

Design Of Optimal Pid Controller Using Genetic Algorithm

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Abstract: One of the most important problems today is robotics and its control. Due to the vast Application of inverted pendulum in robots. In this paper, by using a combination of "GA" Algorithms, we have tried to optimally control the inverted pendulum by nonlinear equations. The result of this simulation has been mentioned in the conclusion. It seems that the results be acceptable results.

Key words: Genetic Algorithm, optimal, classical PID controller, Inverted Pendulum.

INTRODUCTION

There are variety methods for Inverted Pendulum control that are presented since now. The presented methods for Inverted Pendulum control are divided generally in three groups. Classic methods such as PID PI controllers (Paul I-HaiLin, *et al.*, Tang and Chassaing, 1999). Modern methods (adaptation-optimum) (Yang, *et al.*, 2002; Hyun Cheol Cho, *et al.*, 2009; Fallahi, *et al.*, 2009 Artificial methods such as neural networks and fuzzy and Genetic Algorithm and PSO (Jang, 1993; Boumediene ALLAOUA, *et al.*, 2009; Randy Haupt and Sue Ellen Haupt) Theories are the presented methods for Inverted Pendulum angle control.

The design method in linear control comprise based on main application the wide span of frequency, linear controller has a weak application, because it can't compensate the nonlinear system effect completely.

Modeling an Inverted Pendulum:

The cart with an inverted pendulum, shown below, is "bumped" with an impulse force, F . Determine the dynamic equations of motion for the system, and linearize about the pendulum's angle, $\theta = 0$ (in other words, assume that pendulum does not move more than a few degrees away from the vertical, chosen to be at an angle of 0). Find a controller to satisfy all of the design requirements given below.

For this example, let's assume that

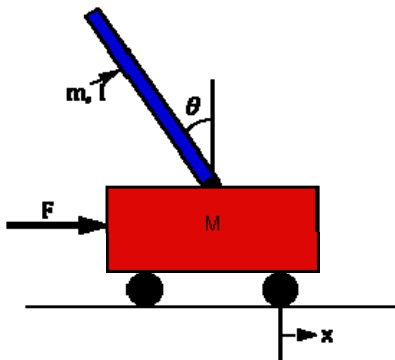


Fig.1: The structure of an Inverted Pendulum.

Table 1: Physical Parameters of Inverted Pendulum.

| | | |
|-------|-----------------------------------|-------------------------|
| M | mass of the cart | 0.5 kg |
| m | mass of the pendulum | 0.2 kg |
| b | friction of the cart | 0.1 N/m/sec |
| l | length to pendulum center of mass | 0.3 m |
| I | inertia of the pendulum | 0.006 kg*m ² |
| F | force applied to the cart | |
| x | cart position coordinate | |
| theta | pendulum angle from vertical | |

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This system is tricky to model in Simulink because of the physical constraint (the pin joint) between the cart and pendulum which reduces the degrees of freedom in the system. Both the cart and the pendulum have one degree of freedom (X and theta, respectively). We will then model Newton's equation for these two degrees of freedom.

$$\frac{d^2x}{dt^2} = \frac{1}{M} \sum_{cart} F_x = \frac{1}{M} \left(F - N - b \frac{dx}{dt} \right) \quad (1)$$

$$\frac{d^2\theta}{dt^2} = \frac{1}{I} \sum_{pend} \tau = \frac{1}{I} (NL \cos(\theta) + PL \sin(\theta)) \quad (2)$$

It is necessary, however, to include the interaction forces N and P between the cart and the pendulum in order to model the dynamics. The inclusion of these forces requires modeling the x and y dynamics of the pendulum in addition to its theta dynamics. Generally, we would like to exploit the modeling power of Simulink and let the simulation take care of the algebra. Therefore, we will model the additional x and y equations for the pendulum.

$$m \frac{d^2x_p}{dt^2} = \sum_{pend} F_x = N \quad (3)$$

$$\Rightarrow N = m \frac{d^2x_p}{dt^2} \quad (4)$$

$$m \frac{d^2y_p}{dt^2} = P - mg \quad (5)$$

$$\Rightarrow P = m \left(\frac{d^2y_p}{dt^2} + g \right) \quad (6)$$

However, x_p and y_p are exact functions of theta. Therefore, we can represent their derivatives in terms of the derivatives of theta.

