A Visual Feedback GA-PID Controller for a Telepointer System

(Suapbalik Visual Pengawal GA-PID untuk Sistem Telepointer)

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ABSTRACT

Telepointer is an important component in real-time distributed collaborative systems. Telepointer technology is widely used in telemedicine applications to monitor patients from afar and improve communication between experts. A telepointer system works by sending additional information in the form of gesture that can convey more accurate information. It leads to more effective communication, precise diagnosis, and better decision. However, laser pointer controller requires responses from variable laser coordinate based on input from client in real-time and high accuracy. In this study, a test was carried out by collecting coordinate data to plan a model and optimize a PID controller on telepointer system. The objectives of this study is to designing the mathematical model using system identification method and developing the PID controller of the telepointer system based on Genetic Algorithm (GA) Optimization Method. A few coordinate data were taken to plan a model system and get the accuracy model by using Identification (IDENT), whereby the model produce is to tune the controller system. The best parameters gain of controller is tested on telepointer system to see the performance. Based on the results, the telepointer system produced faster move and high accuracy when the laser pointing on certain coordinates. Telepointer system has four main components, namely laser, hand, cursor and sketching pointer. It can be seen that telepointer technology has huge potential in real life applications.

Keywords: Telepointer; Telemedicine; Laser pointer; Model System; Controller System

ABSTRAK

Telepointer adalah komponen penting dalam sistem kolaboratif yang diedarkan secara masa nyata. Teknologi telepointer digunakan secara meluas dalam aplikasi telemedicine untuk memantau pesakit dari jauh dan meningkatkan komunikasi antara pakar. Sistem telepointer berfungsi dengan menghantar maklumat tambahan dalam bentuk isyarat yang dapat menyampaikan maklumat yang lebih tepat. Ia membawa kepada komunikasi yang lebih berkesan, diagnosis tepat, dan keputusan yang lebih baik. Walau bagaimanapun, pengawal penunjuk laser memerlukan tindak balas daripada koordinat laser yang berubah berdasarkan tindak balas dari klien dalam masa sebenar dan ketepatan yang tinggi. Dalam kajian ini, ujian telah dijalankan dengan mengumpul data koordinat untuk merancang model dan mengoptimasi pengawal PID pada sistem telepointer. Objektif kajian ini adalah untuk merekabentuk model matematik menggunakan kaedah identifikasi sistem dan membangunkan pengawal PID dari sistem telepointer berdasarkan Kaedah Optimasi Algoritma Genetik (GA). Beberapa data koordinat telah diambil untuk merancang sistem model dan mendapatkan model ketepatan dengan menggunakan Pengenalpastian (IDENT), di mana menghasilkan model adalah untuk menala sistem pengawal. Perolehan parameter terbaik pengawal diuji pada sistem telepointer untuk melihat prestasi. Berdasarkan hasilnya, sistem telepointer menghasilkan langkah yang lebih cepat dan ketepatan yang tinggi apabila laser menunjuk pada koordinat tertentu. Sistem telepointer mempunyai empat komponen utama, iaitu laser, tangan, kursor dan penunjuk lakaran. Ia dapat dilihat bahawa teknologi telefon pintar mempunyai potensi besar dalam aplikasi kehidupan sebenar.

Kata Kunci: Telepointer; Telemedicine; Penunjuk laseri; Sistem Model; Sistem pengawal

INTRODUCTION

Telepointer is a special teleconferencing device that allows a laser pointer on a server system to be controlled from afar by a client computer. Telepointer can be used for Computer-Supported Cooperative Work (CSCW) purposes such as specialist-physician consultation in a surgical operation of a patient.

CSCW is a combination of hardware and software to allow multiple groups of persons to collaborate in static or mobile environments (Abdul Karim et al. 2013). A mechanism is used to provide a telepointer system consisting of video display, indicator device, computer, and camera as a mean of communicating with collaborators.

A camera is used to capture visual information in server areas that controlled by client in Figure 1. The target coordinates of the laser pointer are sent to the server's PC over the internet. On a server PC, real-time video images as well as current position are detected and tracked by laser detectors as well as tracking algorithms in a server PC. This current laser coordinate information is then used as a response to Proportional-Integral-Derivative (PID) control on a server PC. The output of the controller is transmitted to the control box that changes the digital signal to the analog signal of direct current voltage which controls the servo motor that moves the laser pointer.

