Special Issue on Artificial Pancreas Systems

This issue of *IEEE Control System Magazine* presents an introduction and six feature articles that constitute a special issue, "Closed-Loop Control of

Glucose Concentration for People with Type 1 Diabetes—Artificial Pancreas Systems." The introduction is written by Ali Cinar, the organizer of the special issue. Diabetes, in particular type 1 diabetes, is a challenging control problem that has long been studied in the community [1]–[4]. The main challenges in developing artificial pancreas (AP) systems stem from the complexity of glucose homeostasis, the nonlinearities and time-varying changes of the blood glucose dynamics, the occurrence of nonstationary

Contributors

Warren Dixon testing out his custom upper-arm exoskeleton for challenge-based rehabilitation studies.
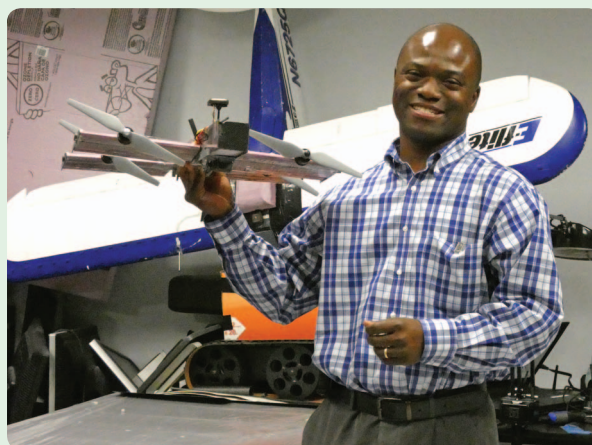
Kingsley Fregene in his Unmanned Aerial Vehicle Lab.

(From left) Eyal Dassau, Francis J. Doyle III, and Howard C. Zisser.

Steve Yurkovich (right), enjoying a round of golf in Hawaii on the Big Island.

disturbances, time-varying time lags in the measurements and insulin infusion, and noisy data from sensors. The six features in this issue present new algorithms and methodologies that address many of these critical challenges in an AP design.

The features begin with "Glucose Sensor Dynamics and the Artificial Pancreas," authored by Lauren M. Huyett, Eyal Dassau, Howard C. Zisser, and Francis J. Doyle III. This article provides a framework to explore the return on investment gained by reducing the glucose sensor diffusion lag, using methods from control theory in combination with simulation studies.

The next feature is "Insulin Estimation and Prediction," by Jorge Bondia, Sergio Romero-Vivó, Beatriz Ricarte, and José Luis Díez. This article considers the design of estimators for the amount of insulin in the patient based on suitable pharmacokinetic models that could be used to control the insulin delivery. The authors discuss the challenges associated with the high variability present in key physiological processes and the resulting impact on the model prediction. The feature "The Artificial Pancreas and Meal Control," by Anas El Fathi, Mohamed Raef Smaoui, Véronique Gingras, Benoit Boulet, and Ahmad Haidar, presents a tutorial on various aspects related to glucose control following meals, with a particular focus on the clinical implications.

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Mirko Messori, Gian Paolo Incremona, Claudio Cobelli, and Lalo Magni contributed the feature "Individualized Model Predictive Control for the Artificial Pancreas," which presents three techniques to individualize the linear models of the patient used to synthesize customized model predictive controllers for an artificial pancreas. The article "Multimodule, Multivariable Artificial Pancreas for Patients with Type 1 Diabetes," by Kamuran Turksoy, Elizabeth Littlejohn, and Ali Cinar, presents a multivariate adaptive AP system to handle the numerous design challenges. In particular, the adaptive control system can tolerate unpredictable changes in a system and the external disturbances by quickly adjusting the controller parameters without any need for knowledge of the initial parameters or conditions of the system.

The final feature, "Overnight Hypoglycemia and Hyperglycemia Mitigation for Individuals with Type 1 Diabetes" by B. Wayne Bequette, Faye Cameron, Bruce A. Buckingham, David M. Maahs, and John Lum, discusses a Kalman filter that was developed to estimate the glucose level in a patient. A series of clinical studies involving participants from ages 4 to 45 have demonstrated the effectiveness of this system in reducing the risk of overnight hypoglycemia. A similar system is currently commercially available (with a prescription).

