Scanning the Issue

Investigating the Prospect of Leveraging Blockchain and Machine Learning to Secure Vehicular Networks: A Survey

M. Dibaei, X. Zheng, Y. Xia, X. Xu, A. Jolfaei, A. K. Bashir, U. Tariq, D. Yu, and A. V. Vasilakos

This article first presents the state-of-the-art communication technologies, standards, and protocols in vehicular networks (either inter-vehicle networking or in-vehicle networking) along with several practical applications, including traffic management, safety, and energy efficiency. Then machine learning and blockchain techniques as novel defense mechanisms are explored to enhance the security of vehicular networks. The authors take into account the integration of blockchain and federated learning in vehicular networks as a direction for future research.

A Survey on Resource Allocation in Vehicular Networks

M. Noor-A-Rahim, Z. Liu, H. Lee, G. G. M. Nawaz Ali, D. Pesch, and P. Xiao

Vehicular networks, an enabling technology for intelligent transportation system (ITS), smart cities, and autonomous driving, can deliver numerous on-board data services, e.g., road-safety, easy navigation, traffic efficiency, comfort driving, infotainment, etc. Providing satisfactory quality of service (QoS) in vehicular networks, however, is a challenging task due to a number of limiting factors such as hostile wireless channels (e.g., high mobility or asynchronous transmissions), increasingly fragmented and congested spectrum, hardware imperfections, and explosive growth of vehicular communication devices. Therefore, it is highly desirable to allocate and utilize the available wireless network resources in an ultra-efficient manner. In this article, the authors present a comprehensive survey on resource allocation (RA) schemes for a range of vehicular network technologies including dedicated short-range communications (DSRC) and cellular based vehicular networks. They discuss the challenges and opportunities for resource allocations in modern vehicular networks and outline a number of promising future research directions.

Deep Learning for Image and Point Cloud Fusion in Autonomous Driving: A Review

Y. Cui, R. Chen, W. Chu, L. Chen, D. Tian, Y. Li, and D. Cao

Recent deep-learning-based data fusion approaches that leverage both image and point cloud are reviewed. This review gives in-depth reviews of camera-LiDAR fusion methods in depth completion, object detection, semantic segmentation, tracking and online cross-sensor calibration, organized based on their respective fusion levels. Finally, this review identified gaps and over-looked challenges between current academic research studies and real-world applications. Based on these observations, they provide their insights and point out promising research directions.

Survey of Deep Reinforcement Learning for Motion Planning of Autonomous Vehicles

S. Aradi

The article presents a survey on the recent advantages in the field of reinforcement learning used to design different autonomous functions. The main elements of designing such a system are modeling the environment, modeling abstractions, describing the state and the perception models, the appropriate rewarding, and the realization of the underlying neural network. The article also describes vehicle models, simulation possibilities, and computational requirements. Strategic decisions on different layers and the observation models, e.g., continuous and discrete state representations, grid-based, and camera-based solutions, are presented. The article surveys the state-of-the-art solutions systematized by the different tasks and levels of autonomous driving, such as car-following, lane-keeping, trajectory following, merging, or driving in dense traffic. Finally, open questions, such as safety, robustness, and sim2real problems are addressed as future challenges on the field.

Optimization of Charging Strategies for Battery Electric Vehicles Under Uncertainty

G. Huber, K. Bogenberger, and H. van Lint

A deterministic framework is proposed which not only allows calculating time optimal routes for battery electric vehicles, but also allows providing recharging recommendations to ensure a reliable arrival at a given destination. Though this framework is basically deterministic, the focus is set on handling uncertainty caused by imperfect energy consumption predictions. This is achieved by reserving a certain part of the battery's energy to compensate for unexpectedly high energy consumption. Several approaches to adjust the size of these "energy buffers" in dependency of the situation are suggested and tested within a simulation study.

Optimized Speed Trajectories for Cyclists, Based on Personal Preferences and Traffic Light Information—A Stochastic Dynamic Programming Approach

A. Dabiri, A. Hegyi, and S. Hoogendoorn

The literature on green mobility and eco-driving in urban areas has burgeoned in recent years, with special attention to using infrastructure to vehicle (I2V) communications to

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obtain optimal speed trajectory which minimize the economic and environmental costs. This article shares the concept with these studies but turns the spotlight on cyclists. It examines the problem of finding the optimal speed trajectory for a cyclist in signalized urban areas. Unlike the available studies on motorized vehicles which predominantly designed for pre-defined, fixed traffic lights timing, this article uses an algorithm based on stochastic dynamic programming to explicitly address uncertainty in traffic light timing. Moreover, through a comprehensive set of simulation experiments, the article examines the impact of the speed advice's starting point as well as the cyclist's willingness for changing their speed on enhancing the performance. The proposed approach targets various performance metrics such as minimizing the total travel time, energy consumption, or the probability of stopping at a red light. Hence, the resulting speed advice can be tailored according to the personal preferences of each cyclist. In a simulation case study, the results of the proposed approach are also compared with an existing approach in the literature.

Taxi Demand Prediction Using Parallel Multi-Task Learning Model

C. Zhang, F. Zhu, X. Wang, L. Sun, H. Tang, and Y. Lv

Considering the correlation between taxi pick-up demand and the drop-off demand, this article proposes a multi-task learning model containing three parallel LSTM layers to co-predict the two kinds of taxi demands. The performance of single demand prediction methodology and that of two demands co-prediction methodology are compared. The experimental results on real-world datasets show that taxi pick-up demand and the drop-off demand are related, and that the author's model can utilize the correlation between the two taxi demands to improve the prediction accuracy.

PSO-Based Adaptive Hierarchical Interval Type-2 Fuzzy Knowledge Representation System (PSO-AHIT2FKRS) for Travel Route Guidance

M. Zouari, N. Baklouti, J. Sanchez-Medina, H. M. Kammoun, M. B. Ayed, and A. M. Alimi

This article describes the application of PSO as optimization methods to instantly tune the MFs of the author's Hierarchical Interval Type-2 Fuzzy Knowledge Representation System (HIT2FKRS) model and design optimal fuzzy logic controllers (FLCs) which assist the driver to achieve his/her destination, while eluding congestions. The suggested system is carried out to adjust promptly the road traffic in a dynamic way and ameliorate the entire road network quality, particularly in case of congestions or jams, considering real-time traffic information and driver' travel time to attain their destinations. Thanks to their advanced system, the user-optimal route is selected before going through each intersection according to the quality of traffic and route length, together with contextual factors pertaining to the driver, the environment, and the path. Essentially, it pertains to the automatic diversion of the traffic into the ideal choice of a set of alternatives or the combination of alternatives toward each vehicle's destination node.

Proactive Rebalancing and Speed-Up Techniques for On-Demand High Capacity Ridesourcing Services

Y. Liu and S. Samaranayake

We present a probabilistic proactive rebalancing method and speed-up techniques for improving the performance of a state-of-the-art real-time high-capacity fleet management framework. We improve on both computational efficiency and system performance. The speed-up techniques include search-space pruning and I/O cost reduction for parallelization, reducing the computation time by up to 97.67%, in experiments on taxi trips in New York City. The proactive rebalancing routes idle vehicles to future demands based on probabilistic estimates from historical demand, increasing the service rate by 4.8% on average, and decreasing the waiting time and total delay by 5.0% and 10.7% on average, respectively.

