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BOOK REVIEW

SOME ALGORITHMS FOR UNMANNED AERIAL VEHICLES NAVIGATION

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Nowadays development of unmanned aerial vehicles (UAV) technology is one of the most dynamically spreading area of hi-tech industries. That is why each effort for improvement of UAV navigation is actual and important; therefore, the appearance of this book is very well-timed. Small UAV navigation hardware and software must satisfy two contradictive requirements: on the one hand, it must be cheap and simple as much as possible in order to comply with the same UAV parameters; on the other hand, it must be accurate enough to perform UAV flight missions, which are getting to be more and more complicated. Achieving acceptable compromise between these requirements is the ultimate goal of this book.

UAV navigation systems are integrated Strapdown Inertial Navigation Systems (SINS) and GPS, and this book is devoted mainly to the algorithms of the inertial navigation. These algorithms are developed based on the specific features of small UAV flight missions: small flight distances, small flight times, small flight speeds, etc. On the other hand, they take into account specific features of the low-cost UAV inertial MEMS-sensors possessing poor accuracy. In order to withstand this disadvantage of sensors, it is necessary to use external correction of inertial sensors data by other sensors readouts (GPS, magnetometers, and barometric altimeters). These features and requirements determine the content of all chapters of this book. The first chapter gives characteristic of contents of the whole book in general and detailed characteristic of content of each next chapter in particular. It helps reader to comprehend the interrelation of each chapter basic results. The second chapter is devoted to the detailed representation of the SINS software structures for conventional SINS using gyros and accelerometers as well as for unconventional gyro-free accelerometer-based SINS. The first of all, the basic relations of classical analytical mechanics are given here as the mathematical background of all results presented in this chapter. New results of the rotational and translational mechanization algorithms are presented. These include:

1. Analytical expressions for approximations of quaternions corresponding to the rigid body small turn. Several methods of these approximations allow variation of the accuracy of kinematic equations integrating, thus making a trade-off between complexity and accuracy of algorithms.

2. The usage of the quadratic spline approximation for quasi-coordinates essentially simplifies the procedures of rotational and translational mechanizations and preserves the accuracy of integration. The algorithms of rotational and translational mechanization for gyro-free accelerometer-based SINS are also considered in this chapter. These algorithms are especially effective for UAV spinning respectively longitudinal axis with large angular rate. It is shown, that increasing of number of the redundant accelerometers above minimal value leads to essential increasing of the accuracy of the rotational and translational mechanization's algorithms of gyro-free SINS. Significant amount of numerical examples illustrate efficiency of proposed algorithms.

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Correction of SINS by external sensors (GPS, magnetometer and barometric altimeter) is the essence of the third chapter. As far as the basic method of the sensors fusion in the navigation systems is the Kalman filtering, several variations of these algorithms along with the gyro's bias compensation are considered. Special attention is paid for usage of the generalized Cholesky factors for improvement of the Kalman filtering procedure convergence. Mathematical modeling proves the efficiency of these algorithms. The 4^{th} chapter is devoted to the methods of SINS initial alignment and calibration of IMU sensors. The MEMS sensors possess reduced accuracy, and in particular, the MEMS gyros cannot measure the Earth rotation rate, so the simplest methods of initial alignment procedures based on the accelerometers and magnetometer readouts are considered. Numerical examples show the efficiency of these methods. The simplest motion table for sensors calibration is proposed, but its simplicity and low cost is reimbursed with algorithms of the experimental data processing. Results of experiments with real accelerometers and rate gyros are given. Solution of the fault detection problem in navigation systems with redundant sensors is described the 5^{th} chapter. The structure of the fault detection system is based on the principle of analytical redundancy, and three algorithms of various complexities based on this principle are created. The choice from these three algorithms might be done by designer taking into account his/her preferences or some other considerations. Numerical examples are good illustration of these algorithms serviceability. The final 6^{th} chapter is devoted to the laboratory, ground and flight testing of integrated SINS for small UAV. Flight-testing was made using small UAV controlled manually as well as automatically. Results of flight experiments were compared with the same results obtained by some COTS-available SINS. This comparison along with results of other testing proves ability of proposed algorithms for the small UAV navigation problem solution. Summarizing all aforementioned it is possible to conclude, that this book will be useful for engineering students, including PhD-level, university educators and practitioners in the vast area of small UAV applications.