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System Identification of MIMO Control System with Minimization of Error

Ms.Anuradha Das

Master of enginerring,Dept of Electrical engg,Jorhat engg. College, Assam

Dr.Mrinal Buragohain

Associate Proff.,Dept of Electrical engg.,Jorhat engg.College, Assam

Abstract:A novel tecknique of system identification of MIMO(multi-input-multi-output) control system using a hybrid controller(neural network+fast transversal filter) has been proposed.In this paper, error is divided into two parts.Non linear part is fed to the neural network,whereas,linear part is fed to the fast transversal filter.Finally,we obtain two different outputs from the two section of the hybrid controller.Each of the output is then compared with estimated outputs.Results are also compared with the MISO(multi-input-single-ouput) control system. This tecknique minimizes the error for both MISO &MIMO control system.

Keywords:Feed-forward neural network,Backpropagation Algorithm, Bayesian regularization,fast transversal algorithm,parameter estimation.

I. INTRODUCTION

System identification is a method of building mathematical model of a dynamic system using input -output data of the system.The method requires the measurement of the input and output signal in frequency or time domain.System identification of SISO(single-input-single-output) system is quite easy as they do not require decoupling method as compared to MISO(multi-input-single-ouput) and MIMO(multi-input-multi-output) systems.

The first step of identification of building a model is to identify the most significant inputs.As we are using time delayed signal so previous inputs,previous outputs and present inputs are taken to predict the output of the system.Parameter estimation is also done for these non-linear systems.

As parameter estimation of non-linear dynamic system is a tough job as compared to linear one so here the use of neural network is entertained.A three layer feed forward neural network with backpropagation is used for this purpose.Afterwards,*fast tranversal filter* is used to minimize the error.In this paper the system under consideration is *Box&Jenkins gas furnace*

II.SYSTEM UNDER CONSIDERATION

We are considering *Box and Jenkins gas furnace* as our system which originally consists of 296 SISO data points (from n=1to 296) where input is the gas flow rate and output is the carbon di-oxide (CO2) concentration.To make it as MISO we are using time delay of six data points.Eventually,for making it as a MIMO same time delay is used but data points are halved i.e a 2*2 MIMO system has been developed.In both the cases,previous inputs,previous outputs and present inputs are taken as inputs to the system to predict the output.

III.IDENTIFICATION METHODS

The two different ways for identification are of one is *parallel identification* and the other one is *series-parallel identification.*

1.*Parallel identification*:The major disadvantage of using this method of identification is, it does not provide assurance of the stability of the system with neural network as well as whether the parameter will converge or not or the output error tends to zero or not.

$$y_{pn}(k+1) = \alpha_0 y_{pn} + \alpha_1 y_{pn}(k-1) + N[u(k)] \qquad (1)$$

2.*Series-parrallel identification*:In this method of identification all input signals to the neural network are bounded as well as static back propagation can be used with no feedback loops.Thus having significant advantages over parallel identification method.

$$y_{pn}(k+1) = \alpha_0 y_{pn} + \alpha_1 y_{pn}(k-1) + N[u(k)] \qquad (2)$$

In this paper,series-parallel identification has been used for system identification.

