A New Phase of IEEE Transactions on Intelligent Vehicles: Being Smart, Becoming Active, and Believing Intelligent Vehicles

Dear All,

Welcome to 2023 and Happy New Year!

Thanks for your great effort, the following is a brief summary for we have achieved in 2022:

- 1682 manuscripts have been submitted, well over the target of 1200 submissions, that is 765% of the submission in 2021, and 186% of the total submission since the creation of IEEE TIV in 2015 [1].
- 2022 SPD (submissions per day) is 4.61, and TIV's quarterly SPD are 4.02, 3.53, 4.98, 5.88, respectively, indicating a healthy trend of growth.
- Except a few manuscripts that require special processing, our average time for the first decision is 19.7 days, and our average total time for the final decision is 57.6 days. On average, we have honored our "DIDO" and "3224" guidelines [2], [3].
- The first journal impact factor of TIV is IF = 5.009 with a CiteScore = 10.9 in 2022 [4], and our current tracking IF is 5.512 according to the Web of Science. Clearly, IEEE TIV is among the best academic publications in the field.
- The George N. Saridis Best Paper Award of the IEEE TRANSACTIONS ON INTELLIGENT VEHICLES has been established and 10 papers published from 2016–2020 have been selected [5]. The Call for Nomination of 2021–2022 Best George N. Saridis Best Paper Award is attached in the end of this editorial after ***Scanning the Issue***.
- Starting from this issue, TIV is a monthly publication, with a page budget of 4800, 533% of 2022, and 112% of the total page count since 2015 [1], [3].

Note that starting from this issue, we will enforce the following policies:

- Authors must fill "Conflict of Interest in Step 6 of the Submission: Details & Comments, if one of the co-authors is a member of the Editorial Board of IEEE TIV.
- For any individual to be listed as a co-author, it is mandatory that the primary email address is an institutional one.
- ORCIDs enable accurate attribution and improved discoverability of an author's published work. All IEEE journals require an Open Researcher and Contributor ID (ORCID) for all authors, IEEE TIV is no exception.
- We encourage reviewers to recommend proper citations of proper papers to authors, however, reviewers must inform the Associate Editor in charge if any of his/her publications are suggested for citation in his/her review reports. The AE must also inform the Senior Editor and the Editor-in-Chief about the citation recommendation. Otherwise, the manuscript would be moved to a special committee for the special evaluation.

With an estimated 2300 manuscripts for 2023 submission, we need more effort to keep up with what we had done so far in order to accommodate the rapid growth in the field of intelligent vehicles. We need to be smart in our operations, become active in serving and promoting our professional communities, especially our authors and contributors, and do our best to make our society believe intelligent vehicles are critical for our future. We need concrete steps for such goals, and for this purpose, an editorial meeting will be held before the end of February. I will come back to you on our plan after this meeting.

SCANNING THE ISSUE

Stochastic Model Predictive Control With a Safety Guarantee for Automated Driving

T. Brüdigam, M. Olbrich, D. Wollherr and M. Leibold

Automated vehicles require efficient and safe planning in uncertain environments. We propose a stochastic model predictive control (SMPC) algorithm with a safety guarantee for automated vehicles. A backup trajectory, based on reachable sets, is used to overwrite the SMPC input if necessary for safety. Recursive feasibility of the algorithm is proved. Highway simulations show the effectiveness of the proposed method.

Driver Anomaly Quantification for Intelligent Vehicles: A Contrastive Learning Approach With Representation Clustering

Z. Hu, Y. Xing, W. Gu, D. Cao and C. Lv

A novel driver anomaly quantification approach is presented. The contrastive learning method is leveraged to quantify the anomalies with a continuous variable rather than the

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classification. A novel clustering supervised contrastive loss is proposed to optimize the distribution of the extracted representation vectors. The experiments demonstrate the proposed approach is more accurate and robust than existing ones in terms of recognition and quantification of unknown abnormal activities. The demonstration can be found on the YouTube website.

MTANet: Multitask-Aware Network With Hierarchical Multimodal Fusion for RGB-T Urban Scene Understanding

W. Zhou, S. Dong, J. Lei and L. Yu

Understanding urban scenes is a fundamental ability requirement for assisted driving and autonomous vehicles. To improve the fusion of multimodal features and the segmentation accuracy, we propose a multitask-aware network (MTANet) with hierarchical multimodal fusion (multiscale fusion strategy) for RGB-T urban scene understanding. Extensive experiments were performed on two benchmark RGB-T datasets to verify the improved performance of the proposed MTANet compared with state-of-the-art methods.

Estimation of Driver's Gaze Region from Head Position and Orientation Using Probabilistic Confidence Regions

S. Jha and C. Busso

Visual attention is one of the most important aspects related to driver distraction. Predicting the driver's visual attention can help a vehicle understand the awareness state of the driver, providing important contextual information. While estimating the exact gaze direction is difficult in the car environment, a coarse estimation of the visual attention can be obtained by tracking the head pose. Since the relation between head pose and gaze direction is not one-to-one, this paper proposes a formulation based on probabilistic models to create salient regions describing the drivers visual attention. The area of the predicted region is small when the model has high confidence, which is directly learned from the data. We use Gaussian process regression (GPR) to implement the framework, comparing the performance with different regression formulations such as linear regression and neural network based methods.

AI-TP: Attention-based Interaction-Aware Trajectory Prediction for Autonomous Driving

K. Zhang, L. Zhao, C. Dong, L. Wu and L. Zheng

This study proposes an Attention-based Interaction-aware Trajectory Prediction (AI-TP) for traffic agents around the autonomous vehicle. Considering traffic scenes as graphs, the AI-TP model uses Graph Attention Networks (GAT) to describe the social interactions of traffic agents and Convolutional Gated Recurrent Units (ConvGRU) to carry out the prediction. Numerical results demonstrate that the AI-TP model requires less inference time and achieves better prediction accuracy.

Deep Instance Segmentation With Automotive Radar Detection Points

J. Liu, W. Xiong, L. Bai, Y. Xia, T. Huang, W. Ouyang, B. Zhu

This paper proposes a method based on the clustering of estimated semantic information to address the challenges of radar detection points instance segmentation: sparsity and practicality. An added head with modified loss is added to the PointNet++ backbone to estimate the offset in latent space to improve the clustering accuracy. In addition, a further enhanced model is proposed by incorporating the visual MLP. Experimental results demonstrate the effectiveness of the model and show its feasibility for real-world application.

