Around and Around

Suppose that you lived in a city or town where all of the streets were one way. Then, every trip from your home and back would form a loop. In a rough sense, your route would be hysteretic since the path that you take depends on the direction you wish to go.

For a dynamical system, hysteretic loops are not the classical phase plane plots in two state variables but rather are output-versus-input plots. Unfortu-

nately, these plots have no established name in the systems literature, so I'll simply call them *IO plots*. For an asymptotically stable linear system with harmonic input, the IO plot converges to an ellipse as a very special Lissajous figure for unequal-amplitude, phase-shifted sinusoids with a frequency ratio of one. The amplitude and phase shift of the output relative to the input are given by the transfer function evaluated at the input frequency. When the amplitude ratio is 1 and the phase shift is $90°$, the IO plot is a circle.

At different frequencies, the transfer function takes on different complex values, and therefore the shape, winding sense (clockwise versus counterclockwise), and orientation (for example, southwest to northeast) of the elliptical IO plot change with frequency. This complex number converges to either a positive or negative number as the input frequency approaches dc (that is, zero), and thus the elliptical IO plot collapses to a line segment. In other words, the loop vanishes in the static limit.

Contributors

Qingze Zou visiting Beidaihe, near Beijing.

Harbir Lamba with his niece Jasmine.

Alexei Pokrovskii with his wife Natasha and their dog Kuzya.

Gene Morelli

Ram and Mary Iyer in Rome.

Hugh McNamara

Now here is something that is both surprising and interesting: Some very special nonlinear systems have the property that, if you force them with a periodic signal and let the period of the input go to infinity, then the IO loop does not collapse but rather converges to a loop. The persistence of this loop in the zero-frequency limit constitutes hysteresis.

Why would such a loop persist? Consider a system with friction, in which the input is force and the output is displacement. If the loop is counterclockwise, then the area of the loop at every frequency is the amount of energy dissipated during one cycle. What this means is that if you take a book and slide it back and forth on your desk, then a certain amount of energy is dissipated, and that amount depends on how quickly you move the book. But here's the crucial fact: No matter how slowly you slide the book back and forth, you will always dissipate at least a certain amount of energy. Therefore, the IO loop has a minimum area at low frequency and thus does not collapse to a line segment, which means that you cannot expend an arbitrarily small amount of energy by moving the book sufficiently slowly. Consequently, friction is hysteretic. If you can imagine for a second that an analogous phenomenon occurs when rainwater enters the soil and then departs by evaporation, then you have an inkling of what the cover article for this issue of *IEEE Control Systems Magazine* (*CSM*) is about.

For this issue of *IEEE CSM*, Xiaobo Tan of Michigan State University and Ram Iyer of Texas Tech University serve as guest editors for a special section on modeling and control of hysteresis. In their introductory article, Xiaobo and Ram discuss the multifaceted nature of hysteresis as well as its role in engineering and scientific applications. Although as control engineers we are familiar with hysteresis as a useful element of many control systems, the goal of this special section is to examine the fascinating properties of systems that possess hysteresis as a natural consequence of nonlinear behavior. The applications addressed in this special section

Xiaobo Tan at Tsinghua University in Beijing

Linda and Bill Powers with their grandchildren (from left) Landon, Bryson, Payton (in Bill's arms) and Colby.

Philip O'Kane

Alexander Pimenov

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Michael Grinfeld

Denis Flynn

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include economic systems, soil-water dynamics, atomic-force-microscope position control, hysteresis inversion, and hysteresis arising from nonlinear feedback. I am extremely indebted to the organizers for their substantial effort in organizing this special issue and bringing it to completion.

In continuation of our series on reminiscences of members of our community, this issue includes a "Historical Perspectives" article by Bill Powers, who has had a long career in both academia and industry, including both aerospace and automotive applications. Bill's article includes valuable advice for all researchers and practitioners in the field.

For "Ask the Experts," Gene Morelli from NASA Langley explains some of the basic principles of identification based on flight data. Gene provides a short and sweet tutorial on the fundamental issues in working with flight test data for model building.

"People in Control" in this issue continues our discussions with editors of systems and control journals worldwide. This discussion began with interviews of Jie Chen and Brett Ninness in the October 2008 *IEEE CSM* and continues with interviews of Milan Mares and Li-Chen Fu in the present issue.

In 2008 we published two new regular columns, "Technical Committee Activities" and "Member Activities." Many thanks to Jay Farrell and Claire Tomlin for their contributions throughout the past year. In this issue, we transition these columns to new officers of the IEEE Control Systems Society.

This issue also includes four book reviews, including one that provides perspectives on stability theory, a subject dear to many in our community. In case you missed the live events, we also bring you reports on the Multi-Conference on Systems and Control held in San Antonio and the UKACC International Conference on Control held in Manchester, U.K., both during September 2008.

We end this issue with a variation on a famous icon, recast for our membership! Thanks to Jin Yan for constructing this eye-catching landmark.

Finally, this issue marks the start of a new year with many exciting projects in the works. *IEEE CSM* always has room for interesting control-related articles, either short or long. If you have an idea for an article, please contact me. Your letters are always welcome as well. See you in April!

Dennis S. Bernstein

Santosh Devasia in front of the Sydney Opera House, Australia.

Kam Leang on the Glacier du Géant, with the Dent du Géant (Tooth of the Giant) in the background, French Alps. (Photo credit Michael Trommsdorff).

Bojana Drincic (right), her father Dragan, and her sister Marija in Kotor, Montenegro.

Andrey Zhezherun