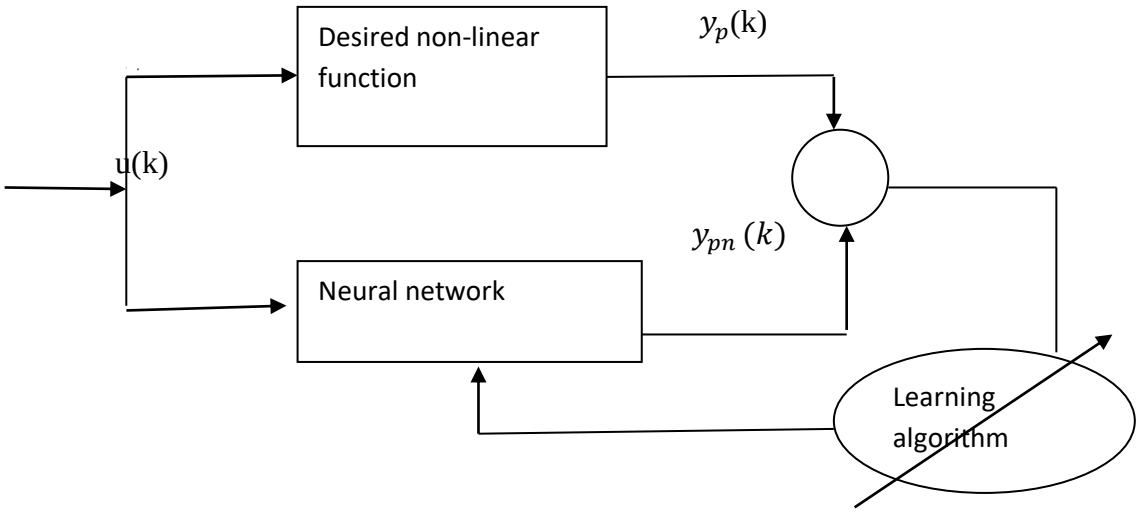


Figure1.Block diagram for identification using Neural Network

IV.DESIGN & IMPLEMENTATION OF THE PROPOSED HYBRID CONTROLLER

In this paper,we are proposing the design of a hybrid controller using neural network and fast transversal filter for MIMO system,where division of input signal into two parts is done.The non-linear part of the input signal given to the neural network whereas linear part is fed to fast transversal filter.The output of the two is combined as one signal then the estimated output is compared with the desired output.It shows that the error is minimized in both the cases.

A.**NEURAL NETWORK**:In this paper,a three layered *feed -forward neural network* with *backpropagation* has been used.In a feed-forward neural network, input is forwarded in one direction which passes through layer by layer i.e through input layer , hidden layer and finally to the output layer .In each layer error is calculated with the help of weights and a definite bias and then it is propagated back to update the weights so that the error can be minimized.Mainly, *gradient descent* optimization algorithm is used to calculate the *loss or cost function* of the gradient to adjust the weights.In our case the output obtained from neural network controller is given by the equation:

$$u_1(k) = \psi[\sum_{k=0}^{n} w_k \ e_k + b \qquad (3)$$

B.**FAST TRANSVERSAL FILTER:**It mainly consists of four different nth order filters . First one is *least squares prediction filter* which uses the required data for optimal prediction of the desired signal.The second one is a *forward prediction error filter* which computes the forward prediction error between prediction based on previous data and present data.The third one is a *backward prediction error filter* that computes backward prediction error between present data and prediction based on the future data.The fourth and last one is a *gain transversal filter*.The purpose of all these four filters together is to minimizes the *least square error*.The output of the filter is given by:

$$u_2(k) = w_{f1} \times r(k) + w_{f2} \times r(k-1) \qquad (4)$$

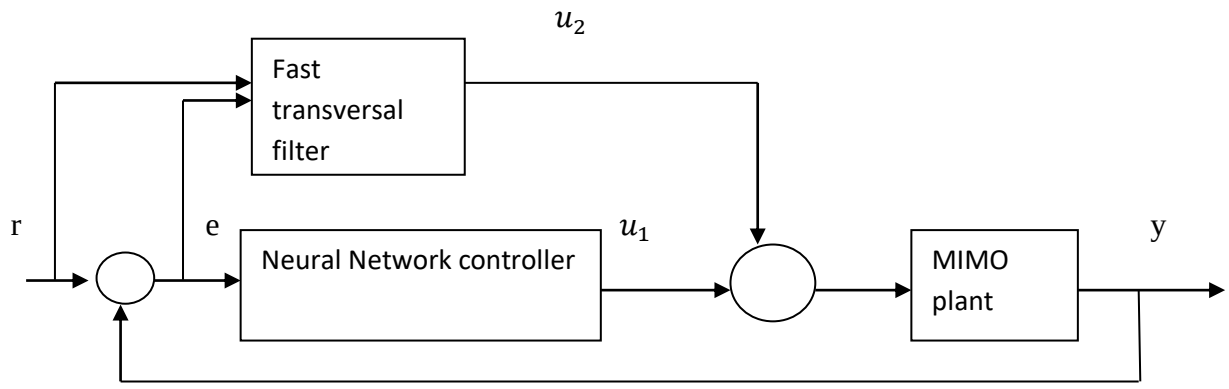


Figure2.Block Diagram of the hybrid controller

V.SIMULATED RESULTS OBTAINED FOR MIMO SYSTEM

As our system under consideration is Box and Jenkins gas furnace,we will first do identification using neural network for non-linear part of the input signal.Afterwards,fast transversal filter is used to estimate the desired output for linear part of the input signal.The below figures shows that there is a noticeable overlapping between desired output and estimated output.

