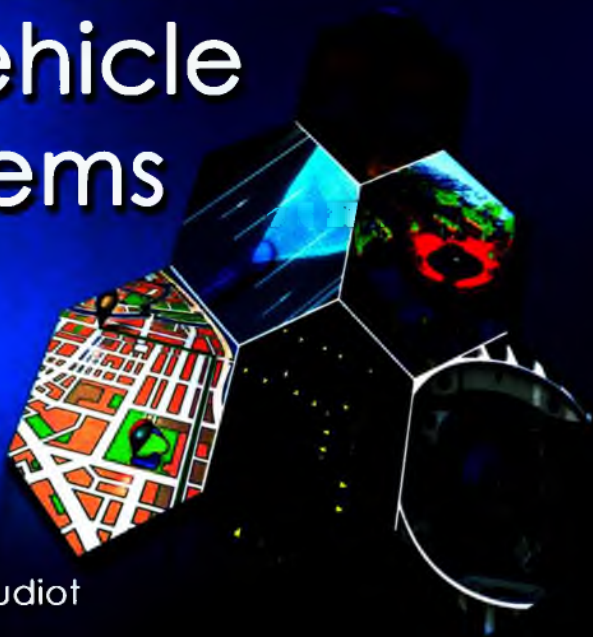




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Creating Autonomous Vehicle Systems

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ABSTRACT

This book is the first technical overview of autonomous vehicles written for a general computing and engineering audience. The authors share their practical experiences of creating autonomous vehicle systems. These systems are complex, consisting of three major subsystems: (1) algorithms for localization, perception, and planning and control; (2) client systems, such as the robotics operating system and hardware platform; and (3) the cloud platform, which includes data storage, simulation, high-definition (HD) mapping, and deep learning model training. The algorithm subsystem extracts meaningful information from sensor raw data to understand its environment and make decisions about its actions. The client subsystem integrates these algorithms to meet real-time and reliability requirements. The cloud platform provides offline computing and storage capabilities for autonomous vehicles. Using the cloud platform, we are able to test new algorithms and update the HD map—plus, train better recognition, tracking, and decision models.

This book consists of nine chapters. **Chapter 1** provides an overview of autonomous vehicle systems; **Chapter 2** focuses on localization technologies; **Chapter 3** discusses traditional techniques used for perception; **Chapter 4** discusses deep learning based techniques for perception; **Chapter 5** introduces the planning and control sub-system, especially prediction and routing technologies; **Chapter 6** focuses on motion planning and feedback control of the planning and control subsystem; **Chapter 7** introduces reinforcement learning-based planning and control; **Chapter 8** delves into the details of client systems design; and **Chapter 9** provides the details of cloud platforms for autonomous driving.

This book should be useful to students, researchers, and practitioners alike. Whether you are an undergraduate or a graduate student interested in autonomous driving, you will find herein a comprehensive overview of the whole autonomous vehicle technology stack. If you are an autonomous driving practitioner, the many practical techniques introduced in this book will be of interest to you. Researchers will also find plenty of references for an effective, deeper exploration of the various technologies.

KEYWORDS

autonomous driving, driverless cars, perception, vehicle localization, planning and control, autonomous driving hardware platform, autonomous driving cloud infrastructures

Contents

Preface	ix
1 Introduction to Autonomous Driving	1
1.1 Autonomous Driving Technologies Overview	1
1.2 Autonomous Driving Algorithms	2
1.2.1 Sensing	2
1.2.2 Perception	3
1.2.3 Object Recognition and Tracking	5
1.2.4 Action	6
1.3 Autonomous Driving Client System	8
1.3.1 Robot Operating System (ROS)	8
1.3.2 Hardware Platform	10
1.4 Autonomous Driving Cloud Platform	11
1.4.1 Simulation	11
1.4.2 HD Map Production	12
1.4.3 Deep Learning Model Training	13
1.5 It Is Just the Beginning	13
2 Autonomous Vehicle Localization	15
2.1 Localization with GNSS	15
2.1.1 GNSS Overview	15
2.1.2 GNSS Error Analysis	16
2.1.3 Satellite-based Augmentation Systems	17
2.1.4 Real-Time Kinematic and Differential GPS	18
2.1.5 Precise Point Positioning	20
2.1.6 GNSS/INS Integration	21
2.2 Localization with LiDAR and High-Definition Maps	22
2.2.1 LiDAR Overview	23
2.2.2 High-Definition Maps Overview	25
2.2.3 Localization with LiDAR and HD Map	29
2.3 Visual Odometry	33
2.3.1 Stereo Visual Odometry	34

