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Modelling and Position Control of Flexible Manipulator Using Artificial Neural Networks

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Abstract:- Complexities of modelling and control of flexible manipulator system is very complex owing to the link vibrations. This paper presents modelling and control of a flexible link manipulator using Artificial Neural Networks (ANN). A feedforward multi-layer network architecture has been trained to learn the dynamical behaviour of the flexible manipulator system. Then a model reference neuro-controller has been proposed for the tip position control of the flexible manipulator.

1 Introduction

Research on the modelling and control on flexible manipulator has received increasing interest during the last decade because of their advantages over the rigid counter parts [1]. Artificial Neural Network (ANN) is an intelligent control paradigm, which has been proved to be the best structures in enabling good learning capability [1]. Some of the previous works on learning the desired plant behaviour have been found in literature [1]. The learning capability of the ANN has been exploited for achieving the desired model reference control of a single link manipulator. In this paper an application to a flexible link is presented in which both aspects are intrinsic, and it is shown how a neural model can handle these features.

In the initial part of the work the objective is to model the dynamics of the flexible manipulator system using the ANN. Then, the resulting model will be utilised to design the model reference adaptive controller for regulating the tip position of the manipulator.

The paper is organised as follows: the dynamics of the flexible manipulator has been introduced in section 2., the structure of the proposed neural network model is included in section 3, section 4 proposes a model reference adaptive controller based on ANN, simulation results and discussions are presented in section 5.

2 Description of Flexible Manipulator System

Fig.1 gives the schematic diagram of a single link manipulator system. Let, OX_oY_o be the stationary co-ordinate frame and the co-ordinate frame OXY is fixed to the driven end of the arm. Thus a clamped-mass configuration of the flexible arm is considered. The clamped end of the flexible arm of length L is attached to the hub with inertia I_h, where an input torque u(t) is applied to move the arm by a motor and the free end carries an inertia payload mass, m_p. The arm has a moment of inertia I_b and a linear mass density r.

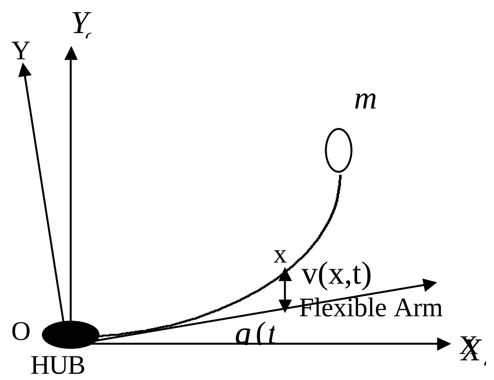


Fig.1 Single Link Flexible Manipulator

Table 1 Physical Properties of the manipulator

L=1.0m, Area=20mm*10mm, r =0.5 Kg/m, EI=1.94 $N.m^2$, I_h =0.3 $Kg.m^2$,mp=0.2Kg

3 Modelling the States through Neural Network

3.1 Structure of the Neural Controller

A four layer feed forward neural network with two hidden layers. The number of nodes in the input is taken to be 6 representing the hub angle, hub velocity, first mode, derivative of the first mode, second mode and the derivative of the second mode.

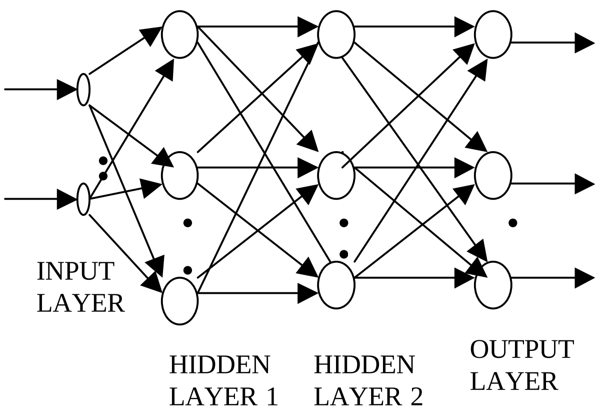


Fig.2 Feedforward Multilayer ANN

Similarly the output layer consists of six nodes. In hidden layers consists of 15 and 9 nodes respectively.

