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From Mission Design to Operations
CubeSat Handbook
Attitude Determination and Control System of a Nanosatellite
A flexible attitude control system for three-axis stabilized nanosatellites
Attitude Determination and Control System for a Small Spacecraft
Advances in Estimation, Navigation, and Spacecraft Control
Space Microsystems and Micro/Nano Satellites
Selected Papers of the Itzhack Y. Bar-Itzhack Memorial Symposium on Estimation, Navigation, and Spacecraft Control
Thermospheric Density and Wind Determination from Satellite Dynamics
Fundamental Spacecraft Dynamics and Control
Attitude Determination and Control System for the Dawgstar Nanosatellite
The Attitude Determination and Control System of the Toroid Satellite
Handbook of Small Satellites
Advances in Spacecraft Attitude Control
An Introduction
Attitude Determination and Control of Nano-Satellites
Spacecraft Modeling, Attitude Determination, and Control
A Practical Engineering Approach

WILLIAMS HUGHES

Nanosatellites AIAA
The purpose of this work is to discuss the attitude determination and control system (ADCS) design process and implementation for a 12 kg, 6U (36.6 cm x 23.9 cm x 27.97 cm) CubeSat class nano-satellite. The design is based on the requirements and capabilities of the Application for Resident Space Object Proximity Analysis and IMAging (ARAPAIMA) proximity operations mission. The satellite is equipped with a cold gas propulsion system capable of exerting 2.5 mN m torques in both directions about each body axis. The attitude sensors include an angular rate gyro and star tracker (STR), supplemented by the payload optical array cameras. The dynamic simulation of the satellite includes extensive environmental models and analyses that show how the satellite attitude is affected by aerodynamic drag, solar radiation pressure, gravity gradient torques, and residual magnetic moments. A mechanical propellant slosh model and a reaction torque analysis of the deployable solar panel hinges approximate the internal dynamics of the satellite. A trade study is presented to justify the use of a reaction control thruster actuated system over the more traditional reaction wheel configuration. Both actuation systems are modeled to hardware specifications and their propellant and energy requirements are examined alongside pointing performance. Two methods of accounting for sensor noise and sampling rates are presented. The first is an extended Kalman filter based on the nonlinear model of a rate gyro coupled with quaternion attitude kinematics. The second presents a gyro-less angular rate observer capable of extrapolating STR measurements to the desired frequency. An additional method uses images from the payload cameras to perform [camera] frame centering maneuvers and to address the possibility of bias in the controller reference signal. Four different controllers are described to reflect the chronological progression of the ADCS design. The first controller, designed to perform long angle maneuvers and target tracking, utilizes fixed gain eigenaxis control. The same controller is then augmented with a parallel proportional-integral-derivative (PID) type control law using scheduled gains. This configuration is designed to switch between eigenaxis and PID control during imaging procedures to take advantage of the integral control introduced by the PID algorithm. To reduce system complexity, a modified eigenaxis control law, which incorporates scheduled integral control but does not require a switch to PID control, is introduced. A discrete time equivalent of the modified eigenaxis control law is also developed. Additionally, a brief description of a detumbling control law is presented. Each of the four control laws is paired and tested with the different feedback and estimation methods discussed. An extensive showcase of numerical simulation results outlines the pointing performance of each system configuration and evaluates their capabilities of meeting a 1 arcmin pointing requirement. A comparison of the different properties and performance of each control system configuration precedes the selection of the discrete modified eigenaxis control law as the best alternative.
Three-axes Attitude Determination and Control System Based on Magnetorquers for Small Satellites Elsevier
The University of Illinois's IlliniSat2 satellite bus is unique in that it is among only a few nano-satellites that implements three-axis, onboard attitude determination and control. Though this is an ambitious goal, it will allow for a wide range of scientific missions to be accomplished on this bus. To complete the system, an accurate attitude determination system needs to be developed. Several methods for determining the attitude state as well as mitigating system noise are