Reducing Waiting Times at Charging Stations With Adaptive Electric Vehicle Route Planning

S. Schoenberg and F. Dressler

This paper proposes a stategy to find optimal routes for electric vehicles on long-distance trips that require charge stops. The adaptive charging and routing strategy considers driving, charging, as well as waiting times at charging stations. To reduce such waiting times, the vehicles coordinate their charge stops with each other using a central charging stations database (CSDB). Simulation experiments show that our algorithm reduces average waiting times at charging stations by up to 97%.

Path Planning based on Deep Reinforcement Learning for Autonomous Underwater Vehicles Under Ocean Current Disturbance

Z. Chu, F. Wang, T. Lei and C. Luo

The path planning issue of the underactuated autonomous underwater vehicle (AUV) under ocean current disturbance is discussed. In order to improve the AUVs path planning capability in the unknown environments, a deep reinforcement learning (DRL) path planning method based on double deep Q Network (DDQN) is proposed. The path planning ability of the proposed method in the unknown environments is validated by simulation analysis.

Fault-Tolerant Cooperative Driving at Signal-Free Intersections

H. Pei, J. Zhang, Y. Zhang, X. Pei, S. Feng and L. Li

This paper proposes a fault-tolerant cooperative driving strategy for signal-free intersections by modeling potential vehicle failure types, aiming to keep a good balance between traffic safety and efficiency. Notably, a rule-based fault-tolerant model

is constructed to mitigate the threat of potential vehicle failures to traffic safety and efficiency, and to effectively recover the cooperative driving system after vehicle failures occur.

Deep Neural Networks With Koopman Operators for Modeling and Control of Autonomous Vehicles

Y. Xiao, X. Zhang, X. Xu, X. Liu and J. Liu

This paper proposes a data-driven vehicle modeling approach based on deep neural networks with an interpretable Koopman operator. The advantage of using the Koopman operator is to represent the nonlinear dynamics in a linear lifted feature space. Furthermore, a data-driven model predictive controller with the learned Koopman model is designed for velocity profile tracking control of autonomous vehicles. The simulation results show that the proposed method has better modeling and control performance than prior approaches.

An Enabling Trajectory Planning Scheme for Lane Change Collision Avoidance on Highways

Z. Zhang, L. Zhang, J. Deng, M. Wang, Z. Wang and D. Cao

A hierarchical three-layer trajectory planning framework for lane changing maneuver is proposed in this paper to realize real-time collision avoidance under complex driving conditions. When the motion states of the surrounding vehicles change abruptly during the lane changing process of the host vehicle, the collision-free trajectory cluster will be generated to enhance vehicle safety based on the speed and the path re-planning mechanism with guaranteed real-time performance.

Robustly String Stable Longitudinal Control for Vehicle Platoons Under Communication Failures: A Generalized Extended State Observer-Based Control Approach

Q. Chen, Y. Zhou, S. Ahn, J. Xia, S. Li and S. Li

A generalized extended state observer-based control (GESOBC) law is contrived to address the robustly string stable longitudinal control of vehicle platoons with external disturbances, parameter uncertainties, and communication failures. Furthermore, it is proved that the proposed GESOBC method can guarantee the exponentially bounded stability of the individual vehicle and the input to state string stability of the whole vehicle platoon. Finally, numerical simulations are conducted to demonstrate the effectiveness and feasibility of the proposed method.

Byzantine-Fault-Tolerant Consensus via Reinforcement Learning for Permissioned Blockchain-Empowered V2X Network

S. Kim and A. Ibrahim

Permissioned blockchains recently garnered particular attention thanks to their improved scalability. One representative example is the Hyperledger Fabric. Due to its unique execute-order procedure, there is a critical need to select an optimal number of peers. There is a tradeoff in the number of peers: a too large number will degrade scalability while a too small number will make the network vulnerable to faulty nodes. This paper proposes a mechanism for selecting an optimal set of peers based on reinforcement learning (RL).

Robust Lane Change Decision Making for Autonomous Vehicles: An Observation Adversarial Reinforcement Learning Approach

X. He, H. Yang, Z. Hu and C. Lv

An observation adversarial reinforcement learning approach is proposed for robust lane change decision making of autonomous vehicles.

A constrained observation-robust MDP is presented to model decision making behaviors under policy constraints and observation uncertainties. Meanwhile, a black-box attack technique is implemented to approximate the optimal adversarial observation perturbations. Furthermore, a constrained observation-robust actor-critic algorithm is advanced to solve the robust optimal policies. Finally, the results demonstrate that our method can enhance the performance while improving the robustness.

Uncertainty-Aware Model-Based Reinforcement Learning: Methodology and Application in Autonomous Driving

J. Wu, Z. Huang and C. Lv

To further improve learning efficiency and performance of reinforcement learning (RL), a novel uncertainty-aware model-based RL method is proposed and validated in autonomous driving scenarios in this paper. Validation results suggest that the proposed method outperforms the model-free RL approach with respect to learning efficiency, and model-based approach with respect to both efficiency and performance, demonstrating its feasibility and effectiveness.

Longitudinal Vehicle Motion Prediction in Urban Settings With Traffic Light Interaction

M. Wegener, F. Herrmann, L. Koch, R. Savelsberg and J. Andert

Predictive cruise control functions designed to reduce the energy consumption of intelligent and automated vehicles require an accurate prediction of the upcoming traffic situation in general and the preceding vehicle in particular. This article presents the implementation of prediction models which do not rely on explicit information of the entire preceding vehicle queue. Using this assumption, prediction algorithms based on Conditional Linear Gauss (CLG) models and Deep Neural Network (DNN) were trained using real-world measurements in an urban setting. The training was conducted with 6.6 hours of driving data specifically collected for this study. The results show that both approaches can provide accurate estimates of a preceding vehicles motion. For the CLG models, a queue-estimation logic was implemented to improve the prediction accuracy.

Computation of Solution Spaces for Optimization-Based Trajectory Planning

L. Schäfer, S. Manzinger and M. Althoff

The nonlinear vehicle dynamics and the non-convexity of collision avoidance constraints pose major challenges for optimization-based trajectory planning of automated vehicles. We propose a novel approach that identifies collision-free driving corridors using set-based reachability analysis which we use to derive simplified collision avoidance constraints for continuous optimization. Combining our approach with existing motion planning methods based on nonlinear programming as well as (successive) convexification procedures enables efficient trajectory planning in arbitrary, cluttered traffic situations using vehicle models of different fidelity.