A Fused Method of Machine Learning and Dynamic Time Warping for Road Anomalies Detection

Z. Zheng, M. Zhou, Y. Chen, M. Huo, L. Sun, S. Zhao, and D. Chen

To discover the condition of roads, a large number of detection algorithms have been proposed, most of which apply machine learning methods by time and frequency processing in acceleration and velocity data. However, few of them pay attention to the similarity of the data itself when the vehicle passes over the road anomalies. In this article, the authors propose a method to detect road anomalies by comparing the data windows with various length using dynamic time warping (DTW) method. They propose a model to prove that the maximum acceleration of a vehicle passing through a road anomaly is linear with the height of the road barrier, and it's verified by an experiment. This finding suggests that it is reasonable to divide the window by threshold detection. They also apply a brief random forest filter to roughly distinguish normal windows from anomaly windows using the aforementioned theory, in order to reduce the time consumption. From their study, a system is proposed that utilizes a series of acceleration data to discover where might be anomalies on the road, named as quick filter-based dynamic time warping (QFB-DTW). They show that their method performs clearly beyond some existing methods. To support this conclusion, experiments are conducted based on three datasets and the results are statistically analyzed. They expect to lay the first step to some new thoughts to the field of road anomalies detection in subsequent work.

A Flexible and Explainable Vehicle Motion Prediction and Inference Framework Combining Semi-Supervised AOG and ST-LSTM

S. Dai, Z. Li, L. Li, N. Zheng, and S. Wang

Accurate trajectory prediction of surrounding vehicles is important for automated vehicles. To solve several existing problems of maneuver-based trajectory prediction, the authors propose four targeted solutions and establish a trajectory prediction model that integrates semi-supervised AND-OR graph (AOG) and spatio-temporal LSTM (ST-LSTM). To reduce the dependence on the well-labeled dataset, they introduce the concept of sub-maneuvers to improve the classifications of vehicle movements based on the given rough maneuver labels. AOG is used as the backbone of the probabilistic motion inference considering sub-maneuvers. They only define the basic units and inference logics of AOG and design a semi-supervised approach to directly learn the sub-maneuvers and the inference model structure from the training data, without manually specifying the structure (layers and nodes) of the inference model. This approach helps to avoid excessive artificial design or biases. The learned hierarchical motion inference model improves the interpretability of the overall trajectory prediction process. To utilize vehicle interaction information and further yield more accurate prediction, they adopt two different methods to consider vehicle interaction in the two sub-models (maneuver recognition and trajectory prediction). The experiment on NGSIM I-80 dataset shows that the maneuver-based model proposed in this article (AOG-ST and refined AOG-ST-TB) performs more accurate trajectory prediction results. Although the AOG-ST seems clumsy and slow, they show that it is a flexible and quick model for trajectory prediction for various driving scenarios through the discussion and experiment.

Robust and Scalable V2V Safety Communication Based on the SAE J2945/1 Standard

O. Gani, Y. P. Fallah, and H. Krishnan

This article analyzes the scheduling protocol for basic safety messages standardized in the SAE J2945/1 and presents large-scale scalability results obtained from a high-fidelity simulation platform. The presented results demonstrate the protocol's efficacy to address the scalability issues in vehicle-to-vehicle communication. The validation results are evaluated using position tracking error as the main performance measure, with age of communicated information as the supporting evaluation measure of the congestion control algorithm. In addition, the optimality of the default settings of the SAE J2915/1 congestion control algorithm parameters is examined. Comprehensive analysis and trade-off study of the control parameters reveal some areas of improvement to further the algorithm's efficacy.

An Enhanced Network-Consistent Travel Speed Generation Scheme on Time-Dependent Shortest Path and Routing Problems

U. M. Yildirim and B. Çatay

A new method for generating network-consistent time-dependent speed and travel time layer on time-independent real and synthetic networks is proposed. The proposed method takes the realistic features such as connectivity of the arcs, direction of the travel, and side road-main road differentiation into account. It is well suited to be used in the time-dependent shortest path and vehicle routing literature which depend on realistic and reasonable test data for demonstration and performance evaluation.

Sparse Road Network Model for Autonomous Navigation Using Clothoids

J. A. Rodrigues da Silva, I. Pachêco Gomes, D. F. Wolf, and V. Grassi, Jr.

To autonomously navigate in traffic roads, an autonomous vehicle must take into account perception information, as well as the topological and geometric structure of the environment. Specifically in urban scenarios, the vehicle has to plan its path across intersections, roundabouts and perform lane changes. In addition, the planning algorithm must also consider the kinematics constraints of the vehicle and passenger' comfort. This article proposes a road network model based on clothoids, which embraces the geometric and topological representation of the environment in a compact data structure. Piecewise linear continuous-curvature paths composed of clothoids, circular arcs, and straight lines are used for this purpose. The proposed approaches are evaluated in an urban scenario composed of curved and straight roads with single and double lanes, roundabouts, and intersections. As a result, a navigation architecture for autonomous vehicles was developed using the model, including global planning with continuous-curvature paths.

A Probabilistic Approach for Cooperative Computation Offloading in MEC-Assisted Vehicular Networks

P. Dai, K. Hu, X. Wu, H. Xing, F. Teng, and Z. Yu

A novel scenario of computation offloading in MEC-assisted vehicular networks, where task upload coordination between multiple vehicles, task migration between MEC/cloud servers and heterogeneous capabilities of MEC/cloud severs, are comprehensively investigated. By modeling the procedure of task upload, migration and computation based on queuing theory, a cooperative computation offloading (CCO) problem is formulated to minimize the delay of task completion. A probabilistic computation offloading (PCO) algorithm is designed to make MEC server independently online schedule offloading decision based on a convex framework called alternating direction method of multipliers. The effectiveness of the proposed algorithm is validated based on realistic vehicular trajectory.

Constrained Model Free Adaptive Predictive Perimeter Control and Route Guidance for Multi-Region Urban Traffic Systems

Z. Hou and T. Lei

A novel data driven scheme called constrained model free adaptive predictive control (cMFAPC) is provided for perimeter control (PC) and route guidance (RG) of the multi-region urban traffic system. Two outstanding advantages of this method are that it can only use the input and output (I/O) data of the controlled MRUTS to design the PC and RG strategies, instead of utilizing the traffic dynamics model, and the merits of model free adaptive control (MFAC) method and model predictive control (MPC) approach are combined in the proposed cMFAPC strategy. The effectiveness of cMFAPC strategy and its superiority over other commonly used PC and RG methods are verified via simulation.

Monocular Visual-Inertial-Wheel Odometry Using Low-Grade IMU in Urban Areas

J. H. Jung, J. Cha, J. Y. Chung, T. I. Kim, M. H. Seo, S. Y. Park, J. Y. Yeo, and C. G. Park

A visual-inertial fusion algorithm for a land vehicle with an intermittent GNSS signal is proposed. Motivated by a degenerate case caused by a large bias of an MEMS IMU, the authors redesign a system model of visual-inertial odometry in a framework of extended Kalman filter. In particular, the system model is propagated through a reduced inertial sensor system composed of a 3-axis gyroscope, a 2-axis accelerometer, and a single-axis odometer. The proposed method is validated through the Monte-Carlo simulation, KITTI benchmark dataset, and an extensive field testing showing a position drift as 1.25% in tunnels on average and a mean position error of 2.81 m in the street canyon over a 6.7 km driving.

