

**STUDIES ON PARAMETER ESTIMATION AND
CONTRACTION BASED CONTROLLER DESIGN OF
AIRCRAFT SYSTEM**

by
MAJEED M.

Department of Electrical Engineering

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Certificate

This is to certify that the thesis entitled “**Studies on Parameter Estimation and Contraction Based Controller Design of Aircraft System**” being submitted by **Majeed M.** to the Department of Electrical Engineering, Indian Institute of Technology Delhi, for the award of the degree of Doctor of Philosophy is the record of the bonafide research work carried out by him under my supervision. In my opinion, the thesis has reached the standards fulfilling the requirements of the regulations relating to the degree.

The results contained in this thesis have not been submitted either in part or full to any other university or institute for the award of any degree or diploma.

(Prof. I. N. Kar)

Thesis Supervisor,

Department of Electrical Engineering,

Indian Institute of Technology Delhi,

Hauz Khas, New Delhi-110 016,

INDIA.

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Abstract

System Identification is the process of determining an adequate mathematical model of physical system, with unknown parameters which have to be determined from measured data. The knowledge of unknown parameters is very essential for controlling the behavior of system. Main motivation of the work presented in this thesis is to relook the established results in the field of parameter estimation and contraction theory analysis, and to explore their applications to aircraft systems. The challenge in parameter estimation to flight control is accurate estimation of flight control and stability parameters from noisy flight data. The estimation problem is difficult because of flight measured quantities available from airdata systems are erroneous due to uncertain environment, and poor quality of measured data. Following estimation problems, related to aircraft system, are addressed in the thesis.

1. Aircraft flow angles in airdata system are calibrated from the simulated data with wind and turbulence effects. The results are compared for various sensor fusion methods using Extended Kalman Filter (EKF) / Unscented Kalman Filter (UKF) algorithms.
2. Adaptive UKF is applied to flight test data for the estimation of aircraft aerodynamic parameters. The efficacy of the Adaptive UKF is compared with standard UKF. It was found that adaptive UKF is superior to standard UKF in the context of time varying noise characteristics.
3. Aerodynamic derivatives of flexible aircraft are identified by the incorporation of aeroelastic model in estimation algorithm, and selection of excitation input. Moreover, an attempt has also been made to identify the structural modes of aircraft from noisy measurements of differential accelerometers.

Finally, stochastic nonlinear observer is presented for the aircraft system using contraction theory. This theory provides a basic framework to analyze the stability of nonlinear systems

in an alternative way to the traditional Lyapunov based analysis. Along with that, this theory offers many significant advantages particularly in establishing exponential stability of stochastic dynamic system. In this connection, a frequency estimator is designed based on the stochastic contraction theory. An upper bound in estimation error is also derived in case of noisy measurements. In addition to this, attempt is also made to derive control law for an aircraft model in contraction framework. The control law is realized through the design of a stochastic observer. The contraction property of the overall closed loop system is proved. The efficacy of the various results presented in this thesis has been validated through the simulation studies.

Contents

1. Introduction

1.1	Aim of the Thesis	4
1.2	Aircraft parameter estimation methods.....	4
1.3	Stability using contraction theory.....	6
1.3.1	Incremental and non-incremental exponential stability.....	10
1.3.2	Stability analysis using the concept of virtual system.....	11
1.3.3	Adaptive control using actual and virtual system concept	12
1.3.4	Contraction theory for observers.....	14
1.3.5	Combinations of contracting systems.....	15
1.4	Stochastic contraction theory.....	16
1.5	Problem formulation	21
1.6	Literature survey and research gap analysis	24
1.7	Organization of Thesis	33

