Scanning the Issue

Context-Aware Machine Learning for Intelligent Transportation Systems: A Survey

G.-L. Huang, A. Zaslavsky, S. W. Loke, A. Abkenar, A. Medvedev, and A. Hassani

This article presents a comprehensive review of recent studies in context-aware machine learning for intelligent transportation, mainly focusing on road transportation systems. State-of-the-art techniques are discussed from several perspectives, including contextual data (e.g., location, time, weather, road condition, and events), applications (i.e., traffic prediction and decision making), modes (i.e., specialized and general), learning methods (e.g., supervised, unsupervised, semi-supervised, and transfer learning). Two main frameworks of context-aware machine learning models are summarised. In addition, open challenges and future research directions of developing context-aware machine learning models for ITS are discussed, and a novel context-aware machine learning layered engine (CAMILLE) architecture is proposed as a potential solution to address identified gaps in the studied body of knowledge.

User Cognition Antecedents of Smart Assistant Systems in Cars

K. Keller, H. Jöntgen, B. M. Abdel-Karim, and O. Hinz

By customizing smart assistance systems to customer needs, car manufacturers can improve their systems and create additional benefits for users. However, it is still unclear which characteristics car drivers perceive as favorable and useful. To examine this, the authors employ a mixed-method approach. In the first study, the authors conduct a survey (N = 301) to investigate general user perception antecedents of smart assistant systems in cars. The authors analyze the indirect effects of different system quality characteristics mediated by user perception on their usage intention. In the second study (N = 270), the authors use a discrete choice experiment to measure the effects of concrete system attributes on user acceptance of IT-based parking systems representing a concrete instantiation of a smart assistance system. Consistent with the first study, the authors observe that the system quality factors user interface intuitiveness, full language flexibility, and system error occurrence significantly influence the consumers' intention to use the technology. Accordingly, car manufacturers should put a particular focus on these factors when developing and implementing their smart assistance systems in cars. For IT-based parking systems, in particular, consumers are very price-sensitive. However, by implementing additional technical features, manufacturers can significantly increase the systems' price value and thus the purchase probability.

Train-Network-HESS Integrated Optimization for Long-Distance AC Urban Rail Transit to Minimize the Comprehensive Cost

M. Chen, Y. Lv, W. Lu, D. Zhang, and Y. Chen

An AC traction power supply system (TPSS) for long-distance urban rail transit is proposed, in which the network power flow distribution is affected by the train trajectory, the parameters of network and hybrid energy storage system (HESS) configuration. For achieving the minimum comprehensive cost including the electricity cost and the life cycle cost (LCC) of HESS, this article aims to develop a Train-Network-HESS integrated model to optimize network power flow distribution. The train trajectory is illustrated based on time-space conversion method and HESS control strategy is discussed to increase the utilization of the RBE. Furthermore, the optimized configuration of the AC TPSS for urban rail transit is obtained by the hybrid GA-PSO algorithm. Finally, the effectiveness of the proposed model is verified by detailed case studies and the comprehensive cost can be reduced up to 39.08% compared with conventional TPSS.

A Learning-Based Discretionary Lane-Change Decision-Making Model With Driving Style Awareness

Y. Zhang, Q. Xu, J. Wang, K. Wu, Z. Zheng, and K. Lu

A learning-based discretionary lane-change decision-making model is designed to integrate the human factors that are represented by driving styles. Specifically, the model takes not only the contextual traffic information but also the driving styles of surrounding vehicles into consideration and makes lane-change/keep decisions. Moreover, the model can imitate human drivers' decision-making maneuvers by learning the driving style of the ego vehicle. The evaluation results show that the proposed model captures human decision-making strategies and imitates human drivers' lane-change maneuvers, which can achieve 98.66% prediction accuracy. Moreover, the authors also analyze the lane-change impact of the proposed model compared with human drivers in terms of improving the safety and speed of traffic.

Network-Wide Traffic Signal Control Using Bilinear System Modeling and Adaptive Optimization

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

This study proposes a new multi-input multi-output optimal bilinear signal control method in which a bilinear dynamic model approximation is used to capture the nonlinear dynamics of the urban traffic networks. With signal green time splits

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as the control input and traffic delay changes as the output for each intersections in the network, a bilinear system model was developed, which, on the basis of linear system modeling, takes interactions among traffic delays and signal timing splits into consideration. Based on the bilinear system modeling framework, the authors conducted two steps in each time interval to derive traffic control strategies: 1) the authors used the normalized least-squared algorithm to estimate system parameters, and 2) the authors solved an online optimization problem to obtain the updated traffic control inputs for the signal timing that minimizes future traffic delays. The authors evaluated the proposed method in a microscopic traffic simulation environment (VISSIM) with a 35-intersection network of Bellevue city in Washington. Two different traffic demand patterns: 1) normal traffic demands, and 2) time-varying traffic demands were simulated to compare the performance of different control strategies. The experimental results show that 1) the proposed bilinear system model can better describe traffic system dynamics than linear-model based methods, such as the previously developed linear-quadratic regulator control, and 2) the proposed method outperforms the state-of-the-art signal control strategies, namely, the max-pressure and the self-organizing traffic light control methods. The authors have also shown that the proposed method is applicable to all other possible network layouts and signal controller phasing structures.

Spatial–Temporal Tensor Graph Convolutional Network for Traffic Speed Prediction

X. Xu, T. Zhang, C. Xu, Z. Cui, and J. Yang

This article proposes a novel factorized Spatial–Temporal Tensor Graph Convolutional Network for traffic speed prediction tasks. The traffic network is first modeled and unified into a graph tensor that integrates spatial and temporal information simultaneously, and then a basic multi-scale spatial–temporal tensor graph convolutional network is constructed. Tucker tensor decomposition operation is further introduced to derive a factorized tensor graph convolution that performs separate filtering in small-scale space, time, and feature modes. Based on the above, the proposed model is capable of modeling complex high-dimensional spatial–temporal traffic data and achieves effectiveness in terms of computational cost, memory requirements, and noise suppression.

Exploring the Impact of Spatiotemporal Granularity on the Demand Prediction of Dynamic Ride-Hailing

K. Liu, Z. Chen, T. Yamamoto, and L. Tuo

A convolutional, long short-term memory model combined with a hexagonal convolution operation (H-ConvLSTM) is proposed to explore the complex spatial and temporal relations on the demand prediction of dynamic ride-hailing, which outperforms conventional methods in terms of prediction accuracy. The multiscale spatiotemporal demand prediction method is proposed based on a comprehensive analysis on the scale effect of spatiotemporal demand prediction, which lays a foundation and provides a guideline to find optimal/near-optimal decisions regarding spatial granularity.

Joint Design for Electric Fleet Operator and Charging Service Provider: Understanding the Non-Cooperative Nature

Y. Zhao, T. Zeng, Z. Allybokus, Y. Guo, and S. Moura

This work proposes a new modeling framework for jointly optimizing the charging network design and the logistic mobility planning for an electric vehicle fleet. Existing literature commonly assumes the existence of a single entity—the social planner, as a powerful decision maker who manages all resources. However, this is often not the case in practice. Instead of making this assumption, the authors specifically examine the innate non-cooperative nature of two different entities involved in the planning problem. Namely, they are the charging service provider (CSP) and the fleet operator (FO). To address the strategic interaction between entities, a bi-level mixed integer program is formulated, with the CSP/FO's problem expressed in the upper/lower levels respectively, in a joint decision making process. These decisions involve the CSP's infrastructure siting, sizing, substation capacity upgrades, the FO's fleet composition, vehicle routing, charging, and delivery assignment. To solve the problem, an iterative fashion is adopted to solve and reach optimality. The authors conduct detailed numerical studies on a synthesized small network and the simulation results reveal the unique aspects of this two-entity framework. This modeling perspective can be generalized to other system design problems with two interacting agents planning and operating resources across networks.

