IV19 | 30TH IEEE INTELLIGENT VEHICLES SYMPOSIUM
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ITSS INTELLIGENT TRANSPORTATION SYSTEMS SOCIETY IEEE

IEEE

IV'19 Workshop (FRCA-IAV, https://goo.gl/qBUUCV)

Flexible and Robust Control Architectures for Intelligent/Autonomous Vehicles (FRCA-IAV): Formal Methods vs. Machine Learning approaches for reliable navigation

Workshop Program -- 13:30-17:30
Preliminary program, may be subject to changes

13:30 - 13:40	Welcome & Introduction
13:40 - 14:30	Keynote speaker 1: "**Verifying Autonomous Vehicles with Unverifiable Software**" (cf. below for more details)
14:30 - 14:50	(paper 1) "**Multi-Controller Architecture for Reliable Autonomous Vehicle Navigation: Combination of Model-Driven and Data-Driven Formalization**"
14:50 - 15:10	(paper 2) "**Algorithmization of constrained monotonic maneuvers for an advanced driver assistant system in the intelligent urban buses**"
15:10 - 15:40	Coffee Break (30mn)
15:40 - 16:30	Keynote speaker 2: "**Multi-Sensor Fusion for High Integrity Localization: how to bound estimation errors?**" (cf. below for more details)
16:30 - 16:50	(paper 3) "**Validation of Perception and Decision-Making Systems for Autonomous Driving via Statistical Model Checking**"
16:50 - 17:10	(paper 4) "**Interval-based/Data-driven Risk Management for Intelligent Vehicles: Application to an Adaptive Cruise Control System**"
17:10 - 17:30	(paper 5) "**How to Improve Object Detection in a Driver Assistance System Applying Explainable Deep Learning**"
17:30	Closing

Keynote speaker 1: Prof. Matthias Althoff (Technische Universität München, Germany)

Title: Verifying Autonomous Vehicles with Unverifiable Software

Abstract: Engineers and computer scientists are currently developing autonomous vehicles whose entire set of behaviors in future, untested situations is unknown: How can we ensure that unverifiable software, such as neural networks, behave correctly in all situations? Keeping in mind that autonomous driving is safety-critical, it is irresponsible to deploy such systems without testing all possible situations---this, however, seems impossible since even the most important possible situations are unmanageably many. The talk proposes a paradigm shift that will make it possible to guarantee safety in unforeseeable situations (under mild model assumptions): Instead of verifying the correctness of a system before deployment, we propose online verification, a new verification paradigm where a system continuously checks the correctness of its next action by itself in its current environment (and only in it) in a just-in-time manner. In order to prove correct behavior, formal

verification techniques are presented that efficiently compute possible future behaviors---subject to uncertain initial states, inputs, and parameters within a small time horizon.

Online verification has the potential to cut development costs, increase the safe range of deployment of automated vehicles, and reduce or even eliminate certain liability claims. The approach is demonstrated using simulations, recorded data, and experiments in real vehicles. The talk will also introduce open-source software so that one can replicate many of the presented results.

Matthias Althoff received the diploma in Mechatronics and Information Technology from the department of mechanical engineering at the Technische Universität München, Germany, in 2005. He received his PhD degree (summa cum laude) in electrical engineering from the same university under the supervision of Univ.-Prof. Dr.-Ing./Univ. Tokio Martin Buss in 2010. From 2010 - 2012 he was a postdoctoral researcher at Carnegie Mellon University, USA, with a joint appointment in electrical engineering and the Robotics Institute. He joined the computer science department at Ilmenau University of Technology, Germany, in 2012 as assistant professor for automation systems. Since 2013 Matthias Althoff is assistant professor in computer science at the Technische Universität München. His research interests include the design and analysis of cyber-physical systems, formal verification of continuous and hybrid systems, reachability analysis, planning algorithms, robust and fault-tolerant control. Main applications of his research are automated vehicles, robotics, power systems, and analog and mixed-signal circuits.

Keynote speaker 2: Prof. Philippe Bonnifait (Université de Technologie de Compiègne, Heudiasyc UMR CNRS 7253, France)

Title: Multi-Sensor Fusion for High Integrity Localization: how to bound estimation errors?

