THE DEVELOPMENT OF A LOW-COST NAVIGATION SYSTEM USING GPS/RDS TECHNOLOGY

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Keywords: *Unmanned Aerial Vehicle, Global Positioning System, Radio Data System, Navigation System*

Abstract

The vast-growing technology development in flight automation, intelligence navigation and control has made the unmanned aerial vehicles (UAV) playing various roles in military and civil applications. The present paper mainly describes the development of a low-cost navigation system incorporated with the Global Positioning System (GPS) and Radio Data System (RDS) to conduct the autonomous, long endurance flight missions. The navigation system is realized by using an on-board computer system with a real-time operating system to execute the whole missions, which include data acquisition, analysis, storage and communication with a ground station. After many ground and flight tests, the RDS/DGPS system developed here has the capability of real-time data transmission, accurate positioning, low operating cost and wide area coverage.

1. Introduction

To make UAV fly fully autonomously, a precise and reliable navigation system is the same important as the flight control system. In the past, an expensive and heavy inertial navigation system (INS) primarily provides on-board flight navigation capability, even though its error augments with time. Therefore, the implementation of INS is impractical especially for small UAV. With the emergence of GPS, UAV have provided the chances to own cheap and light navigation system, and have expanded their applications at the same time. Recently, owing to the development of differential GPS (DGPS) technology, the GPS accuracy gains much higher improvement, especially providing the real-time positioning capability for UAV [1, 2]. The DGPS positioning signals broadcast mostly via DGPS ground stations or satellites. Many commercial UAV have made use of DGPS for more precise navigation and there are also many researches on DGPS applications with regard to the UAV applications [3].

The Radio Data System (RDS) is developed to broadcast the DGPS signals mainly via the civil radio broadcasting stations rather than a specific DGPS ground station or satellite [4]. The RDS system provides high positioning accuracy, low operation cost and wide coverage. Based on the GPS/RDS technique, one can construct a navigation system for the UAV with higher positioning accuracy and broaden its capability. An on-board computer (OBC) with a real-time operation system (RTOS) acquires, stores and forwards the positioning information and other flight data for navigation. Coordinated and distributed programming guarantees the fail-safe property of the whole navigation system. Besides, a PC-based visual ground test-bed verifies the coordination of software and hardware before the virtual flight.

All components of this navigation system are off-shelf with affordable prices and commercial quality. This system investigates the implementation of GPS/RDS on UAV navigation. At the same time, with the PC-based testing and simulation system, the integration of the whole navigation system will be qualified in advance and one needn't take any risk of failure in the sky. Furthermore, it is a stepping stone to construct a complete autonomous UAV system.

2. Mission Objectives

The mission of the present study is to design and construct an UAV having a high reliability and remote data-acquisition system in the air. Only a robust and fail-safe data-link capability assures the availabilities for long range and long endurance flight operations, which extend the mission capabilities of the UAV. Therefore, the primary mission objective is to verify the data acquisition and communication capability between the UAV and the ground station. Through the data-links, the positioning data from the GPS/RDS and other data from the on-board sensors will be transmitted to the ground station, and the commands from the ground station will at the same time be transmitted to the UAV. Through the positioning data, the RDS coverage will be estimated and one could evaluate the feasibility of the GPS/RDS on the UAV's navigation system. In addition, the operation of the on-board computer will be tested through the downlink data in the ground station.

In the near future, this navigation system will be integrated with the autopilot control system and be used as an aerial test-bed for other new sensor technology such as MEMS.

3. RDS-GPS DGPS system

In September 1988, the British Broadcasting Co. (BBS) began to operate the Radio Data System (RDS) as a new public service [4]. The result was successful because the technology used was allowed for multiple new functions to be transmitted. In January 1993, the Electronic Industries Association (EIA) and the National Association of Broadcasters (NAB) put in effect the U.S. RDS standard called the Radio Broadcast Data System (RBDS) which operates as an 57kHz FM subcarrier and implements all of the RDS features. These Groups control the functionality of the RBDS. Different groups are assigned to handle the radio text, traffic, time, and services such as DGPS [4].

Differential Corrections Inc. (DCI) was founded in 1992 to take advantage of these new technologies by combining them to provide broadcast information services to improve the accuracy of GPS receivers in real-time applications. Using a patented approach to solve the accuracy issue, DCI was able to improve commercial GPS accuracy from the standard +100 meters to less than one meter. DCI delivers this service to users by means of FM radio subcarrier, using the Radio Broadcast Data System (RBDS) format at 57kHz with as little as five percent injection. The data that are broadcasting are known as "differential corrections," or Differential Global Positioning System (DGPS) services. Users who subscribe this service can receive these corrections [4].