Context-Aware Navigation Protocol for Safe Driving in Vehicular Cyber-Physical Systems

B. A. Mugabarigira, Y. Shen, J. Jeong, T. Oh, and H.-Y. Jeong

A connected network of automated vehicles on roads can increase the driving safety of driverless vehicles (i.e., autonomous vehicles). The critical level of dangerous situations on the road while driving can be increased by the speed, orientation, and traffic density of the vehicles involved. Therefore, there is a need for a maneuvering mechanism that handles both the current driving vehicle and the oncoming vehicles headed toward an emergency zone (e.g., road hazard and road accident spot). In this article, the authors present a context-aware navigation protocol (CNP) that enhances the safety of vehicles driving in urban roads. First, CNP includes a collision avoidance module that builds on both vehicular networks and on-board sensors to track vehicles' behaviors, and this module analyzes the driving risks to determine the necessary maneuvers in dangerous situations. Second, CNP establishes a collision mitigation strategy that limits the severity of collision damages in hazardous road during non-maneuverable scenarios. The authors conducted a theoretical analysis as well as extensive simulations to prove and evaluate the effectiveness of CNP. The results show that CNP can

reduce communication overhead from a baseline scheme by up to 60% while the risk of road collisions is less than 5%.

Iterative Range and Road Parameters Estimation Using Monocular Camera on Highways

E. Ustunel and E. Masazade

Lane Keeping Assistance and Adaptive Cruise Control in Advanced Driving Assistance Systems (ADAS) requires road parameters for better control of the vehicle. Therefore, in this article, the authors present the Iterative Least Squares with Optimization (ILSO) method based on a monocular front camera which estimates the horizontal, vertical parameters, lateral slope, and the camera's distances to the left/right line as road parameters and longitudinal range. The ILSO algorithm is smartly divided into two steps LS and optimization depending on their estimation capabilities. First of all, the horizontal and vertical parameters, lateral slope, and distances to the left and right lines are estimated by Least Squares (LS). Then, the longitudinal range is estimated by convex optimization. LS and convex optimization are executed in an alternating manner. ILSO is in advance prior to changes on roads and a simple technique due to its analytical solution which does not require complex geometric calculations and does not need a match between left and right lines. In a simulation environment, given the noisy road lines, ILSO outperforms covariance-based and multilayer perceptron (MLP)-based methods under different noise variances. In addition, ILSO provides plausible numerical results in both virtual and real road images.

Stereo RGB and Deeper LIDAR-Based Network for 3D Object Detection in Autonomous Driving

Q. He, Z. Wang, H. Zeng, Y. Zeng, Y. Liu, S. Liu, and B. Zeng

In this article, the authors propose the Stereo RGB and Deeper LIDAR framework which can utilize semantic and spatial information simultaneously such that the performance of network for 3D object detection can be improved naturally. Specifically, the network generates candidate boxes from stereo pairs and combines different region-wise features using a deep fusion scheme. The stereo strategy offers more information for prediction compared with prior works. Then, several local and global feature extractors are stacked in the segmentation module to capture richer deep semantic geometric features from point clouds. After aligning the interior points with fused features, the proposed network refines the prediction in a more accurate manner and encodes the whole box in a novel compact method. The decent experimental results on the challenging KITTI detection benchmark demonstrate the effectiveness of utilizing both stereo images and point clouds for 3D object detection.

A Convex Optimal Control Framework for Autonomous Vehicle Intersection Crossing

X. Pan, B. Chen, S. Timotheou, and S. A. Evangelou

This article addresses the traffic coordination problem for electric, connected, and autonomous vehicles at an urban unsignalized intersection. The problem is approached by a convex hierarchical centralized scheme in the space domain that successively optimizes the crossing order and velocity trajectories of the vehicles to minimize their total energy consumption and travel time required to pass the intersection. The simulation results show the effectiveness and computational efficiency of the proposed approach, and its advantages over a benchmark solution invoking the widely used first-in-first-out policy. The investigation of Pareto optimal solutions highlights the importance of examining the tradeoff between travel time and energy consumption, as small compromises in travel time could produce significant energy savings.

Distributed Signal Control of Arterial Corridors Using Multi-Agent Deep Reinforcement Learning

W. Zhang, C. Yan, X. Li, L. Fang, Y.-J. Wu, and J. Li

This article proposes a fully scalable MARL (multi-agent reinforcement learning) algorithm for arterial traffic signal coordination based on the proximal policy optimization algorithm. The proposed signal coordination method can alleviate traffic congestion more effectively than existing traditional and MARL-based methods. The decentralized execution of this method enables real-time decision-making in real-world ATSC (arterial traffic signal control) because there is no need for communication when making decisions. The constraints in real-world ATSC are considered when defining the action and reward components of the MARL model.

Lightweight and Effective Convolutional Neural Networks for Vehicle Viewpoint Estimation From Monocular Images

S. Magistri, M. Boschi, F. Sambo, D. C. de Andrade, M. Simoncini, L. Kubin, L. Taccari, L. De Luigi, and S. Salti

The article proposes a lightweight Convolutional Neural Network for estimating vehicle viewpoint from monocular images. Vehicle viewpoint is estimated by providing to the network the position of the vehicle within the original image as its appearance is strongly influenced by the position. Furthermore, the results show that prediction performance can be improved by combining a smoothing filter on the output neurons with a data augmentation technique to simulate vehicles close to the camera and not fully visible in its field of view. The final model is lightweight with a low memory footprint and suitable to be deployed on edge devices while retaining state-of-the-art performance.

Robust and Hierarchical Spatial Relation Analysis for Traffic Forecasting

W. Zhang, Z. Wu, X. Zhang, G. Song, Y. Wang, and J. Chen

This article proposes a novel Robust and Hierarchical spatial Relation Analysis (RAHRA) method to calculate the local-period spatial relation, which applies temporal context information in both traffic state and trend similarities. This could capture abundant traffic patterns and learn stable and comprehensive spatial relations for accurate traffic forecasting.

M^{3}AN: Multitask Multirange Multisubgraph Attention Network for Condition-Aware Traffic Prediction

D. Luo, D. Zhao, Z. Cao, M. Wu, L. Liu, and H. Ma

Traffic prediction under various conditions is an important but challenging task. Latest studies have achieved promising results but suffer degraded performance without exception

under abnormal conditions (e.g., accidents), as the traffic patterns under abnormal conditions often deviate from the normal seriously. To adapt to both normal and abnormal conditions, the authors propose the Multi-task Multi-range Multi-subgraph Attention Network (M^3AN), a novel deep learning model to explicitly model the impacts of abnormal events for condition-aware traffic prediction under low computational complexity. The experimental results on two real-world traffic datasets (i.e., PeMS and TaiAn) show that the M^3AN outperforms state-of-the-art approaches under both normal and abnormal conditions.

FatigueView: A Multi-Camera Video Dataset for Vision-Based Drowsiness Detection

C. Yang, Z. Yang, W. Li, and J. See

A new large-scale dataset, FatigueView, is introduced for vision-based drowsiness detection. FatigueView is collected by both RGB and infrared (IR) cameras from five different positions. It contains real sleepy driving videos and various visual signs of drowsiness from subtle to obvious, e.g., with 17,403 different yawning sets totaling more than 124 million frames, far more than recent actively used datasets. It also provides hierarchical annotations for each video, ranging from spatial face landmarks and visual signs to temporal drowsiness locations and levels to meet different research requirements. With FatigueView, representative drowsiness detection methods are structurally evaluated to build viable baselines.

Intelligent Real-Time Power Management of Multi-Source HEVs Based on Driving State Recognition and Offline Optimization

A. M. Ali, B. Moulik, and D. Söffker

This article proposes an intelligent rule-based power management strategy with embedded offline-optimized control parameters and online driving state recognition to achieve optimal power handling decisions for EVs situatively and adaptively. A set of characteristic variables defining driving states have been extracted from representative segments of several driving cycles, to which optimized control strategies are tuned offline. Three different driving cycles representing urban, highway, and mixed trip conditions have been implemented for comparative investigation of achieved results. The analysis of the results reveals the potential of proposed PMS to reduce the energy consumption by 13.6%–30.9%.

