Call for V&VIV: Verification and Validation of Intelligent Vehicles

Dear All,

I am glad to share with you TIV's recent CiteScore: 10.9, an increase of 23.86% over last year's 8.8, ranked TIV the 4th among the 118 journals in the category of control and optimization, the 7th among the 102 journals in the category of vehicular engineering, and the top 11% among the 269 journals in the category of artificial intelligence. We also received our first JCR impact factor (IF), which is IF = 5.009, an excellent start for this young publication.

I would like to take this opportunity to congratulate our Authors, Reviewers, Associate Editors, Senior Editors, and Editorial Assistants for a job well done, and thank the great effort and enthusiastic dedication by all of you.

By now we have processed 951 submissions this year, almost 7 times of the total number of manuscripts received last year. I am glad to share with you the good news that our plan of monthly publication starting from the next year has been officially approved by both the Steering Committee and IEEE ITS Society. Looking forward to this new phase of TIV publication.

The Best Paper Award Committee of TIV has been established, with Dr. Danil Prokhorov as the founding chair. The Call for Nomination has been distributed in June. We are in the process of naming the Award as George N. Saridis Best Transactions Paper Award, in line with our Transactions on ITS.

We have completed the investigation, deliberation, and report to IEEE on our first plagiarism case. It took our emergency management committee (EMC) more than half a year in processing. I would like to thank all the committee members for their effort and hard work. I hope this is the last time that we have to face such issues. At TIV we will do our best to ensure the quality and professional integrity of our published papers.

Scenarios engineering and verification and validation (V&V) are critically important and urgently needed for designing, testing, and building intelligent vehicles [1], [2], [3], [4], [5], [6]. We will have a special issue on the validation & verification of intelligent vehicles, and details of its Call for Papers can be found after the Scanning the Issue.

I. Scanning the Issue

Review and Perspectives on Driver Digital Twin and Its Enabling Technologies for Intelligent Vehicles

Z. Hu, S. Lou, Y. Xing, X. Wang, D. Cao, and C. Lv

A novel concept of a driver digital twin (DDT) is proposed to aid in the development of a complete driving human cyber-physical system (H-CPS) that considers the proactivity and sensitivity of the driver. This study systematically illustrates it and outlines its key enabling aspects. The related technologies are comprehensively reviewed and discussed with a view to improving them by leveraging the DDT. In addition, the potential applications and unsettled challenges are considered.

A Parallel Teacher for Synthetic-to-Real Domain Adaptation of Traffic Object Detection

J. Wang, T. Shen, Y. Tian, Y. Wang, C. Gou, X. Wang, F. Yao, and C. Sun

The mismatch in domain distribution between synthetic datasets and real datasets hinders the application of the synthetic dataset in the actual vision system of intelligent vehicles. In this paper, we propose a novel synthetic-to-real domain adaptation method to settle the mismatch domain distribution from two aspects, i.e., data level and knowledge level. Comprehensive experiments on public virtual and real dataset pairs demonstrate the effectiveness of our proposed synthetic-to-real domain adaptation approach in object detection of traffic scenes.

Federated Vehicular Transformers and Their Federations: Privacy-Preserving Computing and Cooperation for Autonomous Driving

Y. Tian, J. Wang, Y. Wang, C. Zhao, F. Yao, and X. Wang

Towards privacy-preserving computing and cooperation in autonomous driving, this paper reviews recent progress of Transformers, federated learning as well as cooperative perception, and proposes a hierarchical structure of Transformers for intelligent vehicles which is comprised of Vehicular Transformers (VT), Federated Vehicular Transformers (FVT) and the Federation of Vehicular Transformers (FoVT) to exploit their potential in privacy-preserving collaboration.

Real-Time Scheduling of Autonomous Mining Trucks via Flow Allocation-Accelerated Tabu Search

X. Zhang, A. Guo, Y. Ai, B. Tian, and L. Chen

A scheduling model for autonomous mining trucks is presented to improve the transportation system energy efficiency through fusing truck trips and speed optimization. To solve the complicated scheduling model, an efficient tabu search algorithm is proposed. The algorithm accelerates the solution search process by generating better initial solutions with allocation model

Digital Object Identifier 10.1109/TIV.2022.3205050

guidance. A real-time scheduling system with strong robustness in dynamic environments is developed.

Verification and Validation Methods for Decision-Making and Planning of Automated Vehicles: A Review

Y. Ma, C. Sun, J. Chen, D. Cao, and L. Xiong

This paper aims to review various verification and validation (V&V) approaches for the decision-making and planning (DMP) system of automated vehicles and divides these approaches into three distinct categories: scenario-based testing, fault injection testing, and formal verification. Then, six criteria are proposed to compare and evaluate the V&V approaches. Finally, the DMP system is broken down into a hierarchy of modules, and the suitable approaches are matched to verify and validate each module aiming at their different functional requirements.

