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Single Link Robot Arm Trajectory Following Using Model Reference Adaptive Control Algorithm

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Abstract

Robust adaptive tracking control algorithm is proposed in this paper for single link robot arm position control. A model reference adaptive control algorithm is applied to control the angular position of the robot arm by tuning the parameters of the controller. Each parameter of the adaptive controller tuned separately then the controller will reflect the parameters to follow the reference model. The control algorithm was thoroughly tested using the dynamic system modeling package Matlab\Simulink. Comparing with adaptive neural network controller, this technique can provide better angular position control for variable load applications.

السيطرة علي مسار حركة ذراع الإنسان الآلي باستعمال خوارزمية سيطرة النموذجِ المرجعي التكيفية

الخلاصة

خوارزمية سيطرةِ تتبع تكيفي مُقتَرَحةٌ في هذا البحثِ لغرض السيطرة علي مسار حركة ذراع الإنسان الآلي. خوارزمية سيطرة النموذجِ المرجعي التكيفية تم تطبيقها لغرض السيطرة على الموقع الزاوي لذراع الإنسان الآلي عن طريق تنغّيم متغيرات المسيطر. كُلّ متغير ينغّمَ بصورة مُنفصلة ثمّ بقوم جهاز السيطرة بتحديث المتغيرات لإتّباع النموذجِ المرجعي. خوارزمية السيطرة تمت دراستها باستعمال حزمة نماذج الأنظمة الحركية في ماتلاب. مقارنة بمسيطر الشبكة العصبية ألتكيفي فإن المسيطر المنغم المستخدم يمكن أن يوفر أفضل سيطرة للموقع الزاوي لدوران الذراع في التطبيقات التي تستلزم تغيرا في الأحمال.

Introduction

For object transferring robots or other mechanical systems in industries, a precise trajectory control is generally required. As a design procedure the control torque can be calculated based on dynamic model of electromechanical system [1]. In 2005 Schilling developed an adaptive controller for a robotic arm based on auto regressive model, used the least square criterion to obtain the best fit to the manipulator assuming that the parameters of the system being controlled do not change too rapidly [2] For robotic manipulators the system parameters, Such as the inertia and the effect of gravity tends to change rapidly as the Arm moves from configuration to another. A single link robot arm using model reference adaptive control is designed where as the controller parameters tuned according to their effect on the transient and steady state response where the parameters drift are overcome accordingly. The controller parameters are evolved, starting from zero to drive them towards their ideal values that would provide perfect matching between the reference model and the closed-

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loop plant model. The converged controller parameters then provide good estimates for the unknown plant parameters. Figure (1) shows the block diagram of a developed model reference adaptive control system, the output of the closed loop system y and the output of the model y_m are denoted by [3].

$$y(t) = \frac{B_p}{A_p}\ u(t) \qquad (1)$$

$$y_m(t) = \frac{B_m}{A_m}\ u_c(t) \qquad (2)$$

Where u is the control signal and y is the output signal. The symbols A_p and B_p denote polynomials in differential operator command signal u_c and the desired output signal y_m,The symbols A_m and B_m are polynomials in differential operator or the forward shift operator. Let e be the error between the output of the closed loop system y and the output of the model. To minimize the error e, the parameters θ were adjusted in such a way that the loss function and the adaptation parameters are obtained by optimization according to an integral of square error criterion

$$J(q) = \frac{1}{2}\ e^2 \qquad (3)$$

The technique used for adjusting θ is the MIT rule, where we move the parameters in the direction of the negative gradient of J, that is

$$\frac{dq}{dt} = -g\frac{\partial J}{\partial q} = -g\ e\frac{\partial e}{\partial q} \qquad (4)$$

where γ is the adaptation gain.
A general linear control law is

$$R\ u = T\ u_c - G\ y \qquad (5)$$

R , T *and* G are polynomials where

$T_{(s)} = t_0 s + t_1,\ R_{(s)} = s + r_1$ *and* $G_{(s)} = g_0 s + g_1$

Let k is the degree of polynomial R, $\mathbf{l}$ is the degree of polynomial G and m is the degrees of the polynomials T then.