Many studies in the past literature focus on areas associated with practical application of telepointer. This paper aims to investigate the performance of telemedicine system when new models and PID controller with Genetic Algorithm (GA) Optimization Method were applied. The new models were applied together with GA on the PID Controller to produce the best parameters gain. Basically, this paper contributes to the literature on the performance of the system based on the best models system from data acquisition and tuning the controller with GA optimization to produce best parameters gain. GA actually is a parallel, global search optimization technique inspired on the natural selection mechanism (Pereira & Pinto 2005).

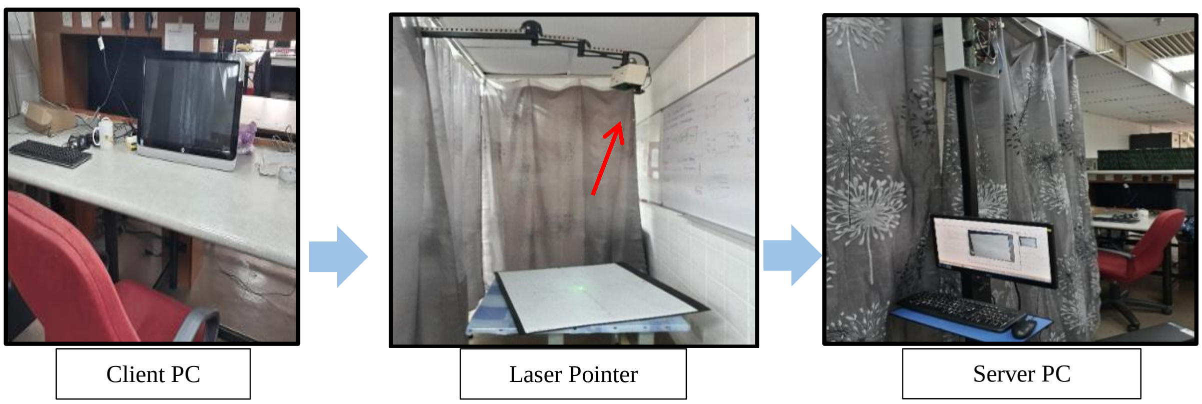

FIGURE 1. Telemedicine System

Obtaining precise coordinate point with the speed of response that is controlled remotely by the client to the desired coordinate point is non-trivial. The hardest part of the system is the physical displacement of the laser indicator which is typically the case because the client rearranged the laser pointer to get optimum distance and orientation in respect of the patient's position. Hence, new system models need to be built by using system identification method. This system models cannot be built by using first principle due to difficulty in deriving a mathematical model of telepointer system. System identification is a methodology developed by choose the best model from a given model set based on the observed input-output data from the system (Katayama 2004).

In situations where people use telepointer to coordinate the interactions closely, incorrect interaction of user actions leads to disappointment and error in collaborative activities. This problem makes the laser pointer forced to act faster. To overcome this problem, the tuning of PID controllers is important to avoid delay or overshoot results. However, the use of PID controllers also has its problems when it is implemented on laser pointer. This is due to certain processors cannot process the data received from the user quickly in order to control the movement of the laser at high speed. Appropriate use of the controller and laser pointer speed control system should be used to obtain smooth movement of laser pointer.

Tuning of PID controllers using the GA method was selected. The PID is designed with GA have faster response than the Ziegler-Nichols (ZN) method. Besides, GA method is better for rise time and settling time. Finally, GA provided better results and less error produced. In the following sections will provide more detail on the experiment of modeling and tuning the controller.

METHODOLOGY

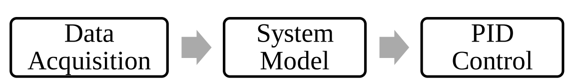

FIGURE 2. Structure of Project

In this project, it involves collecting data coordinate position for x and y axis by deciding the inputs in unit voltage and this data will appear as an image coordinate on server PC in unit pixel. The data will be used to design system models using system identification method. The data are import into MATLAB software and least square method of system identification is use to produce system models. From the system models then a basic system can be design with PID controller in it. An optimization of GA will be used to tune the PID controller. More information is explained on the next sections.

Data Acquisition

Vision feedback is defined as a feedback depends on data derived from two-dimensional images such as captured using camera (Kader et al. 2016). Vision feedback made the system less disturbance and not required right calibration and detailed set-up. The position of the coordinate controlled by client PC, displays the real-time image captured by web camera at the workspace (server). This position coordinate is transferred to server PC via internet/LAN. The same position coordinate is detected and tracked in the server PC. Finally, this position coordinate is then used as feedback to PID controller in server PC.

