Minimizing Multivariate Objective Function Using Improved Genetic Algorithms in Active Control of Oscillation of Structures

A. Banaei[1] J. Alamatian[2]

1- Introduction

A smart structure is a structure that is capable of maintaining itself against external excitation through learning and improving physical and geometric characteristics. Using the active control method and connecting actuators in terms of the dynamic degree of freedom of these structures, forces are created and applied to the structure to minimize the degrees of freedom caused by external excitation. In civil engineering, the idea of using active controls to control structural oscillation was first introduced in 1972. Subsequently, many developments in this method of control have been progressed by researchers. Applying the active control method requires simultaneous application of appropriate instruments as well as an algorithm for determining the controlling forces in the structure. The appropriate optimization methods are essential to control the structure data and finding the proper forces of the actuators to deal with the lateral excitation in each particular time step. The use of numerical methods in dynamic analysis of structures and the optimization of active control systems of the structure have been taken into account for two reasons. The first reason is these methods independence of the limitations of the optimization function's derivative gradient. On the other hand, the speed of numerical methods is very higher than the analytical methods because modeling lacks any complexity. One of these new methods is the intelligent search method, which is based on the natural evolution patterns. The genetic algorithm method is one of the most powerful and effective methods of numerical search that is widely used in optimization processes. The early development of genetic algorithm was made by John Holland and his colleagues at the University of Michigan in 1962 [6]. Also the implications of genetic algorithm were realized and examined by Goldberg in 1989. In 2014, Abbasi and Markazi suggested relationships by comparing the number of sensors found by the genetic algorithm and the improvement made in the seismic behavior of the structure. They assessed the structure oscillation by the numerical Newmark-beta method in the dynamic solution of the structure, the multi-objective genetic algorithm to determine the location of the sensor and to control the system and the second-order Gaussian second-order control.

2- Materials and Methods

By using a logical search method, this algorithm chooses the most appropriate members among the organized random information. In each generation, a new group of members is generated using genetic operators and they are examined as new potential control forces. Genetic algorithm is an efficient optimization method. By applying this method, the optimal structures control forces are found at each step so that the displacement of the structure is minimized. In this study, the LQR method is used as a numerical method for the comparison with the genetic algorithm method.

The genetic algorithm uses an evolutionary pattern to search the entire problem space and can find the appropriate answer by non-linear and non-homogeneous searching without the need for a search in all space. The calculations of this method are simple and do not require restrictive assumptions in search space such as continuity or the derivation gradient of the optimization function. Through this way, an algorithm—inspired by the theory of natural evolution—is created which provides a mechanism for finding the best answer by generating an initial population of possible probabilistic questions in the initial step and modifying its members in later steps. The goal of the genetic algorithm is to find control forces in such a way that the displacement of the structure is minimized. As a result, the objective function is formed to indicate the displacement of all dynamic degrees of freedom of the structure. As the numerical value of this function is reduced, the forces selected by the search algorithm are evaluated more appropriately. In this research, the constrained objective function is introduced as follows:

$$\bar{C} = \sum_{i=1}^{q} x_i \cdot \left[1 + \alpha \sqrt{(x_i - \bar{x})^2} + \beta \left(\max \left\{ \frac{|x_i|}{\Delta x} - 1, 0 \right\} \right) + \gamma \frac{1}{|X_i - x_i|} \right]$$

3- Results

To illustrate the effectiveness of the proposed method for controlling the oscillations of the structure, several numerical examples are solved and the results are presented in the following.

Table 1- The comparison of maximum displacement of six degrees of freedom structures in control modes based on the applied algorithms and without control

Dynamic degree of freedom	maximum displacement on no control state (cm)	maximum displacement on GA control state (cm)	Actuator force $(Kg.Force)$
1	6.22	1.64	28.0
2	11.51	4.02	20.1
3	16.36	4.99	18.1
4	20.84	6.32	18.6
5	25.79	7.72	23.5
6	30.47	8.85	24.9

[1] Ph.D. of Structural Engineering, Islamic Azad University, Mashhad Branch.
[2] Corresponding Author: Associate Professor in Civil Engineering, Islamic Azad University, Mashhad.
Email: Alamatian@mshdiau.ac.ir

Table 2- The comparison of maximum displacement of twelve degrees of freedom structures in control modes based on the applied algorithms and without control

Dynamic degree of freedom	maximum displacement on no control state (cm)	maximum displacement on GA control state (cm)	Actuator force $(Kg.Force)$
1	1.13	0.58	9.47
2	2.21	0.91	9.08
3	3.18	0.75	9.24
4	4.30	0.69	9.68
5	5.03	0.78	8.96
6	6.27	0.92	8.96
7	6.27	0.95	9.82
8	7.03	1.16	9.05
9	7.72	1.16	8.53
10	8.96	0.99	9.93
11	12.23	0.83	8.48
12	12.81	1.48	8.81

4- Discussion

As far as the results are concerned, the efficiency of the proposed method was clear which indicates the efficiency of the genetic algorithm method in the active control of the structure. The use of several Actuators in the structure and their determination with proposed genetic algorithms, reduces the maximum displacement of structures. Also, due to the use of several Actuators, the maximum force applied by Actuators is also reduced. This raises the effectiveness of the proposed method, because in reality, such forces can be produced. With the widespread development of the new search methods in the computer science, the simultaneous use of these methods, along with other numerical search methods and the use of various patterns in data encoding, it is possible to use special algorithms that can deliver a strong performance to optimize the dynamic systems at low cost and within a short period of time . In this research, it was attempted to study and evaluate some of the special features of these methods.