Late Is Early

Is doing nothing a viable control strategy? That question came to mind as I was reading the feature article of this issue of IEEE *Control Systems Magazine* (*CSM*) by Rifat Sipahi, Silviu-Iulian Niculescu, Chaouki Abdallah, Wim Michiels, and Keqin Gu. They write:

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This stability-seeking approach is known as the wait-and-act control strategy. The presence of properly timed multiple delays designed for waiting before executing a decision is an effective stabilizing control strategy.

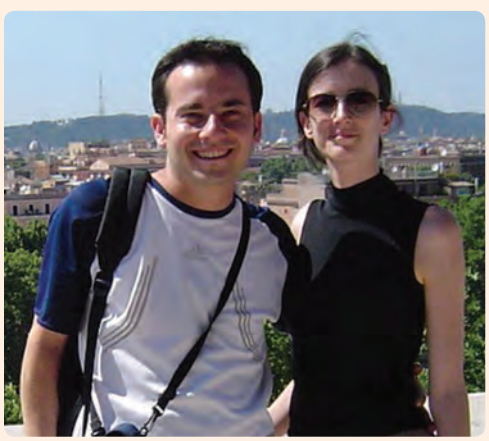
I imagined a control problem with the usual trio of challenges that we face in control, namely, dimensionality, uncertainty, and nonlinearity—numerous states and their combinatoric interactions; uncertainty in parameters, dynamics, noise, and disturbances; and nonlinearity due to dynamics, sensors, actuators, and constraints. The most powerful methods of analysis, synthesis, simulation, and approximation are applied. And the result is: Do nothing. In many situations this approach wouldn't be tolerated. Doing nothing can be

Contributors

Ilkay, Aydin, and Raymond de Callafon in Boston for the IFAC Mechatonics Conference in Septemer 2010.

Christian Gutvik with his wife Siv Anita at a conference banquet in Maui.

Chaouki Abdallah on night duty.

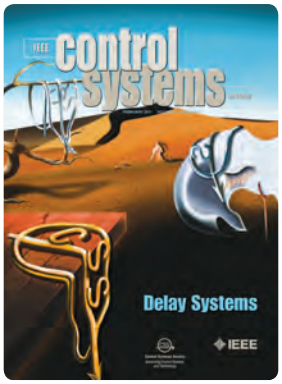


Rifat and Alix Sipahi visiting Rome.

Keqin Gu with his family on vacation in Alaska.

Alf Brubakk in Alagne, Italy.

perceived as weakness, and people demand action. Yet, the wisdom from this feature article is that in many cases the most judicious approach is to wait, observe, learn, plan, and then—and only then—begin to control. Such is the power of a delay.



A delay is merely a transfer function with unit magnitude. Unless we're talking about money and its natural discounting, a delay neither magnifies nor diminishes a signal. Rather, the effect of a delay is entirely due to its phase. Ebb versus flow. Wax versus wane. Sow versus reap. Phase matters.

Delays can destabilize, and they represent one of the most insidious challenges to control. In addition to dimensionality, uncertainty, and nonlinearity and the subtle and complex ways in which they interact, we must face yet a fourth challenge.

A delay that is known is an annoyance; it impedes performance and is difficult to compensate for, short of some kind of prediction, which itself is fraught with difficulties. But once we know the delay, even if it changes in a known way, then we are at least in a position to deal with it. Things get much more difficult, however, when the delay is unknown, even worse if it changes in an unknown way. Worse still, a system may have multiple delays, which can affect its behavior in yet more complicated ways.

The authors of this feature article on delay systems continue the discussion of delays begun in the feature article by Miroslav Krstic in the February 2010 issue of *CSM*. That article considers delay as a prototypical example of infinite-dimensional actuator and sensor dynamics, and develops control strategies to compensate for both known and unknown delays. Extensions of the Smith predictor provide an effective tool in this endeavor. In contrast, one of the underlying themes in the present issue of *CSM* is that delays can be beneficial. How can that be?

