

Chapter 11

Aircraft Aerodynamic Parameter Estimation Using Intelligent Estimation Algorithms

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ABSTRACT

Application of adaptive neuro fuzzy inference system (ANFIS)-based particle swarm optimization (PSO) algorithm to the problem of aerodynamic modeling and optimal parameter estimation for aircraft has been addressed in this chapter. The ANFIS-based PSO optimizer constitutes the aircraft model in restricted sense capable of predicting generalized force and moment coefficients employing measured motion and control variables only, without formal requirement of conventional variables or their time derivatives. It has been shown that such an approximate model can be used to extract equivalent stability and control derivatives of a rigid aircraft.

INTRODUCTION

Parameter estimation methods for extracting aircraft parameters (stability and control derivatives) from recorded time history in the linear flight regime of aircraft have seen good amount of success in the past (Maine et al, 1986). With the introduction of highly maneuverable aircrafts opened fresh research opportunities to look for appropriate models and parameter estimation algorithms exclusively for these aircrafts operating in unstable flight envelopes (Zerweckh et al, 1990). The fundamental problems encountered while performing estimation of parameters of an aircraft is: a full order model of an aircraft has a very large number of parameters to be taken into consideration, and thus, too many of them give satisfactory estimates by any of the conventional parameter estimation methods. To relief some of the effort involved in dynamic analysis and control synthesis and to minimize computational burden during simulation, lower order models of vehicle with simplified dynamics have been proposed by Waszak &

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Schmidt (1988). The model reduction processes mostly depends on numerical techniques and/or transformations, and thereby, in the resulting models, the physics of the system is sometimes not so straight forward (Waszak et al, 1988). Ghosh & Raisinghani (1993) gave a solution to this problem by proposing a reduced order model of an aircraft containing important parameters of aircraft dynamics, and also facilitates physical interpretation of the parameters involved in the reduced order model. The availability of a sound mathematical model is also another issue because the conventional model falls short when describing higher order dynamics of the systems.

This chapter deals with a novel approach to estimate the parameters of any stable aircraft (rigid) from pre recorded time history of the aircraft's motion variables in the absence of an accurate mathematical model. Conventional parameter estimation approaches viz. Maximum Likelihood (ML) method (Peyada et al, 2008), the Filter Error Method (FEM) (Jategaonkar et al, 1988), etc. require a priori postulation of aircraft model. On the other hand, a class of Adaptive Neuro-Fuzzy Inference System (ANFIS) uses neural architecture based fuzzy set theory to map inputs (features in the case of fuzzy classification) to outputs (classes in the case of fuzzy classification), and can efficiently approximate a function (piece-wise continuous) to a desired degree of accuracy (Jategaonkar et al, 1988). Currently, FIS architecture is being used for navigation (Ta, however, there are very few literatures on aircraft parameter estimation using ANFIS model proposed by Sugeno. This work addresses this issue by proposing a novel method of estimating the aircraft parameters from the flight data, and the validation is carried out using simulated and real flight data (stable aircraft).

Computer simulations envisage the efficacy of the proposed method to optimally estimate the aerodynamic parameters by using renowned Particle Swarm Optimization (PSO) (Hui et al, 2006). The selection of PSO is justified because of its simplicity in coding, fewer control parameters, good accuracy (Eberhart et al, 1995) and fast speed of convergence (Zhenya et al, 1998). The essence of the present work is to estimate and validate the model utilizing the measured data without being provided with the mathematical input-output relationship of the model. The design philosophy adopted here is to realize the model input-output relationship using ANFIS platform. It is worth mentioning that our proposed technique does not require either a priori postulation or solution of equation of motion.

NEURO-FUZZY SYSTEM BASED ON TAKAGI AND SUGENO'S APPROACH

The neuro fuzzy system developed based on Takagi and Sugeno's approach of FLC is also known as Adaptive Neuro Fuzzy Inference System (ANFIS). Let us suppose that an ANFIS is to be developed to model a process involving two inputs (I_1 , I_2) and one output (O). The input I_1 is represented using three linguistic terms viz. LW: Low; M: Medium; H: High. Similarly three other linguistic terms, such as SM: Small, LR: Large; VL: Very Large are utilized to indicate another input I_2 . The membership function distributions of the first and second input are considered to be triangular and symmetric in nature. The symbols d_1 and d_2 indicate the base width of the isosceles triangles representing the membership functions of the first and second inputs. We have considered two inputs and each have been represented by three linguistic terms, there is a maximum of $3^2=9$ possible combinations of them. According to Takagi and Sugeno's model of FLC, the output of each rule can be expressed as follows:

According to first-order Takagi and Sugeno's model of FLC

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