General Systems Theory— A Control Systems Perspective

Rob Evans, Frank Barker, Iven Mareels

Engineering mechanisms employing feedback to regulate behavior have been used for 2000 years. Discussion of such ideas can be found in the work of Aristotle and is implicit in the work of Descarte on the scientific method and in Darwin's theory of evolution.

Rigorous scientific and mathematical foundations of feedback systems was initiated when James Clerk Maxwell developed a differential equation model to characterize the stability of Watt's steam engine governor. By the time the biologist Ludwig Von Bertalanffy introduced the world to General Systems Theory in 1936 the theory of feedback control mechanisms had become a cornerstone of the rapidly emerging fields of electronics and telecommunications through the work of Black and Nyquist at Bell Labs.

In 1947 Claude Shannon at Bell Labs developed an ingenious theory of information which established fundamental limits on the rate of transfer of information over noisy transmission channels. Around the same time Norbert Wiener and W. Ross Ashby building on the work of Turing, Shannon and Bode, attempted a qualitative synthesize of general systems theory, information theory and feedback control theory to form the new discipline of cybernetics. The economist Herbert Simon also contributed to this program.

The past 50 years has seen an explosive growth in both feedback control theory and general systems theory, and today the human race and planet earth face systems theory questions which if not properly resolved could spell disaster, and if properly resolved open vast new horizons in systems biology, ecology and neuroscience. For the past 70 years the foundational principles of general systems theory and feedback control theory have been intertwined in a double helix dance, evolving in many ways separately yet linking closely. The stage is now set. Does the massive corpus of feedback control theory impact in any meaningful manner with the life and death general systems theory challenges we face, if so how and if not why not?

In this chapter we summarize the key achievements of the two strands of the helix with a view to understanding their essential interconnections, reveal their strengths and weaknesses and explore the key ideas by arguing the case that feedback control theory in its present form can make a deep foundational contribution to key aspects of general systems theory. We further argue that the recent resurrection of Wiener's vision to incorporate information theory as an integral component of feedback control theory provides a broad and rigorous foundation for critical aspects of complex interconnected systems. We explore the ideas and interpretation of 'boundaries', 'black and white boxes', information flow and causality in the two stands of the helix.