frontiers | Frontiers in Control Engineering

TYPE Editorial
PUBLISHED 11 April 2023
DOI 10.3389/fcteg.2023.1188846

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Networked Control, a section of the journal Frontiers in Control Engineering

RECEIVED 17 March 2023
ACCEPTED 27 March 2023
PUBLISHED 11 April 2023

CITATION
Inga J, Rothfuß S, Saito Y and Sentouh C (2023), Editorial: Model-based methods for human–machine cooperative and shared control systems.
Front. Control. Eng. 4:1188846.
doi: 10.3389/fcteg.2023.1188846

Editorial: Model-based methods for human–machine cooperative and shared control systems

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KEYWORDS

shared control, human-robot interaction, human-machine cooperation, powered wheelchair, cooperative planning, ROV (remote operated vehicle), advanced driver assisance systems (ADAS)

Editorial on the Research Topic
Model-based methods for human-machine cooperative and shared control systems

Human–machine cooperation and shared control have become major areas of interest in various scientific communities. Humans and machines working together as a team yield a high potential which can be leveraged in numerous application domains. The articles in this Research Topic review state-of-the-art methods and present recent approaches for the modeling and design of human–machine cooperative systems, showcasing the latest research for a variety of applications. In addition, the articles show different ways in which the interaction between humans and machines can take place. The huge variety of interaction scenarios as well as the "type" of interaction lead to a similarly large spectrum of models and methods for designing machines that are capable of completing tasks together with a human.

One of the most prominent application domains of cooperative and shared control systems is highly automated driving. This is reflected in two articles reporting on research in this application field.

The article titled "A review of shared control in automated vehicles: System evaluation" by Sarabia et al. acknowledges the pivotal role of human–machine cooperative driving in future transportation and provides a survey of recent literature focusing on studies with real drivers. The authors emphasize the importance of turning the attention to the evaluation methodology of shared control approaches. The article reviews the recent literature, focusing both on the study design and on the various metrics used in the studies. The authors provide valuable conclusions. For example, research on shared longitudinal control should catch up with research on shared lateral control. Control authority shifting based on driver state should keep receiving increasing attention. Lastly, the evaluation of the interaction itself and of safety have not been performed as intensively as the evaluation of driving performance.

The work of Oudainia et al. aims at minimizing conflicts between drivers and lane keeping systems of intelligent vehicles. In their article titled "Online driver model parameter identification using the Lyapunov approach based shared control," the authors present a driving assistance system for lane keeping, which is based on a dynamic driver model. To robustly identify the driver model parameters for different drivers and situations, a

Lyapunov approach is applied. Using this approach, the asymptotic stability of the closed-loop control system can be shown. Furthermore, the resulting control design is applied to a driving simulator. The experimental results demonstrate the effectiveness of their new approach and the utilization of the identified parameters in a shared control design. In addition to an objective performance increase in terms of improved safety and reduced conflicts, the drivers' subjective perception of the assistance system improved as well.

The scopes of the other articles are closely related to the automotive application domain and focus on cooperative human-machine system design for mobile nursing robots that accompany patients, the control of power wheelchairs, and tele-operated underwater vehicles.

The article titled "Negotiation-based cooperative planning of local trajectories" by Schneider et al. considers a situation in a hospital where a nursing robot has to accompany patients who need support for walking from one room to another. One of the key aspects in this scenario is the dynamic negotiation of roles that permits both the human and machine to take the initiative in order to follow a particular path. The authors use a negotiation theoretical approach to model the interaction within the human-machine system and propose a reciprocal tit-for-tat strategy to achieve an agreement concerning the trajectory plan, without resorting to an imposed time-based deadline. The presented simulation study shows how the results of the cooperative trajectory planning change with different kinds of human behavior.

The article titled "Model-based shared control approach for a power wheelchair driving assistance system using a force-feedback joystick" by Nguyen et al. presents a haptic-based assistance system for power wheelchair users to avoid collisions and reduce user effort. Users operate the wheelchair *via* a joystick capable of haptic feedback. The applied shared-control strategy is composed of an operational part and a tactical part. On an operational level, a Takagi-Sugeno fuzzy control approach addresses the time-varying user intentions when supporting the user's driving actions. On a tactical level, conflicts between the assistance system and the user are managed based on the driver's hand torque estimation, ensuring that the user has the final decision. The assistance system proves its effectiveness in an experimental evaluation.

Another interesting area of application for human–machine cooperative systems is investigated in the work of Sato et al. titled "Cooperative path-following control of a remotely operated underwater vehicle for human visual inspection task." In the context of remotely operated underwater vehicles with the purpose of inspecting underwater infrastructure, the authors developed an assistance system to reduce the workload of human operators. The assistance system ensures that the underwater vehicle robustly follows a predefined path while the human operator can focus on determining the vehicle's velocity to properly conduct the inspection task. To validate the system, the article presents an experiment comparing the system performance with and without the assistance systems. The results show the advantages by applying the assistance system compared to manual control in terms of significantly reduced path-following errors and operator workload. Moreover, the cooperative path-following control method enables the intended shift of operator attention, which ranges from tight control of the robot's motion to an inspection task.

Overall, the five contributions to this Research Topic provide a contemporary insight into research on human–machine cooperative and shared control systems from different application domains. The articles demonstrate the multifaceted nature of human–machine cooperation and show how the use of systematic approaches can lead to an effective human–machine system. This Research Topic is presented to encourage research to continue in this direction and to spread to other fields of application.

Author contributions

JI and SR wrote the first draft of the manuscript. JI, SR, YS, and CS contributed to the final draft of the manuscript.

Conflict of interest

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