Preface

What is computational intelligence (CI)? Traditionally, CI is understood as a collection of methods from the fields of neural networks (NN), fuzzy logic and evolutionary computation. Various definitions and opinions exist, but what belongs to CI is still being debated; see, e.g., [1], [2], [3]. More recently there has been a proposal to define the CI not in terms of the tools but in terms of challenging problems to be solved [4].

With this edited volume I made an attempt to give a representative sample of contemporary CI activities in automotive applications to illustrate the state of the art. While CI research and achievements have been illustrated in the book form for other specialized fields (see, e.g., [5] and [6]), this is the first volume of its kind dedicated to automotive technology. As if reflecting the general lack of consensus on what constitutes the field of CI, this volume illustrates automotive applications of not only neural and fuzzy computations[1] which are considered to be the "standard" CI topics but also others, such as decision trees, graphical models, Support Vector Machines (SVM), multi-agent systems, etc.

This book is neither an introductory text, nor a comprehensive overview of all CI research in this area. Hopefully, as a broad and representative sample of CI activities in automotive applications it will be worthy of reading for both professionals and students. When the amount of details appears insufficient, the reader is encouraged to consult other relevant sources provided by the chapter authors.

Chapter "Learning-based Driver Workload Estimation" discusses research on estimation of driver cognitive workload and proposes a new methodology to design driver workload estimation systems. The methodology is based on decision-tree learning. It derives optimized models to assess the time-varying workload level from data which includes not only measurements from various sensors but also subjective workload level ratings.

[1] Another "standard" CI topic called evolutionary computation (EC) is not represented in this volume in the form of a separate chapter, although some EC elements are mentioned or referenced throughout the book. Relevant publications on EC for automotive applications are available (e.g., [7]), but unfortunately were not available as contributors of this volume.

Chapter "Visual Monitoring of Driver Inattention" introduces a prototype computer vision system for real-time detection of driver fatigue. The system includes an image acquisition module with an infrared illuminator, pupil detection and tracking module, and algorithms for detecting appropriate visual behaviors and monitoring six parameters which may characterize the fatigue level of a driver. To increase effectiveness of monitoring, a fuzzy classifier is implemented to fuse all these parameters into a single gauge of driver inattentiveness. The system tested on real data from different drivers operates with high accuracy and robustly at night.

Chapter "Understanding Driving Activity Using Ensemble Methods" complements Chapter "Visual Monitoring of Driver Inattention" by discussing whether driver inattention can be detected without eye and head tracking systems. Instead of limiting themselves to working with just a few signals from preselected sensors, the authors chose to operate on hundreds of signals reflecting real-time environment both outside and inside the vehicle. The discovery of relationships in the data useful for driver activity classification, as well as ranking signals in terms of their importance for classification, is entrusted to an approach called random forest, which turned out to be more effective than either hidden Markov models or SVM.

Chapter "Computer Vision and Machine Learning for Enhancing Pedestrian Safety" overviews methods for pedestrian detection which use information from on-board and infrastructure based sensors. Many of the discussed methods are sufficiently generic to be useful for object detection, classification and motion prediction in general.

Chapter "Application of Graphical Models in the Automotive Industry" describes briefly how graphical models, such as Bayesian and Markov networks, are used at Volkswagen and Daimler. Production planning at Volkswagen and demand prediction benefit significantly from the graphical model based system developed. Another data mining system is developed for Daimler to help assessing the quality of vehicles and identifying causes of troubles when the vehicles have already spent some time in service. It should be noted that other automotive companies are also pursuing data mining research (see, e.g., [8]).

Chapter "Extraction of Maximum Support Rules for the Root Cause Analysis" discusses extraction of rules from manufacturing data for root cause analysis and process optimization. An alternative approach to traditional methods of root cause analysis is proposed. This new approach employs branch-and-bound principles, and it associates process parameters with results of measurements which is helpful in identification of the main drivers for quality variations of an automotive manufacturing process.

Chapter "Neural networks in automotive applications" provides an overview of neural network technology, concentrating on three main roles of neural networks: models, virtual or soft sensors and controllers. Training of NN is also discussed, followed by a simple example illustrating importance of recurrent NN.

Chapter "On learning machines for engine control" deals with modeling for control of turbocharged spark ignition engines with variable camshaft timing.

Two examples are considered: 1) estimation of the in-cylinder air mass in which open loop neural estimators are combined with a dynamic polytopic observer, and 2) modeling an in-cylinder residual gas fraction by a linear programming support vector regression method. The authors argue that models based on first principles ("white boxes") and neural or other "black box" models must be combined and utilized in the "grey box" approach to obtain results which are not just superior than any alternatives but also more acceptable to automotive engineers.

Chapter "Recurrent neural networks for AFR estimation and control in spark ignition automotive engines" complements Chapter "On learning machines for engine control" by discussing specifics of the air-fuel ratio (AFR) control. Recurrent NN are trained off-line and employed as both the AFR virtual sensor and the inverse model controller. The authors also provide a comparison with a conventional control strategy on a real engine.

Chapter "Intelligent Vehicle Power Management - an overview" presents four case studies: a conventional vehicle power controller and three different approaches for a parallel HEV power controller. They include controllers based on dynamic programming and neural networks, and fuzzy logic controllers one of which incorporates predictions of driving environment and driving patterns.

Chapter "Integrated Diagnostic Process for Automotive Systems" provides an overview of model-based and data-driven diagnostic methods applicable to complex systems. Selected methods are applied to three automotive examples, one of them being a hardware-in-the-loop system, in which the methods are put to work together to solve diagnostic and prognostic problems. It should be noted that integration of different approaches is an important theme for automotive research spanning the entire product life cycle (see, e.g., [9]).

Chapter "Automotive manufacturing: intelligent resistance welding" introduces a real-time control system for resistance spot welding. The control system is built on the basis of neural networks and fuzzy logic. It includes a learning vector quantization NN for assessing the quality of weld nuggets and a fuzzy logic process controller. Experimental results indicate substantial quality improvement over a conventional controller.

Chapter "Intelligent control of mobility systems" (ICMS) overviews projects of the ICMS Program at the National Institute of Standards and Technology (NIST). The program provides architecture, interface and data standards, performance test methods and infrastructure technology available to manufacturing industry and government agencies in developing and applying intelligent control technology to mobility systems. A common theme among these projects is autonomy and the four dimensional/real-time control systems (4D/RCS) control architecture for intelligent systems proposed and developed in the NIST Intelligent Systems Division.

Unlike the book's index, each chapter has its own bibliography for convenience of the reader, with little overlap among references of different chapters.

This volume highlights important challenges facing CI in the automotive domain. Better vehicle diagnostics/vehicle system safety, improved control of vehicular systems and manufacturing processes to save resources and minimize impact on the environment, better driver state monitoring, improved safety of pedestrians, making vehicles more intelligent on the road - these are important directions where the CI technology can and should make the impact. All of these are consistent with Toyota vision [10]:

Toyota's vision is to balance "Zeronize" and "Maximize". "Zeronize" symbolizes the vision and philosophy of our persistent efforts in minimizing negative aspects vehicles have such as environmental impact, traffic congestion and traffic accidents, while "Maximize" symbolizes the vision and philosophy of our persistent efforts in maximizing the positive aspects vehicles have such as fun, delight, excitement and comfort, that people seek in automobiles.

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