Fixed-Wing Survey Drone

Functional Description and System Block Diagram

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Introduction

This project will develop an unmanned aerial system, commonly referred to as a "drone". The drone will start as a commercially-available radio-controlled airplane. The addition of microcontrollers, cameras, and other sensors will allow the aircraft to operate autonomously. The purpose of the drone is to perform aerial imaging surveys of user-specified regions, such as crop fields. Such systems are commercially available, but are expensive ($10000+) and lack some features our drone will provide.

The market for unmanned aerial systems is projected to grow by $82 billion from 2015 to 2025, and create over 100,000 new jobs [1]. The majority of this growth is expected to come from "precision farming." This approach to agriculture uses large amounts of data to determine the health and quality of crops. Such data can include soil moisture from sensors spread throughout a field, and various types of aerial imaging. The goal is to use this data to determine where resources such as fertilizer and water are needed most, therefore avoiding waste and improving crop yield.

This project will develop a drone to provide imagery for use in precision farming applications. By producing a high-resolution image of a crop field using specific optical filters, health of the crops can be determined. An important feature of our drone is its autonomous nature. The operator first defines the boundaries of the survey area via GPS coordinates. Next, the drone is hand-launched somewhere near the field. The drone determines its location (via GPS) and calculates a navigational route allowing it to image the entire area. The drone lands in the location from which it was launched, or some other user-specified location. The images are assembled into a single large image which is then emailed to the user, along with a notification that the drone is ready for retrieval.

Project description

The drone will accept GPS (global positioning system) coordinates of a user-selected area of land. In this way, a particular region can be specified for the drone to survey. Using that data, it will generate its own route to navigate the field and capture GPS-registered images of the entire area. The drone will be entirely autonomous, piloting itself on the self-generated flight path. It will also have the ability to detect obstacles (such as towers) during flight, and maneuver to avoid those obstacles. When the survey is complete, software will assemble all of the images it has captured into a single, high-resolution image of the entire area. The GPS data stored with each image will allow the images to be assembled into a single large image. After surveying the entire area, the plane will land where it was launched, or at another user-specified (via GPS) location. The drone will contain a wireless data link to enable internet access via a consumer wireless network. After landing, the drone will email the user that the survey is complete and that the plane is ready to be picked up. A link to the high-resolution image will also be included.

The survey drone will have the following components:

- Ready-to-fly, commercial, radio control airplane (hand launched, electrically powered, servos and radio receiver included)
- Two digital cameras: one for high-resolution imagery, and another for obstacle avoidance
- Two microcontrollers: one for high-level autonomous behavior and image processing, and another for low-level sensor management
- GPS Receiver
- An inertial measurement unit (IMU) containing three accelerometers, three gyroscopes, three magnetometers, and a barometric sensor (for altitude).
- Data link module used for email

Block diagrams and functional descriptions

The fixed-wing survey drone has two primary subsystems. The first is the autopilot system, which includes the front facing camera, GPS receiver, the IMU, and both of the microcontrollers. The second subsystem provides image processing. This system utilizes the BeagleBone Black (or equivalent) microcontroller, GPS receiver, and image processing software to capture all of the images and to create the final complete image.

Two separate microcontrollers are are necessary for the two types of functionality required on the drone. The BeagleBone Black (BBB) is a linux-based machine and excels in multitasking, so it will be used for the overall system control. However, more precise timing is needed to process the real-time responses from the IMU and other sensors. To sustain precise flight control, the plane must receive accurate signals. An Atmel ATmega series (or equivalent) microcontroller has very precise timing and will be used for this function. The two separate microcontrollers will assure precise control of the aircraft while maintaining fast processing ability for the other systems.

Autopilot System

The autopilot subsystem (see Figure 1) runs on the BBB, a Linux-based single-board computer. The developed autopilot software will be loaded onto the BBB where a route for the aircraft will be automatically generated based on the user input. Input data will be sent to the BBB to process and establish navigational waypoints. The aircraft will follow its set path autonomously, driven by the autopilot system. If emergency remote control is necessary, manual operation can be enabled at any point during flight. A standard R/C transmitter will initiate a signal to the BBB to shut down, and the aircraft will respond only to manual control. The transmitter’s signals will manipulate the servos and electronic speed control on the aircraft to direct flight.

