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MULTI-OBJECTIVE TUG OF WAR METHOD FOR OPTIMAL PLACEMENT OF HYDRAULIC ACTUATORS IN SEISMICALLY EXCITED BENCHMARK HIGHWAY BRIDGE

Mostafa GHELICHI
Ph.D. Student, Noshirvani University of Technology, Babol, Iran
mostafa.ghelichi@gmail.com

Alireza M. GOLTABAR
Associate Professor, Noshirvani University of Technology, Babol, Iran
ar-goltabar@nit.ac.ir

Hamid R. TAVAKOLI
Associate Professor, Noshirvani University of Technology, Babol, Iran
tavakoli@nit.ac.ir

Abbas KARAMODIN
Associate Professor, Ferdowsi University, Mashhad, Iran
akaramodin@yahoo.com

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1. DESCRIPTION

In this paper, based on an innovative meta-heuristic optimization method, Tug of War (TWO), firstly an active control algorithm is designed to reduce the structural responses and then the optimum number and location of control devices are found to increase the efficiency of the bridge control system.

1.1. BENCHMARK HIGHWAY BRIDGE

A schematic of the benchmark structure considered in this study is shown in Figure 1 (Agrawal et al., 2009). The bridge structure is modeled after the newly constructed 91/5 (m) over-crossing in Orange County, Southern California. Readers are referred to the definition paper (Tan and Agrawal, 2009; Agrawal et al., 2009) for a detailed description of the structure.

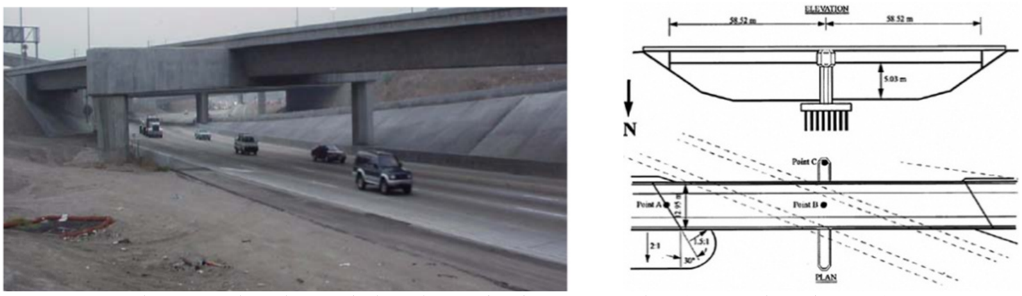


Figure 1. Elevation and plan views of 91/5 over-crossing (Agrawal et al., 2009).

The equations of motion (assumed for controller development only) for this system, in both the orthogonal directions, can be written as:

$$M\Delta\ddot{U}(t) + C\Delta\dot{U}(t) + K(t)\Delta U(t) = M\eta\Delta\ddot{U}_g(t) + b\Delta F(t) \quad (1)$$

1.2. OBJECTIVE FUNCTIONS

In this paper, there are two types of objective functions as follows: Type 1: To design and optimize the proposed active control algorithm. At this stage, a single-objective optimization process is performed. Type 2: To optimal placement of actuators. The optimum number and location of actuators are found based on the use of the multi-objective mode of TWO and minimization of three objective functions. The first one is the maximum of the bridge base shear, second is maximum of mid-span displacement and the third is maximum of mid-span acceleration.

1.3. PROPOSED CONTROL ALGORITHM

The proposed active control algorithm is a neuro-fuzzy adaptive controller that its output functions parameters are optimized by the tug of war optimization method.

1.4. OPTIMUM PLACEMENT OF ACTUATORS

After determining the details of the optimized neural network as the desired controller algorithm, the optimum number and location of active actuators should be determined in order to achieve the maximum efficiency and cost effectiveness of the control system.

1.5. RESULTS

The proposed algorithm reduced the bridge peak base shear, overturning moment, mid-span displacement, mid-span acceleration, normed base shear and normed mid-span acceleration under various earthquakes up to 35%. Among these, the mid-span acceleration index (J4) had the lowest reduction (21%).

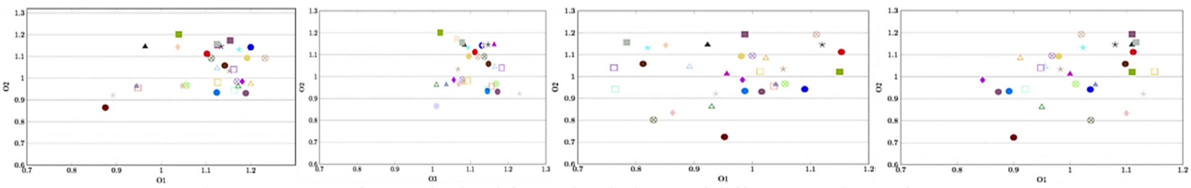


Figure 2. Pareto fronts obtained for optimal places of different numbers of actuators.

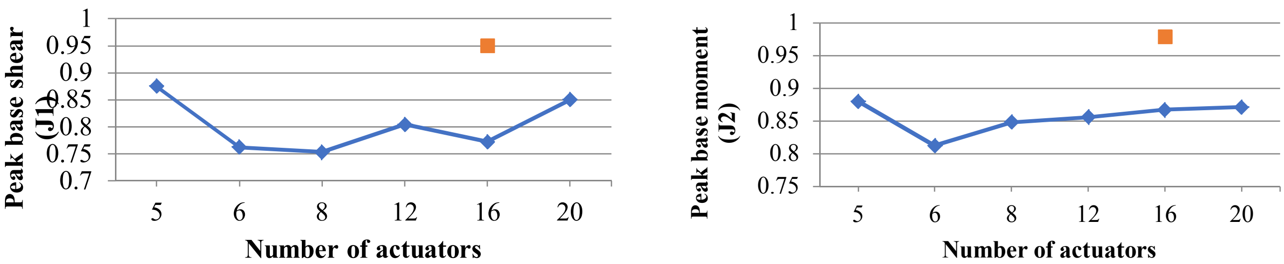
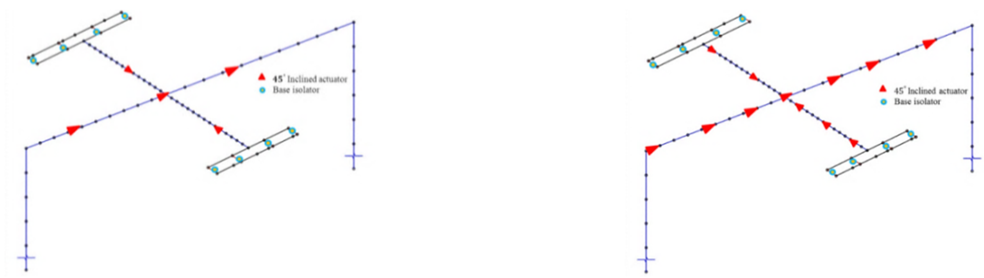


Figure 3. Changes in performance indices versus number of actuators (trade-off scenario).



(a) Number of actuators = 4 (b) Number of actuators= 6

Figure 4. The optimum actuator placement resulted from the optimization algorithm (Trade-Off assignment).

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