A Multi-Modal System for Road Detection and Segmentation

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***Abstract*—Reliable road detection is a key issue for modern Intelligent Vehicles, since it can help to identify the drivable area as well as boosting other perception functions like object detection. However, real environments present several challenges like illumination changes and varying weather conditions. We propose a multi-modal road detection and segmentation method based on monocular images and HD multi-layer LIDAR data (3D point cloud). This algorithm consists of three stages: extraction of ground points from multi-layer LIDAR, transformation of color camera information to an illumination-invariant representation, and lastly the segmentation of the road area. For the first module, the core function is to extract the ground points from LIDAR data. To this end a road boundary detection is performed based on histogram analysis, then a plane estimation using RANSAC, and a ground point extraction according to the point-to-plane distance. In the second module, an image representation of illumination-invariant features is computed simultaneously. Ground points are projected to image plane and then used to compute a road probability map using a Gaussian model. The combination of these modalities improves the robustness of the whole system and reduces the overall computational time, since the first two modules can be run in parallel. Quantitative experiments carried on the public KITTI dataset enhanced by road annotations confirmed the effectiveness of the proposed method.**

***Keywords*—multi-modal perception, monocular vision, LIDAR, Intelligent Vehicle, road detection**

I. Introduction

Intelligent Vehicles (IV) constitutes a research focus in recent years with promising benefits to society, including the prevention of accidents, optimal transportation planning and fuel conservation [11]. Among various tasks, IV needs to be able to perform road detection which greatly helps for scene understanding as well as boosting object (pedestrian, vehicle) detection functions by restricting the search space. Moreover, road detection could be an alternative solution for departure warning in cases when lane keeping assistance system fails (e.g. less structured roads without well-defined lane markers). However, it remains a complex task since the algorithm should be able to deal with surrounding objects (e.g. vehicles, pedestrian), different environments (e.g. urban, highways, off-road), road types (e.g. shape, color), and sensor exposure conditions (e.g. varying illumination, different viewpoints and weather conditions) [2]. Many approaches have been proposed in recent decades, using either passive sensors (e.g. vision), or active ones (e.g. LIDAR and RADAR) [2]. Monocular vision based road detection methods usually rely on features in terms of pixel properties such as intensity [5], color [13], [17] or texture [20], [25], [16], [15] and grouping technologies for segmentation. Among them, color features receive increasing popularity because of their superiority of representing the world and less physical restrictions. To efficiently deal with illumination changes and shadows, several popular color spaces have been introduced including HSI (Hue, Saturation and Intensity) [20], normalized RGB [22] and log-chromaticity space [4]. Stereo vision algorithms not only consider 2D image features but also take advantage of 3D scene information for estimating free space and obstacles using V-Disparity Map techniques [24], [23], [17]. These approaches have improved monocular vision results by the use of a new imaging sensor which grants access to an environment structure prior (i.e. road plane assumption). The variety of sensors opens a large spectrum of possibilities for the use of multiple perception modalities. Multi-modal road detection presented in [6] combines a camera with a LIDAR sensor. [2] propose an interesting method which uses a Geographical Information Systems (GIS) and a GPS receiver to find the corresponding road patch. Later, this information is combined with the image from a monocular camera to obtain the final result.

Hereafter, a multi-modal system is proposed for road detection and segmentation. Two modalities are used, a monocular vision system and an HD multi-layer LIDAR (i.e. Velodyne). The data of both sensors are analyzed by means of three processing stages (see Fig. 1). The first stage extracts the ground from 3D laser data providing the environment structure prior. The second, transforms the color image into an illumination-invariant gray scale space. Finally, road image regions are obtained by the combination of pre-computed data in a probabilistic framework. The approach, detailed in this paper, addresses the common need of a road feature initialization step in methods using monocular vision [22], [2], [17], [24], [4]. To this end, the state-of-the-art usually assumes the lower part of the image being the road surface. However, this assumption is not respected under important pitch changes and in scenarios with heavy traffic. The latter situation implies that vehicles are quite close to the field of view of the camera limiting the visibility of the road surface. In contrast, our proposed method determines a potential road surface from 3D laser data and exploits this knowledge to identify image road features.

The remainder of this paper is as follows: First, the framework of the algorithm is outlined in Sect. II. The three main stages introduced previous are detailed consecutively in Sect. III, Sect. IV, Sect. V. Experimental results are demonstrated and discussed in Sect. VI. Finally, conclusions and future work are outlined in Sect. VII.