Formal Certification Methods for Automated Vehicle Safety Assessment

T. Zhao, E. Yurtsever, J. Paulson and G. Rizzoni

A survey of the automated vehicle (AV) safety verification, validation, and certification processes is provided. State-of-the-art formal safety techniques in AV applications are reviewed, with open questions and challenges listed. A unified scenario coverage framework is also proposed, allowing for sample-based or formal verification methods to achieve full scenario coverage.

Robust Localization for Intelligent Vehicles Based on Compressed Road Scene Map in Urban Environments

L. Li, M. Yang, H. Li, C. Wang and B. Wang

A robust localization method for intelligent vehicles based on the proposed compressed road scene map is presented in this work, aiming to solve the problem of large storage requirement of the map in large-scale areas, drift in the map matching process, noise and outliers in the point cloud. Different from previous works, the grid map is obtained by projecting the 3D grids onto the 'x-z' plane, which is called the compressed road scene map. For localization, a particle filter framework is adopted, where map matching relies on the normalized information distance.

Human-Like Decision Making and Motion Control for Smooth and Natural Car Following

C. Wei, E. Paschalidis, N. Merat, A. Solernou, F. Hajiseyedjavadi and R. Romano

Car-following is an important driving behaviour for intelligent vehicles and has a significant impact on traffic efficiency and traffic safety. In this study, a human-like car-following controller is developed based on the calibrated Wiedemann car-following model, which is a physio-psychological model. Three different scenarios are tested to evaluate the performance of the proposed controller, with enables the autonomous vehicle to have human-like and smooth trajectories at different phases and within different transition zones during autonomous car-following.

Connectivity-Based Delay-Tolerant Control of Automated Vehicles: Theory and Experiments

S. Beregi, S. S. Avedisov, C. R. He, D. Takacs and G. Orosz

Longitudinal and lateral controllers are designed to enable a connected automated vehicle to utilize V2X information from nearby connected human-driven vehicles. The linear stability of the controllers is investigated while taking into account the time delays in the feedback loops. Performance measures are introduced to quantify the stability properties of the controllers from experimental data. The robustness of the designed controllers against latency is demonstrated experimentally using real vehicles.

Learning Based Longitudinal Vehicle Platooning Threat Detection, Identification and Mitigation

E. Khanapuri, V. V. T. K. Chintalapati, R. Sharma and R. Gerdes

The security of connected systems, such as vehicle platoons, is critical to ensuring their proper operation and societal acceptance. In platooning, vehicles follow one another, keeping a safe inter-vehicle distance. Networked systems are prone to malicious attacks. An attacker can change controller settings to cause traffic jams and collisions. This paper focuses on developing learning-based methods to detect and identify vehicles under attack. We also propose a mitigation strategy to minimize the effects of such attacks.

A Mechanical System Inspired Microscopic Traffic Model: Modeling, Analysis, and Validation

M. R. Hajidavalloo, Z. Li, D. Chen, A. Louati, S. Feng and W. B. Qin

This paper develops a mass-spring-damper-clutch based car-following model that can naturally capture the car-following behavior of a rational driver and can characterize the impact of the following vehicle on the preceding vehicle. A new string stability criterion is defined for the multi-vehicle dynamics, and stability analysis is performed. An efficient online parameter identification algorithm is developed to estimate the driving-related model parameters. The proposed model and the parameter identification algorithm are validated on NGSIM and our own vehicle driving data.

Real-Time Optimization of Fuel-Consumption and Travel-Time of CAVs for Cooperative Intersection Crossing

Hadjigeorgiou and S. Timotheou

A novel real-time methodology is introduced to ensure safe and efficient coordination of Connected and Autonomous Vehicles (CAVs) crossing an unsignalized intersection. An intersection controller optimizes the acceleration profiles of approaching CAVs, based on a desired fuel consumption/travel time trade-off. Simulation results demonstrate the quality of the proposed methodology and highlight that small sacrifices in travel time, lead to substantial fuel savings. Finally, simultaneous

coordination of a set of CAVs yields significant performance benefits compared to decentralized control.

A Pareto Optimal Information Flow Topology for Control of Connected Autonomous Vehicles

Y. Yan, H. Du, D. He and W. Li

The paper begins by investigating the effect of different information flow topologies on the performance of connected autonomous vehicles. The paper then proposes a method for off-line searching for platoon's Pareto optimal information flow topology using a non-dominated sorting genetic algorithm. As a result, the platoon's overall performance is improved among three key performance indicators: tracking index, acceleration standard deviation, and fuel consumption.

Probabilistic Charging Power Forecast of EVCS: Reinforcement Learning Assisted Deep Learning Approach

Y. Li, S. He, Y. Li, L. Ge, S. Lou and Z. Zeng

A reinforcement learning assisted deep learning framework is proposed for probabilistic EVCS charging power forecasting to capture its uncertainties. The LSTM is used and trained to obtain the point forecast of EVCS charging power. A Markov decision process is employed to model the change of LSTM cell states, which is solved by our proposed AePPO algorithm based on reinforcement learning. The results and comparative analysis on the real EVCSs charging data verify the effectiveness and outperformance of our proposed framework.

Learning Visual Semantic Map-Matching for Loosely Multi-sensor Fusion Localization of Autonomous Vehicles

Z. Zhang, J. Zhao, C. Huang and L. Li

A multi-sensor fusion localization system is proposed. The novelty lies in using a supervised neural network to infer positions through semantic map-matching. The position estimates are loosely integrated with other onboard sensors by an invariant Kalman filter. The results validate the effectiveness and performance of both the map-matching network and the whole localization system.

A Tube-MPC Approach to Autonomous Multi-Vehicle Racing on High-Speed Ovals

Wischnewski, T. Herrmann, F. Werner and B. Lohmann

The paper proposes a combination of a high-level Tube-MPC with a set of fast low-level feedback controllers for the motion control of an autonomous racing vehicle. The concept is proven to work within the autonomous racing software stack developed by the team of the Technical University of Munich and achieved speeds of up to 270kph with a real-world vehicle at the Las Vegas Motor Speedway.

Parallel Learning-Based Steering Control for Autonomous Driving

F. Tian, Z. Li, F. Wang and L. Li

This paper proposes a parallel learning-based steering control method for autonomous driving. Under the parallel learning framework, an artificial system is built to explore training data efficiently, and a neural network-based feedforward planner is designed to plan steering actions. In addition, a simple enough feedback controller is used to improve the robustness by compensating for the unmodeled dynamics and external disturbance. Testing results validate that the proposed method can achieve better tracking accuracy, stability and computational efficiency.

