Head Positioning parameter optimizing using statistics and evolutionary algorithms

Aminreza Riahi and Jalil Shirazi

Abstract*— Mechatronic equipments such as a head positioning system of hard disks have been required to provide fast and accurate positioning. To achieve these requirements, a mode switching control (MSC), which encompasses such diverse structures and functions of the controller is switching to that was used extensively. To achieve to a desired position in this matter, the model a controller parameters are assessed by some evolutionary algorithms like genetic, patter search and simulated annealing. The obtained parameters show that the values of these algorithms have good effect on their output. In this paper, the best algorithm, could be proper is introduced.

Keywords: Disk drives, mode switching control, genetic algorithm, pattern search algorithm, simulated annealing algorithm.

I. Introduction

Multiple disks on a motor shaft (axis) were spindle shaped and driven. On the disk surface, thousands of track data is located [1-2]. Figure 1 shows a simplified diagram of a combination of hard drive.

Fig. 1 shows a basic schematic diagram of a head disk assembly (HDA). Several disks are stacked on the spindle motor shaft and rotate. On the surface of a disk, there are thousands of data tracks. A magnetic head is supported by a suspension and a carriage, and it is suspended several micro inches above the disk surface. The actuator, called a voice-coil motor (VCM), actuates the carriage and moves the head on a desired track. The mechanical part of the plant, that is, the controlled object, consists of the VCM, the carriage, the suspension, and the heads. The controlled variable is the head position. On the back of the HDA, there is a circuit board, where a microprocessor or digital signal processor (DSP) for servo control is mounted. The position of the head is detected by the sector servo method, and the sampling period is 150 μs in this experimental equipment.

Aminreza Riahi
Young Researchers Club, Gonabad Branch,Islamic Azad University
Iran
a.riahi@ieee.org

Jalil Shirazi
Islamic Azad University, Gonabad Branch, Iran
Iran
J_shirazi@iau-gonabad.ac.ir

Next, a plant model is derived. The mechanical part of the plant consists of a second-order system, due to the bearing stiffness, the natural frequency of which is about 30–50 Hz and several mechanical resonance frequencies over 1 kHz.

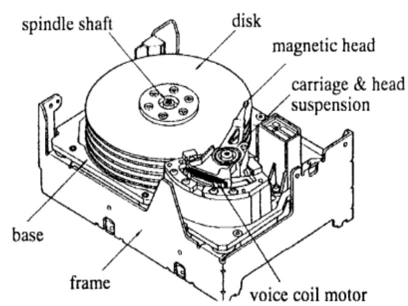

Figure 1. HDA [3]

These resonances are often canceled by notch filters or low-pass filters. Then, it is necessary to take into account the computation time delay of the microprocessor and the phase lag of the power amplifier and the filters. A plant model can be expressed as follows:

$$G(s) = \frac{K}{ms^2 + bs + k} \times \frac{-0.5Ls + 1}{0.5Ls + 1} \quad (1)$$

Where, s is a Laplace operator, m is the mass, k is a spring constant, b is a damping constant, and K is a gain including the VCM torque constant and the power amplifier gain, and L is the total time delay. The plant model is a third-order system and is discretized with a sampling time of 150 μs for digital controller design [1-4].

There are so many attempts related to head positioning control in the literature. In Reference [5], the authors considered a user-friendly loop-shaping method concerning the Robust Bode (RBode) plot for optimizing the head-positioning system in a hard disk drive (HDD).

In this paper we used three searching techniques such as genetic algorithm, annealing simulated algorithm and pattern search algorithm to consider the best results. In reference [6], the system uncertainties are employed as an important point in controlling.

The paper is structured as follows.The Searching techniques we have employed are presented in section 2. In section 3, the design of experiments is taken and a powerful method named TAGUCHI is introduced. The system implementation and experimental results are presented in section 4 and the paper is concluded in section 5.

II.Searching techniques

Searching techniques in computer science are used to find approximate solutions to optimization and search problems. In this section, a brief overview of some searching techniques is given.

