Technical Committee on Healthcare and Medical Systems

The overarching goals of the IEEE Control Systems Society (CSS) Technical Committee on Healthcare and Medical Systems (TC-HMS) are the understanding of medical conditions and the optimization of related medical interventions, also extending to health-care delivery, epidemiology, behavioral health, and neuroscience. These research efforts address timely topics of great societal importance and high public impact that are enabled and underpinned by control systems theory and technology. TC-HMS has broad interests and supports activities in all themes that involve the use of mathematical modeling and control in biomedical settings and implemented on mHealth/mobile/implanted/wearable platforms.

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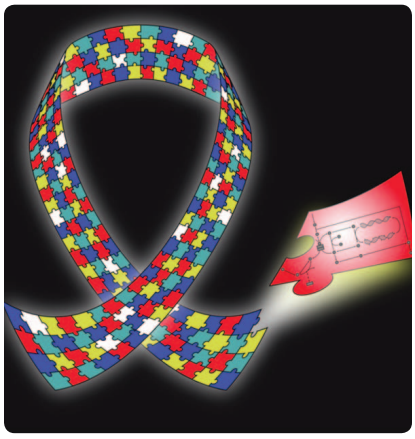
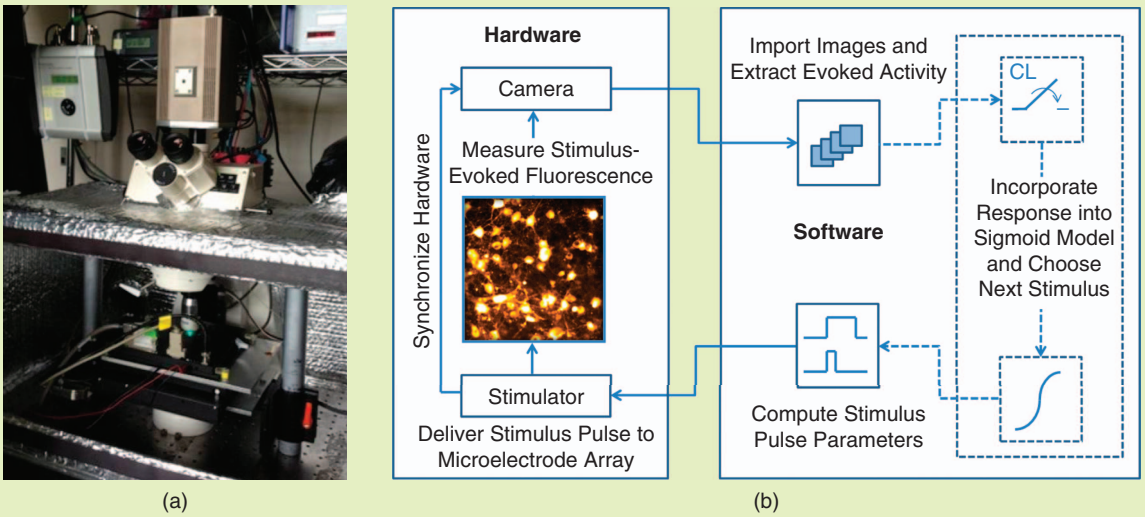


