YAGUANG YANG

SPACECRAFT MODELING, ATTITUDE DETERMINATION, AND CONTROL

Quaternion-Based Approach

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Fundamentals Of Spacecraft Attitude Determination And Control

Ying-Ying Zheng

Fundamentals Of Spacecraft Attitude Determination And Control:

Fundamentals of Spacecraft Attitude Determination and Control F. Landis Markley,John L. Crassidis,2014-06-01 This book explores topics that are central to the field of spacecraft attitude determination and control The authors provide rigorous theoretical derivations of significant algorithms accompanied by a generous amount of qualitative discussions of the subject matter The book documents the development of the important concepts and methods in a manner accessible to practicing engineers graduate level engineering students and applied mathematicians It includes detailed examples from actual mission designs to help ease the transition from theory to practice and also provides prototype algorithms that are readily available on the author s website Subject matter includes both theoretical derivations and practical implementation of spacecraft attitude determination and control systems It provides detailed derivations for attitude kinematics and dynamics and provides detailed description of the most widely used attitude parameterization the quaternion This title also provides a thorough treatise of attitude dynamics including Jacobian elliptical functions It is the first known book to provide detailed derivations and explanations of state attitude determination and gives readers real world examples from actual working spacecraft missions The subject matter is chosen to fill the void of existing textbooks and treatises especially in state and dynamics attitude determination MATLAB code of all examples will be provided through an external website

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on quaternion based methods because of its many merits The book lays a brief but necessary background on rotation sequence representations and frequently used reference frames that form the foundation of spacecraft attitude description It then discusses the fundamentals of attitude determination using vector measurements various efficient including very recently developed attitude determination algorithms and the instruments and methods of popular vector measurements With available attitude measurements attitude control designs for inertial point and nadir pointing are presented in terms of required torques which are independent of actuators in use Given the required control torques some actuators are not able to generate the accurate control torques therefore spacecraft attitude control design methods with achievable torques for these actuators for example magnetic torque bars and control moment gyros are provided Some rigorous controllability results are provided The book also includes attitude control in some special maneuvers such as orbital raising docking and rendezvous that are normally not discussed in similar books Almost all design methods are based on state spaced modern control approaches such as linear quadratic optimal control robust pole assignment control model predictive control and gain scheduling control Applications of these methods to spacecraft attitude control problems are provided Appendices are provided for readers who are not familiar with these topics **Spacecraft Modeling, Attitude Determination, and Control** Yaguang Yang,2025-06-25 This book discusses spacecraft attitude control related topics spacecraft modeling spacecraft attitude determination and estimation and spacecraft attitude controls Unlike other books addressing these topics this book focuses on quaternion based methods because of their many merits It provides a brief but necessary background on rotation sequence representations and frequently used reference frames that form the foundation of spacecraft attitude description It then discusses the fundamentals of attitude determination using vector measurements various efficient including very recently developed attitude determination algorithms and the instruments and methods of popular vector measurements With available attitude measurements attitude control designs for inertial point and nadir pointing are presented in terms of required torques which are independent of actuators in use Given the required control torques some actuators are not able to generate the accurate control torques therefore spacecraft attitude control design methods with achievable torques for these actuators for example magnetic torque bars and control moment gyros are provided Some rigorous controllability results are provided The book also includes attitude control in some special maneuvers and systems such as orbital raising docking and rendezvous and multi body space systems that are normally not discussed in similar books All design methods are based on state spaced modern control approaches such as linear quadratic optimal control robust pole assignment control model predictive control and gain scheduling control Applications of these methods to spacecraft attitude control problems are provided Appendices are provided for readers who are not familiar with these topics

Spacecraft Attitude Determination and Control J.R. Wertz,2012-12-06 Roger D Werking Head Attitude Determination and Control Section National Aeronautics and Space Administration Goddard Space Flight Center Extensiye work has been done

