Security Enhancement of Dynamic System Using PID Controller and Optimization Algorithm

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Abstract — This paper presents a research project on a dynamic system by using a controller known as PID Controller, used to provide the simplest and yet effective solutions to most of the control engineering applications today [4] and some computing algorithm, which is implemented in hardware for obtaining parameters of PID controller, for setting K values of controller, increasing the derivative time and also minimizing the integral error in the system. The system has been applied to a PID Controller system with variable plant transfer function [10]. The procedure has been successfully tested and some results are obtained.

Index Terms— Adaptive control. Dynamic system controller, Genetic Algorithms (GAs), Parameter optimization.

I. INTRODUCTION

The PID controller is the most common form of feedback in use today. According to an estimate nearly 90% of the controllers used in industries are PID controller. Designing and tuning a PID controller appears to be conceptually intuitive, but can be hard in practice, if multiple objectives are to be achieved [4].

In the past few decades, neural networks have been used to meet system complexities like nonlinearities, but their real time implementation is quite difficult. The advantage of optimization algorithms over controller is that the former can be incorporated in PID tuning with ease and simplicity [4].

Often in practice, tuning is carried out by an experienced operator using a ‘trial and error’ procedure and some practical rules. This is often a time consuming and difficult activity. Modern adaptive control algorithms can be a good solution to such problems. When these controllers are introduced in industry, some resistance and difficulties can arise. An attractive alternative is to try to combine the well-known PID Controller with algorithms which are able to provide a set of parameters of PID controller using input/output data from the system [10]

The concept of Genetic Algorithm (GA) comes from the Darwinian idea of natural selection and survival of fittest [1]. For a genetic algorithm to improve a solution, it is necessary to reject the poor solutions and only allow reproduction from the best ones. In this case, the role of the environment is played by an evaluating function, measuring the degree of fitness of a candidate to problem requirements [10].

In this research project aircraft is referred as dynamic system. On 24 June, 1975 in John F. Kennedy Airport a Boeing-727 aircraft had a hard crash, during its landing phase, due to a strong downburst gust (Fig. 1) and its 112 out of 124 passengers died. The study of safe landing of airplanes is a very important issue in the aviation field and is considered by pilots as the most demanding task in every flight. Many accidents have occurred during the landing phase of flights, some of which were due to human error, technical faults, engine failure and so on [8]
.

In this paper firstly the PID Controller will be explained with its objective function for optimization. Next we will describe the genetic algorithm principles and after that define how the PID Controller will be used in dynamic system.

II. PID CONTROLLER

A proportional-integral-derivative controller (PID controller) is a common feedback loop component in industrial control system. The controller takes a measured value from a process or other apparatus and compares it with a reference set point value. The difference (or error signal) is then used to adjust some input to the process in order to bring the process measured value back to its desired set point.

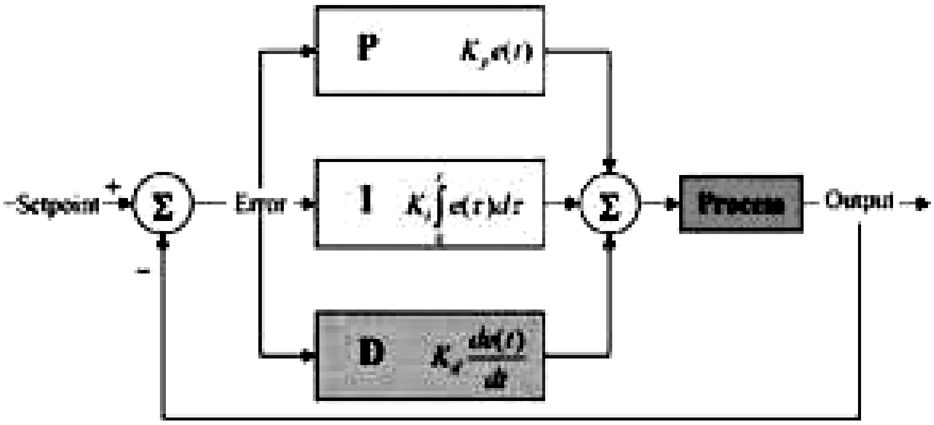

Fig.1 Basic diagram of PID controller

The three main parameters involved are Proportional (P), Integral (I), and Derivative (D). The proportional part is responsible for following the desired set-point, while the integral and derivative part account for the accumulation of past errors and the rate of change of error in the process respectively, illustrated in fig. 1.

