This book is devoted to various forms of autonomous driving (AD) that will drastically transform the transportation of people and goods and enable urban areas to be redesigned, creating more livable and enjoyable spaces, thus meeting several demands simultaneously. Artificial intelligence (AI) takes a prominent position among the technological contributions making automated and connected driving safe, comfortable, efficient, and affordable. AI has found applications in various domains, from safety systems and simulation to monitoring the status of the driver and passengers. Some of these innovative aspects are discussed in this work.

The as-yet unresolved technical challenges and constant endeavours around the world to advance this exciting technology have motivated the creation of this book. The book is structured into eight consequential chapters. It highlights the importance of control engineering, recent advances in environment sensing and perception, in-vehicle architectures, and reliable power computing as well as active and functional safety in AD. There is also a strong focus on validating and testing AD functions. The work concludes with a sample of relevant industry-driven research projects and industrial initiatives.

The authors firmly believe that this book on the application of AI in autonomous vehicles (AV) provides a comprehensive overview of current and emerging technical challenges in the field and gives invaluable insights into industrial demands. The authors also hope the reader will be inspired by the collection of technical articles, selected project summaries, and introductions to renowned national and international initiatives.

Dr Jiri Plihal: He is engaged in developing electronics systems at the Czech Academy of Sciences, Institute of Information Theory and Automation as project manager. He completed his doctoral studies at the Technical University of Brno, Faculty of Civil Engineering in 1998. He has participated in and led numerous national/European R&D projects.

Dr Pavel Nedoma: He successfully defended his dissertation titled ´Modelling the Impacts of Interactions within the Driver-Vehicle System´. He has been working in ŠKODA AUTO´s Technical Development department as a development engineer since 1985.

Dr Zdeněk Herda: He completed his doctoral studies at the Technical University of Liberec. At ŠKODA AUTO, he is active in the area of researching and developing new Human Factors methodology.

Dr Andrei Aksjonov: He received his doctoral honour from Tallinn University of Technology in 2019.

ISBN 978-99949-83-98-8

ELiVA PRESS

Vehicle Systems from an Artificial Intelligence Perspective: Testing & Use Cases

Jiri Plihal et al.

Jiri Plihal Pavel Nedoma Zdeněk Herda Andrei Aksjonov

Vehicle Systems from an Artificial Intelligence Perspective: Testing & Use Cases

ELiVA PRESS

Vehicle Systems from an Artificial Intelligence Perspective:

Testing & Use Cases

Jiri Plíhal
Pavel Nedoma
Zdeněk Herda
Andrei Aksjonov

ELIVAPRESS

ISBN: 978-99949-8-398-8

Cover Design: Eliva **Press**
Cover Im age: lngimage
Email: info@elivapress.com
Website: www.elivapress.com

This Eliva Press imprint is published by the registered company Eliva Press Global Ltd. part of Eliva Press S.R.L. Publishing Group

The registered company address is: Pope Hennessy Street Level 2, Hennessy Tower Port Louis, Mauritius
Eliva Press S.R.L. Publishing Group address is: Bulevardul Moscova 21, Chisinau, Moldova, Europe

Vehicle systems from an Artificial Intelligence perspective: Testing & Use Cases

Jiri Plihal
The Czech Academy o/ Sciences, Institute o/ Information Theory and Automation, Pod Vodarenskou vezi 4, 18100 Praha 8, Czech Republic

Pavel Nedoma , Zdeněk Herda
KODA AUTO a.s., TF. Václava Klementa 869, 193 OJ Mladá Boleslav li, Czech Republic

