Drive Like a Machine: Remembering the Origin and Goal of Autonomous Driving and Intelligent Vehicles

Dear All,

The first half of 2023 has passed, and I would like to share with you the following news:

- We have received 1767 manuscripts so far, exceeding the 1680 submitted manuscripts last year. Our current average number of submissions per day (SPD) is 9.39, a historic high, and the maximum number of SPD is 22 papers on June 30, 2023, a busy and happy day for me as the proud EiC of this young, vibrant, and promising academic publication [1], [2], [3], [4], [5], [6], [7], [8], [9].
- Our rapid development has forced me to assign more papers to our Associate and Senior Editors than I would like to. I promise you that I will speed up our effort and process to recruit more willing and able new AEs for TIV, and will change the situation as soon as possible. In any sense, we should congratulate ourselves on our current situation and your achievement. These accomplishments would not be achieved without the dedicated efforts and unwavering support of our editorial board members, I would like to take this opportunity to express my sincere gratitude to all of you.
- On June 28th, Clarivate released the 2022 Journal Citation Report. The impact factor (IF) of IEEE TIV has hit an impressive 8.2. This represents 63.7% from our first IF = 5.009 received last year.
- According to the Journal Citation Report Impact Factor List, IEEE TIV is ranked the 6th out of 40 publications in the subject category "Transportation Science & Technology", and the 24th of 145 publications in the category "Computer Science, Artificial Intelligence", and the 27th of 275 in the category "Engineering, Electrical & Electronic". Our periodical is classified as Q1 in all subject categories.
- The 2021 George N. Saridis Best Paper Award of the IEEE TRANSACTIONS ON INTELLIGENT VEHICLES [4], [5] has been announced by our TIV Best Paper Award Committee and 2 papers published between Jan. 2019 and Dec. 2022 have been selected. A detailed report will be provided in our next issue.

This issue includes 3 letters and 13 regular papers. All letters are the outcome of our decentralized and hybrid workshops (DHW): the first two letter results from our new DHW on Vehicle 5.0 and the last one from DHW for Scenarios Engineering for Smart Mobility (SE4SM).

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In one of our recent DHW, the issue of driving like a human was brought up again in our discussion for flexible robotics, parallel control, driving without traffic signals, cyber physical and social intelligence [10], [11], [12], [13], [14], [15], [16]. It has been my long-standing position that we must make future smart vehicles drive like a machine, or an intelligent machine in today's terms. To me, this is the original motivation and ultimate goal for autonomous driving and intelligent vehicles. In my opinion, asking future cars to drive like a human is just like asking old automobiles to drive like a horse more than 100 years ago, when the auto industry just started. Ridiculous? You bet! Otherwise, the safety and sustainability of intelligent technology for smart societies would be out of our grasp. I will elaborate on this important issue after Scanning the Issue.

I. Scanning the Issue

A. Communication and Letters

City 5.0: Towards Spatial Symbiotic Intelligence via DAO and Parallel Systems
Y. Lin, W. Hu, X. Chen, S. Li, and F.-Y. Wang

Logistics 5.0: From Intelligent Chains to Sustainable Ecosystems
J. Li, R. Qin, C. Olaverri-Monreal, R. Prodan, and F.-Y. Wang

OpenCDA-ROS: Enabling Seamless Integration of Simulation and Real-World Cooperative Driving Automation
Z. Zheng, X. Han, X. Xia, L. Gao, H. Xiang, and J. Ma

B. Regular Papers

Multi-Modal 3D Object Detection in Autonomous Driving: A Survey and Taxonomy

L. Wang, X. Zhang, Z. Song, J. Bi, G. Zhang, H. Wei, L. Tang, L. Yang, J. Li, C. Jia, and L. Zhao

This paper comprehensively reviews the most recent and advanced progress of multi-modal 3D object detection for autonomous driving. And we propose a taxonomy for multi-modal 3D object detection that exceeds the traditional early, middle, and late fusion split and consists of three aspects: representation, alignment, and fusion. We also comprehensively compare existing methods on several publicly available datasets and provide insightful analysis.