Adaptive Motion Cueing Algorithm Using Optimized Fuzzy Control System for Motion Simulators

H. Asadi, T. Bellmann, S. Mohamed, C. P. Lim, A. Khosravi and S. Nahavandi

In this research, a new framework is designed and implemented by developing a set of novel washout filters using optimized fuzzy control systems to solve the drawbacks associated with the existing optimal MCAs of the motion simulators which can cause false motion cues and simulator sickness. As a pioneering framework, the optimized fuzzy logic controllers generate restitution signals for the washout filters based on the motion sensation error between the real vehicle and simulator divers as well as the platform's position in the workspace aiming to correct the filtered signals, reduce error, and generate realistic motions.

Cascade Learning for Driver Facial Monitoring

C. Gou, Y. Zhou, Y. Xiao, X. Wang and H. Yu

This paper proposes a unified cascade learning framework for driver facial monitoring. The introduced framework can exploit the coupling relationship of facial landmark locations and head pose, as well as the eye center locations and gaze directions. Experimental results demonstrate the utility of the proposed model.

A Less-Disturbed Ecological Driving Strategy for Connected and Automated Vehicles

J. Yang, D. Zhao, J. Jiang, J. Lan, B. Mason, D. Tian and L. Li

As there are huge uncertainties regarding future traffic conditions, this paper proposed a less-disturbed eco-driving strategy. The proposed strategy is formed using offline planning and online tracking, which are combined with average traffic speeds and overtaking maneuvers. The consideration of average speed makes the proposed eco-driving strategy have less disturbance to the traffic system. Therefore, it is more feasible to be applied in practical road transportation systems.

Haptic Assistive Control With Learning-Based Driver Intent Recognition for Semi-Autonomous Vehicles

C. Wang, F. Li, Y. Wang and J. R. Wagner

Semi-autonomous vehicles equipped with assistive control systems may experience degraded lateral behaviors when aggressive driver steering commands compete with high levels of autonomy. This challenge can be mitigated with effective operator intent recognition, which can configure automated systems in context-specific situations where the driver intends to perform a steering maneuver. In this article, an ensemble learning-based driver intent recognition strategy has been developed. A nonlinear model predictive control algorithm has been designed and implemented to generate haptic feedback for lateral vehicle guidance, assisting the drivers in accomplishing their intended action.

Pedestrian Behavior in Shared Spaces With Autonomous Vehicles: An Integrated Framework and Review

M. Predhumeau, A. Spalanzani and J. Dugdale

This article proposes an integrative framework to analyze pedestrian behavior in shared spaces with autonomous vehicles. Following the "perception-cognition-action" cycle, the proposed framework is used to review and synthesize current knowledge on pedestrian behavior in urban shared spaces. The review reveals that autonomous vehicles must consider the variety of pedestrians behaviors and follow socially compliant rules in order to be understood and accepted by pedestrians. Perspectives for AVs in shared spaces and research directions are also identified.

Fixed-Time Path-Following Control of an Autonomous Vehicle With Path-Dependent Performance and Feasibility Constraints

X. Jin, S.-L. Dai and J. Liang

In this work, we study path-dependent constraint requirements, which explicitly depend on the path parameter, instead of depending on the time variable directly. A modified version of the universal barrier function is used in the analysis of path-dependent constraint requirements. We show that the vehicle's line-of-sight distance and angle error terms can converge into small sets near the equilibrium with a fixed-time convergence rate, while the path-dependent constraint requirements are satisfied at all time.

Design of a Switching Nonlinear MPC for Emission Aware Ecodriving

G. P. Incremona and P. Polterauer

A novel switching Nonlinear Model Predictive Control is proposed as solution of emission aware ecodriving. Specifically, the proposal is capable to deal with curvy roads, combining road grade and curvature look ahead to keep the driving comfortable, while also considering pollutant emissions. Its feasibility and potential are shown by means of simulation case studies based on real world test cases, a validated vehicle model, and measured road topology, demonstrating that it is viable option for future ecodriving systems.

Situation-Aware Environment Perception Using a Multi-Layer Attention Map

M. Henning, J. C. Muller, F. Gies, M. Buchholz and K. Dietmayer

The paper proposes a flexible and scalable concept for situation-aware environment perception that is relevant for various intelligent vehicle systems. The system's context is evaluated to identify relevant areas within its environment. Computational resources are allocated towards processing these areas within the data, employing only a subset of available functional modules. The proposed concept is applied to an automated test vehicle, verifying the concept's applicability and effectiveness.

CD-DB: A Data Storage Model for Cooperative Driving

H. Yu, C. Chang, S. Li and L. Li

As a backbone of cooperative driving, road-side units receive massive data from the encountered vehicles via wireless communication and schedule the movements of vehicles. This paper proposed a CD-DB storage model to achieve high write/read performance for supporting cooperative driving applications. We analyze the data structure and algorithms dedicated for cooperative driving applications. Testing results indicate that the proposed data storage model can handle real cooperative driving scenarios and yield significantly better performance than currently widely used relation databases.

Tactical Decisions for Lane Changes or Lane Following: Assessment of Automated Driving Styles Under Real-World Conditions

J. Ossig, S. Cramer, A. Eckl and K. Bengler

This article focuses on the assessment of automated driving styles with two different lane change frequencies and the potential influence of three non-driving related tasks. A driving study ($N = 60$) was conducted on a German highway under real-world conditions using a vehicle with a prototype automation system. Here, the driving style with a low lane change frequency resulted in significantly more discomfort than the driving style with a high lane change frequency.

3D Multi-Object Tracking With Adaptive Cubature Kalman Filter for Autonomous Driving

G. Guo and S. Zhao

A point cloud-based 3D multi-object tracking framework is presented for self-driving systems with inherent uncertainty and

unknown biases. An adaptive cubature Kalman filter is given based on a constant turn rate and velocity motion model. A new affinity model is introduced to evaluate the similarity between trajectories and candidate detections for accurate and reliable data association, which is formulated as a bipartite matching problem. The advantages of the framework in comparison with the baseline methods are evaluated using KITTI 3D multi-object tracking dataset.

