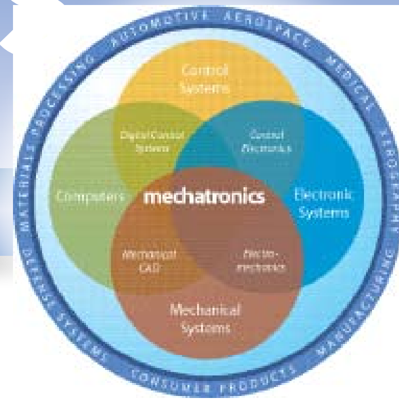
MECHATRONICS IN DESIGN

FRESH IDEAS ON INTEGRATING MECHANICAL SYSTEMS, ELECTRONICS, CONTROL SYSTEMS AND COMPUTERS IN DESIGN



How 'Observers' Enhance Closed-loop Control

BY KEVIN CRAIG

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Take a look at mechatronics' applications in diverse industries, such as automotive engine systems, hard-disk drives and Web-transport systems, and you'll find a growing emphasis on "sensorless control" and the use of "observers" in control system design.

These terms may be unfamiliar to you, but they are becoming increasingly relevant for design engineers as they decide on control systems for mechatronics' projects.

To understand why, let's look at a typical mechatronic system. From a cost and reliability perspective, engineers should use the fewest number of physical sensors possible and you want the physical sensors that you do use to perform optimally, despite noise and inherent response limitations. Also, certain mechanical variables necessary for control may not be measurable due to operational or environmental conditions. To help address these issues, we need to tap the physical and mathematical modeling that is essential in mechatronic system design. And we need to consider this concept of an observer.

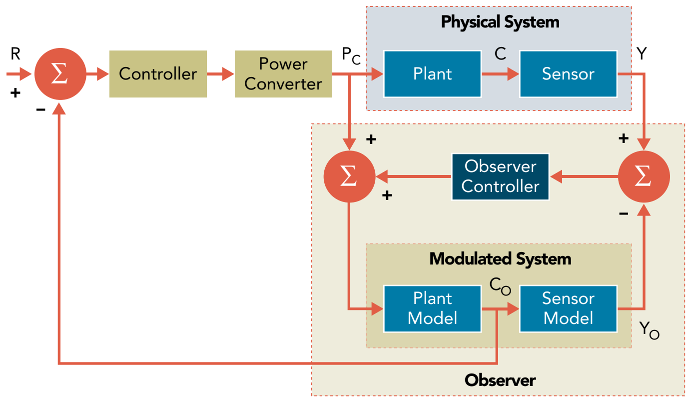
The principle of an observer works like this: By combining a measured feedback signal with knowledge of the physical plant and physical sensor, the behavior of the plant can be known with greater accuracy and precision than by using the feedback signal alone. An observer is a mathematical structure that combines actual sensor output and plant excitation signals with models of the plant and sensor. It compares the actual sensor output with the observed sensor output and it drives that error to zero with a high-gain PID-type compensator, the observer controller.

If you look at the block diagram on this page, you'll see there are five elements of an observer: the two inputs — the actual sensor output (Y) and the power converter output (plant excitation) PC — the model of the plant, the model of the sensor and the observer compensator. In the diagram, it is the plant output, C, that we wish to control. However, we only have access to C through the physical sensor, which is far from ideal. Physical sensors are dynamic systems with phase lag (time delay) and amplitude attenuation. However, in the observer structure, if the error between Y, the actual sensor output, and YO, the observed sensor output, is small, the observed plant state (CO) becomes a reasonable representation of the actual plant state, C. Certainly, it can be much more accurate than the actual sensor output, Y.

In this example, one application of the observer is to use the observed plant state (CO) to close the control loop, as shown in the diagram. The sensor output Y is no longer used to close the loop. Its sole function is to drive the observer to form an observed plant state, CO. As a result, you can remove most of the phase lag and attenuation of the sensor, in the frequency range of interest for the control loop.

In many such applications, observers can augment or replace existing physical sensors, which makes observers an excellent alternative to adding new sensors or upgrading existing ones. But keep in mind the four major components of observer design: modeling the sensor, modeling the plant, selecting the observer compensator and tuning the compensator. The main sources of non-ideal conditions in this observer structure are plant and sensor model inaccuracy, disturbances, and noise. You need to understand these factors well to effectively apply an observer as part of a control system design. But the potential benefits of observers, in terms of cost reduction, reliability and performance, can be enormous.

For further guidance on this important tool in mechatronics design, consult this valuable book, *Observers in Control Systems*, by George Ellis (Academic Press: 2002).



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