

Dexterity Robot Manipulator Gripper Using Auto Tuning of PID Control

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Abstract— Robot manipulator are usually interact with the system, and in industrial activity is usually referred to as a gripper hand. Simulation technique is a method used to design and analyze the characteristic of kinematic motions of the robot manipulator gripper. A novel control architecture has been proposed using auto tune of Proportional, Integral and Derivative controller to improve the kinematic motion responses performance for robot manipulator gripper. By using the auto tuning of PID control is expected kinematic motion response of each joint robot arm achieve the best performance as small overshoot, and steady state within a short time accompanied by a small signal error. Advance through the process of tuning PID parameters obtained complete control amplifier at PID control is $K_p = 0.7194$, $K_i = 8,306$ and $K_d = 0.0061$ so that the best performance kinematic motion for robot arm gripper is achieved as desired by the user with a short rise time, small overshoot maximum, quick stability response and a very small signal error.

Index Terms—robot manipulator gripper, kinematic motions, auto tune, PID control

I. INTRODUCTION

Robot manipulator is a device used to manipulate materials. A robot manipulator system arm mechanism comprising a series of segments, typically shear or jointed, which capture and move objects with multiple degrees of freedom. In the process, the robot arm gripper has been used in carrying out the specific mission and assist operations in space. Robot arms are usually interact with the system, and in industrial activity is usually referred to as a gripper hand [1]. Robot arm gripper is holding an object that functions like the human hand, which resembles a human hand shape design. In a study conducted by Widhiada in 2010 resulted in a three-finger gripper robot to control PD (Proportional-Differential) [2].

In this study, the autors used a method of simulation techniques to determine the robot kinematics motion systems. Simulation has been recognized as an important tool since the beginning of the 20th century in robotics technology. Simulation technique is a method used to

design and analyze the movement of the robot where the results of robot movement response to the result obtained in actual circumstances. Simulations can also save time and costs used in designing the robot manipulator five fingers gripper with prismatic elements.

In the study conducted by Tsuneo Yoshikiwa 2010 [3], a survey research on control grasping of the multifingered robot hand is expected to approach the actual function of the human hand, one of its functions is to grasp and took various objects. In this study, the authors will design five in the finger gripper robot manipulator equipped with prismatic elements.

By using the PID control is expected kinematic motion response of each joint robot manipulator achieve best performance as small overshoot, and calm conditions (steady state) within a short time accompanied by a small driving error.

An integrated both MATLAB/Simulink and Autodesk-inventor are used to investigate the kinematics motions of multifunctional of the robot manipulator five fingered gripper. This paper has focused upon investigating how to develop the modelling and controlling the robot manipulator five fingered gripper. The design and a prototype robot manipulator gripper five fingers are built in this research. The motion of kinematics robot arm gripper are controlled by an advance PID control to achieve the best performance include quickly response and high accuracy respectively.

II. METHODOLOGY OF RESEARCH

A. Research Description

The integrated software programs are used to create the design and simulate robot arm five fingered gripper, namely inventor and Matlab / Simulink. An accurate mathematical model of robot system is applied to obtain the movement of the robot manipulator gripper and how the effect of PID control to achieve the better actual kinematic responses of robot manipulator gripper system.

This article introduces the demonstration of robot arm gripper motions. Matlab/Simulink software package is applied to support the simulation and computation kinematics motions for each robot arm.

The physical model of robot is built using SimMechanics software and the application SimMechanics has also been verified with identical outputs when compared with MATLAB/Simulink simulations [4]. This research indicates that each of dc motor in the gripper can be controlled using PID control.

The toolbox of MATLAB/SimMechanics is especially development to design the robotic system with a suite of tools to specify bodies and their mass properties, their possible motions, kinematic constraints and coordinates system and to initiate and measure body motions.