A Privacy-Preserving Solution for Intelligent Transportation Systems: Private Driver DNA

G. Costantino, M. De Vincenzi, F. Martinelli, and I. Matteucci

The rising connection of vehicles with the road infrastructure enables the creation of data-driven applications to offer drivers customized services. At the same time, these opportunities require innovative solutions to protect the drivers' privacy in a complex environment like an Intelligent Transportation System (ITS). This need is even more relevant when data are used to retrieve personal behaviors or attitudes. In the proposed work, the authors propose a privacy-preserving solution, called Private Driver DNA, which designs a possible architecture, allowing drivers of an ITS to receive customized services. The proposed solution is based on the concept of Driver DNA as characterization of driver's driving style. To assure privacy, the authors perform the operations directly on sanitized data, using the Order Revealing Encryption (ORE) method. Besides, the proposed solution is integrated with ITS architecture defined in the European project E-Corridor. The result is an effective privacy-preserving architecture for ITS to offer customized products, which can be used to address drivers' behaviors, for example, to environmental-friendly attitudes or a more safe driving style. The authors test Private Driver DNA using a synthetic dataset generated with the vehicle simulator CARLA. The authors compare ORE with another encryption method like Homomorphic Encryption (HE) and some other privacy-preserving schemas. Besides, the authors quantify privacy gain and data loss utility after the data sanitization process.

Coordinating Multiple Cooperative Vehicle Trajectories on Shared Road Networks

P. Gun, A. J. Hill, and R. Vujanic

This article addresses the problem of planning trajectories for multiple cooperative agents along specified paths through a road network. The optimization model presented combines the trajectories of a fleet of vehicles. To reduce the computation time, the quantity of discrete decisions is reduced using a heuristic solver that guides two modeling modifications, and an iterative method that targets essential vehicle interactions with a predictive algorithm. Experiments are run on a simulated road network based on real haul trucks on a surface mine. The proposed methods are shown to significantly improve solution costs compared to a reactive approach based on common driving practices, and the modifications significantly reduce computation time, trading off marginal solution quality. The reduction is extended by the iterative scheme without degradation of solution quality.

A Data-Driven Spatio-Temporal Speed Prediction Framework for Energy Management of Connected Vehicles

M. R. Amini, Q. Hu, A. Wiese, I. Kolmanovsky, J. B. Seeds, and J. Sun

The authors present an integrated spatio-temporal framework for multi-range traction power and speed prediction for connected vehicles (CVs). It combines data-driven and model-based strategies to enable CVs energy efficiency optimization. The proposed framework focuses on urban arterial corridors with signalized intersections, and leverages the historical and real-time data collected from CVs and infrastructure to predict location-specific traction loads (e.g. acceleration at intersections), and augment them with time-specific speed profiles (e.g., stop duration at intersections). A Bayesian network is developed to provide a long-term load prediction blackinformed by probabilistic analysis of historical traffic data at intersections and between intersections. Moreover, a shockwave profile model is adopted for modeling the queuing process at intersections by leveraging vehicle-to-infrastructure (V2I) communications, providing a short-range prediction of the vehicle speed with an enhanced accuracy. The benefits

of the proposed load prediction framework are demonstrated for energy management of connected hybrid electric vehicles (C-HEVs). By incorporating the predicted loads into a multi-horizon model predictive controller (MPC), integrated power and thermal management of light-duty C-HEVs is enabled over real-world driving cycles, demonstrating a near globally-optimal fuel consumption blackover the entire trip with a $<1\%$ deviation from the dynamic programming (DP) results.

Motion Sickness Mitigating Algorithms and Control Strategy for Autonomous Vehicles

M. R. Siddiqi, S. Milani, R. N. Jazar, and H. Marzbani

The present work introduces a novel ultimate algorithm that minimizes motion sickness (phase 2) and maximizes handling comfort (phase 3) by reducing major MS thresholds using well defined minimizing technique called Particle Swarm Optimization (PSO) for mainly three land vehicle maneuvers: 1) single lane change, 2) double lane change, and 3) cornering. Second, a novel control strategy has been presented using key motion sickness parameters as objective functions to minimize motion sickness in real time by minimizing vehicle forces that aggravate motion sickness in occupants of an Autonomous Vehicle. Together, the Ultimate Motion Sickness Algorithm (UMSA) and the proposed Motion Sickness Hybrid Control Strategy (MSHCS) reduce motion sickness by up-to 73.1% without the need for slowing the vehicle down to unrealistic speeds, ensuring that the journey time for the passenger is not compromised.

Tabu-Based Adaptive Large Neighborhood Search for Multi-Depot Petrol Station Replenishment With Open Inter-Depot Routes

A. Che, W. Wang, X. Mu, Y. Zhang, and J. Feng

This article studies a new variant of the petrol station replenishment problem (PSRP) by considering a multi-depot vehicle routing problem with open inter-depot routes (MDVRPOI). The problem is formulated as a mixed-integer linear programming (MILP) model, and a tabu-based adaptive large neighborhood search (T-ALNS) algorithm is proposed for solving. The computational results based on the real data of an oil company show that the T-ALNS algorithm significantly outperforms the CPLEX solver and other algorithms in terms of solution quality and computation time.

Robustness Analysis of Platoon Control for Mixed Types of Vehicles

Y. Wang, S. Lin, Y. Wang, B. De Schutter, and J. Xu

This article establishes a model of mixed platoons with mixed types of connected and automated vehicles (CAVs), human-driven vehicles (HDVs) and HDVs without the vehicle awareness device (HDVWs). The H∞ controllers are designed for this model to realize the formation consensus. In addition, the authors use the H∞ norm of mixed platoons as the control objective investigating the robustness of the control algorithms in alleviating the platoon uncertainties. Furthermore, conditions are proved to maintain the stability of the mixed platoons, and the stability is analyzed based on the variation of the penetration rate of the manual vehicles. Finally, the authors formulate conditions for parameters according to the definition of string stability to avoid the collisions of vehicles. The results suggest that the presented controllers can ensure the consensus of mixed platoons under uncertainties.

AGV-Based Vehicle Transportation in Automated Container Terminals: A Survey

P. Z. Sun, J. You, S. Qiu, E. Q. Wu, P. Xiong, A. Song, H. Zhang, and T. Lu

To respond to the rapid growth of shipping container throughput, terminals urgently need to improve the efficiency of their operations and reduce operational costs through automation and intellectualization upgrades, thereby improving service levels and enhancing market competitiveness. Due to the advantages of reliable transportation, efficient operation, and environmental friendliness, AGV-based automated container terminal (ACT) has become the development trend of container terminals. To help ACT improve its operational management capabilities, plenty of scholars have explored the transportation system of ACT. Through the analysis of operational management issues, the article defines the four main research topics in vehicle transportation of the ACT including equipment scheduling, path planning, exception handling, and vehicle management. Then, in each topic, the works in the recent 25 years are summarized and several research opportunities for possible follow-up research directions in different fields are proposed. The authors expect the survey could not only provide references for more scholars on the research of operation and management of terminals, but also provide guidance for system evaluation and improvement for terminal system engineers and operation managers.

A Train Scheduling for Energy Optimization: Tehran Metro System as a Case Study

S. Hasanzadeh, S. F. Zarei, and E. Najafi

In the railway system, most of the electrical energy is consumed by the electrical machines in the traction system. The amount of energy consumption is a function of different operating factors. Among them, the train movement schedule has the highest impact. Proposing an efficient train movement schedule helps energy optimization in the metro system. This article proposes a formulation and modeling approach for developing an optimized scheduling program. Then, the proposed optimized train movement schedule is presented. The proposed scheduling method is also implemented in the Tehran Metro system, and the results are compared with the previous program. According to the results, the proposed method improves the energy efficiency in the studied metro system.