explored. In particular, an extended Kalman lter is developed to obtain accurate angular rate information from noisy rate measurements. These rate measurements may be provided by either rate gyros or by successive vector measurements. A linear Kalman lter is developed to obtain an accurate attitude estimate. The attitude may be measured with two vector measurements via the TRIAD algorithm, while sensor noise may be rejected via the lter. Using these techniques the requirements for an e ective attitude determination and control system are met.
Spacecraft Attitude Dynamics CRC Press
This modern presentation guides readers through the theory and practice of satellite orbit prediction and determination. Starting from the basic principles of orbital mechanics, it covers elaborate force models as well as precise methods of satellite tracking. The accompanying CD-ROM includes source code in C++ and relevant data files for applications. The result is a powerful and unique spaceflight dynamics library, which allows users to easily create software extensions. An extensive collection of frequently updated Internet resources is provided through WWW hyperlinks.
Models, Methods and Applications John Wiley & Sons
Satellites are used increasingly in telecommunications, scientific research, surveillance, and meteorology, and these satellites rely heavily on the effectiveness of complex onboard control systems. This 1997 book explains the basic theory of spacecraft dynamics and control and the practical aspects of controlling a satellite. The emphasis throughout is on analyzing and solving real-world engineering problems. For example, the author discusses orbital and rotational dynamics of spacecraft under a variety of environmental conditions, along with the realistic constraints imposed by available hardware. Among the topics covered are orbital dynamics, attitude dynamics, gravity gradient stabilization, single and dual spin stabilization, attitude maneuvers, attitude stabilization, and structural dynamics and liquid sloshing.
Low Earth Orbit Satellite Design Cambridge University Press
In the past decade, the field of small satellites has expanded the space industry in a powerful way. Hundreds, indeed thousands, of these innovative and highly cost-efficient satellites are now being launched from Earth to establish low-cost space systems. These smallsats are engaged in experiments and prototype testing, communications services, data relay, internet access, remote sensing, defense and security related services, and more. Some of these systems are quite small and are simple student experiments, while others in commercial constellations are employing state-of-the-art technologies to deliver fast and accurate services. This handbook provides a comprehensive overview of this exciting new field. It covers the technology, applications and services, design and manufacture, launch arrangements, ground systems, and economic and regulatory arrangements surrounding small satellites. The diversity of approach in recent years has allowed for rapid innovation and economic breakthroughs to proceed at a pace that seems only to be speeding up. In this reference work, readers will find information pertaining to all aspects of the small satellite industry, written by a host of international experts in the field.
Space and Ground Technologies, Operations and Economics Springer
An extensive text reference includes around an asteroid – a new and important topic Covers the most updated contents in spacecraft dynamics and control, both in theory and application Introduces the application to motion around asteroids – a new and important topic Written by a very experienced researcher in this area
Modeling and Optimization in Space Engineering Universitätsverlag der TU Berlin
Predictive Filtering for Microsatellite Control Systems introduces technological design, modeling, stability analysis, predictive filtering, state estimation problem and real-time operation of spacecraft control systems in aerospace engineering. The book gives a systematically and almost self-contained description of the many facets of envisaging, designing, implementing or experimentally exploring predictive filtering for spacecraft control systems, along with the adequate designs of integrated modeling, dynamics, state estimation, and signal processing of spacecrafts and nonlinear systems. Unifies existing and emerging concepts concerning predictive filtering theory, state estimation, and signal processing for spacecraft control systems Provides a series of latest results in, including but not limited to, nonlinear filtering, attitude determination, and state estimation towards spacecraft control systems Gives numerical and simulation results in each chapter in order to reflect the engineering practice and demonstrate the main focus of the developed analysis and synthesis approach Covers advanced topics in nonlinear filtering with aerospace application
Advances in Aerospace Guidance, Navigation and Control BoD – Books on Demand
Spacecraft Attitude Determination and ControlSpringer Science & Business Media
Spacecraft Dynamics and Control Lulu Press, Inc
This book discusses all spacecraft attitude control-related topics: spacecraft (including attitude measurements, actuator, and disturbance torques), 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 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.
Satellite Orbits Cambridge Scholars Publishing
Comprehensive coverage includes environmental torques, energy dissipation, motion equations for four archetypical systems, orientation parameters, illustrations of key concepts with on-orbit flight data, and typical engineering hardware. 1986 edition.
Spacecraft Attitude Determination and Control John Wiley & Sons
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.
The Attitude Determination and Control System of the Generic Nanosatellite Bus Springer Science & Business Media
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.
Selected Papers of the Second CEAS Specialist Conference on Guidance, Navigation and Control Springer Science & Business Media
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.
State of the Art and New Challenges Springer
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).
Fundamentals of Spacecraft Attitude Determination and Control Springer
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.
The Design and Simulated Performance of the Attitude Determination and Control System of a

Gravity Gradient Stabilized Cube Satellite Springer Science & Business Media

This book explores CubeSat technology, and develops a nonlinear mathematical model of a spacecraft with the assumption that the satellite is a rigid body. It places emphasis on the CubeSat subsystem, orbit dynamics and perturbations, the satellite attitude dynamic and modeling, and components of attitude determination and the control subsystem. The book focuses on the attitude stabilization methods of spacecraft, and presents gravity gradient stabilization, aerodynamic stabilization, and permanent magnets stabilization as passive stabilization methods, and spin stabilization and three axis stabilization as active stabilization methods. It also discusses the need to develop a control system design, and describes the design of three controller configurations, namely the Proportional–Integral–Derivative Controller (PID), the Linear Quadratic Regulator (LQR), and the Fuzzy Logic Controller (FLC) and how they can be used to design the attitude control of CubeSat three-axis stabilization. Furthermore, it presents the design of a suitable attitude stabilization system by combining gravity gradient stabilization with magnetic torquing, and the design of magnetic coils which can be added in order to improve the accuracy of attitude stabilization. The book then investigates, simulates, and compares possible controller configurations that can be used to control the currents of magnetic coils when magnetic coils behave as the actuator of the system.

