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FEEDFORWARD NEURAL NETWORK BASED, NONLINEAR MODELING OF THE TWIN ROTOR MIMO SYSTEM

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INTRODUCTION

The Twin Rotor with Multi Inputs Multi Outputs (MIMO) System (TRMS) (Feedback Co. (1998)) is an aero-dynamical system similar to a typical helicopter as shown in Figure 1. It consists of a beam pivoted on its base with provision to rotate freely both in its horizontal and vertical planes and this motion is defined to be two Degrees of Freedom (DOF). Either the horizontal or the vertical DOF can be restricted to have a motion with one DOF. At both ends of the beam, there are two propellers driven by Direct Current (DC) motors. The aerodynamic force is controlled by varying the speed of the motors. Therefore, the control inputs are the supply voltages of the DC motors. The TRMS system has main and tail rotors for generating vertical and horizontal propeller thrust. The main rotor produces a lifting force allowing the beam to rise vertically making a rotation around the pitch axis (horizontal axis), while, the tail rotor is used to make the beam turn left or right around the yaw axis (vertical axis).

The state of the beam is described by four process variables: horizontal and vertical angles measured by optical encoders fitted at the pivot, and another two additional state variables are the angular velocities of the rotors, measured by tacho-generators coupled to the driving DC motors.

This paper investigates the development of an adaptive dynamic non-linear model inversion control law for a TRMS utilizing Artificial Neural Networks (ANN). A highly non linear one DOF model of the TRMS is considered in this paper and a non linear inverse model is developed for the pitch channel. In the absence of the model inversion errors, an ANN model in place of a Proportional-Integral-Derivative (PID) controller is used to enhance the tracking performance of the system. The neural network model is developed using backpropagation algorithm with Levenberg-Marquardt (LM) training method. The responses between the reference signals and empirical based models of the TRMS are used to validate the accuracy of the models. Simulation results under MATLAB Simulink show the improvement of response and superiority of simplified neural network controller.

Some investigations are reported to have addressed the modeling and control of a TRMS using various model-based and artificial intelligence approaches. For instance, nonlinear modeling of a TRMS using radial basis function network has been addressed in reference (Ahmad, S.M., *et al* (2002)), which presents a nonlinear system identification method for modeling air vehicles of complex configuration. The tracking control algorithms for a laboratory aero-dynamical system has been reported in reference (Gorczyca, O., *et al* (2004)), which has investigated the Real Time Windows Target (RTWT) toolbox in the MATLAB environment used to perform real time experiments. Genetic modeling and vibration control of a TRMS has been proposed in reference (Aldebrez, F.M., *et al* (2004)), which has investigated the dynamic model of the TRMS extracted using Genetic Algorithm (GA). Feedforward neural network based nonlinear dynamic modeling of a TRMS using Resilient Propagation (RPROP) algorithm is described in reference (Shaheed, M.H., (2005)). This investigation deals with developing algorithm, which possesses direct weight update capability without considering the size of the partial derivatives. Mathematical dynamic modeling of a TRMS is described in reference (Rahideh, A., *et al* (2006)), which has investigated the responses of both Newtonian and Lagrangian models. Adaptive nonlinear model inversion control of a TRMS using artificial intelligence has been reported in reference (Bajodah, A,H., *et al* (2007,2008)), which has described the absence of model inversion errors, a

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genetic algorithm tuned Proportional-Derivative (PD) controller for the enhance tracking performance. Time optimal and robust control of TRMS is described in reference (Lu, T.W., *et al* (2007)), which has been implemented to design a time optimal controller for the system. Decoupling control of a TRMS using robust deadbeat control technique (Lu, T.W., *et al* (2006)) - has described the PID based robust deadbeat controller for the system.

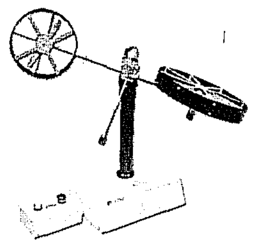

Figure 1: The twin rotor MIMO system

METHODOLOGY

The single hidden layer feedforward ANN architecture is trained offline with model error feedback. The inputs to the network is the error of current time, $e_{(t)}$, pitch angle of the beam at current time, $\alpha_{v(t)}$, pitch angle of the beam at the previous time, $\alpha_{v(t-1)}$, and pitch angle of the beam at two sample before, $\alpha_{v(t-2)}$, and the output, which is the adaptive voltage, $v_{ad(t)}$. Figure 2 shows the structure of the single hidden layer neural network which is used here.