$$x_p = x - L \sin(\theta) \quad (7)$$

$$\frac{dx_p}{dt} = \frac{dx}{dt} - L \cos(\theta) \frac{d\theta}{dt} \quad (8)$$

$$\frac{d^2x_p}{dt^2} = \frac{d^2x}{dt^2} + L \sin(\theta) \left(\frac{d\theta}{dt} \right) - L \cos(\theta) \frac{d^2\theta}{dt^2} \quad (9)$$

$$y_p = L \cos(\theta) \quad (10)$$

$$\frac{dy_p}{dt} = -L \sin(\theta) \frac{d\theta}{dt} \quad (11)$$

$$\frac{d^2y_p}{dt^2} = -L \cos(\theta) \left(\frac{d\theta}{dt} \right)^2 - L \sin(\theta) \frac{d^2\theta}{dt^2} \quad (12)$$

These expressions can then be substituted into the expressions for N and P. Rather than continuing with algebra here, we will simply represent these equations in Simulink. Simulink can work directly with nonlinear equations,

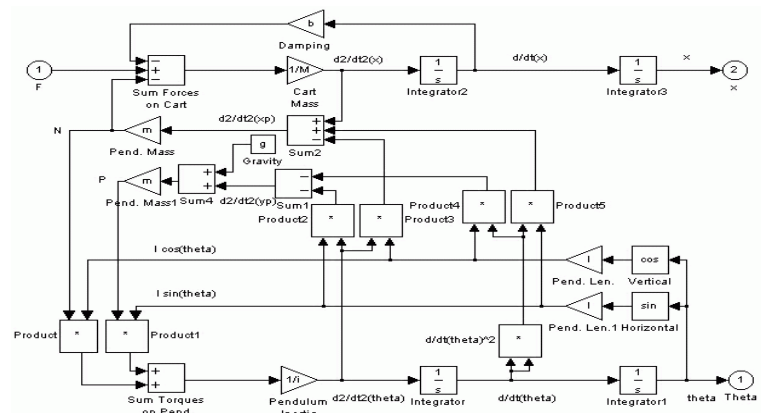


Fig. 2: The block diagram of an Inverted.

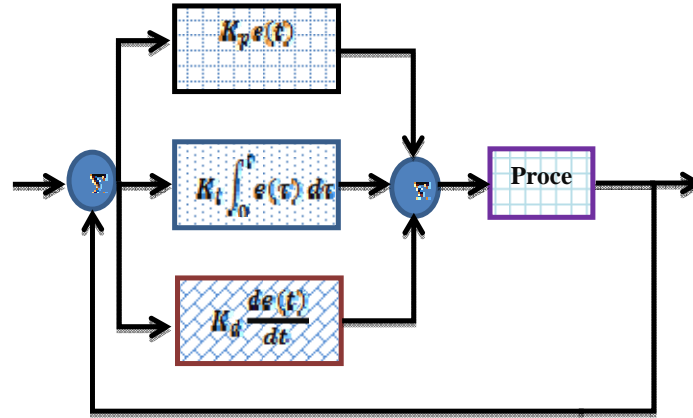


Fig. 3: Generic closed loop control system With a PID controller.

Ga based tuning of the pid controller gains:

Introduction to Genetic Algorithm PID:

In 1975, GA was proposed firstly by (Holland, 1976). It is an optimization algorithm and applied to various fields, including business, science, and engineering. Based on the survival-of-the-fittest strategy proposed by Darwin, this algorithm will eliminate unfit components to select the fittest component by Man-made fitness functions generation by generation.

A. Initialization:

In the initialization, the first thing to do is to decide the coding structure. Coding for a solution, termed a chromosome in GA literature, is usually described as string of symbols from $\{0, 1\}$. These components of the chromosome are then labeled as genes. The number of bits that must be used to describe the parameters is problem dependent.

B. Selection:

GA uses proportional selection; the population of next generation is determined by n independent random experiments.

C. Crossover:

Cross over is an important random operator in GA and the function of this operator is to generate a new 'child' chromosome from two 'parents' chromosomes by combining the information extracted from the parents.

D. Mutation:

Mutation is another important component in GA, though it is usually conceived as a background operator. It operates independently on each individual by probabilistically perturbing each bit string. A usual way of mutation used in GA is to generate a random number between zero and one and then make a random change in the v -th element of the string with probability P_m belonging to $(0, 1)$.

E. Encoding & Decoding:

The design variables are mapped onto a fixed-length binary digit string, which are constructed over the binary alphabet $\{0,1\}$, and is concatenated head-to-tail to form one long string referred as a chromosome. That is, every string contains all design variables. The physical values of the design variables are obtained by decoding the string.

