CONTROL FOR ROBOTIC MANIPULATORS WITH PROPORTIONAL INTEGRAL DERIVATIVE & COMPUTED TORQUE CONTROL

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Abstract

Inspite of long years of research, problem of manipulator path tracking control is the thrust area for researchers to work upon. Non-linear systems like manipulator are multi-input-multi-output, non-linear and time variant complex problem. A number of different approaches presently followed for the control of manipulator vary from classical PID (Proportional Integral Derivative) to CTC (Computed Torque Control) control techniques. This paper presents design and implementation of PID and CTC controller for robotic manipulator. Comparative study of simulated results of conventional controllers, like PID and CTC are also shown. Tracking performance and error comparison graphs are presented to show the performance of the proposed controllers.

INTRODUCTION

According to the Air Resources Board established in 1967, the emission of cars and trucks is the single most significant factor contributing to the air quality issue facing urban areas within the state of California. Although the cars and trucks produced today generate significantly less pollutants than those manufactured in the 1970s, Californians continue to lose billions of dollars a year due to air pollution and its related problems. These problems are not only directly related to human health, but also involve environmental concerns affecting both wildlife and cultivated resources, therefore this issue is of consequence to a wide range of interest groups. The technology involved in creating more fuel-efficient vehicles has come a long way; however one of the most effective methods of maintaining the standards of air quality is to simply burn less fuel. In a highly motorized area such as Los Angeles, however, most people prefer the convenience of providing their own transportation to and from their places of employment.

Henceforth, Manipulators are multi-input-multi-output, non-linear and time variant complex problem [1]. PID controller is a conventional model free feedback control approach and has been extensively applied in industrial application because of its simplicity, easy to implement in hardware or software, and does not require a precise process model to start up and maintain [2]. The principle objective of many of these so called “computed torque” controllers is to linearize and decouple the dynamical equations of motion so that each joint can be considered independently. Computed torque control (CTC) allows the design of considerably more precise, energy efficient, lower feedback gains and compliant controls for robots [3]. Design procedure for the PID Controller does not require the knowledge of the robot dynamics whereas, CTC allows the design more precise, energy efficient, and lower feedback gain [4]. Comparative study between PID and CTC results that, CTC is better as it works for non-linear system [5]. PID controller is applied to tracking problem of robotic manipulator, with guarantees arbitrary disturbances attenuation [6].

DYNAMIC OF ROBOTIC MANIPULATORS

The equations of motion for an n- axis manipulator are given by [7]

\[ \tau = M(q)\ddot{q} + C(q, \dot{q})\dot{q} + G(q) \]  

(1)
Figure 1. Two-link robotic manipulator

where \( l_1 \) and \( l_2 \) are the lengths; \( m_1 \) and \( m_2 \) are the mass of the links, respectively.

Torque equation for PD/PID controller is [8]

\[
\tau = k_p e + k_d \dot{e} \quad \text{(For PD Controller)} \tag{2}
\]

\[
\tau = k_p e + k_d \dot{e} + k_i \int e \quad \text{(For PID Controller)} \tag{3}
\]

Where, \( k_d^2 \geq 2k_p \) \tag{4}

Torque equation for CTC is given below:

\[
M(\ddot{q}^d + k_v \dot{e} + k_p e) + \nabla(q^d + k_v \dot{e} + k_p \int e) + G = T \tag{5}
\]

**DEVELOPMENT OF PROPOSED MODEL**

The word robot refers to both physical robots and virtual software agents, but the latter are usually referred to as bots. There is no one definition of robot that satisfies everyone and many people have their own.

Figure 2. PID Controller

Figure 3. Computed torque control

Figure 4. General flow chart for the various controllers
SIMULATION RESULTS AND ANALYSIS

In this Paper two controllers are proposed for robotic manipulator. The first one is called Proportional Integral Derivative controller. The second one is called Computed torque controller [9,10]. To illustrate the performance of proposed model output results have been calculated and analyze these results with the help of graphs.

In this table comparing the mean squared normalized error for these controllers.

<table>
<thead>
<tr>
<th>Controllers</th>
<th>MSE for joint 1</th>
<th>MSE for joint 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>PID</td>
<td>0.0161</td>
<td>3.2191e-004</td>
</tr>
<tr>
<td>CTC</td>
<td>0.0028</td>
<td>0.1199</td>
</tr>
</tbody>
</table>

Figure 5. Comparison of MSE for different controllers

Figure 6. Path tracking of Joint 1

Figure 7. Path tracking of Joint 2

Figure 8. Error of Joint 1

Figure 9. Error of Joint 2
CONCLUSION

Various control techniques for path tracking of a robotic manipulator for the last 20 years or so have been reviewed. To summarize, they vary from a classical PID [11], CTC etc. mechanism to upcoming intelligent NN control schemes and their hybrid [12,13]. The merits and limitations of these classical control techniques have been discussed individually in the paper as: due to the strong nonlinear characteristics and parameter variations in real environments, model based tracking control of robot manipulator is difficult. All the intelligent control techniques are model free control strategies, hence; perform well as compared to classical model based controllers. Comparison of the proposed model within themselves has been given in the results in CTC control is better than other classical controller.

REFERENCES