2. Calibration of flow angles in airdata systems using extended Kalman filter

2.1	Introduction	37
2.2	Problem formulation	38
2.2.1	Problem statement.....	38
2.2.2	Aircraft system dynamic and measurement models.....	40
2.2.3	Turbulence model to estimate AOA and AOS.....	43
2.1	Kalman filtering algorithm.....	45
2.3.1	Extended Kalman filter.....	45
2.3.2	Adaptive Kalman filter	47
2.2	Results and discussion	50
2.4.1	Results due to wind disturbance.....	50
2.4.2	Results due to turbulence.....	55
2.3	Conclusions.....	62

3. Sensor fusion based approach for the calibration of flow angles in airdata systems

3.1	Introduction	63
3.2	Problem Description	64
3.2.1	Sensor Fusion Methods	64
3.2.2	Unscented Kalman filter	66
3.2.3	Aircraft system measurement models for fusion.....	68
3.3	Results and discussion	70
3.4	Conclusions	74

4. Adaptive UKF based recursive aerodynamic parameter estimation from flight data

4.1	Introduction.....	75
4.2	Problem formulation	77
4.2.1	Problem statement	77
4.2.2	Aircraft dynamic model for parameter estimation	78
4.3	Adaptive UKF structure	79
4.3.1	Master UKF	80
4.3.2	Slave UKF	84
4.4	Results and discussions.....	86
4.4.1	Results from simulated data.....	86
4.4.2	Results from flight test data	91
4.5	Conclusions.....	100

5. Identification of aerodynamic derivatives of a flexible aircraft

5.1	Introduction	101
5.2	Problem Formulation	103
5.2.1	Mathematical model postulates for flexible aircraft.....	103
5.2.2	Identification of Structural modes using accelerometer sensors	109
5.2.3	Output Error Method	110
5.3	Flexible flight test data generation for parameter estimation	112
5.4	Experimental design for optimal inputs	116

5.5	Parameter estimation results	123
5.5.1	Estimation of the rigid body and elastic derivatives	122
5.5.2	Estimation of structural modes from accelerometer sensors	122
5.6	Conclusions.....	128
 6. Contraction theory based nonlinear observer design		
6.1	Introduction.....	129
6.2	Problem formulation.....	130
6.3	Deterministic flight vehicle observer	135
6.3.1	Contraction nature of aircraft system	135
6.3.2	Flight vehicle observer	139
6.4	Stochastic frequency estimator	141
6.4.1	Estimation of two frequencies	141
6.4.2	Generalization to n-frequency case	146
6.5	Numerical simulations.....	153
6.5.1	Results for flight vehicle observer	153
6.5.2	Results for stochastic frequency estimator	154
6.6	Conclusions	158
 7. Stochastic contraction based nonlinear observer and controller design for a flight vehicle		
7.1	Introduction.....	161
7.2	Problem formulation.....	163
7.3	Flight controller design in contraction framework	165
7.3.1	Design of adaptive controller	168
7.4	Stochastic nonlinear flight vehicle observer for pitch controller	170
7.4.1	Contracting controller-observer structure.....	173
7.4.2	Numerical simulations.....	174
7.5	Comparison to the adaptive unscented Kalman filter.....	179
7.6	Conclusions.....	181

8. Conclusions and further scope of the work

8.1 Summary	183
8.2 Further scope of the work	187

REFERENCES	191
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Appendix

A. Discretization of continuous-time state space systems	203
B. Derivation of Kalman filter and extended Kalman filter	204
B1. Extended Kalman filter	206
C. Unscented Kalman filter	207
C1. Unscented transform	209
D. Output error method	212
D1. Principle of maximum likelihood	213
D2. Cramer-Rao lower bound	214
D3. Output error method for dynamic system	215
E. Proof of lemmas	220
E1. Proof of lemma 1.3.3	220
E2. Proof of lemma 1.3.4	220
E3. Proof of lemma 1.3.5	222
F. Nonlinear stability result	223
F1. Contraction theory and Lyapunov analysis	223
F2. Stability of time-varying systems and Barbalat's lemma	224
F3. Proof of Gronwall's-type lemma 1.4.1	225