A Bi-Objective Lane Reservation Problem Considering Dynamic Traffic Flow

T. Li, N. Wang, B. Jiang, and M. Zhang

Lane reservation strategies are widely used to ensure the right of way for eco-friendly vehicles and encourage people to green their commute. In most lane reservation problems (LRPs), the parameters underlying the system traffic conditions (e.g., vehicle speed and traffic flow) cannot be

effectively specified. This article addresses a new dynamic lane reservation problem (DLRP), which aims to optimize lanes that need to be reserved in different time periods based on trajectory data for existing transit network optimization. For passengers in reserved lanes, their travel time is minimized to guarantee traffic priority. Considering that the reserved lanes cause travel time growth on regular lanes, an improved multiobjective mixed integer nonlinear programming (MINLP) is established to minimize the delay. The problem complexity of this article is NP-hard. This article applies a preprocessing method for the actual traffic flow data analysis for link travel time calculation. The authors developed a hybrid evolutionary algorithm decomposing a multiobjective optimization problem (MOP) to a collection of simple MOPs. These subproblems are collaboratively solved. The hybrid crossover strategy exploits the advantages of different crossover operators for a better performance. The experimental results of MOEA/D and NSGA-II with standard test functions show that the proposed algorithm can improve the convergence and distribution of the results. Through numerous analyses and calculations of instances, the proposed algorithm is proven to be effective.

A Lagrangian Relaxation Heuristic for a Bi-Objective Multimodal Transportation Planning Problem

Z. Li, H. Chen, Y. Liu, and K. Jin

The authors study a realistic Bi-objective Multimodal Transportation Planning Problem (BMTPP) faced by logistics companies when trying to obtain cost advantages and improve the customer satisfaction in a competitive market. The two objectives considered are: the minimization of total transportation cost and the maximization of service quality. Given a set of transportation orders described by an origin, a destination, and a time window, solving BMTPP involves determining the delivery path for each order in a capacitated network as well as selecting the carrier with the best service quality for each edge of the path. The BMTPP is formulated as a novel bi-objective mixed integer linear programming model and an iterative-constraint method is applied to solve it. As the NP-hardness of the single-objective problems derived from BMTPP, a Lagrangian Relaxation (LR) heuristic which can not only provide a near-optimal solution but also a lower bound for each of the single-objective problems is developed; 100 randomly generated instances are tested and the computational results demonstrate the effectiveness of the heuristic in obtaining a tight lower bound and a high-quality near-optimal solution for the derived single-objective problem. Various performance indicators show the high-quality of the Pareto front of the bi-objective problem obtained by the heuristic. The authors also provide a case study for the proposed LR heuristic in a logistics network in China.

Personalized Freight Route Recommendations With System Optimality Considerations: A Utility Learning Approach

A.-A. Papadopoulos, I. Kordonis, M. Dessouky, and P. Ioannou

A coordinated pricing-and-routing scheme for truck drivers to efficiently route trucks into the network and improve the overall traffic conditions is studied. The proposed method provides personalized routing instructions based on drivers' individual routing preferences and optimizes over a total system-wide cost through a combined pricing-and-routing scheme that satisfies the budget balance on average property and ensures that every truck driver has an incentive to participate in the proposed mechanism. To introduce personalization, the authors first divide the drivers into disjoint clusters based on their responses to a small number of binary route choice questions and subsequently propose a learning scheme based on the Maximum Likelihood Estimation (MLE) principle that allows us to learn the parameters of the utility function that describes each cluster. The estimated utilities are then used to calculate a pricing-and-routing scheme with the aforementioned characteristics.

Safe Reinforcement Learning for Single Train Trajectory Optimization via Shield SARSA

Z. Zhao, J. Xun, X. Wen, and J. Chen

The single train trajectory optimization, also known as speed profile optimization (SPO), is a traditional problem to minimize the traction energy consumption of trains. As a kind of optimal method, reinforcement learning (RL) has been used to solve the SPO problem. In the learning process of a common RL algorithm, a soft constraint (punishment) is always used to keep the agent away from unsafe states. However, a soft constraint can not guarantee and explain the safety of the result. For the SPO problem, it means that the optimized speed profile obtained by a simple RL may break the speed limit which is unacceptable in reality. This article proposes a protection mechanism called Shield and constructs a Shield SARSA (S-SARSA) algorithm to protect the learning process of the high-speed train. Four different reward functions are used to compare the protective efficacy between the proposed algorithm and the soft constraint. The numerical experiments based on the line data from Wuxi East to Suzhou North verify the protective efficacy and effectiveness.

How Far Two UAVs Should Be Subject to Communication Uncertainties

Q. Quan, R. Fu, and K.-Y. Cai

Unmanned aerial vehicles are now becoming increasingly accessible to amateur and commercial users alike. A safety air traffic management system is needed to help ensure that every newest entrant into the sky does not collide with others. Much research has been done to design various methods to perform collision avoidance with obstacles. However, how to decide the safety radius subject to communication uncertainties is still suspended. Based on assumptions on communication uncertainties and supposed control performance, a separation principle of the safety radius design and controller design is proposed. With it, the safety radius in the design phase (without uncertainties) and flight phase (subject to uncertainties) are studied. Furthermore, the results are extended to multiple obstacles. Simulations and experiments are carried out to show the effectiveness of the proposed methods.

Feature Fusion-Based Inconsistency Evaluation for Battery Pack: Improved Gaussian Mixture Model

J. Tian, X. Liu, C. Chen, G. Xiao, Y. Wang, Y. Kang, and P. Wang

The large-scale grouping of the battery system leads to the inconsistency of the battery pack. Aiming at tacking this issue, an inconsistency evaluation method is deployed for the battery pack based on an improved Gaussian mixture model (GMM) and feature fusion approach. Specifically, the proposed adaptive forgetting factor recursive least squares (AFFRLS) algorithm allows the open-circuit voltage and other parameters to be jointly identified without the open circuit voltage–state of charge (OCV-SOC) test. An online capacity estimation approach with the extended Kalman particle filter (EPF) is put forward for capacity estimation. Furthermore, an improved GMM is proposed to visualize battery pack inconsistency, using the K-means++ algorithm to initialize category centers. The standard deviation coefficient approach quantifies the inconsistency. Finally, the real-life vehicle data are performed to validate the effectiveness of the proposed method. The experimental results show that the proposed method can evaluate the battery parameters accurately. With the increase in service time, the inconsistency of the battery pack is gradually deteriorating.

An Enhanced NSGA-II for Solving Berth Allocation and Quay Crane Assignment Problem With Stochastic Arrival Times

B. Ji, H. Huang, and S. S. Yu

This study addresses a berth allocation and quay crane assignment problem with stochastic arrival times of vessels. An efficient method combining scenario generation is presented to simulate the stochastic arrival times, and a mixed integer linear programming model is proposed to minimize the expectation of the vessels' total stay time in port. A multi-objective constraint-handling (MOCH) strategy is adopted to reformulate the developed model, which converts constraint violations into an objective, thus transforming the single-objective optimization model with complex constraints into a dual-objective optimization model with only easy-handling constraints. Then, an enhanced non-dominated sorting genetic algorithm II (ENSGA-II) is proposed to solve the dual-objective model. Numerical experiments on instances in the literature are conducted to validate the effectiveness of the MOCH and the proposed ENSGA-II. The results show that the average total stay time of vessels is reduced when stochastic arrival times are considered.

Interaction-Aware Trajectory Prediction and Planning for Autonomous Vehicles in Forced Merge Scenarios

K. Liu, N. Li, H. E. Tseng, I. Kolmanovsky, and A. Girard

A novel game-theoretic decision-making algorithm, called the Leader–Follower Game Controller (LFGC), is proposed to handle forced merging scenarios, where the merging vehicle needs to interact with other vehicles to identify or create a gap and safely merge into. The interactions between the autonomous ego vehicle and other vehicles with a priori uncertain driving intentions is modeled as a partially observable leader-follower game. The LFGC estimates the other vehicles' intentions online based on observed trajectories and then predicts their future trajectories and plans the ego vehicle's own trajectory using Model Predictive Control (MPC) to simultaneously achieve probabilistically guaranteed safety and merging objectives. To verify the performance of LFGC, the authors test it in simulations and with the NGSIM data, where the LFGC demonstrates a high success rate of 97.5% in merging.