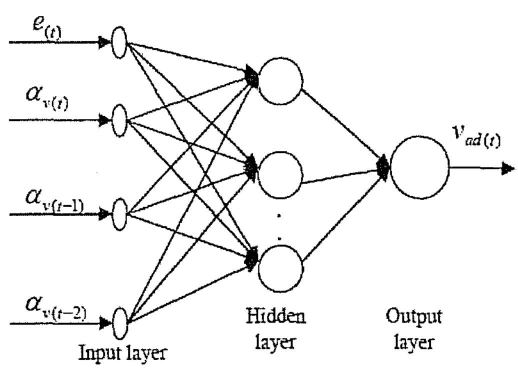

Figure 2: The structure of the single hidden layer neural network

SIMULATION EXPERIMENTS AND RESULTS

To evaluate the effectiveness of the proposed method, the simulation experiments were carried out for the neural network model, and the reference signal and the actual signal were compared. Simulation results of the proposed method are shown for a step input signal. The neural network architecture consists of four inputs neurons and one output neuron. Numbers of hidden neurons and layers are changed according to the performance of the system. First, for a neural network model with one hidden layer of eight neurons, Figure 3 shows the control response to a step input signal. Second, for a neural network model with one hidden layer of ten neurons, Figure 4 shows the control response to a step input signal. Next, a neural network model with two hidden layers having five neurons in first hidden layer and three neurons in second hidden layer was used. Figure 5 gives the corresponding control response for a step input signal. Finally, for a neural network model with two hidden layers containing five neurons each in the two hidden layers, Figure 6 shows the control response to a step input signal.

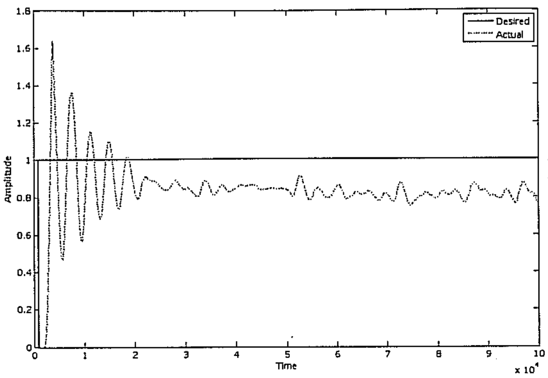

Figure 3: The response of the TRMS to a step input (8-neurons in hidden layer)

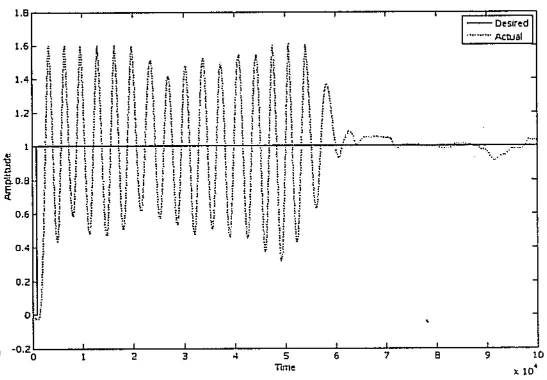

Figure 4: The response of the TRMS to a step input (10-neurons in hidden layer)

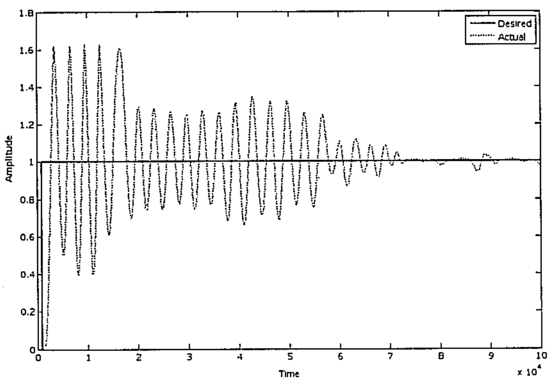

Figure 5: The response of the TRMS to a step input (5*5 neurons in both hidden layer)

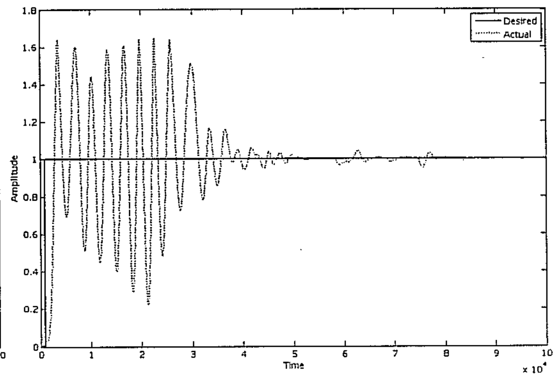

Figure 6: The response of the TRMS to a step input (5*3 neurons in both hidden layer)

CONCLUSION

In this paper adaptive model inversion control approach has been developed and implemented on a TRMS for a one DOF of the system. An identification experiments was to estimate a model for TRMS in the vertical plane motion without any prior system knowledge pertaining to the particular mathematical model structure. After apply the ANN controller, inversion error increased when an adaptive neural network based controller was added to the control system. The experimental results showed that the performance of the model-based controller was poor than expected in tracking trajectories under a step input. The reason for this is that the source data of the system have less variation, and it is difficult to adapt to train the neural network for minimizing the error in the feedback signal. It is therefore necessary to further study employing an auto-tuning PID controller with an artificial neural network.

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