F. Fitness Function:

In GA, the value of fitness represents the performance, which is used to rank the string, and the ranking is used to determine how to allocate reproductive opportunities. This means that individuals with higher fitness value will have higher probability of selection as a parent. Fitness thus is some measure of goodness to be optimized. The fitness function is essentially the objective function for the problem.

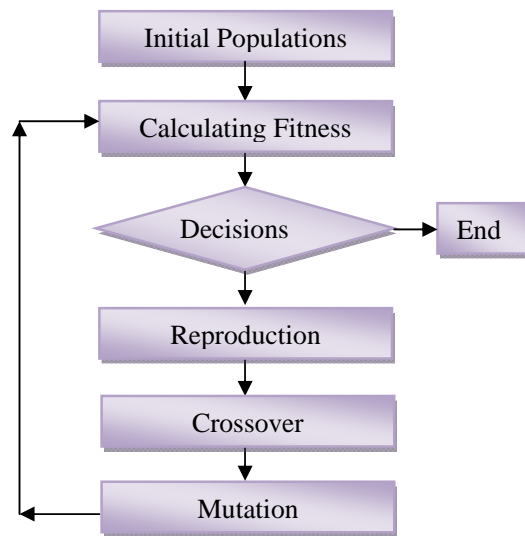


Fig. 4: Illustrates the block structure of the FOPID controller optimizing process with GA.

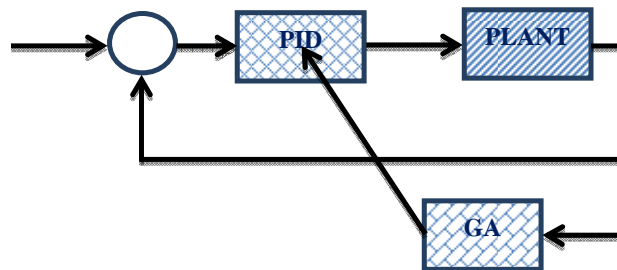


Fig. 5: Tuning process of the PID controller parameters with GA.

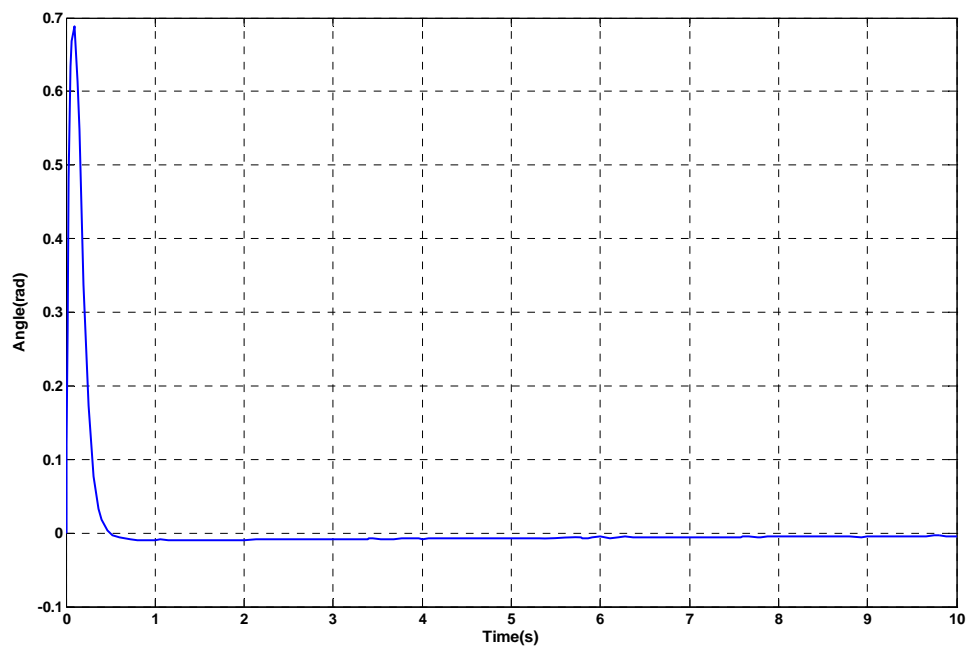


Fig. 6: Inverted pendulum rod angle for initial 0.5 radians (Best result).

