# Scanning the Issue

**Deep Reinforcement Learning for Intelligent Transportation Systems: A Survey**

*A. Haydari and Y. Yılmaz*

The paper surveys deep reinforcement learning (RL)-based traffic control applications. From a broad concept, the theoretical background of RL and deep RL methods, especially those used in ITS literature, are presented. Since there are many deep RL applications in ITS for traffic signal controllers (TSC), predominantly existing TSC works that use RL and deep RL approaches are presented and compared in tables. Similarly, different deep RL applications in other ITS areas, such as autonomous driving, road control, etc., are also evaluated.

**Deep Learning-Based Vehicle Behavior Prediction for Autonomous Driving Applications: A Review**

*S. Mozaffari, O. Y. Al-Jarrah, M. Dianati, P. Jennings, and A. Mouzakitis*

This paper reviews state-of-the-art deep learning-based vehicle behavior prediction studies. A generic problem definition is provided followed by classifications of existing studies based on the input representation, the output type, and the prediction model they used. Finally, commonly used metrics are summarized, the performance of some of the existing studies are discussed, and some future research directions are introduced.

**A Review on Swarm Intelligence and Evolutionary Algorithms for Solving the Traffic Signal Control Problem**

*P. W. Shaikh, M. El-Abd, M. Khanafer, and K. Gao*

The rapid development of urban cities coupled with the rise in population has led to an exponentially growing number of vehicles on the roads for the latter to commute. This is adding to the already overbearing problem of traffic congestion. Short term, costly and short-sighted solutions of road infrastructure expansions are no longer suitable. One effective method of road resource allocation is focusing on the widely used traffic signal controllers' timing schedules. Searching for a suitable or an optimal schedule for the prior via brute force to ease traffic congestion might not be the most elegant or feasible solution. Nature-inspired algorithms including evolutionary and swarm intelligence algorithms are gaining a lot of momentum. Many of these algorithms have been used in the last two decades to address different applications in the smart city era including traffic signal control (TSC). This paper conducts a comprehensive literature review on applications of evolutionary and swarm intelligence algorithms to TSC. Surveyed work is categorized based on the set of decision variables, optimization objective(s), problem modeling, and solution encoding. The paper, based on gaps identified by the conducted review, identifies promising future research directions and discusses where the future research is headed.

**Sensors and AI Techniques for Situational Awareness in Autonomous Ships: A Review**

*S. Thombre, Z. Zhao, H. Ramm-Schmidt, J. M. Vallet García, T. Malkamäki, S. Nikolskiy, T. Hammarberg, H. Nuortie, M. Z. H. Bhuiyan, S. Särkkä, and V. V. Lehtola*

This paper overviews the recognized operational requirements that are imposed on regular and autonomous seafaring vessels, and then proceeds to consider suitable sensors and relevant AI techniques for an operational sensor system. The integration of four sensor families is considered: sensors for precise absolute positioning, visual sensors, audio sensors, and sensors for remote sensing. Auxiliary data sources, such as Automatic Identification System and external data archives, are also discussed. The perception tasks are related to well-defined problems, such as situational abnormality detection, vessel classification, and localization, that are solvable using AI techniques. Machine learning methods, such as deep learning and Gaussian processes, are identified to be especially relevant for these problems. The different sensors and AI techniques are characterized by the operational requirements, and some example state-of-the-art options are compared based on accuracy, complexity, required resources, compatibility, and adaptability to maritime environment, and especially toward practical realization of autonomous systems.

**Two-Echelon Dispatching Problem With Mobile Satellites in City Logistics**

*Y.-L. Lan, F.-G. Liu, Z. Huang, W. W. Y. Ng, and J. Zhong*

At present, city logistics mostly adopts a two-echelon dispatching model which combines distribution centers located in suburbs and fixed satellites located in urban areas for distribution. However, both expensive rental fees and daily changes of customer demand in metropolitan areas make dispatching route generated by fixed satellites inefficient. Moreover, the existing mobile depot model needs a large investment for facilities. In this paper, the authors propose a two-echelon city dispatching model with mobile satellites (2ECD-MS) which locations of mobile satellites change according to demands of customers to ensure the efficiency of delivery routes in every day. A cluster-based variable neighborhood search scheduling algorithm is proposed to determine locations of mobile satellites and dispatching routes of trucks and tricycles. Then, the 2ECD-MS is extended to 2ECD-MS-TDD to allow trucks dispatching directly (TDD) for further cost reduction. The experimental results show that the 2ECD-MS significantly reduces the total cost against the model using fixed satellites mode by 3.5% while the 2ECD-MS-TDD further reduces the total cost against the 2ECD-MS significantly by 3.25% in 54 cases with different customer scales, geographical scopes,

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and distribution types. These show the superiority of the proposed methods in cost reduction for city logistics in comparison to the traditional fixed model.

**Driver Identification and Verification From Smartphone Accelerometers Using Deep Neural Networks**

*S. Hernández Sánchez, R. Fernández Pozo, and L. A. Hernández Gómez*

This paper addresses driver identification and verification using deep learning on tri-axial accelerometer signals from drivers' smartphones. Driver identification refers to the recognition of a driver among a given set, while driver verification is the process of accepting or rejecting the identity assumed by a particular driver. The proposed driver identification architecture includes ResNet-50 followed by two Stacked Gated Recurrent Units. ResNet-50 pre-trained on image classification has been evaluated testing two approaches to map 1D accelerometer signals into 2D images. The first one is based on a frequency domain representation using spectrograms, while the second one uses 2D feature maps from a CNN with 1D inputs. Siamese Neural Networks and Triplet Loss Training have been proposed for driver verification. Experiments on a database of real driving journeys achieved driver identification top-1 and top-5 accuracies of 71.89% and 92.02%, respectively, and driver verification F1 score of 74.09%.

