Chapter 82
Comparative Study on Multi-Objective Genetic Algorithms for Seismic Response Controls of Structures

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ABSTRACT

This chapter introduces three new multi-objective genetic algorithms (MOGAs) for minimum distributions of both actuators and sensors within seismically excited large-scale civil structures such that the structural responses are also minimized. The first MOGA is developed through the integration of Implicit Redundant Representation (IRR), Genetic Algorithm (GA), and Non-dominated sorting GA 2 (NSGA2): NS2-IRR GA. The second one is proposed by combining the best features of both IRR GA and Strength Pareto Evolutionary Algorithm (SPEA2): SP2-IRR GA. Lastly, Gene Manipulation GA (GMGA) is developed based on novel recombination and mutation mechanism. To demonstrate the effectiveness of the proposed three algorithms, two full-scale twenty-story buildings under seismic excitations are investigated. The performances of the three new algorithms are compared with the ones of the ASCE benchmark control system while the uncontrolled structural responses are used as a baseline. It is shown that the performances of the proposed algorithms are slightly better than those of the benchmark control system. In addition, GMGA outperforms the other genetic algorithms.

INTRODUCTION

In recent years, structural control technology has attracted a great attention from the society of civil engineering because the properties of structural systems can be modified in real time without adding too much mass to mitigate severe damage and protect structural poverty and human lives from attacking strong natural hazards such as winds, waves, and earthquakes (Kobori et al.

DOI: 10.4018/978-1-4666-7456-1.ch082

1991; Soong and Reinhorn 1993; Housner et al. 1994; Adeli and Saleh 1999; Kim et al. 2009; 2010a; 2010b; Cha and Agrawal 2011). As a result of this, a lot of control strategies have been proposed. In general, structural control systems can be classified into three different categories: passive, active, and semi-active control systems (Spencer and Nagarajaiah 2003). It is generally said that the passive control system is the most stable and reliable control method because it does not require external power supply, but utilizes material yielding forces or viscosity of fluids or friction forces. Representatives of the passive control devices include viscous fluid damper, viscoelastic damper, friction damper, tuned mass damper, tuned liquid damper, tuned liquid column damper, base isolation systems, etc. Although it is relatively easy and cheap to install into civil structures, the parameters of the passive systems cannot be adjusted during earthquake events. On the other hand, active control systems can adjust control forces according to the maginitude and spectrum of external loads and structural responses. Thus, active control systems are more effective in mitigating natural hazards of large-scale civil structures than the passive systems. However, the active control system requires large external power supply to offer desired control forces that derive actuators. Although semi-active control systems have been proposed to compenstate the drawbacks of the active and passive systems, it is beyond the scope of this book chapter. This study focuses on the application of structural active control systems to large-scale civil structures. Another important thing along with the developed control algorithms and control devices is the mechanism of optimal placement of control devices and sensors within structures. However, the optimal placement of control devices/sensors has not been much investigated even though it can significantly contribute to the improvement of control performance. With this in mind, we propose three new different multi-objective optimization algorithms of not only finding minimum distributions of both actuators and sensors, but also minimizing the seismic responses of structures.

To date, the impact of optimal placement of control devices in large-scale civil structures has been investigated. Arbel (1981) found optimal locations of actuators in an oscillatory dynamic system using controllability measures. DeLorenzo (1990) optimized the placement of actuators and sensors in a solar optical telescope system using successive approximation-based weight-selection technique. Chen et al (1991) used simulated annealing (SA) for finding optimal placement of active/passive members of truss structures. GA was applied to an active truss structure for finding optimal locations of actuators (Rao et al. 1991). Onoda and Hanawa (1992) applied GA to an actuator placement optimization for correcting statistical static distortion of truss structures. Furuya and Haftka (1995) applied GA to optimization problems of finding optimal actuator locations within large space structures. Dhingra and Lee (1995) applied a hybrid gradient based GA to an across-four space structure for finding actuator locations and minimum weights of structures. Liu et al. (1997) used SA to solve an integrated structural topology and actuator placement problem of structures. Agrawal and Yang (1999) studied a variety of heuristic search algorithms for optimal placement of energy dissipative devices within buildings, including Sequential, Worst-Out-Best-In, and Exhaustive Single Point Substitution methods. Linear quadratic Gaussian-based Pareto optimal trade-off curves have been proposed by Brown et al. (1999) for various placements of actuators and sensors in structures.

Li et al. (2000; 2004) developed a multi-level GA to optimize both actuator locations and state feedback control gains for structural control system design. GA is also applied to a forty-story high-rise building to find the optimal locations of the predefined number of actuators (Abdullah et al. 2001). Cheng et al. (2002) applied a sequential iterative procedure for optimal placement of dampers and actuators to a seismically excited three-story