduced the vertical inaccuracy by 72.3 percent.

The test in the real tunnel instance shows that in poor environmental feature areas where the LiDAR-SLAM barely works, the odometer's aid in pre-integration is crucial and may successfully decrease positioning drift along the forward direction and sustain the SLAM in the near term. As a result, the proposed GNSS/IMU/ODO/LiDAR-SLAM integrated navigation system can effectively fuse information from multiple sources to maintain the SLAM process and significantly mitigate navigation error, particularly in harsh environments where the GNSS signal is severely degraded and environmental features are insufficient for LiDAR-SLAM.

Conclusion

It can be claimed that autonomous navigation and sensor fusion are still essential and hot topics, and a lot of work will be done throughout the world. New strategies and procedures for evaluating and extracting data from navigational sensors, as well as data fusion, have been suggested and validated. Some of these will prompt more study, while others are already mature and ready for industrial adoption and development.

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