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## EDITORIAL

# IEEE ACCESS SPECIAL SECTION EDITORIAL: ARTIFICIAL INTELLIGENCE (AI)-EMPOWERED INTELLIGENT TRANSPORTATION SYSTEMS

The topic of Artificial Intelligence (AI)-Empowered Intelligent Transportation Systems (ITS) has drawn more attention recently, with the rapid development of ubiquitous networks and smart vehicles. Researchers around the world have been working on new automotive applications to create a comfortable and safer driving environment. Current challenges include: how to run computing-intensive applications on vehicles; how to enable real-time feedback between vehicles and the traffic management server based on the current Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication modes; and how to provide efficient computing capabilities for resource-consumption applications and reasonable resource allocation for vehicles and infrastructures. Recently, AI has made remarkable achievements in many fields such as image processing, pattern recognition, and natural language processing. It is also involved in computing-intensive applications, such as autopilot and real-time navigation through V2V or V2I. However, AI-Empowered ITS is still in its infancy. How can AI be integrated with ITS and function well in dynamic vehicular network scenarios? In addition, there are still questions on how to design more efficient AI solutions for resource management and coordination in ITS.

The objective of this Special Section in IEEE ACCESS is to introduce the current developments and advancements of technical elements in AI-Empowered ITS, from both theoretical and practical perspectives.

Our Special Section received an enthusiastic response and many high-quality submissions. All articles were reviewed by at least two independent referees. After a rigorous review process, we accepted 58 articles to form this Special Section.

In the article “nLSALog: An anomaly detection framework for log sequence in security management,” by Yang *et al.*, a general anomaly detection framework is proposed. By modeling the log template sequence as a natural language sequence, and using the stacked long short-term memory (LSTM) with a self-attention mechanism, the framework can effectively extract the hidden pattern of the log template sequence and express the dependencies inside the log template sequence.

In the article “A distributed network intrusion detection system for distributed denial of service attacks in vehicular

*ad hoc* network,” by Gao *et al.*, a distributed denial of service (DDoS) network intrusion detection system based on big data technology is proposed to overcome the challenges of big data from vehicular ad hoc network (VANET).

The article by Alqahtani *et al.*, “CMRS: A classifier matrix recognition system for traffic management and analysis in a smart city environment,” introduces a classifier matrix recognition system (CMRS) for improving real-time traffic optimization. The proposed CMRS improves the correlation accuracy with a high similarity index, resulting in less processing time and dissimilarity rate.

In the article “Noise-robust wagon text extraction based on defect-restore generative adversarial network,” by Lei *et al.*, a two-stage wagon text extraction system based on the combination of transfer learning and defect-restore generative adversarial network (GAN) is developed to address the problem of wagon text extraction. The proposed strategy remarkably outperforms the prior arts and performs well on robustness.

The article by Zhang *et al.*, “Spatial-temporal graph attention networks: A deep learning approach for traffic forecasting,” proposes a novel deep learning framework, spatial-temporal graph attention networks (ST-GAT). Compared with previous research, the proposed approach can capture dynamic spatial dependencies of traffic networks with outstanding robustness against noise and works well on reduced graphs of the proposed model.

In the article “DDoS detection mechanism using trust-based evaluation system in VANET,” by Poongodi *et al.*, a framework based on trust with a new mechanism is developed to determine DDoS attacks in VANET. The proposed mechanism is proficiently designed for identification of the attacker while reducing the price in attack detection and optimizing the utilization of bandwidth without compromising the security of the nodes in the network.

The article by Nie *et al.*, “Anomaly detection based on spatio-temporal and sparse features of network traffic in VANETs,” focuses on the problem of anomaly detection in VANETs. It proposes an effective anomaly detection approach based on the convolutional neural network. A comprehensive assessment is provided to validate the proposed approach, which illustrates the effectiveness of this approach.

In the article “A new Markov decision process based behavioral prediction system for airborne crews,” by Zhang *et al.*, a Markov decision process (MDP) model is established via analyzing and modeling of pilot operational behavior and mission requirements for flight processes. An iterative algorithm is used to find the optimal prediction sequence. It is a new solution for the safety of pilot operations and the intrusiveness of the cockpit adaptive automation assistance system.