Feedback-Based Ramp Metering and Lane-Changing Control With Connected and Automated Vehicles

F. Tajdari, C. Roncoli, and M. Papageorgiou

A novel methodology for integrated lane-changing and ramp metering control that exploits the presence of connected and automated vehicles is presented. In particular, an optimal control methodology is formulated, with the aim of robustly maximizing throughput at motorway bottlenecks, whereas optimal set-points are estimated through a tailored extremum seeking algorithm. The method is evaluated via simulation experiments, performed on a first-order multi-lane macroscopic traffic flow model, also featuring the capacity drop phenomenon, which allows to demonstrate the effectiveness of the developed methodology, highlighting the improvement in terms of generated congestion. The findings will allow readers to identify how connected and automated vehicles, as an emerging technology, can facilitate user mobility in transportation networks.

Towards Faster Vehicle Routing by Transferring Knowledge From Customer Representation

L. Feng, Y. Huang, I. W. Tsang, A. Gupta, K. Tang, K. C. Tan, and Y.-S. Ong

In this article, the authors present a new study toward faster vehicle routing by transferring knowledge from customer representations which are learned from past solved vehicle routing problems (VRPs). In particular, they propose to capture the useful traits buried in previous optimized routing solutions by learning a new customer representation, which can be transferred across VRPs, serving as the prior knowledge, to bias the optimization in the target VRP. In contrast to existing approaches, the proposed knowledge transfer is consisting of a learning of new customer representation based on the optimized routing solution, which is general to VRPs possessing different structural properties, and a weighted l1 norm-regularized formulation for building sparse mapping across VRPs, that is easy to solve. Empirical studies on both commonly used VRP benchmarks and real-world vehicle routing application confirmed the efficacy of the proposed method.

Vehicle Trajectory Prediction and Cut-In Collision Warning Model in a Connected Vehicle Environment

N. Lyu, J. Wen, Z. Duan, and C. Wu

A collision warning model in a vehicle-to-vehicle (V2V) communication environment is established. Through the comprehensive prediction model for lane changing behavior, the prediction model for driving trajectory and the oriented bounding box detection algorithm, the identification and warning of vehicle collision risk in the cut-in scenarios are realized. Based on the simulation driving platform and real-vehicle experiments, the effects of the proposed cut-in collision warning model and the traditional collision warning model are compared.

A Unified Multi-Task Learning Architecture for Fast and Accurate Pedestrian Detection

C. Zhou, M. Wu, and S.-K. Lam

This work presents a unified multi-task learning architecture for fast and accurate pedestrian detection. Motivated by the fact that pedestrian regions are highlighted in semantic segmentation result, this work proposes to effectively and efficiently interfuse the task of pedestrian detection and semantic segmentation by exploiting segmentation result as prior knowledge for pedestrian detection under faster R-CNN framework. A semantic segmentation to feature module (SS2FM) is designed to integrate segmentation prior into feature learning while a semantic segmentation to confidence module (SS2CM) is proposed to refine the classification confidence in RPN. This work also introduces an effective anchor matching point transform to alleviate the problem of feature misalignment for heavily occluded pedestrians. The experiment results on well-known pedestrian detection benchmark show that the proposed method is the fastest among all state-of-the-art pedestrian detection methods while exhibiting competitive detection performance.

Decentralized Multi-Agent Path Finding for UAV Traffic Management

F. Ho, R. Geraldes, A. Gonçalves, B. Rigault, B. Sportich, D. Kubo, M. Cavazza, and H. Prendinger

In the context of the development of a real-world unmanned aircraft system traffic management (UTM) system to ensure the safe integration of unmanned aerial vehicles (UAVs) in low altitude airspace, the problem of pre-flight conflict detection and resolution (CDR) to provide collision-free flight paths for all UAVs before their takeoff is addressed. This article proposes a novel multi-agent path finding (MAPF) model that supports the decentralized resolution of conflicts among UAV operations, i.e., possibility of collisions, whereby different “agents,” here UAS Service Providers (UASSPs), manage their UAV operations. A simple yet practical pairwise negotiation approach where UASSPs agents determine an agreement to solve conflicts between their UAV operations is proposed. Experimental simulations show that the proposed negotiation approach improves the “fairness” between UASSPs, i.e., the distribution of costs between UASSPs in terms of total delays and rejected operations.

Dynamic Graph Convolution Network for Traffic Forecasting Based on Latent Network of Laplace Matrix Estimation

K. Guo, Y. Hu, Z. Qian, Y. Sun, J. Gao, and B. Yin

A novel dynamic graph convolution network for traffic forecasting is proposed, in which a latent network of Laplace matrix, based on LSTM and spatial attention, is introduced to extract spatial–temporal features for constructing the dynamic road network graph matrices adaptively. Then, the proposed method is evaluated on three traffic datasets and the experimental results show that it outperforms the state-of-the-art traffic forecasting methods, and from the analysis of results, it also successfully explores the dynamic latent spatial relation in traffic data.

Short-Term Demand Forecasting for On-Demand Mobility Service

X. Qian, S. V. Ukkusuri, C. Yang, and F. Yan

To improve the efficiency of urban on-demand mobility services (OMS), it is important to frame proactive operation strategies before the actual demand is revealed. The task is challenging since the effectiveness depends on the knowledge of passenger demand distribution in immediate future and is prone to prediction errors. In this study, the authors develop the boosting Gaussian conditional random field (boosting-GCRF) model to accurately forecast the distribution of short-term future OMS demand using historical OMS demand data. Comprehensive numerical experiments are conducted to evaluate the performance of boosting-GCRF as compared to four other benchmark algorithms. The results suggest that the boosting-GCRF is superior with the best mean absolute percentage error being 14%. In addition, the model is found to be robust under demand anomalies, and the density functions generated by the boosting-GCRF model are found to well capture the actual distribution of the short-term taxi demand.

Trajectory Planning Based on Spatio-Temporal Map With Collision Avoidance Guaranteed by Safety Strip

T. Zhang, M. Fu, W. Song, Y. Yang, and M. Wang

This article proposes a framework for trajectory planning based on spatio-temporal map. Due to time layer architecture in the map, the trajectory can be generated with velocity and acceleration simultaneously, and the whole trajectory is constrained within a "safety strip," resulting in an efficient and safety guaranteed trajectory. The framework is composed of three sections: rough search, fine optimization and safety strip-based collision avoidance. For rough search, it proposes an improved A* algorithm implemented in the discrete time layer to find out the suboptimal states efficiently. In fine optimization, the B-spline curve is exploited to connect the searched states into a continuous trajectory. And the optimal control points of B-spline are further grouped into several segments, forming "safety strip" which is actually the distribution space of the planned trajectory, to make the entire trajectory completely collision-free. Experiments on public dataset and self-driving simulator proved its effectiveness.

5G V2V Communication With Antenna Selection Based on Context Awareness: Signaling and Performance Study

S. Roger, D. Martín-Sacristán, D. Garcia-Roger, J. F. Monserrat, A. Kousaridas, P. Spapis, and S. Ayaz

Although vehicular communications are by default assumed between single antennas located on the roof of the transmitter and receiver vehicles, prior art has shown that there are other antenna positions more suitable for V2X communication, depending on the specific communication context. In this work, the authors propose a context-aware antenna selection procedure able to enhance the communication with multi-antenna vehicles. To enable such scheme in 5G systems, they discuss the necessary signaling to extend current 5G radio resource control and radio resource management mechanisms, which are mainly focused on single-antenna communication. The signaling overhead caused by context exchange for antenna selection is analyzed and compared to the overhead when reference signals are exchanged for that purpose instead. Finally, simulation results for a 5G platooning use case are presented to show the advantages of antenna selection.

