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Optimization of PID Parameters using Genetic Algorithm for Hard Disk Drive Read/Write Head Control

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Abstract- **Due to the increasing areal density of magnetic hard disk, it has become challenging to design a controller for hard disk drive servo. This paper demonstrates the effectiveness of GA based PID controller tuning for control of hard disk drive read/write head. In comparison with performance of PID controller tuned with conventional methods, the GA based method provides better time response specifications with normalized geometric selection, arithmetic cross over and uniform mutation.**

Index Terms - Hard Disk Drive, PID Controller Tuning, Genetic Algorithm

I. INTRODUCTION

During the early days of development, hard disk drives (HDDs) were used with general purpose computers such as desktops, laptops and servers. Subsequent development of technology led to the use of hard drives in embedded systems such as Redundant Array of Independent Disks (RAID) systems, Network Attached Storage (NAS) systems and Storage Area Network (SAN) systems that are able to provide reliable access to large data volumes. Consumer applications such as digital video players, digital video recorders, and video game consoles also use hard drives for storage.

Technological developments have resulted in better areal densities in HDD and thus storage of more amounts of data per square inch, resulting in smaller dimensional disk drives. Higher areal density requires more precise positioning servomechanism of the read/write magnetic head. There were many attempts reported in literature [1-4] to develop control schemes for improved performance of hard disk drive read/write head controller. This paper proposes a novel scheme of control of hard disk drive read/write head controller, based on genetic algorithm (GA).GA can generate a high quality solutions and stable convergence characteristics. The GA tuned PID controller gives better time response characteristics in comparison with PID controllers tuned with conventional methods.

II. DISK DRIVE READ/WRITE SYSTEM

A hard disk drive is a non-volatile storage device that stores digitally encoded data on rotating rigid platters with magnetic surfaces. As a result, the problem of accessing data on the rapidly rotating disk media has provided a wealth of control challenges [5]. Data are recorded on concentric tracks on the disk which is rotated by a spindle motor [6]. The magnetic heads attached onto a slider read and write data from and to the disk. The slider is bonded to the suspension of the actuator arm which pivots about a ball bearing. The read/write head can be positioned onto the desired track by rotating the actuator of the voice coil motor (VCM). The head positioning servomechanism is a control system which positions the heads over a desired track with minimum deviation from the track centre and repositions the heads from one track to another in minimum time. For efficient performance of sophisticated systems using HDDs¸ it is highly desirable to reach any track as quickly as possible.

A. Modelling of the disk drive system

The initial goals for the Disk Drive Read/Write System are to position the reader head accurately at the desired track and to move from one track to another within minimum time possible. It is necessary to have a model of the system for design of the controller tuning.

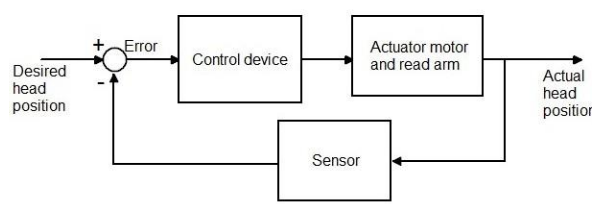

Fig. 1Closed-loop control system for disk drive

A basic diagram of diskdrive control is shown in Fig. 1 [7]. Thegoal ofthediskdrivereaderdeviceistopositionthereaderhead.Thevariableto accuratelycontrol istheposition ofthereaderhead through the actuator motor. The block diagram indicating the individual sections of the system with transfer functions is shown in Fig. 2. The typical parameters depicted in the figure along with their assumed values are listed in Table 1 [7].

Assuming an accurate read head, the sensor has a transfer function H(s) = 1, as shown in Fig. 2.

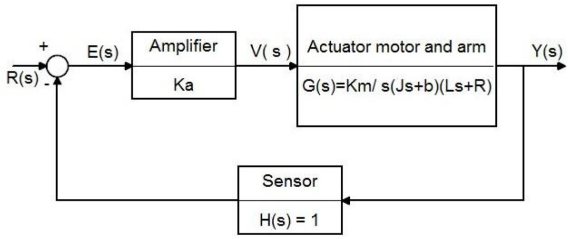

Fig. 2Block diagram model of hard disk drive system

Table 1: Typical parameters for disk drive reader

Parameter	Value
Armature resistance (R)	1Ω
Motor constant (Km)	5 N.m/A
Armature inductance (L)	1 mH
Inertia of arm and read head (J)	1 N.m.s^2/rad
Friction (b)	20 kg/m/s
Amplifier (Ka)	10 - 1000

