Development of Robotic Aerial Remote Sensing System for Field Educational Purposes

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Abstract
Fieldwork data not only plays a crucial role in satellite data standardization, but also signifies in the data expanding. For remote sensing applications in a specific area, the satellite data is sometimes restricted by data recurrence, high data-collecting cost, weather impediment and improper resolution obtaining. In these cases, radio-controlled Robotic Aerial Remote Sensing System exhibits much potential in solving the problems. Furthermore, education throughout aerial observation seems to be one of useful remote sensing applications. In addition to the educational purpose, it can also use in real-time forest monitoring, disaster monitoring, environmental monitoring, military operation, cartography, and getting in-situ ground information to calibrate or compensate the satellite data. This is possible by incorporating the system into the radio-controlled aircraft with flight control, navigation, camera pointing control as well as command and telemetry subsystems.

1. Introduction

Remote sensing (RS) is traditionally in the habit of refers to entire field imagery; technically, it can describe any kind of sensor that measures a quantity devoid of coming into physical contact with the plant. A multiplicity of ground-based "remote" sensors has been developed to compute the spectral reflectance of object. One advantage of using these sensors is that they can be used in real time control conditions. They can also be configured as a handheld sensor to congregate correct information in localized areas. The weakness of ground-based sensors is that they cannot simply offer a complete field image. The user should traverse the field with sensor as gathering sensor and position data and then generate a field map from that data. There are an incredible number research studies that could be cited to show potential applications of RS for agriculture. To present a few information's, (Thomasson et al., 2001) used RS images to conclude soil properties. (Yang et al., 2001) were able to monitor object growth and health using RS images. (GopalaPillai et al., 1999) found strong associations between RS data and crop yield. Single particular application where RS has great possible in Kentucky is in nitrogen managing. The study in Kentucky, which was supported by NASA's AG 20/20 program, illustration that RS could be used to measure nitrogen inconsistency in wheat, but that more work is required to refine measurement and management strategies. There are several other remote sensing projects ongoing at UK. (Wells et al., 2001) are exploring the use of RS to situate compacted areas in the field by looking at soil moisture deviation. The mission investigators are also involved in a newly funded project to develop a multi- faceted lens system used for RS imaging devices (Menguc et al., 2002). Unmanned aerial vehicles (UAV) play the important roles in military activities for decades (Kusanagi, 2000, Kawachi, 2001, Saripalli et al., 2002 and Kubo and Suzuki, 2004). It recently becomes necessary civil tools in reconnaissance over hazardous districts, rescue tasks, meteorological monitoring, and so on. The UAV systems exist in various configurations, sizes and complexities. In civil aviations, most of UAV aircrafts now equipped with highly sophisticated autonomous flight facilities that make the equipments too large and too heavy to install in small compact frames. Therefore, only Global Hawk (Loegering, 2002) frame is practically possible and, to date, the UAVs are mostly available in civil aviation in addition, the larger UAVs involve higher operational cost and need more infrastructures such as longer paved runways to facilitate their tasks on one hand. On the other hand, small UAVs are recently popular due to their benefits in lower operational costs, smaller human resource need, and more readiness available. These advantages are more pleased for civil uses than in military one. Furthermore, small UAV can also be used in special tasks such as high-resolution aerial photography at low altitude, which the larger UAVs are unable to do. Due to rapidly development of small sensors, through Micro-Electro-Mechanical Method

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(MEMM), and microprocessors make it possible to design small UAVs which some of them have already been demonstrated in civil missions (Herrick, 2000, Nordberg et al., 2002, Kitts, 2003, Fahey, 2005, Nebikera et al., 2008 and Arnold et al., 2009). The UAV technology team set in the department of physics faculty of science, Mahasarakham University successfully developed a trial Robotic Aerial Remote Sensing System (RARSs-01) observation platform for remote sensing education. This kind of RARSs-01 is useful for real time forest monitoring, disaster monitoring, environmental monitoring, military operation, cartography, etc (Nordberg al., 2002, Kitts, 2003, AeroSim, 2011 and SU1, 2011) By incorporating with proper equipments (such as radio-controlled aircraft with flight control, navigation and camera as well as command and telemetry subsystems), the modified vehicles can possibly do specific tasks as the inventor wish (such as collect the in-situ local ground information and calibrate or compensate the satellite data).