Data coordinates at server PC are collected from the telepointer. Collections of data coordinates not involve client PC at all. Before collecting the data coordinates, make sure the input y must be constant so that variables of data coordinates on x-axis can be collected. The input y constant and input x is set to

$$yAxis = -5.0, -4.5, -4.0, \ldots, 4.0, 4.5, 5.0 \quad (1)$$

$$xAxis = 5 * Math.Sin(theta * k) \quad (2)$$

$$xAxis = -5 * Math.Sin(theta * k) \quad (3)$$

While when input x is set constant, the input x and input y is set to

$$xAxis = -5.0, -4.5, -4.0, \ldots, 4.0, 4.5, 5.0 \quad (4)$$

$$yAxis = 5 * Math.Sin(theta * k) \quad (5)$$

$$yAxis = -5 * Math.Sin(theta * k) \quad (6)$$

When server PC run the system, the coordinate position of laser pointer is detected and tracked. The output data coordinates position automatically saved on the folder that already initialized in the coding. The output data coordinates of telepointer for x and y shows in the form of graph such as Figure 3(a) and Figure 3(b). This data coordinates are used to design system models using system identification. The following sections provide more detail on designing the system models.

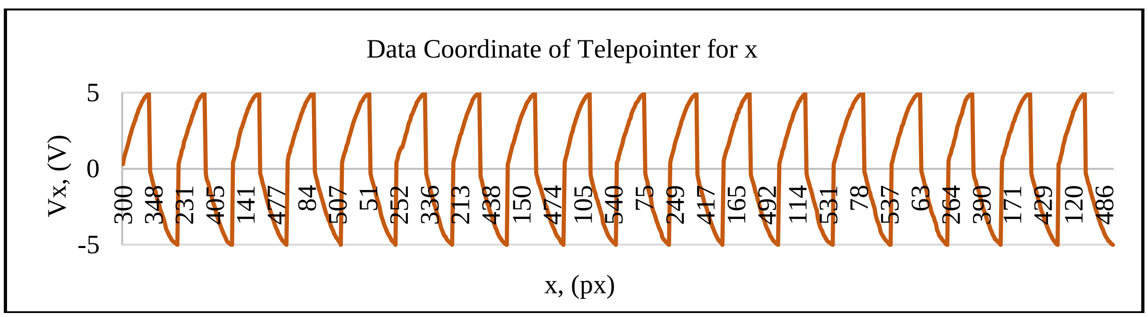

FIGURE 3(a). Output Data Coordinates for x

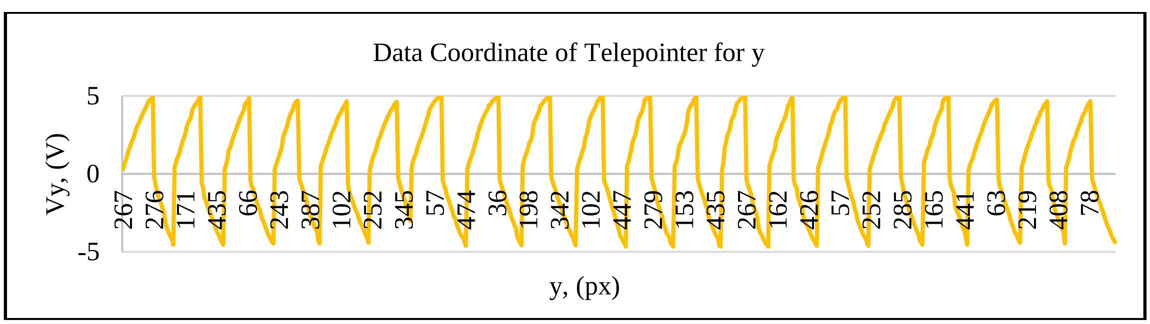

FIGURE 3(b). Output Data Coordinates for y

System Models

Modeling is the abstraction of a real process to characterize its behavior. The input and output calculation data can provide useful information about the system behavior (Katayama 2004). Model based on Eykhoff's view introduces the concept of important aspect that model is represent important aspect of an existing system or a system to build, which represents the system's knowledge in form that can be used (Chinarro 2014).