Human-Machine Shared Driving: Challenges and Future Directions

S. Ansari, F. Naghdy, and H. Du

Distraction and misjudgement can affect a driver, resulting in fatal accidents. In smart cars, sensing, actuation, advanced signal processing and machine learning are deployed to reduce the impact of driving errors by monitoring the state of the driver in real-time, detecting the mistakes, and deploying necessary actions to counteract them. Such strategies are collectively known as human-machine shared driving. The paper conducts an extensive review in this domain and provides challenges and future directions to develop fault-tolerant intelligent vehicles.

A Survey of Intelligent Tires for Tire-road Interaction Recognition

S. Yang, Y. Chen, R. Shi, R. Wang, Y. Cao, and J. Lu

The related research of intelligent tires about the sensing system and tire-road contact state estimation methods is reviewed. In this study, constructive strategies for improving the design of the intelligent tire sensing system is proposed to adapt to the extremely harsh working condition of tires, make full use of the installed sensors, and realize the continuous measurement of tire-road contact information. The specific requirements for the implementation process are also analyzed when applying intelligent tires to autonomous driving.

Millimeter Wave FMCW RADARs for Perception, Recognition and Localization in Automotive Applications: A Survey

A. Venon, Y. Dupuis, P. Vasseur, and P. Merriaux

The recent introduction of millimeter-wave RADARs has broadened their potential applications thanks to their improved angle, range, and velocity accuracy. This survey describes the working principles of mmWave FMCW RADARs as well as the separate ways to represent data, and applications adapted or developed for these sensors in perception, detection, and localization in the field of automotive applications. Current challenges and directions for future works are presented.

A Receding-Horizon Reinforcement Learning Approach for Kinodynamic Motion Planning of Autonomous Vehicles

X. Zhang, Y. Jiang, Y. Lu, and X. Xu

This paper proposes a receding-horizon reinforcement learning approach for kinodynamic motion planning of autonomous vehicles under inaccurate dynamics information and moving obstacles. The highlights are as follows. (i) The receding-horizon planning strategy can be learned both offline and online. (ii) The unknown vehicle dynamics are learned online. (iii) Potential field functions are constructed in actor and critic networks for collision avoidance. The convergence of the proposed approach is analyzed. Simulation results show the performance improvements to state-of-the-art approaches.

Video Action Recognition for Lane-change Classification and Prediction of Surrounding Vehicles

M. Biparva, D. Fernández-Llorca, R. I. Gonzalo, and J. K. Tsotsos

In highway scenarios, alert drivers anticipate early cut-in/cut-out maneuvers of surrounding vehicles using visual cues mainly. Autonomous vehicles must anticipate these situations at an early stage too. In this work, lane-change recognition and prediction tasks are posed as video action recognition problems by stacking visual cues from forward-looking cameras, studying context, observation, and prediction horizons. Different models are trained and evaluated using the PREVENTION dataset, reporting an accuracy higher than 90% in time horizons of between 1-2 seconds.

Resource-Efficient Platooning Control of Connected Automated Vehicles over VANETs

S. Xiao, X. Ge, Q.-L. Han, and Y. Zhang

This paper addresses the distributed cooperative longitudinal control problem of connected automated vehicles over resource-constrained vehicular ad-hoc networks. A new truly distributed resource-efficient platooning control approach is developed to enable platoon control design, event-triggered communication, diversiform spacing policies, and different inter-vehicle data exchange structures to be investigated comprehensively. One promising feature of the approach is its independence on the platoon scale or any global knowledge of the associated communication topology, and thus implementable in a scalable manner.

Communication-Constrained Active Suspension Control for Networked In-Wheel Motor-Driven Electric Vehicles with Dynamic Dampers

I. Ahmad, X. Ge, and Q.-L. Han

The co-design problem of resource-efficient communication and active suspension controller is addressed for in-wheel

motor-driven electric vehicles such that the limited in-vehicle network resources are occupied in an efficient manner, while simultaneously achieving the desired suspension system performance. A networked data transmission framework, incorporating a dynamic event-triggered communication mechanism and a logarithmic quantizer, is developed to accommodate the intermittent and digitalized packet-based transmissions as well as network-induced transmission delays over the in-vehicle controller area network.