Utility-Based Matching of Vehicles and Hybrid Requests on Rider Demand Responsive Systems

Y. Lai, S. Yang, A. Xiong, F. Yang, L. Li, and X. Zhou

A taxi-rider matching scheme that integrates both the real-time and appointment-based requests is proposed. The matching problem is transformed into a minimal cost flow problem which aims to maximize a utility value and could be solved efficiently. Riders and vehicles are modeled as vertices in a bipartite graph, and factors like the length of pickup trajectories, riders' waiting time, and etc., are abstracted as utilities and denoted as weights of the edges which are taken into account during the matching process. The assignments between vehicles and requests could be dynamically adjusted and revoked to maximize the overall utility. Experimental results show that the proposed algorithm can effectively increase the appointment-based matching ratio and decrease the rider' waiting time and vacant vehicle' picking up time.

Bayesian Learning of Occupancy Grids

C. Robbiano, E. K. P. Chong, M. R. Azimi-Sadjadi, L. L. Scharf, and A. Pezeshki

A new Bayesian framework for generating these probabilities that does not assume statistical independence between the occupancy state of grid cells is presented. This approach is made analytically tractable through the use of binary asymmetric channel models that capture the errors associated with observing the occupancy state of a grid cell. Binary-valued measurement vectors, used by the framework in the sequential update of an occupancy grid, are the thresholded output of a sensor in a radar, sonar, or other sensory system. Experiments with sonar data are presented and analyzed using the proposed method and classical occupancy grid methods, and performance is compared.

Virtual Coupling of Railway Vehicles: Gap Reference for Merge and Separation, Robust Control, and Position Measurement

J. Park, B.-H. Lee, and Y. Eun

Virtual coupling, which refers to the operation of railway vehicles that enables the merge and separation of vehicles on the move by controlling the gap between the vehicles without any mechanical coupling, is one of the technologies for increasing the transport capacity and enhancing operational efficiency. This article proposes a robust gap controller based on sliding mode control with a nonlinear train model with uncertainties. Additionally, a gap reference generation scheme is developed that ensures that the merge and separation of two trains is completed before a given location and respects constraints on acceleration and jerk. The position and velocity measurement errors arising from imperfect knowledge of wheel diameters are also considered, and a new error correction scheme is proposed to reduce the perturbation in the gap control performance. The proposed schemes are validated through simulations.

A Model of Extraction of Rail's Vertical Corrugation Based on Flexible Virtual Ruler

Z. Ma, K. Xu, Y. Teng, X. Shao, M. Dong, and Y. Wang

A new mathematic model based on flexible virtual ruler (FVR) is proposed to make the extraction process of rail corrugation (RC) be an executable operation for machine calculation. The model can extract the instantaneous RC with a successive approximation algorithm according to user's requirements and national standards. The proposed FVR model can not only be fully compatible with the traditional extraction method of RC, but also provide a new idea for evaluating R's quality.

Adversarial Reconstruction Based on Tighter Oriented Localization for Catenary Insulator Defect Detection in High-Speed Railways

J. Zhong, Z. Liu, C. Yang, H. Wang, S. Gao, and A. Núñez

This article proposes a novel two-stage defect detection method for catenary insulators. In the localization stage, a novel localization network called TOL-Framework is constructed to reduce the background and realize tighter oriented localization. Compared with general basic framework faster R-CNN, the TOL-Framework cascades a regression module inside basic framework and adds an external postprocess network, which is adversarially trained by standard insulators to refine the localization. These two novel steps greatly improve the oriented localization accuracy. In the defect detection stage, an adversarial reconstruction model that is trained only using normal samples is proposed to evaluate the defect states. A comparison with other methods is conducted using a dataset collected from a 60 km section of the Changsha–Zhuzhou railway line in China. The results show the proposed method has the highest localization accuracy, and is effective for insulator defect detection.

Traffic Sign Recognition With Lightweight Two-Stage Model in Complex Scenes

Z. Wang, J. Wang, Y. Li, and S. Wang

Considering largescale traffic signs and the inherent conflict between location regression and classification of traffic signs in complex scenes, this article proposes a novel and flexible two-stage approach. It combines a lightweight superclass detector with a refinement classifier. With the inception and channel attention, the superclass detector generates multi-scale receptive fields and adaptively adjusting channel features. It alleviates the large-scale variance challenge of traffic signs and the interference of background information. The article also proposes a refinement classifier based on similarity measure learning for the subclass classification. It increases the precision of discriminating similar subclasses and also improves the extensibility of the approach. The competitive performance of the proposed method is demonstrated based on experimental results.

Traffic Information Mining From Social Media Based on the MC-LSTM-Conv Model

Y. Wang, Z. He, and J. Hu

There remains a challenging issue regarding how to sufficiently mine traffic information from social media (e.g., Sina Weibo). The authors propose a deep learning-based method that uses social media data for traffic jam management. The core ideas of the proposed method are twofold. First, a multichannel network with a long short-term memory layer and a convolution layer (termed as MC-LSTM-Conv). The MC-LSTM-Conv is proposed to extract check-in microblogs reflecting traffic jams from mass Sina Weibo data. Second, a series of matching rules are constructed based on the keywords that are related to traffic-jam scenes. Experimental results show that the combination of these two methods can indeed extract detailed information such as congestion location distribution, congestion cause and congestion responsible party from massive Sina Weibo data.

Modeling Adversarial Behavior Against Mobility Data Privacy

R. Pellungrini, L. Pappalardo, F. Simini, and A. Monreale

In this work, the authors propose simulated privacy annealing (SPA), a new adversarial behavior model for privacy risk assessment in mobility data. They model the behavior of an adversary as a mobility trajectory and introduce an optimization approach to find the most effective adversary trajectory in terms of privacy risk produced for the individuals represented in a mobility dataset. They use simulated annealing to optimize the movement of the adversary and simulate a possible attack on mobility data. They finally test the effectiveness of their approach on real human mobility data, showing that it can simulate the knowledge gathering process for an adversary in a more realistic way.

A Matching Framework for Employees to Support Carpooling in the Context of Large Companies

I. Hussain, L. Knapen, T. Bellemans, D. Janssens, and G. Wets

The success of recurrent carpooling depends on trust among the candidates and on spatial and temporal similarity between their respective trips. Therefore, an innovative matching support framework is presented—to notify people about new opportunities to find partners belonging to a closed managed group and interested in carpooling. It proposes carpool solutions based on the optimal matching of candidates to the employees who are potential carpoolers and willing to negotiate about cooperation. The framework supports an automatic advisory tool that aims to find the best carpool solutions for each individual. A large number of feasible groups can be found for a particular individual and scoring functions are used to qualify the best solutions. The best groups are kept and presented to the group members who in turn evaluate them using their own individual scoring criteria and start negotiating to take the final decision.

NeuroIV: Neuromorphic Vision Meets Intelligent Vehicle Towards Safe Driving With a New Database and Baseline Evaluations

G. Chen, F. Wang, W. Li, L. Hong, J. Conradt, J. Chen, Z. Zhang, Y. Lu, and A. Knoll

In this work, the authors build the first-ever database NeuroIV by using a neuromorphic vision sensor that bridges the gap between neuromorphic engineering and intelligent vehicle research. Neuromorphic vision sensors such as the dynamic and active-pixel vision sensor (DAVIS) using silicon retina are inspired by biological vision, they generate streams of asynchronous events to indicate local log-intensity brightness changes. Their properties of high temporal resolution, low-bandwidth, lightweight computation, and low latency make them a good fit for many applications of motion perception in the intelligent vehicle. They present three novel datasets recorded with DAVIS sensors and depth sensor for the distracted driving research and focus on driver drowsiness detection, driver gaze-zone recognition, and driver hand-gesture recognition. To facilitate the comparison with classical computer vision, they record the RGB, depth and infrared data with a depth sensor simultaneously. The total volume of this dataset has 27 360 samples. To unlock the potential of neuromorphic vision on the intelligent vehicle, they utilize three popular event-encoding methods to convert asynchronous event slices to event-frames and adapt state-of-the-art convolutional architectures to extensively evaluate their performances on this dataset. The NeuroIV introduces new ways to sense and perceive the environment that brings new revolution of vision-based perception system in intelligent vehicle. It will serve as a standardized and open-source platform on which new neuromorphic vision-based methods can be developed and evaluated.

