Lecture Notes in Control and Information Sciences

Edited by M. Thoma and A. Wyner

109

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Modern Aircraft Flight Control

Springer-Verlag
Berlin Heidelberg New York
London Paris Tokyo

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Based on the original *Automatsko Upravljanje Letom Aviona*
published by Institute Mihailo Pupin, Beograd, Yugoslavia, 1985.

ISBN 3-540-19119-4 Springer-Verlag Berlin Heidelberg New York
ISBN 0-387-19119-4 Springer-Verlag New York Berlin Heidelberg

Library of Congress Cataloging in Publication Data
Vukobratović, Miomir.
[Automatsko upravljanje letom aviona. English]
Modern aircraft flight control / M. Vukobratović, R. Stojić.
(Lecture notes in control and information sciences, 109)
Translation of: *Automatsko upravljanje letom aviona*.
ISBN 0-387-19119-4 (U.S.)
1. Flight control.
I. Stojić, R. (Radoslav). II. Title. III. Series.
TL589.V8513 1988
629.132'6--dc19 88-12243

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© Springer-Verlag Berlin, Heidelberg 1988
Printed in Germany

Offsetprinting: Mercedes-Druck, Berlin
Binding: B. Helm, Berlin
2161/3020-543210

Preface

Flight dynamics and automatic flight control represent an extensively studied field of technical sciences. This research area has doubtlessly stimulated the development of many aspects of automatic control and systems theory in general. A salient feature of flight control systems is that the requirements imposed are often conflicting, i.e., a highly complex problem must be solved using the simplest possible control algorithms and appropriate control laws which need to be implemented on a reliable control system of relatively small dimensions.

The problem of flight control is exceptionally complex because of the high complexity of the object, the forces acting on it and the ambient in which the flight process takes place.

The mathematical model of the object (aircraft) is an inherently non-linear system which can encompass additional d.o.f. in comparison with the number of d.o.f. of the aircraft as a rigid body, if the elastic shapes of the structure are taken into account.

This textbook considers a class of aircraft whose behaviour can be described adequately by the model of a six-d.o.f. rigid body under the assumption of a quasistationary aerodynamic flow field. Aeroelastic and nonstationary effects will be accepted as second-order influence and will be considered as known or unknown perturbations. Even this, from the theoretical standpoint, simplified model is far too complex for implementation by conventional engineering procedures for the synthesis of flight control systems.

Most of the realized flight control systems have been designed by applying standard methods for the synthesis of multivariable linear systems of automatic control.

This conventional procedure starts from the fact that the behaviour of the object - aircraft is most often described by a set of mutually independent systems of linear differential equations. Furthermore,

longitudinal motion (longitudinal translation, pitch) and lateral motion (roll, yaw), are usually considered separately.

In this textbook the problem of automatic flight control is approached in a somewhat different manner. The behaviour of the controlled object - aircraft motion is considered to be completely described by sufficiently accurate dynamic equations of a rigid body having six degrees of freedom and the synthesis of control is performed on the basis of a complete non-linear model of aircraft flight dynamics. Such treatment of the flight control problem is frequently encountered in current publications on the subject and a number of papers describe the actual realization of control systems based on the complete information on model dynamics, but, with the exception of the principles involved, detailed information regarding elaborated algorithms and synthesis procedures is lacking.

The approach to control synthesis presented in this textbook has so far been successfully applied to controlling robotic mechanisms whereas its theoretical background relies on recently developed areas of systems theory (theory of large-scale systems and application of decentralized control structures) as well as on combined solution of direct and inverse dynamic problems.

The basic principle underlying the synthesis of control algorithms is based on modelling complete object dynamics, so the control itself is referred to as complete (integrated) dynamic control.

It must be mentioned that the complete modelling of object dynamic does not strictly mean that its complete form should always be used in control law synthesis. Considering that, in practice, most appropriate solutions are generally the simplest ones, it must be stressed that this approach can provide the simplest control law which is compatible with object dynamics corresponding to the relevant control task and system operation regime. In obtaining such a solution, one must make full use of the possibilities provided by a detailed dynamic object description, in order to enable the synthesis of dynamic controls of varying complexities.

The textbook comprises five chapters.

The book begins, in the first chapter, with the formulation of aircraft

flight control problem and the introduction of some basic concepts related to the manual and automatic flight control. This is followed by a review of basic approaches to flight control synthesis which are illustrated by examples. Classical (single-input, single-output) and multivariable control synthesis techniques in the linear domain, as well as advanced nonlinear design techniques, based on centralized control approach are considered.

Chapter 2 is on the subject of mathematical modelling of aircraft motions, for the purpose of stability analysis and control synthesis. The aircraft is considered as a rigid body with six degrees of freedom in the quasistationary aerodynamic flow field. Special attention is given to introducing suitable state coordinates which describe perturbations from the nominal motion, to obtain perturbation model system representation which allows for decomposition into controllable subsystems. A new approach to obtain linear small perturbation model is also presented.