Cross-Domain Object Detection for Autonomous Driving: A Stepwise Domain Adaptative YOLO Approach

G. Li, Z. Ji, X. Qu, R. Zhou, and D. Cao

This paper proposed a stepwise domain adaptive YOLO (S-DAYOLO) framework by constructing an auxiliary domain to bridge the domain gap and using a new domain adaptive YOLO (DAYOLO) for cross-domain object detection. DAYOLO based on YOLOv5s was designed with a category-consistent regularization module and adaptation modules for image-level and instance-level features to generate domain invariant representations. Our method was evaluated on five public datasets. Results demonstrated that our method could achieve superior performance in various domain shift scenarios.

Online and Predictive Warning System for Forced Lane Changes Using Risk Maps

T. Puphal, B. Flade, M. Probst, V. Willert, J. Adamy, and J. Eggert

The survival analysis of driving trajectories allows for holistic risk evaluations caused by collisions or curvy roads. In this paper, we therefore present Risk Maps (RM), an application of the survival analysis for online warning support in forced lane changes. RM efficiently probe future situations to determine risk-minimizing behaviors. Hereby, we focus on improving the uncertainty-awareness of the system. We conduct experiments with a real vehicle prototype, whereby we show successful lane change advice for gap and no-gap cases.

A General Safety-Certified Cooperative Control Architecture for Interconnected Intelligent Surface Vehicles with Applications to Vessel Train

W. Wu, Z. Peng, L. Liu, and D. Wang

This paper addresses cooperative control of interconnected intelligent surface vehicles subject to multiple static/dynamic obstacles. A general safety-certified cooperative control architecture capable of achieving various collective behaviors, such as consensus, containment, enclosing, and flocking, is proposed by using control Lyapunov functions and input-to-state safe high-order control barrier functions. In order to facilitate real-time implementations, a one-layer recurrent neural network is employed to solve the constrained quadratic optimization problem. An application to vessel train shows the effectiveness of the proposed architecture.

Towards Guaranteed Safety Assurance of Automated Driving Systems with Scenario Sampling: An Invariant Set Perspective

B. Weng, L. Capito, U. Ozguner, and K. Redmill

How many scenarios are sufficient to validate the safe operable design domain of an Automated Driving System (ADS)? Does a higher number of sampled scenarios guarantee a more accurate safety assessment of the ADS? Through interpreting the scenario sampling safety assurance problem from the set invariance perspective, a series of algorithms are presented to provably resolve the above problems. This remedies the gap between various empirical success of scenario-based ADS safety evaluation and the lack of analytical understandings.

A Survey on Trajectory-Prediction Methods for Autonomous Driving

Y. Huang, J. Du, Z. Yang, Z. Zhou, L. Zhang, and H. Chen

This paper provides a comprehensive and comparative review of trajectory-prediction methods proposed over the last two decades for autonomous driving. It starts with the problem formulation and algorithm classification. Then, the popular methods based on physics, classic machine learning, deep learning, and reinforcement learning are elaborately introduced and analyzed. Finally, this paper evaluates the performance of each kind of method and outlines potential research directions to guide readers in this field.

Classification Of Automotive Targets Using Inverse Synthetic Aperture Radar Images

N. Pandey and S. S. Ram

We provide a high fidelity electromagnetic simulation framework for generating realistic inverse synthetic aperture radar (ISAR) images of automotive targets at millimeter-wave frequency. The framework incorporates multiple target geometries along complex trajectories along with noise and clutter artifacts. The end-to-end open-source radar database and simulation framework are provided. We demonstrate that ISAR images are excellent features for automotive target classification using either traditional machine learning techniques or deep neural network-based transfer learning with above 90% classification accuracy.

GMR-RRT*: Sampling-Based Path Planning Using Gaussian Mixture Regression

J. Wang, T. Li, B. Li, and M. Q.-H. Meng

The motivation of this work is to achieve fast and high-quality path planning for the mobile robot. We propose GMR-RRT* based on the RRT and GMR schemes. The GMR-RRT*

algorithm learns planning experiences from human demonstrations. When the goal position is given, the GMR-RRT* obtains prior knowledge about navigating the environment and then quickly computes a high-quality path. The experimental results demonstrate that GMR-RRT* can significantly save time cost and memory usage on finding the initial and optimal solutions.

Increasing the Efficiency of Policy Learning for Autonomous Vehicles by Multi-Task Representation Learning

E. Kargar and V. Kyrki

This article proposes to learn a low-dimensional and rich latent representation of the environment by leveraging the knowledge of relevant semantic factors. To accomplish this, we train an encoder-decoder neural network to predict multiple application-relevant factors such as the trajectories of other agents and the ego car. Furthermore, we propose a hazard signal based on other vehicles' future trajectories and the planned route which is used in conjunction with the learned latent representation as input to a down-stream policy.

