

Contents

Foreword	xiii
Introduction	xv
About This Book	xvii
Assumptions	xix
Acknowledgments	xxi

CHAPTER 1

Introduction to Advanced Driver Assistance Systems and Automated Driving	<u>1</u>
1.1. Sense Organs of a Vehicle	<u>2</u>
1.1.1. Camera	<u>2</u>
1.1.2. Radar	<u>2</u>
1.1.3. Lidar	<u>3</u>
1.1.4. Ultrasonic Sensors	<u>3</u>
1.1.5. Inertial Measurement Unit Sensors	<u>3</u>
1.1.6. High-Definition Maps	<u>4</u>
1.2. ADAS and Automated Driving	<u>4</u>
1.2.1. Highway Assist and Traffic Jam Assist (Level 2)	<u>5</u>
1.2.2. Remote Parking (Level 2)	<u>5</u>
1.2.3. Traffic Jam Chauffeur (Level 3)	<u>6</u>
1.2.4. Highway Chauffeur (Level 3)	<u>6</u>
1.2.5. Urban and Suburban Pilot (Level 4)	<u>6</u>
1.2.6. Highway Autopilot (Level 4)	<u>6</u>
1.2.7. Valet Parking (Level 4)	<u>7</u>
1.3. Level 5: Full Automation	<u>7</u>
1.4. Operational Design Domain	<u>8</u>
1.5. Dynamic Driving Task	<u>9</u>
1.6. Object and Event Detection and Response	<u>9</u>
1.7. Summary	<u>10</u>
References	<u>10</u>

CHAPTER 2

Design Approaches for Automated Driving Systems	<u>13</u>
2.1. Product Development	<u>13</u>
2.2. Distributed Architecture versus Centralized Architecture	<u>15</u>
2.3. Developing an Automated Driving System	<u>16</u>
2.4. Requirement Elicitation	<u>19</u>
2.5. Quality Function Deployment	<u>21</u>
2.6. Designing a Robust Product	<u>23</u>
2.7. Failure Mode and Effects Analysis	<u>26</u>
2.8. Summary	<u>29</u>
References	<u>29</u>

CHAPTER 3

Different Test Approaches	<u>33</u>
3.1. Verification and Validation	<u>33</u>
3.2. Agility in Verification and Validation	<u>34</u>
3.3. Different Levels of Testing—A Reference from V-Model	<u>35</u>
3.4. Defects at Different Levels of Testing	<u>36</u>
3.5. Simulation and Testing	<u>38</u>
3.5.1. Model-in-the-Loop Simulation	<u>39</u>
3.5.2. Software-in-the-Loop Simulation	<u>40</u>
3.5.3. Hardware-in-the-Loop Simulation	<u>40</u>
3.5.4. Driver-in-the-Loop Simulation	<u>44</u>
3.5.5. Vehicle-in-the-Loop Simulation	<u>45</u>
3.6. Summary	<u>46</u>
References	<u>47</u>

CHAPTER 4

Scenario-Based Testing	<u>49</u>
4.1. Scenario Elicitation, Description, and Structuring	<u>49</u>
4.2. Scenario Implementation and Parameterization	<u>55</u>
4.3. Scenario-Based Simulation and Testing	<u>59</u>
4.4. Scenario-Based Testing at Different Levels	<u>62</u>
4.5. Scenario Database Management	<u>64</u>

4.6. Automation in Scenario-Based Testing	<u>66</u>
4.7. Summary	<u>68</u>
References	<u>68</u>

CHAPTER 5

Simulation Environment for ADAS and Automated Driving Systems	<u>71</u>
5.1. Simulation Tool Selection	<u>72</u>
5.2. Co-simulation in Testing	<u>74</u>
5.3. General Qualification of Simulation Environment	<u>78</u>
5.4. Limitations of Simulation Tools Used in ADAS and Automated Driving	<u>82</u>
5.5. Summary	<u>84</u>
References	<u>84</u>

CHAPTER 6

Ground Truth Generation and Testing Neural Network-Based Detection	<u>87</u>
6.1. Introduction to Data-Driven Software Development	<u>87</u>
6.2. Data Annotation and Dataset Generation	<u>90</u>
6.3. Metric for Detection Quality Evaluation	<u>93</u>
6.4. Evaluating KPIs for Detection Algorithm	<u>95</u>
6.4.1. Preconditions for Sample Data Collection	<u>96</u>
6.4.2. Data and Data Types	<u>96</u>
6.4.3. Performance Evaluation (KPI Measurement)	<u>99</u>
6.4.3.1. Detection Evaluation on a Single Frame (Detection Performance)	<u>100</u>
6.4.3.2. Detection Evaluation on Complete Ground Truth Dataset (Detection Quality)	<u>100</u>
6.4.3.3. Detection Evaluation Using Noise Variants as Input (Detection Performance and Quality)	<u>100</u>
6.4.3.4. Detection Evaluation in the Vehicle (Detection Performance)	<u>101</u>
6.5. Different Acceptance Quality for Detection Algorithms	<u>101</u>
6.6. Challenges in Measuring Quality of Object Detection	<u>102</u>
6.7. Summary	<u>103</u>
References	<u>104</u>