2. Methodology

In briefly, the project framework can be divided into five parts:

2.1 Proper Size Estimation Process

The conventional sizing process illustrated in Figure 1 is for determining the airframe size.

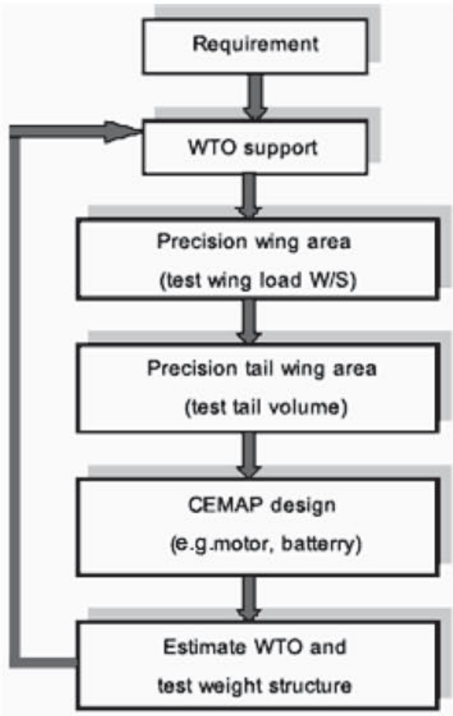

Figure 1: Flowchart of sizing process

Firstly, a takeoff weight W_{TO}, W was assumed. A wing area was estimated by using a specified wing loading (W_{TO} / S), which was derived from Equation below:

$$\frac{W}{S} = \frac{1}{2}\ \rho g r C_{L} \sin \emptyset$$

Equation 1

Where the turn radius was defined as 12.50 m and the bank angle φ and the lift coefficient C_L *was* assumed as 30 deg and 0.70 respectively. The Calculation Electric Model Air Plane software (CEMAP) (Air Force Technology, 2011; CEMAP, 2011) that covered motor models, battery models, and propeller models was used to evaluate battery-motor-propeller matching profiles. Finally, the weights of all components were estimated based on statistical data from the modeled airplanes.

Figure 2: Illustration Lancair

2.2 Airframe Selection

Initially, the entire project requires a stable airframe in order to avoid wasting of building time. It was decided that the Robotic Aerial Remote Sensing System: RARSs-01 was the most suitable almost-ready-to-fly (ARF) airframe. The ARF was also important for compatibility reasons. In case spare parts were required, they were able to obtain from the local hobby shop easily. During the RARSs-01selection process, several different airframes were tested. The investigation was included with exploring a high wing, tail dragger, a low wing, fast and scale “Lancair .40-ARF” (see figure 2). The first experiment began at Mahasarakham University. The field where all flight operations engaged was rather windy that made the RARSs-01 difficult to taxi down and maintain a straight takeoff line on runway.

Additionally, the characteristics of the tail dragger type of landing gear on the Mahasarakham University made it non-conducive for this experiment. When the plane was equipped with camera, the additional weight would cause longer time the tail rising off from ground. The wing spars also manifested another challenge as their attachment manner prevented fuselage accessing. This made internal modifications difficult.

