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Cooperative Coevolution fuzzy Control of MR Damper for Damage Reduction of Structures

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ABSTRACT: In this research, damage reduction of structures is studied using semi-active control of MR dampers. Fuzzy control is an intelligent control method in contrast to classical control with some specific capabilities such as handling non-linear and complex systems, adaptability and robustness to errors and uncertainties. However, due to lack of learning ability of fuzzy controller, it is used in combination with a genetic algorithm, which in turn suffers from some problems like premature convergence around an incorrect target.Therefore, in this research, the introduction of the cooperative coevolution fuzzy controller in which the parameters of membership functions and rules will be searched in two separate species. To investigate and compare the performance of this controller with some other controllers, these methods are implemented on a three story benchmark nonlinear structure. The results showed that the performance of the cooperative coevolution fuzzy controller is better than the other controllers and can reduce the average damage of the structure up to %79.

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1- Introduction

In general, buildings possess little damping capability. To dissipate earthquake energy and reduce harmful vibrations and consequently reduce financial and physical damage, control devices have been used in structures. Active control systems can be used to reduce the structural response to internal and external vibrations such as vibration of devices, wind or earthquake. Number of active-controlled structures is fewer than passive-controlled structures in civil engineering. In design of active-controlled structural systems, the systems can be designed to function according to desirable behavior. These instruments utilize measured responses of structures to produce the required control force [1].

Fuzzy controllers are nonlinear controllers with special structure which provide successful applications of fuzzy theory in practical issues. These controllers by applying fuzzy theory, indicate behavior similar to that of expert humans when they are controlling system. Conversely, fuzzy controllers in comparison with classic controllers, without the need for mathematical model of the system, evaluate systems considering the experience of experts in the form of if - then fuzzy expression rules [2].

One of the main disadvantages of fuzzy controllers is the lack of learning ability triggering use of knowledge and experience of the professionals specializing in controller database. A learning process is employed to solve this problem and to automate the fuzzy controller design [3].

Various methods have been proposed based on fuzzy controllers capable of learning. These controllers, in addition to the method of fuzzy decision-making ability, possess the ability to create or improve their control rules based on past information. One of the effective methods for designing fuzzy controllers is to exploit genetic algorithm. Genetic algorithms inspired from evolutionary theory seek for appropriate fuzzy controller that can satisfy design criteria.

2- Cooperative Coevolution Method-Fuzzy CO.CO

Two types of coevolution is defined in fuzzy cooperative coevolution which are membership functions and rule base. This method is essentially based on the determined framework defined by Potter and de Jong. Cooperative co-evolutionary fuzzy system allocates high degree of freedom to designing fuzzy systems until users can provide interaction between performance and justifiability [4, 5]. The number of fuzzy modeling processes typically needs simultaneous operational and connected parameters. These parameters present a fully complete definition of language knowledge to describe fuzzy system and mapping values from symbolic definition to real values (a complete definition requires structural parameters as dependent variables and number of rules). Therefore, the fuzzy modeling consists of two separate but intertwined

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processes: (1) Seeking for membership functions as fuzzy variables (functional parameters) and (2) seeking for rules (connected parameters) used to derive.

In this paper, target function for fuzzy cooperative coevolution modeling is to minimize the damage in structures. Also, damage control has been conducted based on Park and Ang's damage index while the controller has been designed to reduce this index [6]. In order to assess the introduced controller in this paper, a nonlinear structure under earthquakes has been introduced to check the structural control. This structure has been designed for Los Angeles California region meeting all related seismic standard criteria. Figure 1 shows the case study structure which uses MR damper for structural control. For this purpose, one damper is installed on each floor of the building and they are controlled in turn by a fuzzy controller. The first, second and third floor of the structure are equipped with sensors to measure accelerations [7-9].

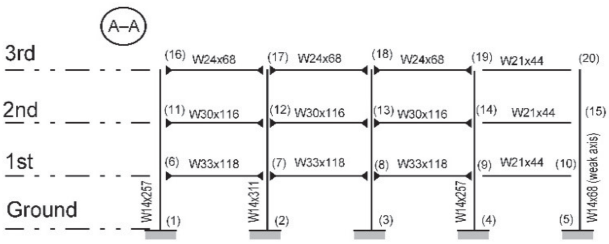

Figure 1. Benchmark frame for consideration in this study

Effect of fuzzy controller in reducing roof displacement in comparison with that of uncontrolled statue has been indicated in Figure 2 where fuzzy cooperative coevolution controller causes considerable decrease in permanent deflection. Ratio of structural damage in controlled mode to uncontrolled mode has been presented in Table 1 to examine the performance of the controller.

