Flight Dynamics Simulation With Integrated Electrical

This first volume of Computational Modelling of Aircraft and the Environment provides a comprehensive guide to the derivation of computational models from basic physical & mathematical principles, giving the reader sufficient information to be able to represent the basic architecture of the synthetic environment. Highly relevant to practitioners, it takes into account the multi-disciplinary nature of the aerospace environment and the integrated nature of the models needed to represent it. Coupled with the forthcoming Volume 2: Aircraft Models and Flight Dynamics it represents a complete reference to the modelling and simulation of aircraft and the environment. All major principles with this book are demonstrated using MATLAB and the detailed mathematics is developed progressively and fully within the context of each individual topic area, thereby rendering the comprehensive body of material digestible as an introductory level text. The author has drawn from his experience as a modelling and simulation specialist with BAE SYSTEMS along with his more recent academic career to create a resource that will appeal to and benefit senior/graduate students and industry practitioners alike.

The book focuses on the synthesis of the fundamental disciplines and practical applications involved in the investigation, description, and analysis of aircraft flight including applied aerodynamics, aircraft propulsion, flight performance, stability, and control. The book covers the aerodynamic models that describe the forces and moments on maneuvering aircraft and provides an overview of the concepts and methods used in flight dynamics. Computational methods are widely used by the practicing aerodynamicist, and the book covers computational fluid dynamics techniques used to improve understanding of the physical models that underlie computational methods.

Advanced Flight Dynamics aim to integrate the subjects of aircraft performance, trim and stability/control in a seamless manner. Advanced Flight Dynamics highlights three key and unique viewpoints. Firstly, it follows the revised and corrected aerodynamic modeling presented previously in recent textbook on Elementary Flight Dynamics. Secondly, it uses bifurcation and continuation theory, especially the Extended Bifurcation Analysis (EBA) procedure devised by the authors, to blend the subjects of aircraft performance, trim and stability, and flight control into a unified whole. Thirdly, rather than select one control design tool or another, it uses the generalized Nonlinear Dynamic Inversion (NDI) methodology to illustrate the fundamental principles of flight control. Advanced Flight Dynamics covers all the standard airplane maneuvers, various types of instabilities normally encountered in flight dynamics and illustrates them with real-life airplane data and examples, thus bridging the gap between the teaching of flight dynamics/ control theory in the university and its practice in airplane design bureaus. The expected reader group for this book would ideally be senior undergraduate and graduate students, practicing aerospace/flight simulation engineers/scientists from industry as well as researchers in various organizations. Key Features: Focus on unified nonlinear approach, with nonlinear analysis tools. Provides an up-to-date, corrected, and unified presentation of aircraft trim, stability and control analysis including nonlinear phenomena and closed-loop stability analysis. Contains a computational tool and real-life example carried through the chapters. Includes complementary nonlinear dynamic inversion control approach, with relevant aircraft examples. Fills the gap in the market for a text including non-linear flight dynamics and continuation methods.

For Rigid and Flexible Aircraft

A Set of Flight Dynamic Equations for Aircraft Simulation

Scientific and Technical Aerospace Reports

Aircraft Control and Simulation

Advances in Aerospace Guidance, Navigation and Control

A textbook for an advanced undergraduate course in which Zipfel (aerospace engineering, U. of Florida) introduces the fundamentals of an approach to, or step in, design that has become a field in and

of itself. The first part assumes an introductory course in dynamics, and the second some specialized knowledge in subsystem technologies. Practicing engineers in the aerospace industry, he suggests, should be able to cover the material without a tutor. Rather than include a disk, he has made supplementary material available on the Internet. Annotation copyrighted by Book News, Inc., Portland, OR