3.2 Training : The purpose of resilient backpropagation training algorithm (RBPA) takes care of the problem that would have been caused due to use of sigmoidal function i.e. it eliminates the drawbacks associated with the magnitudes of the partial derivatives with use of sigmoidal functions.

4 Model Reference Adaptive Controller

Fig.3 gives the proposed model reference where, the NN model replaces the flexible manipulator, for the purpose of training the controller. The error between the states of the reference model and the output of the NN model has been propagated backward through the NN plant model to controller.

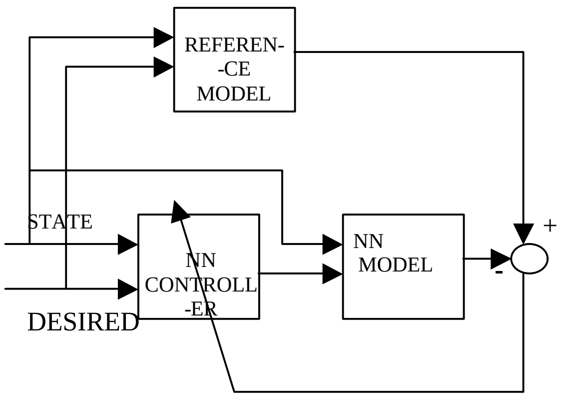


Fig.3 Structure of Model Reference Controller

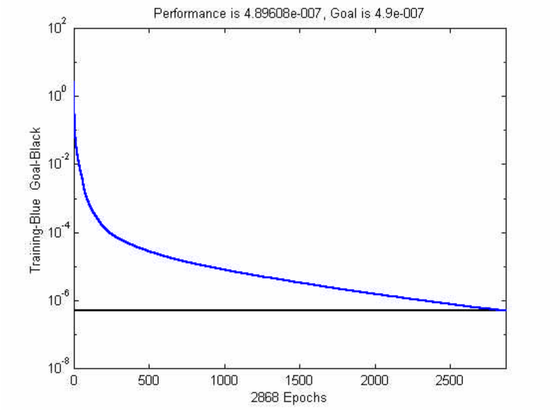
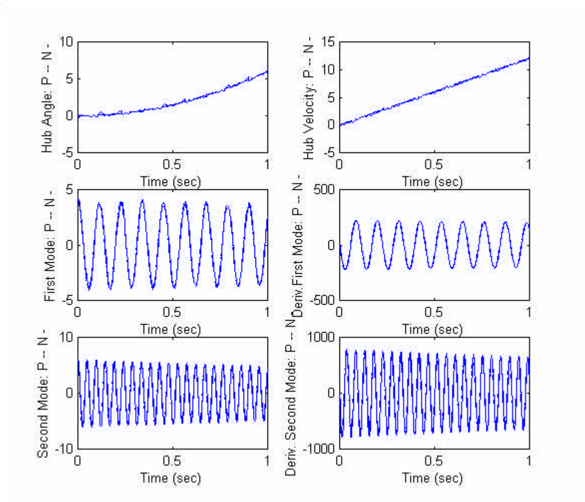


Fig.4 Training Curve

5 Simulation Results

It can be observed from the training curve given in Fig.4 that the Neural Network is able converge to the allowable error limit after 2868 epochs.

It is also observed that the minimum epochs required for convergence has been drastically reduced with the two hidden layer network as compared to a single hidden layer. The simulation was run for 10 seconds.



5. Neural Model (N) and Plant (P) Response

From Fig.5 it is clear that the trained NN is able to model the flexible manipulator dynamics accurately.

Conclusion

The proposed ANN is able to learn the manipulator dynamics accurately. This is because of the inclusion of two hidden layers in the structure of the ANN. It has been confirmed that a single hidden layer in the topology is not efficient enough. The model reference controller as proposed in section 4 is under progress.

References:

[1]. S. Panzer, G. Ulivi, "Neural modelling of a flexible link," *IMACS/IFAC 2nd International Symposium on Mathematical and Intelligent Models in System Simulation,* Brussels, B, pp. 79-83, 1993.

[2]. Matlab Neural Network Toolbox, User’s Guide, Mathworks, July 1998.

[3]. S.Thomas and B.Bandyopadhyay, Position control of single link flexible structure model following control. *Trans.on ASME, Jou. Dynamic Systems and Meas. and Contr*.**119**, 331-335 (1997).