**A BRB-Based Effective Fault Diagnosis Model for High-Speed Trains Running Gear Systems**

*C. Cheng, J. Wang, Z. Zhou, W. Teng, Z. Sun, and B. Zhang*

Fault diagnosis is a key way to improve the efficient, safe and stable operation of high-speed trains. This paper proposes a fault diagnosis method based on belief rule base with mixed reliability (BRB-mr). Different from the traditional BRB, this method considers two kinds of interference factors that affect the observation data in engineering practice, including the performance of sensors and the influence of external environment, and the authors quantify them as static reliability and dynamic reliability of attributes in BRB. In order to integrate two kinds of reliability factors into the reasoning of BRB, a discount method is developed based on Dempster–Shafer theory (D-S theory), which is helpful for more accurate diagnosis. In this paper, the effectiveness and practicability of the method are verified by a single fault of the running gear, and the supplementary numerical data verified its feasibility in multiple fault mode diagnosis. Then this method is compared with traditional methods. The result shows BRB-mr model has stronger diagnostic ability to identify faults and it has a certain engineering application value to be extended to other complex system fault diagnosis.

**Dynamic Driving Risk Potential Field Model Under the Connected and Automated Vehicles Environment and Its Application in Car-Following Modeling**

*L. Li, J. Gan, X. Ji, X. Qu, and B. Ran*

This paper proposes a new dynamic driving risk potential field model under the connected and automated vehicles environment that fully considers the dynamic effect of the vehicle's acceleration and steering angle. The statistical analysis of the model's parameter reveals that acceleration and steering angle will directly affect the distribution of the driving risk potential field and that this strong correlation should not be ignored if one is interested in the vehicl's microscopic motion behavior. The simulation results indicate that the proposed DRPFM model is proved to be a good description of car-following behavior. In addition, this DRPFM model is applied to deduce the safety conditions for vehicle lane-changing. The analysis results prove that this model can reasonably explain the influencing factors between driver types and lane-changing safety conditions in practice.

**Short-Term Prediction of Level of Service in Highways Based on Bluetooth Identification**

*M. R. Wilby, A. B. Rodríguez González, R. Fernández Pozo, and J. J. Vinagre Díaz*

A short-term LOS classifier is proposed to provide traffic managers with a meaningful information about the future traffic behavior. This approach evolves the traditional regression problem of forecasting travel time to a classification problem. The proposed Random Undersampling Boost classifier is fed with arrival travel time data captured by a Bluetooth Monitoring System covering six links in real operation on the SE-30 highway in Seville, Spain. It achieved an average recall of 82.8% for prediction horizons up to 15 min, reaching 92.5% predicting congestion. The results demonstrated that surrounding links even in the opposite direction embed significant information about traffic in the stretch under study.

**A Multi-Scale Attributes Attention Model for Transport Mode Identification**

*G. Jiang, S.-K. Lam, P. He, C. Ou, and D. Ai*

This paper investigates travel mode detection for sparse trajectories consisting of only GPS location data. A novel Multi-Scale Attributes Attention (MSAA) model is developed to explore multi-scale local attributes of travel trajectories to provide discriminating local features, and more attention is given to a critical partition scale that can better characterize the differences across various transport modes. An ensemble model based on Neural Decision Forest is employed to fuse the heterogeneous features consisting of both measurable quantities (e.g., global features such as average speed) and non-measurable elements (i.e., learned latent local attributes). Results on real-world datasets show that the proposed multi-scale local attributes well complement the global features leading to better performance.

**Global Context Assisted Structure-Aware Vehicle Retrieval**

*Y. Tian, T. Chen, G. Cheng, S. Yu, X. Li, J. Li, and B. Yang*

In vehicle retrieval, the vehicle patch should first be localized to remove the irrelevant background information. Moreover, the negative samples are much more prevalent than the positive samples, and the information from the negative samples is not fully exploited in the triple loss. What is required is a way to incorporate global knowledge and structure information to address these two issues. Therefore, the authors introduce a local-global context network for landmark alignment to update the predicted results by using the semantic information and the local compatibility and propose a structure-aware quadruple loss to use multiple and diverse negative samples in retrieval. Experiments on the VehicleID and the ENJOYOR vehicle retrieval data sets demonstrate that this approach obtains accuracy comparable to state-of-the-art approaches in vehicle retrieval.

**Condition-Based Maintenance for Traction Power Supply Equipment Based on Partially Observable Markov Decision Process**

*S. Lin, R. Fan, D. Feng, C. Yang, Q. Wang, and S. Gao*

Actual condition-based maintenance for traction power supply equipment (TPSE) is almost based on completely observable equipment state. However, it is unpractical to accurately reveal the equipment state due to the inescapably uncertainty of state assessment. In order to optimize the maintenance of TPSE, a maintenance model based on partially observable Markov decision process is proposed in this paper. Firstly, the degradation process of the TPSE is described by a four-state Markov process, and the state residence time and its transition probability of the equipment are obtained by equaling fault times in the statistical period. Then, the imperfect maintenance is considered in this paper. And the failure risk of the TPSE after maintenance is quantified for optimizing both the economic cost and the reliability of maintenance strategy. Finally, the practical fault record data of 27.5-kV vacuum circuit breakers for a traction power supply system (TPSS) are used to verify the proposed model. The results show that the maintenance model can provide guidance on decision-making for the maintenance under uncertainty, and the determination of maintenance schemes to optimize both TPSE reliability and operational cost.

