Force Signal Controlling of Surgical Robotic Arm using GA-PID Controller

Umesh Kumar Saket[1]
[1]P.G. Student
[1]Department of Electrical Engineering
[1]Jabalpur Engineering College, Jabalpur (MP) India

Abstract— In this paper output force controlling for three degree freedom (DOF) surgical robotic arm by using genetic algorithm with PID controller. The aim of the controller is to improve and adjust the output force of the arm and optimization parameters such as kp, ki and kd by Genetic Algorithm without hit and trial method is taken. The optimization design methods often consider the system requirements for quickness, reliability, and accuracy. This robot is used in the field of surgery. So surgical robotic arm require don't oscillate and no max. Overshoot. This paper performs to reduce the oscillation, max. Overshoot, settling time, response time and improves stability of system.

Key words: Surgical Robotic Arm, Force Balance Concept, Force Signal Tuning, PID Controller With Genetic Algorithm

I. INTRODUCTION

The robot is very useful technology in modern days, the robot is called a software-controllable mechanical device that uses sensors to direct one or more end-effectors throughout programmed motions in a workspace in arrange to manipulate physical object [1]. now days this technology using in surgery. Surgical robotic devices are dividing in three part, (a) large, high precision robots (b) handheld smart medical tool and (c) miniature endoscopic robots. Minimally invasive (MIS) is an operation technique established in the 1980s [2]. surgical robots are very helpful for surgery, some working area are (1)neurosurgery (2) orthopedics (3)minimally-invasive surgery/laparoscopy (4) radio surgery (5) maxillofacial surgery (6) microsurgery and other non surgical specialties (1) tale ethnography. In this paper represents controlling of 3-DOF surgical robotics arm. The controlling method is a combination of two controller PID controller and Genetic algorithm. The PID controller is the most common form of Controller. It was an essential element of early governors and it became the standard tool when process control emerged in the 1940s. In process control today, more than 95% of the control loops are of PID type. And genetic algorithm of optimization method to optimized PID parameters such as K_p, K_i, and K_d [3]. The simulink block of 3-DOF surgical robotics is given below [4]. These robots have one degree show elongation direction and other two arm show different angular motion of robots. The robots have three outputs and three input, so output control by three PID controllers with genetic algorithm (GA). In each PID controller have three gain K_p, K_i, and K_d this gain value put in genetic algorithm, and optimized the value of PID parameters gain. Then GA provides optimum value to the PID Controller. However PID Controller reduced the error of the system and developed to adjust the output force.

II. DYNAMIC MODEL OF A ROBOTIC ARM

A Robotic arm which is used in surgical operation is shown in figure 1 It consists of two links, a static link and a dynamic link. The junction between the two links has three degrees of freedom represented in the variable of motions d_1 , $\emptyset_2$, and $\emptyset_3$.

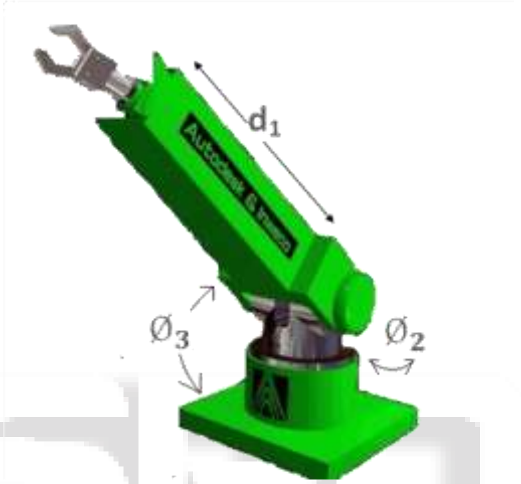

Fig. 1: Three Degree Freedom Robotic ARM

The mathematical model of the dynamic link of the robotic arm is given by the following equations using Lagrange equation [5]

$$\ddot{d_1} = \frac{1}{m}[\, u_1 \cos \emptyset_3^2 + \left(u_2 - m\dot{d_1}\dot{\emptyset_3}\right) \cos \emptyset_3 \sin \emptyset_3 - \dot{\emptyset}_2\dot{\emptyset}_3 \sin \emptyset_3^2] \quad (1)$$