Explore Key Concepts and Techniques Associated with Control Configured Elastic Aircraft A rapid rise in air travel in the past decade is driving the development of newer, more energy-efficient, and malleable aircraft. Typically lighter and more flexible than the traditional rigid body, this new ideal calls for adaptations to some conventional concepts. Flight Dynamics, Simulation, and Control: For Rigid and Flexible Aircraft addresses the intricacies involved in the dynamic modelling, simulation, and control of a selection of aircraft. This book covers the conventional dynamics of rigid aircraft, explores key concepts associated with control configured elastic aircraft, and examines the use of linear and non-linear model-based techniques and their applications to flight control. In addition, it reveals how the principles of modeling and control can

be applied to both traditional rigid and modern flexible aircraft. Understand the Basic Principles Governing Aerodynamic Flows This text consists of ten chapters outlining a range of topics relevant to the understanding of flight dynamics, regulation, and control. The book material describes the basics of flight simulation and control, the basics of nonlinear aircraft dynamics, and the principles of control configured aircraft design. It explains how elasticity of the wings/fuselage can be included in the dynamics and simulation, and highlights the principles of nonlinear stability analysis of both rigid and flexible aircraft. The reader can explore the mechanics of equilibrium flight and static equilibrium, trimmed steady level flight, the analysis of the static stability of an aircraft, static margins, stick-fixed and stick-free, modeling of control surface hinge-moments, and the estimation of the elevator for trim. Introduces case studies of practical control laws for several modern aircraft Explores the evaluation of aircraft dynamic response Applies MATLAB®/Simulink® in determining the aircraft’s response to typical control inputs Explains the methods of modeling both rigid and flexible aircraft for controller design application Written with aerospace engineering faculty and students, engineers, and

researchers in mind, Flight Dynamics, Simulation, and Control: For Rigid and Flexible Aircraft serves as a useful resource for the exploration and study of simulation of flight dynamics.
This book offers a unified presentation that does not discriminate between atmospheric and space flight. It demonstrates that the two disciplines have evolved from the same set of physical principles and introduces a broad range of critical concepts in an accessible, yet mathematically rigorous presentation. The book presents many MATLAB and Simulink-based numerical examples and real-world simulations. Replete with illustrations, end-of-chapter exercises, and selected solutions, the work is primarily useful as a textbook for advanced undergraduate and beginning graduate-level students.
Modified Generalized-Alpha Method for Integrating Governing Equations of Very Flexible Aircraft
Flight Dynamics Analysis and Simulation of Heavy Lift Airships. Volume 1: Executive Summary
An Analysis Tool for Flight Dynamics Monte Carlo Simulations
Rotorcraft Flight-propulsion Control Integration
Modeling and Control for a Blended Wing Body Aircraft
Explore Key Concepts and Techniques Associated with Control Configured

Elastic AircraftA rapid rise in air travel in the past decade is driving the development of newer, more energy-efficient, and malleable aircraft. Typically lighter and more flexible than the traditional rigid body, this new ideal calls for adaptations to some conventional concep

This paper focuses on the time integration of the nonlinear EOM associated with a very flexible aircraft in flight. Various integration methods exist for linear structural dynamics problems. However, a review of the literature indicates little material associated with the integration of nonlinear structural EOM of relatively large order. Moreover, for the problem of simulation of very flexible aircraft, a combination of flight dynamics and aeroelastic degrees of freedom must be integrated concurrently. A modified first and second order Generalized-alpha Method along with an implicit sub-literation scheme were developed. It has shown good agreement with predictor/corrector integration schemes for a reduced set of linear EOM. The method is also seen to be numerically stable when compared to non-dissipative time marching integration schemes and requires less computational time compared to predictor/corrector methods for the full set of nonlinear EOM.

The six degrees of freedom dynamic equations of aircraft motion are documented for use in aircraft simulations at ARL. Earth axes are chosen for the integration of the force equations, and body axes for the integration of the moment equations. The use of quaternions to calculate aircraft attitude and associated direction cosines is described. A brief description of an atmospheric data subroutine for use in aircraft simulation is also included. (Author).

Intermediate Reader of Modern Chinese

Modeling and Simulation of Aerospace Vehicle Dynamics

Rotorcraft Simulations with Coupled Flight Dynamics, Free Wake, and Acoustics

Durip-Visual Simulation Laboratory

Flight Mechanics Modeling and Analysis

This book demonstrates the potential of the blended wing body (BWB) concept for significant improvement in both fuel efficiency and noise reduction and addresses the considerable challenges raised for control engineers because of characteristics like open-loop instability, large flexible structure, and slow control surfaces. This text describes state-of-the-art and novel modeling and control design approaches for