**Analysis of Classifier Training on Synthetic Data for Cross-Domain Datasets**

*A. Cortés, C. Rodríguez, G. Vélez, J. Barandiarán, and M. Nieto*

This paper presents an analysis of synthetic data-based training performance for cross-domain datasets of intelligent transportation systems. The analysis includes the selection of real world domain datasets, the synthetic data generation pipeline by the application of different augmentation techniques or by using a simulator game engine, and finally, the comparison of resulting trained models performances. Due to the heterogeneity of real world acquired datasets, a new detailed method to objectively compare these models' accuracies is also proposed. Results show that synthetic-data approaches outperform real-data training for cross-domain test datasets, and that the generalization capabilities of the model increase while the cost of producing real images is decreased.

**Routing With Traffic Awareness and Link Preference in Internet of Vehicles**

*C. Chen, L. Liu, T. Qiu, J. Jiang, Q. Pei, and H. Song*

In this paper, the authors propose a Traffic aware and Link Quality Sensitive Routing Protocol (TLRP) for urban Internet of Vehicles (IoV). First, the authors design a novel routing metric, i.e., Link Transmission Quality (LTQ), to account for the impact of the number, quality and relative positions of communication links along a routing path on the network performance. Then, to adapt to the dynamic characteristics of IoV, a road weight evaluation scheme is presented to assess each road segment using the real-time traffic and link information quantified by the LTQ. Next, the path with the lowest aggregated weight is selected as the routing candidate. Extensive simulations demonstrate that the proposed protocol achieves significant performance improvements in terms of packet delivery ratio and average transmission delay.

**Improved Vehicle LIDAR Calibration With Trajectory-Based Hand-Eye Method**

*X. Yuwen, L. Chen, F. Yan, H. Zhang, J. Tang, B. Tian, and Y. Ai*

In unmanned vehicles, LiDARs and GPS/INSs are the most popular sensors to achieve perception and positioning. Precise calibration of the extrinsic parameters between the LiDAR and the GPS/INS is necessary for a successful implementation of sensor fusion. The extrinsic transformation between the LiDAR and GPS/INS is 6D (x, y, z, yaw, pitch, roll), but the motion of a vehicle is mainly 3D (x, y, yaw). The problem is to calculate the 6D extrinsic parameters with the limitation of 3D motion (plane constraint). The solution to this problem has been breaking the plane constraint by designing specific vehicle motions. This paper proposes a new method, a trajectory-based hand-eye calibration method, which makes full use of the large range of unmanned vehicles. The trajectories with large and small ranges are used to solve the rotation and translation, respectively. It is proved that the extrinsic parameters can be solved when the trajectory range of the unmanned vehicle is sufficiently large. The method proposed is tested with simulation, custom and KITTI datasets, and compared with the state-of-the-art methods. The results demonstrate that the accuracy and efficiency of the method proposed are comparable to the state-of-the-art methods.

**Short-Term Traffic Flow Forecasting Method With M-B-LSTM Hybrid Network**

*Q. Zhaowei, L. Haitao, L. Zhihui, and Z. Tao*

As the main characteristics of traffic flow, stochasticity and distribution imbalance will induce the uncertainty and overfitting problems of deep network learning and forecasting. To deal with the problems, a new end-to-end M-B-LSTM hybrid network is constructed for short-time traffic flow forecasting. In the network architecture, an online self-learning network is constructed as a data mapping layer to learn and equalize the traffic flow statistic distribution for reducing the effect of distribution imbalance and overfitting problem during network learning, DBLSTM is integrated into stochasticity reducing layer by bidirectional contexts approximation process to inhibit data stochasticity, and LSTM is utilized to forecast the next traffic flow state in the forecast layer. The comparison results show the M-B-LSTM hybrid network has superior and stable forecasting performance and better ability on solving the stochasticity and distribution imbalance problems than state-of-the-art methods.

**Multi-Vehicle Collaborative Learning for Trajectory Prediction With Spatio-Temporal Tensor Fusion**

*Y. Wang, S. Zhao, R. Zhang, X. Cheng, and L. Yang*

A novel multi-vehicle collaborative learning framework with spatio-temporal tensor fusion mechanism for vehicle trajectory prediction is proposed. In order to capture interactions among multiple vehicles, a novel auto-encoder social convolution mechanism and a fancy recurrent social mechanism are developed, and they can fuse multi-agent information via manipulating on the spatial and temporal structure, respectively. Extensive experiments on standard datasets demonstrate that the proposed approach achieves the state-of-the-art level.

**Multi-Robot Source Location of Scalar Fields by a Novel Swarm Search Mechanism With Collision/Obstacle Avoidance**

*R.-G. Li and H.-N. Wu*

This paper focuses on source location for scalar fields through multiple mobile robots with sensors. Combined with field strength measurements and swarm evolution mechanisms, the robots are guided to move toward the source of the field. Upon introducing an adaptive weight strategy, a swarm timely update mechanism and a leading-following behavior into quantum particle swarm optimization (QPSO) algorithm, quantum-leading-following-based optimization (QLFBO) algorithm is proposed to direct the movement of robots for a more efficient search. Meanwhile, a collision/obstacle avoidance strategy is designed for the robot to avert accidents. Considering the minimum problem as an optimization objective, the global convergence is proved for QLFBO algorithm. Besides, the authors study the computational complexity on QLFBO algorithm and the collision/obstacle avoidance strategy. Thus the performance analysis on the global convergence and computational complexity provides theoretical guarantee and feasibility support for multi-robot source location. Finally, simulation tests show the practicality and effectiveness of the developed scheme.