Abstract: Localization with high integrity is crucial for highly autonomous vehicles. To do so, the quality of the information delivered by a localization system must be monitored in real time so that client applications can control that the performance matches the needs of the current navigation task. Dynamic data fusion methods using state filtering remain the most efficient methods today because they allow to manage the uncertainty and the asynchronism of exteroceptive measurements thanks to high frequency dead-reckoning sensors. A key issue that remains opened is to bound estimation errors with a low probability risk. To achieve this goal a possible strategy is to exclude the faulty measurements from the fusion procedure in a first stage and then, to compute a bound of the estimation error by using a heavy-tailed Student's distribution with an adapted degree of freedom (dof). The tuning of the dof can be done experimentally in a learning phase according to the navigation environment. In the talk, this approach will be presented and discussed. To support the proposal, a case study will be described with an experimental vehicle equipped with a CAN bus interface to access speed measurements, a GNSS receiver and a camera that can detect up to four lane markings simultaneously and associate them with a high definition map that contains the accurate coordinates of the markings.

Philippe Bonnifait is a professor in the Computer Science and Engineering department of the Université de Technologie de Compiègne (UTC) in France. He obtained his Ph.D. in automatic control and computer science at the École Centrale de Nantes in 1997. Since 1998, he has been with Heudiasyc UMR 7253, a joint research unit between UTC and CNRS. His research interests are Intelligent Vehicles, high integrity positioning and map-matching for autonomous navigation on roads opened to public circulation.

Workshop motivation: The proposed new series of workshops aims to address the important topic of **flexibility and reliability insurance for Intelligent/Autonomous Vehicles** (I/AV) moving **in the presence of constraints/uncertainties in any navigation context/environment** (e.g., complex urban situations like roundabout or intersection crossing; highway and connected cooperative vehicles, etc.). The constraints (those resulting from the motion environment properties and those imposed directly on a vehicle like for instance: maneuvering in cluttered environments with limited accelerations and/or limited curvature, limited joint angles in articulated vehicles, or limited power resources) and the uncertainties assessment and management (e.g., long-term maneuvering under uncertain perception/localization) are among the key issues which must be addressed to have a large deployment of I/AVs as a common, reliable, and economically effective transportation system in various domains. The development of I/AV has made tremendous advances in the last decade.

Several companies have announced the deployment of highly automated vehicles into a public road in the near future. However, the lack of reliability guarantees for flexible maneuvering with I/AV in the presence of constraints/uncertainties limit drastically these ambitions to strictly limited use cases and operational domains. In order to ensure reliable and flexible operation of automated vehicles in more complex scenarios, comprehensive multimodal design approaches are required. We strongly believe that one of the promising ways to reach the mentioned objective can be obtained by a smart combination of formal methods and data-driven approaches when applied in a coherent, complementary, and synergistic manner. This important subject is of interest to both academia and industry, and it is expected during this workshop to share the different points of view by having presentations from both sides.
Thus, the focus and the ambition of this workshop is to gather the communities, which use either formal (model-driven) methods or machine learning (data-driven) approaches to deal with this important subject, while emphasizing the strength and weakness of each methodology. A possibility of creation of a tight and systemic link between formal and Artificial Intelligence (AI) based approaches in a common control architecture is among the main motivations of such a workshop, which will allow the attendees to share different views on the same problem and initiating honest conversations about the flexibility and reliability of automated vehicles from both the academic and industrial points of view.
Even if the two considered methodologies (i.e., the formal and machine learning ones) could be applied for all the elementary components composing an overall I/AV control architecture (perception / localization / planning and control), the proposed workshop is intended to focus on the integrated approaches, starting from the used perception modeling/features (even simple) and finishing on the control phase in order to show the impact of the whole chain of decision-action process (and its interactions) to evaluate flexibility and reliability of the I/AV obtained motion.

Workshop abstract: **Automated driving systems** have become one of the most exciting and important innovations in the transportation history. Indeed, **the challenge to have fully autonomous vehicles for passengers transportation** is about to become a reality. Nevertheless, the **diversity of driving conditions in the presence of different kinds of uncertainties/constraints, imposed on the vehicles motion control** (perception-decision-action), may **lead to unexpected scenarios and extremely difficult motion**, which may be hazardous. The efficiency and reliability of autonomous vehicles is then subject to the **capability of predicting and managing risks**, while preserving the **vehicles' integrity**, with respect to several aspects, such as: **vehicle dynamics variations, change of the power resources**, **reliability of sensor/perception information** and **variation of driving and environmental conditions**. This workshop aims to discuss how to ensure a **Long-Term Autonomy**[1] of I/AV (Intelligent/Autonomous Vehicles), while maintaining a **high level of** motion **flexibility and reliability** during the navigation process. Moreover, the workshop is expected to initiate interesting discussions about a possible **generic design methodology closing a link between systemic model based approaches and AI** developments in order to **efficiently and reliably address I/AV navigation** in complex environments/situations. The workshop aims at presentation of **cutting-edge research topics**, new **original theoretical achievements**, **practical results** and **high fidelity simulations protocols**, with a focus on **guaranteed flexibility and reliability of navigation** with constrained **I/AV** in various transportation domains, and using different **research methodologies**: the **formal and machine learning** ones. **Submissions illustrating combinations of these two general methodologies leading to synergetic results are in a special interest of the workshop.**

