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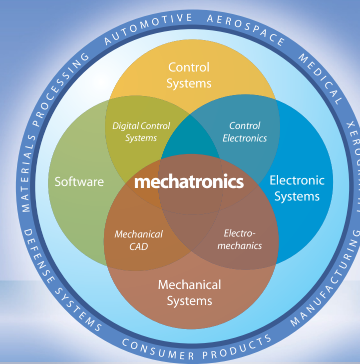
MECHATRONICS IN DESIGN

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



Control Design: Pervasive and Perplexing

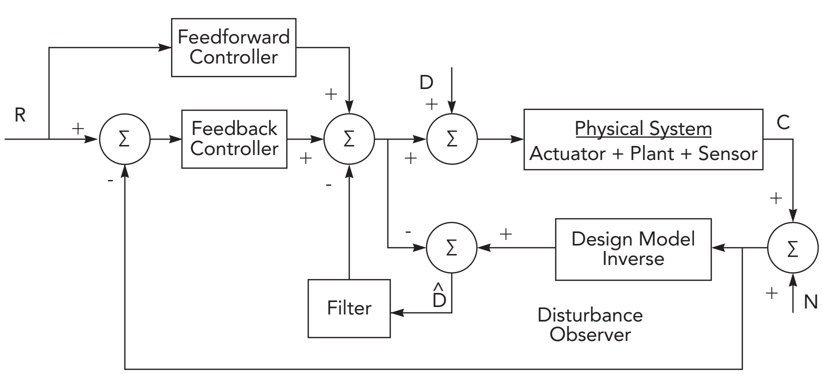
Feedback, feedforward, and a disturbance observer get the job done.

BY KEVIN CRAIG

Kevin C. Craig, Ph.D., Robert C. Greenheck Chair in Engineering Design & Professor of Mechanical Engineering, College of Engineering, Marquette University.

Control is a hidden, enabling technology that is present in almost every engineered system today. Despite this fact, control system design is still mysterious and often falls in the domain of a specialist. Today, every engineer must know how to create, implement and integrate a control system into a design from the start of the design process. An engineer needs to understand how to balance performance, low cost, robustness and efficiency to effectively accomplish these goals.

Evaluating a design concept is best done through modeling, not by building and testing, as modeling provides true insight on which to base design decisions. There is a hierarchy of models possible of varying complexity and fidelity, but a simple design model which captures essential attributes is the most useful, i.e., dominant dynamics. An integrated control system can enhance a design through stabilization, command following, disturbance and noise rejection, and robustness. All of this can be accomplished through a combined approach, rather than trying to accomplish all with a single feedback controller, as is too often the case.



To best understand this combined approach, I had extensive discussions with Dr. Rob Miklosovic, a leading mechatronics innovator at Rockwell Automation in Cleveland, OH. The diagram illustrates just such an approach.

The design model is typically used for both feedback and feedforward controller design. However, in practice, the physical system will deviate from that design model. A disturbance observer regards any difference between the physical system and the design model as an equivalent disturbance applied to the model. It estimates the disturbance and uses it as a cancellation signal. So in addition to enhancing disturbance rejection, the disturbance observer makes the physical system behave like the design model over a certain frequency range, thereby simplifying the design of the feedback and feedforward controllers. Since the design model inverse is not realizable, a unity-gain, low-pass filter, specifying the observer bandwidth, is added.

Next, the feedback controller is designed solely to force dynamic consistency by mitigating the effects of model uncertainty and disturbances, usually with high gain and integral control. A common mistake is made in designing the feedback controller for desired output with no regard for robustness, only to find poor performance when applied to the physical system. However, once consistency is enforced, the desired output can be augmented with a feedforward controller, typically the dynamic model inverse, to recover the dynamic delay of the closed-loop system with no effect on stability or properties of the closed-loop system.

The combination of a disturbance observer with both feedback and feedforward controllers is not new and many researchers have demonstrated its effectiveness. What needs to be done now is to bridge that theory/practice gap and put this technique into the hands of the mechatronics engineers responsible for creating the innovative systems we all need.

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