

論文 / 著書情報
Article / Book Information

題目(和文)	小型衛星のための合理的に信頼性の高い姿勢決定アルゴリズムに関する研究
Title(English)	A Study on Reasonably Reliable Attitude Determination Algorithms for Microsatellites
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(博士課程)

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論文要旨

THESIS SUMMARY

専攻：	機械宇宙システム	専攻	申請学位 (専攻分野)：	博士	(学術)
Department of			Academic Degree Requested	Doctor of	(Philosophy)
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要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words)

Title: **A Study on Reasonably Reliable Attitude Determination Algorithms for Microsatellites**

The chapters of this thesis can be summarized as the followings:

Chapter 1. Introduction presents and evaluates about the trend of the development of microsatellites. Together with the expansion of the application of microsatellites, the satellites themselves become more and more complex, their attitude determination (AD) requirements also become more difficult to achieve. There are a variety of difficulties such as noisy high-integrated environment inside spacecraft, quality of low-cost sensors, limited of onboard computer performance and system power generation. Therefore, it is important to balance between the software reliability of AD system with the payment cost by using the reasonably reliable AD algorithms. A review of other past and continuing studies about AD is made. Within this review, the most significant results in AD field, especially the studies with adaptive and high cost-effective methods are indicated. Based upon this overview the problem definitions of this thesis are finally detailed.

Chapter 2. Mathematical Models describes the relevant background theories. These theories provide foundations upon which the rest of this study is based, such as the attitude representation, frames definitions, system and sensor models. Also some basic, well-known and flight-confirmation AD algorithms which are considered as the conventional methods are presented. These basic AD algorithms, quaternion estimator (QUEST), extended Kalman filter (EKF), separate-bias extended Kalman filter (SEKF) and unscented Kalman filter (UKF), will be shown with detail formulas and parameter selections.

Chapter 3. Real-time Tuning Separate-bias Extended Kalman Filter presents the development of a filter for robust spacecraft attitude estimation in the presence of measurement biases. An adaptive mechanism applied during calculation of Kalman gain in the “bias” filter could help the attitude estimator system have a better response to the larger initial estimated error and unpredicted sensor bias models. The RTSEKF has higher accuracy and faster convergence speed than the conventional methods like SEKF, EKF, and even UKF. The computation cost of RTSEKF could be controlled by choosing the accuracy of the optimal process or using the filter reduction form called Adaptive SEKF.

Chapter 4. Real-time Tuning Unscented Kalman Filter presents the development of an automatic and real-time tuning filter for efficient and flexible power consumption in attitude determination. The proposed filter uses attitude data from a higher-accuracy estimator as a truth reference data to compare with estimated attitude data of a lower-accuracy estimator. Based on the difference between the two attitudes above, the cost function is generated then minimized by a numerical optimization process using the downhill simplex algorithm. Through the tuning process, the convergence speed and estimated accuracy of the lower-accuracy estimator are improved. Based on that, to customize the system power consumption, the proposed filter is used with the suitable duration and frequent repeat of turn-on time of the higher-accuracy estimator data.

Chapter 5. A Residual-Based Adaptive Kalman Filter in Fault Detection and Diagnosis presents the development of a residual-based adaptive unscented Kalman filter (AUKF) for attitude estimation and fault detection and diagnosis (FDD). In the proposed AUKF, the measurement noise covariance matrix is real-time updated when the FDD system gives out a warning signal. The FDD includes two filters, residual generators, statistical tests and isolation process. The proposed algorithms in this chapter are light and fast due to the use of simple algorithms during residual generation parts. Therefore not only the requirement of the onboard computer is reduced but also the delay in isolation/adaptive processes are cut down.

Chapter 6. Design, Development and Verification of Attitude Determination and Control System for the TSUBAME Satellite presents the application of the proposed reasonably reliable AD methods for a real microsatellite. The 50kg TSUBAME is a technology demonstration microsatellite for Earth and astronomical observation developed in the Laboratory for Space Systems (LSS) at Tokyo Institute of Technology and ISAS/JAXA. The numerical simulations are conducted based on a hardware-in-the-loop test platform, which was built for simulating on-orbit environment together with real flight-software and sensors, actuators hardware of the TSUBAME. In addition, the further evaluation plans of AD algorithms are prepared for the real flight data of TSUBAME when it exists.

Chapter 7. Conclusions and Future Works makes the concluding remarks with a list of the principal results. The main conclusion of this study is that the proposed reasonably reliable methods are success and suitable to apply for microsatellites under the given assumptions of the system model. Through proposed methods, user can easier to customize the payment cost, such as calculation cost or power

consumption cost, of AD system for achieving a reasonable estimated result. This content makes AD system is more reliable in practical applications. Moreover, with the adaptive mechanisms applying in general part of filters, these proposed methods also can be expanded for other applications in the field optimal estimation of dynamic systems.

In the first *appendix* is shown the formula of some basic knowledge such as: conversions between the two attitude representations, the reference models of Earth magnetic field and Sun vector. The second appendix is shown computer code for the numerical simulation written in the Matlab® m-file and C++ code of flight software for ADS onboard computer. At the end of the thesis are given a list of references.

備考：論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1 copy of 800 Words (English).