**Data-Driven Models Support a Vision for Over-the-Air Vehicle Emission Inspections**

*P. S. Acharya, H. S. Matthews, and P. S. Fischbeck*

Using data from Colorado's vehicle emissions inspection program, this study finds indirect (OBD-based) inspections to have a false pass rate of 50% when predicting the result of a corresponding tailpipe test. As an alternative, transparent data-driven models—using logistic regression and gradient boosting machines—are proposed, to consistently identify over-emitting vehicles. These models were up to 24% more accurate, or 85% more sensitive than the current test, in a stratified data sample. These results support a vision for cloud-based, selective inspection programs where jurisdictions apply statistical models to data collected over-the-air from vehicles and require additional inspection for only the most probable over-emitters.

**Optimal Driving Strategies for Two Successive Trains on Level Track With Safe Separation**

*A. Albrecht, P. Howlett, and P. Pudney*

When two trains travel on the same track in the same direction rail operators insist that they remain safely separated at all times. For a fixed signal system that divides the track into different sections this means the trains must always be separated by at least one clear section of track. The authors propose and justify a new algorithm—the Least Action Clearance Time Algorithm—that calculates optimal clearance times for both trains on each section of track and thereby allows the trains to complete their journeys on time while minimizing total fuel consumption and also maintaining safe separation.

**Continuous Finger Gesture Spotting and Recognition Based on Similarities Between Start and End Frames**

*G. Benitez-Garcia, M. Haris, Y. Tsuda, and N. Ukita*

A continuous finger gesture spotting and recognition method to control in-car devices. A novel algorithm that takes advantage of the boundary similarities of target gestures is proposed for temporal spotting. Subsequently, a gesture recognition method based on a temporal normalization of features extracted from the set of spotted frames is introduced. In addition, two proposals capable of performing in real-time based on hand-crafted and deep-learned features are presented. The results show the effectiveness of the two proposed methods, which obtain faster and better performance than previous works.

**Unsupervised Learning of Depth, Optical Flow and Pose With Occlusion From 3D Geometry**

*G. Wang, C. Zhang, H. Wang, J. Wang, Y. Wang, and X. Wang*

In autonomous driving, the perceptions of depth, optical flow and camera ego-motion are the fundamental abilities for many high-level tasks, such as SLAM, obstacle avoidance and navigation. The system in this paper can estimate depth, pose and optical flow with high quality by joint unsupervised learning from only monocular video sequences without any labeled ground truth. This paper studies the problem of pixel mismatch caused by occlusion and illumination change, the problem of depth degradation in long-term training, and the problem of optical flow estimation in occlusion area. Through explicitly considering the occlusion from 3D geometry and other strategies, the performances on the three tasks are improved, which is demonstrated in public autonomous driving datasets.

**Learning TBox With a Cascaded Anchor-Free Network for Vehicle Detection**

*R. Liu, Z. Yuan, and T. Liu*

A novel fine-grained vehicle representation TBox is proposed to restrict a tight spatial extent and indicate semantically significant local areas of vehicles. To deal with the TBox detection task, the authors propose a cascaded anchor-free architecture. One subnetwork detects vehicle boxes as a pair of corners and performs corner grouping using an affinity field. The other subnetwork reuses existing features and predicts the TBox as a set of key points utilizing the box results in a top-down manner. Furthermore, a multi-task learning strategy is also proposed to implicitly integrate the global context with local details, introducing improvements for all tasks. The experimental results show that the proposed method outperforms other vehicle detectors both in the bounding box and TBox tasks and runs in real-time.

**Optimizing Signal Timing Control for Large Urban Traffic Networks Using an Adaptive Linear Quadratic Regulator Control Strategy**

*H. Wang, M. Zhu, W. Hong, C. Wang, G. Tao, and Y. Wang*

This study proposes an adaptive multi-input and multi-output traffic signal control method that can not only improve network-wide traffic operations in terms of reduced traffic delay and energy consumption, but also is more computationally feasible than existing centralized signal control methods. In the paper, a linear dynamic traffic system model was built and adaptively updated to reflect how the signal control input affects network-wide vehicle travel delay. An adaptive linear-quadratic regulator (LQR) was designed to minimize both traffic delay and incremental changes in the control input. The control method was evaluated in a microscopic traffic simulation environment with a 35-intersection network of Bellevue City, Washington, and desired results have been obtained.

**Pband: A General Signal Progression Model With Phase Optimization Along Urban Arterial**

*B. Jing, Y. Lin, Y. Shou, K. Lu, and J. Xu*

A novel two-way signal progression model, namely Pband, is developed to simultaneously optimize phase pattern choice from overlapping or split phase, phase sequence, and offsets. The proposed Pband is formulated with a mixed integer nonlinear programming technique. A numerical test based on a field arterial from the county of Jiashan, China is employed to validate Pband under designed traffic patterns and signal timings. Numerical results via traffic simulation experiments have indicated that the Pband can show promise in increasing progression bandwidths and reducing average travel delay and the number of stops compared with the conventional Multiband under most scenarios. Notably, sensitivity analysis has also illustrated that this kind of bandwidth-oriented methods cannot guaranty to minimize travel delay or number of stops for arterial or network vehicles under few specific scenarios even though their objective functions of bandwidth maximization reach to the optimum.

**Graph Similarity-Based Maximum Stable Subgraph Extraction of Information Topology From a Vehicular Network**

*Y. Meng, X. Liu, L. Dai, and H. Huang*

To cope with the frequent reconfiguration in dynamic vehicular network, considering the mobility is restricted by the road, this paper proposes a maximum stable subgraph extraction method. The constructed subgraph similarity can quantify the stability of part of network. In addition, a gradual contraction extraction algorithm is proposed to solve the extraction problem with a low complexity. The simulation results reveal that the proposed algorithm can extract a stable subgraph in a dynamic network, and a case study of application in reducing the resource reallocation is performed.

