Two–Link Manipulator Control
Using Indirect Adaptive Fuzzy Controller

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Abstract

This paper proposes the MIMO indirect adaptive fuzzy controller to control the two-link manipulators. The input-output linearization technique, equivalent control input plus integral term, augmented error model and recursive least square adaptive law are used for the controller. The linear type of fuzzifier-defuzzifier fuzzy logic system used for nonlinear function makes easy to form the error model and able to follow the adaptive system approach. Such that control approach, the control system is not required joint speed and acceleration measurement and easy to implement and tune. The simulation results showed that, the proposed controller has good control performance, stability, very small tracking error, decoupling, fast convergence, robust to parameter variation and load.

1. Introduction

In recent years, the industrial manipulators are mostly required and have tendency to increase the usage in many areas of industry. The advantage of the direct drive manipulators (DDM) is that the speed responses are faster than the indirect drive ones, but DDM have also many disadvantages such as nonlinearity, coupling and sensitive to the external disturbance. Many researches concerning to DDM, such as sliding mode and adaptive control approaches, have been studied to overcome these disadvantages. In the literature, the information of the mathematical models, joint speed and acceleration measurements of DDM are required for controller design. However, the adaptive control approach needs to know the exact mathematical model for creating the adjustable parameters and regressors [1].

This paper proposes a multi-input multi-output indirect adaptive fuzzy controller (MIMO IAFC) for controlling the joint position of DDM. The MIMO IAFC consists of the integral term, linear type fuzzy logic estimator, augmented error model and recursive least square adaptive law with forgetting factors. The input-output linearization technique is used for decoupling the interaction of centripetal, coriolis and gravitational torque (force) of the manipulator. The integral term is added in the equivalent input in order to obtain the small tracking error. The equivalent input that generates the control input is also composed of proportional, derivative and acceleration terms. The linear type fuzzy logic estimator forms the augmented error model that allows to use one joint position measurement and recursive least square adaptive law with forgetting factors. Therefore, the linear type fuzzy logic estimator that forms the adjustable parameters and regressors makes to be able to design the DDM control system without knowing the exact mathematical model.

The MIMO IAFC has been applied to control the joint positions of a two-link planar elbow manipulator which is assumed to be direct drive, rigid link and the power actuator response is faster than the mechanical response of the manipulator [2][3]. The simulation example in this paper will show the performance of proposed control approach, i.e., system stability, tracking error, decoupling, convergence speed, and robustness to parameter variation and load.

2. Mathematical Model

The general form for the rigid manipulators is shown as

$$H(\underline{q})\cdot\underline{\ddot{q}}+C(\underline{q},\underline{\dot{q}})\cdot\underline{\dot{q}}+\underline{G}r(\underline{q})=\underline{u}-\underline{u}_d \qquad (1)$$

where

$H(\underline{q})\in R^{p\times p}$	Manipulator inertia matrix
$C(\underline{q},\underline{\dot{q}})\in R^{p\times p}$	Centripetal and coriolis matrix
$C(\underline{q},\underline{\dot{q}})\cdot\underline{\dot{q}}\in R^{p}$	Centripetal coriolis torque vector
$\underline{G}r(\underline{q})\in R^{p}$	Gravitational torque vector
$\underline{q}\,,\underline{\dot{q}}\,,\underline{\ddot{q}}\in R^{p}$	Position, velocity and acceleration vectors of each joint, respectively
$\underline{u}\in R^{p}$	Driving torque vector
$\underline{u}_d\in R^{p}$	Disturbance torque vector
p	Number of links

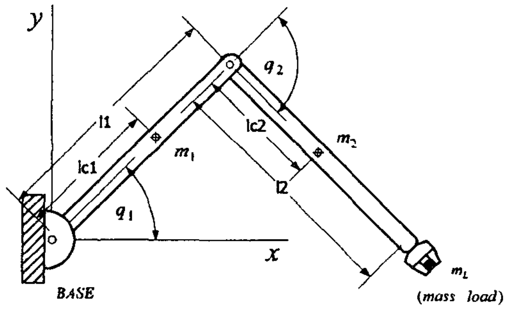

Fig. 1. Planar elbow manipulator.

For the two-link planar elbow manipulator shown in Fig. 1, the elements of the model [2],[3] are

$$H_{11}=m_1\cdot l_{c1}^2+I_1+m_{2e}\cdot[l_1^2+l_{c2e}^2+2\cdot l_1\cdot l_{c2e}\cdot\cos(q_2)]+I_{2e}$$
$$H_{22}=m_{2e}\cdot l_{c2e}^2+I_{2e}$$
$$H_{12}=m_{2e}\cdot l_{c2e}^2+m_{2e}\cdot l_1\cdot l_{c2e}\cdot\cos(q_2)]+I_{2e}$$
$$H_{21}=H_{12}$$
$$Gr_1=m_1\cdot l_{c1}\cdot g\cdot\cos(q_1)+m_{2e}\cdot g\cdot[l_{c2e}\cdot\cos(q_1+q_2)$$
$$+l_1\cdot\cos(q_1)]$$
$$Gr_2=m_{2e}\cdot g\cdot l_{c2e}\cdot\cos(q_1+q_2)$$