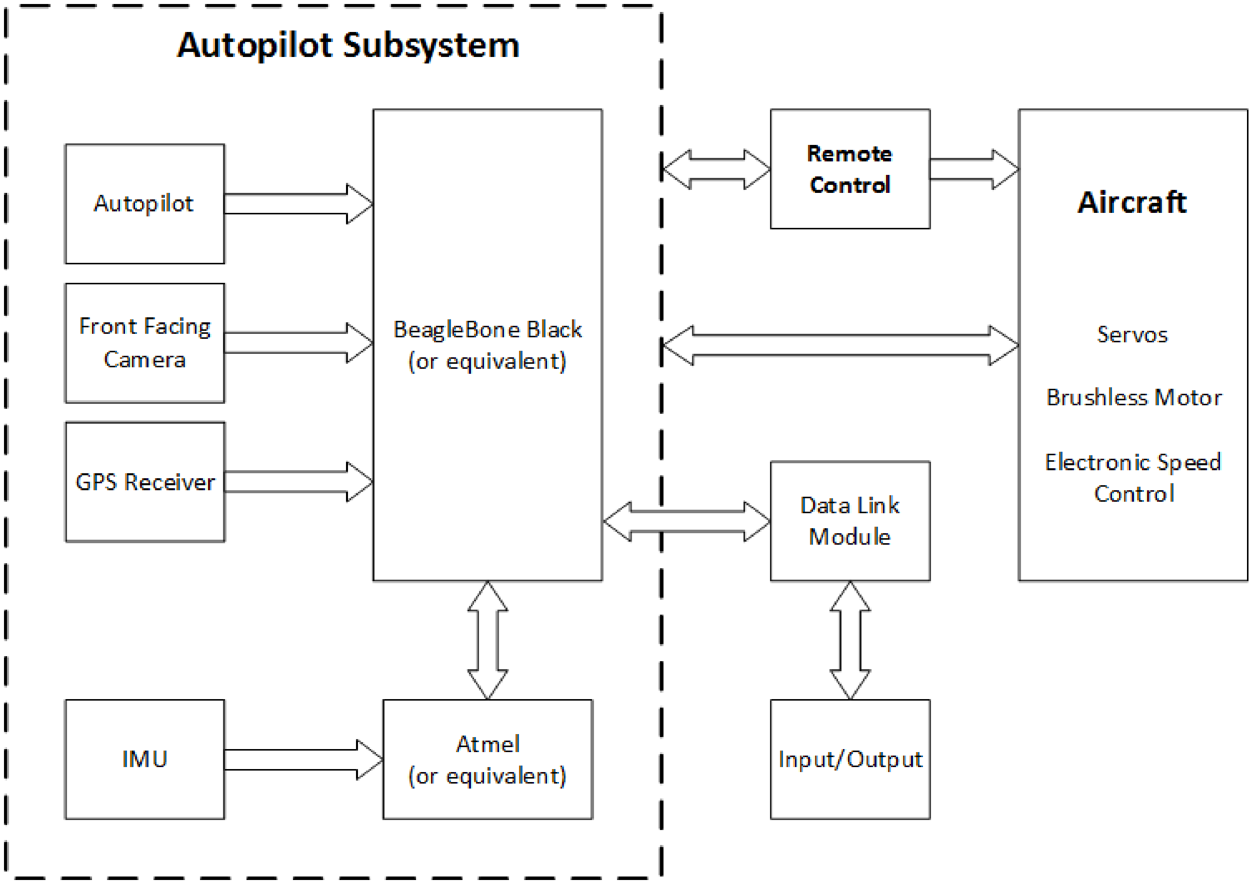

Figure 1. Autopilot Block Diagram

During flight, the front-facing camera will allow obstacle avoidance, using techniques from computer vision such as optical flow and pattern recognition. The autopilot software will automatically adjust the flight path to avoid colliding with the object and remain on course. The Atmel microcontroller will process information gathered from the IMU and other sensors, and communicate that information to the BBB. The software will adjust the flight path based on this data to sustain stable, accurate flight.