Vehicle Trajectory Prediction Method Driven by Raw Sensing Data for Intelligent Vehicles

Q. Meng, H. Guo, J. Li, Q. Dai, and J. Liu

Facing the demand of intelligent vehicle trajectory prediction, a novel multi-task joint framework driven by raw sensing data is proposed. A pyramid network structure integrating point cloud and HD map is designed to simultaneously perform vehicle detection, state assessment, tracking and trajectory prediction. In the parallel integrated task execution mode, the problems of error transmission and computing resource conflicts under the typical module serial structure are overcome.

Lane Change–Intention Inference and Trajectory Prediction of Surrounding Vehicles on Highways

J. Do, K. Han, and S. B. Choi

This paper proposes a multiple model-based adaptive estimator (MMAE) that infers the lane-change intention of the surrounding vehicles and predicts their trajectories. The path is generated in the form of a cubic spline curve using the Frenet coordinate system. Linearized recursive least-squares estimation (LRLSE) is used to predict the future trajectory. The MMAE applies LRLSEs to multiple paths, obtaining the mode probability for each path. The proposed method has high real-time performance, as verified by highD.

A Human-Machine Shared Control Framework Considering Time-Varying Driver Characteristics

Z. Fang, J. Wang, Z. Wang, J. Liang, Y. Liu, and G. Yin

A human-machine shared control framework considering driver's time-varying characteristics is proposed to improve the co-driving cooperation performance. The time-varying driver characteristics including driving intention and driving ability are proposed to describe the driver's involvement level and driver skills respectively, and used to design the human-machine authority allocation strategy. Experimental results show that the proposed control method can reduce human-machine conflicts and improve performances of driving comfort, path tracking, and vehicle stability for the co-driving vehicle.

Blockchain-Based Cooperative Computation Offloading and Secure Handover in Vehicular Edge Computing Networks

P. Lang, D. Tian, X. Duan, J. Zhou, Z. Sheng, and V. C. M. Leung

Facing the challenges of offloading decisions and data handover in vehicular edge computing networks, a blockchain-based cooperative computation offloading and secure handover framework is proposed to guarantee the efficiency and security of computation offloading. Moreover, the paper formulates a computation offloading optimization with blockchain-based handover and designs a decision algorithm to optimize the latency of vehicular computing tasks. Simulation results verify the superior performance of the algorithm with better data security and higher resource efficiency compared to other baselines.

Tire-Road Peak Adhesion Coefficient Estimation Based on Multisource Information Assessment

B. Leng, C. Tian, X. Hou, L. Xiong, W. Zhao, and Z. Yu

A Tire-Road Peak Adhesion Coefficient estimation framework based on multisource information assessment is creatively proposed in this paper, including the assessment of dynamic information the active enhancement method for dynamic information and the fusion estimation. The results of the simulation and vehicle test show that the road estimation error of the proposed method is within 0.035 and the convergence time is within 0.64 s. Compared with other existing estimators, the proposed framework can still perform competitively when the quality of multisource information is poor and achieve reliable TRPAC estimation.

Multi-Modal Sensor Fusion and Object Tracking for Autonomous Racing

P. Karle, F. Fent, S. Huch, F. Sauerbeck, and M. Lienkamp

A modular multi-modal sensor fusion and tracking method for high-speed autonomous racing is presented. The method is based on the Extended Kalman Filter (EKF) and is capable of fusing heterogeneous inputs. A novel delay compensation approach enables to reduce the influence of the perception software latency. It is developed without any labeled data and validated in high-speed real-world scenarios with position tracking residuals below 0.1 m. The related code is available open-source at https://github.com/TUMFTM/FusionTracking.