Many years ago, Vladimir Kolmanovski of the Moscow University of Electronics and Mathematics visited the University of Michigan and gave


Tor Arne Johansen with his wife Trude in Monaco.


Wim Michiels and Barbara visiting the Everglades.


Karl Iagnemma.


Gabe Graham working on a two-dimensional inverted pendulum stabilized by moment exchange wheels.


Christian Gutvik (to the right) on a diving trip with colleagues in Hitra, Norway.


Silviu-Iulian Niculescu visiting Portland.

Cover Artist

Shannon Mash is a native of Holly, Michigan. In 2010 she received the B.A. from the University of Michigan's School of Art and Design with a concentration in three-dimensional (3D) digital art and illustration. She has freelanced for the University of Michigan's Electrical Engineering and Computer Science Department, creating 3D renderings for various research projects. She is currently an intern at With a Twist Studio, which produced 3D effects for the movies *Alice in Wonderland*, *Knight and Day*, and *Wall Street: Money Never Sleeps.*

a seminar on how delays can benefit a system in terms of stability and performance. Prof. Kolmanovski gave several definitive examples to make the point. Years later, Chaouki Abdallah told me essentially the same thing. How can that be, I wondered.

And then I noticed something. While teaching the Nyquist criterion in classical control, I was emphasizing to the class that delay is "bad" since it warps the Nyquist plot clockwise and therefore has the potential to change the "correct" number of encirclements to the "wrong" number of encirclements. But phase is periodic, of course, and I realized that, at certain frequencies, the phase "lag" due to delay is greater than 180° and thus is really a lead—and therefore isn't necessarily "bad." In addition, it seemed possible that a time delay could even provide the "correct" number of encirclements needed for stability in an otherwise unstable system.

The two-edged nature of delays is explored in this feature article by analyzing the spectrum that arises from the nonpolynomial characteristic equation. The authors analyze the locations and movement of the poles as parameters change, and they use these insights to understand how intentional delays can be used to stabilize a system.

This issue also brings you an "Applications of Control" article by Christian Gutvik, Tor Johansen, and Alf Brubakk on the problem of decompression for divers. Divers who work at large depths cannot ascend quickly since gases may be released from the blood, resulting in severe complications. The solution is to ascend slowly, waiting at various depths for the pressure of the gases in the blood to reach ambient levels. The problem then is to determine the depths and length of time needed to reach a safe level of decompression, but not excessively. This optimal control problem is challenging due to modeling uncertainty, limited sensing, and nonlinearities, and its solution has a direct impact on human safety.

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For the "Ask the Experts" column, Raymond de Callafon and Gabe Graham respond to an inquiry about the use of accelerometers to measure the tilt angle of a robotic leg. What seems like a simple question turns out to be surprisingly intricate.

We also announce the 2010 Quarter Century members of IEEE Control Systems Society (CSS), that is, those members of IEEE who have been members of CSS for 25 years. This annual listing recognizes those individuals whose long-term support contributes to the publications, conferences, and other activities of CSS.

For "People in Control," we speak with Shuzhi Sam Ge, CSS vice president for member activities, and Alexis Ball, a Ph.D. candidate at Michigan State University.

Mark Denny, author of the article "The Tourbillon and How It Works," which appeared in the June 2010 issue of *CSM*, contributes another article of historical interest to the current issue. This article postulates that a variation of the centrifugal governor called the tangential governor, also known as the lag governor, was used for depth control in a torpedo that was in operation during the 1890s. Incidentally, Mark has written numerous articles on a wide range of scientific subjects (some on control) as well as several books. His latest book is titled *Froth!: The Science of Beer*.

In this issue, we report, with sadness, the death of Peter Dorato, a lifelong contributor to the control field. Peter will be greatly missed by all of those who knew him.

Finally, this issue announces the CSS award winners, and includes Rick Middleton's first president's message, three conference reports, one book review, numerous book announcements, and a twist on set diagrams.

We invite your letters on any aspect of this publication, as well as your proposals for contributions, either long or short. April arrives next.

Dennis S. Bernstein