the BWB aircraft under consideration. The expert contributors demonstrate how exceptional robust control performance can be achieved despite such stringent design constraints as guaranteed handling qualities, reduced vibration, and the minimization of the aircraft's structural loads during maneuvers and caused by turbulence. As a result, this innovative approach allows the building of even lighter aircraft structures, and thus results in considerable efficiency improvements per passenger kilometer. The treatment of this large, complex, parameter-dependent industrial control problem highlights relevant design issues and provides a relevant case study for modeling and control engineers in many adjacent disciplines and applications.
Modeling and Control for a Blended Wing Body Aircraft presents research results in numeric modeling and control design for a large, flexible, civil BWB aircraft in the pre-design stage as developed within the EU FP7 research project ACFA 2020. It is a useful resource for aerospace and control engineers as it shows the complete BWB aircraft modeling and control design process, carried out with the most recent tools and techniques available.
presents research results in numeric modeling and control design

for a large, flexible, civil BWB aircraft in the pre-design stage as developed within the EU FP7 research project ACFA 2020. It is a useful resource for aerospace and control engineers as it shows the complete BWB aircraft modeling and control design process, carried out with the most recent tools and techniques available. Advances in Industrial Control aims to report and encourage the transfer of technology in control engineering. The rapid development of control technology has an impact on all areas of the control discipline. The series offers an opportunity for researchers to present an extended exposition of new work in all aspects of industrial control.

Twelve essays by leading researchers provide a clear introduction to the basic principles, design, and applications of flight simulators. Among the topics covered are basic principles of flight dynamics, the simulation of aircraft systems, structures and cockpit systems, visual and motion systems, and instructor facilities. Other subjects discussed include the integration, testing, and acceptance of simulators and their use as a research and training tool.

Craig Kluever ‘s Dynamic Systems: Modeling, Simulation, and

Control highlights essential topics such as analysis, design, and control of physical engineering systems, often composed of interacting mechanical, electrical and fluid subsystem components. The major topics covered in this text include mathematical modeling, system-response analysis, and an introduction to feedback control systems. Dynamic Systems integrates an early introduction to numerical simulation using MATLAB®'s Simulink for integrated systems. Simulink® and MATLAB® tutorials for both software programs will also be provided. The author's text also has a strong emphasis on real-world case studies.

Army-NASA Aircrew/Aircraft Integration Program (A3I) Software Detailed Design Document: Phase III

Development of the Reentry Flight Dynamics Simulator for Evaluation of Space Shuttle Orbiter Entry Systems

Computational Modelling and Simulation of Aircraft and the Environment

Flight Dynamics, Simulation, and Control

A Linear Systems Approach to Aircraft Stability and Control

The Book The behaviour of helicopters and tiltrotor aircraft is so complex

that understanding the physical mechanisms at work in trim, stability and response, and thus the prediction of Flying Qualities, requires a framework of analytical and numerical modelling and simulation. Good Flying Qualities are vital for ensuring that mission performance is achievable with safety and, in the first and second editions of Helicopter Flight Dynamics, a comprehensive treatment of design criteria was presented, relating to both normal and degraded Flying Qualities. Fully embracing the consequences of Degraded Flying Qualities during the design phase will contribute positively to safety. In this third edition, two new Chapters are included. Chapter 9 takes the reader on a journey from the origins of the story of Flying Qualities, tracing key contributions to the developing maturity and to the current position. Chapter 10 provides a comprehensive treatment of the Flight Dynamics of tiltrotor aircraft; informed by research activities and the limited data on operational aircraft. Many of the unique behavioural characteristics of tiltrotors are revealed for the first time in this book. The accurate prediction and assessment of Flying Qualities draws on the modelling and simulation discipline on the one hand and testing practice on the other. Checking predictions in flight requires clearly defined mission tasks, derived from realistic performance requirements. High fidelity

simulations also form the basis for the design of stability and control augmentation systems, essential for conferring Level 1 Flying Qualities. The integrated description of flight dynamic modelling, simulation and flying qualities of rotorcraft forms the subject of this book, which will be of interest to engineers practising and honing their skills in research laboratories, academia and manufacturing industries, test pilots and flight test engineers, and as a reference for graduate and postgraduate students in aerospace engineering.