Fail-Safe Behavior and Motion Planning Incorporating Shared Control for Potential Driver Intervention

W. Xue, Z. Wang, R. Zheng, X. Mei, B. Yang, and K. Nakano

A fail-safe architecture is proposed for automated vehicle's behavior and motion planning module incorporating shared control in response to the driver intervention. The method estimates driver intention to cooperate on maneuver selection, and also distributes the driving authority in accordance with the minimal risk condition. We utilizes a critical scenario filter which improve the efficiency. The results show its effectiveness in terms of safety and assistance to the driver.

GA-LNS Optimization for Helicopter Rescue Dispatch

J. Cheng, Y. Gao, Y. Tian, and H. Liu

Aviation emergency rescue has become one of the most effective means for natural disaster relief due to its flexible and timely characteristics. In this paper, a multi-helicopter-multi-trip Aviation Rescue Routing Problem (ARRP) is analysed which covers

the whole rescue process. In addition, a time-domain procedural simulation model is built which can consider different helicopters, refueling or not, various resource locations, multiple disaster sites and other operation factors. Based on that, a Genetic Algorithm (GA) hybridized Large Neighborhood Search (LNS) algorithm (GA-LNS) is proposed for optimization. In ARRP, single search algorithm may lead to the local optimum due to complexity. In contrast, the distance greedy strategy and the load ratio strategy are combined in GA-LNS which can fix the local optimum problem.

Layered Time-Delay Robust Control Strategy for Yaw Stability of SbW Vehicles

B. Zhang, W. Zhao, C. Wang, and Y. Lian

A layered time-delay robust control strategy (LTDRCS) consisting an upper and a lower controller is proposed to deal with the impact of CAN time delay (TD) on vehicle stability. Specifically, a novel Lyapunov-Krasovskii (L-K) TD H∞controller is designed as the lower controller to reduce tracking error by an L-K function and an H∞ norm constraint. As for the upper controller, a novel terminal sliding mode controller (NTSMC) is established to control the yaw rate index.

Adaptive Bioinspired Preview Suspension Control With Constrained Velocity Planning for Autonomous Vehicles

T. Huang, J. Wang, and H. Pan

Autonomous vehicles equipped with numerous advanced sensors are capable of obtaining road preview information, creating new opportunities for vehicle suspension systems. This paper proposes a novel preview suspension control method from adaptive nonlinear control perspectives with less computational burden and is more realistic, unlike optimization-based works or existing linear state-space models-based results that neglected nonlinear terms. The X-shaped bio-inspired dynamics derived from animal or insect skeleton structures are introduced to reduce energy consumption by utilizing beneficial geometrical nonlinearities. Meanwhile, the optimal velocity planning approach is investigated to balance vehicle passage time, vibration suppression, and longitudinal comfort by solving a multi-objective optimization problem with the aid of road preview information. Moreover, acceleration constraint reduces the search space and computing requirements, while ensuring planned velocity optimality. Simulation and experiment results are provided to demonstrate the effectiveness and advantages of the constructed energy-saving adaptive preview control framework with constrained velocity planning.

Object-Level Semantic and Velocity Feedback for Dynamic Occupancy Grids

V. Jiménez, J. Godoy, A. Artuñedo, and J. Villagra

LiDAR-based frameworks that combine occupancy grids and object-level tracking are popular approaches for the estimation of the surrounding environment in autonomous driving applications. This paper proposes a novel backchannel from the object-level module to the grid-level module, enabling enhanced dynamic estimation and object classification at the cell level. The evaluation is conducted using real sensor data in various urban scenarios.

Interpretable Classifiers Based on Time-Series Motifs for Lane Change Prediction

K. Klein, O. D. Candido, and W. Utschick

In this paper, we address the problem of using non-interpretable Machine Learning (ML) algorithms in safety critical applications, especially automated driving functions. In order to understand wrong decisions, we want to interpret an ML algorithm's decision making. To this end, we use motif discovery—a data mining method—to obtain time-series sub-sequences representing typical driving behavior. On top of this, we propose an alternative to non-interpretable ML algorithms with an interpretable method: a Mixture of Experts classifier based on motifs.