Relationship Extraction Method for Urban Rail Transit Operation Emergencies Records

G. Zhu, X. Huang, R. Yang and R. Sun

The records of urban rail transit operation emergencies contain information about the relationship between events, which can provide auxiliary support for emergency decision-making. In to obtain the relationship between events from the records, this paper proposes an approach to extract the event relations from the records of urban rail transit operation emergencies by using natural language processing technology. The experimental results illustrate the proposed approach can accurately extract the relationship between events, which provide an effective reference for emergency decision-making.

Automatic Vehicle Following Under Safety, Comfort, and Road Geometry Constraints

M. Waqas and P. Ioannou

Automatic vehicle following and cruising under all road geometry characteristics and traffic conditions without putting the vehicle occupants or other vehicles in unsafe situations are fundamental for the success of autonomous vehicles. To ensure safety and driving comfort, the following challenges must be addressed: Effective detection of in-path objects, collision avoidance with objects not visible with exteroceptive sensors in high-noise environments and avoiding high accelerations. This paper presents a control design methodology for vehicle following systems that meets these challenges.

Fixed-Time Resilient Edge-Triggered Estimation and Control of Surface Vehicles for Cooperative Target Tracking Under Attacks

S. Gao, Z. Peng, L. Liu, D. Wang and Q.-L. Han

This paper is concerned with the cooperative target tracking of under-actuated unmanned surface vehicles with event-triggered communications subject to denial-of-service attacks. A fixed-time resilient cooperative edge-triggered estimation and control architecture is presented for achieving cooperative target tracking under denial-of-service attacks. By the proposed architecture, the desired formation by a fleet of unmanned surface vehicles can be obtained within a prescribed time under denial-of-service attacks. Moreover, the communication resources can be saved by checking the triggering conditions in different edge links.

End-to-End Autonomous Driving With Semantic Depth Cloud Mapping and Multi-Agent

Natan and J. Miura

An end-to-end model is presented to handle perception and control tasks for an autonomous vehicle. The perception module takes RGBD images to perform semantic segmentation and other vision tasks along with providing latent features. Together with velocity measurement and route location, these features are learned by the controller module to drive the vehicle properly in various environmental conditions with normal and adversarial scenarios. Evaluated in the point-to-point navigation task, the model achieves the best drivability compared to some recent models.

Data-Driven Modeling and Distributed Predictive Control of Mixed Vehicle Platoons

J. Zhan, Z. Ma and L. Zhang

A novel data-driven modeling method based on Koopman operator theory is established to represent the mixed vehicle platoon by a linear expression in a high-dimensional space, where the Koopman operator is approximated by using extended dynamic mode decomposition. Then a distributed MPC (DMPC) algorithm is proposed to address the mixed vehicle platoon control problem. Simulation results show that the proposed data-driven DMPC algorithm exhibits faster convergence speed than the nonlinear model based DMPC algorithm.

An Event-Triggered Scheme for State Estimation of Preceding Vehicles Under Connected Vehicle Environment

Y. Wang, Y. Yan, T. Shen, S. Bai, J. Hu, L. Xu, G. Yin

An event-triggered estimation framework by fusing an event-triggered mechanism with an embedded cubature Kalman filter based on a three-degree-of-freedom model is proposed for state estimation of preceding vehicles. Real-vehicle test results demonstrate that the proposed prediction approach can strike an effective balance between the communication rate and the estimation performance. The proposed method is not limited to estimating the preceding vehicle state, but can also be used for state prediction of surrounding vehicles. The proposed work can be applied to the safety control of intelligent connected vehicles, which can significantly improve vehicle safety.

Traffic Object Detection and Recognition Based on the Attentional Visual Field of Drivers

M. Shirpour, N. Khairdoost, M. Bauer and S. Beauchemin

This research focuses on detecting and recognizing traffic objects including traffic signs, road vehicles, pedestrians, and traffic lights inside and outside the attentional visual area of drivers. This approach uses the driver's 3D absolute coordinates of the gaze point obtained by the combined, cross-calibrated use of a front-view stereo imaging system and a non-contact 3D gaze

tracker. This framework inherits the advantage of deep neural networks (ResNet and Faster R-CNN) and classical machine learning models (multi-scale HOG-SVM).

Lightweight Semantic-Aided Localization With Spinning LiDAR Sensor

Y. Ren, B. Liu, R. Cheng and C. Agia

Autonomous driving demands robust and precise vehicle localization in complex environments with limited on-board computational resources. Incorporating reliable semantic information with localization algorithms can increase accuracy remarkably, however, the process of extracting semantic information from LiDAR point clouds and matching it to semantic maps is computationally intensive. Moreover, pure semantic localization cannot achieve the robustness requirements for safe self-driving as the neccessary quantity of semantic landmarks cannot be guaranteed under extreme conditions. In this paper, we present a lightweight semantic-aided localization method that improves upon traditional techniques in two ways. First, we propose a highly efficient pipeline to extract three semantic classes from a LiDAR scan. Second, instead of semantic 3D point cloud registration, map matching is performed through 2D key point matching. We then integrate these two functions into a dynamic semantic aided localization framework.

Joint Sensing and Processing Resource Allocation in Vehicular Ad-Hoc Networks

R. Chattopadhyay and C.-K. Tham

The performance of smart vehicle (SV) applications like autonomous driving and in-vehicle augmented reality based traffic information system depends on the Field of View (FoV) and the timely processing of the SVs sensor data. Vehicular networking (VN) technology can enhance the performance of these applications by enabling a SV to access the sensing and processing capabilities of other neighbouring SVs. The processing and storage capacity of a SV is limited compared to cloud servers and the communication link between two SVs is unreliable due to their mobility and the nature of wireless channels. Hence, developing efficient processing and sensing schemes for SVs and VNs can help in optimizing the performance of SV applications. In this paper, we propose Contextual Bandits (CB), Markov decision process (MDP) and deep Q-network (DQN) based sensing and processing schemes for VNs.

Vehicle Following on a Ring Road Under Safety Constraints: Role of Connectivity and Coordination

M. Pooladsanj, K. Savla and P. Ioannou'

We design a longitudinal vehicle controller and study a system of vehicles traveling on a ring road to understand the interplay of limited road space, speed, and safety. We show that, depending on the number of vehicles, either many different configurations at the speed limit, or a unique configuration at a lesser speed is possible for the vehicles to occupy the road in. The proposed controller can force the vehicles to converge to a desired configuration when central coordination exists.