The article by Tian *et al.*, “Multi-scale dilated convolution network based depth estimation in intelligent transportation systems,” proposes Multi-scale dilated convolution network (MSDC-Net), a dilated convolution-based deep network, to tackle the problem of fine details lost based encode modules. After that, a pyramid dilated feature extraction module is added to integrate the knowledge learned through forwarding steps with different receptive fields. The proposed approach is evaluated on the KITTI data set and achieves a state-of-the-art result.

In the article “A task-oriented computation offloading algorithm for intelligent vehicle network with mobile edge computing,” by Liu *et al.*, two computation offloading algorithms are proposed, named binary offloading and partial offloading separately. When addressing divisible and complex tasks, the proposed partial offloading algorithm improves the real-time performance of the tasks significantly and conserves the energy of the vehicle terminal.

In the article “Discrimination and prediction of traffic congestion states of urban road network based on spatio-temporal correlation,” by Chen *et al.*, the spatio-temporal correlation characteristics of traffic states based on the existing floating car data is studied and analyzed. According to the traffic jam aggregation and diffusion characteristics of local Moran's I, a mixed forest prediction method considering the spatio-temporal correlation characteristics of urban road traffic state is constructed by improving the existing random forest algorithm.

The article by You *et al.*, “A real-time driving drowsiness detection algorithm with individual differences consideration,” proposes a real-time driving drowsiness detection algorithm that considers the individual differences of the drivers to ensure driver safety and reduce the losses caused by drowsy driving. According to the eye landmarks, a new parameter, called eyes aspect ratio, is introduced to evaluate the drowsiness of drivers in the current frame.

In the article “Intrusion prevention framework for secure routing in WSN-based mobile Internet of Things,” by Haseeb *et al.*, an intrusion prevention framework for mobile IoT devices with its integration to Wireless Sensor Networks (WSNs) is proposed so as to provide data security with improved network delivery ratio. The proposed framework focuses on energy-efficient and shortest routing chains with optimum decisions.

In the article “Machine learning adoption in blockchain-based smart applications: The challenges, and a way forward,” by Tanwar *et al.*, a detailed study on Machine

Learning (ML) adoption for making BT-based (Blockchain Technology) smart applications more resilient against attacks is presented. This architecture can be used to design and deploy an ML-BT based data analysis system.

The article by Zhang *et al.*, “Vehicle-damage-detection segmentation algorithm based on improved mask RCNN,” proposes a vehicle-damage-detection segmentation algorithm based on transfer learning and an improved mask regional convolutional neural network (Mask RCNN). The improved Mask RCNN has better Average Precision (AP) value, detection accuracy, and masking accuracy. It also improves the efficiency of solving traffic accident compensation problems.

In the article “Contract-based computing resource management via deep reinforcement learning in vehicular fog computing,” by Zhao *et al.*, a novel contract-based incentive mechanism is proposed. The mechanism combines resource contribution and resource utilization to improve the performance of task offloading and resource allocation.

In the article “Correcting biases in online social media data based on target distributions in the physical world,” by Wang *et al.*, a data resampling approach is proposed to address the bias calibration issue. The data resampling algorithm calibrates possible biases based on the stochastic stability theory of Markov Chains to collect data samples from the given biased data set.

In the article by Liu *et al.*, “Contour-maintaining-based image adaption for an efficient ambulance service in intelligent transportation systems,” a contour-maintaining-based image adaption method is proposed for an efficient ambulance service in Intelligent Transportation Systems (ITS) to improve the visual effect of adapted images.

In the article “Research on small target detection in driving scenarios based on improved Yolo network,” by Xu *et al.*, a road information collection plus alarm system is designed based on artificial intelligence to monitor road information. The underlying core algorithm of this system adopts the YOLO v3 network with the best comprehensive detection performance in the end-to-end network.

The article by Sun *et al.*, “Exploiting deeply supervised inception networks for automatically detecting traffic congestion on freeway in China using ultra-low frame rate videos,” proposes a traffic-oriented model to classify congestion from a large data set of ultra-low frame rate video captured from the traffic surveillance system to improve the accuracy of traffic congestion detection on congested roads.

In the article “An improved high-density sub-trajectory clustering algorithm,” by Liu *et al.*, an improved high-density sub-trajectory clustering algorithm is proposed to solve the shortcomings of the TRACCLUS algorithm. The proposed algorithm can be widely used in the fields of traffic corridors identification and improvement of urban spatial structure and functions.

