Path Tracking Algorithm for a Robot Manipulator

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Abstract
A number of algorithms for mobile robot path have been described in the robotics control literature. This paper presents a comparative experimental study of the classical controllers for the path tracking 1-link robot. Dynamic model of the robot has been taken here and two types of controls i.e. PD and PID have been compared. Experiments have been done by using MATLAB. Gains for both the controllers have been determined by TAE (Trial And Error) method. PID controller’s efficiency over PD controller has been proved. Both the controllers are composed of mainly four components: a pre-defined path, a predictive model, an offline controlling algorithm and a feedback tuning model.

Keywords: PD, PID, 1-link robot.

Introduction
A robot is a virtual or mechanical artificial agent. Robots have replaced slaves in the assistance of performing those repetitive and dangerous tasks which humans prefer not to do or unable to do due to size limitations or even those such as in outer space or at the bottom of the sea where humans could not survive the extreme environments. The word robotics, used to describe this field of study, was coined by the science fiction writer Isaac Asimov. Robotics is the engineering science and technology of robots, and their design, manufacture, application, and structural disposition. The control of a robot involves three distinct phases - perception, processing, and action (robotic paradigms). Sensors give information about the environment or the robot itself (e.g. the position of its joints or its end effectors). This information is then processed to calculate the appropriate signals to the actuators (motors) which move the mechanical. For a suitable control strategy the robot model must capture the flexible.

Literature Review
The dynamics of a robot arm is highly non-linear. The acceleration, velocity and angle of a single joint affect other joints. Moreover, other external forces including Coriolis force, centrifugal force, gravity, friction etc. are present, and they can influence the states of a robot. The states of a robot have an effect on themselves a well. In order to control the arms, the torque at each joint must be calculated every moment. But with the increase of degree of freedom, calculating time also increases. Moreover the unknown external forces also can be applied to the robot. Noh and Won [1] used a disturbance observer to find the effect of unknown forces like friction and damping effects. So, by taking the known part of the system as linear and unknown part as nonlinear disturbance, a control technique using Proportional Derivative (PD) controller is developed taking linear part into consideration. A closed chain robot has several advantages over an open chain robot. Guo and Zhang [2] taking the fact that closed chain robot system dynamics due to problem associated with unknown link masses and unknown joint frictions used the adaptive control to make robot to follow the right trajectory with minimum possible errors. A PD plus gravity compensation control realized accurate point to point tracking [3], and a PD computed torque control achieved adequate trajectory tracking [4]. To improve the tracking performance, Lin and Chen [5] developed a control system that considered of a model reference adaptive control (MRAC), a modified switching algorithm, a disturbance compensation loop and several feedback loops to control a closed chain linkage.

Seraji in 1986[6] used a simple scheme to control the dynamics of robot using PD controller. Nirav A. Patel et al [7] used a microcontroller to control and to make a robot walk. They had simulated results of a moving robot using stepper motors and microcontroller and realization of the physical robot is under progress. Dexterous and skilled motions in robot manipulators require reliable and robust joint controllers for achieving accurate joint motion tracking despite uncertainties in the robot dynamics, external disturbances, friction and unknown pay load. Jyoti Ohri et al [8] in 2007 used a decentralized robust H∞ PID controller applied to tracking problem to guarantee arbitrary disturbance attenuation. Morris and Madani [9] used a method of approach to develop a single link model and then to expand this into a two link model, taking proper account of the coupling between the two links. Computed torque and quadratic optimal controllers based on this model have been developed. Pole placement control and adaptive control schemes are designed by Ru Lai and Fujio Ohkawa [10] by discretizing the robot model by using the trapezoidal rule and eliminating the nonlinear force terms and external force term from the robot equation.