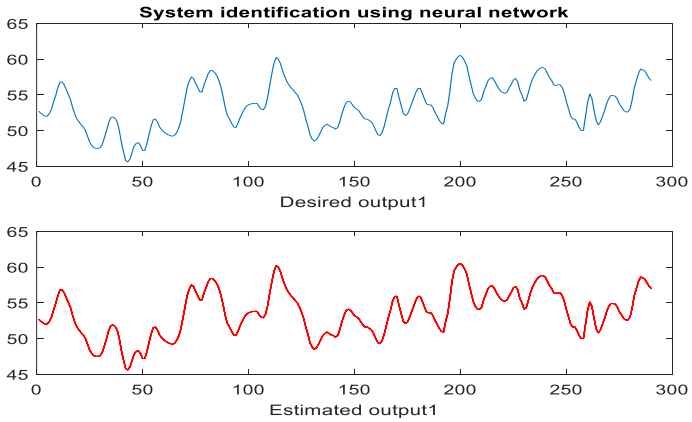


Figure3.Identification using Neural Network for MISO system

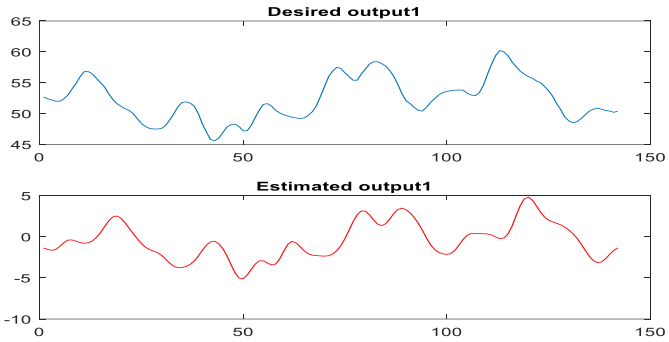


Figure4.Prediction using Neural Network+Fast transversal filter of MISO system

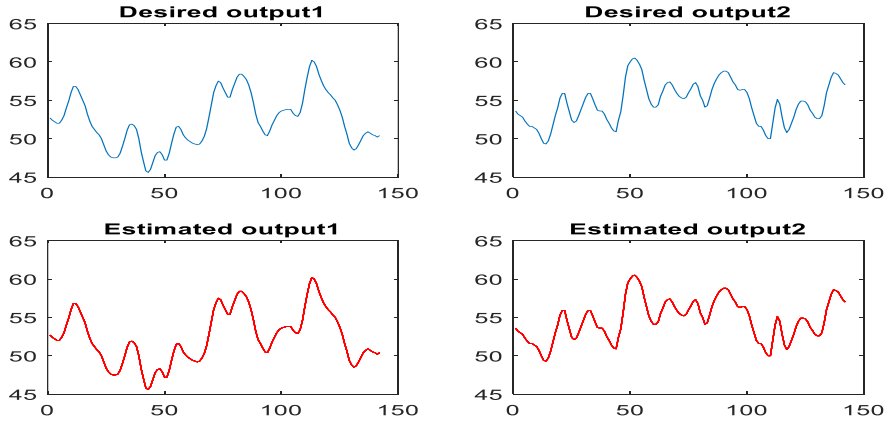
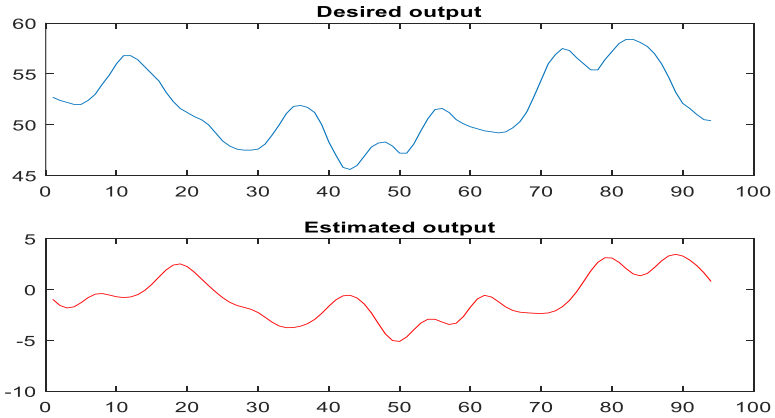
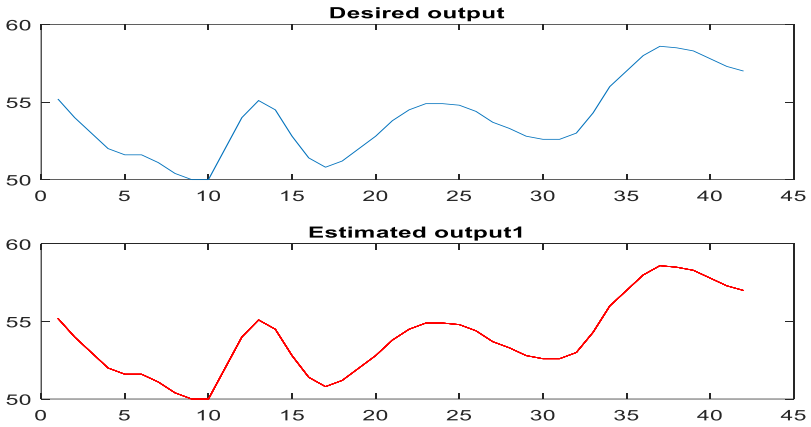


Figure 5.Identification using Neural Network of MIMO system



6.(a)



6.(b)

Figure 6(a&b).Prediction using Neural Network &Fast Transversal Filter of MIMO system .

TABLE1

COMPARATIVE ANALYSIS FOR IDENTIFICATION

Tecknique used	**MINIMUM VALUE OF PERFOMANCE INDEX FOR IDENTIFICATION** **(Trained with Bayesian Regularization)**
NN+FTF for MISO	**0.0206 at epoch 209**
NN+FTF for MIMO	**.000164 at epock 243**