2.3.2	Monocular Visual Odometry	34
2.3.3	Visual Inertial Odometry	35
2.4	Dead Reckoning and Wheel Odometry	36
2.4.1	Wheel Encoders	37
2.4.2	Wheel Odometry Errors	38
2.4.3	Reduction of Wheel Odometry Errors	39
2.5	Sensor Fusion	41
2.5.1	CMU Boss for Urban Challenge	41
2.5.2	Stanford Junior for Urban Challenge	43
2.5.3	Bertha from Mercedes Benz	44
2.6	References	46
3	Perception in Autonomous Driving	51
3.1	Introduction	51
3.2	Datasets	51
3.3	Detection	54
3.4	Segmentation	56
3.5	Stereo, Optical Flow, and Scene Flow	57
3.5.1	Stereo and Depth	57
3.5.2	Optical Flow	58
3.5.3	Scene Flow	59
3.6	Tracking	61
3.7	Conclusions	63
3.8	References	64
4	Deep Learning in Autonomous Driving Perception	69
4.1	Convolutional Neural Networks	69
4.2	Detection	70
4.3	Semantic Segmentation	73
4.4	Stereo and Optical Flow	75
4.4.1	Stereo	75
4.4.2	Optical flow	77
4.5	Conclusion	80
4.6	References	81
5	Prediction and Routing	83
5.1	Planning and Control Overview	83
5.1.1	Architecture: Planning and Control in a Broader Sense	87

5.1.2	Scope of Each Module: Solve the Problem with Modules	85
5.2	Traffic Prediction	88
5.2.1	Behavior Prediction as Classification	89
5.2.2	Vehicle Trajectory Generation	93
5.3	Lane Level Routing	96
5.3.1	Constructing a Weighted Directed Graph for Routing	97
5.3.2	Typical Routing Algorithms	99
5.3.3	Routing Graph Cost: Weak or Strong Routing	103
5.4	Conclusions	104
5.5	References	104
6	Decision, Planning, and Control	107
6.1	Behavioral Decisions	107
6.1.1	Markov Decision Process Approach	109
6.1.2	Scenario-based Divide and Conquer Approach	111
6.2	Motion Planning	118
6.2.1	Vehicle Model, Road Model, and SL-Coordination System	120
6.2.2	Motion Planning with Path Planning and Speed Planning	121
6.2.3	Motion Planning with Longitudinal Planning and Lateral Planning	128
6.3	Feedback Control	132
6.3.1	Bicycle Model	132
6.3.2	PID Control	134
6.4	Conclusions	135
6.5	References	136
7	Reinforcement Learning-based Planning and Control	139
7.1	Introduction	139
7.2	Reinforcement Learning	140
7.2.1	Q-Learning	143
7.2.2	Actor-Critic Methods	147
7.3	Learning-based Planning and Control in Autonomous Driving	149
7.3.1	Reinforcement Learning on Behavioral Decision	150
7.3.2	Reinforcement Learning on Planning and Control	151
7.4	Conclusions	153
7.5	References	153