Andrei Aksjonov
Silo Al, 00100 Helsinki , Finland

Table of contents

Tahle of Contents 2

ABSTRACT 3

ACRONYMS AND ABBREVIATIONS 5

1. INTRODUCTION 7

2. VALIDATION OF COMPREHENSIVE ENERGY MANAGEMENT SYSTEM BASED ON CLOUD-SOURCE INFORMATION 9

3. DETERMINING THE IMPACT OF ASSISTANCE SYSTEMS ON DRJVING STABILITY IN THE E-VECTOORC PROJECT 25

4. DISTRACTED DRIVING RECOGNITION AND EVALUATION SYSTEM 34

5. INFLUENCE OF VEHICLE ASSISTANCE SYSTEM ON TRACK KEEPING 54

6. EFFICIENT DRIVING USING AN OPTIMAL SPEED PROFILE 60

7. DESIGNING THE VEHICLE SPEED PROFILE FOR VARJOUS DRIVING MANOEUVRES 72

8. DEVELOPING AN ADAPTIVE INTERACTIVE SYSTEM TO INCREASE THE SAFETY OF VEHICLE CREWS AND ITS USE IN THE EVALUATION OF ROAD SURFACE PROPERTIES 84

9. TRANSPORT AUTOMATION IN URBAN MOBILITY: A CASE STUDY OF AN AUTONOMOUS PARKING SYSTEM 93

10. CONCLUSION 113

ABSTRACT

This book is devoted to various forms of autonomous driving (AV) that will drastically transform the transportation of people and goods and enable urban areas to be redesigned, creating more liveable and enjoyable spaces, thus meeting several demands simultaneously. The book is structured into eight consequential chapters.

Chapter two covers the development of an application allowing communication between OIKOS and the vehicle dissemination module, using AURIX chip messages to predict the vehicle's speed for the next few seconds while also monitoring other connections. A test application was developed in object-oriented architecture and compiled for various operating system application features: decoding messages, data, real-time visualisation, graphical interpretation, speed profile recommendation in real-time, sending messages with GPS data and loading them from a text file. A graphical user interface was developed, featuring a graph of the anticipated speed profile for semi-autonomous driving. The technical features were tested and evaluated at a test track near Mladá Boleslav. The outputs are visualised in graphs; the speed profile did demonstrate expected values without any extreme values.

Chapter three presents the variables describing the stability of the vehicle's steering response during the considered driving tests: circle drive, slalom, ISO 3888-1 avoidance manoeuvre, Roya! Norwegian avoidance manoeuvre and driving on the interface of surfaces with different adhesion. The vehicle responds by changing its direction of travel, whicb can be described by a turning speed or lateral acceleration.

Chapter four describes distracted driving (DD) recognition in a simulated environment with a block scheme method, including three fundamental blocks: The norma] driving model; an Error Calculation block predicting DD and calculating performance-based errors; and a model for total DD evaluation merged with data from previous steps into a single variable. The results show that the method is efficient in recognising abnormal driving while also being able to detect DD and measuring the level. It allows the secondary impact on safe vehicle control to be studied and a comparative analysis of different secondary tasks influences on DD.

Chapter five collates research on the influence vehicle assistant systems have on track keeping; Electronic Stability Control (ESC) and other assistance systems are tested in a case study, which finds that the proposed ELAT model has

statistically significant results, demonstrating the benefit of ESC in critical situations.

Chapter six focuses on efficient driving using an optimal speed profile and coasting-down strategies. Simulated results for various speed profiles and driving modes are presented along with the following real-road measurements using Semi-Autonomous driving with and without coasting mode. The demonstrated principie of coasting was verified for a real car with the potential benefit of energy savings ofup to 12%. It was necessary to design a new shifting map, considering the electronic motor behaviour for the optima! speed design algorithm. The pre-designed shifting has limitations, but the most significant benefits are expected in cities.

Chapter seven presents the optimisation of energy consumption in various driving conditions, using vehicle GPS localisation to influence the dynamic parameters of the vehicle's movement according to route profile features, including maximum allowed speed, recommended speed, inclination, and the curve radius. The goal of the research is to simulate the accelerator and brake pedals as well as gear shifting. The model was trained to work with d.ifferent drive regimes allowing the neutra! gear. The most important aspects ofthe presented model are the functions modeling vehicle dynarnics and consumption.

Chapter eight includes an overview of the concept of a system evaluating the friction coefficient and road surface roughness based on data recorded by conventional on-board sensors. The concept includes two independent parts: a deterministic vehicle motion model and a stochastic analysis of the correlations between model deviations and surface coefficients based on test drive data. Using the vehicle motion model, it is possible to estimate the values of several variables that can be measured retrospectively using vehicle sensors.