II. Drive Like a Machine or Human?

Yes, it had always been my dream of designing intelligent vehicles that would drive autonomously like a human, until the turn of the 21st century. After two decades of research and development in autonomous driving, I started to doubt my initial objective, and by the middle of 2000s, I have convinced myself that we should and must design intelligent vehicles that would drive like a machine, instead of a human.

I understand that this is an anti-mainstream thinking, and the reason for my changed heart is not the lack of confidence in the intelligent vehicle technology, but the acceptance of the fact that our human driving behaviors are incapable of collaborating with intelligent vehicles for a safe and sustainable mobility which is required and compatible with our future lifestyle in smart societies.

To put it simply, the safety and sustainability demand and requirement of future mobility are beyond the capacity of our human psychology and physiology, just like that of modern mobility are beyond the capacity of horses' behaviors. We had already removed horses from our roads and highways in order to maintain a safe and effective modern lifestyle, we must remove human drivers from our future roads and highways, if we still use those labels, in order to maintain a safe and sustainable lifestyle in a smart society, be both effective and efficient, and do the right things in the right way. Therefore, intelligent vehicles should drive like a machine, and make human riders, not human drivers, safe and comfortable.

Remember the "Red Flag Acts" or the Locomotive Acts of Parliament in the United Kingdom during the beginning of automobile industry in the latter part of the 19th century? For example, the 1865 act required all road locomotives, including automobiles, to move no faster than 2 mph (3.2 km/h) on the urban roads or 4 mph (6.4 km/h) on the country roads, and in addition, a person wavering a red flag to warn pedestrian. As

a matter of fact, a horse-drawn carriage travels at an average speed of 2–4 mph, so Red Flag Acts had actually mandated that an automobile drives like a horse draws a wagon, quite similar to our demand today that a smart computer drives an intelligent vehicle like a human-driven car moves. Sound ridiculous?

The reason is simple: automobiles driving like horses is not efficient, automobiles driving at their designated speed along with horses is not safe, since horses would be scared by the speed of automobiles and their coexistence is beyond horses' biological capacity.

Nowadays you can't see any horse and horse-drawn carriage on the roads except standing or loaded on livestock trucks. Before, horses and horse-drawn carriages were common household assets, and now only the superrich could afford them.

In the future, I believe you would be less likely to see human-driven vehicles on roads except parking on automated or autonomous trucks. Today, cars are average household assets, and only the superrich could afford them in the future.

The reason is very simple too: intelligent vehicles driving like human-driven cars is not efficient, intelligent vehicles driving at their designated speed along with humans is not safe, since human drivers would be scared by the speed of intelligent vehicles and their coexistence is beyond human drivers' biological capacity.

This also reminds me of The Great Horse Manure Crisis of 1894. Georg Hegel famously claimed, "The only thing that we learn from history is that we learn nothing from history." If you have time, please go back and review this interesting story, and learning some lesion from this crisis.

I must tell this: many research problems for intelligent vehicles we are concerning and consuming our times and energies are actually "Horse Manure Problems" for our future smart cars in our smart societies.

III. Call for Participation: Decentralized Hybrid Workshops

At IEEE TIV we will continue to organize decentralized and hybrid workshops or symposia (DHW or DHS) on various issues in ITS and IVs.

Welcome to participate in our investigations on-line or off-line. Our discussions will be summarized and reported as perspectives, letters, or regular papers at IEEE TIV. The following DHWs have been organized so far:

1) Verification and Validation for IVs (V&V4IV)
2) Autonomous Mining (AM)
3) Ethics, Responsibility, and Sustainability (ERS)
4) Intelligent Vehicles for Education (IV4E)
5) Data Science for Intelligent Vehicles (DSiV)
6) Vehicle 5.0 (V5)
7) Scenarios Engineering for Smart Mobility (SE4SM)

Any suggestions or proposals for future topics of DHW/DHS are greatly appreciated. Looking forward to having you in IEEE TIV DHW/DHS.

