



Aerodynamic Stability Analysis of Two Heterogeneous UAVs in Close Formation Flight System

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Abstract: The close formation flight of UAV's has many significant advantages over single vehicle flight. The aerodynamic stability analysis of two heterogeneous UAV's in close formation flight is detailed in the present paper. The issues of altitude changes and the associated shifts or changes in centre of gravity or moments, the equivalent actuator control surface deflections etc., are explained with the help of simulations. The short period frequency variations with these changes are also correlated with the help of pole-zero diagrams.

Keywords: Control, Close Formation Flight, Heterogeneous UAV's, Wing Vortex

1. Introduction

The Close Formation Flight (CFF) of Unmanned Aerospace Vehicles (UAV's) has diverse advantages such as fuel saving, cost reduction and preciseness in image capturing and data collection etc. The formation flight studies of heterogeneous Unmanned Aerial Vehicles (UAV's) in a stability analysis view point is hardly difficult to find. The proposed formation flight model in this paper consists of two members, namely 'leader' and 'follower'. The induced drag reduction caused by vortex effect of leader wing tips in close formation is made use of in this stability analysis work.

2. Literature Review

The most important control techniques used among available literature spanned over the last two decades are Intelligent Management Control Approach [1], Co-operative Control [2], Constraint Forces Approach [3], 3D Potential Field Approach [4], Co-operative tracking control [5], Constrained Adaptive Back-stepping Approach [6] and Vision based Scheme [7]. Proud, A. et al formulated PID feedback tracking control on two member system [8]. Dogan et al presented Linear Control Approach for formation reconfiguration [9]. Vanek and Balint applied Model

Predictive Control to real-time trajectory tracking of UAV formations [10]. Model Predictive Control Algorithm in non-linear dynamics is implemented by Saffarian and Fahimi [11]. The Decentralized Control Design Procedure for obstacle avoidance and collision is done by Haibo Min [12]. The aerodynamics associated with wing vortex effect and the resulting drag reduction is of special focus on the studies of P. Chichka et al. [13]. The simulation of aerodynamic cross-coupling vortex effects [14] is a useful reference for the present study.

After a brief review of relevant literature the stability analysis of two heterogeneous UAV's engaged in close formation flight and their associated aerodynamic interactions are detailed in section-III. The formation consensus of these UAV's from different altitude levels for drag reduction results in centre of gravity (c. g.) shifts and moment changes are quantitatively estimated and simulated in section-IV. These c. g. shifts and moment changes produces short period roots or frequency transitions, as illustrated by a pole-zero diagram at the end before conclusion. The aero stability analysis of the mechanical characteristics of two heterogeneous fixed-wing UAV's during a transformation to a close formation flight is highlighted in the present paper.

Aerodynamic Stability Analysis Of Two Heterogeneous Uavs

**Carlos Pérez Arroyo, Pol Sintes
Arroyo, Xavier Prats, José I. (José
Ignacio) Rojas**

Aerodynamic Stability Analysis Of Two Heterogeneous Uavs:

Proceedings of UASG 2019 Kamal Jain,Kourosh Khoshelham,Xuan Zhu,Anuj Tiwari,2020-02-22 This volume gathers the latest advances innovations and applications in the field of geographic information systems and unmanned aerial vehicle UAV technologies as presented by leading researchers and engineers at the 1st International Conference on Unmanned Aerial System in Geomatics UASG held in Roorkee India on April 6 7 2019 It covers highly diverse topics including photogrammetry and remote sensing surveying UAV manufacturing geospatial data sensing UAV processing visualization and management UAV applications and regulations geo informatics and geomatics The contributions which were selected by means of a rigorous international peer review process highlight numerous exciting ideas that will spur novel research directions and foster multidisciplinary collaboration among different specialists Scientific and Technical Aerospace Reports ,1995

Proceedings of 4th 2024 International Conference on Autonomous Unmanned Systems (4th ICAUS 2024)