Omnisupervised Omnidirectional Semantic Segmentation

K. Yang, X. Hu, Y. Fang, K. Wang, and R. Stiefelhagen

An omnisupervised learning framework is proposed for omnidirectional semantic segmentation with efficient CNNs. The framework bridges multiple heterogeneous data sources that are already available in the community, bypassing the labor-intensive process to have manually annotated panoramas, while improving the reliability of efficient CNNs in unseen omnidirectional domains. Being omnisupervised, the efficient CNN exploits both labeled pinhole images and unlabeled panoramas. The framework is based on a specialized ensemble method that considers the wide-angle and wrap-around features of omnidirectional images, to automatically generate panoramic labels for data distillation. A comprehensive variety of experiments demonstrates that the proposed solution helps to attain significant generalizability gains in panoramic imagery domains. Datasets and codes are available at https://github.com/elnino9ykl/OOSS.

A New Quadratic Spacing Policy and Adaptive Fault-Tolerant Platooning With Actuator Saturation

G. Guo, P. Li, and L.-Y. Hao

This article investigates a fault-tolerant control problem for heterogeneous vehicular platoons with actuator faults and saturation. The occurrence of actuator faults may yield large control signals to avoid performance loss, which can potentially lead to saturation of the actuator that may cause further performance deterioration or even instability. To compensate for the effects of actuator faults and saturation, an adaptive fault-tolerant control method is proposed based on nonlinear vehicle dynamics and a new quadratic spacing policy. The improved quadratic spacing policy is introduced to remove the assumption of zero initial spacing errors. The nonlinear vehicle dynamics is approximated by a radial basis function neural network (RBFNN). The adaptive fault-tolerant platoon control method is developed in the context of PID-type sliding mode control technique, and proved to be capable of guaranteeing individual vehicle stability, string stability and traffic flow stability. The effectiveness of the method is verified through comparison simulation studies.

Testing Scenario Library Generation for Connected and Automated Vehicles: An Adaptive Framework

S. Feng, Y. Feng, H. Sun, Y. Zhang, and H. X. Liu

How to generate testing scenario libraries for connected and automated vehicles (CAVs) is a major challenge faced by the industry. In previous studies, to evaluate maneuver challenge of a scenario, surrogate models (SMs) are often used without explicit knowledge of the CAV under test. However, performance dissimilarities between the SM and the CAV under test usually exist, and it can lead to the generation of suboptimal scenario libraries. In this article, an adaptive testing scenario library generation (ATSLG) method is proposed to solve this problem. A customized testing scenario library for a specific CAV model is generated through an adaptive process based on Bayesian optimization. Comparing with a pre-determined library, a CAV can be tested and evaluated in a more efficient manner with the customized library. Results of a cut-in case study demonstrate that the proposed method can further accelerate the evaluation process by a few orders of magnitude.

An Electric Vehicle Routing Problem With Intermediate Nodes for Shuttle Fleets

S. Hulagu and H. B. Celikoglu

The authors propose an electric vehicle routing problem considering explicitly the intermediate nodes. Ultimately aiming to provide an optimal routing plan for the shuttle fleet that serves to a university settlement, they consider a real road network by explicitly taking into account in the formulation the entire intersections existing and the time-varying passenger demand at shuttle stops, as well as the vehicle dynamics, battery, and recharging features. On purpose, a mathematical program to obtain the joint minimization of a number of objectives in terms of cost is formulated. Solutions employing an exact method are sought using models of mixed integer program within scenarios. Further solutions have been obtained using a benchmark set of instances designed for a large-scale real network. Their findings show that considering a real road network as it is, is significant in exact routing solutions despite the fact that the level of network complexity is an issue.

Dynamic V2I/V2V Cooperative Scheme for Connectivity and Throughput Enhancement

B. L. Nguyen, D. T. Ngo, N. H. Tran, M. N. Dao, and H. L. Vu

This article proposes a new dynamic cooperation scheme for V2I and V2V communications to maintain continuous connectivity and improve throughput. Specifically, an adaptive multi-hop V2V path is generated between a road side unit (RSU) and a target vehicle by employing a dynamic forwarder selection strategy. Furthermore, the authors develop an analytical model to provide insights into the impacts of inter-RSU distance, vehicles' assistance willingness and the target vehicle's buffer size to the network performance. And, closed-form expressions are derived for the average out-of-range connection time, number of service resumptions and achieved throughput. Simulation results with practical parameter settings show the proposed scheme is effective in improving connectivity while offering a high throughput for the target vehicle.

Reliable and Efficient Content Sharing for 5G-Enabled Vehicular Networks

J. Cui, J. Chen, H. Zhong, J. Zhang, and L. Liu

With the arrival of the 5G era, the downloading speed of network services and message transmission speed have significantly improved. Consequently, the content exchanged by users in vehicular networks are not limited to traffic information, and vehicles moving at high speeds can share a wide variety of content. However, sharing content securely and reliably remains challenging owing to the fast-moving character of vehicles. To solve this problem, the authors propose a reliable and efficient content sharing scheme in vehicular networks. The vehicles with content downloading requests quickly filter the adjacent vehicles to choose capable and suitable proxy vehicles and request them for content services. Thus, the purpose of obtaining a good hit ratio, saving network traffic, reducing time delay, and easing congestion during peak hours can be achieved. The security analysis indicates that the proposed scheme meets the security requirements of vehicular networks.

Real-Time Mission-Motion Planner for Multi-UUVs Cooperative Work Using Tri-Level Programing

S. Sun, B. Song, P. Wang, H. Dong, and X. Chen

This article considers a cooperative task of multiple unmanned underwater vehicles (UUVs), where UUVs need to visit a set of marine stations in a time-varying environment. To direct UUVs in real-time, a mission-motion planner is modeled using tri-level optimization frameworks. Specifically, the lower-level designs paths, and the middle-level allocates missions, while the upper-level synchronizes the two levels to achieve the optima of every level simultaneously. To solve the proposed optimization, different heuristic algorithms are chosen according to each level property, and their initialization processes are modified. Finally, the proposed model and algorithms present their outstanding performance in complex and large-scale cases.

Ridesourcing Behavior Analysis and Prediction: A Network Perspective

D. Chen, Q. Shao, Z. Liu, W. Yu, and C. L. P. Chen

To deeply understand ridesourcing behavior, this work collects comprehensive dataset of Didi ridesourcing cars including both temporal and spatial records in a big city of China. This research constructs a large-scale network by considering every traffic flow, and show temporal and spatial features behind this traffic behavior. Furthermore, this research provides a general analytical method to quantify the behavioral predictability by calculating the entropy at a collective level, which can surely be extended to other traffic behavior analysis. This study also proposes a practical neural network-based model for predicting dwelling time of the ridesourcing behavior, by considering the traffic congestion factor. The results suggest that ridesourcing behavior indicates specific non-Markovian characteristics, which can be systematically analyzed from the viewpoint of network sciences.