In Taiwan, four radio stations are now established to broadcast differential corrections signals, which has the same concept of signal broadcasting as the RDS discussed above. Therefore, interesting users can receive differential corrections signals anywhere in Taiwan, which is now getting more popular for use in vehicle navigation and positioning corrections.

4. On-Board Computer System

In order to store as many data as possible and to execute some primary vehicle controls, there should have an on-board computer (OBC) system aboard the UAV to handle the assigned tasks in real time. In this paper, the domestic-made PC-104 industrial standard computer is chosen to undertake those tasks. There are several modules in the OBC system including one analog-to-digital convert module, one serial communication module, one CPU module and one servo control module. Also, the OBC system provides 6 RS232 communication ports, 16 12-bits ADC channels, one x486 CPU, and 6 servo control outputs for further use. For the sake of avoiding the data loss in the critical environment inside the vehicle, a solid-state compact flash disk is used. In the earlier experiment, two GPS receivers are installed, one with RDS aid, the other is just single, to compare the difference of the positioning accuracy during the tests. A 900MHz wireless modem is equipped to download the vehicle status data and receive the upload commands. The whole OBC modules used here is shown in Figure 1.

It is also important to choose a computer operating system to handle the on-line computer hardware. In this paper, the commercial QNX operating system is chosen. QNX is a real time operating system with micro kernel architecture and inter process communication (IPC) feature. It provides a robust and reliable operating platform. In the OBC system, QNX handles all the tasks including acquire data from sensors, convert raw data to engineering data, store data in database, wait clients request data, and send data to terminal devices. Figure 2 clearly depicts the OBC hardware architecture. In order to simplify the post processing work, all data obtained from the sensors and instruments will be assigned a time tag to identify the sampling sequence using the GPS 1pps signal and an on-board real time clock with a frequency of 5.

5. Ground Station

The ground station is made up with a laptop computer, a wireless modem and user graphic interface (GUI) program written by LabVIEW. The ground station receives the UAV status information and uploads commands to the vehicle via a wireless modem. The GUI displays the vehicle house keeping information, position, sensors information and payload information on the screen. The software architecture of the system is shown in Figure 3.

6. Flight Vehicle

A modified home-made model airplane “Piper J3 Cub”, as shown in Figure 4, is used to carry all the OBC-related equipment and GPS/RDS navigation system. All necessary harness is pre-installed and well aligned in order to provide a clear space for the payload. The electromagnetic interference (EMI) generated from the OBC and wireless modem was very serious in the initial development phase, which was then successfully resolved by wrapping the EMI tape around the harness to avoid the EMI problem. The GPS antenna, wireless modem antenna and pittot tube were pre-installed in the wing. The take-off weight of the model with all equipment aboard is 7 kg.

7. Experiments and Flight Tests

All the experiments and flight tests were carried out in the Aerospace Technology Research Center (ASTRC) of NCKU. Some experimental results were obtained before the Selective Availability (SA) was still turned on before 1 May 2000. Of course, after that date of turning off the SA, the GPS can provide much accurate positioning data then ever. In order to validate the functionality of the OBC and RDS/GPS system at the same time, a serial of ground tests were performed before the real flight tests proceed, which including the static tests and kinematic tests. All data collected in the ground tests were stored in the solid-state hard disk of the OBC system. After those tests, data was down load to the ground station. Figure 5 illustrates the ground tracks of the GPS/RDS signals around the ASTRC of the kinematic 2D tests. Very good repeatability of the positioning data is seen in this figure. In addition, the ground test result shows that the RDS/GPS static positioning accuracy is about 1 m as well as the vendor’s specification in comparison with a known point “ASTRC 1” in ASTRC. The flight tests were then performed after both OBC and GPS/RDS system were successfully tested and the ground station was identified. Figures 6, 7 and 8 illustrate some of the flight test results during the take-off phase. It is noted that the GPS/RDS flight data were transmitted down to the ground in real time, which can be displayed on the screen of the ground personal computer system with the digital map. These results also indicate that the RDS/GPS system can provide the positioning accuracy less then 10m, which is better than when a single-GPS is just used.

