Preface

Eigenstructure control entails modification of both eigenvalues and eigenvectors of a dynamic system using feedback. Since the dynamic response of a system is fully characterised by its eigenstructure, its control provides a powerful tool to remove inherent dynamic performance deficiencies in a system by using feedback control. The main objective of the book is to develop algorithms, based on *Eigenstructure Control Theory*, and demonstrate their use in the design of *practical* flight control systems.

Some of the key desirable attributes of any design technique to succeed in the evolution of *practical* control systems are: i) the control problem formulation must give insight into the nature of the existing performance deficiencies of the system to be controlled, in order to evolve suitable control structures to alleviate these deficiencies and ii) the tunable design parameters in the controller should provide good transparency of the cause and effect relation between design parameter change and consequent system performance variation. This is especially required since the design is invariably iterative in nature and re-tuning of the design parameters is inevitable. Indeed eigenstructure assignment concept enjoys these attributes and in particular is tailor made to address improvement of flight vehicle handling qualities, which forms an important flight control law design requirement.

In general when a new attractive control theoretic property is discovered, many computational algorithms are proposed to illustrate enhancement of different facets of system performance using the property. Further the evolution of algorithm structure for solving the problem formulation is influenced by factors such as: i) to mathematically prove the existence conditions of the control theoretic property, ii) to adapt numerically stable linear algebra algorithms to derive the solution etc. In this process, the design parameters available for performance optimization very likely lose the earlier stated attribute of transparency required for evolving good designs. Thus a further attribute of a *practical* control system design tool is to have a set of, simple to use, computational algorithms that produce useful engineering solutions while, as far as possible, retain the transparency attributes. The algorithms developed in this book are driven by such a philosophy. A suite of algorithms has been developed to form a core *design tool set* to handle the flight control design problem.

The present day powerful computers, with their extraordinary computation capability, have made performance optimization techniques an essential element in the control design process. Nevertheless, the design parameters that need to be optimised have to originate from a well thought-out controller structure. In this regard, eigenstructure parameters, by virtue of their direct link to system response, are ideal candidates for design optimization. In the flight control application chapters the role of optimization will be further highlighted.

Books dealing with flight control system design have to be inter-disciplinary in nature encompassing both control theory and flight dynamics. In general, the current books fall into two categories namely: i) books primarily originating from university research that tend to be heavily biased towards theoretical development with simple tutorial flight control examples included for completeness and ii) books originating from experimental flight research, industry experience etc, that highlight wide range of flight test results. In this class of books, the design process adopted to achieve the final control law design is generally not highlighted in detail. However, infusion of a new theory / design process into an already well-established methodology in the aircraft industry would require significant amount of investment (time and financial). This entails learning the new control theoretic properties and adapting them to the specific control design requirements. As the theoretical framework becomes more sophisticated, the infusion effort becomes more involved and complicated.

One of the motivations for writing this book has been to address the above stated difficulties. In this book, in addition to developing the theoretical concepts and associated algorithms, attempt is made to develop a basic reference flight control law design process, based on *Eigenstructure Control Theory*, to meet the *analytical handling qualities* specifications for aircraft and rotorcraft. It is hoped that this approach will facilitate quick absorption and adaptation of the new concepts and algorithms into the practical design environment.

Design of modern fly-by-wire Aircraft / Rotorcraft flight control systems perhaps offers the control engineer the most exciting design challenges. Many multivariable control theories, such as linear quadratic optimal control, eigenstructure control, H_∞ loop shaping, non-linear dynamic inversion, model following etc, usually referred to as 'modern' control techniques, have been and continue to be developed to address this design problem. Despite the large number of analytical studies and some experimental flight test demonstration programs that has been undertaken, there is still some reluctance in the aircraft industry to infuse these techniques into their control design practices. The classical control design techniques still continue to be the preferred design approach. Another objective of this book is to examine how application of eigenstructure control technique can be structured to alleviate some of these justifiable apprehensions.

The book has been written in the format of a research monograph and thus assumes the reader to have a basic background in: i) state variable control system design, ii) linear algebra / matrix theory, iii) flight mechanics / flight control and iv) flight vehicle handling qualities. Some of the excellent books on these basic topics have been listed in the bibliography.

The book, being interdisciplinary in nature, should be of interest to both control and aeronautical engineers. The book should be of use to graduate / doctoral students and flight control researchers in universities and flight control engineers in the aircraft / rotorcraft industry. In particular, control research engineers may find it interesting to adapt the philosophy of formulating other multivariable control design problems, not covered in this book, as an eigenstructure assignment problem. The topics covered in this book are also well suited to teach in a professional development short course for flight control engineers.

While the application chapters are focused on flight control, it is emphasised that the control algorithms and design principles developed in this book are equally applicable to any dynamic system, such as process control, that needs feedback control. A distillation plant control problem is illustrated in chapter 5.

Finally the author will feel his efforts have been well worth it, if the book helps flight control engineers to make a judicious/objective assessment of the applicability of ‘*eigenstructure control*’ in their new aircraft/rotorcraft design projects.