Comparison of Results of PID and Fuzzy Control of Two Linked Rigid Manipulator

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Abstract: In this dissertation Euler-Lagrange’s method is used to model the dynamics of two linked rigid manipulator. The multi input and the multi output model is found to be nonlinear. To observe and control the output response of manipulator, SIMULINK model is designed using S-Function block without any controller and the response found is unbounded. In order to control the position of the manipulator PID and Fuzzy Controllers are used. PID Controller and Fuzzy controllers are designed using RH criteria and linearizing the model about a point respectively. Comparison of controller is made and observed that Fuzzy control is better than PID control.

Keywords: PID Controller, Fuzzy Controller, Membership functions, Simulink, Two Linked Rigid Manipulator

1. Introduction

Manipulator is a machine that has functions similar to human upper limbs, and moves the objects spatially. The Robotics Industries Association (RIA) of USA defines the robot as “A reprogrammable, multifunctional manipulator designed to move material through variable programmed motions for the performance of a variety of tasks.”

The robot anatomy is therefore, the study of skeleton of a robot i.e. the physical construction of a rigid manipulator. The structure of a rigid manipulator that consists of links Connected by means of joints is segmented into an arm that ensures mobility and reaches ability, wrist that confers orientation, and an end factor that performs the required task. Most manipulators are mounted on a base fastened to the floor or on the mobile platform of an Autonomous guided vehicle (AGV).

2. Dynamic Modeling of Two Linked Rigid Manipulator

For the Two linked rigid manipulator the state space model is obtained and then the using the same the M file for the simulink obtained. Fig 2 shows the simulink model of two linked rigid manipulator without any controller.

3. PID Controller

A proportional integral derivative controller (PID controller) is a generic control loop feedback mechanism widely used in industrial control systems. The PID controller attempts to eliminate the error between a measured process variable and a set point by calculating and outputting a corrective action that can adjust the process accordingly. The PID controller algorithm have three unique parameters; proportional, Integral and derivative values. The Proportional part determines the reaction to the error, the Integral part determines the reaction based on the sum of recent errors and the Derivative part determines the reaction to the rate at which the error has been changing. The averaged sum of these actions is used to adjust the process via a control element like the position of a control valve or the power supply of a heating element. By “tuning” the three constants in the PID controller algorithm the PID can control the process as per requirements. The response of the controller can be stated in terms of the responsiveness of the controller to an error, the degree to which the controller deviates...
from the set point and the degree of system oscillations. The use of the PID algorithm for control does not guarantee required control of the system or system stability. Some applications may require using only one or two modes to provide the required system control. This can be achieved by manipulating the gain of undesired control outputs to zero. A PID controller will be called a P, PI, PD or I controller in the absence of the respective control actions. PI controllers are common and derivative action is very sensitive to noise measurements, and the absence of integral value may obsolete the system from reaching its target value due to the control action.

Simulation of two link rigid manipulator using PID Controller was done. All the functions and blocks used in model designing are predefined in Simulink library browser. Results for the same controller are obtained on the Simulink for the both links of the manipulator.

4. Generalized Form of Conventional PID Controller

A PID controller is designated by:

\[ G(s) = P+I+D = K_p + \frac{K_i}{s} + K_d s \]  

\[ = K_p (1 + \frac{1}{T_i s} + T_d s) \]  

Where \( K_p \) = proportional gain, \( K_i \) = integration coefficient, \( K_d \) = derivative coefficient. \( T_i \) = integral action, \( T_d \) = derivative action.

For the best results from the system, there is requirement of adjusting these parameters which is more difficult & time consuming.

5. Designing Of Conventional PID Controller

A PID controller is a design to control the Two-Link Rigid Manipulator parameters. (\( \theta_1 \) and \( \theta_2 \)). For this we calculate the parameters used in this controller.

Parameters of manipulator are

\[ m = \text{mass} = 0.585 \text{ Kg}, \]
\[ l = \text{length} = 0.5 \text{ mm}, \]
\[ b = \text{breadth} = 25 \text{ mm} \]

Closed loop transfer function using PID controller is given as

\[ TF = \frac{1}{Js^2 + Bs} \ast \frac{1}{s} \left( \frac{K_p s + K_d s^2 + K_i}{1 + \frac{(K_p s + K_d s^2 + K_i)}{s(Js^2 + Bs)}} \right) \]

Where \( J = \frac{m l^2}{3} \)
\( B = \text{mean friction coefficient} = 0.05 \)

PID control parameters are obtained using the RH criteria for rigid manipulator are given below

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( K_p )</td>
<td>10</td>
</tr>
<tr>
<td>( K_i )</td>
<td>1.3</td>
</tr>
<tr>
<td>( K_d )</td>
<td>10</td>
</tr>
<tr>
<td>( T_i )</td>
<td>1s</td>
</tr>
<tr>
<td>( T_d )</td>
<td>0.13s</td>
</tr>
</tbody>
</table>

Membership functions for the output parameter are shown in Fig 5, here NB means Negative Big, NM means Negative Medium, NS means Negative Small, ZE means Zero and PB means Positive Big, PM means Positive Medium & PS means Positive Small.
7. Results

The settling time and the peak overshot was measured from both controllers and compared. Response of the two linked rigid manipulator parameters (Ө1 and Ө2) using PID controller are shown below.

![Figure 7.1: Response of Ө1 using PID controller](image1)

![Figure 7.2: Response of Ө2 using PID controller](image2)

Here the response of the two linked rigid manipulator parameters (Ө1 and Ө2) using Fuzzy controller are shown below.

![Figure 7.3: Response of Ө1 using Fuzzy controller](image3)

![Figure 7.4: Response of Ө2 using Fuzzy controller](image4)

8. Comparison and Conclusion

Fig 8.1 and 8.2 shows the comparison responses of Ө1 and Ө2 for both the controllers.
Figure 8.1: Response of Θ1

Figure 8.2: Response of Θ2

Table 1: shown below gives the comparison values of settling time and Peak overshoot.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Settling Time (Seconds)</th>
<th>Peak Overshoot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Θ1</td>
<td>PID Control 6.05</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>Fuzzy Control 2.11</td>
<td>0.05</td>
</tr>
<tr>
<td>Θ2</td>
<td>PID Control 5.05</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>Fuzzy Control 1.67</td>
<td>0.00</td>
</tr>
</tbody>
</table>

This comparison shows that the Fuzzy Control of Two linked Rigid Manipulator is better than PID control.

References


