AC 2008-1035: DEVELOPMENT OF A PC-CONTROLLED AUTONOMOUS AERIAL ROBOT

Sung Kyung Hong, Sejong University

Min-kee Hong, Cheong-Shim International Academy

Yoon-ki Hong, Cheong-Shim International Academy

Jong-hyun Hwang, Sejong University

Development of a PC- Controlled Autonomous Aerial Robot

Abstract

The currently employed autonomous aerial robot uses a complex system of GPS(Global Positioning System), INS(Inertial Navigation System), pressure meter, and so on. Also, the aerial robot carries the control algorithm in FCC(Flight Control Computers). However, in the case of a small aerial robot or MAV(Micro Air vehicle), it is impossible to load these bulky payloads due to the physical limitations. Therefore, this research sets its objectives on making the simplest and smallest autonomous aerial robot. For this project, we tried to build a PC-Controlled Autonomous Aerial Robot. The project provides an opportunity for the high school student to perform a broad range of engineering activities with guidance of trained graduate students.

Introduction

The Sejong University is developing a PC-Controlled aerial robot that can fly autonomously. The aerial robot is practically equivalent to a radio-controlled(RC) plane, except the aerial robot has a ground based PC for the autonomous flight along the preset course while taking positioning signal by the on board GPS receiver and Bluetooth devices. A PC-to-RC circuit adopted in this research provides a bridge between the control software implemented on the PC and conventional RC transmitter.

With this configuration the aerial robot is about the simplest autonomous aerial robot possible. This simplicity makes it easy for students unfamiliar with autonomous aerial robots to understand the system, keeps the system cost low, and allows the existence of a truly miniature autonomous aerial robots. The simplicity also provides engineering challenges, such as navigating using only the infrequent sensor data from the GPS.

Graduate students from the department of Aerospace Engineering are participating in this project, conducted over 10 months. While selected high school students are participating as interns funded by Korea Research Foundation(KRF) with the intention of attracting scientific talent students into the mechatronics engineering fields. The project has required students to perform a broad range of engineering activities, and to document their work well enough for succeeding classes to continue the work. The goal of the project was to create an autonomous aerial robot using a commercially available GPS receiver as its sole sensor. The single sensor arrangement has two main advantage : low cost and ability for miniaturization. Miniaturization is an important goal for groups like armed force, whose desire for a backpackable unmanned vehicles lead to the DARPA MAV program, which created aircraft no larger than 6 inches in any dimension and required extensive miniaturization work[1].

This paper will describe the PC-controlled aerial robot, its control algorithm and electronic assembly, as well as the educational uses it has been.

Aerial Robot System

(1) Aircraft

The model aircraft used in this research is a miniature vehicle (Overall length: 720mm / overall width: 1,000mm / weight: 350g). In order to prevent damages caused by the novice controls of the students the aircraft was built with EPP(Expanded PolyPropylene) material. For the limitations of space and load weight of aircraft, only GPS is loaded. Consequently the attitude and rate of the aircraft (conventionally they can be acquired from INS/AHRS(Attitude Heading Reference System)) will be unknown and this may lead to unstable flight; to compromise the aircraft has been given a relatively large dihedral angle for ensuring roll static stability Because the vehicle must either be open-loop stable or with very slowly diverging unstable modes[2] in order to be successfully controlled with the low-bandwidth sensing used in system.

Figure 1. Model Aircraft

(2) GPS

The aircraft must use a small size GPS to meet the physical limitations. The employed GPS is a 'micro 32 channels MediaTek MT3' used by the present car navigation systems. The positional deviation is 3m CEP (50%), and the signal update rate is 1Hz.

- Based on MediaTek Single Chip Architecture.
- Low power consumption：55mA typical @ acquisition, 30mA typical @ tracking
- High sensitivity：Up to -158 dBm tracking, superior urban performances
- Position accuracy：< 3m CEP (50%) without SA (horizontal)
- Cold Start is under 37 seconds (Typical)
- Data output baud rate： 9600/38400/57600/115200 bps (Default 9600)

(3) Bluetooth

Bluetooth, a commercial tool for wireless communication within short ranges (< 10m), has been extended its communication radius to 1 km by using extension antennas. Parani-SD100 from Sena Inc. was adopted as a Bluetooth device. By incorporations of the antenna 'Patch' on the ground base and the antenna 'Dipole' on the aircraft, the waypoint signals from GPS and Bluetooth can reach to the ground to the extent of 500m.

Figure 2. GPS & Bluetooth

(4) Ground Control System & Flight Control System
Conventionally, in unmanned aerial vehicles (UAV), the FCC containing autopilot algorithms are loaded on the aircraft and flight status are monitored on ground level through Ground Control Systems (GCS). However, for the objective of simplifications, FCC is merged into GCS on the ground level. With received position data of aircraft, the ground FCC calculates the shortest route to go predetermined waypoints and sends generated commands of control surfaces (elevator, aileron, rudder, and throttle) through the PC to RC signal converter. By using PC to RC converter, the existing commercial RC transceiver can be utilized as an uplink tool.

