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Review article

Vibration control of smart base-isolated irregular buildings using neural dynamic optimization model and replicator dynamics

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ABSTRACT

Vibration control of irregular structures subjected to earthquake excitations is a complex civil engineering problem. Base isolation has been used as an earthquake-protective system over the past few decades. It is, however, a passive control system lacking the adaptability to the real-time changes in motion from the earthquake excitation. In order to aid the base isolation system, control devices are installed at the base to provide the real-time vibration control. This research is motivated by evolutionary game theory and uses replicator dynamics as a resource allocation algorithm to determine control decisions. The control algorithm is evaluated using a three-dimensional base-isolated benchmark structure subjected to major historical earthquakes.

Contents

1. Introduction

In 1986, the Foothill Communities Law and Justice Center building was the first building in the U.S. to be built with base isolation for seismic protection [29]. The idea is to *isolate* the base of the structure from the horizontal motions caused by the earthquake. By adding a suspension system (for example, elastomeric rubber bearings) between the base and the main structure, the structure becomes more flexible and its fundamental period is increased resulting in a reduction in the earthquake accelerations and forces acting on the structure. This often creates large lateral displacements at the base of the structure that must be reduced. The conventional approach to overcome this problem is to use mechanical

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dampers [15,23]. Passive base isolation systems have been implemented in several hundred low- and mid-rise structures.

Base isolation is a passive control strategy with no capability to adapt to varying load patterns and the changes in the environment in real-time. To improve the performance of the conventional base isolation system, the idea of adaptive or smart base isolation has been proposed where it is supplemented with an active or semi-active vibration control system [17,17,10,7,8]. The main difference between active and semi-active control is that an active control system requires a considerable power source while a semi-active control system needs limited power and is usually operated by a battery [17].

On the other hand, earthquake protection for irregular structures presents additional challenges [20] and the performance of semi-active and active vibration control of irregular building structures has not been studied extensively. Kim and Adeli [28] investigated hybrid control of tuned liquid column dampers installed at the roof of 3D irregular structures subjected to seismic loading and noted the significance of the coupling effect of lateral and torsional vibrations. Adeli and Kim [2] later pioneered the use of wavelets in structural vibration control for additional robustness in the control algorithm. More detail is found in Adeli and Kim [3]. Jiang and Adeli (2005) pioneered a multi-paradigm model that combines fuzzy logic [38], wavelet transforms [9], and time-delay dynamic neural networks for nonlinear system identification of 3D large irregular building structures subjected to earthquake excitations. Based on this novel nonlinear identification model, Jiang and Adeli [24] created a dynamic fuzzy wavelet neuroemulator for control of 3D irregular structures subjected to earthquake loading including both material and geometric nonlinearities. They consider the dynamic couplings for torsional and lateral structural motions as well as the coupling between the structure and the actuator. The fuzzy wavelet neuroemulator is designed to predict the structural responses on-line based on previous time step measurements of the structure. The optimal control forces are determined using a genetic algorithm optimization [25,1].

The addition of active and semi-active devices to the base-isolation system (Fig. 1a) provides vibration reduction to a wider range of ground excitations in addition to reducing the lateral displacements and has been an area of interest in recent years [18,42,39].

Subasri et al. [39] use an adaptive neural network control law with extreme learning machine algorithm as a control algorithm for active vibration control of the irregular 8-story benchmark structure subjected to earthquake loading. Asai et al. [11] performed real-time hybrid simulation to control a semi-active magnetorheological damper damper installed at the base of a regular experimental six-story base-isolated building model

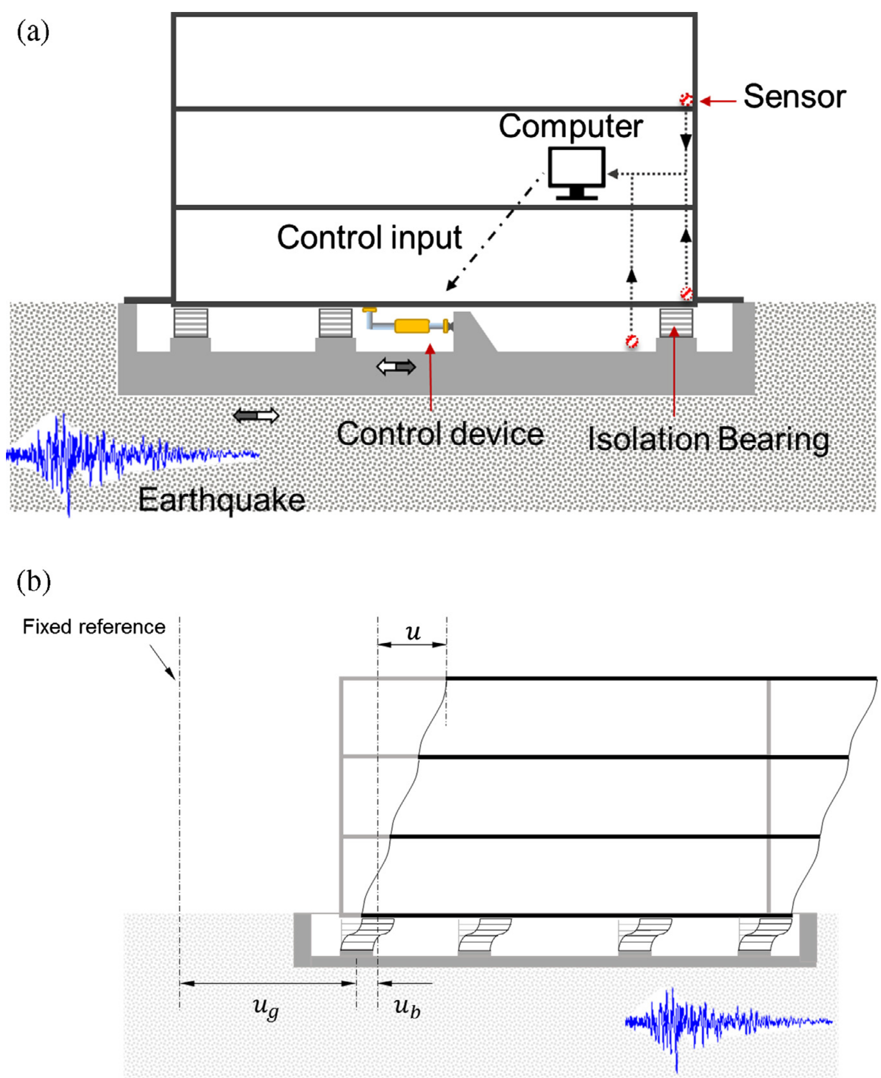

Fig. 1. (a) Base isolation integrated with control devices for seismic resistant structures. (b) Displacements of a base-isolated structure.