II.1 Genetic algorithm

The genetic algorithm is a special type of evolutionary algorithms that use techniques such as inheritance and mutation reverted biology uses. Darwin's principle of natural selection in genetic algorithms is used for finding the optimal formula for predicting or use pattern matching. Genetic algorithms are often a good option for forecasting techniques based on regression. Briefly called the genetic algorithm (or GA) is a programming technique that uses problem solving as a model of genetic evolution. It should be noted that the used GA method finds the minimum fitness. Figure 2 shows the biological genetic algorithm process flow.

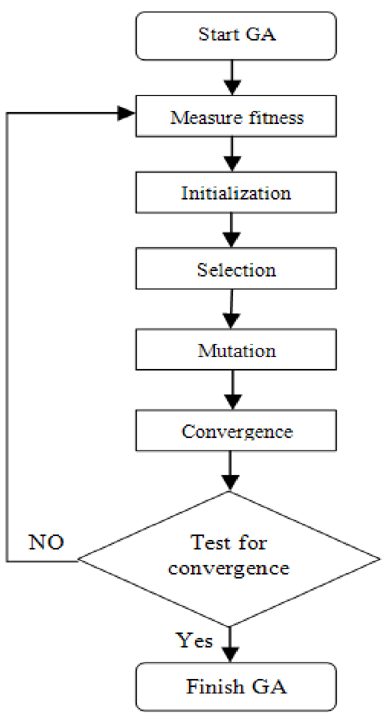

Figure 2. Biological genetic algorithm process flow.

The objective function for the GA is:

$$F = \int_0^{tf} t\,|e(t)|\,dt \quad (2)$$

The objective functions are considered based on an error criterion. The error criterion is given as a measure of index performance given by the equation for integral of time multiplied absolute error (ITAE). Properties of the used genetic algorithm method are given in table 1.

Table1. Properties of the used genetic algorithms

Option	Value
Crossover function	Heuristic
Crossover fraction	0.8
Elite number	2
Initial penalty	10
Mutation function	Adaptive feasible
Penalty factor	100
Population initial range	[-1,1]
Population size	100
Population type	Bit string
Selection function	Stochastic uniform

There are so many algorithms which are used to obtain the best values. In this paper, two other algorithms are taken and results are compared with genetic algorithm.

II.2 Pattern search algorithm

Pattern search is a heuristic method that can be useful approximate solutions for any problem, but can fail on others. Outside of such classes, pattern search is not an iterative method that converges to a solution; indeed, pattern search methods can converge to non-stationary points on some relatively tame problems [8-9].

II.3Annealing simulated algorithm

"Annealing, differs from iterative improvement in that the procedure need not get stuck since transitions out of a local optimum are always possible at nonzero temperature. A second and more important feature is that a sort of adaptive divide-and-conquer occurs. Gross features of the eventual state of the system appear at higher temperatures; fine details develop at lower temperatures" [10].

III. Design of Experiments

To investigate the effects of parameters, Taguchi method is used. In Taguchi analysis, there is an important factor named signal to noise ratio. This ratio is introduced in Formula 3.

$$S/N = -10\log_{10}(MSD) \quad (3)$$

MSD is also, introduced in three categories, when goal is to minimize something, it is defined as "Smaller is Better". When an optimization function is maximized, "Larger is Better" is planned and when the results must converge to a point, "Nominal is Better" is considered. Each of three formulas is expressed in relations 4 to 6 respectively [11].

$$MSD = \frac{1}{n}\sum_{i=1}^{n}(yi - y_0)^2 \quad (4)$$

$$MSD = \frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^{\,2}} \quad (5)$$

$$MSD = \frac{1}{n}\sum_{i=1}^{n}\left(y_i - y_0\right)^2 \quad (6)$$

Table 2 and table 3, show the parameters and their levels employed in L16 experiment respectively.