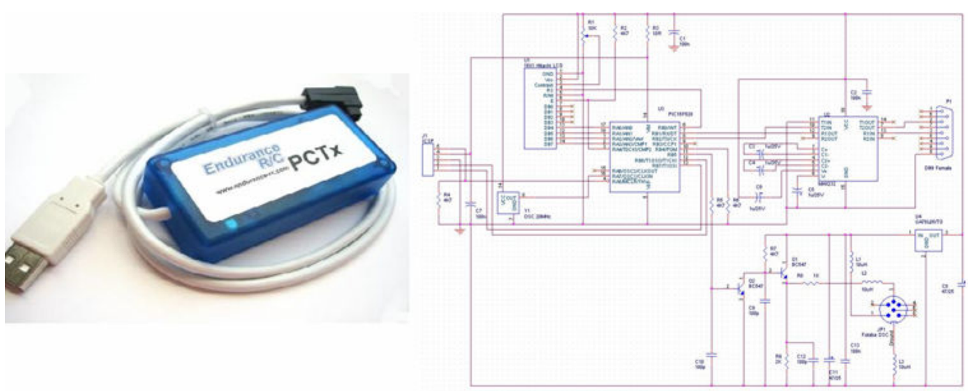

Figure 3. PC to RC & Circuit Diagram

The overall schematic diagram of our system is as follows

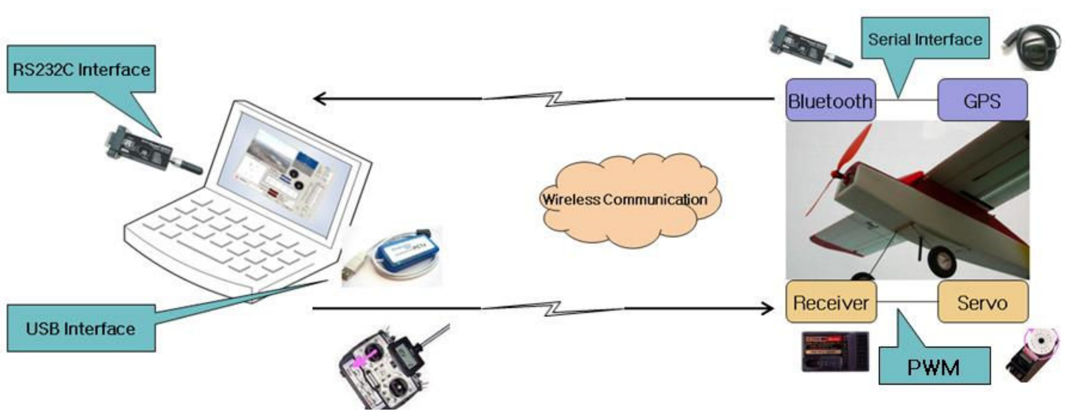

Figure 4. System Integration

Algorithm Description

The Guidance loop calculate the cross-track error, which is the vehicle's perpendicular distance from the course line in 2-dimension space. The heading Command differs from the course leg's heading by an amount proportional to the cross-track error, up to a maximum 0g 90 degrees. For example, when cross-track error is zero, the heading command is the is the course-leg heading, and as the cross-track error increase, the heading command changes to point more and more towards the course line, until it is perpendicular to the course line for large cross-track error[3]. Figure 5 illustrates the parameters and geometry. And Figure 6 illustrates simulation of vehicle by proportional gain change.