Real-Time State of Charge Estimation of Lithium-Ion Batteries Using Optimized Random Forest Regression Algorithm

M. Lipu, M. Hannan, A. Hussaion, S. Ansari, S. Rahman, M. Saad and K. Muttaqi

Abstract-This paper presents an improved machine learning approach for the accurate and robust state of charge (SOC) in electric vehicle (EV) batteries using differential search optimized random forest regression (RFR) algorithm. The precise SOC estimation confirms the safety and reliability of EV. Nevertheless, SOC is influenced by numerous factors which cannot be measured directly. RFR is suitable for real-time SOC estimation due to its robustness to noise, overfitting issues and capacity to work with huge datasets. However, proper selection of RFR architecture and hyper-parameters combination remains a key issue to be explored. Hence, a differential search algorithm (DSA) is employed to search for the optimal values of trees and leaves in the RFR algorithm. DSA optimized RFR eliminates the utilization of the filter in data pre-processing steps and does not require a detailed understanding and knowledge about battery chemistry, rather only needs sensors to monitor battery voltage and current.

An Efficient Multi-task Network for Pedestrian Intrusion Detection

Z. Shi, S. He, J. Sun, T. Chen, J. Chen and H. Dong

With the development of intelligent surveillance, pedestrian intrusion detection has been widely applied in security, automatic driving and many other fields. In this paper, we propose a vision-based method, PIDNet and the advanced cross-PIDNet, to solve the intrusion detection in dynamic scenes. Our network adopts a dual-branch structure, which achieve a good balance between detection accuracy and speed due to efficient network design and network cross-association strategy. Meanwhile, the corresponding dataset and metrics are established to verify the feasibility of the method.

Sequential Convex Programming Methods for Real-Time Optimal Trajectory Planning in Autonomous Vehicle Racing

P. Scheffe, T. M. Henneken, M. Kloock and B. Alrifaee

A model predictive control (MPC) trajectory planner for autonomous vehicle racing is presented. This paper forms a convex approximation of the generally nonconvex trajectory optimization problem using sequential convex restriction (SCR). SCR guarantees that resulting solutions are feasible in the original, nonconvex optimization problem. The paper shows recursive

feasibility of solutions to the restricted optimization problem. Simulation results show that an MPC using SCR yields faster lap times than an MPC using a state-of-the-art convex approximation.

Hierarchical Interpretable Imitation Learning for End-to-End Autonomous Driving

S. Teng, L. Chen, Y. Ai, Y. Zhou, Z. Xuanyuan and X. Hu

End-to-end autonomous driving provides a simple and efficient framework for autonomous driving systems. In this paper, we construct a two-stage end-to-end autonomous driving model for complex urban scenarios, named HIIL (Hierarchical Interpretable Imitation Learning), which integrates interpretable BEV mask and steering angle to solve the problems.

Distributed Trajectory Optimization and Platooning of Vehicles to Guarantee Smooth Traffic Flow

G. Guo, D. Yang and R. Zhang

A distributed trajectory optimization and control problem for a collection of vehicles with a quadratic spacing policy are investigated. The methodology can guarantee the internal stability, string stability and traffic flow stability with ignorable turbulence of spacing and speed, as demonstrated by numerical simulations.

ATOP: An Attention-to-Optimization Approach for Automatic LiDAR-Camera Calibration via Cross-Modal Object Matching

Y. Sun, J. Li, Y. Wang, X. Xu, X. Yang and Z. Sun

To achieve automatic LiDAR-Camera calibration, a novel self-adaptive calibration approach named ATOP is proposed. Firstly, a cross-modal matching network is designed for producing 2D-3D object correspondences. Then, a cascaded-PSO optimization algorithm is designed to estimate the LiDAR-Camera relative poses. Experimental results on KITTI datasets demonstrate the superiority of our method.

Down-Sized Initialization for Optimization-Based Unstructured Trajectory Planning by Only Optimizing Critical Variables

Y. Guo, D. D. Yao, B. Li, H. Gao and L. Li

A fast and light-weighted initialization strategy is proposed for optimization-based unstructured trajectory planning. Its key idea is to seek the initial guess for critical variables that are deterministic in strictly satisfying inequalities with a small equation violation by solving two linear problems. Analysis and simulation results validate that the proposed initialization strategy can greatly facilitate the solution process of an optimization-based trajectory planner, thereby making the planner well outperform the prevalent competitors in autonomous driving.

Train-Centric Communication Based Autonomous Train Control System

H. Song, S. Gao, Y. Li, L. Liu and H. Dong

With the development of advanced sensors and control algorithms, the train intends to be equipped with a decision-making capability.The paper presents the structure and principle of an Autonomous Train Control System, and its potential operation scenarios and data flow logic are discussed. For engineering implementation, data prediction and edge-based information fusion algorithms are proposed to locate the train and estimate the dynamic train data, respectively. With the assistant of essential data processing ability, advanced train strategies can be implemented.

Differential Framework for Submeter-Accurate Vehicular Navigation With Cellular Signals

J. Khalife and Z. M. Kassas

A framework that could achieve submeter-level-accurate navigation with carrier phase differential measurements from cellular signals is developed. This framework is composed of a base and a rover making carrier phase measurements to cellular base transceiver stations. The framework is designed to guarantee that the rover's position error remains below a pre-defined threshold with a desired probability. Experimental results are presented of an unmanned aerial vehicle flying for 2.24 km, achieving an accuracy of 70.48 cm position root mean-squared error.

Distributed Coordinated Brake Control for Longitudinal Collision Avoidance of Multiple Connected Automated Vehicles

M. Hu, J. Li, Y. Bian, J. Wang, B. Xu and Y. Zhu

This paper proposes a distributed coordinated brake control algorithm for longitudinal collision avoidance of multiple CAVs. The centralized model predictive control problem that minimizes the total relative kinetic energy is firstly transformed into a quadratic programming problem and then separated into several sub-problems assigned to each CAV. The distributed optimization technique is introduced to solve the sub-problems in a distributed manner. Numerical simulation demonstrates the advantage of the proposed algorithm.

MLFNet: Multi-Level Fusion Network for Real-Time Semantic Segmentation of Autonomous Driving

J. Fan, F. Wang, H. Chu, X. Hu, Y. Cheng and B. Gao

This paper presents a well-deployed real-time semantic segmentation model named MLFNet, which has a better tradeoff between segmentation accuracy and speed on resource-constrained platforms. A double-branch encoder with semantic information and spatial details is designed, and the outputs from multiple modules are fully aggregated in our multi-level fusion decoder. The effectiveness of the proposed model is demonstrated based

on the experimental results on three public datasets and a vehicle platform.