Multisensor Attitude Estimation Academic Press

The Generic Nanosatellite Bus (GNB) is a spacecraft platform designed to accommodate the integration of diverse payloads in a common housing of supporting components. The development of the GNB at the Space Flight Laboratory (SFL) under the Canadian Advanced Nanospace eXperiment (CanX) program provides accelerated access to space while reducing non-recurring engineering (NRE) costs.The work presented herein details the development of the attitude determination and control subsystem (ADCS) of the GNB. Specific work on magnetorquer coil assembly, integration, and testing (AIT) and reaction wheel testing is included. The embedded software development and unit-level testing of the GNB sun sensors are discussed. The characterization of the AeroAstro star tracker is also a major focus, with procedures and results presented here. Hardware models were developed and incorporated into SFL's in-house high-fidelity attitude dynamics and control simulation environment. This work focuses on specific contributions to the CanX-3, CanX-4&5, and AISSat-1 nanosatellite missions.

Spacecraft Mission Design CRC Press

MEMS for automotive and aerospace applications reviews the use of Micro-Electro-Mechanical-Systems (MEMS) in developing solutions to the unique challenges presented by the automotive and aerospace industries. Part one explores MEMS for a variety of automotive applications. The role of MEMS in passenger safety and comfort, sensors for automotive vehicle stability control applications and automotive tire pressure monitoring systems are considered, along with pressure and flow sensors for engine management, and RF MEMS for automotive radar sensors. Part two then goes on to explore MEMS for aerospace applications, including devices for active drag reduction in aerospace applications, inertial navigation and structural health monitoring systems, and thrusters for nano- and pico-satellites. A selection of case studies are used to explore MEMS for harsh environment sensors in aerospace applications, before the book concludes by considering the use of MEMS in space exploration and exploitation. With its distinguished editors and international team of expert contributors, MEMS for automotive and aerospace applications is a key tool for MEMS manufacturers and all scientists, engineers and academics working on MEMS and intelligent systems for transportation. Chapters consider the role of MEMS in a number of automotive applications, including passenger safety and comfort, vehicle stability and control MEMS for aerospace applications are also discussed, including active drag reduction, inertial navigation and structural health monitoring systems Presents a number of case studies exploring MEMS for harsh environment sensors in aerospace

Quaternion-Based Approach Spacecraft Attitude Determination and Control

This book presents advanced case studies that address a range of important issues arising in space engineering. An overview of challenging operational scenarios is presented, with an in-depth exposition of related mathematical modeling, algorithmic and numerical solution aspects. The model development and optimization approaches discussed in the book can be extended also towards other application areas. The topics discussed illustrate current research trends and challenges in space engineering as summarized by the following list: • Next Generation Gravity Missions • Continuous-Thrust Trajectories by Evolutionary Neurocontrol • Nonparametric Importance Sampling for Launcher Stage Fallout • Dynamic System Control Dispatch • Optimal Launch Date of Interplanetary Missions • Optimal Topological Design • Evidence-Based Robust Optimization • Interplanetary Trajectory Design by Machine Learning • Real-Time Optimal Control • Optimal Finite Thrust Orbital Transfers • Planning and Scheduling of Multiple Satellite Missions • Trajectory Performance Analysis • Ascent Trajectory and Guidance Optimization • Small Satellite Attitude Determination and Control • Optimized Packings in Space Engineering • Time-Optimal Transfers of All-Electric GEO Satellites Researchers working on space engineering applications will find this work a valuable, practical source of information. Academics, graduate and post-graduate students working in aerospace, engineering, applied mathematics, operations research, and optimal control will find useful information regarding model development and solution techniques, in conjunction with real-world applications.

ACS Without an Attitude John Wiley & Sons

There has been an increasing interest in multi-disciplinary research on multisensor attitude estimation technology driven by its versatility and diverse areas of application, such as sensor networks, robotics, navigation, video, biomedicine, etc. Attitude estimation consists of the determination of rigid bodies' orientation in 3D space. This research area is a multilevel, multifaceted process handling the automatic association, correlation, estimation, and combination of data and information from several sources. Data fusion for attitude estimation is motivated by several issues and problems, such as data imperfection, data multi-modality, data dimensionality, processing framework, etc. While many of these problems have been identified and heavily investigated, no single data fusion algorithm is capable of addressing all the aforementioned challenges. The variety of methods in the literature focus on a subset of these issues to solve, which would be determined based on the application in hand. Historically, the problem of attitude estimation has been introduced by Grace Wahba in 1965 within the estimate of satellite attitude and aerospace applications. This book intends to provide the reader with both a generic and comprehensive view of contemporary data fusion methodologies for attitude estimation, as well as the most recent researches and novel advances on multisensor attitude estimation task. It explores the design of algorithms and architectures, benefits, and challenging aspects, as well as a broad array of disciplines, including: navigation, robotics, biomedicine, motion analysis, etc. A number of issues that make data fusion for attitude estimation a challenging task, and which will be discussed through the different chapters of the book, are related to: 1) The nature of sensors and information sources (accelerometer, gyroscope, magnetometer, GPS, inclinometer, etc.); 2) The computational ability at the sensors; 3) The theoretical developments and convergence proofs; 4) The system architecture, computational resources, fusion level.