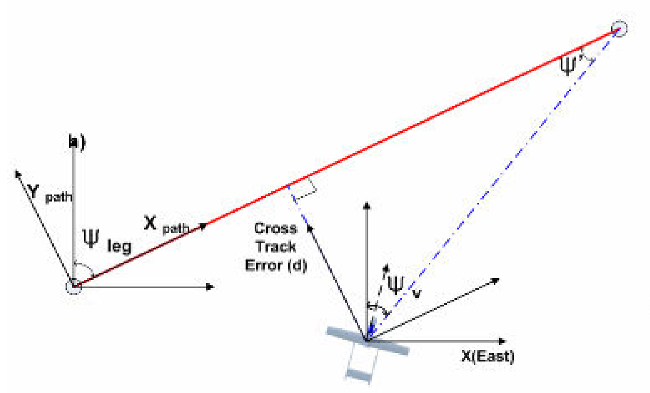

Figure 5. parameters and geomatry

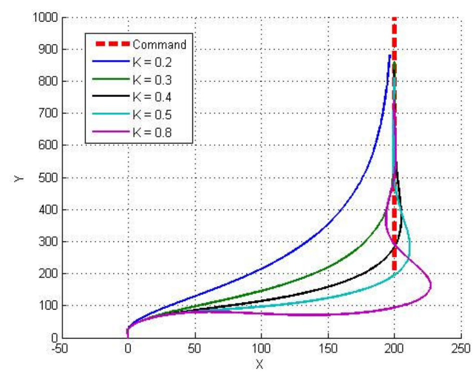

Figure 6. simulation by proportional gain change

Course Description

1. Basic Flight Theory

This project is an education towards high school students who never had any experience in the field of aerospace engineering. Therefore, before delving into the in-depth autonomous aerial robot project, providing the basic principles of flight theory seemed necessary. With the explanation for each part of the aircraft, such as interrelation lift, drag, gravity, and thrust the students successfully comprehended the 6 degree of freedom motions in aircrafts. We use audio-visual materials in NASA's homepage[4], explain basic flight theory and aircraft structure.

2. Introduction to Autonomous Aerial Robot System

The general contents of autonomous flight robot are examined. The autonomous aerial robots that are used presently are introduced, and the critical subsystems of aerial robots are observed. With focus of the challenging problems of MAVs, the possibilities that our proposed scheme could be implemented on MAV are suggested.

3. Introduction to the Control System

The basic outlines of the control system are introduced. The superiorities of feedback (closed loop) system over open loop system are emphasized. To implement the closed loop system into aerial robots, the route following with positioning feedback control schemes are suggested.

Figure 7. team members

4. Construct the Model Aircraft
To trigger the interests of students, each student constructs model aircrafts by themselves. By assembling the actuator, linkage, servo, motor and propeller, we improved understanding about structure and shape of the aircraft.

5. Downlink Communication System (Bluetooth)
Data communications through Bluetooth are experimented. In the experiments, findings the possible operating ranges are focused. By sending and receiving data each other through Laptop Computer connected with Bluetooth, students could calculate the actual communication distance. Students experiment that exchange data that use Hyper-terminal or serial communication program after connect each Bluetooth on two computers.

6. GPS (Navigation)
The principles of 3-dimensional localization are presented, and the applications of these principles into satellite based GPS navigation are introduced. The location data is defined by the NMEA 0183 protocol, and the students learned how to recognize GPGGA signal data. Students connect GPS in Bluetooth that experimented at last time. Then, students receive GPS signal in other computer that is connected by Bluetooth. The position signals are each 4 corners of Sejong University's playground.

Point	Latitude(N)	Longitude(E)
P1	3733.033921	12704.492690
P2	3733.062975	12704.518128
P3	3733.044623	12704.547626
P4	3732.997005	12704.505133
P5	3733.015627	12704.470839
P6	3733.033022	12704.491030

Table 1. GPS Data

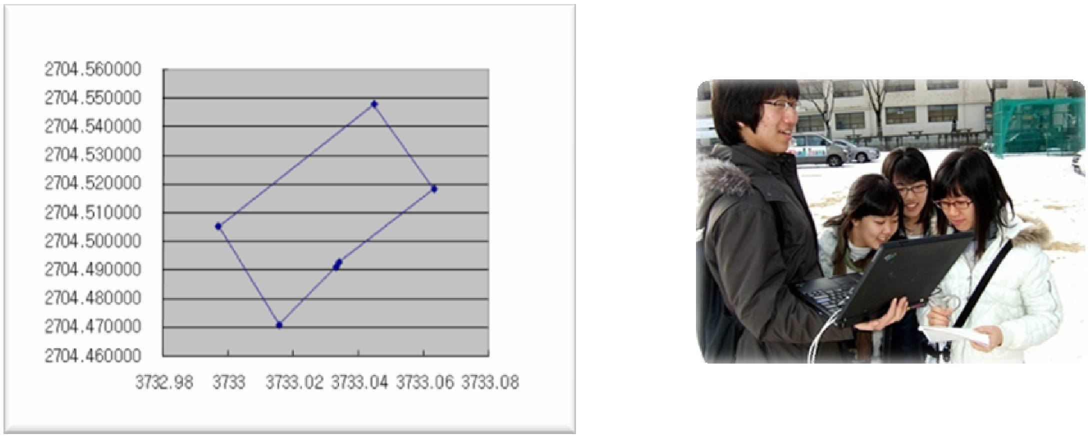

Figure 8. GPS data receive test

7. Control Algorithm

The simple autopilot algorithms that can calculate how to fly to the desired locations are implemented in the FCC. For the way point navigation, we calculate the destined coordinates' shortest and most suitable route and activate the actuators of control surfaces. By using the change in positions of the aircraft caused by the actuators, students study how the aircraft moves to the destination by the algorithm.