Main topic of interest: The workshop encourages contributions coming from applications of formal methods or machine learning approaches reporting on original research, work under development, experimental results and high fidelity simulations protocols, related, but not limited, to one of the following topics:
- Control architecture design and standardization for flexible constrained navigation and guidance of I/AV
- Model-driven and data-driven methods for ensuring flexibility and reliability of I/AV navigation
- Navigation flexibility and reliability: modelling, analysis and validation for I/AV
- Constrained motion algorithmization (constrained planning and control) for flexible and reliable maneuvering with I/AV
- Risk of constraints violation: assessment and management under uncertainties
- Short- versus Long-term planning in the presence of constraints/uncertainties

[1] It is important to note that LTA means in this workshop that the **vehicle can deal with a large variety of driving situations** (e.g., navigation in dense urban traffic, round-about/intersection or unstructured area) and **environment conditions** (e.g., wet ground, fog conditions), without obliging the vehicle to stop or to delegate the driving to the person inside.

- Flexibility and reliability in connected and cooperative I/AV systems
- Simulation benchmarking for characterizing flexibility and reliability of I/AV navigation
- Flexibility and reliability in advanced driver assistance systems (ADAS)
- Perception, map building, and obstacles detection methods for flexible and reliable applications
- Applications of I/AV in the public, freight and agriculture transportation domains in the presence of constraints.

Keywords: Intelligent/autonomous vehicles, flexible and robust control architectures, short- vs. long-term planning, long-term autonomy, flexible navigation/maneuvering, reliability guarantees, motion algorithmization, risk assessment and management, connected and cooperative vehicles, model-based approaches, data-driven approaches, ADAS.

Workshop format & Information for authors: The workshop is proposed as a half-day event comprising two sessions organized in series. Each session will contain 4-5 presentations (duration of around 20 minutes with Q&A for every presentation), followed by a panel discussion (around 20 minutes) during which the audience will have interactive discussions with all the presenters playing a role of panelists. Each session will be started by an invited talk of about 30 minutes duration. The two keynote speakers (one for each session) will be invited from leaders of academic or industrial I/AV-ecosystem community. Invited speakers will be announced very soon and are expected to deliver a talk on cutting-edge research topics and innovative field developments, with special attention paid on emerging technologies and practices applied in order to ensure flexibility and reliability of I/AV for various navigation contexts/scenarios in the presence of constraints/uncertainties.

Authors are encouraged to submit high-quality, original research (i.e., not been previously published). Authors of accepted workshop papers will have their paper published in the conference proceeding. For publication, at least one author needs to be registered for the workshop and the conference and should present his/her work.

During the submission phase, it is important to mention the code: FRCA-IAV (corresponding to the acronym of the workshop).

The format and instructions of the paper submissions are identical to all the IV symposium papers and are available at: http://iv2019.org/information-for-authors/.

Important dates:

Workshop paper submission deadline:	February 7, 2019
Notification of workshop paper acceptance:	April 5, 2019
Final workshop paper submission:	April 26, 2019
Workshop date:	June 9, 2019

Workshop organizers:

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Lounis Adouane is an Associate Professor since 2006 at the Institut Pascal - Polytech Clermont-Ferrand. He obtained in 2005 a PhD in automatic control from FEMTO-ST laboratory-UFC Besançon, where he deeply investigated the field of mobile multi-robot systems, especially those related to bottom-up and hybrid control architectures. Dr. Adouane had the opportunity to visit several institutions/laboratories, such as 1 month in 2009 at LIST (Luxembourg), 6 months in 2014 at Cranfield and Kingston universities (United Kingdom) and 2 months in

