Radio Flyers

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Contents

List of Figures

1 Introduction

This project explores the use of available motion and positioning sensors to develop an automated control system for an existing aerial platform in order to conduct surveillance without the need of a human operator.

2 Problem Statement and Proposed Solution

Existing Unmanned Aerial Vehicle (UAV) technology has a high cost barrier and requires constant supervision for control. The Raven system, for example, requires the employment of multiple U.S. Army field units costs around $200,000 for the airframe alone and requires a remote operator. A more practical approach would involve uploading a pre-defined mission plan to an autopilot on-board and having the UAV fly autonomously. This will allow the operator to focus only on gathering the required intelligence rather than on flying the aircraft to and from the target area. This system would allow an operator to take control if desired. Additionally, we wish to demonstrate that such a system could be produced at a much lower cost than typical UAVs.

While an inexpensive, yet readily available, GPS receiver as well as an accelerometer and barometer will be employed to guide the microcontroller based autopilot. Surveillance data will be acquired using a CCD camera and transmitted wirelessly to the ground station.

3 System Requirements

There are a number of primary system requirements that must be fulfilled to address the problem at hand. In any aerial system, safety must be the first priority. Therefore, one requirement is to have a robust method of allowing the user to control the aircraft if the autopilot system malfunctions or the system loses power.

The second consideration is to purchase an RC plane that will be able to fly with the weight of all the components required by the autopilot system. Light radio controlled aircrafts have limited payload capacities which must be strictly adhered to. Overloading the aircraft will necessitate a larger motor, which in turn requires a bigger battery, both of which add more weight intrinsically. The aircraft will require enough payload capacity to carry the autopilot board, the video camera, wireless transmitter, and any additional battery capacity required by those systems. Comparing the typical weights of these components, the RC plane will need to be able to carry a payload of at least 1 pound.

A third consideration is the usability of the autopilot. In order to conduct surveillance, the aircraft will need to provide a stable platform for the camera. To that end, we will need to ensure that the autopilot control software provides smooth and pertinent corrections to fly the aircraft, and that the quality and variety of sensor data provided to the autopilot is sufficient to derive accurate position and velocity inputs to the autopilot. This will likely require that the microcontroller perform integral and differential calculus.

Another desgin requirement will be to choose the correct wireless interface for the UAV. The handheld radio controller needs at least 5 channels (4 for primary flight control and a 5th to engage the autopilot). The video transmitter will need to be on a noninterfering wireless band that is powerful enough to send usable data over at least the line-of-sight range of the aircraft.

The system can be powered by two sets of on on-board batteries, the type of batteries are yet to be determined. The first set will power the microcontroller, camera, and sensors. The second set, providing higher current, will provide sufficient power to the servomotors that are used to propel and maneuver.

The user interface will consist of inputting the desired GPS coordinates and taking radio control for takeoff, landing and manual override. An interface to view the video will also be required. This can be accomplished by connecting the video receiver to a monitor to show real-time flight video.

4 Block Diagram

4.1 Overall System

A block diagram detailing all of the major components for the proposed UAV is shown in Figure 1.

