FROM THE EDITOR

Digital Divide

Years ago, while I was teaching analog-to-digital (A/D) conversion to a lab class, I stressed the difficulty of obtaining true 18-bit data. The students seemed to follow the discussion about noise without any problem, so a question at the end caught me by surprise: "Isn't the Sony PlayStation 32 bit?" Somehow my lecture failed to explain why the data acquisition system in the lab was at least 14 bits inferior to a household video game.

In control applications, we continually cross the fine line between the analog and digital worlds. Both worlds have their advantages and disadvantages—analog signals have theoretically infinite resolution but are more susceptible to noise, whereas digital technology packs the analog continuum into neat bins but introduces quantization and discretization errors. There's a lot to worry about on both sides.

Given our reliance on digital technology, I sometimes wonder whether control theory has somehow slighted discrete-time systems. Among the several hundred books on systems and control sitting on my shelves, only a handful of books take a discrete-time approach. Why?

When I raise this question in casual conversation, I find that some of my colleagues take a view that can be summarized as "digital effects are a detail." Digital systems are continually getting faster, they argue, while sufficiently fast sampling makes discrete-time systems indistinguishable from continuous-systems. I guess the key word is "sufficient" since I'm thinking about those applications in which sampling speed never seems to catch up with requirements.

I believe, however, that there is a more basic reason why many theorists and practitioners favor the continuous-time setting, namely, that we have a much better feel for continuous-time dynamics than for their discretizations. Since we spend a lot of time thinking about the physics of the plant before we set up the A/D and D/A hardware, we become resistant to burying continuous-time insights in a blizzard of ks and $k+1$s. Unfortunately, dynamics are messier and less intuitive in discrete time. I've even seen engineers approximate digital control systems with s-domain block diagrams simply to give other engineers a better understanding of how the systems work.

TYRONE VINCENT

Dennis Bernstein on a hike inside Barrington Tops, a World Heritage area with a rain forest climate north of Newcastle, Australia.

Tyrone Vincent and Dennis Bernstein overlooking Nelson Bay, near Newcastle, Australia. Photo taken courtesy of a friendly Australian.

Discrete-time systems are also messier because of chaos. It's easy to find chaos in one-dimensional dynamics since trajectories can jump over each other, but one has to examine three-dimensional dynamics in continuous time to find it, which is exactly what Poincare and Lorenz did. Chaos would have undoubtedly been discovered much earlier had there been more interest in discrete-time dynamics.

Kalman's breakthrough state estimation paper was written for discrete-time systems. The analog analogue entails much more sophisticated and challenging mathematics, thereby providing the opportunity for researchers to publish impressive theory papers. Interesting math is perhaps one motivation for cherishing continuous-time models.

If our goal were to validate continuous-time models, we could use sampled data—the only real kind of data—to estimate physical parameters. But for model-based digital controller tuning, it makes sense to use the sampled data to construct discrete-time models. A true-blue digital control engineer would take discrete-time data, identify a discrete-time model, tune a discrete-time controller, and never look back.

The interface between the continuous-time and discrete-time worlds also provides opportunities for enhancing stability and performance. Instead of seeing aliasing as a scourge to be prevented, some researchers exploit the aliased frequency response to modify zeros, especially nonminimum-phase zeros, which drastically impede performance in analog linear time-invariant control. Likewise, replacing the traditional zero-order hold with a nonconstant sampled-data hold function provides the means to move nonminimum-phase zeros in advantageous ways. These effects are mathematically subtle but have real practical ramifications.

As a community of researchers and practitioners, we see these issues differently because we work with different problems with different features. Some of us work on one side of the dividing line, some work on the other, and some straddle the boundary looking for opportunities. This is what we do.

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IEEE Control Systems Magazine