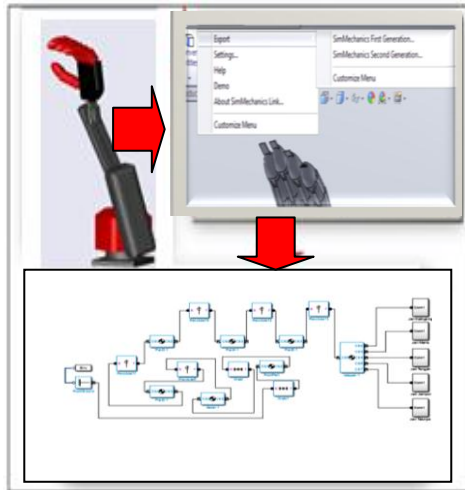


Figure 1. The process of design robot gripper

In this paper the kinematics motions such as angular position, angular velocity and angular acceleration results of a robotic gripper are showed. The design of robot arm gripper is build in Autodesk-Inventor software as follow the dimension of human arm. The picture of robot manipulator gripper design is transferred from physical model in 3D to xml file into some block diagrams in Simulink/Simmechanics is shown in Fig. 1. SimMechanics

is a tool to facilitate a reserve to deriving equations and performing them with base blocks.

B. Mathematics Model for DC Servo Motor

All movements are assumed to be operating robot-based visualization running time can be expressed as a function of the signal [5]. Characteristics input (reference), the system controller, the system is controlled and output can be expressed in a mathematical equation that represents the nature or in response to changing times. Laplace transformation is one method to declare a signal equation in function of time. The robot can be controlled based on the position, velocity and acceleration [6]. Arm movements can shape the direction of movement and anti clockwise. The position of the movement is expressed by θ .

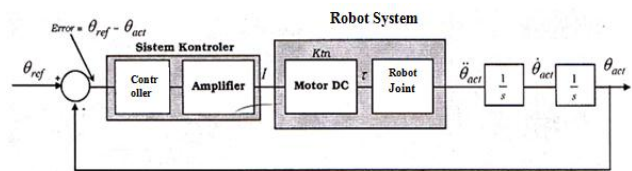


Figure 2. Robot system block diagram

The equation of dc motor voltage is

$$V_a = L \frac{di_a}{dt} + RI_a + K_b \omega \tag{1}$$

K_b is a constant that is measured from the voltage generated by the motor when it rotates every unit of speed. The eq. 1 is developed to be the transfer function of DC servo motor which is used to drive the motor in each arm and finger. Transfer function is the ratio of Laplace output and Laplace input in dynamics system. Fig. 2 shows the mathematics model of DC Motor is applied in block Simulink/Simmechanics.

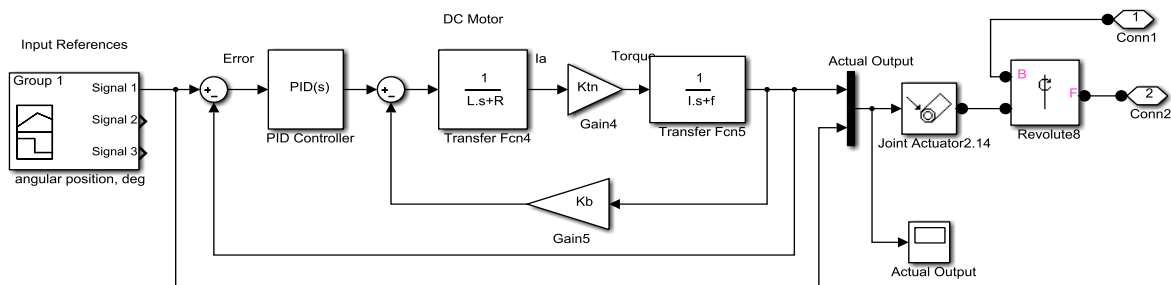


Figure 3. The transfer function block of DC servo motor

Fig. 3 shows the all states mathematical model of the motor. In applications can rarely be obtained data specification/motor parameters in full. Motor manufacturers usually only provide information in a graphical representation of the torque motor current, torque with voltage, speed and torque with some information that is visual. Making it virtually impossible ideal modeling in the design of the engine control system. Except motor used is the result of his own design. Consequently, in the majority of the design process is mostly done assumptions are simplified mathematical

model. Unknown parameters are usually compensated or settled through the control system engineering.