STCLoc: Deep LiDAR Localization With Spatio-Temporal Constraints

S. Yu, C. Wang, Y. Lin, C. Wen, M. Cheng, and G. Hu

In this article, a novel LiDAR-based absolute pose regression network with spatio-temporal constraints is proposed, termed STCLoc, to reduce scene ambiguities and achieve more accurate localization. First, the authors propose to regularize regression in the spatial dimension with a novel classification task to reduce outliers. Specifically, the classification task categorizes the point cloud in terms of position and orientation and then couples it with the regression task to conduct multi-task learning. Second, to learn discriminative features to reduce scene ambiguities, the authors propose using attention-based feature aggregation to capture the correlation in LiDAR sequences. Extensive experiments on two benchmark datasets show that the model outperforms state-of-the-art methods.

A Cross-Layer Defense Method for Blockchain Empowered CBTC Systems Against Data Tampering Attacks

H. Liang, L. Zhu, F. R. Yu, and X. Wang

This article proposes a novel cross-layer defense method for cyber security in blockchain-empowered CBTC against data tampering attacks. In the physical layer, the joint Kalman filter and $ \chi^{2} $ detector is proposed for the train state estimation and detection. In the cyber layer, the blockchain-based distributed key management system with the adaptive consensus mechanism are designed for data communication security. Furthermore, a partially observable Markov (POMDP) decision model is constructed to derive the optimal adaptive consensus strategies for balancing cyber security and efficiency. The extensive simulation results show that the proposed method can effectively improve the cyber security protection capability and minimize the impact of data tampering attacks on the train operation.

Reliable Autonomous Driving Environment Model With Unified State-Extended Boundary

X. Jiao, J. Chen, K. Jiang, Y. Wang, Z. Cao, M. Yang, and D. Yang

A new view of autonomous driving environment is proposed as the unified state-extended boundary (USEB), aiming to improve the reliability of the commonly applied environment model as the element list. For driving decision requirements, different types of elements are consistently converted into boundary constraints. Semantics and dynamics are expressed as the status of drivable area boundary, making it possible to merge space occupation to improve reliability against missed detection and irregular objects. Evaluation of USEB is carried

out on the nuScenes dataset. The comparative results show that the proposed USEB could cover the required information for driving decision, whereas achieving higher reliability than the commonly applied element-oriented model.

Operation Management of Electric Vehicle Battery Swapping and Charging Systems: A Bilevel Optimization Approach

B. Li, K. Xie, W. Zhong, X. Huang, Y. Wu, and S. Xie

This article studies optimal day-ahead scheduling of a battery swapping and charging system (BSCS) for electric vehicles (EVs) from a new perspective of multiple decision makers. It is considered that the BSCS locally incorporates the battery swapping and charging processes, and the two processes are managed by two operators, called a battery swapping operator (BSO) and a battery charging operator (BCO), respectively. The main contribution is to propose a bilevel model where the BSO acts as the leader to receive and serve the battery swapping requests from EV users, and the BCO acts as the follower to interact with the grid and control battery charging and discharging power. The authors reformulate the bilevel optimization problem into an equivalent single-level problem that is a nonconvex mixed-integer nonlinear program (MINLP), and its size can easily become very large. To solve the problem efficiently, the authors develop a new heuristic composed of two parts, i.e., an estimation of the integer solution and an algorithm based on the alternating direction method (ADM). The results show that the proposed heuristic performs well in solving large-scale problems, providing close-to-optimal solutions quickly. In addition, compared to a social welfare maximization model that follows most existing related works, the proposed bilevel model can increase the number of swapped-out batteries by 35% and the batteries' average energy state by 6%, improving the quality of battery swapping services.

DeepCar 5.0: Vehicle Make and Model Recognition Under Challenging Conditions

A. Amirkhani and A. H. Barshooi

Inspired by multi-agent systems (MASs) and ensemble models, a novel method of vehicle make and model recognition (VMMR) based on a vehicle's front-view images is presented in this article. By exploiting the attention mechanism in this work, it is demonstrated that most of the features used for classifying a vehicle are extracted from its headlight, grill, scoop, and bumper sections. These areas are designated as the regions of interest (ROIs) in the proposed approach. Contrary to the other methods in which a whole ROI is fed to a deep convolutional neural network, in this scheme, different ROIs are extracted from each image, and then a preprocessing block and a distinctive network are designed for each ROI, which is considered as a single agent. Each agent is then trained separately, and a vehicle's type is determined with the collaboration of these agents and based on the blackboard classification system. Also, a new dataset (DeepCar 5.0) is compiled by using the data from the top 50 automakers. This dataset contains 40,185 images of the front views and the front three-quarters of vehicles in 480 different classes, and all the parts of dataset are labeled manually. The proposed technique is able to achieve the accuracies of 92.14 and 96.72% in the automated and the manual scenarios, respectively; contrary to the current methods, it can perform flawless classification even when just a portion of a vehicle's front view image is available for processing. The dataset and parts of the code are available at: https://github.com/DeepCar/DeepCar5.0.

The Impact of a Single Discretionary Lane Change on Surrounding Traffic: An Analytic Investigation

J. He, J. Qu, J. Zhang, and Z. He

A real-world trajectory data-based analytic method is proposed to investigate a single discretionary lane change's impact on surrounding traffic quantitatively. This method includes two steps: a method to calculate response time of the lane-changing vehicle and its following vehicles, and a time sequence data processing method based on feature points to analyze the change pattern of the variable minimum space. A lane change's temporal and spatial on surrounding traffic can be captured by the 'decreasing-increasing' pattern of minimum space. The high-precision Zen-traffic trajectory data set is employed to demonstrate the effectiveness of the proposed methods and reach some interesting conclusions.

An Active and Contrastive Learning Framework for Fine-Grained Off-Road Semantic Segmentation

B. Gao, X. Zhao, and H. Zhao

This work proposes an active and contrastive learning framework for fine-grained off-road semantic segmentation. In this approach, annotations are made on a few image patches, mainly to distinguish semantic differences rather than semantic categories, which can greatly reduce the burden of manual annotation. A feature representation is learnt using the contrastive pairs of image patches, and semantic categories are adaptively modeled from the data. To actively adapt to new scenes, a risk evaluation method is developed to discover and select hard frames with high-risk predictions for supplementary labeling, to update the model efficiently. Extensive experiments and analyses are conducted on self-developed and public datasets. The experimental results demonstrate that fine-grained semantic segmentation can be learned with only dozens of weakly labeled frames, and the model can efficiently adapt across scenes by weak supervision, while achieving competitive performance with the typical fully supervised ones.

Security and Privacy in a Blockchain-Powered Access Control System for Low Emission Zones

C. Anglés-Tafalla, A. Viejo, J. Castellá-Roca, M. Mut-Puigserver, and M. M. Payeras-Capellá

Low Emission Zones (LEZs) are areas where access restrictions to polluting vehicles are enforced to deal with urban traffic and environmental pollution. Regarding the centralization issues identified in the privacy-preserving LEZ access management systems found in the literature, this article proposes a new scheme that decentralizes the LEZ management, dealing with vehicle accesses as blockchain transactions, and pricing and charging them using smart contracts. The new scheme has

been implemented and tested in both a controlled environment and a low-traffic street. The evaluation of the smart contracts' costs in terms of gas has been included in the performed tests. The results obtained are satisfactory and show the feasibility of the new proposal.