Safety Monitoring of Neural Networks Using Unsupervised Feature Learning and Novelty Estimation

A. Ranjbar, S. Hornauer, J. Fredriksson, S. X. Yu, and C.-Y. Chan

Autonomous vehicles often use machine learning in parts of the driving functions. The aim of this paper is to increase safety when using neural networks, by proposing a monitoring framework based on novelty estimation of incoming driving data, able to predict performance degradation. The idea is to use unsupervised instance discrimination to learn a similarity measure across ego-vehicle camera images, providing competitive results compared to state of the art anomaly detection, while also being applicable to real world driving data.

Bi-Risk-RRT Based Efficient Motion Planning for Mobile Robots

H. Ma, F. Meng, C. Ye, J. Wang, and M. Q.-H. Meng

A bidirectional search sampling strategy that bypasses TBVP using the reverse tree as a heuristic is proposed. A bidirectional motion planning algorithm, namely Bi-Risk-RRT, is developed for dynamic environments. Simulation experiments in various scenarios and discussions on bidirectional search sampling strategies and different parameter settings demonstrate the efficiency and practicability of the proposed method.

EV-Auth: Lightweight Authentication Protocol Suite for Dynamic Charging System of Electric Vehicles with Seamless Handover

P. R. Babu, A. G. Reddy, B. Palaniswamy, and S. K. Kommuri

Dynamic charging is an exciting technology that has the potential to reduce long charging times by allowing electric vehicles to charge while driving. This article offers "EV-Auth," a lightweight authentication protocol that allows for secure communication between an electric vehicle and a dynamic charging station. The security analysis demonstrates that the proposed protocol is resistant to well-known security attacks and seems to be appropriate for real-world applications. The proposed protocol's performance in terms of communication and computation cost is presented.

Online Trajectory Replanning for Sudden Environmental Changes during Automated Parking: A Parallel Stitching Method

B. Li, Z. Yin, Y. Ouyang, Y. Zhang, X. Zhong, and S. Tang

This paper proposes a parallel stitching strategy for online trajectory replanning in an automated parking scheme. When the ego vehicle tracks an originally planned parking trajectory online, an evasive trajectory is replanned once a blocking obstacle is found. Thereafter, a connective trajectory is generated, the two ends of which are future poses along the original trajectory and the evasive trajectory, respectively. The two ends of the connective trajectory are chosen greedily via parallel computation.

Early Lane Change Prediction for Automated Driving Systems Using Multi-Task Attention-based Convolutional Neural Networks

S. Mozaffari, E. Arnold, M. Dianati, and S. Fallah

Lane change (LC) is one of the safety-critical manoeuvres in highway driving according to various road accident records. Thus, reliably predicting such manoeuvre in advance is critical for the safe and comfortable operation of automated driving systems. The majority of previous studies rely on detecting a manoeuvre that has been already started, rather than predicting the manoeuvre in advance. Furthermore, most of the previous works do not estimate the key timings of the manoeuvre (e.g., crossing time), which can actually yield more useful information for the decision making in the ego vehicle. To address these shortcomings, this paper proposes a novel multi-task model to simultaneously estimate the likelihood of LC manoeuvres and the time-to-lane-change (TTLC). In both tasks, an attention-based convolutional neural network (CNN) is used as a shared feature extractor from a bird's eye view representation of the driving environment. The spatial attention used in the CNN model improves the feature extraction process by focusing on the most relevant areas of the surrounding environment. In addition, two novel curriculum learning schemes are employed to train the proposed approach. The extensive evaluation and comparative analysis of the proposed method in existing benchmark datasets show that the proposed method outperforms state-of-the-art LC prediction models, particularly considering long-term prediction performance.

LiDAR-Based Global Localization Using Histogram of Orientations of Principal Normals

L. Luo, S.-Y. Cao, Z. Sheng, and H.-L. Shen

A global localization method that is capable of matching local LiDAR scans with a global map is developed. The method

projects point clouds into bird's-eye view (BV) images and introduces the HOPN descriptor to perform matching. Additionally, it presents a consensus set maximization algorithm to reject outliers from the HOPN matches. The experimental results show that our method achieves state-of-the-art global localization performance.

Cooperative Computation Offloading in Blockchain-Based Vehicular Edge Computing Networks

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

As an innovative application of blockchain in vehicular edge computing, a novel secure data sharing architecture and a consensus mechanism based on blockchain are designed to prevent malicious attacks in vehicular edge computing networks. Moreover, the paper proposes a cooperative offloading decision-making method using a game-theoretical approach and theoretically proves its convergence to the Nash equilibrium. Simulation results verify the superior performance of the scheme with better data security and higher resource efficiency compared to other baselines.