Each method of control is different in terms of accuracy, scope, time horizon and cost. To facilitate an adequate level of control, the developer has to be responsive to the characteristics of different methods, and determine if a particular method is appropriate for the undertaken situation.
before embarking its usage in real application. As a result, the choice of a control method is one of the important factors that will influence the control accuracy. Control techniques can broadly be divided into two categories i.e. intelligent and Non-Intelligent techniques. One of the major limitations of non-intelligent methods is that it requires a very accurate model, without that there are many errors in the system. So, to reduce the modeling errors and to make the controls which can work without models, Artificial Intelligent (AI) techniques came into existence. James M. Adams and Kuldeep S. Rattan [11] used a multistage Fuzzy Logic Controller (FLC) for a 2-link, direct drive robot and results have been compared with the classical PID controller without any change in the plant parameters. Also, in 2003, Partricia Melin and Oscar Castillo [12] used type-2 FLC in spite of type-1 FLC. The main advantage of using AI control technique is due to the greater ability of this theory in modeling uncertainties in the control of non-linear plants.

Robot Dynamics

There are several methods to develop a trajectory that a robot has to follow. Robot has to pass from the initial point and then has to follow the path as close as possible. There are many control algorithms are present to control the robot and to make it move on the desired trajectory. A set of pre-decided points are taken to develop a path, robot now start from the initial point of path and then move. Feedback from the robot’s position is taken at every point and is given to the controller to decide the input torque to the robot. This type of control is called as the position control in the robot dynamics. Here, for these experimental results the path taken is given in equation (1) and its pictorial view is given in Fig.1.

\[ q_d = 30 + 6t^2 - 1.2t^3 \]  

(1)

Two Control Approaches

For a suitable control strategy the robot model must capture the flexible dynamics. In this section, two approaches for control of a 1-link robot, whose dynamics are mentioned has been given investigated.  

PD controller: The majority of existing industrial manipulators are controlled using proportional derivative (PD) controllers [14]. PD control is a conventional feedback control approach which has been extensively used. This type of controller is very simple and easy to design, which still makes this controller to be used in almost all the industrial robots. General equation for PD controller is given in equation (3).

\[ \tau = K_p e(t) + K_d \dot{e}(t) \]  

(3)

In most current robotic applications, PD controllers are functional and sufficient due to the high reduction ratio of the transmissions used.

Here, PD feedback controller is used to take the feedback from the output of the robot dynamics. Error is being calculated by comparing the feedback quantities with the desired one. These errors are further used to set the values of the PD controller. Values of the controller constants i.e. \( K_d \) and \( K_p \) are being decided by TAE (Trial And Error) method. Error in the path covered by robot and the actual path is shown in Fig. 2. Average error coming out is 1.2801.
PID controller: PID stands for Proportional, Integral and Derivative. Controllers are designed to eliminate the need for continuous operator attention. A proportional–integral–derivative controller (PID controller) is a generic control loop feedback mechanism (controller) widely used in industrial control systems—a PID is the most commonly used feedback controller. A PID controller calculates an "error" value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting the process control inputs. General equation for PD controller is given in equation (4).

$$\tau = K_p e(t) + K_d \dot{e}(t) + K_i \int e(t) dt \quad (4)$$

In most current robotic applications, PID controllers are functional and sufficient due to the high reduction ratio of the transmissions used.

Here, in this block diagram it has been shown that PID feedback controller is using the feedback from the output of the robot dynamics. Error is being calculated by comparing the feedback quantities with the desired one. These errors are further used to set the values of the PID controller. Values of the controller constants i.e. $K_d$, $K_p$ and $K_i$ are being decided by TAE (Trial And Error) method. Error in the path covered by robot and the actual path is shown in Fig. 3. Average error coming out is 0.6867.

From the above two models it can be seen that the average error of the PID model is lesser than the PD controller. Also the comparison graph for both the controllers is shown in Fig.4.

<table>
<thead>
<tr>
<th>Type of Controller</th>
<th>% error</th>
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<tbody>
<tr>
<td>PD</td>
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<tr>
<td>PID</td>
<td>0.6867</td>
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References