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 optimize PID parameters such as Kp, Ki, and Kd [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 Kp, Ki, and Kd 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 d1, O2, and O3.

![Fig. 1: Three Degree Freedom Robotic ARM](image)

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

\[ \ddot{d}_1 = \frac{1}{m_1} u_1 \cos \dot{\theta}_2^2 + \left( u_2 - m_1 \dot{d}_1 \dot{O}_3 \right) \cos O_3 \sin \Theta_3 - \dot{O}_3 \dot{O}_3 \sin \Theta_3^2 \]

\[ \ddot{O}_2 = \frac{1}{m_2} u_2 \sin \dot{\theta}_2^2 + \left( u_1 + m_2 \dot{O}_2 \dot{O}_3 \right) \cos O_3 \sin \Theta_3 + \dot{q}_1 \dot{q}_3 \cos \Theta_3^2 \]

\[ \Theta_3 = \frac{u_3}{T} \]

where

* d1 = Arm elongation
* O2 = Heading direction
* O3= angle with O2-plane
* m= mass of the robotic arm
* I= robotic arm inertia about the axis of rotation.
* u1, u2, u3/ are the forces along the d1, O2, O3 directions.
* These equations are derived from Lagrange equation to get.

\[ u_1 = m \dot{d}_1 - \lambda \sin \Theta_3 \]

\[ u_2 = m \dot{O}_2 \dot{O}_3 \cos \Theta_3 \]

\[ u_3 = \dot{O}_3 \]

Where \( \lambda \) is Lagrange multiplier, by applying the velocity constraint

\[ d_1 \sin \Theta_3 - \dot{O}_2 \cos \Theta_3 = 0 \]

Differentiating this constraint, we get,

\[ d_1 \sin \Theta_3 + d_1 \dot{O}_3 \cos \Theta_3 - \dot{O}_2 \Theta_3 \cos \Theta_3 + \dot{O}_2 \dot{O}_3 \sin \Theta_3 = 0 \]

Solving above equation
\[ \lambda = (u_2 - md_3 \dot{\Theta}_3) \cos \Theta_3 - (u_3 + m\dot{\Theta}_2 \dot{\Theta}_3) \sin \Theta_3 \]  

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 \(K_p\), \(K_i\), and \(K_d\) this parameter optimize by GA. Then output response better from PID controller, reduce maximum over shoot, rise time and settling time.

![Fig. 2: Close Loop Control of Robotics ARM](image)

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](image)

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 $u_1$, $u_2$, and $u_3$ 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.

<table>
<thead>
<tr>
<th>PID control variable</th>
<th>Output $u_1$</th>
<th>Output $u_2$</th>
<th>Output $u_3$</th>
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<tbody>
<tr>
<td>Rise time</td>
<td>0.223 sec</td>
<td>0.202 sec</td>
<td>0.09 sec</td>
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<td>Peak time</td>
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<td>Peak amplitude</td>
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<td>1.1673</td>
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<td>Settling time</td>
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<td>0.2958 sec</td>
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<td>Max Overshoot</td>
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<td>18.09%</td>
<td>20.5%</td>
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<table>
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<tr>
<th>GA PID control variable</th>
<th>Output $u_1$</th>
<th>Output $u_2$</th>
<th>Output $u_3$</th>
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<td>0.0821 sec</td>
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<tr>
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<td>Peak amplitude</td>
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<td>Max Overshoot</td>
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<td>0.1%</td>
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</table>
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