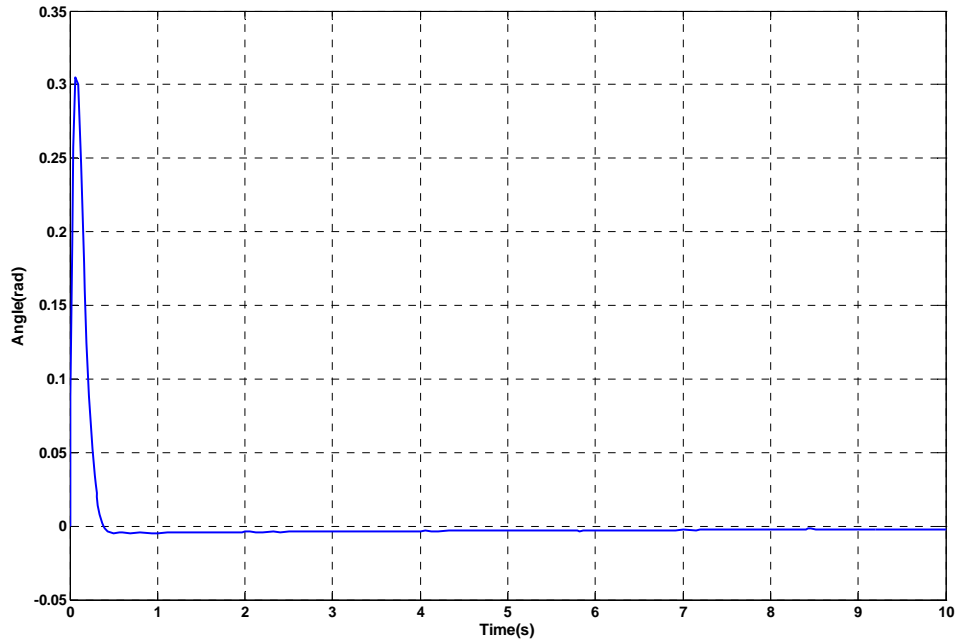


Fig. 7: Inverted pendulum rod angle for initial 0.3 radians(Best result).

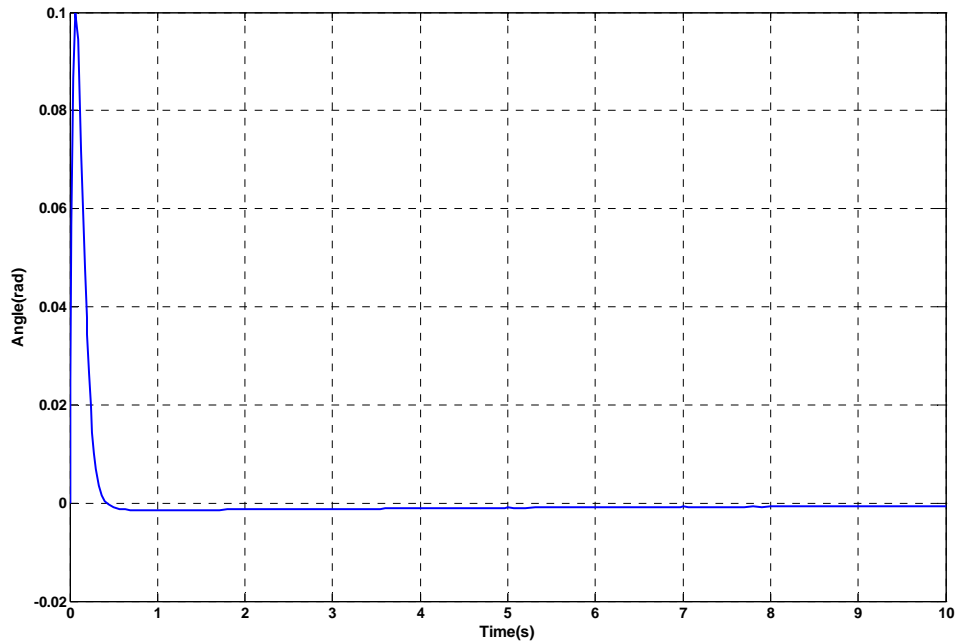


Fig. 8: Inverted pendulum rod angle for initial 0.1 radians(Best result).

Conclusion:

Parameters adjustment at different problems takes more time up by hard mathematical calculating. At this paper was tried one simple application from algorithm "GA" considered by control engineering problem. We can find the optimal answer with "GA" algorithm. This answer should be careful and simple rarely acceptable.

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