Joules in Motion

A fluid is a large-scale system. When a large number of objects, such as molecules, move in concert, we recognize the impracticality of keeping track of each object. The concept of flow provides a useful and intuitive model of the motion of the system. Although cars and trucks are far larger than molecules, we routinely use fluid analogies to model traffic flow.

The concept of flow is pushed yet further when we talk about energy flow, with heat flow as a special case and whose rate of flow is power. Intuitively, energy as a fluid seems quite natural; when the energy in one body is transferred to another body, we think of this transition as being due to flow. Although neither Newton nor Lagrange nor Lyapunov whisper a word about energy flow in the analysis of dynamical systems, it's common to hear researchers explain the dynamics of a system in these terms.

In control, we often need to move energy around in a way that minimizes losses and maximizes efficiency. What we want, in effect, is to efficiently control the flow of energy. So why don't physical theories treat energy as a fluid?

What is fascinating about this issue of *IEEE Control Systems Magazine (CSM)* is that we have two articles that do just that. The leadoff article by Peter Gawthrop and Geraint Bevan is a tutorial on bond graphs. By using pictorial representations and power balance, bond graphs provide an energy-flow-based technique for modeling and representing dynamical systems. The next article, by García-Canseco, Griñó, Ortega, Salichs, and Stankovíc, analyzes energy transfer in power circuits using the notion of cyclodissipativity.

The third article, by Sciarretta and Guzzella, also concerns energy flow, in this case within the context of hybrid vehicles. Optimal control of hybrid vehicles is fundamentally a task of energy flow management, involving the fuel supply, the internal combustion engine, the batteries, the

Contributors

Eloisa del Carmen Garcia-Canseco with her husband Miguel Alonso.

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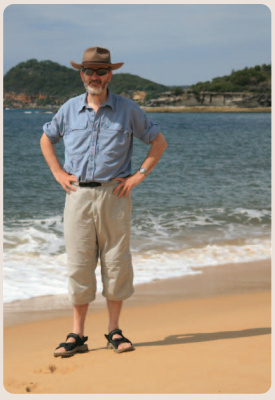
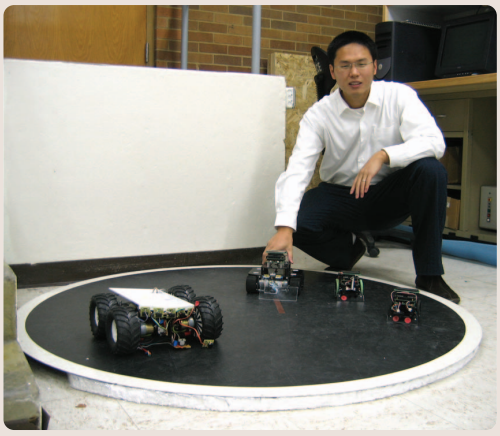


Peter Gawthrop



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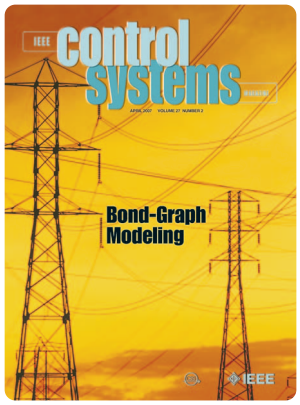
vehicle itself, and the regenerative braking system. The interplay of sources and sinks in a hybrid vehicle is a control engineer's dream.

Finally, the fourth article, by Ren, Beard, and Atkins, involves flow, not of energy, but of information. Through the flow of information between nearest neighbors, a collection of vehicles can arrive at an agreement, as a kind of information balance. The analogy to energy is almost perfect.



In addition to the serendipitous juxtaposition of these articles, I am pleased to note that the article by Gawthrop and Bevan is a special invited contribution. During a visit I made to the University of Glasgow, Peter was kind enough to explain to me some of the subtleties and benefits of bond graph models. I promptly invited him to write a tutorial on the subject to enhance the accessibility of the topic for *IEEE CSM* readers. He and Geraint undertook this major task and produced an outstanding article of lasting value. Their article is essentially the kickoff article of a planned series of articles on modeling. Future modeling articles will explore alternative modeling concepts that are important to systems and control practitioners and researchers.

In addition to the four feature articles, this issue includes all of the standard columns, including "Feedback" (your letters), "25 Years Ago," and the "President's Message." For "People in Control," we talk to Thomas Vincent and Katalin Hangos, while for "Applications of Control" we hear about robotic vacuum cleaners and lawn mowers. We have four book reviews on diverse topics, and we have reports on two workshops. With sadness we remember George Saridis and W.P. Dayawansa.

Finally, we replace the "New Products" column with "Product Spotlight," which focuses on a single new product with details of development, potential uses, and technical specifications. Vikram Kapila, corresponding editor for new products, seeks your suggestions for future installments of this column.

Please write to me about any aspect of the magazine. Tell me—and all *IEEE CSM* readers—what you like and what you don't like, and share your ideas with us. We are your magazine.

See you in June!

Dennis S. Bernstein