Low-Cost Miniature GPS/INS for Small UAVs with Reduced Order Kalman Filter

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INTRODUCTION

For the small UAVs, the conventional GPS/INS is difficult to implement because the resource of on-board microprocessor is highly restricted. Therefore, "pseudo-attitude" derived from GPS velocity measurements under the assumption of coordinated flight is typically used. However, the accuracy of pseudo-attitude is considerably degraded under the non-steady flight. In this paper, the authors proposed a low-cost miniature GPS/INS with reduced order EKF capable of producing accurate attitude of small UAVs. The required computing power of the proposed GPS/INS is less than 10% of the conventional GPS/INS with 15 states EKF. The in-flight performance of the proposed GPS/INS was verified through hardware-in-the-loop simulations (HWILs) using GPS RF simulator and experimental flights.

DESIGN OF SIMPLIFIED GPS/INS

The proposed GPS/INS consists of strapdown navigation, a 6 states EKF combined with a simple 3 states complementary filter (CF). Fig.1 shows the block diagram of the proposed GPS/INS. The velocity and attitude is updated using rate and acceleration input from IMU based on the strapdown navigation. The EKF estimates and compensates the attitude error and gyro bias, the simple CF compensates the velocity error. GPS velocity measurements are used on these filters.

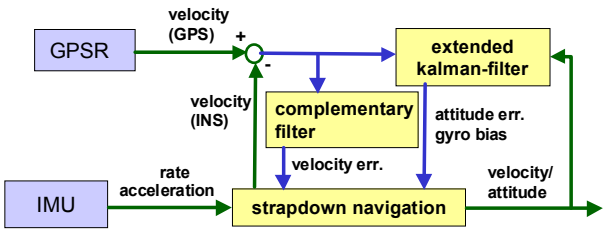
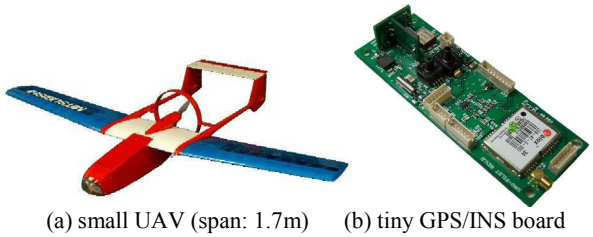


Figure 1. Block diagram of proposed GPS/INS

SIMULATIONS AND FIELD TESTS

The authors developed a small UAV (weight: 2 kg, span; 1.7 m) and a tiny GPS/INS board (weight: 17 gram) for the UAV (Fig.2). Automobile-grade low-cost MEMS inertial sensors, a GPS module, and a 32bit micro-controller are incorporated on the board. The in-flight performance of the proposed GPS/INS was verified through hardware-in-the-loop simulations (HWIL) using GPS RF simulator and experimental flight.



(a) small UAV (span: 1.7m) (b) tiny GPS/INS board

Figure 2. small UAV and MEMS based GPS/INS

For the HWILs, a typical flight pattern of the small UAV consisted of takeoff/climb, cruise and way-point guidance is simulated.

A flight experiment was carried out using an aircraft equipped with a high performance reference GPS/INS. Fig.3 shows the error in the attitude. The error of attitude on roll/pitch/yaw axis was 0.24/0.17/1.4deg (r.m.s.) respectively. A flight experiment using a small UAV shown in Fig.2(a) was also carried out. A photogrammetry–based attitude was used as the reference. The accuracy of attitude was nearly same as that of the conventional GPS/INS.

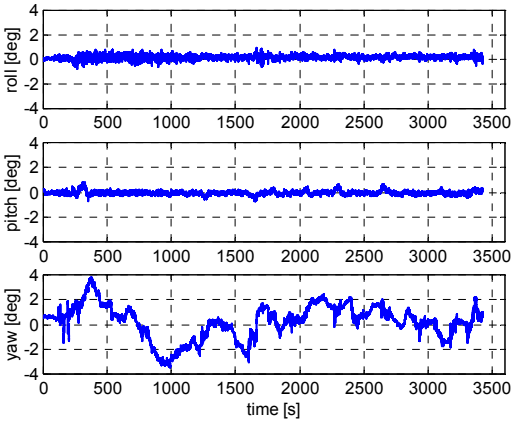


Figure 3. Error history of attitude on flight experiment

CONCLUSION

The proposed reduced-order GPS/INS requires considerably reduced computing power, while the performance is comparable with the conventional low-cost GPS/INS.