Lianqing Liu,Yifeng Niu,Wenxing Fu,Yi Qu,2025-04-24 This book includes original peer reviewed research papers from the 4th ICAUS 2024 which provides a unique and engaging platform for scientists engineers and practitioners from all over the world to present and share their most recent research results and innovative ideas The 4th ICAUS 2024 aims to stimulate researchers working in areas relevant to intelligent unmanned systems Topics covered include but are not limited to Unmanned Aerial Ground Surface Underwater Systems Robotic Autonomous Control Navigation and Positioning Architecture Energy and Task Planning and Effectiveness Evaluation Technologies Artificial Intelligence Algorithm Bionic Technology and their Application in Unmanned Systems The papers presented here share the latest findings in unmanned systems robotics automation intelligent systems control systems integrated networks modelling and simulation This makes the book a valuable resource for researchers engineers and students alike **Lighter than Air Robots** Yasmina Bestaoui Sebbane,2011-11-15

An aerial robot is a system capable of sustained flight with no direct human control and able to perform a specific task A lighter than air robot is an aerial robot that relies on the static lift to balance its own weight It can also be defined as a lighter than air unmanned aerial vehicle or an unmanned airship with sufficient autonomy Lighter than air systems are particularly appealing since the energy to keep them airborne is small They are increasingly considered for various tasks such as monitoring surveillance advertising freight carrier transportation This book familiarizes readers with a hierarchical decoupled planning and control strategy that has been proven efficient through research It is made up of a hierarchy of modules with well defined functions operating at a variety of rates linked together from top to bottom The outer loop closed periodically consists of a discrete search that produces a set of waypoints leading to the goal while avoiding obstacles and weighed regions The second level smoothes this set so that the generated paths are feasible given the vehicle s velocity and accelerations limits The third level generates flyable timed trajectories and the last one is the tracking controller that attempts to minimize the error between the robot measured trajectory and the reference trajectory This hierarchy is

reflected in the structure and content of the book Topics treated are Modelling Flight Planning Trajectory Design and Control Finally some actual projects are described in the appendix This volume will prove useful for researchers and practitioners working in Robotics and Automation Aerospace Technology Control and Artificial Intelligence

Holistic Approach to Quantum Cryptography in Cyber Security Shashi Bhushan,Manoj Kumar,Pramod Kumar,Renjith V. Ravi,Anuj Kumar Singh,2022-08-09 This new book discusses the concepts while also highlighting the challenges in the field of quantum cryptography and also covering cryptographic techniques and cyber security techniques in a single volume It comprehensively covers important topics in the field of quantum cryptography with applications including quantum key distribution position based quantum cryptography quantum teleportation quantum e commerce quantum cloning cyber security techniques architectures and design cyber security techniques management software defined networks and cyber security techniques for 5G communication The text also discusses the security of practical quantum key distribution systems applications and algorithms developed for quantum cryptography as well as cyber security through quantum computing and quantum cryptography The text will be beneficial for graduate students academic researchers and professionals working in the fields of electrical engineering electronics and communications engineering computer science and information technology

International Aerospace Abstracts ,1999 **NASA SP.** ,1992 **Aeronautical Engineering** ,1992 A selection of annotated references to unclassified reports and journal articles that were introduced into the NASA scientific and technical information system and announced in Scientific and technical aerospace reports STAR and International aerospace abstracts IAA

Aeronautical Engineering: A Cumulative Index to a Continuing Bibliography (supplement 274) ,1992 Key-words-in-context Title Index ,1962 A Cumulative Index to a Continuing Bibliography on Aeronautical Engineering ,1986 *Government Reports Annual Index* ,1977 Sections 1 2 Keyword Index Section 3 Personal author index Section 4 Corporate author index Section 5 Contract grant number index NTIS order report number index 1 E Section 6 NTIS order report number index F Z

