Contents

Preface

Acknowledgements

1 Introduction
1.1 Multivariable system synthesis
1.2 Eigensystem assignment formulations
1.3 Algorithm development
1.4 Flight control system design
1.5 Flight vehicle handling qualities design
1.6 Flight control law design process
References

2 Eigenstructure assignment characterisation
2.1 Definitions
2.2 Introduction
2.3 State feedback design
2.4 Examples
2.5 Summary
References

3 Eigenstructure synthesis algorithm
3.1 Introduction
3.2 Eigenstructure synthesis
3.3 Example
3.4 Special eigenvector structures
3.5 Assignment of repeated eigenvalues
3.6 Summary
Reference

4 Eigenstructure assignment by output feedback
4.1 Introduction
4.2 Problem formulation
4.2.1 Assignment of max (m,r) eigenvalues
4.2.2 Assignment of (m+r-1) eigenvalues
4.3 Eigenstructure assignment for systems with proper outputs
4.4 Eigenstructure assignment with dynamic output feedback
4.5 Examples
4.6 Summary
References

5 Robust eigenstructure assignment
5.1 Introduction
5.2 Robustness metrics
5.3 Robust eigenstructure characterisation

5.4 Robust eigenstructure assignment
5.5 Examples
5.6 Summary
References

6. Modal canonical observers
6.1 Introduction
6.2 Problem formulation
6.3 Unknown input observer with mixed outputs
6.4 Unknown input observer with strictly proper outputs
6.5 Known input observer
6.6 Examples
6.7 Summary
References

7 Model following control systems
7.1 Introduction
7.2 Command generator tracker
7.3 Tunable command generator tracker
7.4 Explicit and implicit model following control
7.5 Perfect implicit model following control
7.6 Examples
7.7 Summary
References

8 Flight control system design guidelines
8.1 Introduction
8.2 Flight vehicle handling qualities requirements
8.3 Lateral-directional aircraft handling qualities requirements
8.4 Longitudinal aircraft handling qualities requirements
8.5 Rotorcraft handling qualities requirements
8.6 Control system performance specifications
8.7 Summary
References

9 Aircraft lateral-directional handling qualities design
9.1 Introduction
9.2 Control problem formulation
9.3 Feedback sensor considerations
9.4 Aircraft eigenstructure assignment
9.4.1 Synthesis of mode decoupled eigenvectors
9.5 Aircraft eigenstructure optimization
9.5.1 State feedback design (SF)
9.5.2 Dynamic output feedback design (DF)
9.6 Aircraft performance assessment
9.6.1 Feedback design characteristics
9.6.2 Handling qualities performance
9.6.3 Departure resistance characteristics
9.6.4 Single loop stability margins

9.6.5 Multivariable stability margins
9.6.6 Gibson's PIO resistance criterion
9.6.7 Turbulence response
9.7 Roll / yaw damper design example
9.8 Summary
References

10 Aircraft longitudinal handling qualities design
10.1 Introduction
10.2 Flight mechanics analyses of control problem
10.2.1 Short period model and time response
10.2.2 Control inter-connect to augment pitch rate zero
10.2.3 Estimation of angle of attack and angle of attack rate signals
10.3 Aircraft model for design studies
10.4 Control of relaxed static stability aircraft
10.5 Conventional controller design
10.5.1 Feedback design
10.5.2 Command filter design
10.6 Superaugmented controller design
10.7 Single input controller performance assessment
10.7.1 Control law performance analysis
10.7.2 Handling qualities characteristics
10.7.3 Time response performance
10.7.4 Stability margins
10.8 Implicit model following control design
10.8.1 Time response performance
10.8.2 Handling qualities characteristics
10.9 Pitch Pointing mode controller design
10.10 Summary
10.11 References

11 Rotorcraft handling qualities design
11.1 Introduction
11.2 Helicopter handling qualities requirements
11.3 BO–105 Helicopter model
11.4 Feedback controller design
11.4.1 Feedback sensors and control law structure
11.4.2 Pitch-roll cross coupling
11.4.3 State feedback control law design
11.4.4 Functional observer design
11.5 Feedback controller performance analysis
11.5.1 Eigenvector decoupling characteristics
11.5.2 Dynamic Stability and Bandwidth
11.5.3 Pitch-roll-yaw inter-axis coupling
11.5.4 Stability margins
11.5.5 Multivariable Gain Locus
11.5.6 Time response characteristics
11.6 Command path controller

11.7 Summary
References

12 Aircraft flutter control system design
12.1 Introduction
12.2 AFW flutter suppression problem
12.2.1 Wind-tunnel model
12.2.2 Mathematical Model
12.3 Flutter mechanism
12.4 Flutter control problem formulation
12.4.1 Design objectives and specifications
12.4.2 Feedback controller evolution
12.4.3 Controller structure
12.4.4 Flutter filter controller
12.4.5 Eigenstructure controller
12.5 Controller performance assessment
12.5.1 System robustness
12.5.2 Wind tunnel turbulence response
12.6 Wind tunnel experiment
12.6.1 Test objectives
12.6.2 Controller configuration
12.6.3 Wind tunnel test results
12.7 Multiple flutter mode suppression
12.8 Summary
References

Epilogue

Appendix A Relevant flight mechanics models

Appendix B F-8C Aircraft state variable models

Appendix C BO –105 Helicopter state variable models

Appendix D Properties of singular matrix pencils

Appendix E Conversion of FPS units to SI units

Bibliography

Index