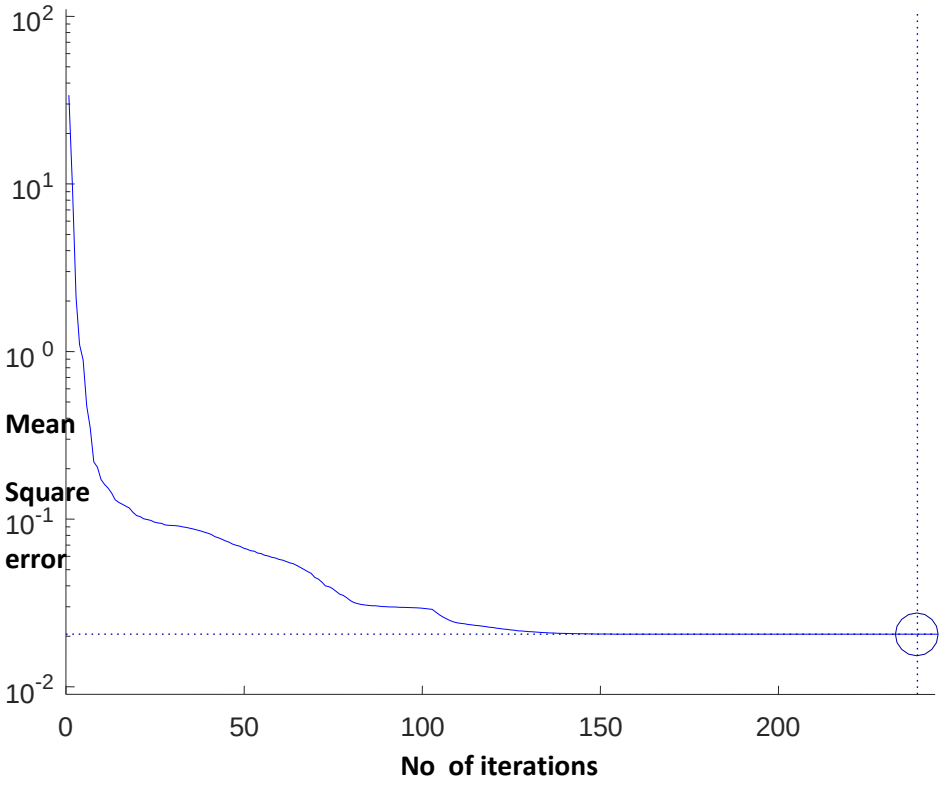


Figure7.Plot for performance index using NN+FTF of MISO

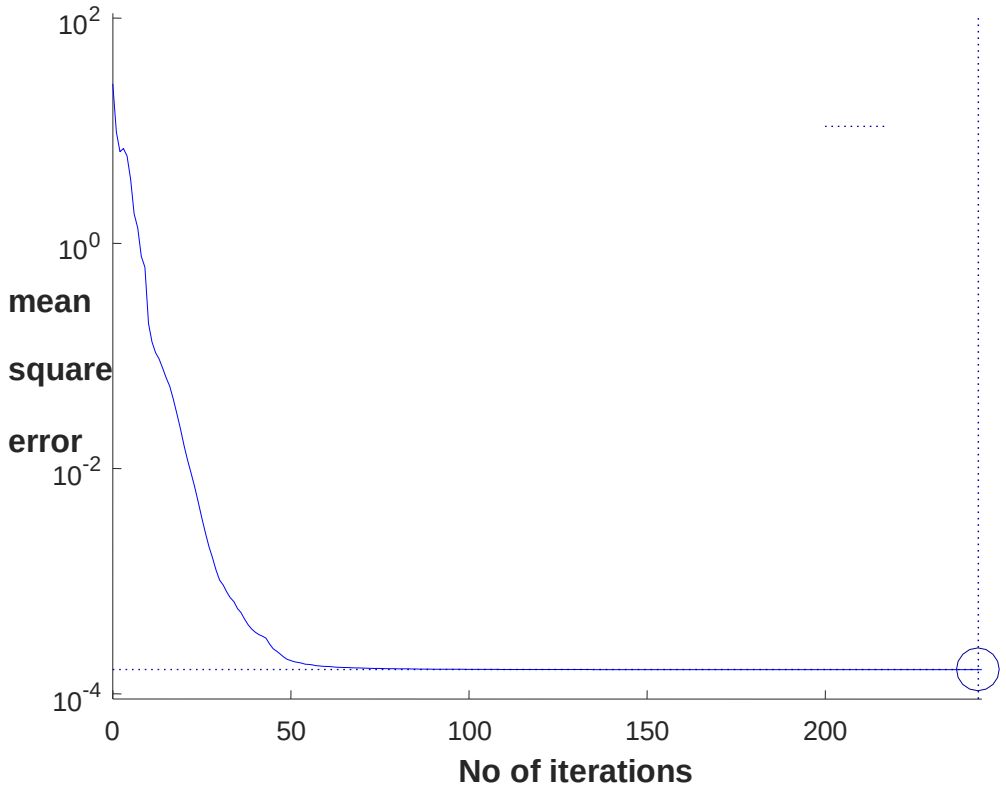


Figure8.Plot for identification using NN+FTF of MIMO

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VI.CONCLUSION

The paper mainly emphasizes the use of hybrid controller i.e combination of neural network and fast transversal filter for MIMO control system.The main advantage of this tecknique is that it requires less no of samples for training which makes the system fast,also the error can also be minimized.

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Kumpati S.Narendra (S'55-M'60-SM'63-F'79) received the B.S degree with honors in electrical engineering from Madras University in 1954 and M.S and Ph.D degrees from Harvard University in 1955 and 1959,respectively .From 1961 to 1965 he was an Assistant Professor in the division of Applied Physics at Harvard. He joined the Department of Enginering and Applied Science at Yale in 1965 and was made professor in 1968.