Advanced UAV Aerodynamics, Flight Stability and Control Pascual Marqués,Andrea Da Ronch,2017-04-19 Comprehensively covers emerging aerospace technologies Advanced UAV aerodynamics flight stability and control Novel concepts theory and applications presents emerging aerospace technologies in the rapidly growing field of unmanned aircraft engineering Leading scientists researchers and inventors describe the findings and innovations accomplished in current research programs and industry applications throughout the world Topics included cover a wide range of new aerodynamics concepts and their applications for real world fixed wing airplanes rotary wing helicopter and quad rotor aircraft The book begins with two introductory chapters that address fundamental principles of aerodynamics and flight stability and form a knowledge base for the student of Aerospace Engineering The book then covers aerodynamics of fixed wing rotary wing and hybrid unmanned aircraft before introducing aspects of aircraft flight stability and control Key features Sound technical level and inclusion of high quality experimental and numerical data Direct

application of the aerodynamic technologies and flight stability and control principles described in the book in the development of real world novel unmanned aircraft concepts Written by world class academics engineers researchers and inventors from prestigious institutions and industry The book provides up to date information in the field of Aerospace Engineering for university students and lecturers aerodynamics researchers aerospace engineers aircraft designers and manufacturers CRREL Bibliography ,1998 **Aerodynamics, Stability and Control Computational Analysis for UAVs** Carlos Pérez Arroyo,Pol Sintés Arroyo,Xavier Prats,José I. (José Ignacio) Rojas,2007 *Analysis of Linked Aircraft Aerodynamics and Flight Dynamics* Edgar Adrian Cuji,2011 In this research I have analyzed different aircrafts with nonconventional wings The analyses have included aerodynamic modeling flight dynamics and trajectory optimization Two different nonconventional aircrafts are analyzed a V shape morphing wings and a Linked UAV system A modern adaptation of Prandtl's liftingline method is utilized to analyze the aerodynamics of both systems This method can compute the aerodynamic forces for a system of lifting surfaces with arbitrary camber sweep dihedral position and orientation The V shape morphing wings consist of a wing configuration that has two panels an out of plane dihedral section and a horizontal section An analysis of the aircraft turning dynamics shows that by manipulating the dihedral angles of the V shape wings either by symmetric or asymmetric wing shape changes can affect the turning capabilities of an aircraft to perform a variety of different missions depending on the importance of each of the turning performance measurements A linked UAV concept where individual UAVs link at high altitude creates an aerodynamically efficient system of aircraft which has long endurance capabilities and can cruise for extended periods with significantly reduced power loads This dissertation presents an analysis of close proximity aerodynamics and aircraft dynamics of two Linked UAVs As the UAVs approach each other for wingtip docking there are strong aerodynamic coupling between their wings tips An aerodynamic disturbance intensity field has been generated utilizing both simulation and wind tunnel data to determine a trajectory for the two UAVs to approach each other for midair docking Finally two optimal trajectories a 2 D and 3 D docking trajectories are generated and compared Dynamic wind tunnel test are performed to compare different midair wingtip docking trajectories The results of the optimization concludes that a trajectory with a span wise approach is more desirable since it goes through the least aerodynamic disturbances and requires less control effort to perform the midair docking maneuver **Wind Tunnel Investigation of the Static Stability and Control Effectiveness of a Rotary Tail in a Portable UAV** JOSA(C) R. RIVERA PARÇA,2025-05-22 The Air Force Research Lab Munitions Directorate Flight Vehicles Integration Branch AFRL MNAV developed a manportable carbon fiber matrix UAV with a flexible rectangular wing of 24 span and 6 chord 18 2 length There is a need for the development of smaller and lighter UAV s to perform certain missions The objective of this experimental study was to determine the behavior and the aerodynamic characteristics of rotary tails The bird inspired rotary tail mechanism studied enabled control of two degrees of freedom and was configured to provide elevator deflection and rotation