$$q^0 = \left(r_1' ..... r_k', g_0 ..... g_{\mathbf{l}}, t_0 ..... t_m\right)^T$$

Where q^0 are the true regulator parameters. The filter error can be written as

$$e_f = \frac{b_0 Q}{A_0 A_m}\left(\frac{1}{P_1}u + j^T q^0\right) \qquad (6)$$

$$P = P_1 P_2 = A_m A_0 \qquad (7)$$

$$T = A_0 B_m / b_0 \qquad (8)$$

A_m is the desired model poles, A_0 is the observer poles, Q is strictly positive and j is the regression vector, The feedback law is

$$u = -q^T(P_1 j) \qquad (9)$$

Where q is the actual regulator parameter. The Gradient Rule that used for updating parameters is.

$$\frac{dq}{dt} = g\ j\ m \qquad (10)$$

$$m = e_f + \frac{b_0 Q}{A_0 A_m} V \qquad (11)$$

$$V = -\left(\frac{1}{P_1}u + j^T q\right) \qquad (12)$$

Where m denotes the augmented error and ς is the error augmentation.

Single link robot arm

Robot manipulator consists of an arm with some kind of tools called end-effector, which can perform tasks such as paint spraying, welding and moving objects. Robot arm is generally consist of links connected in series at the joints, the joint variable is a joint angle some times the link can become longer as in prismatic joint where the joint variable is the link length. In robots we need to know the last link (end-effector) position and orientation in terms of the joint variables. The robot force control literature reports two broad approaches for the control of robots executing constrained motion: impedance control and hybrid (force/position) control. In impedance control, a prescribed static or dynamic relation is sought to be maintained between the robot end effector force and position. In hybrid control, the end effector force is explicitly controlled in selected directions and the end effector position is controlled in the remaining (complementary) directions [4]. The hybrid control is the type we used for controlling the robot arm. For finding the equation of motion for a single driven link we can draw a diagram of the forces and torques involved as shown in figure (2), assuming that the joint is a revolute joint, (this technique work equally for prismatic link and helical joints). The total wrench can act the link is W where

$$W = t + G_w + R_w \qquad (14)$$

Where τ is the magnitude of the torque. G_w is the weight of the link and R_w is the reaction wrench at the bearing, the mass of the link assumed to be unity [5]. The single-link robot arm is shown in figure (3). The objective is to control the angular movement of a single-link robot arm. The equation of motion for the arm is

$$\frac{d^2 f}{dt^2} = t - 10\sin f - 2\frac{df}{dt} \qquad (15)$$

f is the output angle of the arm. Figure (4) shows the Simulink model for a single link robot arm

Neural network model reference adaptive control system

A neural network controller is used to learn a nonlinear function in the controller. The Matlab/Simulik of the second order reference model is shown in figure (5), the neural network control system and the plant is shown in figure (6). The simulation result is shown in figure (7).

Model Reference Adaptive Control for a single link robot arm

Figure (8) shows the model reference adaptive control system block diagram. The reference model is a second order model. The effect of the controller parameters studied separately with no adaptation (adaptation gain $\gamma = 0$). The effective parameter is chosen as the first parameter to be tuned and the second parameter used to improve the plant response and so on for the other parameters. By adjusting the first controller parameter (t1), by starting from zero to the max value reached before the system drift occur. The robot arm and the model responses are shown in figure (9). The second parameter (r1) tuned to improve the system response as shown in figure (10). The other parameters (go, to and g1) are tuned separately and respectively as shown in figure 11, 12 and 13. After tuning the effective controller parameters, run the system using the identified parameters and set the adaptation gain (γ=0.05). The response is shown in figure (14). The result shows that the system is stable and the error between the robot arm and the reference model approaches to zero. Comparing with the results obtained from the neural network reference model adaptive control system we noticed significant improvement in behavior, maximal error is decreased and good transient response of the adaptive system in different operating point. The advantage of tuning method used in this paper is the ability of choosing optimal controller parameters which yields best system performance. The robot joint follow the model response exactly with fast and stable trajectory form.

