Editorial

The present IEEE Transactions on Human-Machine Systems (THMS) finds its origins in several previous titles, including parts of the IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS (between 1971–1995 and 1998–2012) and the IEEE TRANSACTIONS ON MAN-MACHINE SYSTEMS (T-MMS; from 1968–1970). As some may recall, the latter title actually preceded the Systems, Man and Cybernetics Society within IEEE and was a product of the IEEE Group on Systems Science and Cybernetics. For many researchers working in the area of human–automation interaction, the T-MMS served as an outlet for high-quality scholarship. Over the years, a number of articles appearing in the issues of T-MMS were identified as seminal works in different areas, including the following:

1) state of the art in human–adaptive manual control;
2) state of the art in human–computer coordination in multitasking scenarios;
3) state of the art in participatory modes of human control of dynamic systems and failure detection;
4) state of the art in human monitoring behavior in supervisory control;
5) state of the art in human decision making and workload in supervisory control scenarios;
6) state of the art in modeling of human–machine interaction;
7) state of the art in human workload modeling in supervisory control;
8) state of the art in adaptively automated systems for human control;
9) state of the art in human–automation interaction modeling.

The issue received more than 20 submissions, and many were considered to fall within the scope of the issue and to represent high-quality submissions. Among these submissions, only nine were successful through the revision process. This editorial provides a summary of those review papers accepted as part of the issue. The order in which the summaries appear reflects the order of papers in the issue and serves to provide some conceptual organization of the research.

As an overview of the papers in the issue, two contributions by Strauch and Eisma et al. address fundamental aspects of how humans interact with automation systems. Two other papers by Hooey et al. and Heard et al. address human workload modeling and methods for measurement as well as moderation. Three papers in the issue focus on manual control (Mulder et al.; van der El, Padmos et al.; and van der El, Pool et al.) with the first being a theoretical work and the other two studies being empirical in nature. One paper addresses human and agent shared control (Abbink et al.), and a final paper, by Van Paassen et al., focuses on extending contemporary supervisory control interface design methods to new domains. Although the issue was limited to nine papers, the authors provided approximately 145 pages of results and inference for advancing the fundamental research themes that were explored some time ago by papers in T-MMS and other related IEEE journals.

We begin with a review by B. Strauch (“Ironies of Automation: Still Unresolved After All These Years”) documenting the unresolved “pitfalls” of automation in human-in-the-loop systems, including operator complacency. Strauch takes us back to fundamental observations made by Bainbridge [item 1 in the Appendix] on the ironic influences of automation on overall system performance and the performance of human operators. Research and systems development have demonstrated that machines can replace humans in many tasks but unexpected costs may arise, such as human over-reliance on highly sophisticated and reliable automation to the extent of operator manual control skill decay over time. Strauch notes the critical observation made by Bainbridge was the potential for operators to disengage from system control when necessary and potential compromises in safety. Strauch also notes that
over history, there have been many cases in which human operators have incorrectly intervened in system performance following extensive reliance upon automated systems. He also contends that we still have yet to resolve this issue in automated and human-in-the-loop system designs and that it represents a fundamental dilemma for the design of future systems. This particular submission addresses the special issue’s target area of state of the art in human–automation interaction research.

Strauch’s work is followed by an extensive review by Heard et al. (‘‘A Survey of Workload Assessment Algorithms’’) on human cognitive workload measures and real-time assessment algorithms for predicting operator demands in contemporary complex automated systems. The authors note that workload assessment is actually an integral part of human–machine systems design as workload is directly related to operator performance. Heard et al. offer that the majority of workload assessment has been conducted in a post hoc manner and that new technological and methodological advances now allow for real-time assessment, which also allow for operator state classification and more effective workload management. Heard et al. applied four psychometric criteria for evaluating the potential application of contemporary workload assessment algorithms in supervisory control of human–machine systems, including sensitivity, diagnosticity, population generalizability, and task environment generalizability. The main outcome of this review is that no existing assessment methods actually completely address the criteria, primarily due to diagnosticity and generalizability limitations (not analyzing all workload demand components and not being extensible across a range of domains). Consequently, Heard et al. identify specific needs for future workload assessment algorithms. This submission addresses the issue’s target area of state of the art in human workload modeling. The work applies a set of criteria for making recommendations of specific algorithms.

The issue continues with a related study by Hooey et al. (‘‘The Underpinnings of Workload in Unmanned Vehicle Systems’’) on the underpinnings (or ‘‘drivers’’) of cognitive workload for operators in unmanned systems. Hooey et al. reviewed workload research across multiple domains, including unmanned aerial vehicle operation, unmanned ground vehicles, and unmanned underwater vehicles. These modern unmanned vehicle systems represent a wave of unprecedented automation and autonomy as well as sophisticated human–machine interfaces, which fundamentally change how humans control and/or interact with the systems. The authors defined workload as the interaction of multiple contextual variables in unmanned systems operation and human perception of those variables. They focused on workload drivers in overload and underload events as well as transitions between these states. Beyond workload drivers, Hooey et al. also identified system design approaches, automation capabilities, and interface features as potential moderators of the influence of workload drivers in complex and highly automated human–machine systems. They discuss how specific moderators and drivers interact in various contexts and provide a basis for future models of human workload responses for use in conceptual and detailed systems design. This submission also addresses the special issue’s target area of state of the art in human workload modeling.