8	Client Systems for Autonomous Driving	155
8.1	Autonomous Driving: A Complex System	155
8.2	Operating System for Autonomous Driving	157
8.2.1	ROS Overview	157
8.2.2	System Reliability	159
8.2.3	Performance Improvement	160
8.2.4	Resource Management and Security	161
8.3	Computing Platform	161
8.3.1	Computing Platform Implementation	162
8.3.2	Existing Computing Solutions	162
8.3.3	Computer Architecture Design Exploration	163
8.4	References	167
9	Cloud Platform for Autonomous Driving	169
9.1	Introduction	169
9.2	Infrastructure	169
9.2.1	Distributed Computing Framework	171
9.2.2	Distributed Storage	171
9.2.3	Heterogeneous Computing	172
9.3	Simulation	173
9.3.1	BinPipeRDD	174
9.3.2	Connecting Spark and ROS	175
9.3.3	Performance	176
9.4	Model Training	176
9.4.1	Why Use Spark?	177
9.4.2	Training Platform Architecture	178
9.4.3	Heterogeneous Computing	179
9.5	HD Map Generation	179
9.5.1	HD Map	180
9.5.2	Map Generation in the Cloud	181
9.6	Conclusions	182
9.7	References	183
	Author Biographies	185

Preface

Autonomous vehicles, be they on land, on water, or in the air, are upon us and are finding a myriad of new applications, from driverless taxi services to automatic airborne surveillance of sensitive remote areas. Continued technological advances in the past few decades have made these innovations possible, but the design problems which must be surmounted in order to provide useful, efficient, and, supremely importantly, safe operations of these independent units are equally numerous and daunting.

It is thus the purpose of this book to provide an overview of these problems and lead the reader through some common design solutions. High technological capabilities, complete integration of hardware and software, and deep synergy with resident platforms (such as cloud servers) are a must for an eventual successful deployment. The focus is on land vehicles, and more specifically cars in urban or country road environments, as well as off-road operations. The aim of this book is to address an audience of engineers, be they from the academic or the industrial side, with a survey of the problems, solutions, and future research issues they will encounter in the development of autonomous vehicles, from sensing, perception to action, and including support from cloud-based servers. A copious amount of bibliographic references completes the picture and will help the reader navigate through a jungle of past work.

STRUCTURE OF THE BOOK

A brief history of information technology and an overview of the algorithms behind autonomous driving systems, of the architecture of the systems, and of the support infrastructure needed is provided in [Chapter 1](#). Localization, being one of the most important tasks in autonomous driving, is covered in [Chapter 2](#) where the most common approaches are introduced. The principles, advantages, and drawbacks of GNSS, INS, LiDAR, and wheel odometry are described in detail and the integration of various versions of these strategies are discussed. As for detection, i.e., “understanding” the environment based on sensory data, it is described in [Chapter 3](#), with an exploration of the various algorithms in use, including scene understanding, image flow, tracking, etc. The large datasets, highly complex computations required by image classification, object detection, semantic segmentation, etc. are best handled by the deep learning approaches to perception advocated for in [Chapter 4](#), where applications to detection, semantic segmentation, and image flow are described in detail. Once the environment is understood by the autonomous vehicle, it must somehow predict future events (e.g., the motion of another vehicle in its vicinity) and plan its own route. This is the purpose of [Chapter 5](#). Next ([Chapter 6](#)), comes an even more detailed level of decision making,

planning, and control. Feedback between modules with possibly orthogonal decisions as well as conflict resolution (e.g., one module could recommend a lane change, but another one has detected an obstacle in the lane in question) are covered with an emphasis on describing algorithms for behavioral decision making (e.g., Markov decision processes, scenario-based divide and conquer), and for motion planning. This is what leads us into [Chapter 7](#) for a demonstration of the need to supplement the design with Reinforcement Learning-based Planning and Control for a complete integration of situational scenarios in the development of an autonomous system. Underneath it all, the on-board computing platform is the topic of [Chapter 8](#). It includes an introductory description of the Robot Operating System, followed by an actual summary of the real hardware employed. The need for heterogeneous computing is introduced with a strong emphasis on meeting real-time computing requirements as well as on-board considerations (power consumption and heat dissipation). This means that a variety of processing units (general-purpose CPU, GPUs, FPGAs, etc.) must be used. Finally, [Chapter 9](#) covers the infrastructure for the cloud platform used to “tie it all together” (i.e., provide services for distributed simulation tests for new algorithm deployment, offline deep learning model training, and High-Definition (HD) map generation).