CHAPTER 7**Testing and Qualification of Perception Software [107](#)**

7.1. Overview of Automated Driving Systems	108
7.2. Perception—An Architecture Overview	109
7.3. Different Methods for Perception Software Testing	111
7.4. Methods for Evaluating Perception Software Components	115
7.4.1. Evaluation of Static and Dynamic Object Fusion	115
7.4.2. Evaluation of Grid Fusion	118
7.4.3. Evaluation of Localization	120
7.4.4. Evaluation of Prediction Algorithms	121
7.5. Measuring Performance and Quality of Perception Software	122
7.5.1. Preconditions for Measurements	124
7.5.2. Data and Data Types	125
7.5.3. Performance Evaluation (KPI Measurement)	125
7.6. Testing Robustness of the Perception Software	126
7.7. Challenges in the Measurement and Evaluation of Perception	131
7.8. Summary	132
References	132

CHAPTER 8**Calibration of ADAS and Automated Driving Features [135](#)**

8.1. Calibration—An Overview Based on Ideality Equation	135
8.2. Common Types of Calibration in an Automated Driving System	138
8.2.1. End of Line (EoL) Calibration	139
8.2.2. Service Calibration	140
8.2.3. Online Calibration	141
8.2.4. Functional Calibration	142
8.3. Calibration of ADAS and Automated Driving Features	142
8.4. Calibration Environment for Automated Driving Vehicles	145
8.5. Calibration over Diagnostics Interface	147
8.6. Summary	148
References	149

CHAPTER 9**Introduction to Functional Safety and Cybersecurity Testing** [153](#)

9.1. Functional Safety and Cybersecurity in Automotive	<u>154</u>
9.2. Safety Qualification of Tools and Toolchain	<u>156</u>
9.3. An Overview of Functional Safety Testing	<u>161</u>
9.4. Fault Injection Testing Using Diagnostics	<u>165</u>
9.5. Safety Testing of Artificial Neural Networks—An Overview	<u>167</u>
9.6. An Overview of Cybersecurity Testing	<u>171</u>
9.7. Summary	<u>174</u>
References	<u>175</u>

CHAPTER 10**Verification and Validation Strategy** [179](#)

10.1. Test-Driven Development and Feature-Driven Development	<u>180</u>
10.2. Purpose of Test Design and Test Depth	<u>181</u>
10.3. Developing a Test Suite	<u>185</u>
10.4. Test Process	<u>190</u>
10.5. Testing in the Vehicle	<u>192</u>
10.6. Summary	<u>194</u>
References	<u>195</u>

CHAPTER 11**Acceptance Criteria and Maturity Evaluation** [197](#)

11.1. Need for Acceptance Criteria	<u>198</u>
11.2. Defining Maturity of the System and Features	<u>198</u>
11.3. Maturity Evaluation for the System	<u>201</u>
11.4. Maturity Evaluation for the Features	<u>201</u>
11.5. Vehicle Testing and Feature Maturity Evaluation	<u>204</u>
11.6. Case Study on How Various ADAS Features Are Deployed	<u>209</u>
11.7. Summary	<u>210</u>
References	<u>211</u>

CHAPTER 12

Data Flow and Management in Automated Driving	<u>213</u>
12.1. Importance of Data in Automated Driving	<u>214</u>
12.2. Types of Data Collected	<u>215</u>
12.3. Data Acquisition Strategy and Data Loggers	<u>219</u>
12.4. Data Reuse Strategy	<u>222</u>
12.5. Data Analysis and Data Flow	<u>223</u>
12.6. Data Storage and Management—A Case Study	<u>226</u>
12.7. Challenges in Data Acquisition and Management	<u>230</u>
12.8. Summary	<u>231</u>
References	<u>232</u>

CHAPTER 13

Challenges and Gaps in Testing Automated Driving Features	<u>235</u>
13.1. Challenges due to Infrastructure Quality	<u>236</u>
13.2. Challenges in the Design of Automated Driving Systems	<u>236</u>
13.3. Challenges in Performing Simulation-Based Testing	<u>238</u>
13.4. Challenges in Laboratory-Based Tests and Vehicle Tests	<u>239</u>
13.5. Challenges in Using AI	<u>241</u>
13.6. Challenges in Scenario-Based Testing	<u>242</u>
13.7. Challenges in Testing for Functional Safety and Cybersecurity	<u>243</u>
13.8. Challenges with Legal Aspects, Liabilities and Its Economic Impacts	<u>245</u>
13.9. Summary	<u>246</u>
References	<u>247</u>
Index	<u>249</u>
About the Author	<u>255</u>