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References

[1] F.-Y. Wang, "MetaVehicles in the metaverse: Moving to a new phase for intelligent vehicles and smart mobility," *IEEE Trans. Intell. Veh.*, vol. 7, no. 1, pp. 1–5, Mar. 2022.
[2] F.-Y. Wang, "The state of IEEE transactions on intelligent vehicles: From passive publication to active and smart exchange and dissemination," *IEEE Trans. Intell. Veh.*, vol. 7, no. 2, pp. 157–163, Jun. 2022.
[3] F.-Y. Wang, J. Ibanez-Guzman, and Y. Lv, "Call for V&VIV: Verification and validation of intelligent vehicles," *IEEE Trans. Intell. Veh.*, vol. 7, no. 3, pp. 401–406, Sep. 2022.
[4] F.-Y. Wang, "The milestones of IEEE TIV: The best associate editors and George N. Saridis best papers awards," *IEEE Trans. Intell. Veh.*, vol. 7, no. 4, pp. 801–803, Dec. 2022.
[5] F.-Y. Wang, "A new phase of IEEE transactions on intelligent vehicles: Being smart, becoming active, and believing intelligent vehicles," *IEEE Trans. Intell. Veh.*, vol. 8, no. 1, pp. 3–15, Jan. 2023.
[6] F.-Y. Wang, J. Hu, and J. Lai, "Testing intelligence: Accelerating the verification and validation of intelligent vehicles," *IEEE Trans. Intell. Veh.*, vol. 8, no. 1, pp. 1003–1016, Feb. 2023.
[7] F.-Y. Wang, "Linguistic intelligence for intelligent vehicles: ChatGPT and future logistics and mobility," *IEEE Trans. Intell. Veh.*, vol. 8, no. 3, pp. 2011–2019, Mar. 2023.
[8] Z. Wang, C. Lv, and F.-Y. Wang, "A new era of intelligent vehicles and intelligent transportation systems: Digital twins and parallel intelligence," *IEEE Trans. Intell. Veh.*, vol. 8, no. 4, pp. 2011–2019, Apr. 2023.
[9] L. Xuan and F.-Y. Wang, "Scenarios engineering: Enabling trustworthy and effective AI for autonomous vehicles," *IEEE Trans. Intell. Veh.*, vol. 8, no. 5, pp. 3205–3210, May 2023.
[10] F.-Y. Wang and Y. Gao, "*Advanced Studies of Flexible Robotic Manipulators: Modeling, Design, Control and Applications*," vol. 4.Singapore: *World Scientific*, Aug. 2003.
[11] Q. Wei, H. Li, and F.-Y. Wang, "Parallel control for continuous-time linear systems: A case study," *IEEE/CAA J. Automatica Sinica*, vol. 7, no. 4, pp. 919–928, Jul. 2020.
[12] L. Chen, X. Hu, W. Tian, H. Wang, D. Cao, and F.-Y. Wang, "Parallel planning: A new motion planning framework for autonomous driving," *IEEE/CAA J. Automatica Sinica*, vol. 6, no. 1, pp. 236–246, Jan. 2019.
[13] S. Teng et al., "Motion planning for autonomous driving: The state of the art and future perspectives," *IEEE Trans. Intell. Veh.*, vol. 8, no. 6, pp. 3692–3711, Jun. 2023.
[14] Y. Meng, L. Li, F.-Y. Wang, K. Li, and Z. Li, "Analysis of cooperative driving strategies for nonsignalized intersections," *IEEE Trans. Veh. Technol.*, vol. 67, no. 4, pp. 2900–2911, Apr. 2018.
[15] F.-Y. Wang, N.-N. Zheng, D. Cao, C. M. Martinez, L. Li, and T. Liu, "Parallel driving in CPSS: A unified approach for transport automation and vehicle intelligence," *IEEE/CAA J. Automatica Sinica*, vol. 4, no. 4, pp. 577–587, Dec. 2017.
[16] F.-Y. Wang, "Parallel intelligence in metaverses: Welcome to Hanoi!," *IEEE Intell. Syst.*, vol. 37, no. 1, pp. 16–20, Jan./Feb. 2022.