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Electrical Engineering

Elixir Elec. Engg. 95 (2016) 41132-41134

ISSN: 2229-712X

Force Controlling of Surgical Robotic Arm Using PID Controller with Genetic Algorithm

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ARTICLE INFO

Article history:
Received: 3 June 2015;
Received in revised form:
15 June 2016;
Accepted: 21 June 2016;

Keywords
Surgical robotic arm,
Force balance concept,
Force signal tuning,
PID controller with genetic algorithm.

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 k_p, k_i and k_d by Genetic Algorithm without hid and trail 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 and improves stability of system.

Introduction

The surgical robotic is a new technology, there are using in surgery. The Definition of robot "the robot is 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]. Surgical robotic devices are dividing in three part, 1-large, high precision robots 2-handheld smart medical tool and 3-miniature endoscopic robots. Minimally invasive (MIS) is an operation technique established in the 1980s [2]. Now days 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 1.PID controller and 2.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]. 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 (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 error of the system and developed to adjust the output force of the robotic arm.

Dynamic Model of A Robotic Arm

A Robotic arm which is used in surgical operation is shown in figure. No.1. It consists of three links, two static links and one dynamic link. The junction between the two links has three degrees of freedom represented in the variable of motions d_1, $\varnothing_2$, and $\varnothing_3$.

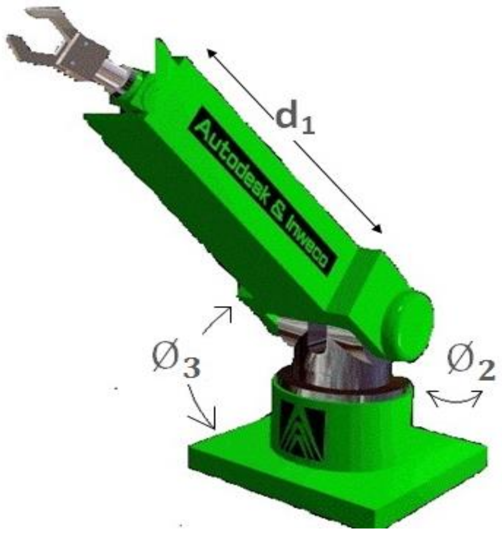

Figure 1. three degree freedom robotic arm

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

$$\ddot{d}_1 = \frac{1}{m}[\, u_1 \cos \varnothing_3^2 + (u_2 - m d_1 \dot{\varnothing}_3) \cos \varnothing_3 \sin \varnothing_3 - \dot{\varnothing}_2 \dot{\varnothing}_3 \sin \varnothing_3^2] \quad (1)$$

$$\ddot{\varnothing}_2 = \frac{1}{m}[\, u_2 \sin \varnothing_3^2 + (u_1 + m \dot{\varnothing}_2 \dot{\varnothing}_3) \cos \varnothing_3 \sin \varnothing_3 + \dot{q}_1 \dot{q}_3 \cos \varnothing_3^2] \quad (2)$$

$$\ddot{\varnothing}_3 = \frac{u_3}{I}$$

d_1 = Elongation of arm.
$\varnothing_2$ = Heading direction
$\varnothing_3$ = angle with $\varnothing_2$ plane
m= mass of the robotic arm
I= robotic arm inertia about the axis of rotation.

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u_1, u_2 Are the forces along the (d_1,$Ø_2$) directions. And u_3 is the torque about an axis through the contact point and orthogonal to the plane. These equations are derived from Lagrange equation to get.

$u_1 = md_1$ -

$\sin Ø_3$ (4)

$u_2 = mØ_2 + \lambda \cos Ø_3$ (5)

$u_3 = IØ_3$ (6)

Where λ is Lagrange multiplier, by applying the velocity constraint

$\dot{d}_1 \sin Ø_3 - \dot{Ø}_2 \cos Ø_3 = 0$ (7)

Differentiating this constraint, we get.

$\ddot{d}_1 \sin Ø_3 + \dot{d}_1 \dot{Ø}_3 \cos Ø_3 - (Ø_2 \cos Ø_3 + \dot{Ø}_2 \dot{Ø}_3 \sin Ø_3) = 0$ (8)

Solving above equation

$\lambda = (u_2 - md_1 Ø_3) \cos Ø_3 - (u_1 + mØ_2 Ø_3) \sin Ø_3$

Control Scheme

The control schemes are shown in figure No. 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

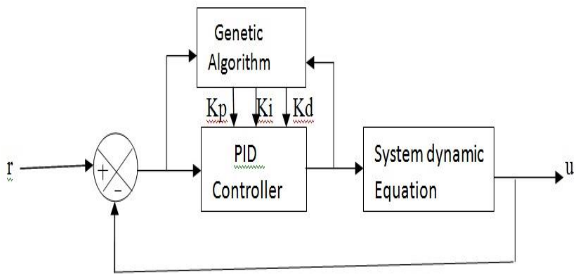


Figure 2. close loop control of robotics arm

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.