$$\ddot{\emptyset}_2 = \frac{1}{m}[u_2 \sin \emptyset_3^2 + \left(u_1 + m\dot{\emptyset}_2\dot{\emptyset}_3\right) \cos \emptyset_3 \sin \emptyset_3 + \dot{q_1}\dot{q_3} \cos \emptyset_3^2] \quad (2)$$

$$\ddot{\emptyset}_3 = \frac{u_3}{I} \quad (3)$$

d_1 = Arm elongation
$\emptyset_2$ = Heading direction
$\emptyset_3$= angle with $\emptyset_2$plane
m= mass of the robotic arm
I= robotic arm inertia about the axis of rotation.
$u_1,\ u_2,\ u_3$Are the forces along the d_1,$\emptyset_2$,$\emptyset_3$ directions. These equations are derived from Lagrange equation to get**.**

$$u_1 = md_1 - \lambda \sin \emptyset_3 \quad (4)$$

$$u_2 = m\emptyset_2 - \lambda \cos \emptyset_3 \quad (5)$$

$$u_3 = I\, \emptyset_3 \quad (6)$$

Where λ is Lagrange multiplier, by applying the velocity constraint

$$\dot{d}_1 \sin \emptyset_3 - \dot{\emptyset}_2 \cos \emptyset_3 = 0 \quad (7)$$

Differentiating this constraint, we get.

$$\ddot{d}_1 \sin \emptyset_3 + \dot{d}_1\dot{\emptyset}_3 \cos \emptyset_3 - (\emptyset_2 \cos \emptyset_3 + \dot{\emptyset}_2\dot{\emptyset}_3 \sin \emptyset_3) = 0 \quad (8)$$

Solving above equation

$$\lambda = \left(u_2 - m\dot{d}_1\dot{\varnothing}_3\right)\cos\varnothing_3 - \left(u_1 + m\dot{\varnothing}_2\dot{\varnothing}_3\right)\sin\varnothing_3 \quad (9)$$

III. CONTROL SCHEME

The control schemes are shown in figure 2 and the simulink block diagram of robotic arm. The control system is designed to control the output force signal of the robotic arm. The system responses are shown before and after inserting the controller. The robots have three outputs and three input, so output control by three PID controller and genetic algorithm (GA). In each PID controller have three gains K_p, K_i, and K_d this gain value (in a range form) put in genetic algorithm, and optimized the value of PID parameters gain. Then GA provides optimum value to the PID Controller. However PID Controller reduced error of the system and developed to adjust the output force of the robotic arm. The responses of system are controlled by PID controller with genetic algorithm. The unity feedback take output y (t) compare from input r (t) and generate error e (t). This error minimizes by PID controller and PID has parameter K_p, Ki, and K_d this parameter optimize by GA. Then output response better from PID controller, reduce maxim um over shoot, rise time and settling time.

