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Applications of multi-height sensors data fusion and fault-tolerant Kalman filter in integrated navigation system of UAV

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Abstract

This paper presents a scheme for integrated navigation systems with applications of multi-height sensors data fusion and fault-tolerant Kalman filter(FTKF). It can complete data fusion for multi-height sensors, detect faulty sensors online and conduct fault tolerance in real time. First, implement optimal data fusion of multi-height sensors by weighted method based on output error variance of every height sensor. Then, a fault-tolerant Kalman filter scheme is designed, including three sub-filters(GPS/barometric altimeter /radar altimeter) and a main Kalman filter. The FTKF can detect and isolate the faulty sensors by using fault detection based on method of residuals Chi-Square test and state Chi-Square test with two state vectors propagators. The comparative analysis of simulation results in case of radar altimeter fault shows that the proposed scheme may achieve the expected fault-tolerant performance in integrated navigation system of UAV.

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Keywords: integrated navigation; data fusion; fault-tolerant federated Kalman filter; chi-square test; fault detecition and isolation.

1. Introduction

The Strapdown Inertial Navigation System(SINS) errors would quickly accumulate over time because of inertial element errors, so the SINS can't be used independently for long-term navigation and localization of unmanned aerial vehicle (UAV)[1]. The global positioning system(GPS) can provide location information, which does not diverge over time, so GPS often is used in combination with SINS[2]. But the height error of GPS is very large, especially when all visible satellites are located near the ground plane[3].

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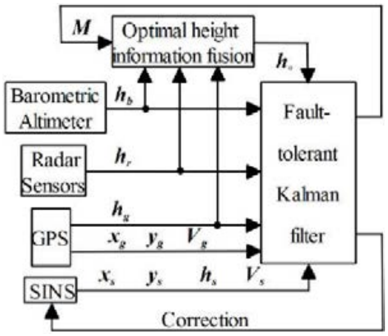

Fig. 1. Diagram of the integrated navigation system.

Currently height sensors mainly are used in UAV include: barometric altimeter, radar altimeter and laser altimeter, etc. They have their own disadvantages, for example when the actual atmospheric conditions are inconsistent with the standard atmosphere, barometric altimeter have a greater principle error; the measurement accuracy of radar altimeter and laser altimeter easily get great affected by ground conditions and inclination of UAV platform[4,5]. Therefore, these height sensors also are not suitable for using independently.

We add barometric altimeter and radar altimeter in integrated navigation system in this paper, and realize optimal height information fusion using weighted method based on output errors variances of sensors, so as to measure the UAV flying height more accurately. In order to make the UAV have the capability of autonomous navigation.

In Fig. 1 shows the diagram of the integrated navigation system. As shown in this figure, in addition to the integrated navigation system includes a variety of height sensors and navigation systems, also contains two block diagram: Optimal height information fusion and Fault-tolerant Kalman filter. In this paper we mainly made specific presentation for these two blocks and simulation to verify the feasibility our design scheme.

2. Optimal height information fusion

In this paper implement optimal data fusion of multi-height sensors by using the weighted method, which can be written as following:

$$h_o = WMH = \left[w_g, w_b, w_r \right]\left[diag(m_g, m_b, m_r) \right]\left[h_g, h_b, h_r \right]^T .$$

where W is a weight matrix; M is a fault matrix; H is a height information matrix.

The principle of this data fusion method is adding weight for output of every height sensor[6], which can be cautlated based on variance error. For example the weight of the GPS output can be wright as:

$$w_g = \frac{1}{\sigma_g^2 \left(1/\sigma_g^2 + 1/\sigma_b^2 + 1/\sigma_r^2 \right)} . \tag{1}$$

where σ_g , σ_b and σ_r - output variance error of GPS, barometric altimeter and radar altimeter.