Deep Learning Model Based CO_2 Emissions Prediction Using Vehicle Telematics Sensors Data

M. Singh and R. Dubey

Climate change is one of the greatest environmental hazards of today. Global warming, due to an increase in greenhouse gases has resulted in a continuous global increase in temperature. CO_2 continues to be the leading contributor to the greenhouse effect, with transport being a major CO_2 emission source. The majority of transport emissions are from road transport i.e., vehicular emissions. To control vehicular emission, first, an efficient emission monitoring system is required. Direct sensor installation in individual vehicles is neither cost-effective nor the data is easy to collect. In this paper, a scalable vehicle CO_2 emission prediction model is proposed which uses vehicle On-Board Diagnostics (OBD-II) port data. The proposed system uses real-time in-vehicle sensor data to estimate CO_2 emission of the vehicle using a Recurrent neural network (RNN) based Long short-term memory(LSTM) model. OBD-II dongles can be used to easily transmit the vehicles sensor data to the cloud, where the LSTM model uses this data to estimate the real-time CO_2 emission of the vehicle. The proposed model provides a scalable and efficient system to monitor emissions at a vehicular level. The proposed model has been evaluated using public OBD-II dataset as reported in literature.

Convex Vision-Based Negative Obstacle Detection Framework for Autonomous Vehicles

D. Dodge and M. Yilmaz

This study investigates accurate negative obstacle detection as well as depth estimations in convex optimization frameworks for superior real-time autonomous vehicle operations. The stereo camera vertical baseline configuration yields depth jumps in the disparity space image and studies geometrical analysis of potential occlusion regions to detect sudden disparity, angle profile, and intensity variations for potential negative obstacles and to estimate the internal depth of the detected obstacles. Results demonstrate the efficacy of the proposed framework to identify negative obstacle attributes.

Performance Analysis of Robust Cooperative Positioning based on GPS/UWB Integration for Connected Autonomous Vehicles

Y. Gao, H. Jing, M. Dianati, C. M. Hancock and X. Meng

A Robust Cooperative Positioning (RCP) scheme, based on the tight integration between GPS code pseudo-range and UWB ranging measurement using Robust Kalman Filter (RKF), is proposed for connected autonomous vehicles application. The proposed scheme is evaluated based on field experiments and a simulated dataset generated from the field experiment dataset. Results show that the proposed scheme effectively mitigates the effects of outlier measurements and enhances the positioning performance especially in low GPS visibility and GPS outages.

GNSS Repeater Based Differential Indoor Positioning With Multi-Epoch Measurements

X. Li

A carrier phase measurement based differential positioning method is proposed to improve the positioning accuracy with GNSS repeaters in indoor environments such as an underground parking lot and an enclosed depot. The carrier phases measured by using the repeated signals are differenced between repeaters and the differenced phase measurements at two consecutive epochs are combined to find the receiver position. This technique can achieve high positioning accuracy which is verified by close-to-reality simulations.

Thermal Infrared Single-Pedestrian Tracking for Advanced Driver Assistance System

M. Ding, W.-H. Chen and Y. Cao

This paper proposes a method of single-pedestrian tracking using thermal infrared cameras to meet the needs of driver assistance systems operating in nighttime and low-visibility conditions. Experimental results show that the proposed algorithm outperforms the existing 9 competing tracking algorithms and can be used in vehicle platforms as a module of DAS to improve the safe level of driving in nighttime.

Concept of an Automotive LiDAR Target Simulator for Direct Time-of-Flight LiDAR

S. Grollius, M. Ligges, J. Ruskowski and A. Grabmaier

Autonomous driving can make traffic safer by reducing human errors. Different sensor types in autonomous vehicles could introduce additional technical failures. We offer a target simulator testing LiDAR systems under automotive conditions. Therefore, data are projected over-the-air by laser signals on the LiDAR detector. This work presents a concept of a LiDAR target simulator with regards to LiDAR systems using the direct time-of-flight principle. We develope design considerations for a screen discussing undesired screen reflections, a curved screen form and the positioning of light sources on this screen. As one main solution, we introduce a concept of an antireflective screen. For the scenario simulation, we derive a model delivering the required optical power representing a simulated target, which is combined with the simulated time-of-flight. Considering no prior knowledge of the LiDAR system under test, we discuss the required calibration data and timing resolution.

Utilizing Human Social Norms for Multimodal Trajectory Forecasting via Group-Based Forecasting Module

H. Minoura, T. Hirakawa, Y. Sugano, T. Yamashita and H. Fujiyoshi

Trajectory forecasting to generate plausible pedestrian trajectories in crowded scenes requires an understanding of human-human social interactions. This paper introduces a group-based forecasting module for modeling inter- and intra-group interactions to enable an understanding of the social norm of humans for trajectory forecasting. In addition, group-based forecasting module takes the trajectory predicted by another prospection module as input to consider potential interactions with other groups in the future. Our network can predict plausible social trajectories by introducing two forecasting modules.

Mixed-Integer Motion Planning on German Roads Within the Apollo Driving Stack

T. Kessler, K. Esterle and A. Knoll

Most motion planning algorithms from research are only assessed in simulation. Our work contributes methodology and implementation for integrating a novel mixed-integer optimization-based planning algorithm in the open-source driving stack Apollo and assesses its real-time capability in theory and practice. We further discuss the necessary modifications to the Apollo stack for deployment on a different vehicle and present real-world driving experiments on a public road showing smoothness and robustness alongside a detailed experience report.

Structured Learning of Safety Guarantees for the Control of Uncertain Dynamical Systems

M.-A. Beaudoin and B. Boulet

The article proposes the safe uncertainty-learning principle, which complements learning-based control methods for uncertain dynamical systems with state constraints. It can be used to evaluate whether a control method preserves safety guarantees when learning modeling uncertainty. To demonstrate the principle, two example problems are solved with control barrier functions: a lane-change controller for an autonomous vehicle, and an adaptive cruise controller.

Localization Using Global Magnetic Positioning System for Automated Driving Bus and Intervals for Magnetic Markers

T. Ando, H. Mukumoto, K. Aoki, S. Okazaki, T. Nagao, H. Aoyama, M. Yamamoto and K. Nakano

A localization method based on the global magnetic positioning system (GMPS) using a magneto-impedance sensor is addressed. The aim of this study is to verify the stability, robustness, and high accuracy of the proposed method, and propose appropriate intervals for magnetic markers. The estimated positions and orientation are filtered through an extended Kalman filter as the vehicle passes the magnetic markers. Experimental results indicate that the maximum intervals to avoid lane deviation of vehicles depend on the reference path curvature.