This contribution is followed by a set of three papers that are focused on the state of the art in human manual control of complex machine systems (‘‘Manual Control Cybernetics: State-of-the-Art and Current Trends’’ by Mulder et al.; ‘‘Effects of Preview Time in Manual Tracking Tasks’’ by van der El, Padmos et al.; and ‘‘Effects of Linear Perspective on Human Use of Preview in Manual Control’’ by van der El, Pool et al.). The first contribution comes from one of several teams of authors at Delft University of Technology (Mulder et al.). The work focuses on extending mathematical models for describing human manual control of dynamic systems based on pioneering contributions from Kendel, McRuer, Kleinman, Baron, Levison, Young, Stassen, and Sheridan, which were published through IEEE and other forums during the 1960s and 1970s. Consideration of communication issues in human control of semiautomatic systems and modeling performance is not new, but the challenge Mulder et al. address is adapting and extending the existing theory relative to modern interface technologies, such as augmented reality displays and haptic interfaces. This exploration leads the authors to recognize that existing cybernetics theory and tools only allow us to accurately model a very specific case of human control, compensatory tracking, and that even small diversions from this case (e.g., control interface design) quickly leads to fundamental problems. On this basis, Mulder et al. identify the need for modeling adaptive human control with tuning of models to address human interaction through specific types of interfaces. The authors develop a new framework for studying and mathematically modeling adaptive human control. Specific aspects of this framework are addressed by the two follow-on papers led by van der El with a focus on human tracking performance with preview displays.

The paper by van der El and Padmos et al. (also from Delft) focuses on understanding how humans adapt to predictive or preview displays in manual control of dynamic systems, such as teleoperators. The research extends very early research by Sheridan [item 2] in the Appendix on ‘‘Three Models of Preview Control.’’ The authors initially observe that, despite decades of research on preview control models, there is still little understanding of how humans make use of advance target trajectory information in tracking tasks, depending upon the degree of ‘‘look ahead’’ that is provided. The authors make use of the cybernetics modeling extension presented by Mulder et al. to develop predictions of how people effectively adapt to preview control. Experimental results reveal how control behavior changes relative to restrictions placed on available target trajectory preview. The overarching aim of this paper is to advance human manual control models in order to support systematic design of future human-in-the-loop automated systems, such as vehicles with advanced driver assistance systems.

The paper by van der El and Pool et al. as part of the issue is also closely linked to the paper by Mulder et al., in which the authors make extension of the seminal mathematical model of human manual control (for aviation systems) by McRuer and Jex [item 3] in the Appendix in order to account...
for variable targets when using different types of predictive displays. The authors note that the original form of McRuer’s model was mainly restricted to describing compensatory tasks. Based on Mulder et al.’s contribution as part of this issue, van der El and Pool et al. extend the applicability of the new framework to driver steering on winding roads. They also explore how different types of tracking displays (2-D and 3-D) influence driver control behavior. The authors tease out the influence of linear perspective mapping on how humans make use of preview control. The research supports modeling and quantitative predictions of how humans control and adapt to task scenarios providing preview under a broader range of displays than was originally studied by McRuer.

The issue continues with an extension of research on human manual control of complex systems (in which control is typically traded between either a human or machine from time-to-time) to focus on shared control, in which a human and automated agent jointly control a dynamic system to execute tasks. In “A Topology of Shared Control Systems—Finding Common Ground in Diversity,” Abbink et al. attempt to bring a unifying perspective to the body of shared control research that has developed over the past five to six decades. They offer that the challenges of human interaction with control and control over intelligent machines was addressed by pioneers in the human–systems engineering field, such as Wiener, Sheridan, Rasmussen, Stassen, and others. In recent years, the shared control approach has gained increasing attention in a variety of application domains, such as car driving, robot-assisted surgery, brain–machine interfaces, and personalized learning systems. The authors contend, however, that cross-fertilization of research efforts among these domains has been hampered by a lack of a unified design and evaluation approach. To address this issue, Abbink et al. develop a definition of shared control, based on a review of influential papers in human–machine interaction literature and identify when shared control is preferable to manual control or traded control. They go on to distill design and evaluation axioms from the definition. Subsequently, the generalizability of the definition and axioms is examined by analytical application to the four domains of active shared control research. Finally, the authors propose a novel framework of shared control that accounts for different hierarchical levels of control in human–machine systems unlike earlier human-based or task-based control frameworks. In general, all of the contributions to the special issue make extensions of early seminal research in the area of human factors considerations in human–machine systems design. The research presented in this issue spans from emphasis of on-going needs in the design of automation to approaches for assessing human workload responses to systems designs. Other work provided advances in modeling of manual control behavior and shared control, as well as identifying factors in human visual behavior that contribute to information processing time. Finally, some research addressed the need for effective design of supervisory control interfaces for dynamic systems. I hope that readers of the issue will enjoy the papers as much as I did and that the results serve to further advance the science of human–machine systems.

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APPENDIX

RELATED WORKS


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Dr. Kaber is a Fellow of the Human Factors and Ergonomics Society and the Institute of Industrial and Systems Engineers. He is a Certified Human Factors Professional and a Certified Safety Professional.