For this telepointer system, it is modeling of x and y models of laser coordinates. System models for x and y are gained based on the data collected before. The data coordinate collections are saved in the form of Excel so that the data can be imported into MATLAB software. The data coordinates are imported into MATLAB and batch least square method are performed using least square function. Åström and Eykhoff paper will explain and shows in finding the least square method in detail (Åström & Eykhoff 1971). Therefore, the models system for x and y are produced. The models of x and y axis as follows

$$x(k) = 0.9993x(k-1) + 1.3437u_x(k-1) \quad (7)$$

$$y(k) = 0.9955y(k-1) + 1.5988u_y(k-1) \quad (8)$$

This models system is then used to find the accurate models. The flow to find the accurate models as shown in Figure 4. The accurate models produced shows the same models system as (7) and (8).

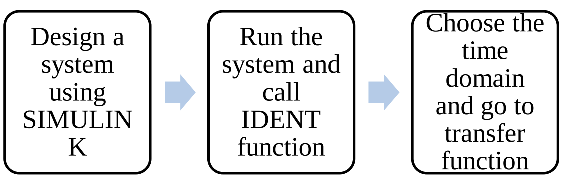

FIGURE 4. Main actions in find the accurate models

PID Controller

The PID controller is a common feedback control mechanism that is used in the control system industry (Namazov 2010). Figure 5 shows the basic block diagram of a control system (Saad et al. 2012). The system has two different PID controllers each for x-axis and y-axis. The basic formula for PID controller is

$$K(S) = P + I + D = K_P + \frac{K_I}{S} + K_D S \quad (9)$$

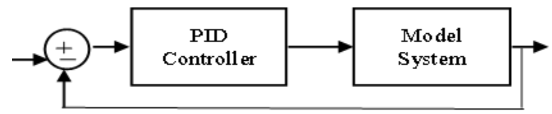

FIGURE 5. Control System

In this study, GA Optimization Method is used in tuning the PID controller. GA starts with an initial population containing number of chromosome and this chromosome represents a solution of the problem. GA has fitness function that use to evaluate the performance of the chromosome. GA consists of three stages: Selection, Crossover and Mutation. However, the ZN tuning method is also performed in this project to compare with the result of GA Optimization later. Since the model system is known then those controllers can be tuned by set the proportional control gain. The steps that will be explained are for ZN tuning method. The tuning involves of using SIMULINK. A system is built as Figure 6. To get the value of K_P, K_I and K_D, the K_I and K_D gain must be set to zero. The K_P gain is adjusted until it generates a periodic oscillation at the output response. The best adjustable gain of K_P is actually the ultimate gain, K_C while the ultimate period, P_u is the period where the oscillation occurs. Based on those two parameters, K_C and P_U, The PID control gain are calculated according to the Table 1 (Hang et al. 1991).

TABLE 1. Ziegler-Nichols Method

Controller Type	K_P	T_I	T_D
PID	$0.6 * K_C$	$0.5 * P_U$	$0.125 * P_U$

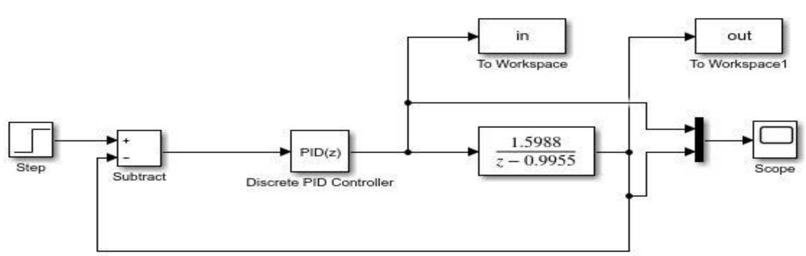

FIGURE 6. Basic System

Amplitude Analysis

For GA Optimization method, the system design is continued from ZN method but the system need to add an error workspace before the control gains. The command is needed to call the function when m-file is run for execution. This command includes the fitness function for GA Optimization. The sampling time for the system are set to 0.0019s on the blocks in Figure 6. This sampling time used to allow for all video processing of the controller to be completed. The codes below are the command that used for GA Optimization

```
function [out1]= fitness1(x)

Kp = x(1)
Ki = x(2)
Kd = x(3)

sim('PIControl');
ISE= sum(err1.*err1);  % ISE criteria

n=size(err1);
m=n(1,1);
%calculate risetime
risetime=100000;
for i=1:m
   if (err1(i)<0)
      risetime=i;
      break;
   end
end

%overshoot criteria
overshoot=0;
for i=1:m
   if (err1(i)<0)
      overshoot=overshoot+abs(err1(i));
   end
end
out1 = 0.1*risetime + 1*overshoot + 1*ISE;
```

The system is run as well as the GA Optimization from MATLAB to gain the best value of K_P, K_I and K_D. This algorithm will repeat for many generations and eventually stops when it comes to individuals who represent the optimal solution of the problem (M.S. Saad, H. Jamaluddin 2012).The best value of K_P, K_I and K_D is then used on the telepointer system.