Delegating Authentication to Edge: A Decentralized Authentication Architecture for Vehicular Networks

A. Yang, J. Weng, K. Yang, C. Huang, and X. Shen

This article proposes an edge-assisted decentralized authentication architecture for vehicular networks. The proposed architecture provides secure and communication-efficient authentication by enabling an authentication server to delegate its authentication capability to distributed edge nodes such as roadside units and base stations. Under this architecture, a threshold mutual authentication protocol that supports fast handover is designed, where the involved edge nodes can be efficiently authenticated in a batch by the vehicle. In addition, the article presents a flexible method to support dynamic joining and leaving of edge nodes without the assistance of a trusted center. Security analysis and performance evaluation demonstrate that the proposed protocol is secure and efficient.

Adaptive Deep Learning for High-Speed Railway Catenary Swivel Clevis Defects Detection

S. Gao, G. Kang, L. Yu, D. Zhang, X. Wei, and D. Zhan

The swivel clevis (SC) is a vulnerable part of the overhead catenary system (OCS). Regular inspection using computer vision technology is an effective way to detect SC defects and improve the OCS operation safety. However, achieving full automation of SC defects detection is still a difficult task due to defective sample scarcity and data distribution shift. To overcome these problems, this article proposes a novel defects detection method that combines an adaptive SC segmentation network (Adaptive SSN) and local operators. During the inspection process, an unreliability index defined by the model uncertainty and prior knowledge is used to monitor the reliability of the Adaptive SSN. When data distribution shift causes the Adaptive SSN to be unreliable, human annotator will be asked to update the training set and retrain the Adaptive SSN to adapt to the new data distribution. Then the geometric features obtained from segmentation masks and the local features extracted by local operators are used to detect the SC defects. Effectiveness of the proposed method is demonstrated by the experimental results on the data from several high-speed railway lines.

MagMonitor: Vehicle Speed Estimation and Vehicle Classification Through A Magnetic Sensor

Y. Feng, G. Mao, B. Cheng, C. Li, Y. Hui, Z. Xu, and J. Chen

The Internet-of-Things (IoT) is playing an increasingly important role in intelligent transportation systems (ITSs) for real-time sensing and communication. In ITS, vehicle types, volume and speeds provide important information for road traffic management. However, the present methods for on-road traffic monitoring are lacking in providing cost-effective means to meet the demands. In this article, the authors propose MagMonitor, a novel method for on-road traffic surveillance through a single small and easy-to-install magnetic sensor. The developed magnetic sensor system is wireless-connected, cost-effective, and environmentally friendly. First, a magnetic model of a moving vehicle is presented. The model employs multiple magnetic dipoles for modeling moving vehicle and varies depending on the on-road vehicle types. Through modeling of local magnetic field perturbations caused by moving vehicles, they extract the characteristics of magnetic waveforms for vehicle identification and speed estimation. The proposed model and estimation technique are validated with real field experimental data. Furthermore, they analyze and compare the performance of the proposed estimation technique with other speed estimation algorithms, which shows the superior accuracy of the proposed technique.

A Feature-Based Approach to Large-Scale Freeway Congestion Detection Using Full Cellular Activity Data

S. Li, Y. Cheng, P. Jin, F. Ding, Q. Li, and B. Ran

Most existing cellular probe-based freeway congestion detection methods rely on on-call wireless location technologies (WLTs) signal transition data. However, these techniques facing difficulties such as small sample size, frequent road tests, safety, and privacy issues. This article presents a novel approach using the FCA data for traffic congestion detection on freeways. Two cellular activity features, the link pseudo speed and link probe activity, are defined and calculated. A rule-based algorithm is then developed to determine the traffic congestion state. The proposed method has been implemented and a prototype system has been deployed for a major freeway corridor in China. Validated by fixed-point detector data and incident records, the proposed method is able to identify real-time freeway traffic congestion accurately.

Improving the Security of LTE-R for High-Speed Railway: From the Access Authentication View

Y. Wang, W. Zhang, X. Wang, W. Guo, M. K. Khan, and P. Fan

The security problem of long-term evolution for railway (LTE-R) is discussed. A well-designed access authentication scheme is proposed for satisfying the authentication requirements of different scenarios in LTE-R. The proposed scheme consists of three main security mechanisms: a novel elliptic curve cryptosystem certificateless proxy signature (ECC-CLPS) designed for authentication security, a hash-based puzzle introduced to defend against denial of service (DoS) attack and a key pre-generation mechanism used to improve the efficiency of fast handover authentication. The effectiveness and security of the proposed scheme are demonstrated by the theoretical derivation and numerical investigations.

Multi-Objective Multi-Index Transportation Model for Crude Oil Using Fuzzy NSGA-II

R. Latpate and S. S. Kurade

In this article, the business restricted multi-objective multi-index transportation problem is developed for the crude oil supply chain network of India. Binary variables are used to introduce the business restrictions such as war situations or any of eventualities in the two stage supply chain network transportation model. Various uncertainty levels are considered in the formulated model. Triangular fuzzy numbers are used to represent the uncertain information of a supply chain network consisting of independent source countries, ports and cities. Pareto decision space of the model is obtained at various levels of uncertainty using the formulated optimization algorithm viz., NSGA-II. The algorithm is formed by taking into account the fuzzy set theory and evolutionary algorithm. Novelty of the algorithm is tested on real world data of Daya Corporation Ltd., Taiwan, which produces better results. The presented model is useful in supply chains of manufacturing and distributing industries.

Rapid Ship Detection Method on Movable Platform Based on Discriminative Multi-Size Gradient Features and Multi-Branch Support Vector Machine

J. Feng, B. Li, L. Tian, and C. Dong

A rapid ship detection method on a movable platform based on discriminative multi-size gradient features and multi-branch support vector machine is proposed. To deal with the different appearances of ships caused by sizes and viewpoints, this work integrates the information of different sizes of ships into the multi-size gradient features including the coarse and fine gradient features. Since the proposed feature dimensions vary with sizes of ships, a multi-branch SVM is designed to deal with these features in different feature space to identify ships rapidly and locate ships precisely. Experimental results show that the proposed method achieve real-time performance and satisfactory detection precision, which is helpful for inshore ship detection and intelligence surveillance at maritime.

Safe and Efficient Cooperative Platooning

S. Thormann, A. Schirrer, and S. Jakubek

A novel concept for distributed model predictive control of the platoon vehicles is proposed which safely allows dense spacing and keeps communication requirements small while being robust against communication loss. A safety-extension separates safety constraints from the design of the tracking control goals and enables agreed-upon behavior in terms of temporarily limited decelerations. Driving corridors based on position errors are utilized to select suitable control modes or trigger prediction updates to the following vehicles. Realistic vehicle dynamics co-simulations demonstrate the platoon safety and performance in selected scenarios, including emergency braking and maneuver tracking subject to traffic disturbances. The proposed measures are effective with realistic model errors, provide implicit collision safety and show string stability with low communication requirements.