The study of flight dynamics requires a thorough understanding of the theory of the stability and control of aircraft, an appreciation of flight control systems and a grounding in the theory of automatic control. Flight Dynamics Principles is a student focused text and provides easy access to all three topics in an integrated modern systems context. Written for those coming to the subject for the first time, the book provides a secure foundation from which to move on to more advanced topics such as, non-linear flight dynamics, flight simulation, handling qualities and advanced flight control. New to this edition: Additional examples to illustrate the application of computational procedures using tools such as MATLAB®, MathCad® and Program CC® Improved compatibility with, and more

expansive coverage of the North American notational style Expanded coverage of lateral-directional static stability, manoeuvrability, command augmentation and flight in turbulence An additional coursework study on flight control design for an unmanned air vehicle (UAV)
This study presents the integration of a flight simulation code (PSUHeloSim), a high fidelity rotor aeromechanics model with free wake (CHARM Rotor Module), and an industry standard noise prediction tool (PSU-WOPWOP) into a comprehensive noise prediction system. The flight simulation uses a Dynamic Inversion autonomous controller to follow a prescribed trajectory for both steady and maneuvering flight conditions. The aeromechanical model calculates blade loads and blade motion that couple to the vehicle flight dynamics with suitable resolution to allow high fidelity acoustics analysis (including prediction of blade-vortex interaction (BVI) noise). The blade loads and motion data is sent to PSU-WOPWOP in a post-processing step to predict external noise. Particular attention is paid to the development of PSUHeloSim and to the enhancement of the closed-loop response characteristics of the coupled simulation. Specifically, is studied the use of reduced-order linear models, derived by linearization of the coupled simulation, in the feedback linearization of the Dynamic

Inversion controller in different flight conditions. The different reduced-order models obtained are compared by the use of eigenvalue analysis and frequency response in order to link their differences to physical phenomena occuring in the coupled simulation. A validation of these reduced-order models is provided by performing a frequency sweep of the coupled simulation. Finally their effectiveness in the feedback linearization loop is evaluated by analysing the closed loop time response of the coupled simulation to the coupling.The coupled analysis is being used to evaluate the influence of flight path on aircraft noise certification metrics like EPNL and SEL for various rotorcraft in work for the FAA. The software was used to analyze the acoustic properties of a blade planform similar to the Blue Edge rotor blades developed by DLR and Airbus Helicopters - predicting BVI noise reduction as compared to more conventional blade geometries on the same order as that reported for the Blue Edge rotor.

Flight Simulation

Computational Modelling and Simulation of Aircraft and the Environment, Volume 1

Aircraft Dynamics

Advanced Flight Dynamics with Elements of Flight Control

Helicopter Flight Dynamics

The behaviour of helicopters is so complex that understanding the physical mechanisms at work in trim, stability and response, and thus the prediction of Flying Qualities, requires a framework of analytical and numerical modelling and simulation. Good Flying Qualities are vital for ensuring that mission performance is achievable with safety and, in the first edition of Helicopter Flight Dynamics, a comprehensive treatment of design criteria was presented. In this second edition, the author complements this with a new Chapter on Degraded Flying Qualities, drawing examples from flight in poor visibility, failure of control functions and encounters with severe atmospheric disturbances. Fully embracing the consequences of Degraded Flying Qualities during the design phase will contribute positively to safety. The accurate prediction and assessment of Flying Qualities draws on the modelling and simulation discipline on the one hand and testing methodologies on the other. Checking predictions in flight requires clearly defined 'mission-task-elements', derived from missions with realistic performance requirements. High fidelity simulations also form the basis for the design of stability and control augmentation systems, essential for conferring Level 1 Flying Qualities. The integrated description of flight dynamic modelling, simulation and flying qualities forms the subject of this book, which will be of interest to engineers in research laboratories and manufacturing industry, test pilots and flight test engineers, and as a reference for graduate and postgraduate students in aerospace engineering. The Author Gareth Padfield, a Fellow of the Royal Aeronautical Society, is the Bibby Professor of Aerospace Engineering at the University of Liverpool. He is an aeronautical engineer by training and has spent his career to date researching the theory and practice of flight for both fixed-wing aeroplanes and rotorcraft. During his years with the UK's Royal Aircraft Establishment and Defence Evaluation and Research Agency, he conducted research into rotorcraft dynamics, handling qualities and flight control. His work has involved a mix of flight testing, creating and testing simulation models and developing analytic approximations to describe flight behaviour and handling qualities. Much of his research has been conducted in the context of international collaboration – with the Technical Co-operation Programme, AGARD and GARTEUR as well as more informal collaborations with industry, universities and research centres worldwide. He is very aware that many accomplishments, including this book, could not have been achieved without the global networking that aerospace research affords. During the last 8 years as an academic, the author has continued to develop his knowledge and understanding in flight dynamics, not only through research, but also through teaching the subject at undergraduate level; an experience that affords a new and deeper kind of learning

