The Science of Control

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The primary objectives of control are somewhat different from those of much of fusion plasma physics. Magnetic fusion physics has historically focused on understanding the physics of plasmas in magnetic confinement devices, while fusion plasma control seeks to capitalize on the understanding already gained to cause the system (fusion device plus plasma) to behave in certain desirable ways. For example, early uses of plasma control in fusion devices had simple goals such as extending the survival of discharges by minimizing plasma-wall interaction or by regulating density. Present applications are primarily aimed at achieving conditions with better potential fusion performance or conditions under which fusion plasmas can be more easily studied. The demanding performance requirements and significant constraints expected on control of future fusion reactors suggest that plasma control is a critical enabling technology for progress toward commercial fusion power. A greater understanding of control techniques for fusion plasmas and a more widespread use of these techniques in existing devices is required in order to develop the solutions needed.

The science of control is old [1] — much older than either the science of plasma physics or its application to magnetic fusion. The maturity of control theory and thousands of proven applications in dozens of disciplines imply that a wealth of techniques already exist for developing control solutions for fusion plasmas. This talk will provide an introduction to the language, concepts, and tools of this broad discipline. Some of the concepts introduced have counterparts in approaches that will be familiar to many physicists, but use a somewhat different language to describe those concepts.

Our focus in this presentation is to provide attendees with a basic understanding of the tools used to analyze systems and to develop controls for those systems, as well as some intuition for how these tools work and under what conditions to apply them. We first describe several ways in which systems to be controlled and the algorithms used to control them may be represented. We then describe the basic concepts behind feedback and feedforward control and introduce the metrics by which controlled systems are evaluated. Finally, we describe several frequently used control techniques and discuss their advantages, disadvantages, and areas of intended application.

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[1] Stuart Bennett, A Brief History of Automatic Control, IEEE Control Systems Magazine, June 1996, 17-25