Development of Connected and Automated Vehicle Platoons With Combined Spacing Policy

Y. Zheng, M. Xu, S. Wu, and S. Wang

A connected and automated vehicle platoon with a combined spacing policy is proposed, where the leader adopts the constant time gap (CTG) and the followers use the constant spacing (CS) policy. Based on the h2-norm stability criteria, the notion of exogenous-head-to-tail string stability is newly introduced, and the sufficient conditions of local stability and string stability in the frequency domain are derived using the Routh-Hurwitz criterion and Laplace transform, respectively. Numerical experiments are conducted to verify the string stability and the effectiveness of the proposed vehicle platoon in efficiency, safety, energy, and emission aspects. The results show that the proposed vehicle platoon performs better than the CS-based platoon in all aspects except for efficiency, and has obvious advantages over the CTG-based platoon in efficiency and safety aspects. The findings have demonstrated the merits of the combined spacing policy for the vehicle platoon in enhancing stability and traffic performance.

Airport Capacity Prediction With Multisource Features: A Temporal Deep Learning Approach

W. Du, S. Chen, H. Li, Z. Li, X. Cao, and Y. Lv

The imbalance of multi-source features and temporal dependences in aviation systems are considered in this article to improve the accuracy of airport capacity prediction. The authors propose a novel temporal deep learning method based on the multi-channel fusion Transformer model (MF-Transformer). Besides the commonly used aviation features, the authors unprecedentedly harness the power of the high-dimensional meteorological feature. As to the model, a multi-channel feature fusion structure which includes a three-channel network for multi-source features extraction is constructed and an attention-based module between channels is designed for feature fusion. In each channel, the Transformer-based model is utilized to capture the temporal dependences of features. The experiments on Beijing Capital International Airport which is the largest airport in China show that the proposed MF-Transformer outperforms benchmarks under different prediction horizons.

A Dual-Flow Attentive Network With Feature Crossing for Chained Trip Purpose Inference

S. Lyu, T. Han, P. Li, X. Luo, and T. Kusakabe

Trip purpose is essential information supporting tasks in intelligent transportation systems, such as travel behavior comprehension, location-based service, and urban planning. The observation of trip purpose is a necessary aspect of travel surveys. However, owing to the sampling volume, survey budget, and survey frequency, relying solely on travel surveys in the era of big data is a difficult task. There has long been a demand for an accurate, generalizable, and robust inference method for trip purposes. Although existing studies contributed significant efforts to improve the trip purpose inference, the potential of leveraging the trip chain is insufficient. The spatial correlations and chaining patterns hidden in traveled zones are worthy of further exploration. The unequal importance within trip chains has not been clearly represented. In addition, complex activity-zone mutual interdependence has not been considered in previous models. Herein, the authors propose a framework-Dual-Flow Attentive Network with Feature Crossing (DACross), specifically for inferring the chained trip purpose. The authors form trip chains innovatively that treat trip activities and traveled geographic zones as two chains with mutual interactions. The authors propose DACross, which consists of two parallel attentive branches and a co-attentive feature crossing module, for fully learning the intra- and inter-chain dependencies. The authors conducted extensive experiments on four large-scale real-world datasets to evaluate not only the performance of DACross but also the generalizability of the proposed framework among different cities and scenarios. Notably, the experimental results prove the overall superiority of the proposed DACross.

Event-Triggered Asymptotic Tracking Control of Underactuated Ships With Prescribed Performance

Y. Deng, Z. Zhang, M. Gong, and T. Ni

Adapting to the navigational high-precision tracking tasks, this article develops an event-triggered adaptive neural asymptotic tracking control framework for underactuated ships. The prescribed performance control (PPC) technique is employed to address spatial constraints in navigation, where the positional tracking errors are transformed via the transformation functions. By using the approximation of radial basis function neural networks (RBF NNs) in the form of minimum learning parameters (MLPs), the uncertainties coming from the unknown model dynamics, the environmental disturbances, and the derivation of virtual control laws are offset altogether, and a succinct computation is guaranteed. Assisted by the property of neural basis function, the "algebraic loop" problem in the backstepping design is released. To achieve the asymptotic tracking performance, the hyperbolic tangent functions are incorporated into the control laws, which are characterized by the integral-bounded terms. The event-triggered control (ETC) is designed in the controller-to-actuator (CA) channel. Two separate triggering conditions are constructed for the surge and the yaw motions respectively, which are characterized by the compound thresholds composed of a variable and a constant. The "Zeno" behaviors can thereby be avoided. The proposed scheme has three notable characteristics: 1) the computational complexity is reduced by using the MLP technique with lumped uncertainties; 2) the high-precision tracking performance can be achieved through the asymptotic tracking control; and 3) the practical problems of spatial constraints and communication burdens can be solved by fabricating a uniform control framework including PPC and ETC. With the aid of direct Lyapunov candidates and the Barbalat's lemma, the asymptotic convergence of all the tracking errors is proved.

Finally, a numerical experiment corroborates the feasibility of the proposed scheme.

Decentralized Time and Energy-Optimal Control of Connected and Automated Vehicles in a Roundabout With Safety and Comfort Guarantees

K. Xu, C. G. Cassandras, and W. Xiao

A general decentralized framework for controlling Connected and Automated Vehicles (CAVs) in a roundabout is proposed. CAVs are optimally controlled in order to jointly save travel time and energy consumption, as well as maximizing the comfort of passengers. The article uses the solution of the tractable optimal control problem as the basis for the design of a real-time control-barrier-function-based controller with particular emphasis on safety guarantees. Simulation experiments show its effectiveness under different roundabout configurations, balanced and imbalanced traffic rates, and different sequencing rules for CAVs. An auxiliary method is also included in the appendix to bridge the gap between theoretical analysis and implementation.

A Mathematical Modeling of Stuxnet-Style Autonomous Vehicle Malware

H. Ahn, J. Choi, and Y. H. Kim

This article studies the spread of Stuxnet-style malware on autonomous vehicles (AVs) at a city level. Traditional analysis tools are insufficient to cope with the emerging security challenges of AVs or adequately predict the behavior of the AV epidemic. This study aims to analyze the behavior of malware to bridge the methodological gaps between traditional tools and new challenges. The malware propagation was simulated by a mathematical model based on the malaria spread model and transportation gravity model. This study is the first attempt to recognize the significant threats of AVs malware and defend against the AVs epidemic.

Optimization Framework for Crowd-Sourced Delivery Services With the Consideration of Shippers' Acceptance Uncertainties

S. Hou, J. Gao, and C. Wang

Crowd-Sourced Delivery Services (CDS) use in-store customers, as crowd-shippers, to deliver online orders directly to other customers. As independent contractors, the crowd-shippers are free to decide whether to accept or reject the online orders assigned by the retailer. High-order rejection rates can significantly influence the retailer's delivery costs due to frequent reassignments and shifting the orders to more expensive professional fleet. To incentivize crowd-shippers to accept the matched orders, in this work, the authors propose a two-stage optimization framework that integrates bipartite matching with an individual compensation scheme. The first stage of the optimization framework computes the optimal matching between crowd-shippers and online orders to minimize the delivery detours and unassigned orders. Given the matching solutions as inputs, the second stage computes personal compensation for each crowd-shipper based on the characteristic of the matched order and his or her acceptance behavior uncertainty, with the goal of minimizing the expected total delivery cost of the retailer. Numerical experiments are conducted using the survey data to illustrate the performance of the proposed framework and compare it with existing matching and pricing strategies in the literature. The results show that the proposed framework reduces the delivery cost by up to more than 15% and reduces the crowd-shippers' rejection rate by an average of 55%.

Optimizing Two-Truck Platooning With Deadlines

W. Xu, T. Cui, and M. Chen

The authors study a transportation problem where two heavy-duty trucks travel across the national highway from separate origins to destinations, subject to individual deadline constraints. The objective is to minimize their total fuel consumption by jointly optimizing path planning, speed planning, and platooning configuration. Such a two-truck platooning problem is pervasive in practice yet challenging to solve due to hard deadline constraints and enormous platooning configurations to consider. The authors first leverage a unique problem structure to significantly simplify platooning optimization and present a novel formulation. The authors prove that the two-truck platooning problem is weakly NP-hard and admits a Fully Polynomial Time Approximation Scheme (FPTAS). The FPTAS can achieve a fuel consumption within a ratio of $(1+)$ to the optimal (for any >0) with a time complexity polynomial in the size of the transportation network and 1/. These results are in sharp contrast to the general multi-truck platooning problem, which is known to be APX-hard and repels any FPTAS. As the FPTAS still incurs excessive running time for large-scale cases, the authors design an efficient dual-subgradient algorithm for solving large-/national- scale instances. It is an iterative algorithm that always converges. The authors prove that each iteration only incurs polynomial-time complexity, albeit it requires solving an integer linear programming problem optimally. The authors characterize a condition under which the algorithm generates an optimal solution and derive a posterior performance bound when the condition is not met. Extensive simulations based on real-world traces show that the joint solution of path planning, speed planning, and platooning saves up to 24% fuel as compared to baseline alternatives.