C. Flow Chart of Research

The Fig. 4 shows the stages activity research of making modeling and system control manipulator robot gripper using the program Simulink / MATLAB. The finally stage is to analyze of the kinematics motions of robot manipulator gripper when the simulation is valid.

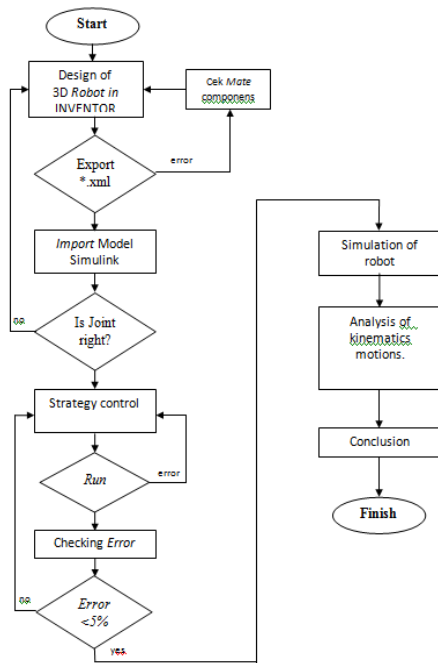


Figure 4. Research Flow chart

The input references are generated for the trajectory planning to the motion control system, which ensures that the five fingered gripper robot executes the planned trajectories [7].

D. Kinematics Analysis

The concept of kinematics and dynamics analysis is needed to obtain the mathematic model for the robot manipulator gripper fingers. The kinematics analysis discusses the trajectory motion of robot manipulator gripper and the dynamics analysis discusses the dynamics motion as computation of torque and force [8].

For the kinematic analysis of a robot finger position, two methods are available to compute the position of robot finger: Forward kinematics and inverse kinematics respectively as shown in Fig. 5

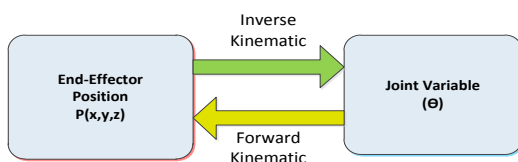


Figure 5. Forward and Inverse Kinematics Diagram

E. Control Strategy for Robot Manipulator Gripper

According to Amit that modeling simulation and control of Stuart type 6-DOF parallel manipulator which not only has industry standard PID controller but also includes compensator for drastically improving tracking performance. Dynamic equations of the parallel manipulator are derived by using Kane's method, inheriting all the advantages while circumventing all the disadvantages of NewtownEuler and Euler-Lagrangian formulations. [9].

The auto tuning PID control has been used to control the kinematics motion of robot manipulator gripper. By tuning suitable values of the three constant gains in the

PID controller algorithm such as gain of Proportional (Kp), Integral (Ki) and Differential gain (Kd) value are determined by auto tuning to achieve a stability response and small error signal. Fig. 6. presents the basic concept of PID control for robot manipulator gripper.

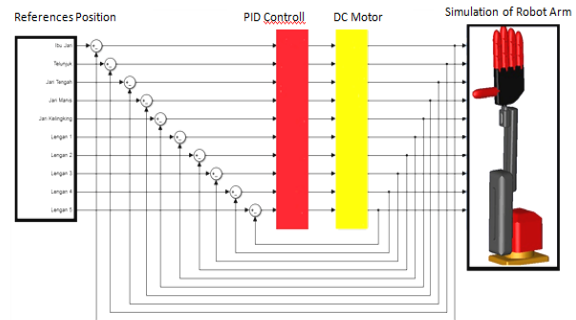


Figure 6. Robot Gripper Control System

The automatic tuning of PID gives a fast and considerably use able both single and multi-loop PID tuning methods for the Simulink PID controller blocks. By using this technique, the user can tune gain parameters to obtain a robust design with the ideal response time. Thus, the author used the PID tuner from the Simulink toolbox to find the best performance of motion. Fig. 7 shows the identification of functions block parameters PID Controller.