**FS-MOEA: A Novel Feature Selection Algorithm for IDSs in Vehicular Networks**

*J. Liang and M. Ma*

For Intrusion Detection Systems (IDSs) in Vehicular Ad Hoc Networks (VANETs), single-objective optimization algorithm has inherited limitations for the feature selection problem with the multiple objectives. Moreover, the imbalanced problem commonly exists in various datasets. Thus, in this paper, a feature selection algorithm based on a many-objective optimization algorithm (FS-MOEA) is proposed for IDSs in VANETs, in which Adaptive Non-dominant Sorting Genetic Algorithm-III (A-NSGA-III) serves as the many-objective optimization algorithm. Two improvements, called Bias and Weighted (B&W) niche-preservation and Information Gain (IG)-Analytic Hierarchy Process (AHP) prioritizing, are further designed in FS-MOEA. The former is used to counterbalance the imbalanced problem in datasets by assigning rare classes higher priorities, while the latter is employed to search the optimal feature subset for FS-MOEA. In IG-AHP prioritizing, a more distinct measurement, i.e., average IG, is used as the dominant factor to guide the decision analysis of AHP. The experimental results show that the proposed FS-MOEA can not only improve the performance of IDSs in VANETs but also alleviate the negative impact of the imbalanced problem.

**New Aspects of Integrity Levels in Automotive Industry-Cybersecurity of Automated Vehicles**

*Á. Török, Z. Szalay, and B. Sághi*

The spread of connected vehicles is expected to multiply the effects of the growing penetration of cyberspace in our life, and with this it remarkably influences the vulnerability of society to cyberattacks in an unfavorable way. Accordingly, the paper aims to reconsider safety integrity levels in the automotive industry related to the field of cybersecurity. Following this, the article provides a comprehensive structure of integrity levels that serves the safety requirements of nowadays new cybersecurity challenges. To adapt the new cybersecurity integrity level architecture to the conventional automotive safety integrity level framework, the authors have verified a specific clustering model. This new approach makes it possible to order hazard classification category combinations to specific integrity levels. Finally, security evaluation procedure is presented to emphasize the practical applicability of the newly developed framework.

**Multi-Modal Traffic Signal Control in Shared Space Street**

*L. Tang, Q. He, D. Wang, and C. Qiao*

This paper explicitly addresses the multi-modal traffic signal control problem in the shared space street (SSS), where there are multiple travel modes (e.g., passenger cars, buses, and light rails) competing for their spaces in the same lane. SSS widely exists in central business districts where the road space is limited and the multi-modal travel demand is high. An optimization framework with a multi-modal cell transmission model (M-CTM) is developed to model the multi-modal traffic in the network. Also, this study models the passenge's choice of choosing among different travel modes based on travel costs. Regarding multi-modal signal coordination, a cycle-based traffic signal plan selection model is developed to choose the best offline optimized signal plan to minimize the total travel cost of all three modes. Therefore, the computation burden is significantly reduced in the optimization model. Moreover, a particle swarm optimization (PSO) method is implemented to solve the proposed optimization model. A case study in downtown Buffalo validates the proposed model with microscopic traffic simulation VISSIM.

**Short-Term Traffic Flow Forecasting Using Ensemble Approach Based on Deep Belief Networks**

*J. Liu, N. Wu, Y. Qiao, and Z. Li*

To effectively manage the traffic in transportation systems, it is vitally important to accurately forecast the traffic flows. Due to the randomness and volatility of traffic flows, the short-term traffic flow forecasting problem is very challenging. Moreover, various factors, such as raining, temperature, wind speed, humidity, holiday type, and weekday type, have effect on traffic flows. This greatly complicates the traffic flow forecasting problem further. Thus, the key is how to extract these diversity features for traffic flow forecasting. To do so, this paper investigates an ensemble approach, namely EEMD-mRMR-DBN, which integrates Ensemble Empirical Mode Decomposition (EEMD), minimum Redundancy Maximum Relevance Feature Selection (mRMR), and Deep Belief Networks (DBN), for short-term traffic flow forecasting. With real-life traffic data, extensive experiments are done. Results show that the proposed method can significantly improve the forecasting quality over the existing methods.

**Relational Fusion Networks: Graph Convolutional Networks for Road Networks**

*T. S. Jepsen, C. S. Jensen, and T. D. Nielsen*

The Relational Fusion Network (RFN) is a novel type of Graph Convolutional Network (GCN) designed specifically for machine learning on road networks. Like GCNs, the RFN can leverage road network structure during the prediction process. However, GCNs rely on assumptions concerning the relationships between adjacent intersections and road segments which hold only conditionally in road networks. By relaxing these assumptions, the RFN achieves substantial predictive performance improvements over state-of-the-art GCNs in the experiments. The RFN achieves improvements of 21%–24% and 32%–40% over state-of-the-art GCNs on the tasks of speed limit classification and driving speed estimation, respectively. In addition, the RFN can leverage road network structure in cases where the state-of-the-art GCNs cannot. Finally, the RFN demonstrates superior generalizability to state-of-the-art GCNs when making predictions about road segments in an unseen road network.