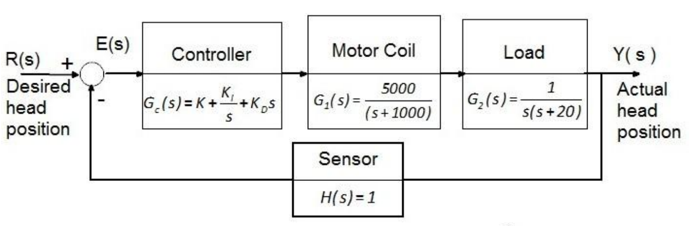

Fig. 3 Block diagram model of hard disk drive control with PID controller

The closed loop transfer function of the disk drive read system is given by

$$\frac{Y(s)}{R(s)} = \frac{Ka.G(s)}{1+Ka.G(s)} \quad (1)$$

A system for controlling the hard disk drive using PID controller is shown in Fig. 3, with transfer functions of motor coil and load shown explicitly.

$$G(s) = G_1(s).G_2(s) = \frac{5000}{s(s+20)(s+1000)}$$

Using the approximate second-order model for G(s) [7], we obtain

$$\frac{Y(s)}{R(s)} = \frac{5Ka}{s^2+20s+5Ka} (2)$$

The design of a disk drive system is an exercise in optimization and compromisation. The disk drive must be accurately position the head reader while being able to reduce the effects of external shocks, parameter changes and vibrations. The flexure and mechanical arm will resonate at frequencies that may be caused by excitations such as a vibrations to a laptop. Disturbances to the operation of the disk drive includes wear or wobble in the spindle bearings, physical block as well as parameter changes due to component changes.

III. Disk Drive Control with PID controller

The PID controller is the most resorted and the most complete controller available because it provides a quick response, minimum steady state error and a control signal that tends to provide stability to the system. It is an important control tool for industrial processes because only the three gains have to be tuned. Almost 90% of industrial controllers are still implemented based on PID algorithms, particularly at lowest levels, because no other controllers match the clear functionality, simplicity, ease of use and applicability offered by the PID controller. A PID controller in its standard form is also known as the three-term controller, whose transfer function is written in the form given by (3)

$$G_c(s) = K_p\left(1 + \frac{1}{T_i s} + T_d s\right) (3)$$

where$K_P$is the proportional gain, T_i the integral time constant and $T_d$the derivative time constant. The P term provides a control action in proportional to the error signal through the all-pass gain factor. The I term reduces steady-state errors through the low frequency compensation by an integrator and the D term improves the transient response through the high-frequency compensation by a differentiator.

Closed-loop transfer function of the system neglecting the disturbances is

$$\frac{Y(s)}{R(s)} = \frac{G_c(s)G_1(s)G_2(s)}{1+G_c(s)G_1(s)G_2(s)H(s)} (4)$$

It is a challenging task to obtain the optimum values of PID controller, suited for each plant. Various types of tuning rules are reported in literature [8]. One of the most preferred method is Ziegler-Nichols Tuning.

A. Ziegler-Nichols Tuning

Ziegler and Nichols proposed rules for determining values of the proportional gain K_P, integral time $T_i$and derivative time $T_d$arebased on the transient response characteristics of a given plant [8].The Ziegler–Nichols tuning methodisa heuristic methodof tuning a PID controller.These procedures are now accepted as standard in control systems practice.

B. Genetic Algorithm based Tuning

Genetic Algorithms (GAs) are adaptive methods which may be used to solve search and optimisation problems [9]. It is one of the modern heuristic algorithms based on a principle of Darwiniantheory of evolution. Genetic algorithms use biologically inspired mechanisms and survival of the fittest theory in order to refine a set of solution iteratively. GAs belongs to the class of probabilistic algorithms, but they are very different from random algorithms as they combine elements of directed and stochastic search. Because of this, GAs is also more robust than existing directed search methods. Another important property of such genetic based search methods is that they maintaina population of potential solutions; all other methodsprocess a single point of the search space. A block diagram showing the different steps involved in the optimisation process using GA is given in Fig. 4 [10]. Mainsteps involved are selection, crossover, mutation andevaluation.