2.3 Power Systems

With suitable RARSs-01and engine selections, consideration to power distribution system of the plane servos and payload might be needed. The RARSs-01utilized four separate power systems for redundancy and safety purposes. Upon consideration, single high energy Lithium Ion battery was declined for several reasons. Firstly, since different components have their own specific voltage requirements, simple strategy to avoid integrated hassle was to use custom designed regulators which were able to supply power to all on-board equipments. Secondly, while payload weight was a concerned point, evaluation of RARSs-01's capacity could indicate whether a redundant four battery system was usable or not. In other words, use of multi-battery powering system was more efficient than single battery powering system. Table 1 shows disintegrate of power systems on RARSs-01 board. Figure 3 show the accessories device was installed on RARSs-01 board. This ensured that the autopilot voltage would not drop too low leading the computer was reset during the tasks. A high capacity servo battery was also selected to support 6 operational servos and to reduce risks from running out of power. The reason for selection of a 12 volt battery for video-package and modem was simple, due to their voltage requirements. This power system was considered a secondary system as the RARSs-01could still work properly although battery fails. The RARSs-01also contained a separate battery, receiver, antenna and servo to control a redundant engine kill switch. The use of this emergency switch provided the ability to limit the RARSs-01range by stopping the engine in case of an autopilot or main servo battery failure.

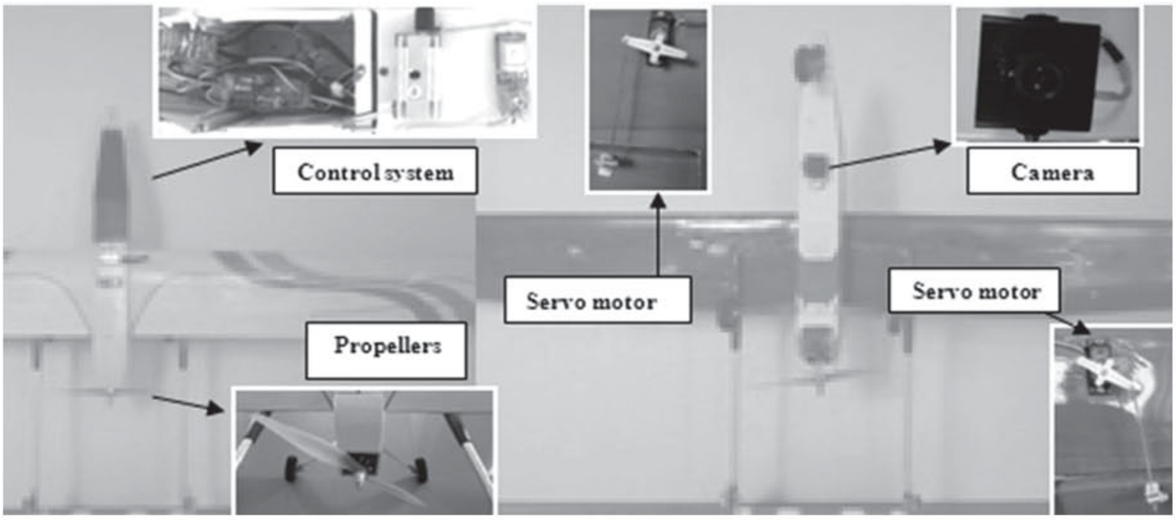

Figure 3: RARSs-01's system

Table 1: The Power Systems on RARSs-01board

Purpose	Battery Size
Autopilot system	4.8V 1800 mAh NiCd
Flight servos	4.8V 2700 mAh NiMH
Radio modem	12 V 1100 mAh NiMH
Redundant engine kill switch	4.8V 600 mAh NiCd

