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Neuro-predictive Algorithm for Structural Control

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Abstract
A new neural network (NN) predictive controller (NNPC) algorithm has been developed and tested in the computer simulation of active control of nonlinear benchmark buildings. Although in classical model predictive control (MPC) usually a linear model of structure is used, NNPC provides a nonlinear model. In the present method an NN is used as an emulator. This emulator NN has been trained to predict the future response of the structure. The trained NN provides a model of structure which is employed to determine the control force via a numerical minimization algorithm. Since the NNPC controller is very time consuming and not suitable for real-time control, it is then used to train a NN controller. The approach is validated by using simulated response of a nonlinear benchmark building excited by several historical earthquake records. The simulation results are then compared with a linear quadratic Gaussian (LQG) active controller. The results indicate that the proposed algorithm is effective in relative displacement reduction which is here selected for control.
Keywords: Structural control, Active controller, Neural network controller, Neuro-predictive algorithm, Model predictive control (MPC).

1. Introduction

With the increasing studies in the field of structural control, various control methods have been proposed. Generally these methods can be divided in two groups. The first one includes control methods which require a mathematical model of the system upon which to operate. Although structural models can be developed, there are many sources of uncertainty, measurement noise and nonlinearity that resulted in less-effective control algorithms. LQR, LQG, H2 and sliding model control methods are some instances of this group. The second group includes control methods which do not require an accurate mathematical model. They are based on the actual measured responses of the system and are therefore, referred to as nonmodel-based control methods. This group includes fuzzy and neural network control methods.

Model predictive control (MPC) belongs to a class of algorithms which compute a sequence of manipulated variable adjustment to optimize the future behavior of a plant. A state model is utilized to predict the open-loop future behavior of the system over a finite time horizon from present states. The predicted behavior is then employed to find a finite sequence of control actions that minimize a particular cost function within pre-specified constraints. MPC displays its effectiveness in its computational expediency, treatment of constraints, real-time applications, intrinsic compensation for time delays, and potential for future extensions of the methodology. The MPC scheme has been commonly utilized for the control of chemical processes and applications to automotive and aerospace industries [1, 2]. Rodellar et al. [3] and Lopez- Almansa et al. [4, 5] applied a special case of MPC that is a predictive control scheme in civil engineering studies. Recent applications of MPC to the control of civil engineering structures have been demonstrated by Mei et al. [6, 7] and Karamodin and Kazemi [8]. Linear MPC refers to a family of MPC schemes in which linear models are used to predict the system dynamics, even though the dynamics of the closed-loop system is nonlinear. Many systems are, however, in general inherently nonlinear. In these cases, linear models are often inadequate to describe the process dynamics and nonlinear models have to be used. This motivates the use of nonlinear model predictive control.

Interest in a new class of computational intelligence systems known as artificial neural networks (ANNs) has grown in the last few years. This type of network has been found to be a powerful computational tool for organizing and correlating information. They have been proven to be useful for solving certain types of problems that are complex and poorly understood. The applications of ANNs to the area of structural control have grown rapidly through controller replication, system identification, or system inverse identification [9–11].

In this paper active neural network predictive controller (NNPC) is used to control nonlinear structures subjected to ground excitations. A neural network model of nonlinear structure predicts future structure response. The controller then calculates the control input that will optimize a cost function over a