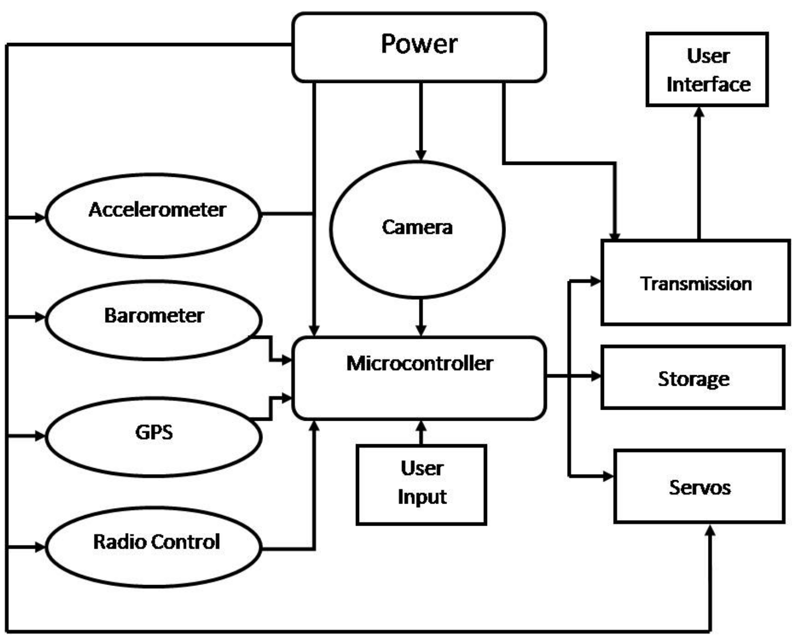

Figure 1: Block diagram of major components

4.2 Subsystem and Interface Requirements

The UAV will need to be able to accurately track position, as well as roll, pitch and yaw. The sensors shown in Figure 1. will provide the UAV with information for roll, pitch and yaw, while GPS receivers can provide the location with an accuracy to at most 15 ft. Data will be taken via on-board cameras and both stored via an SD-card and transmitted to a remote user. The user will have the option of controlling the UAV if desired.

4.3 Future Enhancement requirements

Future enhancements for the proposed UAV are under consideration. The on-board camera is planned to be stationary, but can be upgraded to a pan/tilt camera by employing another set of servos that can be controlled by radio control. Another enhancement is the application of solar panels to the wings of the airplane. These are commercially available for purchase and could be utilized to extend the operational life of the system before needing to recharge.

5 High Level Decisions

The manual and radio control interface will most likely be the same RC control unit that the aerospace engineers use. This system will be used for take off, landing, and manual override of the UAV.

The autopilot algorithm will start with a user input of GPS coordinates into the microcontroller. This will constitute as the flight plan. The GPS and barometer will provide x, y and z coordinates that will determine where the plane is in space. The autopilot algorithm will then track these coordinates relative to the current location of the UAV, decide on a flight plan and prompt the servo motors to respond appropriately. The servo motors will also need to be able to respond to accelerometer readings for orientation in the case of sudden wind gusts and to manage turns. The camera on board will send real-time visual data back to a user interface.

The GPS will interface with the microcontroller using a digital to serial protocol using a transmit (Tx) and receive (Rx) pins. The barometer connects to the microcontroller using I^2C protocol which requires data and clock pins. The accelerometer provides an analog out signal which will connect to the microcontroller via three pins (x, y, z). The camera has a TTL serial to digital output which connects to the microcontroller via Tx and Rx pins. The video transmitter connects to the microcontroller with a serial to digital protocol using Tx and Rx pins. The SD card interfaces using SPI to the microcontroller. A computer will use a USB interface with the microcontroller to program the flight plan. A radio controller will transmit user inputs to the receiver on-board the airplane. The receiver will then pass these inputs to the microcontroller. The microcontroller will decide (using the autopilot toggle input) whether or not to pass the user inputs to the servos or ignore them and send the autopilot output to the servos. This will require at least 5 digital pins (contingent on necessary control channels) between the receiver and microcontroller and at least 4 digital pins between the microcontroller and servos (one less than the radio controller sends). In total, the microprocessor will require at least 17 digital I/O pins, 3 analog input pins, a USB interface, and an SPI interface.

6 Open Questions

Several potential problems are foreseen in the testing and demonstration of the plane's autopilot. The first problem, is that we will be unable to test the autopilot before the board is built. This will require a test bench for the algorithm. The same holds true for testing of the GPS. A second problem arises with the data collection for analysis of a test flight. We also see an issue with the sensitivity of the system, mainly the accelerometer, with detecting and reacting to unpredictable vibrations and wind gusts. A third problem is the potential interference between the University's WiFi network and the RC controller since they both operate in the 2.4 GHz range. Our final problem will be the scale of our demo. For example, we need a testing area large enough to make obvious that the flight pattern is being acquired from GPS data, but small enough where we can keep the system within eyesight and take manual control if needed.

7 Major Component Costs

Below are listed typical costs for the major components required for this UAV:

Hobbyking Bixler EPO ARF Aircraft Kit - $70
Turnigy 9 Channel Radio - $40
12 Channel 900Mhz Tx/Rx video system with CCD camera - $57
3 Axis Accelerometer - $25
Barometric Pressure Sensor - $9
GPS module - $40
Microcontroller board - $50
This will result in a total of $291

8 Conclusion

This project expands the usefulness of UAV technology by making it more automated and lowering the cost barrier of existing technology. By using a commercial RC plane and consumer level GPS, accelerometer and barometer, we will be able to accomplish this task within the five hundred dollar budget. This high level design has allowed us to consider potential problems and to determine how to manage the complexity of the overall system.