Conclusions

A parameter adaptation strategy improves transient performance comparing with the neural network reference model method. Fast parameter adaptation performed by the system with frequent parameter variations. The simulation shows improvement in system behavior caused by the adaptation mechanism. In addition, adaptation coefficients were obtained by optimization for one of the variable controller parameters. The same strategy was used for the whole changeable controller parameters.

References

1-Hong Zhe Jin and Jang Myung Lee, "An RMRAC Current Regulator for Permanent-Magnet Synchronous Motor Based on Statistical Model Interpretation", IEEE Transactions on Industrial Electronics, Vol. 56, No. 1, January 2009.

2-Schilling, "Fundamentals of Robotics" , 2002.

3- Karl John Astrom, Bjorn Wittenmark ,"Adaptive Control", India, 2002.

4- Jaydeep Roy and Louis L. Whitcomb ,"Adaptive Force Control of Position/ Velocity Controlled Robots: Theory and Experiment" IEEE Transactions on Robotics and Automation, Vol. 18, No. 2, April 2002.

5- J. M. Selig, "introductory robotics", south bank polytechnic, prentice hall international (uk) ltd, 1992.

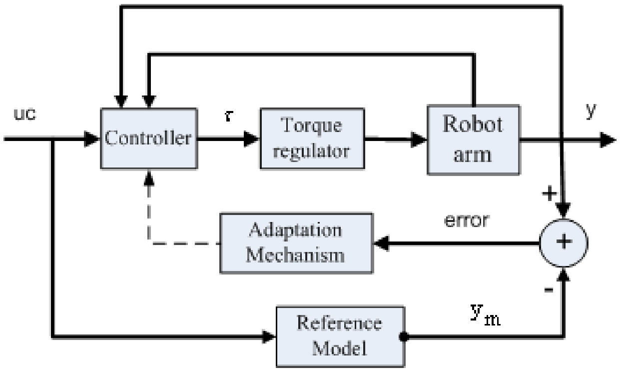
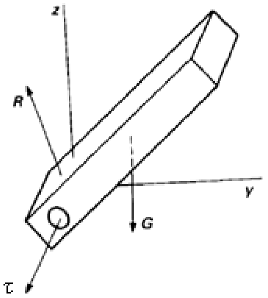


Figure (1) Block diagram of the model reference adaptive control



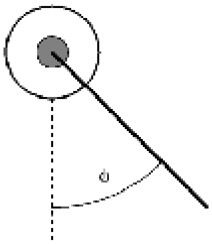


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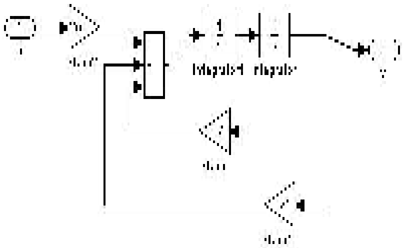
Figure (2) single driven link free body diagram