Table2. Parameters and levels

	m	*k*	*b*	*K*	*L*
1	**0.01**	**1**	**1**	**1**	**0.001**
2	**0.1**	**10**	**10**	**10**	**0.01**
3	**1**	**100**	**100**	**100**	**0.1**
4	**10**	**10000**	**10000**	**1000**	**1**

Table 3. L16 Taguchi table

	m	*k*	*b*	*K*	*L*	*Output*
1	1	1	1	1	1	1.09E-05
2	1	2	2	2	2	1.10E-07
3	1	3	3	3	3	1.15E-09
4	1	4	4	4	4	2.50E-12
5	2	1	2	3	4	1.00E-07
6	2	2	1	4	3	2.23E-08
7	2	3	4	1	2	3.00E-09
8	2	4	3	2	1	2.68E-07
9	3	1	3	4	2	2.50E-06
10	3	2	4	3	1	3.00E-07
11	3	3	1	2	4	6.28E-08
12	3	4	2	1	3	2.96E-08
13	4	1	4	2	3	1.00E-05
14	4	2	3	1	4	1.17E-06
15	4	3	2	4	1	6.17E-05
16	4	4	1	3	2	1.99E-06

In this paper, the output is located in the last column and describes as Formula 7.

$$F = \int_{0}^{tf} |e(t)|^2 dt \quad (7)$$

Where, e is the error of desired signal and output. In figure 3, SNR, describes the effect of each parameter output. As this figure shows, m is the most effective one and K as again is the poor effective parameter.

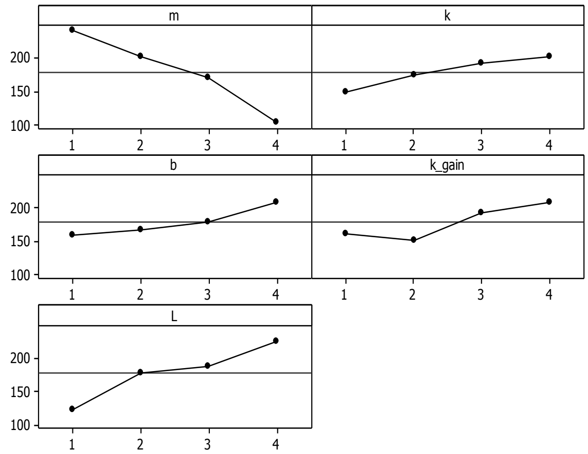

Figure 3. SNR criterion for parameters

Also, figure 3 shows the best level for each parameter. In signal to noise ratio, the highest level is the best one for that parameter.

In this experience for instance, in parameter m, the best level is 1. It means for having the minimum error, mass must be selected at a minimum level.

In figure 4, a total plot is shown to depict all 16 experiments.

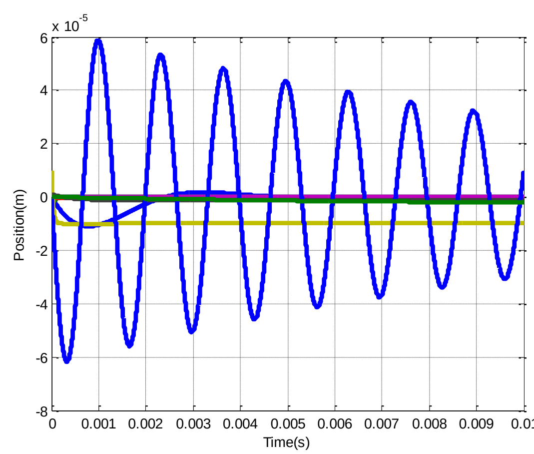

Figure 4. Figures of output based on 16 experiments

IV. Results and discussion

In this paper, three methods discussed are used to consider the best results.

Figures 5- 8, interpret the genetic algorithms in various iterations.