2.4 Communication Links

For physical control of the plane, the RARSs-01supported two primary communication means. Since two modems were needed for serial communication with the RARSs-01. The Maxstream wireless radio modem (transceiver and receiver) (see figure 4) with traditional RC link were used in this research project. Upon testing however, several concerns were appeared. The modems, while able to maintain a connection over long distance, were very difficult to connect initially. It was necessary to dial up with a particular modem at 30 seconds after 'hand-shaking' occurred. Even the connection was success; the modems still had many dropouts that made data transferring unreliable. The modems were also much heavier and took too much valuable cargo space up. The Maxstream modem looked greatly simplify the wireless connection process to the auto pilot. The initialization process simply involved turning on each modem. The RC link was selected because it provided the plane a standard interface. It was a fact that the RARSs-01could not be operated outside one's sight range, so it was unnecessary to explore at longer RARSs-01control range. The RC link could allow the pilot controlled the RARSs-01manually. This was considered as the pilot in-control mode. Through a switch on the transmitter, the pilot had the ability to switch between computer in-control mode and pilot in-control mode. The radio modem provided real-time link to the plane and was a way to communicate with the RARSs-01 in flight and permit flight-paths and commands uploading. Real-time information such as airspeed, altitude, and positional location could also be received from the RARSs-01through the radio modems. The camera and transmitter system were selected due to their ability in long range data transmitting. Several experiments were taken for less expensive camera solutions and it was finally settled on this particular product. According to expected flight range of this project it was important to obtain a solution that made the UAV able to work effectively, at least one kilometer away. The selected system consisted of a CCD camera, transmitter and servo to control tilt. This provided the ability to scan out any areas between forward position and twenty degrees aft. The camera system was designed with the ability to solve several problems. Firstly, the need to carry several stationary cameras looking in different directions was eliminated, thus reducing much of weight. Secondly, a video camera was more effective than static camera because operators could receive continuous streams of images in which to be analyzed. Finally, the need to 'time' the moment in which to take a photo when passing over a target was also eliminated. (see figure 5). The camera tracking process was as follow. When creating a flight plan for the RARSS-01and there was a designated location to observe in mind, a series of waypoints were created at specified distances leading up to a target set. As the plane crossed the path leading up to the target set, it gradually shifted the camera to downward positions so that when the RARSs-01 crossed the target set, the camera was looking straight down. With the ability to stream the live video to the ground, the operator benefited from the ability to analyze real time data which was opposed to those obtained from static photos.

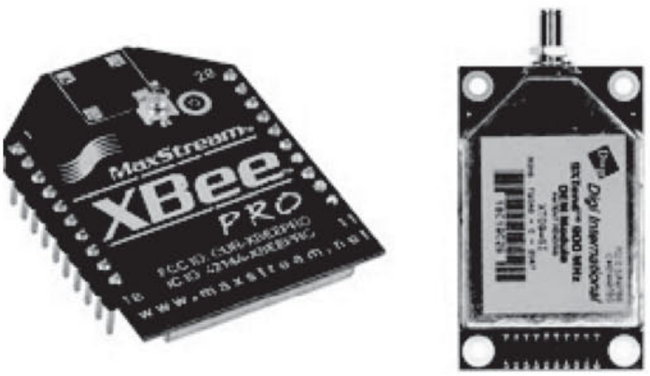

Figure 4: Maxstream wireless radio modem

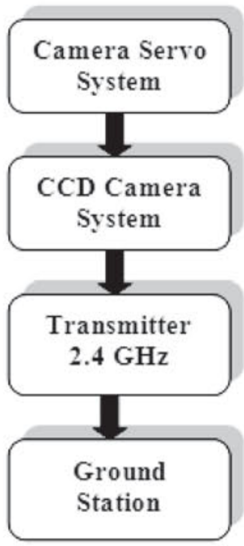

Figure 5: Video data flowchart

2.5 Field Educational Remote Sensing Platform

The effectiveness and efficiency in the flight play the major role in determining field education through new remote sensing observation platform. The directly reflected the accuracy of aerial image taking by RARSs-01 system. Since this was an important part of the field educational remote sensing platform. In any flight plans, a combination between waypoints manipulating in the Graphical User Interface (GUI) and manually fly file editing was created (figure 6). This allowed visual placement of desired waypoints and provided an opportunity to fine tune the RARSs-01path by editing and adding specific commands. When the flight purpose is to observe thing aerially, the targets must be approached in a particular way. A series of waypoints before and after target areas should be laid out in a straight line. The proper camera mounting design may be required as the plane must fly in proper line and level in order to obtain accurately captured data on target. The aerial photography in Mahasarakham University show in figure 7 and the mosaic aerial image after make Ground Control Point (GCP) was illustrated in figure 8.