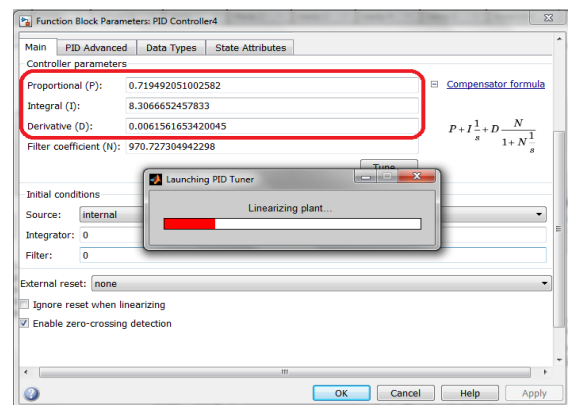


Figure 7. Identification of PID control parameters

III. RESULT AND DISCUSSION

A. Simulation Motion Responses

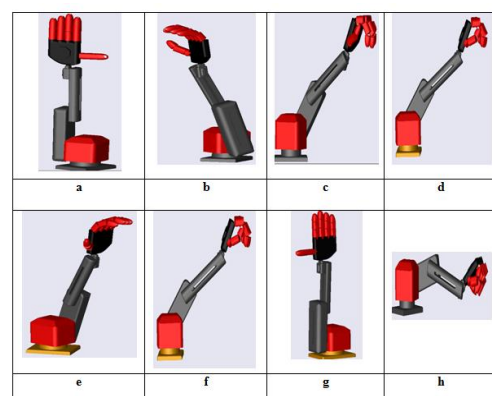


Figure 8. Visualizations of robot manipulator gripper

The graphical visualization of robot manipulator gripper is shown in Fig. 8. In this animation the robot manipulator gripper move from one coordinate to other coordinates in accordance with a given reference input.

Proportional controller gives the effect of reducing the rise time, but does not remove steady-state error. Integral controller gives effect to remove the steady-state error, but the resulting deterioration of transient response. Derivative controller gives the effect of increasing the stability of the system, reduce the overshoot, and raise the transient response. Automatic tuning Proportional, Integral, and Derivative gains are used to determine the best gain value for three finger robot gripper system with $K_p = 0.7194$, $K_i = 8.306$ dan $K_d = 0.0061$.

B. Analysis of Kinematics Motions Response for Robot Manipulator Gripper

In this paper raised only one response kinematics motion such as angular position, angular velocity and angular acceleration of robot respectively. From the graph shown above red line is a reference of motion to do the motor, and the blue line shows the results of simulating movement on the motor. In Fig. 9 below referenced 2nd arm joints one moves up shows DC motors on 2nd Manipulator moves up from the position angle of 0° to 20° angle position at the time of 0.5s, and 5,5s, the angular position 20° to 40° angle position at the time of 1s and 6s, and the angular position 40° to 80° angle position at the time of 1.5s, and 6,5s. DC motors MP moved down from the position angle of 80° to 40° angle position at the time of 2,5s and 7.5s, position angle of 40° to 20° angle position at the time of 3s and 8s, position 20° angle position to a position on the corner 0° 3,5s time and 8.5s.

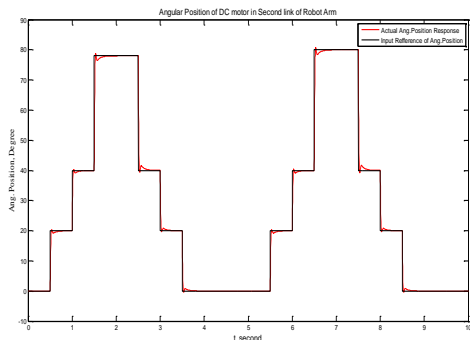


Figure 9. Angular Position response for 2nd Manipulator

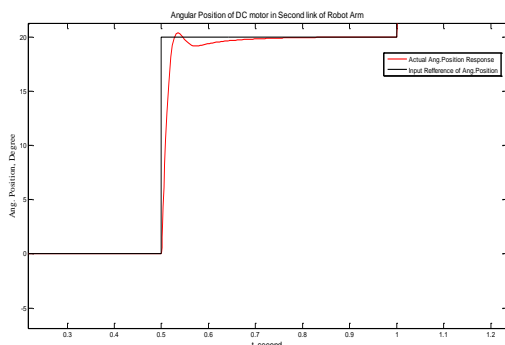


Figure 10. Graph response in angular position 20°

Then from the graph in Fig. 10 shows the parameter data of the results obtained as below,

