Guest Editorial
New Developments and Applications in Performance Limitation of Feedback Control

THIS special section is devoted to an area of research that studies the fundamental limitation and tradeoff of feedback control, a subject deeply rooted in the classical feedback theory. Indeed, classical control design frequently used loop-shaping ideas, which, though in an *ad hoc* way, took account of the need to balance various conflicting requirements, including the constraints dictated by Bode gain-phase relation. Modern control design makes use of more sophisticated tools that allow more complex situations to be handled, but these tools run the danger of obscuring insight otherwise useful for design. Performance limitation studies serve as an adjunct to modern control tools. They help a control system designer specify reasonable goals, and understand the inherent limits of a design and the interplay between conflicting design requirements. The understanding of performance limitations thus promises to be of intrinsic as well as practical value. With this perspective, we felt that it is both useful and timely to gather the contemporary research developments in this area of long history and yet continuing vitality.

What do we mean by "performance limitations of feedback control?" What is the importance of this area? What new contributions has the area brought to the theory and practice of control engineering? To answer these questions, we describe a philosophy of feedback control that we think is valuable in practical applications. This philosophy is based in part on our observations that: 1) it is rare, in practical control applications to complicated systems, that control design is a single cycle of modelling, performance specification, controller synthesis and implementation, but instead an iterative process of multiple iterations by its engineering nature; 2) in engineering of systems that include control loops, it is important that a control engineer be able to rapidly, but approximately, assess and predict the consequences of decisions in the system design and, consequently, make judicious modifications and revisions on the design. The purpose of this Special Issue, therefore, is to facilitate the understanding, and provide benchmarks and guidelines useful for this process. We are primarily interested in obtaining rapid, controller-independent limits on the achievable feedback control performance, and understanding the tradeoffs between various control attributes such as disturbance rejection, transient response, robustness, and noise reduction.

The area of performance limitations has a highly developed theory for the case of linear-time invariant feedback systems, beginning with the work of Bode in the 1940s on logarithmic sensitivity integrals, for open-loop stable single-input–single-output feedback systems. Bode's work has had a lasting impact on the theory and practice of control, and has been extended to multivariable systems, open-loop unstable processes, and other variants of the integrals such as Poisson sensitivity integrals, discrete-time and sampled-data systems, etc. As a common feature, works in this area seek to address such issues as: 1) what and how certain system characteristics may inherently constrain the performance achievable; 2) what and how conflicting performance objectives may necessitate design tradeoffs; 3) what are the fundamental performance limits? Recently, there has been an expansion of interest in both new perspectives on these areas, and understandings of more general problem classes, leading to new results and understandings for nonlinear systems, the influence of peak or average power constraints on actuation, tracking of multiple sinusoids, more general control settings, and applications of performance analysis in practical designs. The 10 articles that comprise this special issue contribute to the understanding of these problems, and address the performance limitations in the following aspects:

- design limitations of general control configuration (Freudenberg, Hollot, Middleton, and Toochinda);
- optimal tracking and regulation performance (Su, Qiu, and Chen; Jemma and Davison; Goodwin, Salgado, and Yuz; Chen, Hara, and Chen);
- discrete-time and sampled-data systems (Jemma and Davision; Schmid and Zhang);
- nonlinear systems (Lau, Middleton, and Braslavsky; Perez, Goodwin, and Seron);
- mechanical systems and process control (Havre and Skogestad; Iwasaki, Hara, and Yamauchi);
- performance analysis applications (Freudenberg, Hollot, Middleton, and Toochinda; Iwasaki, Hara, and Yamauchi).

These results are rather representative of the current state of performance limitation studies, which we commend to your reading.

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