II. Modalitees of the Perception System

The perception set-up assumed for this study, makes use of a monocular vision system mounted facing forward and an HD multi-layer LIDAR installed on the roof of the

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A Multi Modal System For Road Detection And Segmentation:

Automated and Autonomous Navigation Powered by GNSS Mauro Cardone,2025-04-25 This book is the result of one year investigation in all the available technologies necessary to build an efficient navigation system usable on rovers moving on the ground and at the sea centered on GNSS Global Navigation Satellite System It is used as instruction note for the calls for tender in the Italian Space Agency It targets the applications of automated and autonomous navigation for the following types of rover trains at level 2 of ERTMS ETCS autonomous cars starting from level 3 of SAE MASS Maritime Autonomous Surface Ships at level 4 of IMO The material is already edited for the using of professionals and engineers who need to build a navigation system on top of COTS hardware The topics cover in a thorough view all the necessary subjects to build an efficient positioning system for the rover enabling coping with all kind of environments and all interferences and always warranting a minimum level of the positioning KPIs reliability availability integrity and accuracy The localization system built according to these guidelines will be ready to be certified and the product will be at TRL 6 i e technology demonstrated in the relevant environment **LiDAR Technology for Intelligent Transportation and Autonomous Systems** Rajalakshmi Pachamuthu,Bhaskar Anand,Abhishek Thakur,Parvez Alam,2025-11-05 This book explores the critical role of LiDAR technology in autonomous navigation and advanced driver assistance systems ADAS It explores the fundamental principles of LiDAR comparing it with other sensor technologies like radar and cameras while examining the various types of LiDAR systems including time of flight flash and frequency modulated continuous wave systems It emphasises real world use cases including setting up LiDAR data acquisition systems and addressing challenges like sensor calibration alignment and integration into autonomous systems Discusses in detail LiDAR s working principles laser pulse wavelengths point cloud data motion compensation and datasets commonly used in LiDAR research Examines the effects of ambient light adverse weather conditions rain fog snow and practical strategies for mitigating these challenges Describes advanced methods for object detection segmentation and multi object tracking using LiDAR point clouds including solutions like AnchorPoint and Smart3DMOT Presents techniques for creating high definition 3D maps and implementing SLAM Simultaneous Localization and Mapping that are essential for autonomous navigation Offers practical insights into autonomous navigation including LiDAR based localization path planning obstacle avoidance and real world case studies like autonomous shuttles Explores multi LiDAR calibration emphasizing alignment fusion and synchronization to enhance coverage and reduce blind spots in autonomous systems Offers a detailed guide on open source LiDAR processing tools like PCL Open3D and ROS for data handling and visualization By combining theoretical principles with practical applications and case studies this book serves as a reference book for academics and researchers in computer science electronics communication engineering and autonomous technologies **Hybrid Artificial Intelligent Systems** Pablo García Bringas,Hilde Pérez García,Francisco Javier Martínez de Pisón,José Ramón Villar Flecha,Alicia Troncoso Lora,Enrique A. de la Cal,Álvaro Herrero,Francisco

Martínez Álvarez,Giuseppe Psaila,Héctor Quintián,Emilio Corchado,2022-09-11 This book constitutes the refereed proceedings of the 17th International Conference on Hybrid Artificial Intelligent Systems HAIS 2022 held in Salamanca Spain in September 2022 The 43 full papers presented in this book were carefully reviewed and selected from 67 submissions They were organized in topical sections as follows bioinformatics data mining and decision support systems deep learning evolutionary computation HAIS applications image and speech signal processing and optimization techniques

Advanced Driver Intention Inference Yang Xing,Chen Lv,Dongpu Cao,2020-03-15 Advanced Driver Intention Inference Theory and Design describes one of the most important function for future ADAS namely the driver intention inference The book contains the state of art knowledge on the construction of driver intention inference system providing a better understanding on how the human driver intention mechanism will contribute to a more naturalistic on board decision system for automated vehicles Features examples of using machine learning deep learning to build industry products Depicts future trends for driver behavior detection and driver intention inference Discuss traffic context perception techniques that predict driver intentions such as Lidar and GPS **Low-Carbon Oriented Market Mechanism and Reliability Improvement of Multi-energy Systems** Minglei Bao,Sheng Wang,Liang Du,Zhengmao Li ,Weiqi Hua,2024-12-17 The energy crisis has brought great challenges to the low carbon and economic development of the energy system To achieve net zero emissions energy systems can have an increasing penetration of renewable energy and a deep coupling of multiple energy sectors i e electricity gas and heat To deal with the increasing fluctuations of renewable energy in multi energy systems the market mechanism is an effective solution for the optimal allocation of resources An optimal market design could stimulate different resources to actively assist the carbon reduction and reliability improvement of multi energy systems Therefore research on low carbon oriented market design and optimal operation is expected to improve the reliability and sustainability of multi energy systems The objective of this Research Topic is to explore the latest advances in market design and reliability improvement technologies of multi energy systems with a focus on low carbon reliability and resilience We have the following research goals 1 Effective market mechanisms and interaction frameworks to support the operation of energy systems 2 Advanced operation and control methods for flexible resources such as traditional units energy storage electric vehicles electric hydrogen production etc 3 Advanced planning strategies and portfolio management for flexible resources in multi energy systems 4 Advanced evaluation methods for flexibility resilience and carbon emissions of energy systems 5 Effective applications of integrated demand response in energy systems with new technical and economic models Original research and review articles in theoretical methodological or practical focuses such as models policies algorithms and applications are all welcome Research areas may include but are not limited to the following Low carbon oriented market mechanism Interaction framework designs for flexible resources Modeling and optimization technologies for multi energy systems Evaluation methods for the system resilience flexibility and carbon emissions Operation control and planning methods of

