Dynamics Identification of a Monocopter Using Neural Networks

Mostafa Ezabadi, Mohammad Hasan Sabeti, and Afshin Banazadeh

Abstract—In this investigation, a neural network approach is presented for dynamics identification of a single-bladed aerial vehicle or a monocopter. Implementation of neural networks lets us do the non-parametric identification process regardless of the system dynamics. Here, we have initially designed a feedforward network and found that this approach is insufficient for the mentioned purpose. Therefore, a novel network with NARX structure with one hidden layer, tansig activation function and 15 neurons is designed and excellent results are obtained due to consideration of past outputs in the training process.

Index Terms—Monocopter, dynamics identification, feedforward neural network, NARX.

I. INTRODUCTION

System identification for complex dynamics by means of conventional methods is highly time-consuming and requires practical flight tests. Significant advancements in the field of small air vehicles have caused a widespread demand. Single-bladed aerial vehicle or monocopter is a type aerial vehicles which has drawn many attentions in recent years. This vehicle is able to carry out all flight phases like a conventional helicopter including hover, vertical takeoff and landing and forward flight, with simpler configuration compared to helicopters (Fig. 1). It is capable of producing high aerodynamic efficiency due to its dynamics [1], [2].

As seen in Fig. 1 and 2, sensitivity analysis is also performed on the following parameters. In feedforward network, number of hidden layers and number of neurons are studied. Activation function in each layer was "logsig" and biases through back-propagating of the errors from the last layer to the first. After the training process, step and ramp inputs are implemented for the purpose of validation.

II. NETWORK STRUCTURE

For the purpose of identification, two kinds of networks are used: feedforward and NARX network. We first used feedforward network structure because this kind of structure popular for curve fitting problems [9]. On the other hand, NARX network structure, as a dynamic structure is more effective for the identification of single-bladed aerial vehicle. This network gives the best output in comparison with other dynamic networks [9]. General structures for both networks are given below:

Fig 1. Schematic of the monocopter.

Fig 2. Schematic of the feedforward network.
III. RESULTS AND DISCUSSION

A. 5 Neurons in the Hidden Layer

For initial investigation, we have considered 5 neurons in the hidden layer of feedforward network. The simulation results are given in Fig. 6. As shown in this Fig. 5 neurons in hidden layer are not sufficient so the network is not capable of capturing the vehicle’s complex dynamics.

B. 15 Neurons in the Hidden Layer

For next investigation, we have considered 15 neurons in the hidden layer. The simulation results are given in Fig. 7. The results are not still perfect, although increasing the number of neurons makes better results.
C. Effect of Hidden Layers

Vehicle’s dynamics is very complex. So, one hidden layer is not likely to be sufficient for the identification process. Here, we have considered three hidden layers and 15 neurons in each layer in the feedforward network. As the results in Fig. 8 shows, increasing the number of hidden layers is not still adequate for dynamics identification of this kind of air vehicle. Whatever the number of neurons and hidden layers are changed this kind of structure is not capable to identification would urge a dynamic network.

D. NARX Network

Feedforward network is a static one, which uses instant inputs and outputs for training process. This structure was not able to identify given dynamics, so a dynamic structure is proposed here for this purpose. This structure utilizes past inputs and outputs in addition to the instantaneous inputs and outputs. We have chosen NARX network that is very popular for the identification purpose.

E. Effect of Number of Neurons in Hidden Layer

For initial investigation, we have considered 5 neurons in the NARX hidden layer. The simulation results are presented in Fig. 9. The results show that this kind of network can predict more accurate results in comparison with the feedforward network. However, the number of neurons could be increased regarding the vertical velocity estimation, \( w \). Increasing the number of neurons to 15 gives the capability of producing more accurate outputs, which leads to perfect identification as presented in Fig. 10.
Fig 9. Linear and angular velocities for 5 neurons in the hidden layer.

Fig. 10. Linear and angular velocities for 5 neurons in the hidden layer.

Fig. 11. Linear and angular velocities for 15 neurons in the hidden layer.
IV. CONCLUDING REMARKS

Identification of single-bladed aerial vehicle has not yet been performed. In this paper, dynamic identification of a monocopter with the help of neural networks was presented. Feedforward network with different structures was designed that was not able to correctly identify the vehicle dynamics. A NARX network is then designed with one hidden layer, 15

REFERENCES


Mostafa Ezabadi was born in Tehran, Iran in 1993. He obtained his bachelor degree in aerospace engineering from Sharif University of Technology in 2015 and is currently the M.Sc. student in flight dynamics and control. His main areas of research interest are neural networks, modeling, and control.

Mohammad Hasan Sabeti was born in Hamadan, Iran in 1993. He received his B.Sc. in aerospace engineering from Sharif University of Technology in 2015 and is currently the M.Sc. student in flight dynamics and control. His research interests include airplane design, neural networks, and identification.

Afshin Banazadeh is an associate professor in the Faculty of Aerospace Engineering at Sharif University of Technology. He received his Ph.D in 2008 from Aerospace Engineering Department at SUT, where he also received his M.Sc. in flight dynamics and B.Sc. in mechanical engineering. His current research interests span system identification, aircraft design and flight test engineering. Besides, he consults for industry on matters dealing with modeling, simulation and control, as well as technology demonstration schemes.