Editorial: IEEE Systems, Man, and Cybernetics Society's Continuing Legacy in Human–Machine Systems

THIS first issue of the IEEE TRANSACTIONS ON HUMAN–MACHINE SYSTEMS (THMS) provides an opportunity to recognize the IEEE SYSTEMS, MAN AND CYBERNETICS SOCIETY'S (SMCS) contributions with respect to the dissemination of results in the area of human–machine systems (HMS) that inform theory and improve engineering practice by:

1) taking into account human sensory, motor, and cognitive capabilities, knowledge, skills, preferences, emotions, limitations, biases, learning, and adaptation;
2) considering human synchronous and asynchronous interactions with each other, intelligent agents, computational support, and assistive devices via associated input and output technologies within the person's operational, organizational, cultural, and regulatory contexts;
3) developing, instantiating, testing and refining measures, methods, models, and apparatus that address 1) and 2) and that can provide insights given real world imprecision, uncertainty, and constraints that impact human characteristics, performance, behavior, and learning; and
4) supporting operational concept development, architecture, design, implementation, and evaluation of dynamic, complex systems that include human participants in their multifaceted roles (such as analyst, decision maker, operator, collaborator, communicator, and learner).

THMS has inherited its HMS focus from two former SMCS journals: the IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS PART A: SYSTEMS AND HUMANS [1]–[4] published (along with IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS PART B: CYBERNETICS) from 1996 until 2012 and the IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS PART C: APPLICATIONS AND REVIEWS published from 1998 until 2012. It has inherited its volume number from *Part C*. From 1971 to 1995, the SMCS published HMS research in the IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS.

The HMS focus predates the formation of the IEEE SMCS in 1970 (when the IEEE Group on Man-Machine Systems (MMS) merged with the IEEE Group on Systems Science and Cybernetics) [5], [6]. From 1968 to 1970, the IEEE Group on MMS supported the IEEE TRANSACTIONS ON MAN–MACHINE SYSTEMS [7]. From 1963 to 1967, the IEEE Group on Human Factors in Electronics supported the IEEE TRANSACTIONS ON HUMAN FACTORS IN ELECTRONICS.

One can even trace the HMS roots to before the founding of the IEEE. The American Institute of Electrical Engineers (AIEE) and the Institute of Radio Engineers (IRE) merged in 1963 to become IEEE Institute of Radio Engineers (IRE) [8], and from 1960 to 1962 the IRE published the IRE TRANSACTIONS ON HUMAN FACTORS IN ELECTRONICS. Before 1960, human–machine systems papers appeared in the *Proceedings of the IRE* (see for example [9] which advocated for providing integrated information and feedback from the operator's control actions).

Thus, the launching of this "*new*" SMCS journal is part of a continuing legacy in HMS. This inaugural issue results from a planned transition and includes manuscripts accepted by the editors-in-chiefs (EiCs), associate editors-in-chiefs (AEiCs), associate editors (AEs), and reviewers of the former *Parts A* and *C*. Without their and the authors' efforts, this inaugural issue, as well as the ones to follow, could not have happened.

This first issue includes ten papers that represent a part of the SMCS's HMS scope. Manual control, movement, and motor skill development have been important topics for decades (see for example [10]–[20]). Modeling approaches such as McRuer's crossover model [21]–[23], as well as interventions such as input shaping [24] (where reference commands reduce controlled element oscillations and associated displays [25]), continue to be of interest. While many forms of controlled-element dynamics have been studied, in this issue Potter and Singhose's [26] modeling, analysis, and evaluation of manual control of systems with oscillatory dynamics show promise for continuous tracking ability of such systems.

Supervisory control and decision-making and the related topics of function allocation, methods for designing, and evaluating human–automation interaction, and display design have also been main areas of focus for the SMCS [27]–[73]. Studies have evaluated traffic-flow and human factors aspects of car following with different adaptive cruise control (ACC) systems in various driving conditions [74], [75] and in this issue, Saffarian *et al*. [76] consider distributing the control information (in this case to drivers of nonequipped cars). In their system, vehicles equipped with cooperative ACC (CACC) provide state data and advice on the rear window. In a simulator study, drivers directly control the vehicle and have access to the rear window notification display (RWND) showing visual feedback on lead-car acceleration and time headway. The RWND supporting reducing time headway without increasing the occurrence of potentially unsafe headways of less than 1 s.

Mettler and Kong [77] describe a mapping method to support the investigation of human guidance behavior and its associated optimal-control model. The method employs an ensemble of trajectories distributed spatially over an extended task space. The method is evaluated using precision interception tasks

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with a miniature helicopter. As behavior can be meaningfully embedded in a spatial value function map, it supports understanding guidance performance from a spatial standpoint. Map-based performance and optimality metrics support determining level of coordination and bandwidth and how these requirements change over the task space. The results indicate that guidance performance can be modeled as a guidance policy based on a simple closed-loop mass-point model.