multi energy systems Applications of artificial intelligence technology in reliability improvement Renewable energy prediction and integration **Deep Learning and Its Applications for Vehicle Networks** Fei Hu,Iftikhar Rasheed,2023-05-12 Deep Learning DL is an effective approach for AI based vehicular networks and can deliver a powerful set of tools for such vehicular network dynamics In various domains of vehicular networks DL can be used for learning based channel estimation traffic flow prediction vehicle trajectory prediction location prediction based scheduling and routing intelligent network congestion control mechanism smart load balancing and vertical handoff control intelligent network security strategies virtual smart and efficient resource allocation and intelligent distributed resource allocation methods This book is based on the work from world famous experts on the application of DL for vehicle networks It consists of the following five parts I DL for vehicle safety and security This part covers the use of DL algorithms for vehicle safety or security II DL for effective vehicle communications Vehicle networks consist of vehicle to vehicle and vehicle to roadside communications This part covers how Intelligent vehicle networks require a flexible selection of the best path across all vehicles adaptive sending rate control based on bandwidth availability and timely data downloads from a roadside base station III DL for vehicle control The myriad operations that require intelligent control for each individual vehicle are discussed in this part This also includes emission control which is based on the road traffic situation the charging pile load is predicted through DL andvehicle speed adjustments based on the camera captured image analysis IV DL for information management This part covers some intelligent information collection and understanding We can use DL for energy saving vehicle trajectory control based on the road traffic situation and given destination information we can also natural language processing based on DL algorithm for automatic internet of things IoT search during driving V Other applications This part introduces the use of DL models for other vehicle controls Autonomous vehicles are becoming more and more popular in society The DL and its variants will play greater roles in cognitive vehicle communications and control Other machine learning models such as deep reinforcement learning will also facilitate intelligent vehicle behavior understanding and adjustment This book will become a valuable reference to your understanding of this critical field Advanced Deep Learning Algorithms for Multi-Source Data and Imaging Jicheng Wang,Haoyu Chen,2025-11-24 Deep learning technology has been widely applied to multi source data and imaging in the past decade It aims to handle multi modality data from different sources including images text audio and sensor data thereby facilitating seamless integration and interpretation of heterogeneous data for downstream tasks such as image classification object detection medical imaging analysis etc Although the continuous development of deep learning algorithms for multi source data and imaging has brought significant progress to various fields there are still challenges in terms of learning efficiency generalization ability interpretability and transfer ability This Research Topic aims to bring together current research progress from both academia and industry on novel deep learning aglorithms to address the challenges to multi source data and imaging Specifically three main objectives

are as follows Pursue new discoveries and theoretical foundations in various areas such as computer vision data science biomedical engineering autonomous driving etc For example which deep learning frameworks can effectively process and fuse multi source data How to use deep learning algorithms to improve the accuracy and efficiency of imaging How to efficiently optimize multi modal imaging data Develop new deep learning algorithms and tools for multi source data and imaging For example how to design more efficient feature extraction and data fusion methods for multi source data with complex scenarios What innovative deep learning models are suitable for specific application scenarios such as environmental monitoring and disease diagnosis Explore the application and potential impact of these advanced deep learning algorithms in socioeconomic areas For example how can these technologies improve public health and personal health management How do they contribute to improving the quality and efficiency of medical services How to overcome ethical challenges while ensuring data privacy and interpretability This Research Topic focuses on the theory and applications of deep learning for multi source data and imaging aiming to establish a forum for researchers to share their achievements and discoveries We sincerely invite researchers to submit their original research article to explore advanced deep learning algorithms for multi source data and imaging The following topics are the specific interests of this special issue including but not limited to Deep learning Multimodal analysis Zero shot learning Representation learning Data fusion Reinforcement learning Medical image processing Transfer Learning **Proceedings of the ... IEEE Intelligent Vehicles Symposium** ,2003 1998 IEEE Workshop on Visual Surveillance IEEE Computer Society,1998 Aimed at researchers professors practitioners students and other computing professionals this is a collection of papers on computational intelligence specifically visual surveillance **Mobile Robots** ,1991 **Advanced Measurement and Test** Riza Esa,Yan Wen Wu,2011-07-27 Selected peer reviewed paper from 2011 2nd International Conference on Advanced Measurement and Test AMT 2011 on June 24 26 2011 Nanchang China *Proceedings of the Twenty-second AAAI Conference on Artificial Intelligence* ,2007 *Storage and Retrieval for Media Databases* ,2001 IEEE Intelligent Vehicles Symposium ,2005 *Image Understanding Workshop* ,1998 **Algorithms for Synthetic Aperture Radar Imagery V** Edmund G. Zelnio,1998 A presentation of algorithms for synthetic aperture radar imagery It studies image formation image registration and fusion image quality assessment and feature extraction **Proceedings** ,1983 **Algorithms for Synthetic Aperture Radar Imagery** ,1998 *Proceedings of the Intelligent Vehicles ... Symposium* ,1995 *Stochastic and Neural Methods in Signal Processing, Image Processing, and Computer Vision* Society of Photo-optical Instrumentation Engineers,1991

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