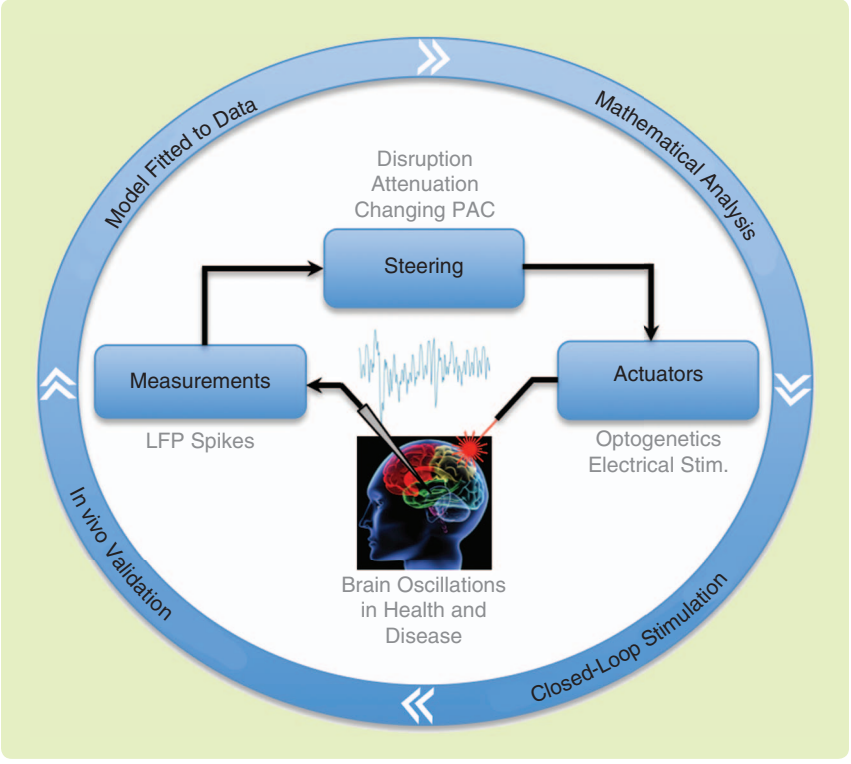
Jurgen Hahn at the Rensselaer Polytechnic Institute and collaborators have been working on using systems approaches on biomedical data related to autism spectrum disorder (ASD). A multivariate statistical approach on measurements of several metabolites is able to predict if an individual has ASD or is neurotypical with a very high degree of accuracy. No existing test for ASD currently exists. These results are a very promising step in this direction [1].

TC-HMS currently has 48 members. Daniel Rivera established the committee and chaired it from January 2013 to December 2014. Caterina Scoglio has been the TC-HMS chair since January 2015. Among the topics of interest currently pursued by the membership are anesthesia modeling and delivery, HIV treatment, stroke rehabilitation, the development of assistive devices and therapeutics, diabetes management and the artificial pancreas, the analysis of electronic medical records, epidemic networks, cancer treatment, deep brain stimulation, the quantification of symptoms, electrocardiography, the prevention and treatment of drug abuse, behavioral health care, and rehabilitation robotics. The figures in this column illustrate a sample of projects from TC-HMS members.

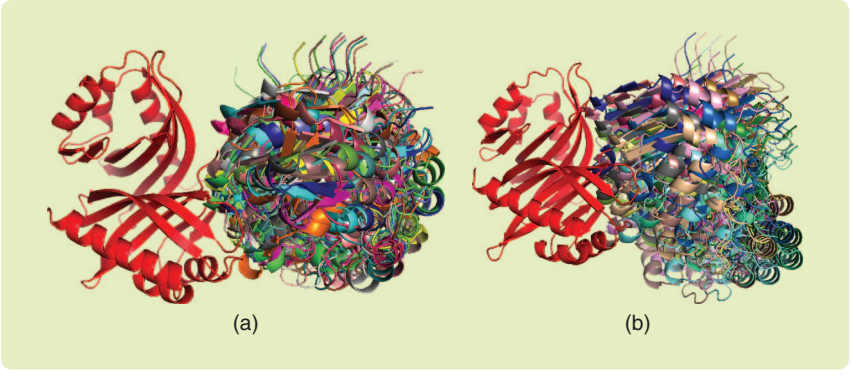
TC-HMS has been active in organizing invited and special sessions



Martha Grover at the Georgia Institute of Technology and collaborators are developing the open- and closed-loop system of electrical stimulation, optical recording, automated image analysis, and activation-curve modeling. (a) A picture of the system apparatus. A camera is mounted atop a microscope with an inline piezoelectric actuator connected to the 20× objective for high-precision focal plane adjustments. Light-emitting diode fluorescence excitation is digitally controlled, eliminating the need for a shutter. The neuronal culture lives atop the microelectrode array, which is nested inside of the heated multichannel systems preamplifier. Imaging is carried out inside an enclosure to eliminate ambient light exposure and reduce the effects of other environmental factors, including the laboratory heating and ventilation. The preamplifier is housed inside this "light tight" imaging chamber and interfaces with the external stimulator. (b) The hardware for delivering electrical stimuli and for optically recording evoked responses (left) interfaces directly with the Matlab-based software system (right) [2].

