More Mini Essays

COLORFUL DISTINCTION

In many disciplines, such as circuits and fluids, the goal is to model and simulate to better understand the real world. In control, our goal is to interact with the real world to make it do something other than what it might normally wish to do. This interaction requires that we keep careful track of what we know and don't know. For example, we know that a rigid body has an inertia matrix, but we realize that we may not know it precisely. To keep track of this distinction, we learn through experience in the controls field to make a mental note of the status of each quantity that we write down. But it occurred to me that a simple technique might make our papers easier to understand. For example, instead of writing the usual $\dot{x} = Ax + Dw, y = Cx$, where x is a state and w is a disturbance, we could write $\dot{x} = Ax + Dw, y = Cx$, where green indicates a quantity that we know and red indicates a quantity that we don't know. Readers of papers typeset this way will easily be able to identify the uncertainty status of each quantity and won't be forced to wonder "Does this algorithm require that I know the torque constant?" Perhaps *IEEE Control Systems Magazine* (*CSM*) will be the first venue to publish a paper that uses this device, but I won't hold my breath.

Dennis and his son Sam at the original Wright Brothers' bicycle shop, located in Dearborn, Michigan.

BEYOND ALGEBRA

Beyond using colors, it's also critical to keep track of calculations involving uncertain quantities. For example, if we multiply two variables whose values are known, then certainly we know their product. Thus, known × known = known. If, however, one of the variables is unknown, we obviously have known × unknown = unknown. Unknown begets more unknown. Matching conditions, which arise in robust control, consider the situation in which an unknown might be removable so that unknown × unknown becomes known. The first unknown in this product is a quantity in the plant, while the second unknown is a value that we hope to produce through feedback. In adaptive control a similar but more sophisticated situation arises. In this case it is merely assumed that there exists an unknown gain that can remove what is unknown in the plant. Hence, as in the robust control case, unknown × unknown = known. The resulting known quantity is then used to compute another quantity, say, the solution of a Lyapunov equation with known coefficients, which is used in the adaptive control law. This approach has been worked out in numerous books and papers, but without the benefit of colored fonts.

PUZZLING PARADIGM

Jigsaw puzzles seem like a pointless pastime—why take apart a picture only to put it back together again?

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Nevertheless, I like to think of jigsaws as a paradigm for research but with one key exception, namely, we don't get to look at the image when we start. As we develop tools, methods, algorithms, and theories for systems and control, we often seem to be assembling knowledge in bits and pieces. At first, only the border pieces are found, with those being the easiest. Then more subtle pieces are developed and linked up. Missing pieces can come from unlikely sources at unlikely times, perhaps over years or decades. As more of the "picture" comes into view, the still-missing pieces become more evident and help motivate research directions. With luck, progress speeds up. Then it's time for another puzzle.

In control, our goal is to interact with the real world to make it do something other than what it might normally wish to do.

BIGGER AND BETTER

When I mark up *CSM* articles, I sometimes find sentences that bother me for reasons I cannot always explain. In a recent epiphany, I realized why I hesitate when I read "simple solution" or "accurate model." The issue is the distinction between relative and absolute. In the world of modeling, we recognize that all models, no matter how painstakingly constructed, are ultimately erroneous. As off-putting as it sounds to say this, it's true. But some models are more accurate than others—the point being that accuracy is a relative term. Likewise, "simple" doesn't suggest a universal condition, but we usually agree on whether something is simpler than something else. The same observation applies to the word "general," since the best we can say is that one idea is more general than another. Saying that something is "relatively simple" doesn't solve the problem unless we know what "relative" refers to.

TRIDACTIC

Good things come in threes. When choosing examples to illustrate a new idea or technique, three seems to work well. The first example can illustrate the method in a transparent way, on a problem whose solution is already known and obtainable by existing methods. Nothing surprising, just illustration and assurance. The next example could be a problem that cannot be addressed by existing methods, thereby showing the strength of the method in advancing the state of the art. The last example applies the method to a problem that is not encompassed by the theory, and thus there is no guarantee that the method will work. If the method is successful, then the example, if not specially contrived, might suggest that the method is more powerful than the theory implies. If the method fails, then the example successfully "breaks" the method and shows its limitations. Both are interesting. Come to think of it, maybe four is a good number.

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MORE OR LESS RELEVANT

Does this magazine do a good job serving readers who work in industry? The same question could be asked of *IEEE Transactions on Automatic Control* and *IEEE Transactions on Control Systems Technology*, but *CSM*, which is received by all IEEE Control Systems Society members, has the explicit mission to be relevant to all members. Control engineers who work in industry know first and foremost that control systems must operate reliably and safely, and it is rare that a new technique is implemented for its own sake, as a kind of "pushing the envelope" experiment. Innovation in control is usually sought only when there is a compelling reason. To get a feel for what is relevant to practitioners, I used to read the trade publication *Control Engineering*. The articles in this publication gave useful guidelines and insights into "basic" control methods such as PID. But this publication recently went defunct, although probably not for lack of interest by practitioners in advice on practical methods. It's true that the overwhelming portion of articles in *CSM* are written by academics, a notable exception being the February 2008 issue on inertially stabilized platforms, where every article originated from industry. There are two main reasons for this situation. First, academics are expected to publish in the open literature as part of their job, whereas it's rare for an industrial project to require or even encourage publication. Second, technological innovation is often most valuable when it's kept confidential. When that isn't the case, a patent usually suffices. So it's hard for me to say that we're doing a good job providing material that is truly useful to practitioners. But we'll keep trying.

Dennis Bernstein