Its effects on the static stability and control effectiveness were measured using the Air Force Institute of Technology AFIT low speed wind tunnel. The yaw moment provided by each rotary tail was found to be on the same order of magnitude as a typical rudder and in that respect it offers promise as an effective flight control scheme. However it was also found that the side force and consequently the yaw moment generated by the two tail controls elevator deflection and rotation were strongly coupled which could lead to challenging aircraft control issues. A benefit is that the configurations used in this thesis would reduce the storage length by 48%. This work has been selected by scholars as being culturally important and is part of the knowledge base of civilization as we know it. This work was reproduced from the original artifact and remains as true to the original work as possible. Therefore you will see the original copyright references, library stamps as most of these works have been housed in our most important libraries around the world and other notations in the work. This work is in the public domain in the United States of America and possibly other nations. Within the United States you may freely copy and distribute this work as no entity individual or corporate has a copyright on the body of the work. As a reproduction of a historical artifact, this work may contain missing or blurred pages, poor pictures, errant marks, etc. Scholars believe and we concur that this work is important enough to be preserved, reproduced, and made generally available to the public. We appreciate your support of the preservation process and thank you for being an important part of keeping this knowledge alive and relevant.

Robust Aeroservoelastic Stability Analysis Rick Lind, Marty Brenner, 2012-12-06. The series *Advances in Industrial Control* aims to report and encourage technology transfer in control engineering. The rapid development of control technology impacts all areas of the control discipline: New theory, new controllers, actuators, sensors, new industrial processes, computer methods, new applications, new philosophies, new challenges. Much of this development work resides in industrial reports, feasibility study papers, and the reports of advanced collaborative projects. The series offers an opportunity for researchers to present an extended exposition of such new work in all aspects of industrial control for wider and rapid dissemination. The high performance control systems applications in aerospace and astronautics almost have a tradition of exploiting the most advanced control theoretical developments: first, the optimal control and filtering paradigm associated with the names of Kalman, Bucy, Anderson, and Moore found application in the astronautics of the 1960s and 1970s. At the beginning of the 1980s, control theory moved on to robustness, singular values, and μ analysis. This new work was associated with the names of James Doyle, Glover, Balas, among others. The *Advances in Industrial Control* monograph series have published several volumes over the years which have archived the applications experience garnered from applying robust control to the aerospace sector problems. Rick Lind and Marty Brenner add to this set with their volume on robust aeroservoelastic stability. This volume reports the application of the structured singular value to aeroelastic and aeroservoelastic aerospace problems.

Comparative Evaluation of Computational Techniques for Estimating UAV Aerodynamic, Stability and Control Derivatives Robert Ritchie, 2013. *Dynamic System Identification and Modeling of a*

Rotary Wing UAV for Stability and Control Analysis Matthew D. McEwen, Naval Postgraduate School (U.S.), 1998-06-01 This thesis presents a method for the dynamic system identification and simulation model development of a small rotary wing UAV Using aerodynamic parameterization and linear state space modeling techniques the Bergen Industrial UAV was modeled for computer simulation to analyze its inherent stability and control characteristics The NPS designed JANRAD software was utilized to determine the stability and control derivatives used in the simulation model The identification of the UAV dynamic model will aid in the development of closed loop controllers capable of autonomous UAV control The fidelity of the simulation model was verified by comparing the simulation responses with data collected from on board sensors during test flight

The book delves into Aerodynamic Stability Analysis Of Two Heterogeneous Uavs. Aerodynamic Stability Analysis Of Two Heterogeneous Uavs is a vital topic that must be grasped by everyone, from students and scholars to the general public. The book will furnish comprehensive and in-depth insights into Aerodynamic Stability Analysis Of Two Heterogeneous Uavs, encompassing both the fundamentals and more intricate discussions.

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 - Chapter 3: Aerodynamic Stability Analysis Of Two Heterogeneous Uavs in Everyday Life
 - Chapter 4: Aerodynamic Stability Analysis Of Two Heterogeneous Uavs in Specific Contexts
 - Chapter 5: Conclusion
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 6. In chapter 5, this book will draw a conclusion about Aerodynamic Stability Analysis Of Two Heterogeneous Uavs. This chapter will summarize the key points that have been discussed throughout the book.
- The book is crafted in an easy-to-understand language and is complemented by engaging illustrations. This book is highly recommended for anyone seeking to gain a comprehensive understanding of Aerodynamic Stability Analysis Of Two Heterogeneous Uavs.

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