$$u = K_P e + K_I \int e\,dt + K_D \frac{de}{dt}$$

The variable (e) represents the tracking error, the difference between the desired input value (R) and the actual output (u). This error signal (e) will be sent to the PID controller, and the controller computes both the derivative and the integral of this error signal. The signal (u) just past the controller is now equal to the proportional gain (Kp) times the magnitude of the error plus the integral gain (Ki) times the integral of the error plus the derivative gain (Kd) times the derivative of the error. Defining $u(t)$ as the controller output, the final form of the PID algorithm is:

The **transfer function** of the PID controller looks like the following:

$$K_P + \frac{K_I}{s} + K_D s = \frac{K_D s^2 + K_P s + K_I}{s}$$

In this paper, an efficient and fast tuning method based on a modified GA structure is proposed to find the optimal parameters of the PID controller so that the desired system specifications are satisfied. To demonstrate the effectiveness of presented method, the step responses of closed loop system were compared with that of the existing methods in the literature [5].

III. GENETIC ALGORITHM

Genetic algorithms (GAs) are stochastic optimization techniques founded on the concepts of natural selection and genetics. Genetic algorithm belongs to the group of Optimization methods called as nontraditional optimization Methods. The algorithm starts with a set of solutions called population. Solutions from a population of chromosomes are used to form a new population. Once the initial population is formed, the GA creates the next generation using three main operators: (1) reproduction, (2) crossover and (3) mutation [5]. The overall process can be represented in form of flow chart illustrated in fig. 2.

During the reproduction phase the fitness value of each chromosome is assessed. The crossover operation swaps certain parts of the two selected strings in a bid to capture the good parts of old chromosomes and create better new ones. Genetic operators manipulate the characters of a chromosome directly, using the assumption that certain individual’s gene codes, on average, produce fitter individuals.

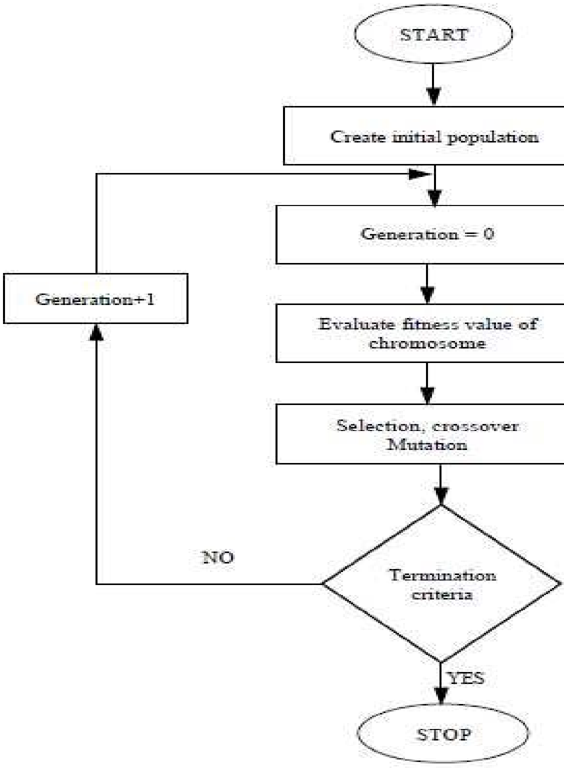

Fig. 2 Flow chart of Genetic Algorithm.

A probability of 0% means that the .offspring will be exact replicas of their .parents and a probability of 100% means that each generation will be composed of entirely new offspring [6].

Single Point Crossover- The simplest crossover technique is the Single Point Crossover. If the strings *10000* and 01110 are selected for crossover and the value of *k* is randomly set to 3 then the newly created strings will be 10010 and 01100 as shown in Figure 3 [7].