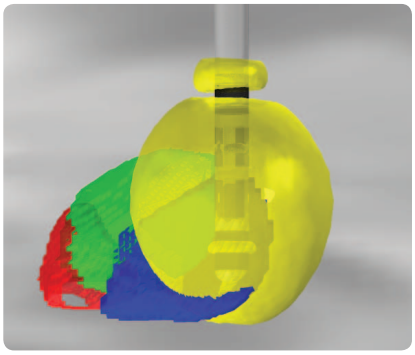


Antoine Challet at CentraleSupélec, France, and collaborators are developing realistic closed-loop strategies to alter targeted brain oscillations, in view of the variety of technological means now available to influence brain activity (electric, magnetic, optic, and pharmacologic). The employed models rely on oscillators and neural-mass models that take into account axonal transmission delays and the spatiotemporal nature of brain oscillations [3]. Experimental assessment of these techniques is ongoing, with neurosurgeons S. Palfi and S. Senova of H. Mondor hospital, in the framework of the ANR project SynchNeuro.



Ioannis Paschalidis at Boston University and collaborators are developing realistic representations of local rotational and translational grids employed by the high-throughput protein interaction scoring methods: (a) rotation and (b) translation. The receptor molecule, shown in red, is fixed. Ligand orientations correspond to different grid points and are shown in different colors. The initial ligand orientation that defines the center of the cluster was taken from global docking simulation. For clarity of the picture, only 20 rotations out of 3200 are shown for this complex. Note that only relatively small rotations are employed in the local resampling procedure [4].

during the American Control Conference (ACC) and IEEE Conference on Decision and Control (CDC). During CDC 2015 in Osaka, this TC (with organizers Alexander Medvedev and Ming Cao) co-organized an invited session, "Biological Oscillators" (TuA17) with the TC on Systems Biology, to



Alexander Medvedev and collaborators at Uppsala University and the Uppsala University Hospital, Sweden, are working on the optimization and individualization of deep brain stimulation (DBS), a well-established treatment in neurodegenerative diseases, such as Parkinson's disease (PD). It consists of delivering electrical stimuli to a target in the brain via a chronically implanted lead. To expedite the tuning of DBS stimuli and guide medical personnel to the best therapeutic effect, patient-specific mathematical models have been developed. The image depicts DBS in a PD patient with the subthalamic nucleus (STN) selected as the target. Motor (blue), limbic (green), and associative (red) circuits of the STN are depicted. A preoperative MRI image, with conductivity segmentation used in the calculation of the stimulated area (in yellow), is shown in gray scale in the background. The motor STN circuit is to be covered by the stimulation, while other parts of the STN must be avoided. This is achieved by posing an optimization problem in three dimensions over solutions of a partial differential equation [6].

celebrate 50 years of Goodwin's oscillator. The session focused on clocks, rhythms, and cycles that are ubiquitous at all levels of a biological system, from a single cell to a multicellular organism. The included talks aimed at demonstrating the diversity of mathematical techniques that are applied in studies of biological oscillators as well as the broad scope of the ongoing research.

This committee organized two invited sessions for ACC 2016 in Boston. The first was proposed by Caterina Scoglio and Alexander Medvedev, "Mathematical Modeling of Diseases and Medical Intervention Effects" (WeB12). The session talks were devoted to the mathematical modeling of diseases as well as the assessment of therapies and treatment strategies.

The second session, "Application of Control Theory in Legged Locomotion" (ThC10), was organized by Robert D. Gregg and Koushil Sreenath and coendorsed by the TC on Manufacturing Automation and Robotic Control. The goal of this invited session was to bring together leaders in the control of legged locomotion from the control, dynamics, and robotics communities to exchange ideas and exhibit complex experimental systems. Caterina Scoglio and Fahmida N. Chowdury also organized a special session, "Role of Controls and Systems Science in Health-Related Research." This session consisted of an introduction and four presentations, followed by a panel discussion, with participation of a National Science Foundation program director and the audience.