The final chapter nine presents a case study of an autonomous parking system (APS) for transport automation in urban mobility. APS development elements, including communication technology, human machine interface concepts and validation methodology, prioritising the safety aspect of the system are introduced. In addition, this chapter provides examples of decoding signals and presents the results ofparking functionality in the conceptual environment as well as tests consisting of two phases - parking space reservation with autonomous parking and autonomous vehicle recall from the drop-off/pick-up zones.

ACRONYMS AND ABBREVIATIONS

ABS - anti-lock braking system.
ACC - adaptive emise control.
AD - autonomous driving.
ADAS - advanced driver assistance system.
APS - autonomous parking system.
AV - autonomous vehicle.
BASt - Germany Federal Highway Research Institute.
CAN - control area network.
CEN - European Committee for Standardization.
DD - driver d.istraction.
DIL - driver-in-the-loop.
DSRC - dedicated short range communication.
ESP - the German term Elektronisches Stabilitiitsprogramm and stands for Electronic Stability program (system). It is also known as ESC Electronic Stability Control
ETSI - European Telecommunications Standard Institute.
FEV - fully electric vehicle.
FL - fuzzy logic.
GPS - global positioning system.
GUI - graphical user interface.
HMI - human-machine interface.
ICT- Information and Communications Technologies.
IEEE - Institute of Electrical and Electronics Engineers.
IoT- internet of things.
IPA - lnformation Technology-Promotion Agency.
ISO- lntemational Organization for Standardization.
IT- informational technology.
ITS- intelligent transportation system.
IVIS - in-vehicle information system.
k-NN - k-nearest neighbor.
ML- machine learning
MQTT - message queuing telemetry transport.
NHTSA - National Highway Tratlic Safety Administration.
QoS - quality of service.
SAE - Society of Automotive Engineers.
SDO - standard developing organizations.
ST - secondary task.
TC - Technical Committees.
TV - Torque vectoring.
US - United States.

V2I - vehicle-to-infrastructure.
V2V - vehicle-to-vehicle.
VDA- Gennan Association ofthe Automotive Industry.
WAVE - wireless access for vehicular environment.

1. INTRODU CT ION

Nowadays, ADAS such as ACC are state-of-the-art. Once activated by the driver, these systems support the driver in specific driving situations and control either the longitudinal or Iateral movement of the vehicle. Should the system become unstable, the driver is required to step in immediately and retake control of the vehicle. AV systerns allow the driver to relinquish active control over the vehicle for a certain period. These systems control the vehicle's longitudinal and lateral movement simultaneously. The degree of automating a driving function ranges from partial automation and pennanent supervision by the driver to full automation without any driver supervision. For automated vehicles, real-time V2V cornmunication and V2I cornmunication are mandatory for improving traffic infonnation for each traffic participant. As advancements are made in automated and connected driving, new requirements to ensure safe systems arise conceming the accuracy ofthe digital representations oftheir environment at any given time, under all weather conditions and in any traffic situation.

Beyond the technical aspects, several action iterns for the faster introduction of automated vehicles need to be addressed by govemments to ensure the publit's expectations regarding lega! responsibility, safety and privacy are fully met. Authorities must draw up and revise legislation to remove Iiability traps, encourage test regions, review Jong-term infrastructure investments, provide open access, and establish the lega! framework for inter-car cornmunication.

The as-yet unresolved technical challenges and constant endeavors around the world to advance this exciting technology have motivated the creation of this book. The editor invited authors among various stakeholders, including car manufacturers, suppliers, and research organisations to get a balanced view ofthe state of development; current practices and state-of-the-art AD building blocks are extensively reviewed and future trends are predicted. The book highlights the importance of control engineering, recent advances in environment sensing and perception, in-vehicle architectures, and reliable power computing as well as active and functional safety in AVs. There is also a strong focus on validating and testing AV functions. The work concludes with a sample of relevant industry-driven research projects and industrial initiatives.

The authors finnly believe that this book on AVs provides a comprehensive overview of current and emerging technical challenges in the field and gives invaluable insights into industrial demands. The authors also hope the reader will be inspired by the collection oftechnical articles, selected project surnmaries, and introductions to renowned national and international initiatives.