for many years in the areas of attitude determination attitude prediction and attitude control During this time it has been difficult to obtain reference material that provided a comprehensive overview of attitude support activities This lack of reference material has made it difficult for those not intimately involved in attitude functions to become acquainted with the ideas and activities which are essential to understanding the various aspects of spacecraft attitude support As a result I felt the need for a document which could be used by a variety of persons to obtain an understanding of the work which has been done in support of spacecraft attitude objectives It is believed that this book prepared by the Computer Sciences Corporation under the able direction of Dr James Wertz provides this type of reference This book can serve as a reference for individuals involved in mission planning attitude determination and attitude dynamics an introductory textbook for stu dents and professionals starting in this field an information source for experimen ters or others involved in spacecraft related work who need information on spacecraft orientation and how it is determined but who have neither the time nor the resources to pursue the varied literature on this subject and a tool for encouraging those who could expand this discipline to do so because much remains to be done to satisfy future needs **Spacecraft Dynamics and Control** Enrico Canuto,Carlo Novara,Donato Carlucci,Carlos Perez-Montenegro,Luca Massotti,2018-03-08 Spacecraft Dynamics and Control The Embedded Model Control Approach provides a uniform and systematic way of approaching space engineering control problems from the standpoint of model based control using state space equations as the key paradigm for simulation design and implementation The book introduces the Embedded Model Control methodology for the design and implementation of attitude and orbit control systems The logic architecture is organized around the embedded model of the spacecraft and its surrounding environment The model is compelled to include disturbance dynamics as a repository of the uncertainty that the control law must reject to meet attitude and orbit requirements within the uncertainty class The source of the real time uncertainty estimation prediction is the model error signal as it encodes the residual discrepancies between spacecraft measurements and model output The embedded model and the uncertainty estimation feedback noise estimator in the book constitute the state predictor feeding the control law Asymptotic pole placement exploiting the asymptotes of closed loop transfer functions is the way to design and tune feedback loops around the embedded model state predictor control law reference generator The design versus the uncertainty class is driven by analytic stability and performance inequalities The method is applied to several attitude and orbit control problems The book begins with an extensive introduction to attitude geometry and algebra and ends with the core themes state space dynamics and Embedded Model Control Fundamentals of orbit attitude and environment dynamics are treated giving emphasis to state space formulation disturbance dynamics state feedback and prediction closed loop stability Sensors and actuators are treated giving emphasis to their dynamics and modelling of measurement errors Numerical tables are included and their data employed for numerical simulations Orbit and attitude control problems of the European GOCE mission are the inspiration of numerical exercises and simulations The suite

of the attitude control modes of a GOCE like mission is designed and simulated around the so called mission state predictor Solved and unsolved exercises are included within the text and not separated at the end of chapters for better understanding training and application Simulated results and their graphical plots are developed through MATLAB Simulink code

Fundamentals of Space Systems Vincent L. Pisacane,2005 Fundamentals of Space Systems was developed to satisfy two objectives the first is to provide a text suitable for use in an advanced undergraduate or beginning graduate course in both space systems engineering and space system design The second is to be a primer and reference book for space professionals wishing to broaden their capabilities to develop manage the development or operate space systems The authors of the individual chapters are practicing engineers that have had extensive experience in developing sophisticated experimental and operational spacecraft systems in addition to having experience teaching the subject material The text presents the fundamentals of all the subsystems of a spacecraft missions and includes illustrative examples drawn from actual experience to enhance the learning experience It included a chapter on each of the relevant major disciplines and subsystems including space systems engineering space environment astrodynamics propulsion and flight mechanics attitude determination and control power systems thermal control configuration management and structures communications command and telemetry data processing embedded flight software survuvability and reliability integration and test mission operations and the initial conceptual design of a typical small spacecraft mission Spacecraft Momentum Control Systems Frederick A. Leve,Mason A. Peck,Brian J. Hamilton,William Bialke,2025-09-01 With space industry professionals and university students this book offers a practical technical reference for seeking to understand the state of the art in spacecraft momentum control systems The focus is control moment gyroscope CMG technology but general principles of momentum control for example through reaction wheels magnetic torque actuation and other means are presented These key topics are treated in several contexts systems engineering and spacecraft architecture attitude control and dynamics and mission operations The subject matter is developed with theoretical rigor and in terms of practical implementation in flight hardware software This book is the first to address CMG technology in depth let alone from a practitioner s perspective It is also timely given the rise of commercial Earth imaging the imminent need for high torque manipulation of satellites for servicing and assembly the advances in privately built spacecraft including small satellites and the growing popularity of the subject matter in academia over the past two decades The current edition includes exercises suitable for upper level undergraduate courses and graduate level courses in spacecraft attitude dynamics and control spacecraft design and space systems engineering This second edition provides more applications attitude control momentum and nutation dumping isolation system identification systems engineering bearings and structures as well as more in depth discussions of equations of motion as well as the numerics and complexity associated with generalized inverses that are used for steering algorithms Fault Tolerant Attitude Estimation for Small Satellites Chingiz Hajiyev,Halil Ersin Soken,2020-12-22 Small satellites use commercial off the