A procedure for nominal aircraft control and state space trajectory synthesis is considered in Chapter 3. As a background to this, the inverse problem of system dynamics is treated, and the existence and uniqueness of solution are discussed. Then the aircraft inverse model is constructed to determine thrust and control surface deflections from the specified flight path representing an arbitrary spatial manoeuvre.

Chapter 4 deals with the stability of aircraft motion analysis and control synthesis, using the decentralized control concept. The aircraft is considered as a large-scale mechanical system. The decomposition of which into controllable subsystems was made. The local control is synthesized to stabilize isolated subsystems as well as the overall system. However, if the coupling between subsystems is too strong, the global control is introduced to reduce subsystem performances deterioration. A considerable emphasis is placed on the suboptimality of decentralized control. The numerical aspects of control synthesis procedure are analyzed and its computer implementation is described.

An illustrative example for the proposed procedure is presented in Chapter 5. For the concrete combat aircraft, the task of realizing a complex spatial manoeuvre is defined. Nominal, local and global control is then synthesized to provide the desired system performances. Simu-

lation of desired manoeuvre tracking with control laws of various complexities is given. This chapter concludes with the analysis of implementation aspect on several types of microcomputers, showing that the integrated flight control synthesis approach is feasible from the engineering point of view.

This book is predominantly monographic in character and is a result of research into dynamic flight control of aircraft, carried out over a number of years. However, the methodology of research in the field of dynamic control, as presented by the authors, has been greatly influenced by research undertaken in the field of robotics which has successfully resolved the problem of dynamic control based on robot dynamic models of varying complexities.

In spite of the predominantly monographic character of this book, the authors believe that it will be useful to all designers, since contemporary design is unimaginable without a prior analysis of aircraft dynamic characteristics on the basis of which the synthesis of autopilot and other devices for active stabilization can be performed. The textbook will, certainly, be useful to postgraduate students at aeronautical departments of engineering faculties and aeronautical-technical higher military schools.

The authors wish to mention that the Ph. D. Thesis: *Contribution to the synthesis of aircraft dynamic control*, by R. Stojić defended in 1985 at the University of Zagreb was used as background material in writing this book.

The authors wish to express their gratitude to Dr Dragan Stokić, senior research associate at the Robotics laboratory of the Mihailo Pupin Institute in Belgrade for his valuable discussions in particular phases of work in the field of aircraft control, to M. Sc. Goran Bežanov assistant at the same Laboratory who acted as the professional translator of this textbook from Serbocroat into English, and to Vera Ćosić for her careful and excellent typing of the whole text.

December 1987

Belgrade, Yugoslavia

Authors

Contents

Chapter 1

Generally on Automatic Flight Control	1
1.1. Flight control problem	1
1.2. Classical methods of flight control synthesis	8
1.3. Multivariable control design and analysis techniques ..	18
1.4. Centralized control methods based on the complete model	36
References	56

Chapter 2

Complete Model of Aircraft Perturbed Motion	60
2.1. Introduction	60
2.2. The complete model of aircraft motion	63
2.3. Conventional model of perturbed motion	74
2.4. Model of relative perturbed motion	78
2.5. Algorithmic realization of the perturbed motion model .	85
2.6. Small perturbation equations	89
2.6.1. The linearized classical perturbed motion model	90
2.6.2. The linearized relative perturbed motion model .	91
2.6.3. Numerical linearization	93
Example	97
2.7. Programme realization of the relative perturbed motion model	100
Appendix	111
2.8. Kinematic relations resulting from the rotation of the coordinate systems	111
References	115

Chapter 3

Nominal Aircraft Dynamics	116
3.1. Nominal control and state space trajectory	116
3.2. Inverse dynamic problem	117

VIII

3.3. Nominal control and state space trajectory for a given flight path	135
3.4. Approximate models for nominal control and trajectory determination	143
3.5. Stability and implementation aspects of the inverse model	145
References	155
Chapter 4	
Stabilization of Nominal Motion	156
4.1. Problem definition	156
4.2. Decentralized dynamic flight control - basic concepts	158
4.3. System decentralization	161
4.4. Control synthesis and stability analysis	164
4.5. Control suboptimality	173
4.5.1. Suboptimality index	173
4.5.2. Suboptimality of decentralized control	179
4.6. Computer aided design of dynamic flight control	183
4.6.1. Development of concepts relating to computer application to control systems design	183
4.6.2. Numerical aspects of dynamic flight control synthesis	190
4.6.3. Software for computer aided flight control synthesis	203
4.6.4. Software implementation	216
References	223
Chapter 5	
Application of Dynamic Flight Control to Realization of Aircraft Spatial Flight Manoeuvre	228
5.1. Problem definition	228
5.2. Control synthesis	232
5.3. Influence of actuator dynamics	250
5.4. Simulation of nominal trajectory tracking	256
5.5. Numerical complexity of control laws	273
Conclusion	284
Subject index	286