What's Inside

Modern control theory dates from around 1960, when frequency response functions and Laplace transforms were eclipsed by state-space models. State-space models per se were not really new; differential equations have been studied since the advent of the calculus. What perhaps was new was the mating of matrix theory with differential equations to provide an all-encompassing framework for control, especially extensions to nonlinear systems and the ability to exploit time-domain stability methods, in particular, Lyapunov's method, which lay dormant for half a century.
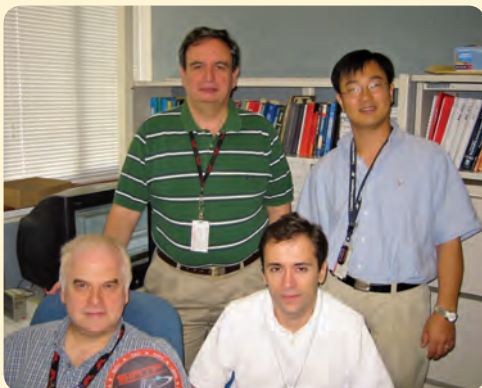
Contributors

Andrew Harvey hiking in the Pyrenees.

John Ringwood with his wife Laurina in Portpatrick, Scotland, and (left) with his sons Rory (on right) and Seán in Nice, France.
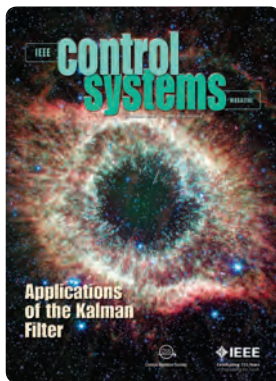

(From left) David Bayard, Dhemetrios Boussalis, Paul Brugarolas, and Bryan Kang.

Bryan and Hyeon Kang with daughters (from left) Shanna, Simone, and Sophia at Big Bear Lake.

What the state space provided was a way to capture the internal workings of a system. An input-output model in terms of the Laplace variable doesn't provide much insight into what's going on inside. In contrast, a state-space model allows us to look at each state and decide whether the behavior of the state is desirable.

What really was new and remarkable about state-space models is controllability and observability. These concepts are intuitive but nevertheless remarkable in their ironclad rigor and innumerable ramifications. But intuitive does not mean obvious: I find it continually surprising that a state-space model with 50 states can be controlled (at least in theory) by a single input. For design purposes, controllability and observability tell us how to choose and place sensors and actuators to make a system do what we want it to do.

Observability has the remarkable consequence that it's possible to estimate the states of a system that are not measured directly. This is the role of an observer, which may in addition be statistically optimal in the presence of noise, in which case the observer is an estimator. An estimator can thus serve as a noise filter, where the model is used to mitigate the effects of noise. The estimated or filtered states might be used for guidance, prediction, or diagnostics, or perhaps for feedback control.

The Kalman filter is often motivated as a means for feedback control; but control need not be based on state

Juan Del Valle Gamboa (left) after hiking to the top of the active volcano Rincon de la Vieja, Costa Rica, and (right) trekking in one of Costa Rica's rainforest national parks.

Paul and Kiet Brugarolas with their children Julie and Timothy.

David and Pam Bayard with their daughters Ali and Katie (right) at Mount McKinley in Alaska.

Tristan Perez.

estimates, especially when the ultimate goal is to regulate specific outputs or when the values of the internal states are not of any particular interest. In fact, the overwhelming application of state-space models is for building observers and estimators as an end in itself. Observer-based control tends to rely excessively on models and states when such models and states are a distraction from the ultimate goal of controlling the system.

This issue of *IEEE Control Systems Magazine* (*CSM*) is the second issue of 2009 devoted to the Kalman filter, whose 50th anniversary occurs in 2010. The June 2009 issue of *CSM* explored large-scale applications such as weather forecasting, where nontraditional methods such as the ensemble Kalman filter were highlighted. In the present issue we focus on "bread-and-butter" applications of the type that have made crucial contributions to key branches of technology. The first feature, by Thor Fossen and Tristan Perez, describes the application of Kalman filter techniques to motion control of ships. The next feature, by David Bayard, Bryan Kang, Paul Brugarolas, and Dhemetrios Boussalis, presents a space application of Kalman filtering, in particular, calibration of the Spitzer telescope for infrared imaging. Economic forecasting is the topic of the feature by Andrew Harvey and Siem Jan Koopman, who discuss applications of Kalman filtering to economic issues such as inflation and unemployment. Finally, Yaakov Bar-Shalom, Fred Daum, and Jim Huang discuss applications of the Kalman filter to remote sensing when the source of the data is uncertain, for example, when multiple targets are present.

This issue also includes an "Applications of Control" column by Shane Lynn, John Ringwood, and Juan Del Valle Gamboa, who use an observer to estimate temperatures in an electric propulsion rocket engine.

For "People in Control," we speak with Masayuki Fujita, and we introduce the 2010 IEEE Control Systems Society President Roberto Tempo.

This issue brings us to the close of 2009. The year ends with an historic CDC held in Shanghai, China. Whether or not you are able to celebrate this unique occasion in person, let me take this opportunity to wish all readers a healthy and prosperous 2010.

Dennis S. Bernstein

Yaakov Bar-Shalom sailing the Syrah.

Shane Lynn (front) after a day surfing in Costa Rica with Ad Astra co-workers Rodrigo Vargas and Daithí de Faoite.

The Syrah.

Shane Lynn wakeboarding in County Roscommon, Ireland.