RESULT AND DISCUSSION

Learning Analysis

The controller parameters gain calculate according to Table 1. The summary of the controller parameters and performance are given in Table 2.

TABLE 2. Controller Parameters and performance

Parameters	K_P	$1/T_I$	T_D	Rise Time	Settling Time	Overshoot
Controller x(k)	0.8928	526.7316	0.0005	0.019sec	0.0095sec	1.2
Controller y(k)	0.7494	526.7316	0.0005	0.019sec	0.0095sec	1.2

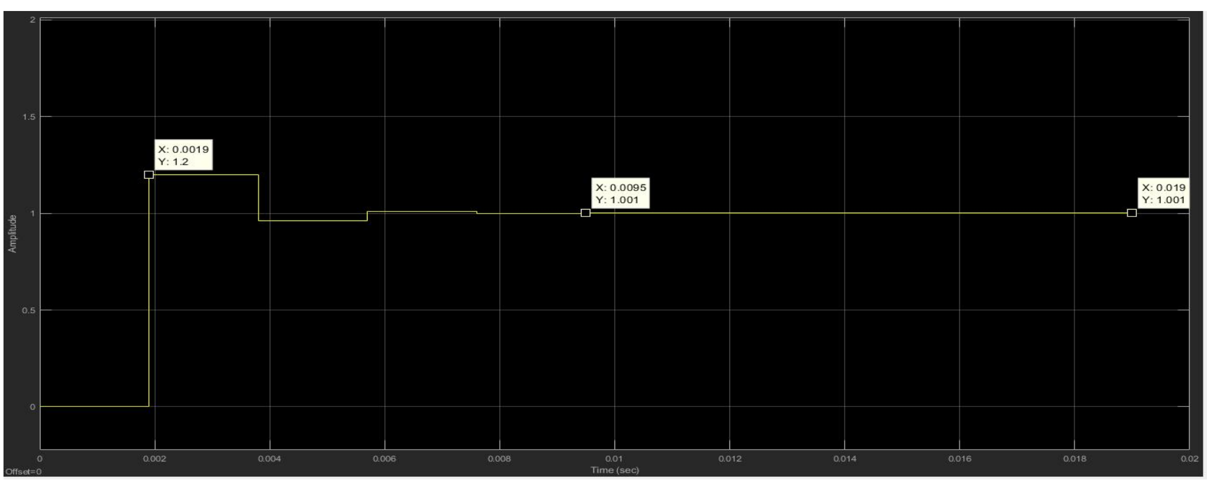

FIGURE 7(a). Output Response for Controller x

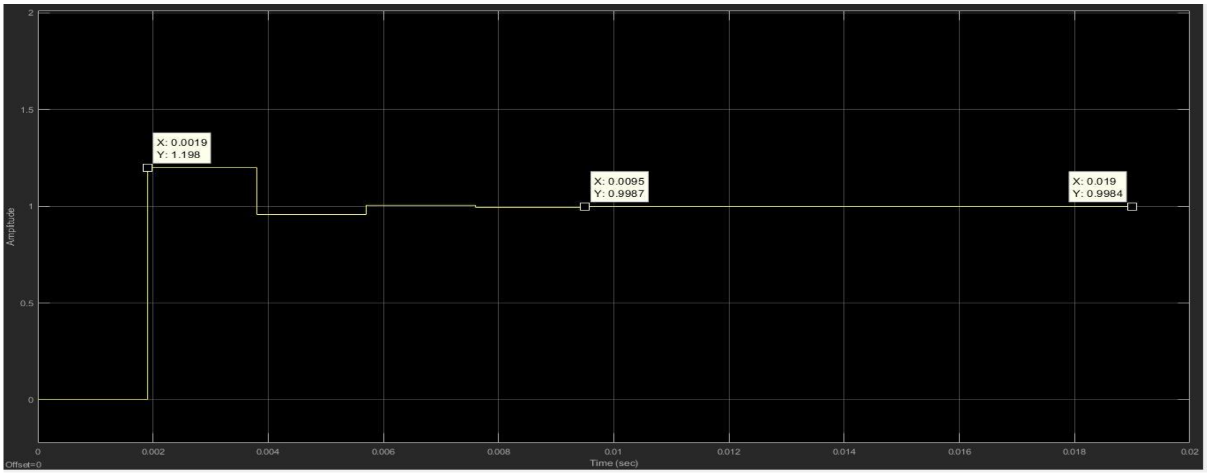

FIGURE 7(b). Output Response for Controller y

Figure 7(a) and Figure 7(b) shows the response when tuning using the parameters controller values calculated for controller x and controller y respectively. Figures 7(a) and 7(b) shows that the rise time, settling time and overshoot for both controllers are same. The two performance criteria (rise time≤0.05s; settling time≤0.1s) were met with the ZN method (Kader et al. 2016) but one performance criteria are not met because the both controller have overshoot value.

The results of ZN method are compared with GA Optimization method to see the difference and performance of both methods. The best parameters controller for both x and y controllers when performed the GA Optimization method given in Table 3

TABLE 3. GA Optimization Parameters controller

Parameters	K_P	K_I	K_D
Controller x(k)	0.538	1.834	0
Controller y(k)	0.549	1.268	0

The output response for both controller was shown in Figure 8(a) and Figure 8(b). The error for Figure 8(a) before performed the GA Optimization is -0.00117. After performed the GA Optimization, the error before becomes -0.00383. For Figure 8(b) the error before is 0.0016 and the error after is 0.00115 when performing the GA Optimization. The results when performing this GA Optimization has shown that GA Optimization gives a better result in tuning the PID controller. Performance for this controller given in Table 4.