The article by Kong *et al.*, “HUAD: Hierarchical urban anomaly detection based on spatio-temporal data,” proposes a hierarchical urban anomaly detection (HUAD) framework to detect regional anomalies. This article analyzes the traffic

flow of the target area and adjacent areas from different perspectives, using large crowd gathering activities to verify the validity of the model.

In the article “Back propagation neural network based cluster head identification in multi-input multi-output (MIMO) sensor networks for intelligent transportation systems,” by Mukherjee *et al.*, back propagation neural network (BPNN) is combined with the distributed gradient drop method to identify Cluster Head (CH) for MIMO sensor networks, which can minimize the total estimation error. This article addresses the location identification problem of CHs for MIMO sensor networks for ITS applications.

In the article “A bus arrival time prediction method based on position calibration and LSTM,” by Han *et al.*, a bus arrival time (BAT) prediction method is proposed. The proposed method performs well in both peak time and off-peak time multi-stop BAT prediction.

The article by Nie *et al.*, “Traffic measurement optimization based on reinforcement learning in large-scale ITS-oriented backbone networks,” studies the problem of traffic measurement optimization and proposes a reinforcement learning-based method to decrease the cost of direct measurement.

In the article “Radio environment map construction using super-resolution imaging for intelligent transportation systems,” by Deng *et al.*, a novel radio environment map (REM) construction method is proposed using super-resolution technology which is combined with Kriging interpolation, dictionary learning, and random forest. The proposed method can effectively implement offline training and online REM mapping, which can reduce the complexity of the system significantly.

The article by Yu *et al.*, “Co-tracking: Target tracking via collaborative sensing of stationary cameras and mobile phones,” introduces the co-tracking system, which uses fixed nodes (road camera) and mobile nodes (pedestrians and their mobile phones) to collaborate on taking photos or videos to track specific moving objects.

In the article “Artificial intelligence-empowered edge of vehicles: Architecture, enabling technologies, and applications,” by Ji *et al.*, two key technologies, namely mobile edge computing (MEC) and artificial intelligence (AI), are analyzed by focusing on the development of intelligent Internet of Vehicles (IoV) and previous research on combining the two technologies.

The article by El-Sayed *et al.*, “DyReT: A dynamic rule framing engine equipped with trust management for vehicular networks,” proposes a generic rule framing decision engine targeting a broad range of ITS use-cases. The engine is implanted with a two-stage mechanism for cleaning the voluminous vehicular data set and framing dynamic traffic rules along with their actions using real-time vehicular data.

In the article “Artificial intelligence knowledge graph for dynamic networks: An incremental partition algorithm,” by Leng *et al.*, an incremental partition algorithm is designed for dynamic domain knowledge. It provides an effective allocation scheme for data distributed storage. This scheme

effectively solves the problems of edge cut and load balancing in distributed storage by defining the mixed object function.

In the article by Zhao *et al.*, “P-LPN: Toward real-time pedestrian location perception in complex driving scenes,” a novel framework called “P-LPN (pedestrian location perception network)” for real-time pedestrian location perception is proposed. The method enables an end-to-end framework producing semantic segmentation and pedestrian location inference simultaneously.

In the article “Intelligent traffic engineering in software-defined vehicular networking based on multi-path routing,” by Abugabah *et al.*, a combined method of traffic construction in a transport network is proposed based on software-defined networks.

The article by Alharbi and Alharbi, “Design and evaluation of an authentication framework for wearable devices,” aims to develop a unique Authentication Framework for Wearable Devices (AFWD). This framework works as a basis to build a transparent and continuous authentication method for wearable devices to protect sensitive data and respects limitations at the same time.

In the article “Soft set based intelligent assistive model for multiobjective and multimodal transportation problem,” by Sharma *et al.*, a soft set-based approach is developed and successfully illustrated for a numerical example based on real data sets for multi-objective and multi-model transportation problems.

The article by Bagga *et al.*, “Authentication protocols in internet of vehicles: Taxonomy, analysis, and challenges,” discusses an emerging trend of IoV technology and highlights the benefits and the security aspects in IoV communication.

