Abstract

The aim of this research project was to investigate the benefits and shortfalls of Energy-Shaping controllers and use them to gain insight into industry standard control methods. Energy is a fundamental quantity in nature and is conserved due to the first law of thermodynamics. Actuators, necessarily, add energy into the system or remove energy from the system. Sensors remove (in some cases, negligible amounts of) energy from the system in order to measure some variable of interest. All control algorithms employing feedback, must measure at least one physical variable of the system to be controlled. Furthermore, all control algorithms must have at least one actuator in order to control the system. Hence, by proxy, all control algorithms affect the energy of the system. Two key ideas in energy shaping are: Energy Balancing and Power Shaping. Other control algorithms, ultimately, can be classed under these two ideas. Three constructive energy shaping algorithms were investigated, these were: Controller Interpolation via a common Lyapunov function, Energy-Shaping Robot control and Interconnection and Damping Assignment Passivity Based Control (IDAPBC). In this dissertation, a modelling paradigm has been proposed which is a multi-dimensional extension of *The Energy Method.* It is also shown that dissipation acts as a constant disturbance in the power of the system. A non-linear PI-like controller has been proposed to compensate for it. A clear link between the phase portrait and the system's energy is shown. By shaping the system energy, the phase portrait is altered and by shaping the phase portrait, the time domain performance is altered. In this dissertation, the various techniques used to shape a system's energy and power are all applied to the same non-linear control problem i.e. the simple pendulum. With hindsight, popular existing control strategies are reinterpreted via energy and power shaping. A notable example is that PID is shown to affect the potential and dissipation functions of the closed loop system. A pattern that emerged during the research was that: in order to fully control the system, it appears that the controller must be at least as computationally complicated as the plant. This is dubbed, the Controller Complexity Principle. A formal proof of it is a recommended research direction. The main conclusion of this work is that energy and power are concepts of tremendous value in control engineering. In this dissertation, energy and power are used to tie seemingly disparate work in control together. It is this re-interpretation of existing techniques in terms of energy and power which demonstrates the value of physical reasoning in control.