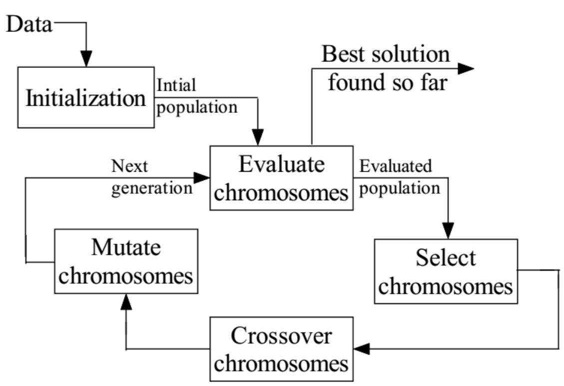

Fig. 4 Optimization using GA

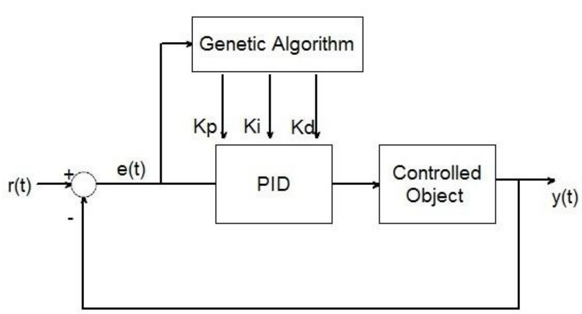

Fig.5 Optimization of PID controller based on GA

In this paper, GA has been used to obtain the optimised P, I, D values for effective control of hard disk drive read/write Head, as shown in Fig. 5. An objective function or fitness function is required to evaluate the best PID controller for the system. Any function that would be a measure of proper control of the system can be used as an objective function. In this paper, mean of the squared error (MSE), as given in (5), is selected as the objective function.

$$MSE = \frac{1}{t}\int_0^{\tau}(e(t))^2\,dt \quad (5)$$

where*e(t)* is the error signal in time domain.

IV. RESULTS

Genetic algorithm is applied for optimisation of PID values, with parameters shown in Table 2. Normalised geometric selection, arithmetic crossover and uniform mutation are observed to give better results. It was observed that the optimisation procedure converges within reasonable time and yields good results.

Table 2: GA Parameters used in simulation

GA property	Value/method
Fitness function	Mean squared error
Population size	50
Maximum no. of generations	300
Selection	Roulette wheel
Crossover	Multipoint
Mutation	Uniform

Unit step response of the hard disk drive read/write system with GA tuned PID controller is shown in Fig. 6. Optimum PID values were computed manually with Ziegler-Nichols (Z-N) method. Unit step response of the system using the PID controller tuned with Z-N method is shown in Fig. 7.

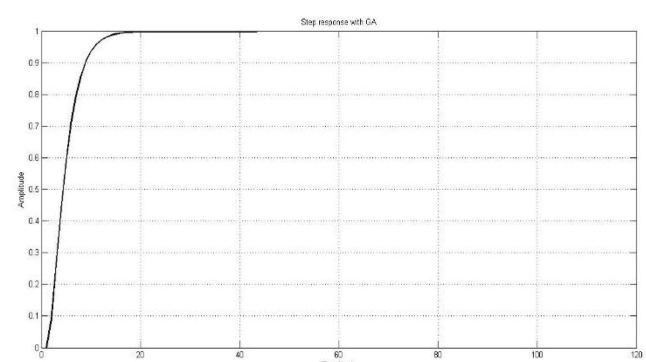

Fig. 6Unit step response with GA based PID controller

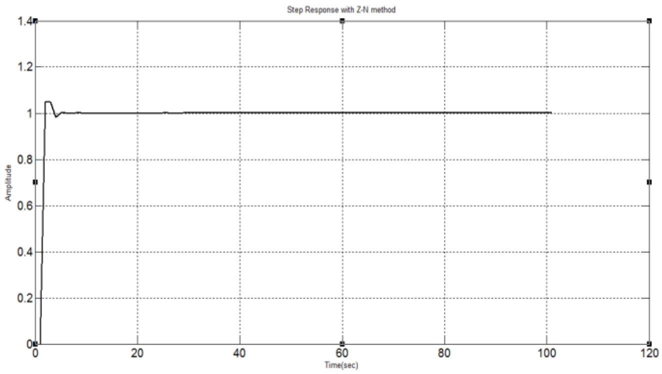

Fig. 7Unit step response with Z-N tuned PID controller

From the comparison of step responses,it is observed that GA based PID controller yields much better results in comparison with Z-N based PID controller. Performances of the two methods are depicted using performance measures such as rise time, settling time, and maximum overshoot in Table 3. Although the GA based method has deterioratedin terms of rise time, it has a much better performance considering settling time and maximum overshoot.

Table 3 Comparison of PID controller results

Tuning method	Rise time(s)	Settling time(s)	Maximum overshoot(%)
Z-N	0.076	0.2427	4.8
GA	0.075	0.0975	0.5

V. CONCLUSION

Basically,majority of the commercially available Hard Disk Drive servo systems are designed by using conventional PID approach. In real world application, one would have to make compromise between maximum overshoot and the track following capability by selecting the appropriate control gains. This is done by utilizing the three actions of the PID controller that are tuned using different nonlinear functions. In this paper the effectiveness of GA based PID controller for control of hard disk drive read/write head is demonstrated.

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