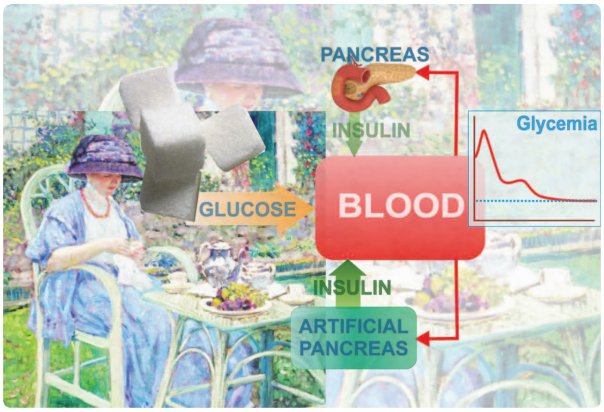
For ACC 2017 in Seattle, Caterina Scoglio and Alexander Medvedev organized the invited session "Computational Models in Health and Care" (WeA04). It consisted of papers addressing a range of problems in medicine and care by applying mathematical and computational modeling of processes and systems. For CDC 2017 in Melbourne, TC-HMS has proposed two invited sessions: "Dynamics in Neuroscience: Modeling, Estimation, and Control" (organizers: Alexander Medvedev and Warren Dixon) and "Individualization and Optimization of Therapies" (organizers: Levente Kovacs, Alexander Medvedev, and Pasquale Palumbo). The former highlights the role of dynamical systems in neural systems, while the latter gives an update of the latest developments in individualization and optimization of therapies in a number of medical fields.

TC-HMS, in cooperation with the IEEE CSS TCs on System Biology and System Identification and Adaptive Control, is organizing a special issue for *IEEE Transactions on Control Systems Technology* on system identification and control in biomedical applications.

TC-HMS member Ioannis Paschalidis was the chair and organizer of the Smart and Connected Health (SCH) PI workshop in Boston, Massachusetts, on March 20–22, 2017. The workshop's goal was to identify new opportunities, meet others in the field, enhance and strengthen multidisciplinary directions, and develop a longer-term agenda for SCH research areas that include the potential scientific benefits, novel exploration, and challenges involved in advancing smart health, especially in connected communities.

TC-HMS maintains a webpage at http://healthcare-and-medical-systems.ieeecss.org, with a list of all members and their affiliations. Contact and research interest details are available under the Member Roster tab. Future meetings and activities are announced under Events, while minutes of previous meetings can be found under Documents.

We would like to thank all TC-HMS members who have helped in the past three years. Special thanks to Filippo Cacace and Pasquale Palumbo for leading the meetings at CDC. A broader participation is highly encouraged. Interested people can easily get involved by participating in the TC-HMS meeting during the ACC and CDC, which are open to all interested, or by sending an e-mail to Caterina Scoglio (caterina@ksu.edu) or Alexander Medvedev (alexander.medvedev@it.uu.se).



Pasquale Palumbo at IASI-CNR Rome and collaborators are working on a project on the artificial pancreas (AP), based on the design of control laws for type 2 diabetes mellitus (T2DM), that is, for patients with an impaired and/or insufficient endogenous insulin delivery rate. A model-based approach is followed, with the control law designed by properly exploiting a minimal model of the glucose-insulin system, a delay differential equation system able to account for the nonnegligible insulin production of T2DM. Past research investigated the use of feedback linearization with delay cancellation to track a desired glucose profile and showed safe and efficient results as well as a good level of robustness with respect to the many technological limits in real-time sensors and insulin pumps. Simulations have been carried out on a population of virtual patients, built according to a different, independent model recently accepted by the U.S. Food and Drug Administration as a substitute for animal trials. Present research is dedicated to the design of a model-based, global sampled-data controller, synthesized according to Sontag's universal formula, to provide a closed-loop stable system in the sample-and-hold sense. The input-to-state stability redesign method is used to attenuate the effects of bounded actuation disturbances and observation errors [5].

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Alexander Medvedev