100 00 → 10010
011 10 → 01100

Fig.3. Crossover operation.

Mutation: - Mutation is the occasional random alteration of a value of a string position. It is considered a background operator in the GA. If the GA chooses bit position 4 for mutation in the binary string *10000*; the resulting string is *10010* as the fourth bit in the string is flipped as shown in Figure 4[7].

.

10000 → 10010

Fig.4. Illustration of Mutation Operation

Algorithm--------

This mechanism searches the all neighboring solution space for the existing best solution and provides to increase of genetic diversity leads to effectiveness of the algorithm. Because of the problem type and the use of neighborhood mechanism in the presented algorithm structure, binary coded genetic algorithm was preferred. At each generation of GA search, there are a lot of neighbor chromosomes of the chromosome with high quality [5]. The algorithm is as follows:

Initialize population;
While predetermined termination condition not satisfied;
{
Evaluate chromosomes in population;
Keep the best solution;
Obtain the neighbor solutions for the best solution;
Compare the best solution and best neighbor solution;

Keep the new best solution;
Reproduction;
Apply crossover and mutation to chromosomes in population;
New population = population + new best solution;
}

IV. Safe Landing Control

During the landing phase, pilots descend from cruising altitude to an altitude of approximately 1200 ft above the ground. The pilot then takes position the aircraft on a heading towards the centerline of runway. When the aircraft reaches the outer airport marker, which is approximately 4 nautical miles from the runway, the glide path signal is intercepted, as shown in fig. 4 [1].

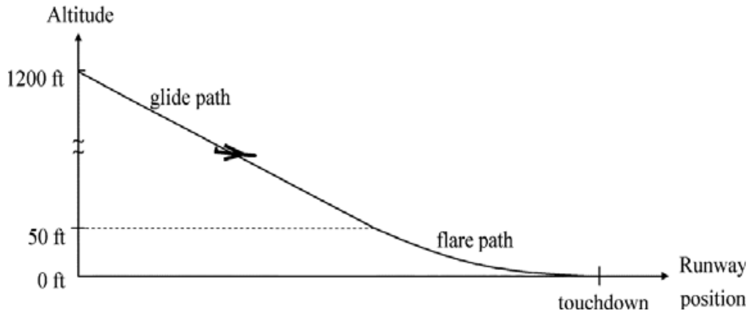

Fig.5 aircraft landing path with different approaches.

The forces acting on an aircraft during flying are lift (L), drag (D), thrust (T), and weight (W) of aircraft. The approach and landing exercise deals with landing of the aircraft from the turn on to downwind position to the completion of the landing run. A good landing follows a steady approach. The final landing approach begins when the flight path is aligned with the runway in preparation for straight ahead descent and landing and ends when aircraft contacts the landing surface [7].

The stability is most important issue in control systems and engineering, because an unstable control system represents a latent danger.

V. Methodology

The process of selecting the controller parameters to meet given performance specifications is known as controller tuning. If a mathematical model of the plant can be derived, then it is possible to apply various design techniques for determining parameters of the controller that will meet the transient and steady-state specifications of the closed-loop system. Then we must resort to experimental approaches to the tuning of PID controllers [12].

In this method, we first set value of Ti to infinite and Td to 0. Using the proportional control action only, increase Kp from 0 to a critical value Kcr at which the output first exhibits sustained oscillations. (If the output does not exhibit sustained oscillations for whatever value Kp may take, then this method does not apply.) . T In this chapter, it will be shown that the inefficiency of designing PID controller using the classical method. This design will be further improved by the optimization method such as .steepest descent gradient method [12].

PID controller is used to control the system. The PID controller has the transfer function-----

$$G_c(s) = K_p (1 + 1/T_i s + T_d s)$$

Let us apply a tuning rule for the determination of the values of parameter Kp, Ti and Td. Then obtain a unit-step response curve and check to see if the designed system exhibits approximately 25% maximum overshoot. If the maximum overshoot is excessive (40% or more), make a fine tuning and reduce the amount of the maximum overshoot to approximately 25% or less [12].