that, hopefully, readers of this book will benefit from.
An updated and expanded new edition of an authoritative book on flight dynamics and control system design for all types of current and future fixed-wing aircraft Since it was first published, Flight Dynamics has offered a new approach to the science and mathematics of aircraft flight, unifying principles of aeronautics with contemporary systems analysis. Now updated and expanded, this authoritative book by award-winning aeronautics engineer Robert Stengel presents traditional material in the context of modern computational tools and multivariable methods. Special attention is devoted to models and techniques for analysis, simulation, evaluation of flying qualities, and robust control system design. Using common notation and not assuming a strong background in aeronautics, Flight Dynamics will engage a wide variety of readers, including aircraft designers, flight test engineers, researchers, instructors, and students. It introduces principles, derivations, and equations of flight dynamics as well as methods of flight control design with frequent reference to MATLAB functions and examples. Topics include aerodynamics, propulsion, structures, flying qualities, flight control, and the atmospheric and gravitational environment. The second edition of Flight Dynamics features up-to-date examples; a new chapter on control law design for digital fly-by-wire systems; new material on propulsion, aerodynamics of control surfaces, and aeroelastic control; many more

illustrations; and text boxes that introduce general mathematical concepts. Features a fluid, progressive presentation that aids informal and self-directed study Provides a clear, consistent notation that supports understanding, from elementary to complicated concepts Offers a comprehensive blend of aerodynamics, dynamics, and control Presents a unified introduction of control system design, from basics to complex methods Includes links to online MATLAB software written by the author that supports the material covered in the book

Principles of Flight Simulation is a comprehensive guide to flight simulator design, covering the modelling, algorithms and software which underpin flight simulation. The book covers the mathematical modelling and software which underpin flight simulation. The detailed equations of motion used to model aircraft dynamics are developed and then applied to the simulation of flight control systems and navigation systems. Real-time computer graphics algorithms are developed to implement aircraft displays and visual systems, covering OpenGL and OpenSceneGraph. The book also covers techniques used in motion platform development, the design of instructor stations and validation and qualification of simulator systems. An exceptional feature of Principles of Flight Simulation is access to a complete suite of software (www.wiley.com/go/allerton) to enable experienced engineers to develop their own flight simulator – something that should be well within the capability of many university engineering departments and research organisations. Based on C code modules from an actual flight simulator developed by the author, along with lecture material from lecture series given by the author at Cranfield University and the University of Sheffield Brings together mathematical modeling, computer graphics, real-time software, flight control systems, avionics and simulator validation into one of the faster growing application areas in engineering Features full colour plates of images and photographs. Principles of Flight Simulation will appeal to senior and postgraduate students of system dynamics, flight control systems, avionics and computer graphics, as well as engineers in related disciplines covering mechanical, electrical and computer systems engineering needing to develop simulation facilities.

STORESIM

Platform Kinematics and Synthetic Environment

Principles of Flight Simulation

The Theory and Application of Flying Qualities and Simulation Modelling

Get a complete understanding of aircraft control and simulation Aircraft Control and Simulation: Dynamics, Controls Design, and Autonomous Systems, Third Edition is a comprehensive guide to aircraft control and simulation. This updated text covers flight control