8. Concluding Remarks

This paper presents the development of a low-cost navigation system using the GPS/RDS navigation system for an unmanned aerial vehicle to conduct the real-time data transmission through the on-board computer system as an on-line measurement, data processing and navigation system. The input ports of the OBC provide the access of low cost and high reliability navigation data, including GPS/RDS system, pressure sensors, and airborne safe-false conditions. Many ground and airborne flight tests have demonstrated that the whole system is very reliable and able to transmit data using the OBC and its real-time operating system (RTOS). Because the OBC system is so developed to have the capability of adding devices in the inputs and outputs ports for future expansion, the control law design, for instance, can then be added to the OBC to fly the UAV automatically. In summary, the main characteristic of the present low-cost navigation and OBC system can provide as a platform for the users to test their new sensors or control laws aboard an UAV. In order to reduce the risk during the flight tests, the present system can also perform as a ground simulator to check the whole system design before one starts the real hardware construction. This is the main concept in the developing the UAV navigation system to be low cost and reliable for flight testing.

Acknowledgement

This work is supported in part by National Science Council, ROC, Contract no. NSC 89-2612-E-006-016 and National Defense Foundation, ROC.

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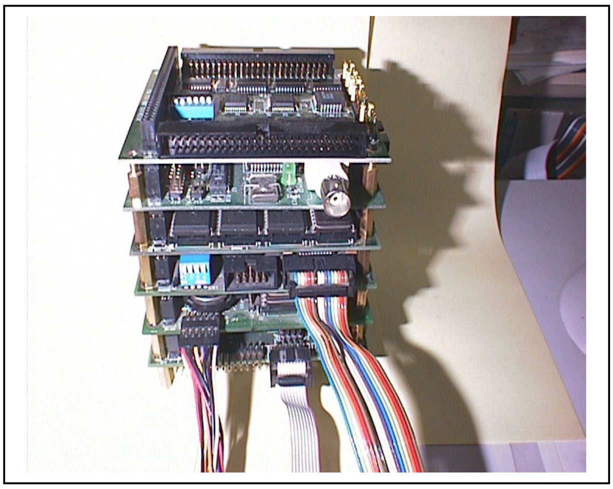