ClusterST: Clustering Spatial–Temporal Network for Traffic Forecasting

G. Luo, H. Zhang, Q. Yuan, J. Li, and F.-Y. Wang

Traffic forecasting aims to capture complex spatial–temporal dependencies and non-linear dynamics, which plays an indispensable role in intelligent transportation systems and other domains like neuroscience, climate, etc. Most recent works rely on graph convolutional networks (GCN) to model the dependencies and the dynamics. However, the over-smoothing issue of GCN would produce indistinguishable features among nodes, leading to poor expressivity and weak capability of modeling complex dependencies and dynamics. To address this issue, the authors present a novel clustering spatial–temporal (ClusterST) unit, which incorporates unsupervised learning into GCN for extracting discriminative features. Specifically, the authors first exploit a neural network to learn

a dynamic clustering, i.e., learning to partition the neighbors of each node into clusters at each time step. Two probabilistic losses are proposed to improve the separability of clusters. Then, the extracted features of different clusters can be distinguished. Based on the dynamically formed clusters, a vanilla GCN is applied to aggregate features within each cluster. By purely exploiting such a ClusterST unit, large improvements over the state-of-the-art are achieved. Furthermore, ClusterST units with a different number of clusters can be regarded as basic components to construct an inception-like ClusterST network for going deeper. The authors evaluate the framework on two real-world large-scale traffic datasets and observe an average improvement of 18.19% and 7.62% over state-of-the-art baselines, respectively. The code and models will be publicly available.

Do Automated Vehicles Reduce the Risk of Crashes—Dream or Reality?

Á. Török

To assess the possible social benefits of automated vehicle systems objectively, it is necessary to analyze the possible negative effects in detail as well. Accordingly, the aim of this article is to present a statistical survey of crashes involving automated vehicles today in order to identify and evaluate the factors that are relevant in the crashes. The analyzed data showed that when the autopilot mode was turned off and the human driver made the control decisions, the severity of crashes on straight roads was greater at $\alpha = 0.1$ significance level than when the vehicle was in autopilot mode and the vehicle system made the control decisions. In addition, if the α significance level is 0.2, then crashes on plain terrain, during the day, or in the speed range of 80-100 km/h are generally less serious for vehicles driven in autopilot mode than for vehicles with autopilot mode turned off.

Bi-Level l_1 Optimization-Based Interference Reduction for Millimeter Wave Radars

Z. Xu

A novel bi-level L1 optimization-based approach is proposed for reducing interferences between Automotive millimeter radars for range, velocity, and angle measurement. First, sparse difference analysis between the interfering signal and the target signal is investigated. According to the analysis results, one bi-level-based signal optimization model is further derived by using L1-norm penalized least squares. This bi-level optimization enables a tradeoff between suppressing interference and preserving radar targets. In real road interference suppression experiments, the proposed method improves the signal-to-interference plus noise ratio (SINR) for the target from 5.06 to 19.26 dB in the range-Doppler domain and from 6.86 to 22.10 dB in the azimuth spatial domain.

Using fNIRS to Verify Trust in Highly Automated Driving

J. R. Perello-March, C. G. Burns, R. Woodman, M. T. Elliott, and S. A. Birrell

Trust in automation is crucial for the safe and appropriate adoption of automated driving technology. Current research methods to measure trust mainly rely on subjective scales, with several intrinsic limitations. This empirical experiment proposes a novel method to measure trust objectively, using functional near-infrared spectroscopy (fNIRS). Through manipulating participants' expectations regarding driving automation credibility, the authors have induced and successfully measured opposing levels of trust in automation. Most notably, the results evidence two separate yet interrelated cortical mechanisms for trust and distrust. Trust is demonstrably linked to decreased monitoring and working memory, whereas distrust is event-related and strongly tied to affective (or emotional) mechanisms. This article evidence that trust in automation and situation awareness are strongly interrelated during driving automation usage. The findings are crucial for developing future driver state monitoring technology that mitigates the impact of inappropriate reliance, or over trust, in automated driving systems.

Threshold-Adaptive Unsupervised Focal Loss for Domain Adaptation of Semantic Segmentation

W. Yan, Y. Qian, C. Wang, and M. Yang

This article proposes a novel two-stage entropy-based unsupervised domain adaptation (UDA) method for semantic segmentation in driving scenarios. In stage one, the threshold-adaptive unsupervised focal loss is first introduced into UDA for semantic segmentation without requiring pseudo labels in the target domain, helping to optimize hard samples. In stage two, cross-domain image mixing (CIM) is employed to bridge the semantic knowledge between two domains with long-tail class pasting to alleviate the class imbalance problem. Extensive experiments on synthetic-to-real and cross-city benchmarks demonstrate the effectiveness of the method. It achieves state-of-the-art performance using DeepLabV2, as well as competitive performance using the lightweight BiSeNet with great advantages in training and inference time.

Toward Extremely Lightweight Distracted Driver Recognition With Distillation-Based Neural Architecture Search and Knowledge Transfer

D. Liu, T. Yamasaki, Y. Wang, K. Mase, and J. Kato

A novel knowledge-distillation-based neural architecture search framework is proposed to design lightweight Convolutional Neural Networks (CNNs) for recognizing distracted driving from a dashcam. The proposed framework first constructs a high-performance teacher network by progressively strengthening the robustness to illumination changes from shallow to deep layers of a CNN. Then, the teacher network is used to guide the architecture searching process of a student network through knowledge distillation. After that, the teacher network is used again to transfer knowledge to the searched student network by knowledge distillation. The searched student networks achieve state-of-the-art accuracy with very small parameters on widely used distracted driving recognition datasets.

Compaction Prediction for Asphalt Mixtures Using Wireless Sensor and Machine Learning Algorithms

S. Yu and S. Shen

An innovative prediction model based on machine learning algorithms and sensing technology was proposed to improve

the compaction quality of the asphalt pavement. A wireless particle-size sensor, SmartRock, was used to collect the particle kinematic data during compaction. The particle rotation, shearing resistance, and temperature were identified as the most critical variables for the compaction prediction. The models achieved higher than 98% prediction accuracy using the Support Vector Machine (SVM) classifier and logistic regression model. The results demonstrated the effectiveness of the model and a promising solution for asphalt mixture compaction quality control.

Dynamic Event-Triggered Adaptive Neural Output Feedback Control for MSVs Using Composite Learning

G. Zhu, Y. Ma, Z. Li, R. Malekian, and M. Sotelo

This article investigates the control issue of marine surface vehicles (MSVs) subject to internal and external uncertainties without velocity information. Utilizing the specific advantages of adaptive neural network and disturbance observer, a classification reconstruction idea is developed. Based on this idea, a novel adaptive neural-based state observer with disturbance observer is proposed to recover the unmeasurable velocity. Under the vector-backstepping design framework, the classification reconstruction idea and adaptive neural-based state observer are used to resolve the control design issue for MSVs. To improve the control performance, the serial-parallel estimation model is introduced to obtain a prediction error, and then a composite learning law is designed by embedding the prediction error and estimate of lumped disturbance. To reduce the mechanical wear of actuator, a dynamic event-triggering protocol is established between the control law and actuator. Finally, a new dynamic event-triggered composite learning adaptive neural output feedback control solution is developed. Employing the Lyapunov stability theory, it is strictly proved that all signals in the closed-loop control system of MSVs are bounded. The simulation and comparison results validate the effectiveness of the control solution.