systems, flight dynamics, aircraft modeling, and flight simulation from both classical design and modern perspectives, as well as two new chapters on the modeling, simulation, and adaptive control of unmanned aerial vehicles. With detailed examples, including relevant MATLAB calculations and FORTRAN codes, this approachable yet detailed reference also provides access to supplementary materials, including chapter problems and an instructor's solution manual. Aircraft control, as a subject area, combines an understanding of aerodynamics with knowledge of the physical systems of an aircraft. The ability to analyze the performance of an aircraft both in the real world and in computer-simulated flight is essential to maintaining proper control and function of the aircraft. Keeping up with the skills necessary to perform this analysis is critical for you to thrive in the aircraft control field. Explore a steadily progressing list of topics, including equations of motion and aerodynamics, classical controls, and more advanced control methods Consider detailed control design examples using computer numerical tools and simulation examples Understand control design methods as they are applied to aircraft nonlinear math models Access updated content about unmanned

aircraft (UAVs) Aircraft Control and Simulation: Dynamics, Controls Design, and Autonomous Systems, Third Edition is an essential reference for engineers and designers involved in the development of aircraft and aerospace systems and computer-based flight simulations, as well as upper-level undergraduate and graduate students studying mechanical and aerospace engineering.

The drive for aircraft efficiency and minimum environmental impact is requiring the aerospace industry to generate technologically innovative and highly integrated aircraft concepts. This has changed the approach towards conceptual design and highlighted the need for modular low fidelity aircraft simulation models that not only capture conventional flight dynamics but also provide insight into aeroservoelasticity and flight loads. The key aspects that drive the need for modularity are discussed alongside integration aspects related to coupling aerodynamic models, flight dynamic equations of motion and structural dynamic models. The details of developing such a simulation framework are presented and the utility of such a tool is illustrated through two test cases. The first case focuses on aircraft response to a gust that has a spanwise varying profile. The second

investigates aircraft dynamics during control surface failure scenarios. The Cranfield Accelerated Aeroplane Loads Model (CA2LM) forms the basis of the presented discussion.

The design, development, analysis, and evaluation of new aircraft technologies such as fly by wire, unmanned aerial vehicles, and micro air vehicles, necessitate a better understanding of flight mechanics on the part of the aircraft-systems analyst. A text that provides unified coverage of aircraft flight mechanics and systems concept will go a lon

Atmospheric and Space Flight Dynamics

Selected Papers of the Second CEAS Specialist Conference on Guidance, Navigation and Control

Helicopter Flight Dynamics, 3rd Edition

A Case Study

Flight Dynamic Modelling and Simulation of Large Flexible Aircraft

This work uses a fundamental approach to the problem of simulating the flight of flexible aircraft. To this end, it integrates into a single formulation the pertinent disciplines, namely, analytical dynamics, structural dynamics, aerodynamics, and controls. It considers both the rigid body motions of the aircraft, three translations (forward motion, sideslip and plunge) and three rotations (roll, pitch and yaw), and the

elastic deformations of every point of the aircraft, as well as the aerodynamic, propulsion, gravity and control forces. The equations of motion are expressed in a form ideally suited for computer processing. A perturbation approach yields a flight dynamics problem for the motions of a quasi-rigid aircraft and an 'extended aeroelasticity' problem for the elastic deformations and perturbations in the rigid body motions, with the solution of the first problem entering as an input into the second problem. The control forces for the flight dynamics problem are obtained by an 'inverse' process and the feedback controls for the extended aeroservoelasticity problem are determined by the LQG theory. A numerical example presents time simulations of rigid body perturbations and elastic deformations about 1) a steady level flight and 2) a level steady turn maneuver.Waszak, Martin R. (Technical Monitor) and Meirovitch, Leonard and Tuzcu, IlhanLangley Research CenterAEROSERVOELASTICITY; AERODYNAMICS; FLEXIBLE WINGS; AIRCRAFT MANEUVERS; FLIGHT SIMULATION; AIRCRAFT CONTROL; ROLL; SIDESLIP; YAW; ELASTIC DEFORMATION; EQUATIONS OF MOTION; LINEAR QUADRATIC GAUSSIAN CONTROL; FEEDBACK CONTROL
Funds in the amount of $124,000 were awarded for the purchase of visual simulation equipment. The items purchased with this grant are being integrated with a Frasca simulator cockpit which has flight dynamics resident in a DEC personal computer. Two Evans and Sutherland SPX image generators are to be integrated with this system and the Electro Holme projectors will be used to project the visual images they generate.