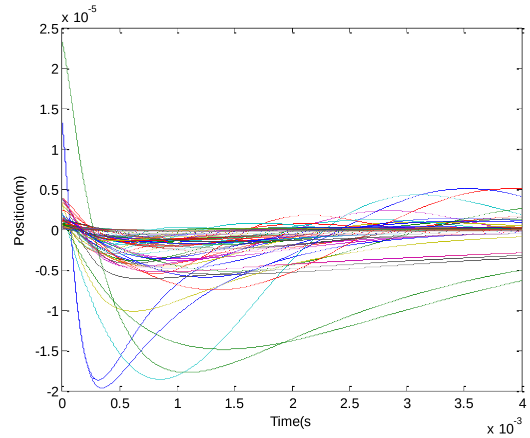

Figure5. A control system by GA in the first stages of replication

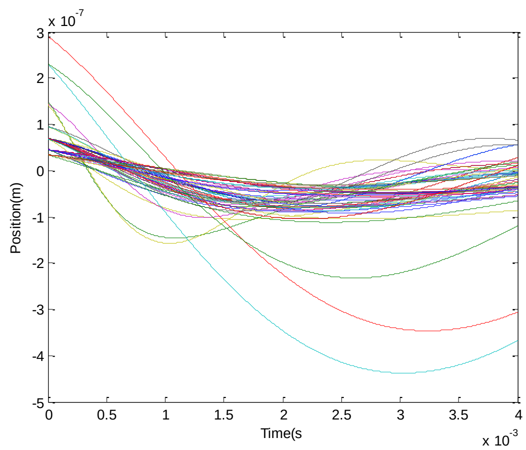

Figure6. A control system by GA after 10 iterations

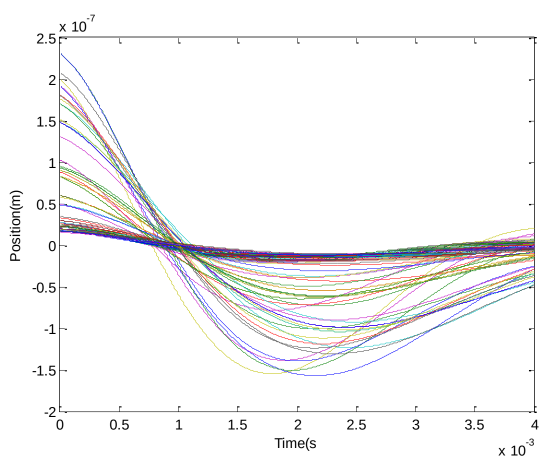

Figure7. A control system by GA after 20 iterations

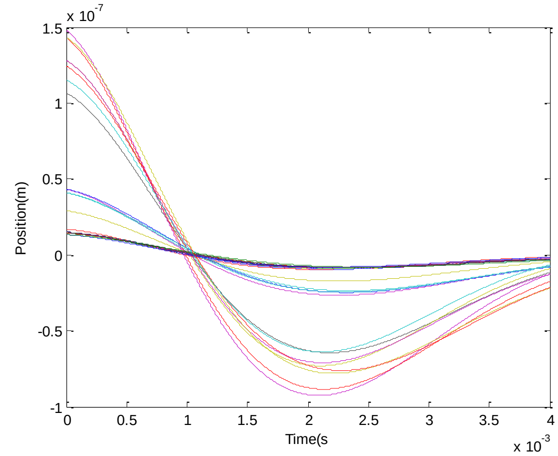

Figure8. A control system by GA after 30 iterations

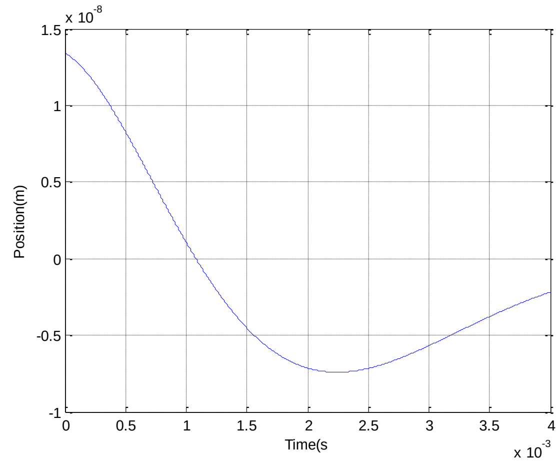

Figure9. Final result of GA

In figure 9 the final result of the GA is depicted. All parameters achieved using GA and others are located in table 4. As shown, simulated annealing is the best in settling the curve on axis, but the time is long. Whereas the pattern search is a short time algorithm. Therefore among them, simulated annealing is the best.