shelf sensors and actuators for attitude determination and control ADC to reduce the cost These sensors and actuators are usually not as robust as the available more expensive space proven equipment As a result the ADC system of small satellites is more vulnerable to any fault compared to a system for larger competitors This book aims to present useful solutions for fault tolerance in ADC systems of small satellites The contents of the book can be divided into two categories fault tolerant attitude filtering algorithms for small satellites and sensor calibration methods to compensate the sensor errors MATLAB will be used to demonstrate simulations Presents fault tolerant attitude estimation algorithms for small satellites with an emphasis on algorithms practicability and applicability Incorporates fundamental knowledge about the attitude determination methods at large Discusses comprehensive information about attitude sensors for small satellites Reviews calibration algorithms for small satellite magnetometers with simulated examples Supports theory with MATLAB simulation results which can be easily understood by individuals without a comprehensive background in this field Covers up to date discussions for small satellite attitude systems design Dr Chingiz Hajiyev is a professor at the Faculty of Aeronautics and Astronautics Istanbul Technical University Istanbul Turkey Dr Halil Ersin Soken is an assistant professor at the Aerospace Engineering Department Middle East Technical University Ankara Turkey Smart Computing and Control Renewable Energy Systems Mustapha Hatti,2025-03-03 This essential book bridges the gap between cutting edge artificial intelligence and the dynamic world of renewable energy systems Embark on a journey to the forefront of sustainable energy innovation with this groundbreaking collection of research papers and expert insights Designed for curious minds and industry leaders alike this comprehensive resource offers A deep dive into the latest advancements in smart computing for sustainable energy Exploration of AI driven techniques revolutionizing energy efficiency and management Real world applications showcasing the transformative power of intelligent systems in renewables Insights into futuristic energy infrastructures powered by artificial intelligence A perfect blend of theoretical foundations and practical implementations To a seasoned researcher pushing the boundaries of knowledge a graduate student aspiring to make a mark or an industry professional staying ahead of the curve this book is a gateway to the future of energy Discover how machine learning is reshaping solar forecasting uncover the potential of autonomous systems in energy storage and explore the role of AI in crafting smarter more sustainable cities From predictive maintenance that ensures uninterrupted power to intelligent control systems optimizing energy generation this book covers it all Don t just witness the renewable energy revolution be part of it This book equips readers with the knowledge and inspiration to drive innovation in this critical field It is more than a collection of papers it is a roadmap to a sustainable future where smart computing and renewable energy converge Prepare to challenge your assumptions expand your expertise and contribute to a greener tomorrow Order your copy today and position yourself at the vanguard of the smart energy movement **Applied Modern Control** Le Anh Tuan,2019-02-13 This book describes recent studies on modern control systems using various control techniques The control systems cover large complex systems such

