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PLENARY TALK



Trustworthy Human-Machine Systems: Formal Methods for Safety-by-Design

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Short bio: Dr.-Ing. Balint Varga is Head of the Cooperative Systems Research Group at the Institute of Control Systems (IRS), Karlsruhe Institute of Technology (KIT), where he leads and coordinates industrial and publicly funded research projects and supervises research staff and doctoral candidates. He received his Ph.D. in Electrical and Information Engineering from KIT in 2023, specializing in human-machine systems. He earned his M.Sc. in Mechanical Engineering from KIT in 2017 (Theoretical Mechanical Engineering) and his B.Sc. in Mechatronics from Budapest University of Technology and Economics in 2016.

In his work, he develops human-in-the-loop and shared-control methods for robotic and autonomous systems, focusing on limited-information cooperation, interaction-aware decision-making, and cooperative trajectory planning. His approach combines cooperative and predictive control with differential-game formulations, model-based shared control, and inverse optimal/dynamic game methods to infer intent, resolve conflicts, and improve transparency, with applications in large mobile manipulators, teleoperation, autonomous driving, and robot-assisted medical systems. He collaborates closely with industrial partners, translating shared-control and cooperative autonomy concepts into deployable prototypes and validation pipelines.

Dr. Varga serves as Chair of the IEEE SMC Society Technical Committee on Shared Control and is an Associate Editor for IEEE Transactions on Human-Machine Systems and the International Journal of Robotics and Automation. He has organized several special sessions and workshops at IEEE SMC, IEEE RO-MAN, and IEEE SACI, and regularly reviews for leading IEEE and Elsevier journals. He also teaches courses in control engineering, robotics, and systems/software engineering at KIT and the Baden-Württemberg Cooperative State University.

Abstract: Society repeatedly faces complex challenges where robotic solutions are deployed. In many of these applications, humans and machines work together to accomplish shared tasks – for example, robots that assist patients or support human operators in their work. However, ensuring safety and trustworthiness in such systems cannot rely on learning-based models alone. These models often behave as non-verifiable “black boxes,” which makes it difficult to provide rigorous guarantees. As a result, real-world deployment of human-robot systems is frequently delayed or restricted: Autonomous driving is a prominent example.

In our research group at KIT, we investigate how to develop verifiable mathematical models for human-machine systems. Such models can formally describe system behavior and enable safety-by-design, where safety and performance guarantees are built into the system from the beginning. The talk will also show how these mathematical models can be integrated with data-driven learning methods, combining formal guarantees with the flexibility of modern machine learning. Finally, application scenarios will be presented in which the safety of human-machine systems is considered essential, since societal acceptance and trust cannot be expected without credible and convincing safety guaranties.



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