**Energy-Efficient Strategy for Improving Coverage and Rate Using Hybrid Vehicular Networks**

*D. Saluja, R. Singh, N. Saluja, and S. Kumar*

A decade back, emergency voice communication was the only target to support the patient in an ambulance. It is now evolved from emergency voice communication to vital signal monitoring and operating the machines from the remote place. This evolution requires support from technology to meet the high data-rate along with reliability for the specified applications. The millimeter-wave (mmWave) communication support high data rate requirements of vehicular communication. However, in the case of mmWave, the radio signals vary fast. It poses the implementation challenge to the mmWave system in this scenario. The other implementations challenges of mmWave are high path loss, severe blockage, and frequent beam updates which inhibit seamless connectivity (reliability) to vehicular nodes. However, reliability is always a prime concern for any vehicular communication system. This paper addresses these challenges by implementing a novel energy-efficient strategy based on RSUs deployment and radio access technology (RAT). The strategy is to deploy RSUs on either side of the road and use an optimal combination of mmWave and microwave RAT. The essential analysis of such a hybrid system involves the evaluation of parameters based on the analytic model. Hence, this paper analytically obtains the expression for seamless coverage and connectivity. The analysis is also extended to rate and energy efficiency calculations. The analysis is supported by probabilistic models-based simulations that agree closely with computation results. The results claim that the proposed model leads to improved performance in terms of coverage and rate while maintaining the cost and energy-efficiency within the limits.

**Random-Positioned License Plate Recognition Using Hybrid Broad Learning System and Convolutional Networks**

*C. L. P. Chen and B. Wang*

A framework combing a fully convolutional network with broad learning system for license plate recognition is proposed. It is expected to distinguish the target license plate from complex background. Experiments conducted on Macau license plates show that the proposed method outperforms some state-of-the-art approaches. The compatibility and generality can be expected by applying the proposed method to other regions or countries.

**Two-Phase Scheduling for Efficient Vehicle Sharing**

*J. Liu, C. Bondiombouy, L. Mo, and P. Valduriez*

Cooperative Intelligent Transport Systems (C-ITS) is a promising technology to make transportation safer and more efficient. Ridesharing for long-distance is becoming a key means of transportation in C-ITS. In this paper, the authors focus on private long-distance ridesharing. The authors propose a comprehensive cost model and a two-phase journey scheduling approach. On this basis, the authors propose two path generation methods: a simple near optimal method and a reset near optimal method as well as a greedy-based path scheduling method. The authors carried out an experimental evaluation with different path generation and path scheduling methods. The experimental results reveal that the proposed scheduling approach significantly outperforms baseline methods in terms of total cost (up to 69.8%) and scheduling time (up to 84.0%) and the scheduling time is reasonable (up to 0.16s). The results also show that the proposed approach has higher efficiency (up to 141.7%) than baseline methods.

**Learning From the Fleet: Map Attributes for Energetic Representation of Driving Profiles**

*T. Straub, M. Frey, and F. Gauterin*

Driving electric vehicles can help to reach the goals set by international greenhouse gas legislation. Still, drivers of electric cars are facing a lower range, longer charging time, and a sparse infrastructure compared to fuel-based concepts. These drawbacks inhibit the market penetration of fully electric cars. Smart functions such as range prediction can moderate such inhibitors in daily usage but need detailed information on energy demand along the route. For that, the authors present a novel analytical method to energetically represent velocity profiles on a map. Here, the presented method provides 63% more accurate results compared to existing state-of-the-art benchmarks. These findings enable more precise route energy demand prediction and thus range prediction. The improved range prediction will boost the acceptance of individual electric mobility.

**Towards Enhanced Recovery and System Stability: Analytical Solutions for Dynamic Incident Effects in Road Networks**

*W. Yue, C. Li, S. Wang, Z. Xu, and G. Mao*

An incident management policy considering both signal control and route choice is developed. The condition for equilibrium existence under incident effects is given and sufficient conditions for the dynamic road system to be stable are also derived. The analytical results indicate that opposite signal control policies should be applied in road networks under different incident circumstances and the proposed control policy can achieve the improved recovery rate and system stability in terms of dynamic incident effects in road networks.

**Joint Optimal Power Flow Routing and Vehicle-to-Grid Scheduling: Theory and Algorithms**

*S. Zhang and K.-C. Leung*

This paper proposes a hierarchical system model to jointly optimize power flow routing and V2G scheduling for providing regulation service. At the grid level, the problem of optimal power flow (OPF) routing is formulated by installing power flow routers (PFRs) inside the power grid so as to improve the quality of power flow. After solving the grid-level OPF routing problem, an online scheduling algorithm is devised at the EV level to coordinate EVs by providing the V2G regulation service, in order to cope with the forecast uncertainties. The simulation results show that the devised online scheduling algorithm can outperform the existing algorithms, which is able to flatten the power fluctuations at the buses with EVs attached so as to alleviate the grid stability issue. Then, the uses of PFRs can further reduce the power loss while providing voltage regulation.

**Incorporating Phase Rotation Into a Person-Based Signal Timing Optimization Algorithm**

*Z. Yu, G. Xu, V. V. Gayah, and E. Christofa*

This paper proposes a person-based traffic signal optimization algorithm that simultaneously optimizes signal phase sequence, cycle length, and green split to minimize total person delay at an intersection. It builds upon previous person-based work that uses a mathematical program to optimize signal timings based on real-time passenger car flows and knowledge of bus arrivals and passenger occupancies. Phase rotation is directly accommodated within the mathematical program by introducing new binary variables to describe the phase sequence. The program can either be solved directly or through an enumeration approach to reduce computational complexity. The proposed method is tested using numerical simulations of an intersection in Athens, Greece. The results reveal that phase rotation can reduce person delay significantly, especially when the intersection flow ratio is relatively low. These reductions in person delays are achieved by implicitly prioritizing the movement of high-occupancy buses to the detriment of lower-occupancy cars. Furthermore, to balance the person delay reduction and phase rotation frequency, a threshold can be applied in the phase sequence selection process to eliminate phase rotations actions with limited benefits.