as train operation systems to micro systems in nanotechnology Various control trends and techniques are discussed from practically modern approaches such as Internet of Things artificial neural networks machine learning to theoretical approaches such as zero placement bang bang optimal control predictive control and fuzzy approach Flexible Spacecraft Dynamics, Control and Guidance Leonardo Mazzini,2015-10-27 This book is an up to date compendium on spacecraft attitude and orbit control AOC that offers a systematic and complete treatment of the subject with the aim of imparting the theoretical and practical knowledge that is required by designers engineers and researchers After an introduction on the kinematics of the flexible and agile space vehicles the modern architecture and functions of an AOC system are described and the main AOC modes reviewed with possible design solutions and examples The dynamics of the flexible body in space are then considered using an original Lagrangian approach suitable for the control applications of large space flexible structures Subsequent chapters address optimal control theory attitude control methods and orbit control applications including the optimal orbital transfer with finite and infinite thrust The theory is integrated with a description of current propulsion systems with the focus especially on the new electric propulsion systems and state of the art sensors and actuators **Spacecraft Dynamics and Control** Anton H. de Ruiter,Christopher Damaren,James R. Forbes,2012-12-05 Provides the basics of spacecraft orbital dynamics plus attitude dynamics and control using vectrix notation Spacecraft Dynamics and Control An Introduction presents the fundamentals of classical control in the context of spacecraft attitude control This approach is particularly beneficial for the training of students in both of the subjects of classical control as well as its application to spacecraft attitude control By using a physical system a spacecraft that the reader can visualize rather than arbitrary transfer functions it is easier to grasp the motivation for why topics in control theory are important as well as the theory behind them The entire treatment of both orbital and attitude dynamics makes use of vectrix notation which is a tool that allows the user to write down any vector equation of motion without consideration of a reference frame This is particularly suited to the treatment of multiple reference frames Vectrix notation also makes a very clear distinction between a physical vector and its coordinate representation in a reference frame This is very important in spacecraft dynamics and control problems where often multiple coordinate representations are used in different reference frames for the same physical vector Provides an accessible practical aid for teaching and self study with a layout enabling a fundamental understanding of the subject Fills a gap in the existing literature by providing an analytical toolbox offering the reader a lasting rigorous methodology for approaching vector mechanics a key element vital to new graduates and practicing engineers alike Delivers an outstanding resource for aerospace engineering students and all those involved in the technical aspects of design and engineering in the space sector Contains numerous illustrations to accompany the written text Problems are included to apply and extend the material in each chapter Essential reading for graduate level aerospace engineering students aerospace professionals researchers and engineers **Modern Spacecraft Guidance, Navigation,**

and Control Vincenzo Pesce,Andrea Colagrossi,Stefano Silvestrini,2022-11-13 Modern Spacecraft Guidance Navigation and Control From System Modeling to AI and Innovative Applications provides a comprehensive foundation of theory and applications of spacecraft GNC from fundamentals to advanced concepts including modern AI based architectures with focus on hardware and software practical applications Divided into four parts this book begins with an introduction to spacecraft GNC before discussing the basic tools for GNC applications These include an overview of the main reference systems and planetary models a description of the space environment an introduction to orbital and attitude dynamics and a survey on spacecraft sensors and actuators with details of their modeling principles Part 2 covers guidance navigation and control including both on board and ground based methods It also discusses classical and novel control techniques failure detection isolation and recovery FDIR methodologies GNC verification validation and on board implementation The final part 3 discusses AI and modern applications featuring different applicative scenarios with particular attention on artificial intelligence and the possible benefits when applied to spacecraft GNC In this part GNC for small satellites and CubeSats is also discussed Modern Spacecraft Guidance Navigation and Control From System Modeling to AI and Innovative Applications is a valuable resource for aerospace engineers GNC AOCS engineers avionic developers and AIV AIT technicians Provides an overview of classical and modern GNC techniques covering practical system modeling aspects and applicative cases Presents the most important artificial intelligence algorithms applied to present and future spacecraft GNC Describes classical and advanced techniques for GNC hardware and software verification and validation and GNC failure detection isolation and recovery FDIR **Spacecraft Attitude Determination and Control** Computer Sciences Corporation. Attitude Systems Operation,1978 *Dynamic System Modelling and Analysis with MATLAB and Python* Jongrae Kim,2022-10-18 Dynamic System Modeling Analysis with MATLAB Python A robust introduction to the advanced programming techniques and skills needed for control engineering In Dynamic System Modeling Analysis with MATLAB Python For Control Engineers accomplished control engineer Dr Jongrae Kim delivers an insightful and concise introduction to the advanced programming skills required by control engineers The book discusses dynamic systems used by satellites aircraft autonomous robots and biomolecular networks Throughout the text MATLAB and Python are used to consider various dynamic modeling theories and examples The author covers a range of control topics including attitude dynamics attitude kinematics autonomous vehicles systems biology optimal estimation robustness analysis and stochastic system An accompanying website includes a solutions manual as well as MATLAB and Python example code Dynamic System Modeling Analysis with MATLAB Python For Control Engineers provides readers with a sound starting point to learning programming in the engineering or biology domains It also offers A thorough introduction to attitude estimation and control including attitude kinematics and sensors and extended Kalman filters for attitude estimation Practical discussions of autonomous vehicles mission planning including unmanned aerial vehicle path planning and moving target tracking Comprehensive explorations of biological network modeling