The IRIS 4D and the IMI 600SN will serve as alternate workstations that will be driven by the flight simulator. This configuration of equipment will allow the exploration of a wide range of behavioral issues that are relevant to flight simulation.

This text provides a comprehensive guide to the derivation of computational models from basic physical mathematical principles, giving the reader sufficient information to be able to represent the basic architecture of air vehicles and their embedded systems.

Modeling and Simulation with MATLAB® and Simulink®

Dynamics, Controls Design, and Autonomous Systems

Models, Techniques and Technologies

Performance Analysis, Dynamic Simulation and Control of Mass-actuated Airplane

Modeling, Simulation, and Control

Spacecraft design is inherently difficult due to the nonlinearity of the systems involved as well as the expense of testing hardware in a realistic environment. The number and cost of flight tests can be reduced by performing extensive simulation and analysis work to understand vehicle operating limits and identify circumstances that lead to mission failure. A Monte Carlo simulation approach that varies a wide range of physical parameters is typically used to generate thousands of test cases. Currently, the data analysis process for a fully integrated spacecraft is mostly performed manually on a case-by-case basis, often requiring several analysts to write additional scripts in order to sort through the large data sets. There is no single method that can be used to identify these complex variable interactions in a reliable and timely manner as well as be applied to a wide range of flight dynamics problems. This dissertation investigates the feasibility of a unified, general approach to the process of analyzing flight dynamics Monte Carlo data. The main contribution of this work is the development of a systematic approach to finding and ranking the most influential variables and combinations of variables for a given system failure. Specifically, a practical and interactive analysis tool that uses tractable pattern recognition methods to automate the analysis process has been developed. The analysis tool has two main parts: the analysis of individual influential variables and the analysis of influential combinations of variables. This dissertation describes in detail the two main algorithms used: kernel density estimation and nearest neighbors. Both are non-parametric density estimation methods that are used to analyze hundreds of variables and combinations thereof to provide an analyst with insightful information about the potential cause for a specific system failure. Examples of dynamical systems analysis tasks using the tool are provided. The electronic version of this dissertation is accessible from http://hdl.handle.net/1969.1/150935

The control of space, aerial and underwater vehicles requires moment generation mechanisms to change their orientation. In addition to or in place of conventional moment generation actuators, internally moving-mass actuation has been proposed and/or used for such vehicles. The primary principle for mass-actuation is to reposition gravitational force to change the associated moment while the secondary effect may come from the inertial force due to the motion of the masses. Recent development/miniaturization in flight control sensor, computing and actuation, and electric motors and expansion of applications for small UAV (Unmanned Aerial Vehicle) offer a potential for implementation of internal mass-actuation in small UAV. The massactuation offers various advantages over the conventional mechanisms in airplane flight such as reduced drag and lift loss due to aerodynamic control surface deflections, simplified wing and tail design, improved lift-generation performance of wing, smaller radar signature for stealth aircraft. This dissertation research investigates the feasibility and benefit of mass-actuation of a small UAV in various flight phases and full missions consisting of all these flight phases and transitions between them. Three different configurations of the same airplane are considered: (1) aero-actuated, conventional airplane with three standard aerodynamic control surfaces, aileron, elevator and rudder, (2) mass-actuated, a mass moving along the fuselage to mainly generate pitching moment, and another mass moving along the wing to generate rolling moment, and (3) mass-rudder actuated, mass-actuation as in case-2 augmented with a rudder. The airplane is an electric powered and has a single propeller at the nose. A full 6-DOF (Degrees of Freedom) nonlinear equations of motion are derived, including the terms modeling inertia forces induced by the motion of the internal masses, and the effect of this internal mass motion on the variation of the center of mass and inertia matrix. The dynamics of the electric motor of the propeller and the servos of the actuators are also modeled. The effect of the propeller on the dynamics of the aircraft is also included. Modeling also includes electric power consumption by the electric motor driving the propeller, and servos of the aerodynamic and mass actuators. An integrated simulation environment is developed that includes all these factors and can be switched between the different configurations defined above. Trim analyses of all three configurations of the airplane are carried out in all four flight conditions (steady climb, cruise, steady turn, steady descent). Trim analyses consider all the constraints of the control and state variables such as limits on the deflections of the aerodynamic surfaces, position of the mass actuators, battery provided voltage, and angle of attack. These analyses demonstrate the feasibility of flying the airplane with mass-actuation only within varying speed ranges depending on the actuation mechanism. The results also show the benefit of mass-actuation over the conventional aero-actuation in terms of range and endurance especially in cruise flight, as compared to the other two configurations. In the second phase of the research, controllability of the airplane with each actuation mechanisms is determined and compared over the feasible speed range of each trim condition. A new relative controllability metrics is defined and calculated for this purpose. This analysis, based on the linearized model of the aircraft in each trim flight condition, show that the mass-actuation provides full controllability with various degree over the speed ranges. Once the controllability is verified, an LQR-based gain scheduling controller is designed for each aircraft configuration to track commanded climb/descent rate, altitude, airspeed, and turn rate. These controllers are implemented in the integrated simulation environment to simulate various flight profiles including full missions that start with a hand-launch of the airplane, climb to a specified altitude, and cruise at that altitude with various commanded speed, and loiter with commanded left and right turn rates, and descend to land with varying approach speed. These simulations also demonstrate the feasibility potential benefits, and/or limitations of mass actuation.