VARID: Viewpoint-Aware Re-IDentification of Vehicle Based on Triplet Loss

Y. Li, K. Liu, Y. Jin, T. Wang, and W. Lin

With the increasing prevalence of intelligent traffic control and monitoring, research on vehicle re-identification (Re-ID) draws substantial attention in recent years. Different from other cross-view searching tasks such as person Re-ID, the vehicle Re-ID problem is more challenging and unpredictable as viewpoint variations can greatly affect the appearance of vehicles. Existing studies mainly focus on extracting global features based on visual appearance to represent the identity of the target vehicle, while the impact of viewpoint variation is rarely considered. In this article, the authors take the view information into account to boost vehicle Re-ID, and introduce latent view labels by clustering and incorporates view information into deep metric learning to tackle the challenge. They also develop a stricter center constraint to further improve the intra-class compactness of feature space. Moreover, they adopt an orthogonal regularization to increase the separability between different vehicles. VARID achieves 79.3% mAP on VeRi-776 and 88.5% mAP on VehicleID which surpasses state-of-the-arts a lot. Comprehensive experimental analyses and evaluations on four benchmarks demonstrate that the proposed method outperforms significantly state-of-the-art baseline methods.

Effects of Non-Driving Related Tasks During Self-Driving Mode

S. Minhas, A. Hernández-Sabaté, S. Ehsan, and K. D. McDonald-Maier

Perception reaction time and mental workload have proven to be crucial in manual driving. Moreover, in highly automated cars, take-over performance is also a key factor when taking road safety into account. This study investigates how the immersion in non-driving related tasks affects the take-over performance of drivers in given scenarios. The article also highlights the use of virtual simulators to gather efficient data that can be crucial in easing the transition between manual and autonomous driving scenarios. An experiment comprising 40 subjects was performed to examine the reaction times of driver and the influence of other variables in the success of take-over performance in highly automated driving under different circumstances within a highway virtual environment. The implications of the results acquired are important for understanding the criteria needed for designing human–machine interfaces specifically aimed toward automated driving conditions. Understanding the need to keep drivers in the loop during automation, whilst allowing drivers to safely engage in other non-driving related tasks is an important research area which can be aided by the proposed study.

Software-Defined Vehicular Networks With Trust Management: A Deep Reinforcement Learning Approach

D. Zhang, F. R. Yu, R. Yang, and L. Zhu

The appropriate design of a vehicular ad hoc network (VANET) has become a pivotal way to build an efficient smart transportation system, which enables various applications associated with traffic safety and highly-efficient transportation. VANETs are vulnerable to the threat of malicious nodes stemming from its dynamicity and infrastructure-less nature and causing performance degradation. Recently, software-defined networking (SDN) has provided a feasible way to manage VANETs dynamically. In this article, they propose a novel software-defined trust-based VANET architecture (SD-TDQL) in which the centralized SDN controller is served as a learning agent to get the optimal communication link policy using a deep Q-learning approach. Specifically, the authors use the expected transmission count (ETX) as a metric to evaluate the quality of the communication link for the connected vehicles' communication. Moreover, they design a trust model to avoid the bad influence of malicious vehicles. Simulation results are presented to show the effectiveness of the proposed SD-TDQL framework.

Dynamic Pricing for Differentiated PEV Charging Services Using Deep Reinforcement Learning

A. Abdalrahman and W. Zhuang

This article proposes a differentiated pricing mechanism for a multiservice plug-in electric vehicle (PEV) charging infrastructure. The proposed framework motivates PEV users to avoid over-utilization of particular service classes. The proposed pricing mechanism utilizes model-free deep reinforcement learning (RL) to learn and improve automatically without an explicit model of the environment. The simulation results demonstrate that the proposed RL-based differentiated pricing scheme can adaptively adjust service pricing for a multiservice PEV charging infrastructure to maximize charging facility utilization while ensuring service quality satisfaction.

Game-Theoretic Modeling of Multi-Vehicle Interactions at Uncontrolled Intersections

N. Li, Y. Yao, I. Kolmanovsky, E. Atkins, and A. R. Girard

Motivated by the need for simulation tools for testing, verification and validation of autonomous driving systems that operate in traffic consisting of both autonomous and human-driven vehicles, they propose a game-theoretic framework for modeling the interactive behavior of vehicles at uncontrolled intersections. The proposed vehicle interaction model is based on a novel formulation of dynamic games with multiple concurrent leader–follower pairs, induced from common traffic rules. Based on simulation results for various intersection scenarios, the authors show that the model exhibits reasonable behavior expected in traffic, including the capability of reproducing scenarios extracted from real-world traffic data and reasonable performance in resolving traffic conflicts. The model is further validated based on the level-of-service traffic quality rating system and demonstrates manageable computational complexity compared to traditional multi-player game-theoretic models.

Test Coverage Index for ADAS/ADS Assessment Based on Various Real-World Information Points

T. Machida and K. Shitaoka

In this article, the authors propose a novel index that expresses the comprehensiveness of the real scenes using various information points (e.g., map information, road structure rules, and traffic investigation) to correctly assess an advanced driving assistance system (ADAS)/autonomous driving system (ADS). There are two key points. One is to establish an index that enables them to judge whether a test has been sufficiently performed and locate “dropouts” in the ADAS/ADS assessment by constructing a database of the scene structure in the real world, instead of the current index which is the running distance of the field operational test (FOT) based on knowledge/experiences. The other is that designed evaluation scenarios with the proposed index enable to guarantee that the scenes targeted by the ADAS/ADS are mostly covered and to grasp the priority of the target scenes without the bias of the appearance frequency. Specifically, they defined the real world as a combination of five types of scene features. Then, they formulated the test coverage index by integrating the existence and appearance frequency of real-world information corresponding to each scene feature. Furthermore, they searched optimal evaluation courses by maximizing the score on each road segment based on the index. In experiments, they showed the results of visualizing the test coverage ratios which enable to compare both optimal designed course and manually designed course that assumes the current process. They also showed the test coverage ratios in several countries and in several scene, feature patterns toward the various quantitative ADAS/ADS assessment.

A Multi-Stream Feature Fusion Approach for Traffic Prediction

Z. Li, G. Xiong, Y. Tian, Y. Lv, Y. Chen, P. Hui, and X. Su

Recent advances in graph-based neural networks have achieved promising traffic prediction results. However, some challenges remain, especially regarding graph construction and the time complexity of models. In this article, the authors leverage a data-driven adjacent matrix instead of the distance-based matrix to construct graphs. Then, a multi-stream feature fusion block (MFFB) module is proposed, which includes a three-channel network and the soft-attention mechanism. The three-channel networks are graph convolutional neural network (GCN), gated recurrent unit (GRU), and fully connected neural network (FNN). The soft-attention mechanism is also utilized to integrate the obtained features. The MFFB modules are stacked, and a fully connected layer and a convolutional layer are used to make predictions. They conduct experiments on two real-world datasets and verify that their proposed approach outperforms the state-of-the-art methods within an acceptable time complexity.

Near Real-Time Freeway Accident Detection

Y. W. Liyanage, D.-S. Zois, and C. Chelmis

This article proposes a Bayesian quickest change detection formulation to detect accidents in freeways in near real-time using spatially distributed sensors. The proposed methods consider both detection delay and false alarm rate, and are able to detect accidents as they happen. To account for unknown post-accident conditions, they estimate unknown parameters and aggregate sensors’ decisions during the accident detection process. Experimental results on real-world data from the I405 freeway in Los Angeles County demonstrate the utility of the proposed methods.

Learning a Dynamic Feature Fusion Tracker for Object Tracking

Z. Li, K. Nai, G. Li, and S. Jiang

This article proposes an effective and efficient feature fusion tracker to dynamically fuse gradient and color features for robust visual tracking. Specifically, two complementary correlation filters for gradient and color features are maintained during tracking, and the proposed method adaptively assigns different weights to them to deal with large appearance changes of the target object in challenging tracking scenes. Moreover, a failure detection scheme is designed to alleviate the model drift issue caused by undesirable model updates to improve the tracking accuracy. Extensive experiments on multiple tracking benchmarks demonstrate that the proposed tracker can achieve impressive tracking accuracy and speeds.