The article by Zheng *et al.*, “Intelligent regulation on demand response for electric vehicle charging: A dynamic game method,” presents a differential game model of the grid and electric vehicle (EV) users to optimize power grid loading and minimize the cost for EV users. Based on this differential game model, the power grid and the benefit of the EVs’ users are guaranteed at the same time, and both finally achieve a mutually beneficial win-win situation.

In the article “Artificial intelligence-empowered path selection: A survey of ant colony optimization for static and mobile sensor networks,” by Chen *et al.*, several typical ACO-based transmission strategies are introduced and compared on the basis of classifications and primary metrics.

The article by Liu *et al.*, “Stochastic runway scheduling problem with partial distribution information of random parameters,” studies an ambiguous two-stage stochastic runway scheduling problem with partial distribution information available, in which the uncertainty mainly arises from the random aircraft arrival times. The runway scheduling efficiency and effectiveness using the proposed model and algorithm is remarkable.

In the article “A period-specific combined traffic flow prediction based on travel speed clustering,” by Feng *et al.*, a novel time-decomposition prediction method is developed according to the fluctuation of traffic flow over time to optimize a traditional 24-hr prediction logic. The proposed

combined method can provide reliable information for traffic police departments on signal timing optimization and traffic guidance.

The article by Liu *et al.*, “Stochastic check-in employee scheduling problem,” studies the problem of stochastic check-in employee scheduling in an airport terminal. This work addresses the issue of assigning airline check-in employees to tasks related to departing flights under uncertain circumstances at an international terminal of a large airport.

In the article “Automatic vehicle license plate recognition using optimal k-means with convolutional neural network for intelligent transportation systems,” by Pustokhina *et al.*, a new OKM-CNN technique is presented for effective detection and recognition of LPs. The proposed OKM-CNN model can be employed as the major element of intelligent infrastructures like toll fee collection, parking management, and traffic surveillance.

The article by Pham *et al.*, “Deep learning for optical vehicular communication,” provides a comprehensive architecture for a vehicular Optical Camera Communication (OCC) system with AI support. Based on a conventional ROI signaling OCC system architecture with two predefined tasks, different AI techniques are considered in terms of performance enhancement in the system to address the challenges of vehicular environments.

In the article “Intelligent resource allocation for utility optimization in RSU-empowered vehicular network,” by Tang *et al.*, a Euclidean distance-based algorithm is proposed to improve the efficiency of resource allocation and optimize the utility values from the perspective of road side unit (RSU) cloudlet.

The article by Yang *et al.*, “GPU-accelerated polar harmonic transforms for feature extraction in ITS applications,” proposes GPU-based polar harmonic transform (PHT). Parallel GPU threads can manipulate pixels simultaneously by using the symmetric properties and mathematical properties of trigonometric functions. The proposed method can fully unleash GPU parallel computational capability for real-time systems and large multimedia databases.

In the article “A practical weather detection method built in the surveillance system currently used to monitor the large-scale freeway in China,” by Sun *et al.*, a vision-based weather detection approach using images from large-scale surveillance systems is proposed to obtain dense weather information.

The article by Benkraouda *et al.*, “Traffic data imputation using deep convolutional neural networks,” proposes a convolutional encoder–decoder neural network model to learn traffic speed dynamics from space–time diagrams to address the problem of estimating dynamic traffic states (e.g., speeds) from limited probe vehicle data.

In the article “A super-learner ensemble of deep networks for vehicle-type classification,” by Hedaya *et al.*, a super-learner ensemble is proposed for the vehicle-type classification problem. A densely connected single-split super learner is utilized to exploit the strengths and diminish

the weaknesses of the individual base learners ResNet50, Xception, and DenseNet.

The article by Alkinani *et al.*, “Detecting human driver inattentive and aggressive driving behavior using deep learning: Recent advances, requirements, and open challenges,” discusses the causes and effects of another human risky driving behavior called aggressive driving behavior (ADB). The authors present an in-depth investigation of the most recent deep learning-based systems, algorithms, and techniques for the detection of distraction, fatigue/drowsiness, and aggressiveness of a human driver.

In the article “A fatigue driving detection algorithm based on facial multi-feature fusion,” by Li *et al.*, a new fatigued driving detection algorithm is proposed based on facial multi-feature fusion. It simplifies the initialization and avoids inaccuracies due to entering the identity manually.

