Chapter 8.7
Developments in Structural Optimization and Applications to Intelligent Structural Vibration Control

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ABSTRACT

The chapter introduces developments in intelligent optimal control systems and their applications in structural engineering. It provides a good background on the subject starting with the shortcomings of conventional vibration control techniques and the need for intelligent control systems. Description of a few basic tools required for intelligent control such as evolutionary algorithms, fuzzy rule base, and so forth, is outlined. Examples on vibration control of benchmark building and bridge under seismic excitation are presented to provide better insight on the subject. The chapter provides necessary background for a reader to work in intelligent structural control systems with real-life examples. Current trends in the research area are given and challenges put forward for further research.

INTRODUCTION

Civil engineering structures (e.g., tall buildings, long-span bridges, nuclear power plants), are an integral part of a modern society. Present trend in civil engineering is to build more flexible structures like long-span bridges and high-rise buildings. Dynamic loads (e.g., earthquake, wind gusts, wave forces, blasts), can cause severe vibratory motion especially for very flexible long span bridges and slender tall buildings (Soong, 1990). Protection of these structures, their material content and human occupants, against damage induced by large environmental loads (e.g., earthquake, strong winds) is no doubt a worldwide priority.

The control of structural vibration can be achieved by various means such as modifying structural rigidities, masses, damping, and by attaching external devices, known as control devices, either to dissipate vibrational energy of the structure or to impart a restoring force to the structure so as to minimize vibration. These control devices may be grouped into three broad categories (Soong & Spencer, 2002). They are passive energy dissipation system, active control system and combination thereof, (i.e., hybrid and semiactive systems). Each of these control systems has their own merits and demerits as discussed later. Parameters of control devices deployed in active systems are driven by control algorithm based on measured structural responses. An accurate structural model is important. Performance of control devices and algorithms decreases with uncertainties and nonlinearities in external load and sudden change in material properties (Soong & Spencer).

Major effort has been devoted in recent years to develop new unconventional control techniques to handle uncertainties and nonlinearities in external load and material properties with ease. These techniques incorporate knowledge assimilated from diverse area such as neurology, psychology, operation research, conventional control theory, computer science, and communication theory. These methods are collectively known as soft computing techniques. Intelligent control is a derivative of soft computing techniques, which focus on stochastic, vague, empirical, and associative situations. It establishes functional relationship (linear and nonlinear) between input and output space from empirical data without using an explicit model for the control plant (King, 1999). Intelligent control seeks solution to the problem of controlling plants from the viewpoint of replacing human operators. This is the point where intelligent control departs from conventional control. The near reproduction of human intelligence and the mechanism for inferring, decision making for an appropriate control action, and strategies or policy that must be followed are embedded in these tools. Computational intelligence includes expert systems; fuzzy logic; artificial neural network, and evolutionary computing like genetic algorithm; simulated annealing; and swarm optimization and their derivatives.

This chapter traces concurrent developments in areas of optimization, fuzzy logic and control theory leading to the present state of the art in intelligent optimal structural control and future directions. The chapter dwells on the basic approaches of intelligent control and offers examples from benchmark exercises in control of building and bridge vibration under seismic excitation.

BACKGROUND OF CONVENTIONAL CONTROL TECHNIQUES

The structural engineering community first embraced the notion of structural control in the 1960s (Zuk, 1980). Since then, a number of new techniques and devices have emerged and have been installed in different structures.

Conventional Control Techniques

Most civil engineering structures have low damping characteristics. Thus, there is a need for devices that can enhance structural damping and/or stiffness properties to mitigate excessive vibrations. This characteristic may be achieved by passive energy dissipating devices. Passive systems do not need external power while they enhance energy dissipation of the system. They have an inherent property of mitigating the structural responses within a particular frequency range, tuned at the time of installation. Passively controlled systems show undesirable responses when the frequency content of the external forces is out of the bandwidth for which the passive system is preset.

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