Modeling and Simulation of Crowd Evacuation With Signs at Subway Platform: A Case Study of Beijing Subway Stations

M. Zhou, H. Dong, X. Wang, X. Hu, and S. Ge

This article proposes a modified social force (SF) model to investigate crowd evacuation dynamics taking into account the influence of emergency signs. The perceiving probability model is formulated for the quantitative description of the probability that pedestrians can successfully notice the sign and clearly perceive the guidance information. Simulation experiments and controlled experiments are designed to calibrate the parameters of the proposed model. The effectiveness of the modified SF model is preliminarily verified by comparing the simulation results with experimental data and/or empirical results. A case study of crowd evacuation simulations at a typical Beijing subway station is conducted to evaluate evacuation performance of maximal covering (MaxCover) scheme, uniform scheme, and random scheme, as well as contrasted scheme without emergency signs. The effects of the quantity and distribution of emergency signs on crowd evacuation efficiency are studied quantitatively by simulations.

Robust Lane Extraction From MLS Point Clouds Towards HD Maps Especially in Curve Road

C. Ye, H. Zhao, L. Ma, H. Jiang, H. Li, R. Wang, M. A. Chapman, J. M. Junior, and J. Li

This article presents a semiautomated method to extract the lane features along the curved roads from mobile laser scanning (MLS) point clouds. The proposed method consists of four steps. After data pre-processing, a road edge detection algorithm is performed to distinguish road curbs and extract road surfaces. Then, textual and directional road markings are detected by intensity thresholding and conditional Euclidean clustering algorithms. Furthermore, lane markings are extracted by local intensity analysis and distance thresholding methods. Finally, centerline points on lanes are estimated based on the coordinates of extracted lane markings. Quantitative evaluations show that the average recall, precision, and F1-score obtained from four datasets for road marking extraction are 93.87%, 93.76%, and 93.73%, respectively.

An Artificial Neural Network-Based Model for Real-Time Dispatching of Electric Autonomous Taxis

L. Hu and J. Dong

This article presents a real-time dispatching model for electric autonomous vehicle (EAV) taxis that combines mathematical programming and machine learning. The EAV taxi dispatching problem is formulated and solved as an integer linear program that maximizes the total reward for serving customers. The optimal dispatch solutions are generated by simulating electric autonomous taxis that are dispatched by the optimization model. The artificial-neural-network-(ANN)-based model was trained using the optimization mode's dispatch solutions to learn the optimal dispatch strategies. Although the dispatch decisions made by the ANN-based model are not optimal, the system's performance is very close to the optimization dispatch model in terms of customer service and taxi' operational efficiency. In addition, the ANN-based dispatch model runs much faster. EAV taxis dispatched by the ANN-based model can reduce empty travel distance and fleet size compared with the current taxis.

Spatial Positioning Token (SPToken) for Smart Mobility

R. Overko, R. Ordóñez-Hurtado, S. Zhuk, P. Ferraro, A. Cullen, and R. Shorten

A permissioned distributed ledger technology (DLT) design for crowdsourced smart mobility applications is developed. The design is based on a directed acyclic graph architecture and uses consensus mechanisms to provide protection against spam attacks and malevolent actors. The architecture is suitable for distributed privacy-preserving machine learning algorithms and can be implemented in simple the Internet-of-Things (IoT) devices. An application of reinforcement learning settings to smart mobility is presented, where a third party is interested in acquiring information from agents without perturbing the environment. Virtual tokens are proposed to act as surrogates of real agents (vehicles) to explore geographical areas of interest. These tokens are used to emulate the probing actions of commanded (real) vehicles on a given planned route by "jumping" from a passing-by vehicle to another to complete the planned trajectory. Numerical results from large-scale simulations are provided to validate the proposed approach.

FusionLane: Multi-Sensor Fusion for Lane Marking Semantic Segmentation Using Deep Neural Networks

R. Yin, Y. Cheng, H. Wu, Y. Song, B. Yu, and R. Niu

A deep neural network method is proposed to help the construction of high-precision maps. In order to obtain the accurate 3-D spatial position of the lane marking, the main object of the semantic segmentation in this method is a bird's-eye view converted from LiDAR points cloud instead of an image captured by a camera. Meanwhile, A long short-term memory (LSTM) structure is added to the neural network to assist the network in semantic segmentation of lane markings by enabling use of time series information. Experiments on datasets containing more than 14 000 images, which were manually labeled and expanded, showed that the proposed method provides accurate semantic segmentation of the bird's-eye view LiDAR points cloud. Consequently, automation of high-precision map construction can be significantly improved.

Multi-Agent Fuzzy-Based Transit Signal Priority Control for Traffic Network Considering Conflicting Priority Requests

M. Xu, J. Chai, Y. Yan, and X. Qu

This study proposes a multi-agent transit signal priority (TSP) method to realize TSP at the network level and meanwhile resolve conflicting multiple TSP requests. Fuzzy inference is used to manage signal control. The authors further develop a specific control algorithm. The performance of the proposed method is verified by a case study with a sizeable traffic network with 20 intersections and 49 links.

Robust Nonlinear Control Using Barrier Lyapunov Function Under Lateral Offset Error Constraint for Lateral Control of Autonomous Vehicles

Y. Hwang, C. M. Kang, and W. Kim

In this study, the authors propose a robust nonlinear control method using the barrier Lyapunov function (BLF) under the lateral offset error constraint for lateral control of autonomous vehicles. They propose a second-order lateral dynamics scheme based on the look-ahead distance of the vehicle. In the second-order lateral dynamics, the system functions with unknown parameters, and the external disturbances can be lumped into a disturbance term. The proposed method consists of an extended state observer (ESO) and a nonlinear controller. The ESO is designed to estimate the full state variable and disturbance, including the system modeling and external disturbance. The nonlinear controller is developed using the BLF to compensate for the disturbances and to guarantee the constraint for the lateral offset error.

Rapid Extraction of Urban Road Guardrails From Mobile LiDAR Point Clouds

J. Gao, Y. Chen, J. M. Junior, C. Wang, and J. Li

Mobile laser scanning (MLS) systems provide highly dense 3-D point clouds that enable the acquisition of accurate traffic facilities information for the intelligent transportation system. Road guardrails with safety features that can separate traffic and define moving spaces for pedestrians and vehicles face challenges such as diverse guardrail types and continuous slopes in point clouds data. A novel approach is proposed for rapidly extracting urban road guardrails from MLS point clouds, and adapting for most types of guardrails and rough slope roads. The proposed method achieves high precisions for the lane-separating guardrails and the anti-fall guardrails. It is valuable for the application of providing for 3-D high maps.

Global-Local Temporal Convolutional Network for Traffic Flow Prediction

Y. Ren, D. Zhao, D. Luo, H. Ma, and P. Duan

A novel global-local temporal convolutional network (GL-TCN) is proposed to comprehensively capture the spatial–temporal dependency by jointly modeling the global and local flow patterns and other external influence features. Specifically, a local temporal convolutional mechanism is designed to capture the long-term local dynamics effectively. Meanwhile, the global and local flow patterns are integrated to handle the effect of the global flow trend on local dynamics. Experiments on two real-world datasets demonstrate the superior performance of their method over several state-of-the-art baselines.

AZIM ESKANDARIAN, *Editor-in-Chief*
Nicholas and Rebecca des Champs Professor and Department Head
Mechanical Engineering Department
Virginia Tech
Blacksburg, VA 24061 USA