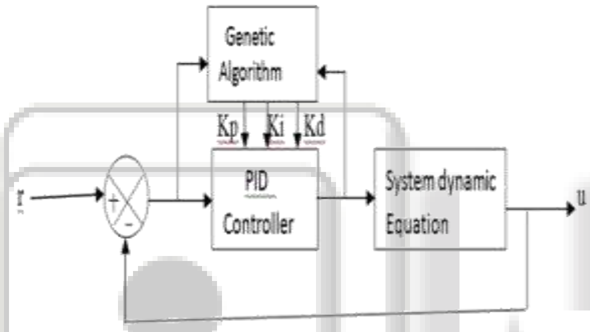

Fig. 2: Close Loop Control of Robotics ARM

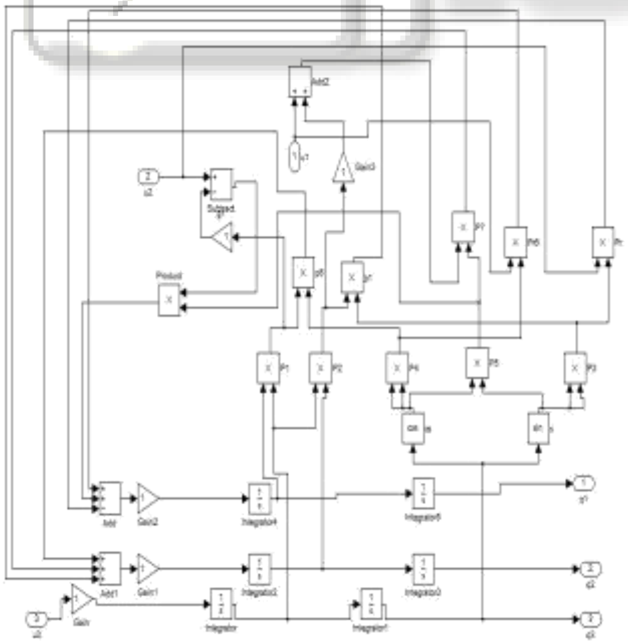

Fig. 3: Simulink Block Diagram Model for The Simulated Robotic ARM (q_1=d_1, q_2=$\varnothing_2$, q_3=$\varnothing_3$)

IV. GENETIC ALGORITHM (GA)

In GA supply of the initial population seriously affect the performance of the convergence. if the performance of the initial population is poor, the convergence of the algorithm will slow, even have no convergence. Initial population is randomly generated in the search space, and this method is used to give better response and select the optimum value for control variable. First we divide the range of each parameter to be optimized into groups, the total number of groups is the population size, and then in each inter-cell randomly generates. This method ensures that the initial population contains rich modes, attractive the possibility of converge to the global optimum [6].

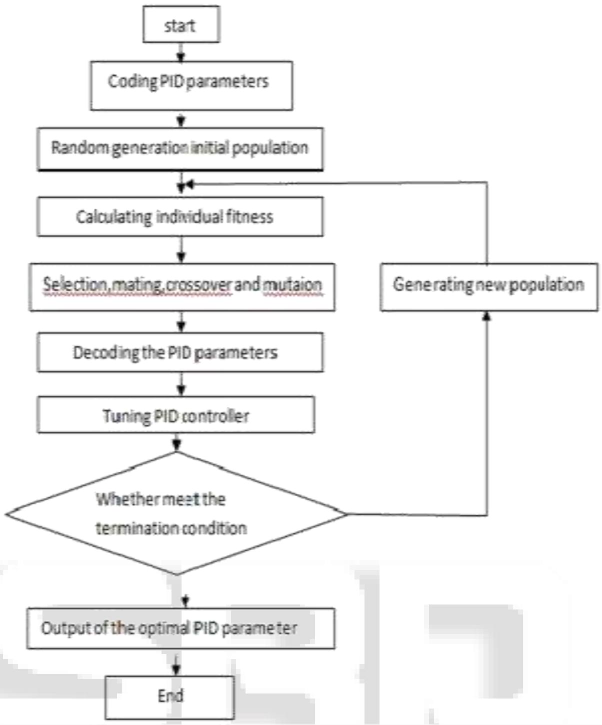

Fig. 4: Flow Chart of Genetic Algorithm

It is an optimization algorithm is 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 [7].

A. Initialization

In the initialization, the first thing to do is decide the coding structure. Coding for a solution, termed a chromosome in GA literature, in 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 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

In this step, mutation operation is performed to produce new offspring (results) after crossover operation. Mutation-flipping operation is performed and new offspring are produced. Once the offspring are obtained after mutation, they are decoded to value and fitness values are computed.

E. Encoding & Decoding

Each chromosome encodes a binary bit [0, 1] string. Each bit in the string can represent some characteristics of solution. Every bit string therefore is a solution but not necessarily the best solution. The way bit strings can code differs from problem to problem. This encoding is not natural for many problems and sometimes correction must be made after genetic operation is completed. Length of the string depends on the accuracy, and decoding process.

F. Fitness Function

A value of fitness is assigned to each solution (chromosome) depending on how close it actually is to solving the problem. 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.

G. Tuned Force Signal Results

First construct the simulation model and simulating without using any controller. Then output responses figure No. 5$\boldsymbol{u_1}$, $\boldsymbol{u_2}$ and $\boldsymbol{u_3}$ there are give unstable output. The simulate using PID controller. Then output figure No.7 and the simulating using GA PID controller *in figure No.7,8,9* this output represents force from the robotic arm.