Figure (3) single link robot arm



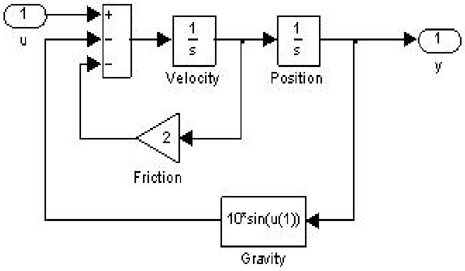


Figure (4) Simulink model for a robot arm

Figure (5) the reference model

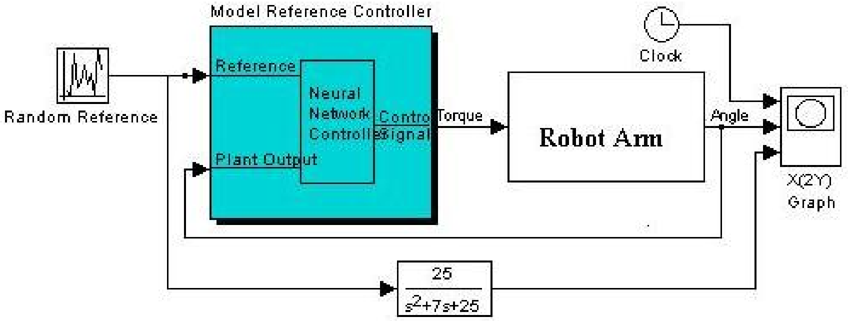


Figure (6) The Neural Network reference model control system

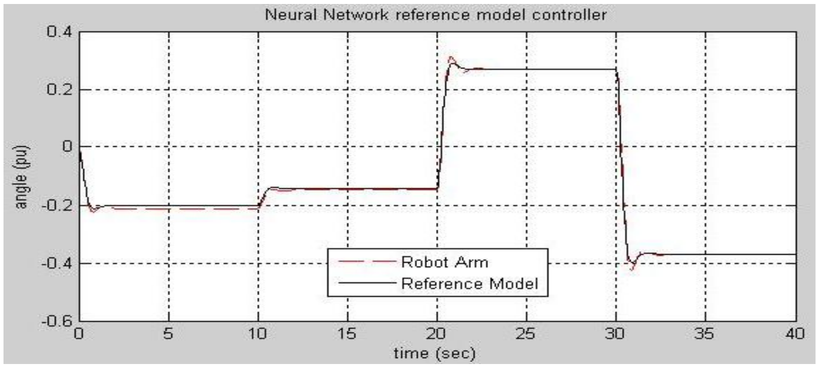


Figure (7) The Neural Network reference model response

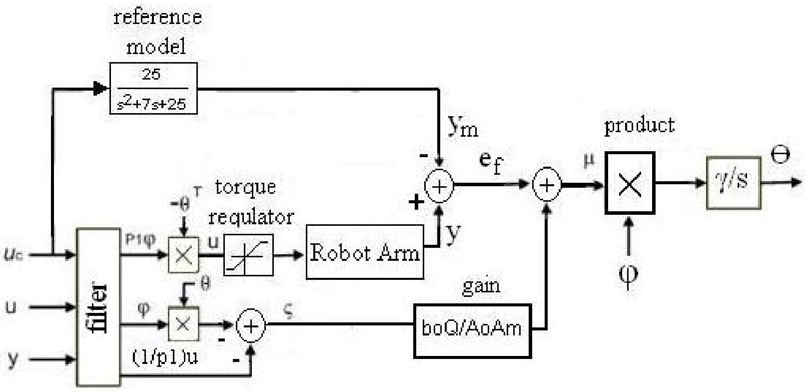


Figure (8) Model Reference Adaptive Control System Matlab/Simulink

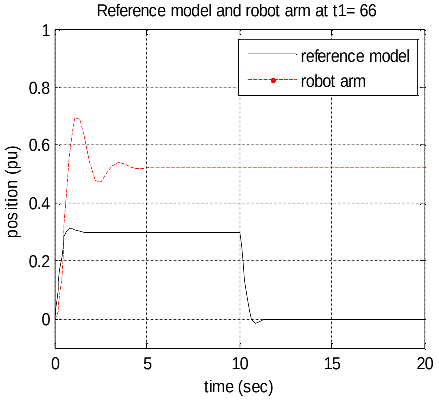


Figure (9) Robot arm and reference model

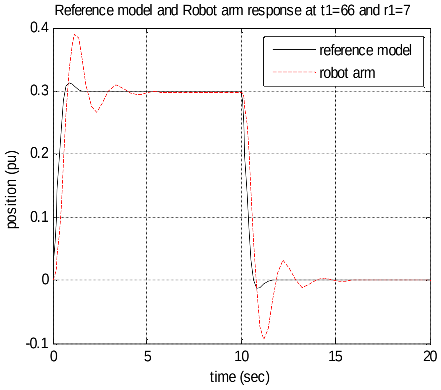


Figure (10) Robot arm and reference model
Adaptation gain = 0 and t1=66 adaptation gain = 0, t1=66 and r1=7

