Connected and Autonomous Driving

The automotive industry is transitioning toward connected, autonomous, and electric vehicles; offering contextual, intelligent, and personal consumer experiences; and innovating disruptive ecosystems and business models such as car sharing and hailing services. All of these are primarily driven by fast-moving technology and innovations from 5G communication, cloud and edge computing platforms to artificial intelligence and big data. These changes are predicted to dominate our lives in about 10 years, leading to significant consumer and business values, including improved traffic and safety, smart journey management, cleaner environments, intelligent and personal mobility experiences, and competitive cost management. Similar to companies like Apple, Google, and Baidu heavily investing in connected and autonomous vehicles, car manufacturers are moving to be more like software companies in their use of big data, machine learning, and artificial intelligence to understand the driving context and consumer behavior. These days, a car is not just for going from point A to point B; rather, it delivers a holistic experience that revolves around our daily activities, with the future being the autonomous vehicle.

Our vision is to have a user-centric, connected, autonomous vehicle that

a) operates in isolation from other vehicles using internal sensors,
b) communicates with nearby vehicles and infrastructure (V2X), and
c) leverages holistic user modeling that can better understand the user’s intentions and proactively takes corresponding actions like a virtual personal assistant.

To meet this vision, even though there has been considerable progress toward connected vehicle technologies, traffic, transportation, and cloud-based computing, major challenges remain in innovating and integrating these technologies into our society to create a seamless digital mobility lifestyle—for example, communication, computation platform, machine-learning algorithms for big data, privacy preservation, legislation, user experience design, and education, to name a few.

IN THIS ISSUE

This special issue of IT Professional intends to explore recent advances that address these challenges for connected and autonomous vehicles, providing a perspective of the current state of the art and the issues that need to be addressed to make connected and autonomous vehicles become mainstream for consumers. We aim to provide readers with an overview of the current topics and practices related to connected and autonomous vehicles. The authors’ contributions to this collection of
Context-Aware Fog Computing for Intelligent Transportation Systems (ITS)

This issue begins with “CFC-ITS: Context-Aware Fog Computing for Intelligent Transportation Systems” by Q. T. Minh, E. Kamioka, and S. Yamada. In this paper, the authors propose a novel context-aware fog computing framework for ITS, named CFC-ITS, which consists of the IoT tier, the fog service tier, and the global cloud service tier supporting edge analytics for ITS services in connected car environments. The framework has been validated by a prototype where experimental results reveal the effectiveness of the proposed scheme in terms of latency, energy, and cost reduction, demonstrating its possibility to maximize the IoT potential, specifically for smart cities.

Learning to Navigate Connected Autonomous Cars

The next article is “Learning to Navigate Connected Autonomous Cars for Long-Term Communication Coverage” by Z. Chen, C. H. Liu, and R. Wang. In this paper, the authors propose a highly effective and practical DRL-based framework called DRL-C3 to control connected and autonomous cars to improve communication coverage in network-congested areas, which can learn to control a group of autonomous cars to cover as many points of interest (POIs) as possible in the long run. To solve the problem of continuous action space with hard constraint, it applies the DDPG method with actor and critic neural networks to make decisions and guide the autonomous cars’ movements. The authors conducted extensive simulations to evaluate the performance of the proposed framework compared with two baseline methods. Also, on certain occasions, actions that autonomous cars take may serve different tasks—for example, while providing long-term communication coverage, autonomous cars need to decide when they will replenish energy and drive toward a charging station.

Connected and Autonomous Electric Vehicles (CAEVs)

“Connected and Autonomous Electric Vehicles (CAEVs): A Service Management Perspective” by A. A. Alkheir, M. Aloqaily, and H. T. Mouftah focuses on service management. The powerful capabilities of CAEVs will make it a popular provider of a wide range of services, including mobility, sensing, computing, traffic control, and energy management. This paper uses a characterization of these services to devise a service management framework and pricing schemes. This paper lays the foundations for studying the CAEV as an autonomous service provider, which the authors claim is the first work to address this topic and also the first work to bring the CV, the AV, and the EV together as a single unit. CAEVs will bring forth significant economic benefits that can only be reaped through efficient service management. Properly designing a service management platform requires effective pricing and vehicle selection schemes.

Designing the Product-Service System for Autonomous Vehicles

“Designing the Product-Service System for Autonomous Vehicles” by W. Wang, F. Zhou, W. Li, and J. Budd focuses on user-centric service design. From a product-service system perspective, the authors examine the user experience issues that will arise with the introduction of autonomous driving, including attention-activity changes and related design considerations. They then discuss current disciplinary-specific design methodologies and introduce a more comprehensive approach to the design space to optimize the opportunities for user interaction with examples to meet the changes in the vehicle and the associated transportation service. Thus, the transition to autonomous vehicles will require a much more comprehensive approach to design to integrate and optimize the product-service system. The advent of autonomous vehicles will change the human relationship with driving...
machines, the transportation service, and the related ecosystems. The attention-activity changes and the conceptual design space presented in this article offer a new perspective in response to these design issues in the next autonomous driving age.

