An Intelligent Controller For A Single Link Flexible Joint Manipulator

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Abstract—Flexible manipulators are extensively used in industries. A theoretical analysis of intelligent tracking controller based on emotional learning model in mammalians brain for single-link flexible-joint manipulator is presented. Brain emotional learning based intelligent controller (BELBIC) is an intelligent controller based on the model of emotional part of brain. In this paper, BELBIC is applied to control flexible manipulator system. The contribution of BELBIC in improving the control system performance is shown by in comparison with results obtained from robust controller. BELBIC control flexible manipulator system with Shorter Setting Time and Lower Control Signal than robust controller.

Keywords—Intelligent Control, BELBIC, Flexible Manipulator.

I. INTRODUCTION

Robotic manipulators are greatly accustomed to assist in risky, lacking in variety, and tiresome jobs. Most of the existing robotic manipulators are planned and create in a way to maximize inflexibility in an try to minimize the vibration of the end-effector to obtain a competent condition exactness. This high inflexibility is obtained by applying heavy material and a large formulation. Hence, the existing heavy hard manipulators are exhibited to be inefficient in connection with power consumption or speed with regards to the operating payload. Ako, the performance of high exactness robots is seriously restricted by their dynamic deviation, which insists for a period of time after a move is completed.

In this article, BELBIC is applied to control flexible manipulator system. BELBIC control flexible manipulator system with Shorter Setting Time and Lower Control Signal than robust controller.

[1] describes research in active tools for increase exactness in micro-surgery. Meggiolaro [2] examined the patient positioning system used for cancer patient treatment at Massachusetts General Hospital, and Flanz studied the same at the Northe-


The paper is organized as follows. Section 2 describes Flexible Manipulator system. Section 3 presents a Brain Emotional Based Learning Intelligent Controller (BELBIC) and it is applied to Control Flexible Manipulator system. In section 4 simulation results of Flexible Manipulator system is represented. In section 5 the overall discussion of the simulation results for different systems presented. Section 6 provides conclusion of the study.

II. SINGLE LINK FLEXIBLE JOINT MANIPULATOR

The proposed scheme above will be applied to a single-link flexible-joint manipulator in this section. Giving a priori the motor inertia, it identifies the rest parameters of the system without requiring acceleration signals. Details are given in the following.

The dynamics of a single-link flexible-joint manipulator, in state-space representation, can be described by [8].

\[
\begin{align*}
\dot{x}_1 &= x_2 \\
\dot{x}_2 &= -\frac{mgl}{J_l}\sin x_1 - \frac{k_e}{J_l}(x_1 - x_3) \\
\dot{x}_3 &= x_4 \\
\dot{x}_4 &= \frac{k_e}{J_r}(x_1 - x_3) - \frac{\mu}{J_r}x_4 + \frac{1}{J_r}u(t)
\end{align*}
\]

Where \(x_1\) is the link position, \(x_2\) is the link angular velocity, \(x_3\) is the motor rotor position, \(x_4\) is the motor rotor angular velocity, \(J_l\) is the link inertia, \(J_r\) is the motor rotor inertia, \(k_e\) is the joint elastic constant, \(m\) is the link mass, \(l\) is the link length, \(g\) is the gravity constant, \(\mu\) is the viscosity, and \(u(t)\) is the control input. The system parameters are chosen from [9] that list in table I.
TABLE I
PARAMETERS OF SYSTEM

<table>
<thead>
<tr>
<th>Symbols</th>
<th>Values</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>( m_{gt} )</td>
<td>5</td>
<td>([N \cdot m])</td>
</tr>
<tr>
<td>( J_i )</td>
<td>1</td>
<td>([Kg \cdot m^2])</td>
</tr>
<tr>
<td>( J_r )</td>
<td>0.3</td>
<td>([Kg \cdot m^2])</td>
</tr>
<tr>
<td>( \mu )</td>
<td>0.1</td>
<td>([Kg \cdot m^2/\text{sec}])</td>
</tr>
<tr>
<td>( k_c )</td>
<td>100</td>
<td>([N \cdot m])</td>
</tr>
</tbody>
</table>

III. BELBIC CONTROLLER

Emotions and their nature have been studied for a long time and psychologists have proposed a wide-range of different theories of emotion. Emotion has traditionally been conceived as something that is irrational and detractive from reasoning. But scientists have recently learned about the surprisingly positive rules played by human emotions especially in decision making processes.