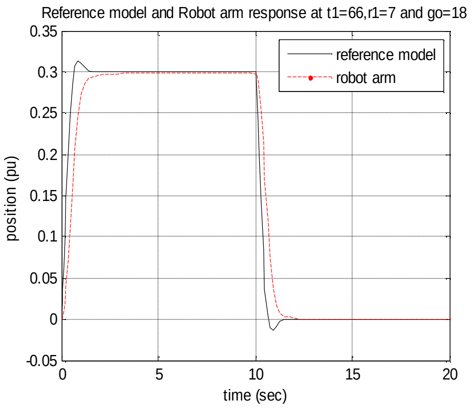


Figure (11) Robot arm and reference model γ = 0, t1=66, r1=7 and go=18

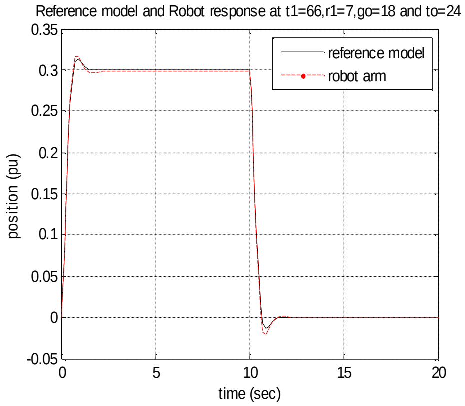


Figure (12) Robot arm and reference model
γ = 0, t1=66, r1=7, go=18 and to=24

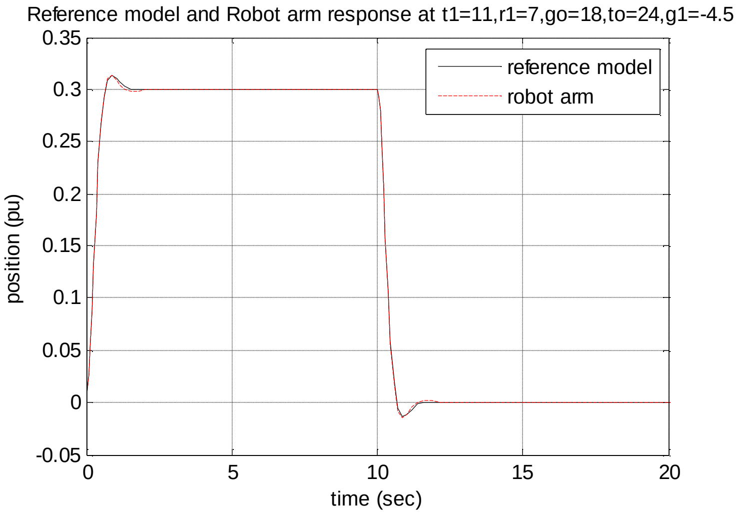


Figure (13) Robot arm and reference model responses with Adaptation gain (γ) = 0, t1=66, r1=7, go=18 to=24 and g1=4.5

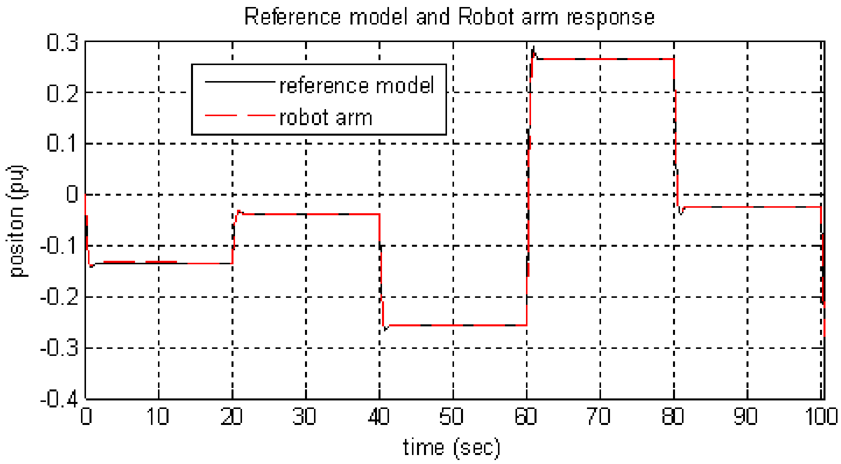


Figure (14) Robot arm and reference model responses with Adaptation gain (γ) =0.05, t1=66, r1=7, go=18 to=24 and g1= 4.5