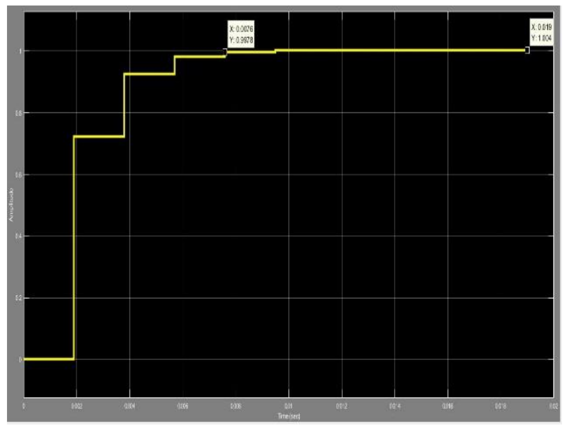

FIGURE 8(a). Output Response for Controller x

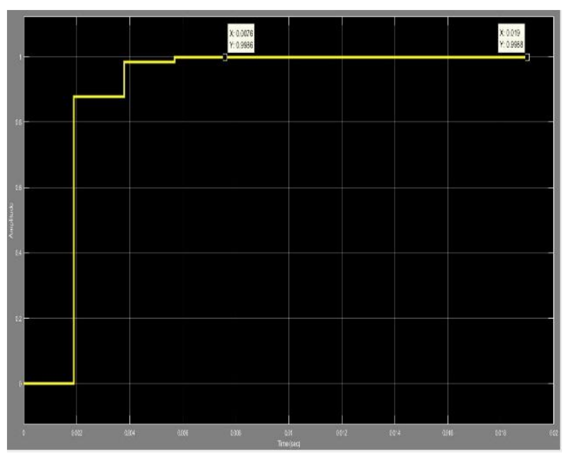

FIGURE 8(b). Output Response for Controller y

TABLE 4. GA Optimization Parameters controller

Parameters	Settling time	Overshoot
Controller x(k)	0.0076	0.9986
Controller y(k)	0.0076	0.9978

Test Analysis

The value parameters controller for x and y will be used for testing the performance of telepointer system. The result should show that the performance of telepointer system is better than before the experiment. Telepointer system need to do some tuning on the controller if the system still has an overshoot.

CONCLUSION

Overall this work explained about the development of system model and laser pointer controller. Most important part of telepointer system is actually the performance of the controller. Without the best controller, the system performance might be overshoot or delay when performed the system. Hence, a GA Optimization method is used because it produced better overshoot, rise time and settling time compare with ZN method. From the collections of data and performed the system identification, it can be seen that this process producing a precise system modeling. Designing a best model system and good tuning of controller system not only resulted in fast response but it is also produces a better overshoot, smaller error of the system and robust against changes in sampling time and disturbances.

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