II. Call for Papers: Validation & Verification of Intelligent Vehicles

The Intelligent Vehicles domain has experienced over the past years rapid progress, with several results becoming an integral part of current passenger vehicles, field trials in public roads involving driverless vehicles, etc. We have witnessed the implementation of unmanned public rail transportation systems, numerous applications in air and sea, for the transportations of people and goods. Considerable progress has been achieved using data-driven methods, the emergence of advanced sensors, connectivity and computing power, and deployments in real operating conditions. The Intelligent Vehicles domain has shifted from the unknown-unknown to a known-unknown condition. That is, numerous scientific contributions have been tested and deployed. We have grown our awareness of the navigation problems associated with intelligent vehicles applications (the known), with several still to be solved (the unknown). These include societal and safety concerns.

The challenges encountered with the verification & validation (V&V) of Advanced Driving Assistance Systems (ADAS) to provide evidence on their performance and assurance of their safe operation have demonstrated a growing need for testing methods, performance metrics and theoretical approaches. This is compounded by two factors: Increased levels of automation that remove humans from the vehicle control loop. The extensive use of data driven methods, namely machine learning (ML) across different functions has added complexity to the V&V process. For example, the evaluation of an Automated Emergency Braking System that avoids collisions with vulnerable road users (VRUs), depends for their detection on ML. The verification on whether the perception systems can detect the VRUs in hazardous conditions has proven to be difficult. Tests conditions that include the randomness found in public roads are hard to replicate. Higher levels of automation imply growing V&V demands, evidence is needed to satisfy stakeholders, to facilitate improvements.

Artificial Intelligence (AI) technologies, by themselves or combined with model-based methods are increasingly applied to intelligent vehicles (e.g., autonomous cars, aircraft, vessels), achieving remarkable results. Nevertheless, the quality assurance of existing AI application remains a challenge with increasing demand to attain demonstrable levels of confidence. Metrics to measure the functional performance are needed, on systems which rely on datasets that might not represent all the scenarios to be encountered. Yet, AI technologies provide an exciting opportunity to improve the V&V process through machine learning, data mining, knowledge representation, constraint optimization, multi-agent systems, etc. Nevertheless, there is the intrinsic need to deepen our domain understanding with new theories, methodologies, techniques, processes models, etc., and to improve procedures with new tools and resources. These significant changes have created new challenges when it comes to explainability, interpretability, predictability and correctness: How could we explain that a bollard at a Y-junction has not been perceived? Can I be sure that under all conditions my autonomous vehicle can cross safely and adequately a complex road intersection? These are questions with far-reaching consequences for safety, accountability and public adoption of intelligent vehicles. From an academic perspective, for graduate students, it has become very difficult to measure progress beyond the use of datasets. The formulation of metrics takes at times considerable efforts to complete their research.

There is the need to V&V Intelligent Vehicles to address these concerns in a manner that responds to the requirements of all stakeholders, different approaches are needed including formal methods, metrics, performance indicators, datasets, testing frameworks, etc. The purpose of this special issue is to bring together the different approaches applied to the V&V of Intelligent Vehicles, it welcomes results ranging from the concept formulation that connects them with existing research topics in verification, through algorithms, methods and tools for analysing Intelligent Vehicles, to case studies and examples that cover theoretical proofs, the use of benchmarking datasets, field tests as well as simulation technologies.

The purpose of this special issue is to provide a collection of different approaches to create awareness within the scientific and industry communities for their application, but also to identify gaps for future research The topics covered, but are not limited to, include Testing approaches at the system and component level, Formal specifications, Statistical approaches to Verification, Techniques to analyse components & Systems, Metrics & Performance Indicators, Verifiable Properties, Safety Cases, Normative efforts, etc. The special issue is to be published in Q1/2023 a detailed call for papers will have been shared by the time of publication of this Editorial.

The topics covered, but are not limited to, include:

- Case Studies
- Testing approaches at the system and component level,
- Formal specifications,
- Statistical approaches to Verification,
- Techniques to analyse components & Systems,
- Metrics & Performance Indicators,

- Verifiable Properties,
- Safety Cases,
- Normative efforts, etc.

Important Dates

- Manuscript Submission 21st November 2022
- Notification of Acceptance 20th February 2022
- Expected Publication April 2023

Guest Editors

- Prof Joseph Sifakis, Université Grenoble Alpes, France
- Prof. Holger Caesar, Technical University of Delft
- Prof. Michael Fisher, University of Manchester, U.K.
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