Adaptive Cooperative Load Transportation by a Team of Quadrotors With Multiple Constraint Requirements

X. Jin and Z. Hu

Cable-suspended load carried by multiple unman- ned aerial vehicles (UAVs) has applications in many areas. However, most existing aerial load transportation works are tailored to a specific type of load transportation tasks, or assume simplified system models or transportation scenarios. Furthermore, no existing works on this topic can provide a unified framework to address multiple performance and safety constraints during the cooperative transportation operation. In this article, the authors propose and investigate a new constrained cooperative control architecture for an UAV team, which are collaboratively carrying a three-dimensional load, subject to multiple user-defined time-varying performance and safety constraint requirements. A unified framework using universal barrier functions has been proposed to deal with different types of constraint requirements. Moreover, control saturation and uncertainties in UAV inertia matrices are dealt with by employing adaptive estimators. Exponential convergence on the distance and attitude tracking errors can be guaranteed by the algorithm. Lastly, the authors discuss a simulation example that further shows the efficacy of the proposed cooperative control framework.

Optimal Traffic Signal Control of Isolated Oversaturated Intersections Using Predicted Demand

R. Mohajerpoor, C. Cai, and M. Ramezani

The optimal traffic signal control of isolated oversaturated intersections is formulated and solved. An analytical signal control algorithm is proposed to find the global optimal signal timings with dynamic cycle lengths, and phase splits to minimize the vehicle delay throughout the oversaturation period at a generic multi-phase junction. The traffic dynamics are modeled based on the kinematic wave theory and the predicted traffic flows. Moreover, spillback avoidance is incorporated during the queue formation oversaturated regime by adopting a mixed delay and probability of spillback objective function. Microsimulation experiments demonstrate the proposed signal control method's optimality, practicality, and robustness to system uncertainties.

Loss Function Design for Data-Driven Predictors to Enhance the Energy Efficiency of Connected and Automated Vehicles

E. Hyeon, T. Ersal, Y. Kim, and A. G. Stefanopoulou

A novel strategy for designing the loss function of data-driven vehicle trajectory predictors is presented to enhance the energy efficiency of connected and automated vehicles (CAVs). A mean-squared-error loss function is reformulated by imposing different weights on prediction steps based on the quantified influence of uncertainty at each prediction step on the energy efficiency of the CAVs. By simply changing the loss function formulation, the proposed method brings 2% additional energy saving to an eco-driving battery electric vehicle in simulation.

Recommending-and-Grabbing: A Crowdsourcing-Based Order Allocation Pattern for On-Demand Food Delivery

X. Wang, L. Wang, S. Wang, J. Pan, H. Ren, and J. Zheng

A crowdsourcing-based order recommending-and-grabbing system is presented to facilitate the on-demand food delivery service. Specially, the system considers the preferences of crowdsourced riders and allocates orders by recommending them to suitable crowdsourced riders. To optimize the experience of both customers and crowdsourced riders, a hierarchical solution framework composed of prediction and optimization is also proposed to generate satisfactory order allocation schemes at each decision moment. An XGBoost model and an allocating-and-sequencing algorithm are developed for the implementation of the hierarchical solution framework. Experiments on real-world datasets from Meituan delivery platform validate the superiority of the proposed methods, indicating great application value in on-demand food delivery business.

Multi-Agent DRL-Based Lane Change With Right-of-Way Collaboration Awareness

J. Zhang, C. Chang, X. Zeng, and L. Li

Lane change is a common-yet-challenging driving behavior for automated vehicles. To improve the safety and efficiency of automated vehicles, researchers have proposed various

lane-change decision models. However, most of the existing models consider lane-change behavior as a one-player decision-making problem, ignoring the essential multi-agent properties when vehicles are driving in traffic. Such models lead to deficiencies in interaction and collaboration between vehicles, which results in hazardous driving behaviors and overall traffic inefficiency. In this article, the authors revisit the lane-change problem and propose a bi-level lane-change behavior planning strategy, where the upper level is a novel multi-agent deep reinforcement learning (DRL) based lane-change decision model and the lower level is a negotiation based right-of-way assignment model. The authors promote the collaboration performance of the upper-level lane-change decision model from three crucial aspects. First, the authors formulate the lane-change decision problem with a novel multi-agent reinforcement learning model, which provides a more appropriate paradigm for collaboration than the single-agent model. Second, the authors encode the driving intentions of surrounding vehicles into the observation space, which can empower multiple vehicles to implicitly negotiate the right-of-way in decision-making and enable the model to determine the right-of-way in a collaborative manner. Third, an ingenious reward function is designed to allow the vehicles to consider not only ego benefits but also the impact of changing lanes on traffic, which will guide the multi-agent system to learn excellent coordination performance. With the upper-level lane-change decisions, the lower-level right-of-way assignment model is used to guarantee the safety of lane-change behaviors. The experiments show that the proposed approaches can lead to safe, efficient, and harmonious lane-change behaviors, which boosts the collaboration between vehicles and in turn improves the safety and efficiency of the overall traffic. Moreover, the proposed approaches promote the microscopic synchronization of vehicles, which can lead to the macroscopic synchronization of traffic flow.

GridDehazeNet+: An Enhanced Multi-Scale Network With Intra-Task Knowledge Transfer for Single Image Dehazing

X. Liu, Z. Shi, Z. Wu, J. Chen, and G. Zhai

Adverse weather conditions such as haze can deteriorate the performance of autonomous driving and intelligent transport systems. As a potential remedy, the authors propose an enhanced multi-scale network, dubbed GridDehazeNet+, for single image dehazing. The proposed dehazing method does not rely on the Atmosphere Scattering Model (ASM), and an explanation as to why it is not necessarily performing the dimension reduction offered by this model is provided. GridDehazeNet+ consists of three modules: pre-processing, backbone, and post-processing. The trainable pre-processing module can generate learned inputs with better diversity and more pertinent features as compared to those derived inputs produced by hand-selected pre-processing methods. The backbone module implements multi-scale estimation with two major enhancements: 1) a novel grid structure that effectively alleviates the bottleneck issue via dense connections across different scales; and 2) a spatial-channel attention block that can facilitate adaptive fusion by consolidating dehazing-relevant features. The post-processing module helps to reduce the artifacts in the final output. Due to domain shift, the model trained on synthetic data may not generalize well on real data. To address this issue, the authors shape the distribution of synthetic data to match that of real data and use the resulting translated data to finetune the network. The authors also propose a novel intra-task knowledge transfer mechanism that can memorize and take advantage of synthetic domain knowledge to assist the learning process on the translated data. The experimental results demonstrate that the proposed method outperforms the state-of-the-art on several synthetic dehazing datasets, and achieves the superior performance on real-world hazy images after finetuning.

Self-Configurable Stabilized Real-Time Detection Learning for Autonomous Driving Applications

W. J. Yun, S. Park, J. Kim, and D. Mohaisen

Guaranteeing real-time and accurate object detection simultaneously is paramount in autonomous driving environments. However, the existing object detection neural network systems are characterized by a tradeoff between computation time and accuracy, making it essential to optimize such a tradeoff. Fortunately, in many autonomous driving environments, images come in a continuous form, providing an opportunity to use optical flow. In this article, the authors improve the performance of an object detection neural network utilizing optical flow estimation. In addition, the authors propose a Lyapunov optimization framework for time-average performance maximization subject to stability. It adaptively determines whether to use optical flow to suit the dynamic vehicle environment, thereby ensuring the vehicle's queue stability and the time-average maximum performance simultaneously. To verify the key ideas, the authors conduct numerical experiments with various object detection neural networks and optical flow estimation networks. In addition, the authors demonstrate the self-configurable stabilized detection with YOLOv3-tiny and FlowNet2-S, which are the real-time object detection network and an optical flow estimation network, respectively. In the demonstration, the proposed framework improves the accuracy by 3.02%, the number of detected objects by 59.6%, and the queue stability for computing capabilities.

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