- Rise time (rise time), $t_d = 0.52$ second
- Peak time (peak time), $t_p = 0.53$ second
- Maximum overshoot, $M_p = (20.39 - 20) / 20 \times 100\% = 1.95\%$
- Settling time (preset time), $t_s = 0.8$ second
- Error signal, $e = \text{motion reference} - \text{actual motion} = 20 - 19.96 = 0.04$

Fig. 11 shows the angular velocity in 2nd joint arm.

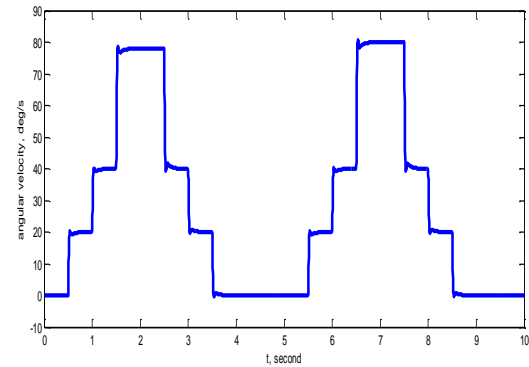


Figure 11. Angular Velocity in 2nd joint arm

The actual response of angular velocity is obtained by using a differential block in Simulink library. From the images obtained speeds above 10 Manipulator 2 moves up from the position angle of 20° angle position 0° ke in 0.5 seconds is 1348 deg / s, 1 second of the angular position 20° ke 40° angle position is 1339 deg / s, 1.5 times second from a corner position 40° to 80° angle position is 2561 deg / s. Then move down, or back at a time of 2.5 seconds 80° angle position to a position angle of 40° is 2549 deg / s, within 3 seconds of the position angle of 40° to 20° angle position is 1308 deg / s, and within 3.5 seconds of angular position to angular position 0° 20° is 1325 deg / s, and so on.

The angular acceleration is also computed by using a differential block in Simulink library and shows in Fig. 12.

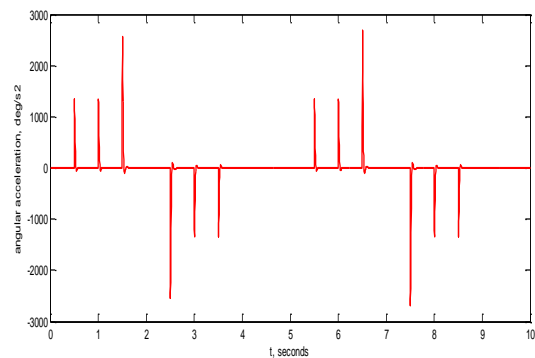


Figure 12. Angular Acceleration in 2nd joint arm

From the graph in Fig.12 that an angular acceleration is obtained the highest results from the position of 40° to 80° position of $1.4e + 14 \text{ deg} / \text{s}^2 \times (10)^{14}$ with long simulation time 10 second.

IV. CONCLUSION

The author developed the advance PID controller to control the kinematics motion of robot manipulator gripper. This PID control provides the best performance for both grasping and manipulation such as giving the smallest error, small overshoot, fast settling time and a stable system. The new toolbox of PID control provides the advance control motion by using the automatic tune available in this software MATLAB/Simulink program.

The process of Advance tuning PID control obtained parameters of the amplifier in the PID control is $K_p = 0.7194$, $K_i = 8,306$ and $K_d = 0.0061$ with the rise time is short 0:52 second, short peak time 0:52 seconds, maximum overshoot a small 1.8%, stability response was achieved in 0.76 seconds.

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