**Evaluating the Effectiveness of Integrated Connected Automated Vehicle Applications Applied to Freeway Managed Lanes**

*Y. Guo, J. Ma, E. Leslie, and Z. Huang*

This study proposes an operational concept of an integrated connected automated vehicle (CAV) operations on freeway managed lanes, including cooperative adaptive cruise control (CACC), cooperative merge, and speed harmonization. Despite the low projected market penetration of CAVs during the next decade, the use of managed lane facilities has the potential to support the realization of increased mobility benefits by their very nature. The study develops and examines the effectiveness of an integrated algorithm bundling the three CAV applications. The simulation results show the effectiveness of the bundled application to enhance system throughput and reduce delay, even at low CAV penetration rates. The conclusions provide operational insights and guidance for traffic management centers to implement CAV-based traffic control in the future.

**Multimodal End-to-End Autonomous Driving**

*Y. Xiao, F. Codevilla, A. Gurram, O. Urfalioglu, and A. M. López*

End-to-end driving approaches try to learn a direct mapping from input raw sensor data to vehicle control signals, which are gaining popularity since they are less demanding in terms of sensor data annotation than traditional modular pipelines. So far, most proposals for end-to-end driving rely on RGB images as input sensor data. However, autonomous vehicles will not be equipped only with cameras, but also with active sensors providing accurate depth information (e.g., LiDARs). Accordingly, this paper analyses whether combining RGB and depth modalities, i.e. using RGBD data, produces better end-to-end AI drivers than relying on a single modality. The authors consider multimodality based on early, mid and late fusion schemes, both in multisensory and single-sensor (monocular depth estimation) settings. Using the CARLA simulator and conditional imitation learning (CIL), the authors show how, indeed, early fusion multimodality outperforms single-modality.

**Differential Impact of Autonomous Vehicle Malfunctions on Human Trust**

*M. Seet, J. Harvy, R. Bose, A. Dragomir, A. Bezerianos, and N. Thakor*

The impact of autonomous vehicle (AV) malfunctions on driver's trust-in-automation and electroencephalographic (EEG) signals is investigated. AV malfunctions reduced drive's trust-in-automation during full automation driving, but not during conditional automation driving when drivers were able to take over vehicle control to avoid danger. These trust dynamics were also reflected in frontal alpha power in drive's EEG signals. Since frontal alpha power is easily computable and localized only to the frontal area of the scalp, it has the potential to be used in driver trust monitoring with streamlined wearable technology to support driver-vehicle adaptivity.

**A Decentralized Trust Management System for Intelligent Transportation Environments**

*X. Chen, J. Ding, and Z. Lu*

The new generation of communication technologies can provide vehicles fast and reliable dissemination of information under an intelligent transportation system. However, such service still suffers from risks or threats due to malicious information producers. The traditional public critical infrastructure (PKI) cannot restrain such untrusted but legitimate publishers. Decentralized trust management system (DTMS) is a novel blockchain-enabled trust evaluation and management system that provides fair and transparent assessment and traceable records of trust values. The decentralized design allows all users holding and participating in the evaluation and management activities compared to the conventional applications that depend on trusted third parties. Additionally, the designed system creatively applies a trusted execution environment (TEE) to secure the trust evaluation process, together with an incentive model that is used to stimulate more participation and penalize malicious behaviors. Finally, novel formal modelling and numerical analysis techniques are used for efficient and accurate performance evaluation.

**Online EV Charge Scheduling Based on Time-of-Use Pricing and Peak Load Minimization: Properties and Efficient Algorithms**

*W. Wu, Y. Lin, R. Liu, Y. Li, Y. Zhang, and C. Ma*

Dynamic EV charging problems with two critical objectives are addressed: 1) minimizing the total charging cos, and 2) minimizing the peak load. The properties are investigated. A non-myopic charging strategy accounting for future demands is proposed to achieve global optimality for Objective 2, which is addressed by a heuristic algorithm combining a multi-commodity network flow model with customized bisection search algorithm in a rolling horizon framework. The impact of traffic conditions on the system performance is discussed.

**Wasserstein Loss With Alternative Reinforcement Learning for Severity-Aware Semantic Segmentation**

*X. Liu, Y. Lu, X. Liu, S. Bai, S. Li, and J. You*

Semantic segmentation is important for autonomous vehicles and robotics, which classifies each pixel into a predetermined class. Recent cross entropy (CE) loss-based deep networks achieved significant progress w.r.t. the mean Intersection-over Union (mIoU). However, the CE loss can essentially ignore the different severity of an autonomous driving system with different misclassified results. For instance, classifying a car into the road is much more terrible than recognize it as a bus. In this paper, the authors propose to incorporate the severity-aware inter-class correlation in a Wasserstein training framework by configuring its ground matrix. The ground matrix can be pre-defined following the experience on a specific task, and the previous importance-aware method can be a particular case. The authors extend the ground metric as a linear, convex or concave increasing function w.r.t. pre-defined ground metric from an optimization perspective. Furthermore, the ground matrix can be adaptively learned in a high-fidelity simulator following a reinforcement alternative learning scheme. The authors evaluate their method on CamVid and Cityscapes datasets with different backbones (SegNet, ENet, FCN, and Deeplab) in a plug and play manner. Wasserstein loss demonstrates superior segmentation performance on the predefined critical classes for safe-driving, and significantly improves the survival time in CARLA simulator.