"From the Editor" presents "Getting Involved in the IEEE Control Systems Society," which discusses the dependence of the IEEE Control Systems Society (CSS) on volunteer support and encourages readers to reach out and get involved. In the "President's Message," Francesco Bullo continues with the topic in "The Visible Values of Volunteering in the Hidden Technology World," in which he notes that there is always an opportunity and a need for engagement
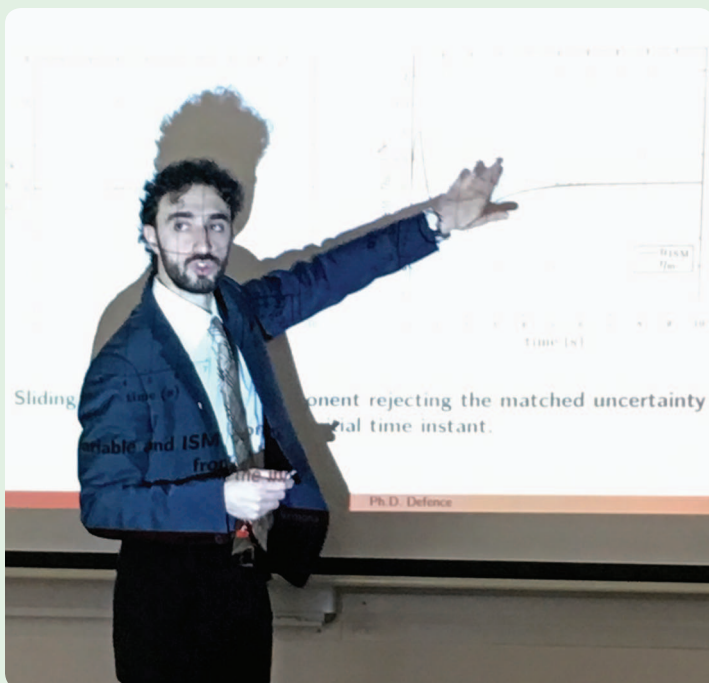

Faye Cameron

John Lum

Lauren M. Huyett at Duomo Milano.

Gian Paolo Incremona defending his Ph.D. thesis.

B. Wayne Bequette pole vaulting.

Beatriz Ricarte

Anas El Fathi

Mirko Messori defending his Ph.D. thesis.

in the CSS. Since most roles within the CSS have term limits, there is always a need for the next generation of volunteers to lead. "CSS News" solicits nominations for the CSS Board of Governors. "People in Control" has interviews with John S. Baras, the 2017 recipient of the American Automatic Control Council (AACC) Richard E. Bellman Control Heritage Award; Jacquelien M.A. Scherpen, who presented one of the semiplenaries at the 2017 American Control Conference; and Ketan Savla, the 2017 recipient of the AACC Donald P. Eckman Award.

"Technical Activities" provides updates from Warren Dixon on the IEEE Technical Committee on Intelligent Control and Kingsley Fregene on the IEEE Technical Committee on Aerospace Control. "Conference Reports" has an article by Steve Yurkovich on the Inaugural IEEE Conference on Control Technology and Applications (CCTA 2017) held on the Big Island of Hawaii along the Kohala coast on August 27–30, 2017 and a summary by Martin Steinberger, Martin Horn, and Leonid Fridman on the 2017 Summer School on Sliding Mode Control held at Graz University of Technology, Austria, September 4–8, 2017.

Among the regular columns, "25 Years Ago" revisits the article "Modified Root Locus Plots for SISO Systems with Time Delay" by Jeremy J. Gribble. "Conference Calendar" lists upcoming conferences sponsored or cosponsored by the CSS. "Book Reviews" provides a discussion by Jeff T. Scruggs of *Hydrodynamic Control of Wave Energy Devices*, authored by U.A. Korde and J.V. Ringwood. "Book Announcements" contains summaries of books recently published in the control field. "Obituary" presents memories of Roberto Tempo by Fabrizio Dabbene and B. Ross Barmish. Finally, "On the Lighter Side" illustrates the "The Adaptive ProfessionAL."

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