Atmospheric and Space Flight DynamicsModeling and Simulation with MATLAB® and Simulink®Springer Science & Business Media

Integrated Approach to the Dynamics and Control of Maneuvering Flexible Aircraft

Flight Physics

Including a Treatment of Tiltrotor Aircraft

An Integrated System for Multi-body Cfd Simulations Using Unstructured, Adaptive Grids

Flight Dynamics Principles

Good flying qualities are vital for ensuring that mission performance is achievable with safety and, in the first edition of Helicopter Flight Dynamics, a comprehensive treatment of design criteria was presented. In this second edition, the author complements this with a new chapter on degraded flying qualities, drawing examples from flight in poor visibility, failure of control functions and encounters with severe atmospheric disturbances. Fully embracing the consequences of degraded flying qualities during the design phase will contribute positively to safety. The accurate prediction and assessment of flying qualities draws on modelling and simulation discipline on the one hand and testing methodologies on the other. Checking predictions in flight requires clearly defined 'mission-task-elements', derived from missions with realistic performance requirements. High fidelity simulations also form the basis (or the design of stability and control augmentation systems, essential for conferring level one flying qualities. The integrated description of flight dynamic modelling, simulation and flying qualities forms the subject of this book, which will be of interest to engineers in research laboratories and manufacturing industry, test pilots and flight test engineers, and as a reference for graduate and postgraduate students in aerospace engineering.

Following the successful 1st CEAS (Council of European Aerospace Societies) Specialist Conference on Guidance, Navigation and Control (CEAS EuroGNC) held in Munich, Germany in 2011, Delft University of Technology happily accepted the invitation of organizing the 2nd CEAS EuroGNC in Delft, The Netherlands in 2013. The goal of the conference is to promote new advances in aerospace GNC theory and technologies for enhancing safety, survivability, efficiency, performance, autonomy and intelligence of aerospace systems using on-board sensing, computing and systems. A great push for new developments in GNC are the ever higher safety and sustainability requirements in aviation. Impressive progress was made in new research fields such as sensor and actuator fault detection and diagnosis, reconfigurable and fault tolerant flight control, online safe flight envelop prediction and protection, online global aerodynamic model identification, online global optimization and flight upset recovery. All of these challenges depend on new online solutions from on-board computing systems. Scientists and engineers in GNC have been developing model based, sensor based as well as knowledge based approaches aiming for highly robust, adaptive, nonlinear, intelligent and autonomous GNC systems. Although the papers presented at the conference and selected in this book could not possibly cover all of the present challenges in the GNC field, many of them have indeed been addressed and a wealth of new ideas, solutions and results were proposed and presented. For the 2nd CEAS Specialist Conference on Guidance, Navigation and Control the International Program Committee conducted a formal review process. Each paper was reviewed in compliance with good journal practice by at least two independent and anonymous reviewers. The papers published in this book were selected from the conference proceedings based on the results and recommendations from the reviewers.

NASA Technical Paper

Dynamic Systems

An Eclectic Design Concept