2018 at KIT (Karlsruhe Institute of Technology, Germany). In 2015, he obtained from Blaise Pascal University a HDR (habilitation to steer research in Robotics). Dr. Adouane's current research focuses on **Intelligent Vehicles**, more specifically; he is working on three main topics: **1. Autonomous navigation of mobile robots/vehicles in complex environments; 2. Cooperative control architectures for multi-robot/vehicle systems** and **3. Optimized energy management of dynamic hybrid electric vehicles**. He is the author/coauthor of more than **100 refereed international papers** and **2 books** on these topics. Dr. Adouane is an active member of the international community of mobile robotics/autonomous vehicles, he is member of Technical Committee of Intelligent Autonomous Vehicles – IFAC and Multi-Robot Systems – IEEE RAS, and he serves as an Editorial Board Member of the Journal of Intelligent and Robotic Systems. He has been participated to more than 15 program committees of international conferences and workshops. Further, Dr. Adouane supervised (or currently supervising) 12 PhD Thesis (all linked to mobile robotics and/or intelligent vehicles). More specifically, his main research include planning and control, hybrid (continuous/discrete) and hybrid (reactive/cognitive) multi-controller architectures, Lyapunov-based synthesis and stability, obstacle avoidance, cooperative multi-robot systems, navigation in formation, artificial intelligence for optimization and control (e.g., Markov decision process, Bayesian decision network and Multi-agent systems), energy management (optimal control and Neuro-Fuzzy approaches) and multi-robot/agent simulation.

Maciej Marcin Michałek received the Ph.D. (with honors), and D.Sc. (Habilitation) degrees in the field of automation and robotics from the Poznan University of Technology (PUT), Poznań, Poland, in the years 2006, and 2015, respectively. He is currently an Assistant Professor with the Institute of Automation and Robotics, Faculty of Computing, PUT. His current research interests include motion algorithmization (planning and control) for nonholonomic mobile robots, intelligent vehicles, and the N-trailer articulated structures in the presence of state and control constraints. He developed and introduced the VFO (Vector-Field(s)-Orientation) control design methodology which has been successfully applied so far in various robotic systems. Dr. Michałek presented numerous talks during scientific-engineering domestic and international conference meetings within regular and invited sessions. In year 2016 he delivered the plenary lecture entitled 'Articulated N-trailer mobile robots: kinematic properties and cascaded control' during the domestic XIV National Robotics Conference. He is the author/coauthor of more than 80 refereed papers and 1 textbook in the field of robotics and control. Currently, Dr. Michałek belongs to the key research staff of the R&D project realized in cooperation with the bus manufacturer Solaris Bus & Coach S.A. company concerning algorithmization of maneuvers for the purpose of an Advanced Driver Assistance System to be applied in intelligent urban buses. Dr. Michałek has been a member of the IEEE organization since 2009 (with a senior member grade received in year 2016); he is a member of the IEEE Robotics and Automation Society, and the IEEE Control Systems Society. In years 2014-2017 he served as a Secretary of the Polish Chapter of IEEE Robotics and Automation Society. Since 2011 he serves as an editorial board member of the *Journal of Intelligent and Robotic Systems* (currently as an Executive Advisory Board member), where he organized (in years 2014 and 2018), as a principal guest editor, two special issues devoted to articulated mobile robots and motion strategies for underactuated robotic vehicles in the presence of constraints. Since the year 2017 he belongs to the Conference Editorial Board for the IEEE Control Systems Society. Dr. Michałek is invited as one of plenary speakers for the IFAC Intelligent Autonomous Vehicles (IAV) Symposium in year 2019.

Antonios Tsourdos obtained an MEng on Electronic, Control and Systems Engineering from the University of Sheffield (1995), an MSc on Systems Engineering from Cardiff University (1996) and a PhD on Nonlinear Robust Flight Control Design and Analysis from Cranfield University (1999). He is a Professor of Autonomous Systems and Control with Cranfield University. He was appointed Head of the Autonomous Systems Group in 2007, Head of the Centre of Autonomous and Cyber-Physical Systems in 2012 and Director of Research - Aerospace, Transport and Manufacturing in 2015. Professor Tsourdos was member of the Team Stellar, the winning team for the UK MoD Grand Challenge (2008) and the IET Innovation Award (Category Team, 2009). Professor Tsourdos is chair of the IFAC Technical Committee on Aerospace Control, and member of the UK Autonomous Systems National Technical Committee. He is editorial board member for the IEEE Transactions on Aerospace and Electronic Systems, the Proceedings of the Institution of Mechanical Engineers, Part G: Journal of Aerospace Engineering, the Aerospace Science and Technology, the International Journal of Systems Science and the Journal of Intelligent and Robotic Systems.