By setting Ti to infinite and Td to 0, we obtain the closed-loop transfer function as follows

$$\frac{C(s)}{R(s)} = \frac{K\,p}{s\,(s+1)\,(s+5) + K\,p}$$

Since the characteristic equation for the closed-loop system is

$$S^3 + 6\,s^2 + 5\,s + Kp = 0$$

The Routh array becomes as follows:

Table 1 Routh array.

s^3	1	5
s^2	6	Kp
s^1	(30 – Kp)/6	
s^0	KP	

Examining the coefficients of the first column of the Routh table, we find that sustained oscillation will occur if Kp = 30. Thus, the critical gain K cr is

$$Kcr = 30$$

With gain Kp set equal to Kcr (=30), the characteristic equation becomes

$$S^3 + 6\,s^2 + 5\,s + 30 = 0$$

The frequency of the sustained oscillation can be determined by substituting the s terms with $j\omega$ term. Hence the new equation becomes

$$(J\omega)^3 + 6\,(j\omega)^2 + 5\,(j\omega) + 30 = 0$$

This can be simplified to

$$6\,(5.\,\omega)^2 + j\omega\,(5.\,\omega) = 0$$

From the above simplification, the sustained oscillation can be reduced to

$$\omega^2 = 5$$

Or

$$\omega = \sqrt{5}$$

The period of the sustained oscillation can be calculated as

$$Per = 2\pi/\sqrt{5}$$
$$= 2.8099$$

Table 2. PID value setting

Type of controller	Kp	Ti	Td
PID	0.6 Kcr	0.5 Pcr	0.125 Pcr

Referring to table 2, we determine Kp, Ti and Td as follows

Kp= 0.6 Kcr = 18
Ti = 0.5 Pcr = 1.405
Td = 0.125 Pcr = 0.35124

The transfer function of the PID controller is thus

$$G_c(s) = Kp\,(1 + 1/Ti\, s + Td\, s)$$
$$= 18\,(1 + 1/1.405s + 0.35124s)$$
$$= [6.3223\,(s + 1.4235)\,\hat{}2]\,/2$$

The PID controller has a pole at the origin and double zero at s = -1.4235 [12].
Next, let us examine the unit-step response of the system. The closed-loop transfer function C(s) /R(s) is given by

$$\frac{C(s)}{R(s)} = \frac{6.3223\, s^2 + 18\, s + 12.811}{s^4 + 6\, s^3 + 11.3223\, s^2 + 18\, s + 12.811}$$

V. Result

From the unit step response function the following graph obtained, as shown in fig. 3

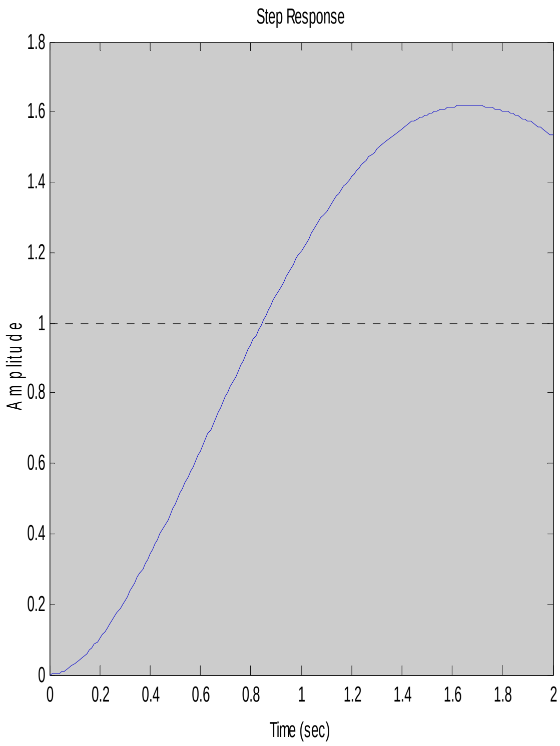

Fig. 6. PID unit step response.

VI. Conclusion

The designed PID with GA has much faster response than response of the classical method. The error associated with the genetic based PID is much lesser than the error calculated in the conventional scheme [3].

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