Adaptive Multi-Lane Detection Based on Robust Instance Segmentation for Intelligent Vehicles

S. Yi, J. Li, X. Xu and Y. Shi

A novel anchor-free adaptive multi-lane detection approach named CenLaneNet is proposed for extracting lane instances without requiring lane category predefinition. By combining the lane center estimation with discriminative instance embedding, CenLaneNet achieves robust performance in challenging traffic scenarios. It can be extended to other instance segmentation tasks, e.g., vehicle segmentation.

A Shared Control Design for Steering Assistance System Considering Driver Behaviors

Y. Lu, J. Liang, G. Yin, L. Xu, J. Wu, J. Feng and F. Wang

This paper proposes a shared control approach to assist drivers in path-tracking and collision avoidance. A high-fidelity CarSim vehicle model embedded driver simulator is built to collect the driver data to quantify the driving performance. Then, A multi-constraints model predictive control is designed to follow the desired path, and simultaneously ensure the vehicle stability. The test results show that the path-tracking performance and vehicle stability can be guaranteed with less control effort.

Adaptive Cost Volume Representation for Unsupervised High-Resolution Stereo Matching

W. Tong, Z.-H. Sun, E. Wu, C. Wu and Z. Jiang

Learning-based stereo matching methods have produced remarkable results in recent years. However, typical supervised learning-based methods always suffer from the non-negligible problem of costly and time-consuming depth annotations. To mitigate this issue, in this work, a multi-stage unsupervised stereo matching method based on the cascaded Siamese network is proposed. To obtain a better performance on depth annotations, the improvements of this work are as follows. Firstly, sparse costs are constructed to predict the coarse disparity, and an adaptive sampling strategy is developed to dynamically adjust the sampling interval and effectively narrow the disparity search range. The proposed cost sparse and sampling

strategy can certainly guarantee the accuracy of disparity estimation under the limited memory requirements. Then, geometric constraints with left and right semantic features are integrated into the loss function to learn the inherent matching correspondences. Next, information entropy of the probability volume is used to measure the quality of estimated disparity and designed as weighted guidance for the photometric loss. Finally, a pixel-wise disparity refinement module is designed to achieve high-resolution disparity estimation at the final stage.

High-Level Decision Making for Automated Highway Driving via Behavior Cloning

L. Wang, C. Fernandez and C. Stiller

We propose a behavior cloning concept for learning safe and interpretable high-level decisions from recorded trajectories of real traffic for highway driving. The output behavior is able to handle the intention uncertainty of surrounding agents, and provide human-like decisions in the sense of well-balanced behavior between efficiency, comfort, perceived safety, and politeness.

Rate-Splitting Multiple Access for UAV-Based RIS-Enabled Interference-Limited Vehicular Communication System

Bansal, N. Agrawal and K. Singh

This work focuses on the performance evaluation of rate-splitting multiple access (RSMA) scheme for reconfigurable intelligent surface (RIS) aided air-to-ground multi-user vehicular communication network with the existence of multiple co-channel interferers. For the complete flight time of an unmanned aerial vehicle (UAV), the expression for average outage probability (AOP) is obtained. Moreover, the RSMA parameters in an arbitrary time slot of UAV flight time are optimized by minimizing the sum AOP of all the desired vehicles.

Applications and Services Using Vehicular Exteroceptive Sensors: A Survey

F. Molano Ortiz, M. Sammarco, L. H. M. K. Costa and M. Detyniecki

Currently, the trend of intelligent vehicles towards full autonomy is more tangible. Therefore, it is necessary to analyze both in-vehicle external sensing to monitor and audit the autonomous vehicle to increase human safety. This paper presents an overview of exteroceptive vehicle sensors and Off-the-Shelf (OTS) devices for intelligent vehicle applications. We organize these in four macro-areas: safety, driving behavior, road monitoring and navigation. Furthermore, a perspective of this research on vehicle safety macro-areas is given, early-stage solutions in various areas are identified, and potential challenges on each area are discussed.

Intelligent Amphibious Ground-Aerial Vehicles: State of the Art Technology for Future Transportation

X. Zhang, J. Huang, Y. Huang, K. Huang, L. Yang, Y. Han, L. Wang, H. Liu, J. Luo and J. Li

By analyzing the existing amphibious vehicles with flexible air-land mobility, this paper hightlights autonomous fly-driving functionality for the effective uses of amphibious vehicles in complex three-dimensional urban transportation systems. The authors review and summarize the key enabling technologies for intelligent flying-driving in existing amphibious vehicle designs, identify major technological barriers and propose potential solutions for future research and innovation. This paper aims to serve as a guide for research and development of intelligent amphibious vehicles for urban transportation toward the future.

Formal Development of Safe Automated Driving Using Differential Dynamic Logic

Y. Selvaraj, W. Ahrendt and M. Fabian

For commercial deployment of autonomous vehicles, their correct behavior in all scenarios is crucial. This paper demonstrates how mathematical models and proofs of different design variants of a decision and control module for an autonomous vehicle can provide convincing arguments for the safe and correct behavior of the controlled vehicle. The approach uses differential dynamic logic and the KeYmaera X interactive theorem prover for hybrid systems.

Call for Nomination of 2021-2022 Best George N. Saridis Best Paper Award

This is a call for nominations for The ***George N. Saridis Best Paper Award*** of the IEEE Transactions on Intelligent Vehicles.

Criteria:

All papers published in the IEEE Transactions on Intelligent Vehicles during the three calendar years preceding the year of the award. This call for nomination is to recognize the best regular papers, and survey papers published in the IEEE Transactions on Intelligent Vehicles between January 2019 and December 2022. The paper publication date is determined by the journal volume date (not the online publication date).

Selection:

For regular papers and survey papers, respectively, the following selection process will be conducted: (1) Top 15 most-cited papers according to Google Scholar, plus any papers solicited or nominated through the open call for Candidate Papers. (2) The Award Committee is responsible for organizing the review process to select 2-3 papers as the Finalist Papers from the Candidate

Papers. (3) The Award Committee will decide the Best Papers from the Finalist Papers.

Nomination:

For nominated papers, please send the nomination letter (no more than one page) to: ieeetivawards@gmail.com. The nomination letter should include the statement on why this paper is nominated, including its major contribution and significance.

Nomination Deadline: March 31, 2023.

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