Windridge *et al*. [78] address modeling driving behavior with the goal to classify driver intentional behavior using a perception–action (P–A) hierarchy with a future goal to support intelligent driver assistance. Percepts are discrete internal representations of observable objects for an embodied cognitive agent, actions cause changes in percepts, and intentions are planned actions performed by the embodied agent. Thus, such models consider that one's perceptual domain is learned in response action outcome so that it is appropriately maintained in relation to one's motor capabilities. Intentional behavior is characterized by a high-level perceptual goal that requires subtasks to be carried out, each with lower-level perceptual goals. The authors classify driver intentions with respect to *a priori* extended control model (ECOM) [79] and highway code derived driving protocols by linking the *a priori* ECOM intentions to stochastic low-level features such as computer vision, eye gaze, and control inputs. The authors perform a proof of concept evaluation of the model with respect to logic-based methods. The results indicate that a deductive model provides better intentional classification performance due to the structure the driving environment.

Human–robot interaction (HRI) plays a major roles in SMCS [80]–[103]. Because remotely piloted vehicles (RPVs) have the potential to be a significant component in commercial aviation, the Federal Aviation Administration in the U.S. is developing new policies, procedures, and approval processes for them. Prior research and development to improve the HRI of RPVs has largely focused on flight and navigation, while support for the acquisition of data and mission-related information is less studied, particularly for small-scale systems. In this issue, Peschel and Murphy [104] focus on the mission specialist role in human–RPV teams and identify the human–machine interfaces used in practice.

Subjective rating techniques [105] may be useful but researchers in HRI have been looking for ways to enhance their utility by integrating them with other measures. In this issue, Swangnetr and Kaber [106] develop an algorithm using physiological responses and subjective ratings of valence (happy/unhappy) and arousal (excited/bored) for patient emotional state classification. In an experiment with 24 senior center residents, two subjective measures of emotion, arousal, and valence were significantly impacted by robot feature settings. The algorithm shows promise for future service robot real-time detection of patient emotional states and behavior adaptation in the healthcare setting. This method may be an option in domains where using facial expressions via image processing (e.g., see [107]) fails.

Prosthetics and assistive technologies are important application areas for the SMCS (see for example [108]–[114]). In this issue, Gurari and colleagues [115] show that one need not overload the visual channel to provide proprioceptive information. Using the psychophysical method of constant stimuli [116], with a reference stiffness of 290 N/m, the authors quantified performance of healthy participants in a spring discrimination task where motion cues were relayed visually and/or proprioceptively. Their participants perceived proprioceptive motion to be more useful than visual motion for the experimental task. These results show promise for the upper limb prosthesis experience. The authors also describe a novel experimental apparatus that mimics the usage of a myoelectrically controlled upper limb prosthesis in a spring discrimination task.

HMS research continues to address different modalities for human input and output. Such research includes finger print recognition [117], [118], face recognition [119]–[121], handwriting recognition [122], [123], haptics and associated tacile displays [124]–[131], neural models and brain–machine interfaces (BMI) [132]–[138], olfaction [139], speech and speaker recognition [140]–[142], visual system modeling and recognition, coordination, and gaze interaction [143]–[159]. With respect to support for the sight-impaired, Keefer *et al.* [160] describe the development of a stochastic Petri net (SPN) [161] for use in the development of a voice user interface (VUI) of a mobile reading device for the blind. A decision ladder [59], [162], [163] was used to describe the interaction. Task analytic methods were used to develop a model and grammar for the VUI. Three field studies with blind participants were conducted to develop and refine the models and the development of the SPN.

Body sensor networks (BSNs) provide new opportunities for input from wearers (see for example [164]–[169]). In this issue, Fortino and colleagues [170] present their approach to the development of BSN applications. They lay out the requirements and then describe SPINE, an open-source programming framework, designed to support rapid and flexible prototyping and management of BSN applications. They evaluate SPINE's computational performance (execution time, memory usage, energy consumption, and communication bandwidth). They define and implement an application profile using SPINE, CodeBlue, and Titan. They indicate the benefits from using SPINE in this case. They also present applications implemented using SPINE (physical activity recognition and rehabilitation support, handshake detection, emotional stress indication, physical energy expenditure estimation, and gait analysis).

Research in group decision making, communication, and computer supported collaborative work [171]–[186] continues to advance while hand gesture recognition improves [169], [187], [188]. In this issue, Cornelius *et al*. [189] present a framework for characterizing approaches for communicating gestures in a virtual environment. This study compares the use of natural gestures (natural hand videos projected on the drawing surface) with virtual-sketching (sitting at separate tables where pairs could hear but not see each other while they sketched together in a shared virtual drawing space created by the virtual sketching tool) and face-to-face gestures (jointly sketching while sitting next to each other at the same table, using an electronic drawing tool). The users' cognitive workload (mental demand, physical demand, temporal demand, performance, frustration level, and effort) was significantly reduced when natural hand videos were added to a virtual-sketching environment. These results suggest that natural gestures provide benefits over sketched gestures in terms of reduced cognitive workload and may warrant incorporation in collaborative design tools.

These ten papers thus help to continue SMCS's legacy in HMS. In the short term, future issues of THMS will continue to "inherit" papers from the former *Parts A* and *C* and benefit from the efforts of the prior EiCs, AEiCs, AEs, reviewers, and authors. I invite you to reap those benefits and encourage you to participate with new submissions and review opportunities as we move forward with this "new" HMS journal.

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