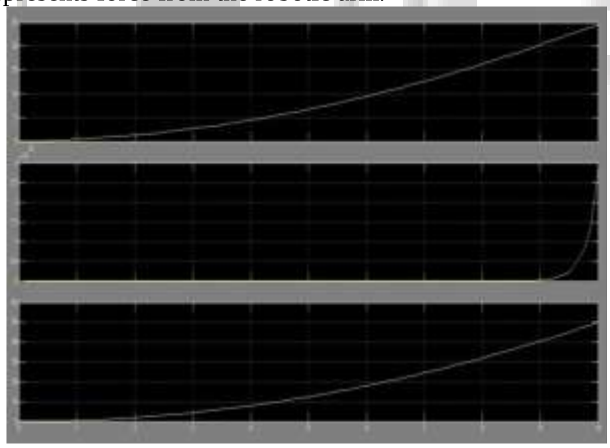

Fig. 5: Output $\boldsymbol{u_1}$, $\boldsymbol{u_2}$ *and* $\boldsymbol{u_3}$ without Controllers

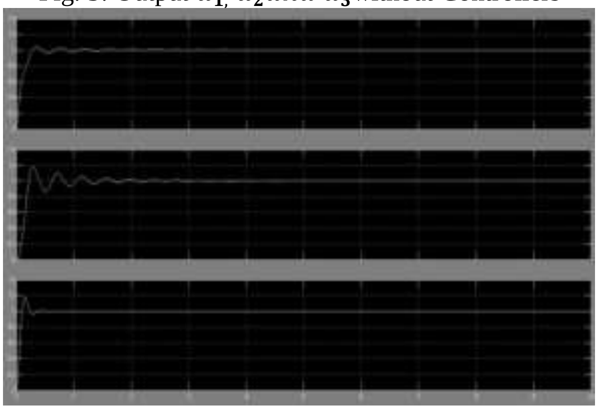

Fig. 6: Output $\boldsymbol{u_1}$, $\boldsymbol{u_2}$ *and* $\boldsymbol{u_3}$ PID with Controllers