A major motivation to mimic emotions in control engineering applications is the belief strongly held by the authors that in the development of intelligent control systems, too much attention has been focused on fully rational deliberative approaches, whereas in many real world decision making situations human agents select their action via bounded rationality. Various factors like computational complexity, multiplicity of objectives, and prevalence of uncertainty leads desirability of more ad hoc rule-of-thumb decisions. Emotional decision making is particularly appealing since it is neither completely cognitive nor entirely behavioral.

Fig.1 the abstract structure of the computational model mimicking some parts of mammalian brain.

The limbic system is seen as the seat of emotion, memory and attention in the brain [13]. Researchers have found that the amygdala and OFC, parts of the limbic system, play an important role in the coding of the emotional significance of sensory stimuli [10,11,14]. Also neurons in the amygdala are driven particularly strongly by stimuli with emotional significance. During experiments to investigate the role of emotion in brain mechanisms, the amygdala and OFC have been implicated as the focal point that determines the emotional significance of many kinds of emotional stimuli [10,11,14].

The emotional learning model in amygdala and OFC is illustrated in Fig. 1. BELBIC is essentially an action generation mechanism based on sensory inputs and emotional cues (reward signals). The emotional learning occurs mainly in amygdala. The learning rule of amygdala is given in following formula:

\[
\Delta V_i = \alpha_a S_i \max(0, REW - \sum A_i) \tag{2}
\]

Where \( V_i \) is the gain in amygdala connection, \( \alpha_a \) is the learning step in amygdala, \( S_i \) is sensory input at each instance, \( REW \) and \( A_i \) are the values of reinforcing signal and amygdala output at each time. The term \( \max \) in the formula (2) is for making the learning changes monotonic, implying that the amygdala gain can never be decreased as it is modeled to occur in biological process in amygdala [12]. Similarly, the learning rule in OFC is shown in formula (3).

\[
\Delta W_i = \alpha_o S_i (E' - REW) \tag{3}
\]

Where \( W_i \) is the weight of OFC connection and \( \alpha_o \) is OFC learning rate. The \( E' \) node sums the outputs from \( A \) except \( A_{th} \) (thalamic connection (5)) and then subtracts from inhibitory outputs from the \( O \) nodes, where it can be calculated as formula (4):

\[
E' = \sum_i A_i - \sum_i O_i \quad (not \ including \ A_{th}) \tag{4}
\]

In which, \( O \) represents the output of OFC. The thalamic connection \( (A_{th}) \) is calculated as the maximum over all stimuli \( S \) and becomes another input to the amygdaloid part:

\[
A_{th} = \max(S_i) \tag{5}
\]

There is one output node in common for all outputs of the model, called \( E \). The \( E \) node simply sums the outputs from the \( A \) nodes, and then subtracts the inhibitory outputs from the \( O \) nodes. The result is the output from the model:

\[
E' = \sum_i A_i - \sum_i O_i \quad (including \ A_{th}) \tag{6}
\]

In fact, by receiving the sensory input, the model calculates the internal signals of amygdala and OFC by the relations in (7) and eventually yields the output:

\[
A_i = S_i V_i
\]
\[ O_i = S_i W_i \]  \hfill (7)

Since amygdala does not have the capability to unlearn any emotional response that it ever learned, inhibition of any inappropriate response is the duty of OFC. Controllers based on emotional learning have very good robustness and uncertainty handling properties, while being simple and easily implementable. To utilize our version of the Moren–Balkenius model as a controller, it should be noted that it essentially converts two sets of inputs (sensory input and emotional cue) into the decision signal as its output. Closed loop configurations using this block (termed BELBIC) in the feed-forward-loop of the total system in an appropriate manner have been implemented so that the input signals have the proper interpretations. The block implicitly implemented the critic, the learning algorithm and the action selection mechanism used in functional implementations of emotionally based (or generally reinforcement learning based) controllers, all at the same time.