Image Processing System

Figure 2 shows the data collection and delivery process. As the drone passes over the selected area, the down-facing camera will collect images that cover the entire area. As each image is taken, the BBB will store location data from the GPS receiver. These images will later be assembled into one image of the entire user-selected area based on GPS location. This camera will also have optical filter capabilities to allow specialized imaging applications.

After all the GPS data and images have been stored in the BBB, the image processing software will create a single large image of the surveyed area (or several images, depending on how many filters were used). This image will be transferred to a Dronecell GPRS (General Packet Radio Service) data link module (or equivalent), with cell phone capabilities and internet access. The data link module will email the final image(s) to the operator and provide notification that the aircraft can be retrieved at the user-specified landing site.

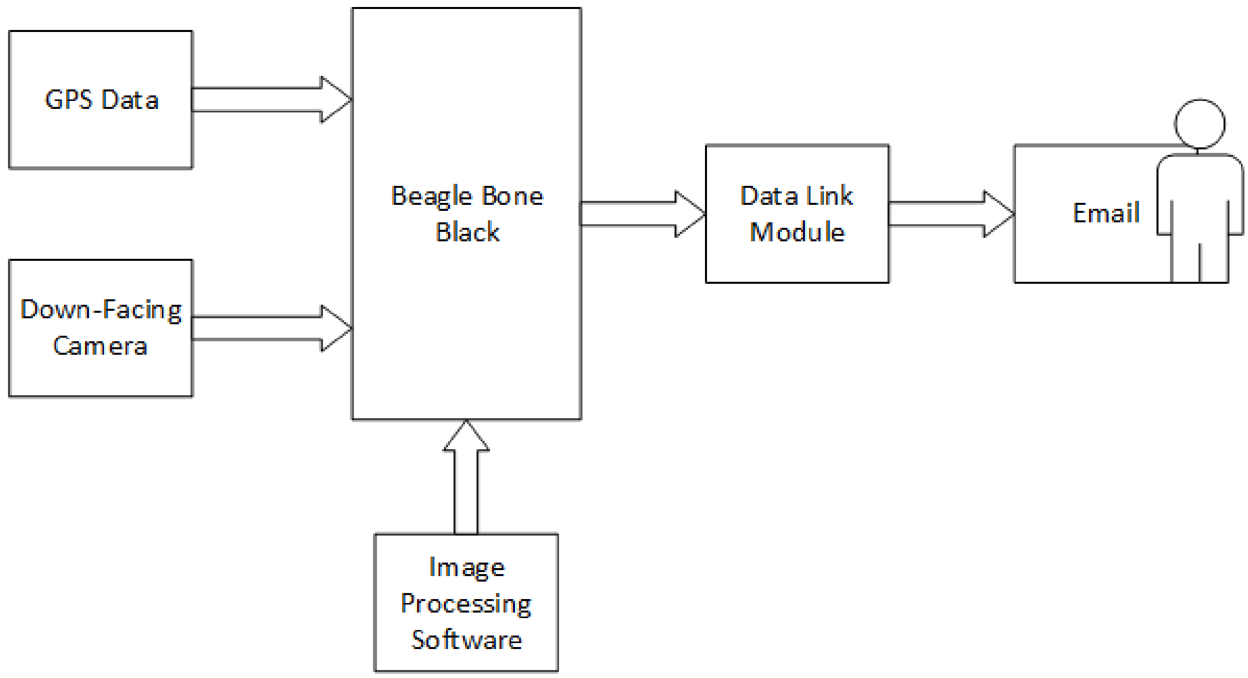

Figure 2. Image Processing Software and Final Image Delivery

Summary

We have described a proposed fixed-wing survey drone that will autonomously image a user-selected area. The drone will accept GPS coordinates that define the area to be surveyed. It then will generate and navigate an autonomous flight plan for that area, and assemble a final aerial image of the selected area from multiple images taken during flight. The final image will be uploaded using a data link module and emailed to the operator. After flight, the survey drone can be collected at the starting location or some other user-specified location. This image information can be very valuable in precision farming applications, where details of crop health can be used to maximize yield and minimize use of resources. In the future, this design could be expanded to include other tasks such as search and rescue.

References

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