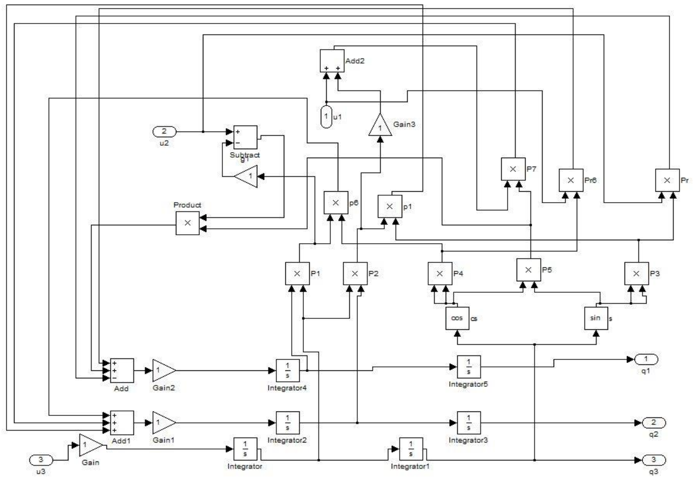
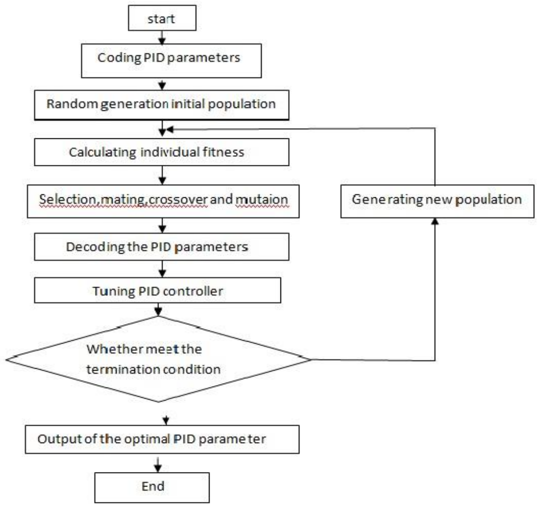


Figure 4. Block diagram simulink model for the simulated robotic arm (q_1=d_1, q_2=$Ø_2$,q_3=$Ø_3$)

This method ensures that the initial population contains rich modes, attractive the possibility of the converge to the global optimum [6].



Introduction to Genetic Algorithm PID

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].

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.

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.

Tuned Force Signal Results

First construct the simulation model and simulating without using any controller. Then output responses figure No. 5u_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

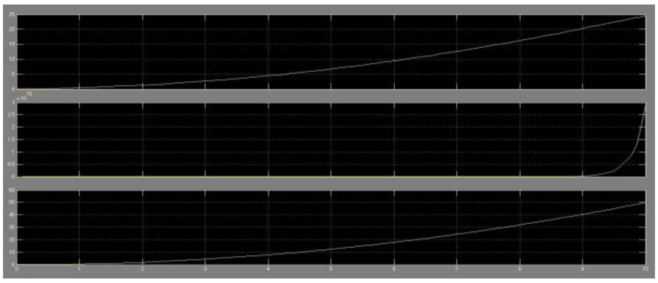


Figure 5. output $u_{1,}$ u_2 *and* u_3 without controllers

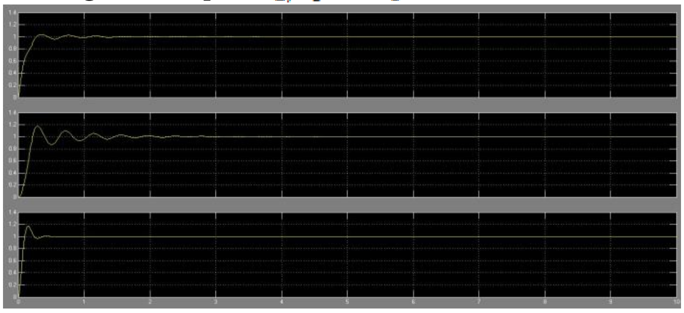


Figure 6. output $u_{1,}$ u_2 *and* u_3 PID with controllers

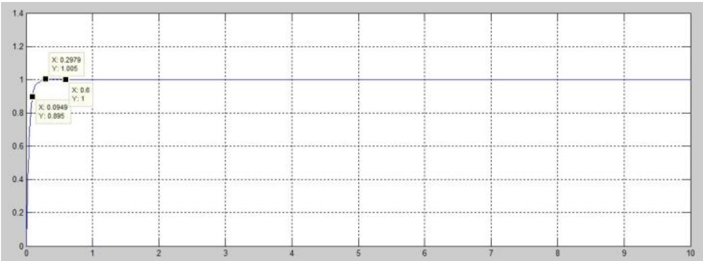


Figure 7. for output u_1 with GA PID controller

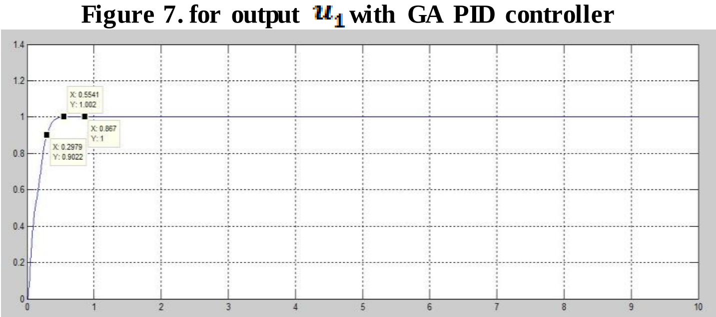


Figure 8. for output u_2 with GA PID controller

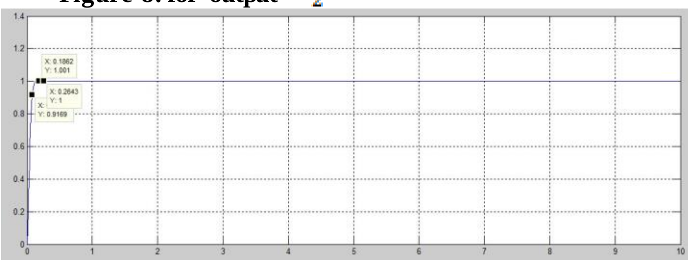


Figure 9. for u_3 with GA PID controller

PID control variable	Output u_1	Output u_2	Output 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%

GA PID control variable	Output u_1	Output u_2	Output 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%

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].

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.*

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