including bio molecular networks and stochastic modeling In depth examinations of control algorithms using biomolecular networks including implementation Dynamic System Modeling Analysis with MATLAB Python For Control Engineers is an indispensable resource for advanced undergraduate and graduate students seeking practical programming instruction for dynamic system modeling and analysis using control theory *Advanced Motion Control and Navigation of Robots in Extreme Environments* Allahyar Montazeri,Nargess Sadeghzadeh-Nokhodberiz,Khoshnam Shojaei,Kaspar Althoefer,2024-11-20 Advances in robotics and autonomous systems have opened new horizons for the scientists by creating new opportunities to explore extreme environments that would previously not have been possible For example robots that are deployed to study environmental processes such remote volcanos monitor the climate variables under the adverse weather conditions understand underground mines and explore deep oceans which are all inaccessible or hazardous for the human Industrial applications can also often be situated in extreme environments such as offshore oil and gas and nuclear industries In such applications the autonomous robot is expected to complete tasks such as repair and maintenance exploration reconnaissance inspection and transportation which is either done in isolation or as a team of cooperative robots Due to the harsh and severe conditions of such environments designing an advanced robotic system that can endure them is a challenging task The robot needs to cope with the time varying restricted uncertain and unstructured nature of the environment to achieve the planning and execution of the tasks This in turn demands development of advanced robust and adaptive motion control and navigation algorithms along with machine learning and deep learning algorithms with high cognitive capability for the robot to perceive the surrounding environment effectively The use of both single and multi robot platforms can be advantageous depending on the specific application and environment ADCS - Spacecraft Attitude Determination and Control Michael Paluszek,2023-04-27 ADCS Spacecraft Attitude Determination and Control provides a complete introduction to spacecraft control The book covers all elements of attitude control system design including kinematics dynamics orbits disturbances actuators sensors and mission operations Essential hardware details are provided for star cameras reaction wheels sun sensors and other key components The book explores how to design a control system for a spacecraft control theory and actuator and sensor details Examples are drawn from the author s 40 years of industrial experience with spacecraft such as GGS GPS IIR Mars Observer and commercial communications satellites and includes historical background and real life examples Features critical details on hardware and the space environment Combines theory and ready to implement practical algorithms Includes MATLAB code for all examples Provides plots and figures generated with the included code **A Concise Introduction to Classical Mechanics** Vakhtang Putkaradze,2025-06-03 Mechanics is one of the oldest and most foundational subjects in undergraduate curricula for mathematicians physicists and engineers Traditionally taught through a classical or analytical approach modern advancements have introduced a geometric perspective that has found applications in diverse fields such as machine learning climate research satellite navigation and

more This book bridges the gap between classical mechanics and its modern geometric counterpart Designed for students and educators it presents the essential topics typically required in mechanics courses while integrating a geometric approach to deepen understanding Key features include Clear explanations of core concepts including Lagrangian mechanics variational methods canonical transformations and systems with constraints Numerous solved problems and real world examples to solidify understanding Sample midterms and final exams to help students prepare for coursework and assessments Every chapter includes a looking forward section outlining modern applications of the material The book minimizes mathematical abstraction introducing only the necessary concepts to make the material accessible and practical Whether you re a student looking to master the essentials or an instructor seeking a fresh perspective this book provides a comprehensive approachable and modern exploration of mechanics ACS Without an Attitude Harold L. Hallock,Gary Welter,David G. Simpson,Christopher Rouff,2017-05-03 This book de emphasizes the formal mathematical description of spacecraft on board attitude and orbit applications in favor of a more qualitative concept oriented presentation of these topics The information presented in this book was originally given as a set of lectures in 1999 and 2000 instigated by a NASA Flight Software Branch Chief at Goddard Space Flight Center The Branch Chief later suggested this book It provides an approachable insight into the area and is not intended as an essential reference work ACS Without an Attitude is intended for programmers and testers new to the field who are seeking a commonsense understanding of the subject matter they are coding and testing in the hope that they will reduce their risk of introducing or missing the key software bug that causes an abrupt termination in their spacecraft s mission In addition the book will provide managers and others working with spacecraft with a basic understanding of this subject

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Table of Contents Fundamentals Of Spacecraft Attitude Determination And Control

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