**Autonomous Cars: Social and Economic Implications**

Finally, the special issue concludes with “Autonomous Cars: Social and Economic Implications” by R. Hussain, J. Y. Lee, and S. Zeadally. One of the major issues with autonomous cars is their future impact on society, as well as on the research community, academia, and industry. As interest in autonomous car technology grows, the social and economic implications of this technology will affect various stakeholders, including its commercialization. The authors critically review and analyze both the economic and social implications of the autonomous car. The significance of these implications will play an important role in the future of autonomous cars among consumers.

**CONCLUSION**

It is clear that the future of the vehicle is autonomous, connected, and electric. This special issue has addressed the topics that are of the utmost importance and need to be examined to enable the realization of autonomous, connected, and electric vehicles in our society. This is in no way meant to be an exhaustive list of topics and issues, but nevertheless provides a comprehensive survey into the specific research and development issues that academics and industry researchers need to take note of and solve before deploying these vehicles to the masses. In the end, the vehicle still needs to take us from point A to point B; however, it will be intelligent enough to free us from the burdens of driving and journey management and provide us with a sense of mobility, joy, and safety.

**ABOUT THE AUTHORS**

**Jilei Tian** is leading machine learning research at BMW Technology Corporation Chicago. His research interests include machine learning, big data processing and rich context modeling, personalized services, and spoken-language processing. He has authored more than 100 publications and has more than 100 patents and applications. He has managed more than ten university collaborative and EU-funded projects to bring the research from lab to product. He has chaired or served as a member of technical committees in international conferences and on the editorial boards of journals. He has received several awards for outstanding innovation and best papers. Contact him at jilei.tian@bmwna.com or via http://jileitian.wix.com/jileitian.

**Alvin Chin** is a Senior Researcher in machine learning with BMW Technology Corporation, Chicago, IL, USA, where he works on big data and machine learning for improving driving behavior and enabling intelligent driving. His current research involves studying user behavior in driving and in social networks, mining big data from the car data, and creating recommendations of items based on user profiling and context such as predicted destinations and trips to provide intelligent user and car experiences. He has authored more than 30 publications and 10 patents, including those pending. He received the Ph.D. degree in computer science from the University of Toronto, Toronto, ON, Canada. He is a member of various technical committees in international conferences such as IEEE VTC. He is a member of ACM, is on the editorial board of the *New Review of Hypermedia and Multimedia* from Taylor & Francis, and is editor of *Mobile Social Networking: An Innovative Approach*, published by Springer. He is active in the Chicago community, as Chair of the IEEE Vehicular Technology Society Chicago Chapter, Vice-Chair of the IEEE Computer Society Chicago Chapter, and Vice-Chair of ACM Chicago. He was the Co-Chair of the Industry Track for the IEEE Vehicular Technology Conference in Fall 2018 and Chair of the Panel on Opportunities and Challenges in Autonomous, Connected, and Electric Vehicles at that conference. Contact him at alvin.chin@bmwna.com or via http://www.alvinychin.com.
Halim Yanikomeroglu is a Full Professor with the Department of Systems and Computer Engineering, Carleton University, Ottawa, ON, Canada. His research focuses on wireless communications systems and networks. He has supervised 20 Ph.D. and 28 M.Sc. students (all completed with theses), and several of his Ph.D. students have received the Carleton University Senate Medal for Outstanding Doctoral Thesis. He has coauthored 360+ peer-reviewed research papers, including 120+ published in IEEE journals; these publications have received 11,000+ citations. In recent years, his research has been funded by Huawei, Telus, Allen Vanguard, Blackberry, Mapsted, Samsung, Communications Research Centre of Canada (CRC), DragonWave, and Nortel. This collaborative research resulted in 25 granted patents (plus about a dozen applied). He is a Distinguished Lecturer for the IEEE Communications Society and a Distinguished Speaker for the IEEE Vehicular Technology Society in 5G wireless technologies. He has been involved in the organization of the IEEE Wireless Communications and Networking Conference (WCNC) from its inception in 1998 in various capacities including serving as a Steering Committee member, the Technical Program Chair/Co-Chair of WCNC 2004 (Atlanta), WCNC 2008 (Las Vegas), and WCNC 2014 (Istanbul). He was the General Chair of the IEEE Vehicular Technology Conference (VTC 2010-Fall) held in Ottawa and IEEE VTC 2017-Fall held in Toronto. He has served on the editorial boards of IEEE TRANSACTIONS ON COMMUNICATIONS, IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, and IEEE COMMUNICATIONS SURVEYS & TUTORIALS. He was the Chair of the IEEE’s Technical Committee on Personal Communications (now called Wireless Technical Committee with more than 1700 members). Contact him at halim@sce.carleton.ca.