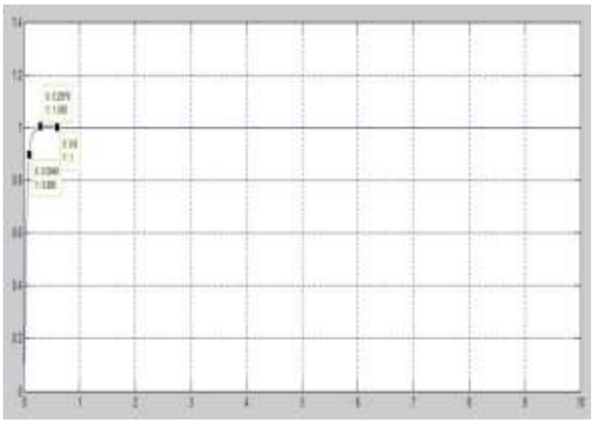

Fig. 7: for Output u_1 with GA PID Controller

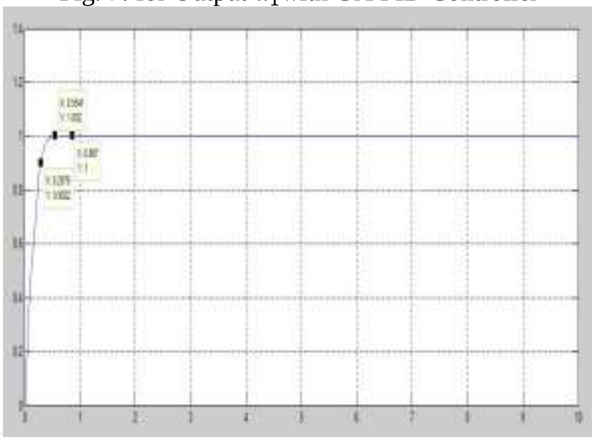

Fig. 8: for Output u_2 with GA PID Controller

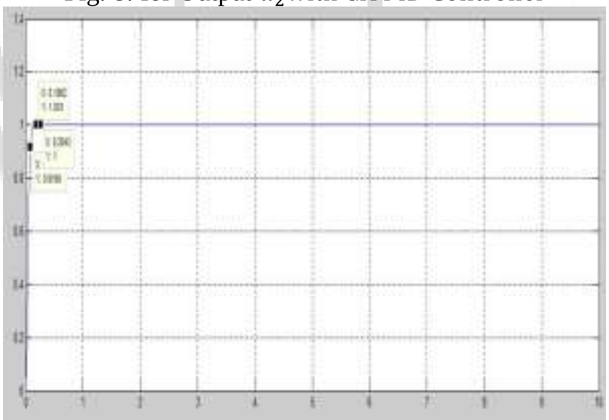

Fig. 9: for $\boldsymbol{u_3}$ with GA PID Controller

PID control variable	Output $\mathbf{u_1}$	Output $\mathbf{u_2}$	Output $\mathbf{u_3}$
Rise time	0.223 sec	0.202 sec	0.09 sec
Peak time	0.332 sec	0.295 sec	0.1641 sec
Peak amplitude	1.0362	1.1798	1.1673
Settling time	1.007 sec	4.925 sec	0.2958 sec
Max Overshoot	5.7%	18.09%	20.5%

Table 1: output Response of PID controller

GA PID control variable	Output $\mathbf{u_1}$	Output $\mathbf{u_2}$	Output $\mathbf{u_3}$
Rise time	0.0949 sec	0.2979 sec	0.0821 sec
Peak time	0.2979 sec	0.5541 sec	0.1654 sec
Peak amplitude	1.005	1.002	1.001
Settling time	0.6 sec	0.867 sec	0.2 sec
Max Overshoot	0.5%	0.2%	0.1%

Table 2: Output Responses of GA-PID controller

V. CURRENT APPLICATION OF ROBOTICS IN SURGERY

Robotic surgical systems have been used in many different surgical discipline including urology, cardiac surgery, gynecology, general surgery and pediatric surgery. Despite the Important role general surgery has played in advancing minimally invasive surgical techniques [8].

VI. CONCLUSION

Tuning output force of robotic arm, the Parameters adjustment at different problems takes more time up by hard mathematical calculating. At this paper was tried one simple application from Genetic algorithm considered by control engineering problem. We can find the Optimal answer by Genetic algorithm .This answer should be careful and simple acceptable. this paper are Three controllers for the three dimension reference forces were added but the results of three dimension forces (u_1, u_2,u_3) Continued having great oscillation and percentage of Overshoot to the anticipated Outcome. The introduction of PID controller into our Study and refining its gain values the results began to convert towards the required results. But more iteration is need. So this paper use PID controller with genetic algorithm this controller optimize value of K_P, K_i and K_d. So this cause less time requires compared to PID controller and give optimum value of gain.

REFERENCES

[1] Robert J. Schilling, Fundamentals of Robotics Analysis and control. This is a Book in publication of Prentice-Hall of India Private limited new delhi-110001 (2001).
[2] Gary S. Gut hart, J. Kenneth Salisbury, Jr. The Intuitive TM Telesurgery System: Overview and Application Proc. IEEE ICRA'2000
[3] Sedigheh Dehghani, Humid D. Táchira and Mohammad Derain 'Self-Tuning Dynamic Impedance Control For Human Arm Motion' 978-1-4244-7484-4110/$26.00 ©2010 IEEE Proceedings of the 17th Iranian Conference of Biomedical Engineering (ICBME2010), 3-4 November 2010
[4] Gamal I. Selim, Noha H. El- Amary, and Dina M. Aboul Dahab 'Force Signal Tuning for a Surgical Robotic Arm Using PID Controller', International Journal of Computer Theory and Engineering Vol. 4, No. 2, April 2012
[5] Howie Choset, Kevin M. Lynch, Seth Hutchinson, George A. Kantor, Wolfram Burgard, Lydia E. Kavraki, and Sebastian Thrun, Principles of robot motion : theory, algorithms, and implementation, MIT press, Cambridge, MA, June, 2005.
[6] Ying Chen, Yong-jie Ma*, Wen-xia Yun, Application of Improved Genetic Algorithm in PID Controller Parameters Optimization TELKOMNIKA, Vol.11, No.3, March 2013, pp. 1524 ~ 1530 ISSN: 2087-278X
[7] Mohammad Reza Dastranj, 1Kazem Esmaeili Khoshmardan, 2Faezeh Sayad Sijani, 3Younes Ghezi. Design of Optimal PID Controller Using Genetic Algorithm Australian Journal of Basic and Applied Sciences, 5(10): 996-1001, 2011 ISSN 1991-8178
[8] James Wall, MD, Venita Chandra, MD and Thomas Krummel, MD Robotics in General Surgery www.intechopen.com [2007] Intuitive Surgical, Inc