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主 論 文 の 要 旨

論文題目 Development of a 3D LiDAR Database and Knowledge-base for Improving Autonomous Driving Perception
(自動運転の認識機能の改善のための 3D LiDAR データベースおよび知識ベースの開発)

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論 文 内 容 の 要 旨

Autonomous driving technology promises to reduce the number of driving accidents and increase human productivity. Due to the many projected benefits such as allowing for reallocation of time lost during driving, improved standards of living for the movement impaired and reduced pollution levels, autonomous vehicles will certainly revolutionize human society. While self-driving cars are advertised as “almost ready” for widespread deployment, there in fact remains many unresolved performance issues.

Many of the challenging problems in current autonomous driving systems are related to understanding the environment surrounding the vehicles. These perception tasks require exteroceptive sensors like color cameras to act as the eyes of the vehicle. Perception algorithms interpret this data, extracting information needed for safe navigation. For example, detecting objects in the space surrounding the vehicle is critical for safe driving. Tracking objects over time and anticipating their future trajectory to avoid potential collision is also necessary. In essence, safe navigation is conditioned on the accurate understanding of the external world.

Modern digital cameras with their high frequency, large resolution images are appealing as exteroceptive sensors. They produce clear, easily interpretable data --- at least for human eyes. However, for autonomous driving and robotics applications, cameras come with significant drawbacks: the information is in the form of 2D images, so recovering the 3D information needed for navigation can be tricky. Multiple camera arrays address their limited field of view but introduce calibration uncertainties. Finally, camer

as can be inadequate in settings with insufficient illumination.

As alternative, a range-sensing device called the LiDAR has recently been developed and used in autonomous mobile systems. Modern 3D LiDAR devices have 360 degree horizontal field of view and can produce millions of 3D point measurement per second. Essentially, one sensor can monitor entire scenes when mounted on top of a car. Through this point cloud data, objects can be detected directly in the same 3D space as the ego-vehicle. It is an ideal sensor for autonomous driving, but also has downsides. The data lacks consistent color information that images provide and sparsity is pronounced at long ranges, which makes object detection much more difficult. LiDAR algorithms show promise but computer vision has polished image-based methods over several decades and produce accurate results.

Given the current challenges with LiDAR-based perception, it is necessary to ask if this sensor can achieve sufficient levels of precision necessary for self-driving cars. Given their ability to individually observe entire scenes, it is important to determine their level of performance when used outside of fusion pipelines, which use LiDAR alongside other sensors. The general objective of this dissertation is to determine the feasibility of LiDARs for autonomous driving perception. What are the inherent limits of LiDARs for this task and can they be overcome? Answering this question and evaluation the performance of perception pipeline is necessarily data-driven, but the available LiDAR data in driving scenes is also limited.

The research presented in this dissertation demonstrates the advantages of using 3D LiDARs for autonomous driving perception unequivocally. Simple perception pipelines only using a single LiDAR can achieve performance levels adequate for autonomous navigation in many scenarios. Mapping, localization, object detection and tracking are tasks that can be accomplished through LiDARs though several difficult situations limit robustness. Recent deep learning methods have been developed to improve detection performance, but the accuracy and detection range is shown to be limited and largely insufficient for some applications. Potential improvement are proposed in this work, related to both hardware and software. It is demonstrated that the potential of LiDAR is highly dependent on hardware that is yet to be optimized.

To develop and propose these improvements to LiDAR software and hardware, this dissertations contributes several open datasets to the research community. We first develop methods for 3D LiDAR dataset creation with minimal human labor and put it to the test, creating a large scale pedestrian tracking dataset. This dataset, featuring half a million segmented point clou d, can be used for testing perception algorithms. Another dataset is proposed in this work, containing multiple LiDARs dataset and over 200 kilometers of dynamic driving data. This collection of data in the same domain using different LiDARs is used as a basis to compare the variety of LiDAR hardware available for autonomous driving. A static dataset was also collected to directly benchmark LiDAR performance in a controlled environment, for which standardized testing methodology was developed. Finally, the dataset includes LiDAR data in adverse weather to assess the impact of rain, fog and strong light on LiDAR reliability. Overall, this dataset allows the benchmarking and comparison of both LiDAR hardware and software.

The datasets and methods presented have contributed to produce a clear assessment of 3D LiDAR potential for autonomous driving perception and identifying current challenges. The emerging research and collaborations from the published datasets pave the way for a next generation of sensors and algorithms that overcome current limitations.