8. Ground Control System (Programming)

At this time, we study the ground control system (GCS) that delivers commands to the aircraft after observing the position of it on the ground. GCS changes gain, and transmit flight command to vehicle after shows vehicle's state that enter by real time through Bluetooth. The ability to change gain without reprogramming the FCC is a key to the autonomous aerial robot use as an educational tool, since students may test various gain quickly.

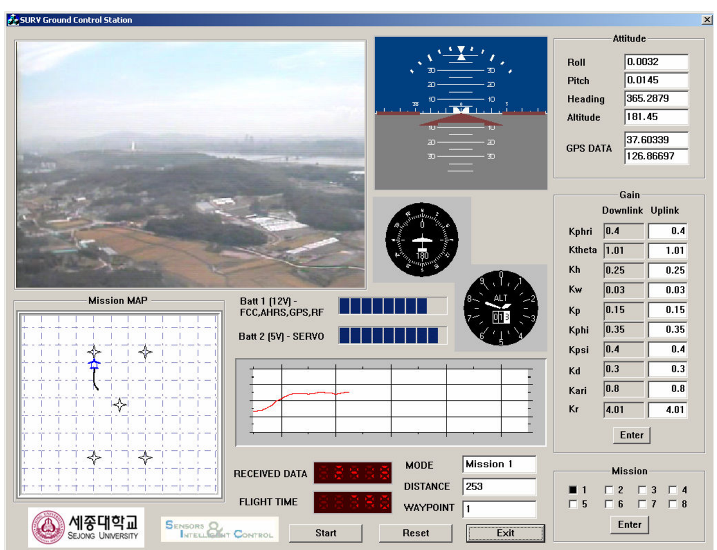

Figure 9. Ground Control System

9. Ground Test
By using ground HILS (hardware in the loop simulation), we tested combined real hardware with aerodynamic simulations. Through this ground tests, the reliabilities of both software and hardware can be verified. Because there are a lot of various uncertainly constituents about flight performance, students must experiment the ground test that confirm performance of the vehicle before flight.

10. Flight Test
After the verification of the total system of aerial robot through ground tests we are conducting a real flight tests. Through the test we make our system one step closer to perfectness. Figure 11 illustrate flight path by predesigned command.

Figure 10. Ground Test & Test Flight

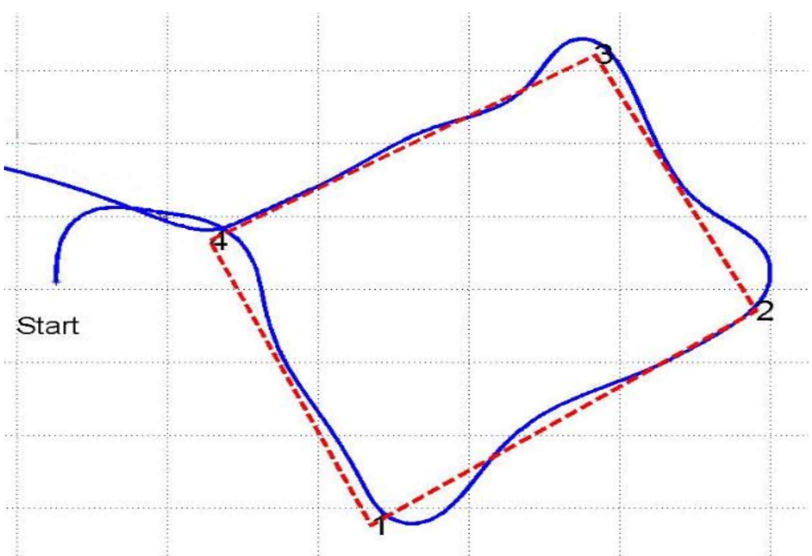

Figure 11. Result Flight

Conclusion

The advantages of going through this project are as follows.
1. Simplified system helps so that high school students who did not contact autonomous aerial robot may understand easily. It can provoke interest to related field by experimenting directly with understanding of simplified system. Also, it provides students an opportunity to apply the knowledge they learned in class.
2. The vehicle that replace FCC by GCS loads only GPS does not require expensive inertia sensor or air data sensor, can make by cheap price. Also, It is possible to achieve small size and light weight because required loading space is decrescent. And It is enable direct application to MAV.

Bibliography

1. S. Morries and M. Holden, "Design of Micro Air Vehicle and Flight Test Validation", Conference on Fixed, Flapping and Rotary Wing Vehicles at Very Low Reynolds Numbers, University of Notre Dame, June 2000
2. K. Ogata, Modern Control Engineering, 4th edition, Prentice Hall, 2002
3. Micheal E.Holden, "Low-Cost Autonomous Vehicles Using Just GPS", *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition, 2004, ASEE, Salt Lake City*
4. http://www.grc.nasa.gov/WWW/K-12/airplane/bga.html