In figure 10 all of three algorithms, inspect their responses.

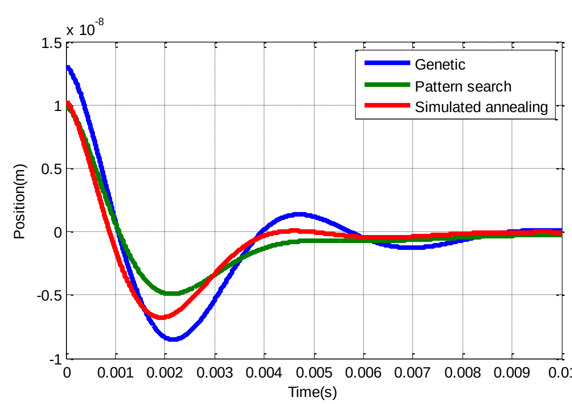

Figure10. Comparison between GA,PS And SA

Table4. Parameters achieved by GA,PS And SA

Method	K	M	b	K	L	Elapsed Time (second)
GA	9.3477	8.3424	5.6816	9.9948	0.1321	**56**
PS	10	10	9.9999	9.9999	0.1000	**22**
SA	6.0609	9.79496	8.6027	9.6669	0.1008	**140**

V. Conclusion

In this paper a head positioning control is proposed. For having a dynamic model an approximation of the disk drive is achieved. This transfer function added to a lead lag controller. To investigate the most strong and poor effective parameter, the effect of each parameter is considered by TAGUCHI design of experiment. Disk drive and also controller parameters are obtained using evolutionary algorithms like GA, PS and SA.

References

[1] S. Ashley, "Getting a hold on mechatronics," Mech. Eng., vol. 119, no. 5, pp. 60–63, May 1997.

[2] G. F. Franklin, J. D. Powell, and M. L. Workman, Digital Control of Dynamic Systems, 2nd ed. Reading, MA: Addison-Wesley, 1990.

[3] H. Hanselmann and A. Engelke, "LQG-control of a highly resonant disk drive head positioning actuator," IEEE Trans. Ind. Electron., vol. 35, pp. 100–104, Feb. 1988.

[4] M. Hirata, K. Liu, T. Mita, and T. Yamaguchi, "Head positioning control of a hard disk drive using H1 theory," in Proc. 31st Conf. Decision and Control, 1992, pp. 2460–2461.

[5] Atsumi, Takenori, and William C. Messner. "Optimization of head-positioning control in a hard disk drive using the RBode plot." *Industrial Electronics, IEEE Transactions on* 59.1 (2012): 521-529.

[6] Kawafuku, Motohiro, Masato Mizoguchi, and Makoto Iwasaki. "Head positioning control system design based on dynamic characteristic of rolling friction in HDDs." *Advanced Motion Control (AMC), 2012 12th IEEE International Workshop on*. IEEE, 2012.

[7] Hooke, R.; Jeeves, T.A. (1961). ""Direct search" solution of numerical and statistical problems". Journal of the Association for Computing Machinery (ACM) 8 (2): 212–229

[8] Powell, Michael J. D. 1973. "On Search Directions for Minimization Algorithms." Mathematical Programming 4: 193—201.

[9] McKinnon, K.I.M. (1999). "Convergence of the Nelder–Mead simplex method to a non-stationary point". SIAM J Optimization 9: 148–158

[10] S. Kirkpatrick, C. D. Gelatt, Jr., M. P. Vecchi," Optimization by Simulated Annealing, SCIENCE, Volume 220, Number 4598

[11] Genichi Taguchi, Taguchi quality engineering handbook. 2005,New Jersey

About Authors:

Aminreza Riahi received the B.S. degree in control & automation engineering 2011 at the Islamic Azad University,Gonabad Branch.currently he is M.S. Student at the Islamic Azad University,Gonabad Branch. His main research are is about fractional and modern control engineering.