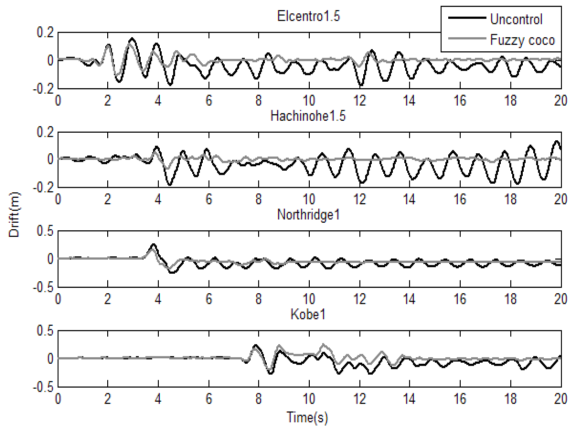

Figure 2. Effect of Fuzzy logic controller cooperative evolutionary in reducing structural roof displacement

3- Conclusion

In this paper, control of structural damage through semi-active control on MR damper by cooperative evolutionary fuzzy controller was studied. Based on obtained results, cooperative evolutionary fuzzy controller caused remarkable decrease in structural damage such that amounts of structural damage under the El Centro earthquake with 0.5 and 1.5 scales, the Haicheng earthquake with 0.5, 1 and 1.5 scales and the Northridge earthquake with o.5 scale reduced to zero. Also structural damage under the El Centro earthquake with 1.5 scale, the Northridge earthquake with 1.0 and the Kobe earthquakes with 0.5 and 1.0 scales reduced respectively 51.7, 42.1, 38.8 and 37.7%. Co-evolutionary fuzzy controller also substantially decreases the amount of permanent deformation of the structure.

Comparison of the evolution of the fuzzy controller with other controllers examined in this study showed that the studied controllers significantly reduce the damage.

Table 1. Damage ratio comparison under different earthquakes

Earthquake	Intensity	Damage uncontrolled	Fuzzy CoCo		Percent Decrease
			controlled	Ratio	
EL Centro	0.5	0.11	0	0	100
	1	0.1666	0	0	100
	1.5	0.2318	0.1119	0.483	51.7
Hachinohe	0.5	0	0	0	100
	1	0.1586	0	0	100
	1.5	0.2458	0	0	100
Kobe	0.5	0.2131	0.1304	0.612	38.8
	1	0.4264	0.2656	0.623	37.7
Northridge	0.5	0.2577	0	0	100
	1	0.3794	0.2196	0.579	42.1

References

[1] Housner, G.W., Bergman, L.A., Caughey, T., Chassiakos, A., Claus R., Masri, S., Skelton, R., Soong, T.T., Spencer, B. and Yao., J., "Structural control: past, present, and future". Journal of Engineering Mechanics, 1997, vol. 123, pp. 897-97.

[2] Ross, T.J., "Fuzzy Logic with Engineering Applications". Second Edition.

[3] Cordon, O., Herrera, F., Hoffmann, F., & Magdalena, L. "Genetic fuzzy systems evolutionary tuning and learning of fuzzy knowledge bases", World Scientific. 19, 2001.

[4] Pena-Reyes, C.A., Sipper, M., "Fuzzy Co Co: A cooperative-coevolutionary approach to fuzzy modeling". IEEE Transactions on Fuzzy Systems 2001, 9(5);727-737.

[5] Potter, M.A., "The design and analysis of a computational model of cooperative coevolution". 1997,Citeseer.

[6] Williams, M.S. and R.G. Sexsmith, "Seismic damage indices for concrete structures." a state-of-the-art review. Earthquake Spectra, 1995. 11(2): pp. 319-349.

[7] Ohtori, Y., Christenson, R. E., Spencer, B. F. Jr., and Dyke, S. J., "Benchmark control problems for seismically excited nonlinear buildings". J. Eng. Mech. 2007, 130(4), pp. 366–385.

[8] Dyke, S.J., Spencer, B. F., Sain, M. K., and Carlson, J. D., "Modeling and control of magnetorheological dampers for seismic response reduction", Smart Mater. Struct.1996, 5,565-75.

[9] Yang, G., Spencer, B. F. Jr., Carlson, J. D., and Sain, M. K., "Large-scale MR fluid dampers: Modeling and dynamic performance considerations", Eng. Struct., 2002, 24(3), 309-323.

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