Figure 1 PC-104 on-board computer

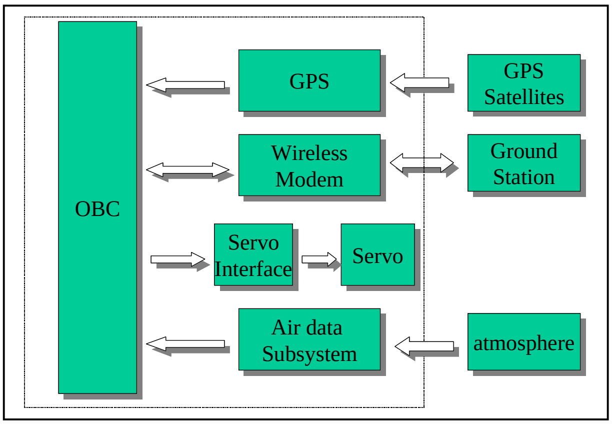

Figure 2 OBC hardware architecture

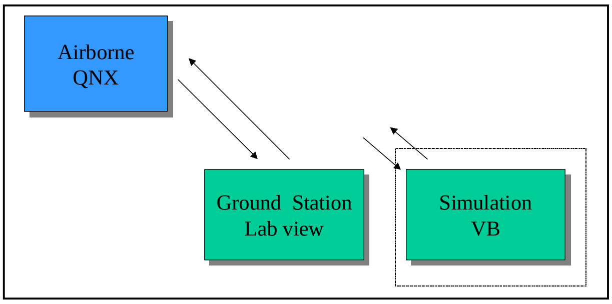

Figure 3 Software architecture of the system

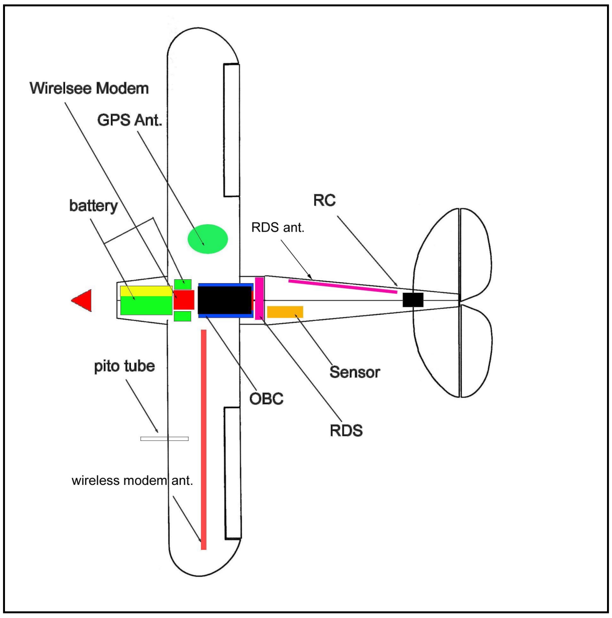

Figure 4 Piper J3 CUB

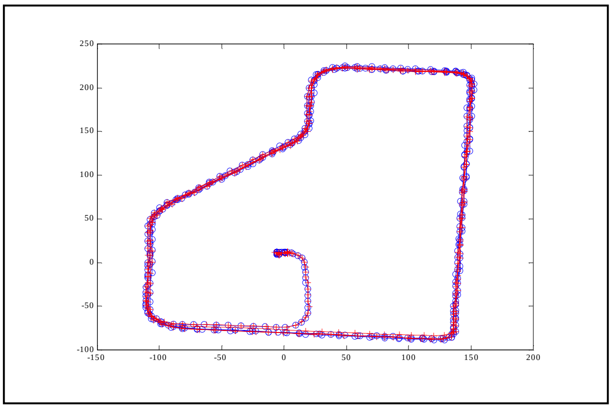

Figure 5 Kinematic 2D test in ASTRC

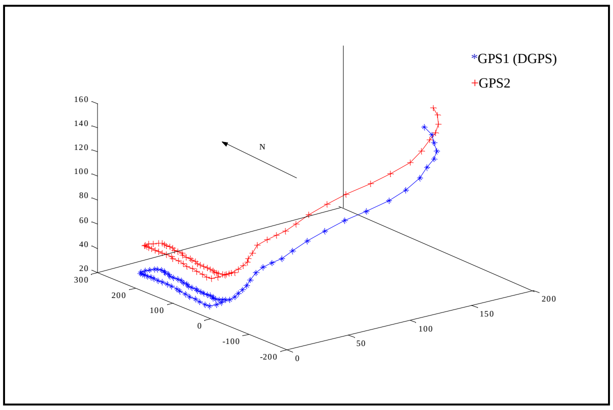

Figure 6 Flight test during take off

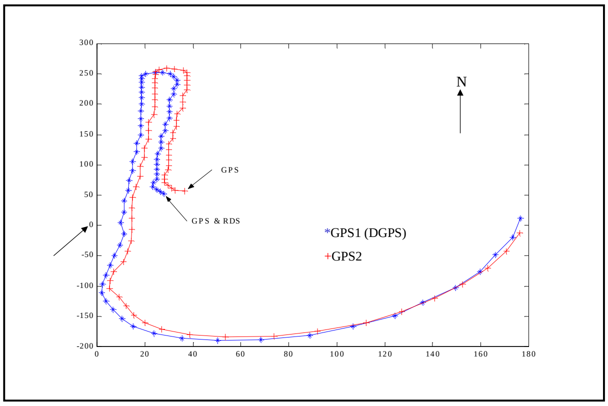

Figure 7 Top view of the take off track

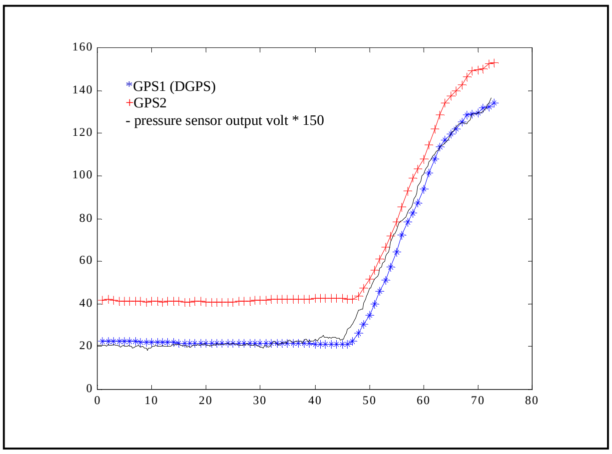

Figure 8 Altitude variation during takes off