**Mobility Model for Contact-Aware Data Offloading Through Train-to-Train Communications in Rail Networks**

*M. Saki, M. Abolhasan, J. Lipman, and A. Jamalipour*

In this paper, the authors propose a novel mobility model providing train traffic traces essential for train-to-train communication models. As the proposed mobility model works only based on trip timetables and train timetables are currently available in real-time, the produced mobility traces will be also in real-time. Additionally, as no GPS module is used in this method, the proposed model can provide a practical solution when signal from GPS or Assisted GPS is poor or unavailable such as in urban area or inside tunnels. Furthermore, as the authors used an energy optimization function, the proposed mobility model will provide a guidance trajectory for trains to have an energy-optimized operation. The authors also develop an algorithm that can determine the specifications of contacts between trains based on the traffic traces obtained from the mobility model. Such specifications include duration, rate and location of train contacts used for estimation of data exchange capacity between trains through train-to-train communications. The authors validate the proposed model using data collected from Sydney Trains of Australia. The results obtained from the proposed model show over 98% accuracy in comparison with the real data collected via a GPS module from Sydney Trains.

**Understanding V2V Driving Scenarios Through Traffic Primitives**

*W. Wang, W. Zhang, J. Zhu, and D. Zhao*

Understanding driver interaction behavioral semantics has potential benefits to autonomous car's decision-making design. This paper presents a framework of analyzing various encountering behaviors through decomposing driving encounter sequential data into small building blocks, called traffic primitives, using a Bayesian nonparametric learning (BNPL) approach. This framework offers a flexible way to gain semantic insights into complex driving encounters without any prerequisite knowledge of interaction behavior categories. Its effectiveness is then validated using 976 naturalistic driving encounters from which more than 4000 traffic primitives were learned with the BNPL approach. After that, a dynamic time warping method integrated with $k$-means clustering is then developed to cluster all these extracted traffic primitives into groups. The experimental results identify 20 kinds of traffic primitives capable of representing the essential components of driving encounters in the database. Based on the results, the authors conclude that the proposed primitive-based analysis could prove useful for autonomous vehicle applications.

**Comparative Analysis of a Vehicular Safety Application in NS-3 and Veins**

*T. T. de Almeida, L. d. C. Gomes, F. M. Ortiz, J. G. Ribeiro Júnior, and L. H. M. K. Costa*

The adoption of DSRC technology in vehicles is expected to be one of the fundamental factors to increase safety and efficiency in traffic. This leads to the need to evaluate the IEEE 802.11p standard through real experiments before the complete automotive deployment. Nevertheless, due to the cost and complexity of carrying out real experiments, evaluations using simulations is still the most common method used. This work evaluates the behavior of a periodic beaconing application using IEEE 802.11p-compliant devices and compares the results with those obtained by the popular simulators NS-3, integrated with the PhySim-WiFi module, and Veins, whose physical layer is modeled by the MiXiM. The goal is to evaluate the capacity of the network simulators to mimic realistic settings.

**RF-DCM: Multi-Granularity Deep Convolutional Model Based on Feature Recalibration and Fusion for Driver Fatigue Detection**

*R. Huang, Y. Wang, Z. Li, Z. Lei, and Y. Xu*

For real-world driver fatigue detection, the large pose deformations exhibited by the captured global face significantly increase the difficulty of extracting effective features. Furthermore, previous fatigue detection methods have not achieved desired results in distinguishing actions with similar appearance, such as yawning and speaking. In this paper, the authors propose a multi-granularity Deep Convolutional Model based on feature Recalibration and Fusion for driver fatigue detection (RF-DCM). The proposed deep model leverages cue from partial faces to alleviate the pose variations and obtains robust feature representations from both the global face and different local parts. The core innovative techniques are as follows: A multi-granularity extraction sub-network extracts more efficient multi-granularity features while compressing the parameters of the network. In order to match multi-granularity features, a feature rectification sub-network and a feature fusion sub-network are designed to adaptively recalibrate and fuse the multi-granularity features.

**End-to-End Self-Driving Approach Independent of Irrelevant Roadside Objects With Auto-Encoder**

*T. Wang, Y. Luo, J. Liu, R. Chen, and K. Li*

A novel training method for an auto-encoder that equips it to ignore irrelevant features in input images while simultaneously retaining relevant features is developed. The entire end-to-end self-driving approach can ignore the influence of irrelevant features even though there are no such features when training the network. The simulation results demonstrates the effectiveness of the approach.

**Resource Planning Under Hypercube Queuing Equilibrium With Server Disruptions and Cooperative Dispatches**

*H. Liu, J. Wang, and Y. Ouyang*

This paper proposes a reliable hypercube queueing model for emergency response systems where servers can be subject to probabilistic disruptions and dispatched jointly in cooperative units. Formulas for steady-state system performance metrics are derived and embedded into a mixed-integer nonlinear program to optimize the allocation of resources which influences the reliability of servers. The advantages and disadvantages of cooperative dispatches and resource pooling, as well as sensitivity of the optimal system performance to various system parameters, are discussed through numerical examples.

**Stability of a Large-Scale Connected Vehicle Network in Ring Configuration and With Multiple Delays**

*D. Wang and R. Sipahi*

An approach is presented to analytically characterize the asymptotic stability of a linearized large-scale connected vehicle-velocity dynamics in ring configuration and with communication, sensor, and human reaction delays. Insights are obtained on how certain eigenvalues associated with the model affect stability on the plane of model parameters. Comparing with the traditional model where connectedness between vehicles is removed, one renders larger stability regions, which can be matched by using weaker gains in the connected vehicle model. Results can inform future studies regarding trade-offs between the advantages that the connected vehicles offer and the use of high/weak gains to render certain degree of stability robustness in model parameters against time delay.

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