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Improving fragility curves for controlled structures including sensor fault

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Abstract

In this study the effect of sensor fault on damage of active controlled nonlinear structures is investigated. A fault detection neural network and a fault accommodation neural network are proposed to reduce the effect of sensor fault. The fault detection network monitors structural responses and automatically detects faulty sensor that can reduce control performance and effectiveness, while the fault accommodation network accounts for the faulty sensors. Fault is accommodated by using data from the remaining healthy sensors to estimate what the faulty sensors should have been reading. To demonstrate the performance of proposed method, a 3-story full-scale nonlinear benchmark building and several ground motions are selected. The fragility curves are developed for structures using nonlinear dynamic time history analysis through the computer simulation. Fuzzy logic controller (FLC) is employed as a sample of intelligent controller to control the structure using actuators. Here, the fragility curves are represented by lognormal distribution function with two parameters and developed considering three performance levels specified in FEMA 356 includes the Immediate Occupancy (IO), the Life Safety (LS) and the Collapse Prevention (CP). Results show that the sensor fault can reduce the effect of controllers and even can increase the probability of damage compare to the uncontrolled structure. Moreover, results of the proposed method confirm its effectiveness for decreasing the probability of damage of faulty control system.

Keywords: fault-tolerant controller (FTC), fault detection, fault accommodation, fuzzy logic controller (FLC), fragility curves.

1. INTRODUCTION

In structural engineering field, mitigation of structural damage and human loss is a major problem. Structural control has shown its effectiveness for attaining this purpose by different control strategies such as passive, active and semi-active. The active control system involves sensor to measure the building's response and actuators to apply control forces to the structure in a prescribed manner. Since in this system external source supply the control forces, not properly working of controller can increase structural energy and damage. One challenge of employing a control system is designing robust controller to treat properly in different probable situation. One way to guarantee reliable operation of a system is fault-tolerant control (FTC) strategies.

FTC strategies provide a valuable tool for designing robust systems against actuator, sensor and/or other components faults. FTC can be achieved either passively by the use of a control law designed to be insensitive to some known faults [1, 2], or actively by a fault detection and isolation (FDI) mechanism, and the redesign of a new control law [3, 4]. The active methods are more realistic because all the faults that may affect the system cannot be known a priori. The design of an FTC requires quick FDI to retain the system stability and performance. Generally two FDI methods can be used: (1) hardware redundancy; and (2) analytical redundancy. In hardware redundancy the outputs of identical components are compared to check if one of them is faulty. Most applications of FTC schemes are based on the hardware redundancy which needs more equipment, space and cost. To overcome these problems, analytical redundancy methods have been developed. In these methods, the relations among the system variables are compared to check inconsistencies. Because these methods need to have an accurate model of the systems, they are applicable to linear and simple systems [5, 6]. These methods are known as model-based FDI methods. An evolution of these model-based FDI methods is data-based FDI methods, such as neural networks, fuzzy sets or their combination [7, 8]. These methods are borrowed from the qualitative reasoning in artificial intelligence, with the aim of understanding the human common sense to catch the interactions between physical phenomena, without knowing the quantitative aspects.