In utilization of BELBIC, it should be pointed out that since this model has originally been proposed for descriptive purpose with no control engineering motivation, the model is essentially open-loop. To be used as a controller, the designer has to choose the sensory input fed back from the system response as well as the reward function in accordance to the control engineering requirements of the problem on hand and not merely from neurocognitive insights. The design of BELBIC, is therefore, no different than the design of any other non-linear and adaptive control schemes.

The structure of the control circuit we implemented in this study is illustrated in Fig. 2.

IV. NUMERICAL SIMULATIONS

This section presents numerical simulations Flexible Link Manipulator. The Brain Emotional Learning Based Intelligent Controller (BELBIC) is applied to control Flexible Manipulator system and eventually the results of this Controller would be compared with the control result of Robust Method (RM) [15]. The simulations are given in the following four cases:

- Case 1 : Stabilization to the Origin Point \((0,0,0,0)\).
- Case 2 : Tracking Step Input \(r(t) = 1\).
- Case 3 : Tracking Reference Input \(r(t) = \cos t\).
- Case 4 : Tracking Reference Input \(r(t) = 2 – 2e^{-t}\).

Fig.3 shows that \(x_1\) state of Manipulator system can be stabilized with the BELBIC to the origin point \((0,0,0,0)\). Fig.4 shows that \(x_2\) state of Manipulator system can be stabilized with the BELBIC to the origin point \((0,0,0,0)\). Fig.5 shows that \(x_3\) state of Manipulator system can be stabilized with the BELBIC to the origin point \((0,0,0,0)\). Fig.6 shows that \(x_4\) state of Manipulator system can be stabilized with the BELBIC to the origin point \((0,0,0,0)\). Fig.7 shows the control law of BELBIC to the origin point \((0,0,0,0)\). Fig.8 shows that the scalar output Link Position can track the Step Input. Fig.9 shows that the scalar output Link Position can track the desired trajectory \(r(t) = \cos t\). Fig.10 shows that the scalar output Link Position can track the desired trajectory \(r(t) = 2 – 2e^{-t}\).
Fig. 5 the time response of the Motor Rotor Position for the controlled Single-Link Flexible-Manipulator where the control input is BELBIC.

Fig. 6 the time response of the Motor Rotor Angular Velocity for the controlled Single-Link Flexible-Manipulator where the control input is BELBIC.

Fig. 7 the time response of the control signal of the BELBIC for the controlled Flexible Manipulator system.

Fig. 8 output Link Position of a Single-Link Flexible-Manipulator tracks the Step Input.

Fig. 9 output Link Position of a Single-Link Flexible-Manipulator tracks the trajectory \( r(t) = \cos t \).

V. DISCUSSION

By comparing the figs, the following results can be obtained.

- In the BELBIC in relation to the Robust Method [15], the system states are stabilized by a more limited control signal. Consequently, it is less possible that the control signal to be saturated.
- In the BELBIC in relation to the Robust Method [15], Control will be accomplished in a much Shorter Time and Overshoot.

Considering the results obtained from simulations, the much more efficiency of BELBIC in relation to the Robust Method will be demonstrated.

VI. CONCLUSION

A single link manipulator is the most manipulators are extensively used in industries. The design of brain emotional learning based intelligent controller (BELBIC) through the Single-link Flexible-Joint Manipulator is considered in this paper. The results obtained from BELBIC to control Flexible Manipulator system were improved in proportion of those from gained robust...
controller. BELBIC could control Flexible Manipulator with Shorter Setting Time and Lower Control Signal than robust controller. The numerical results obtained showed the BELBIC was very effective and could Guarantee the Control of the system.

REFERENCES