The article by Wang *et al.*, “Segmented trajectory clustering-based destination prediction in IoVs,” proposes a segmented trajectory clustering-based destination prediction method, including trajectory segmentation, sub-trajectory clustering, and destination prediction process. The proposed method can predict the final destination with acceptable errors and outperform the other methods in most cases.

In the article by Singhal *et al.*, “Artificial intelligence enabled road vehicle–train collision risk assessment framework for unmanned railway level crossings,” a road vehicle–train collision risk prediction assessment model based on AI is developed for accident avoidance for road vehicles approaching unmanned railway level crossings.

In the article “Intelligent vulnerability analysis for connectivity and critical-area integrity in IoV,” by Liu *et al.*, an intelligent vulnerability analysis method is proposed considering connectivity and critical-area integrity. The proposed method exhibits outstanding advantages in locating vulnerable elements and preventing performance loss in IoV systems.

The article by He *et al.*, “The intelligent offense and defense mechanism of internet of vehicles based on the differential game-IP hopping,” proposes using the mobile target defense strategy (MTD) to dynamically change the IP address of the RSU, which increases the difficulty of the attacker’s attack. A differential game approach is employed to adjust the RSU’s IP hopping frequency intelligently and adaptively, and maximize its defense benefits. The proposed mechanism can effectively prevent attackers and is superior to fixed blind IP hopping defense mechanisms.

The article by Luo *et al.*, “A secure and anonymous communication scheme for charging information in vehicle-to-grid,” proposes a lightweight privacy protection scheme based on the improved Diffie–Hellman protocol and fragment transmission for the problem of safe transmission of charging information in vehicle-to-grid (V2G). This scheme uses the Diffie–Hellman protocol to dynamically generate session keys and complete secure access authentication.

In the article “Performance evaluation of data dissemination protocols for connected autonomous vehicles,” by Malik *et al.*, a detailed evaluation of three commonly used

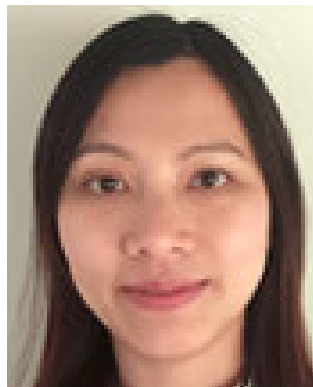


protocols is presented, i.e., *ad hoc* on-demand distance vector routing (AODV), dynamic source routing (DSR), and destination-sequenced distance-vector routing (DSDV), under three different traffic environments.

The article by Duan *et al.*, “A bandwidth-aware video segments request strategy to optimize user’s quality of experience (QoE) in connected vehicle networks,” proposes a bandwidth-aware video segment request strategy to optimize users’ QoE (for short Bw-QoE), which consists of two parts, namely available bandwidth estimation and segment’s bitrate selection, from the perspective of adaptive matching among segment bitrate, network bandwidth, and buffer occupancy.

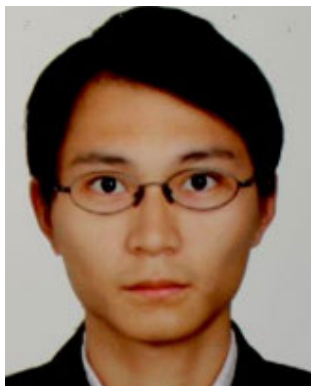
The article by Sarwar *et al.*, “Fuzzy logic based novel hybrid fuel framework for modern vehicles,” proposes a framework to solve a major transportation problem regarding CO<sub>2</sub> emissions, vehicle mileage, and driving range. The proposed system uses fuzzy logic to efficiently manage energy resources including electric, solar, and gasoline power.

In the article “Agent architecture for adaptive behaviours in autonomous driving,” by Da Lio *et al.*, a sensorimotor architecture is described based on a few biologically inspired principles, which is capable of producing adaptive autonomy while incorporating logical criteria. The position is supported by open accessible working examples.



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The Guest Editors would like to thank all the authors, including those whose articles were not selected in this Special Section. They would also like to thank the reviewers, as well as the Editor-in-Chief, editors, and staff members of the journal for their great efforts and outstanding support.

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