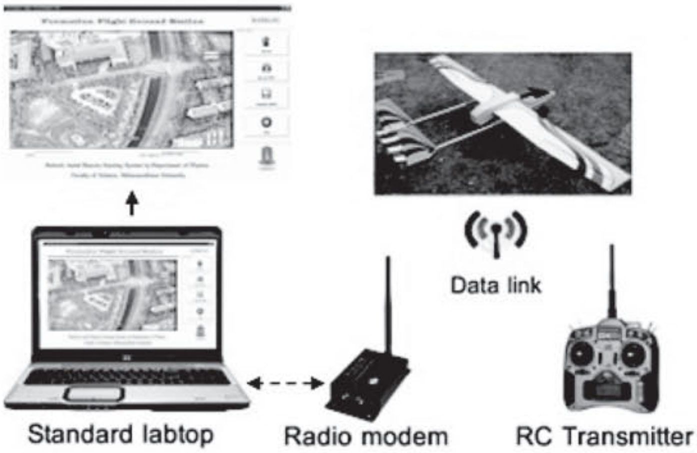

Figure 6: GUI in ground control system

Figure 7: Aerial photography in Mahasarakham University

Figure 8: Aerial photography mosaic using GCP

3. Result and Conclusions

For a global and long time-duration changes, the satellite visual image or spectral data will provide useful and sufficient information to the analyzing procedure. Meanwhile, the local or continuous real time remote sensing applications (such as in the disaster monitoring and emergency rescue missions that use only the satellite data) is insufficient to analyze in details. The visible data from some areas may possibly miss because of cumulus cloud. Tropical southern islands are usually covered by thick cloud for long period of time. To cope with this problem, new remote sensing techniques like microwave SAR or INSAR have been successfully developed. However, most satellite cannot always stand over the specific area except the ones on geo-stationary orbit. To get real-time quasi data of the specific area all the time, multi satellite constellation is required. Even if the size of satellite can be smaller, it will be very expensive to launch and maintain a large number of satellites from the constellation network. Moreover, the satellite image is also limited in resolution in case of small satellite. In this research project, using the event driven controls, a wireless video camera on the RARSs-01 will track a designated target when the RARSs-01 approaches and passes a ground object. By creating a tilting camera system, the total time during a target is viewed by the camera will be increased and thus enhances the investigating accuracy. To maintain the highest standard of safety, additional RC receiver, servo, and battery pack are included to facilitate the secondary kill switch performance. This provides an ability to turn off the engine in case of autopilot failure, primary RC receiver failure, or power systems failures; and thus limits the magnitude of collateral damage. The safety and simplicity of design contribute to a competent autonomous RARSs-01 reconnaissance system. Outstanding features of the system involve easy-to-use GUI application which coordinates the flight of the RARSs-01and manages the formed algorithms. The flight effectiveness and efficiency play a major role in determining field observation platform of remote sensing education. The program's graphical user-interface exhibits GPS locations, airspeeds, and altitude telemetries in both planes; the interface can also plot real-time paths of the planes in two dimensions. In this project, the experimental flight was successful, the RARSs-01plane is a faithful simple maneuver with an average accuracy approximately +/- 20 meters over the duration of the experiment; this accuracy is consistent to the accuracy limit of GPS receivers used in this project. This project has successfully demonstrated several things including an autonomous formed flight algorithm and low-cost Robotic Aerial Remote Sensing System for field educational remote sensing observation. The authors think that this flying platform with simple, low-cost, and easy to transport is a powerful alternative way to overcome significant weaknesses of the satellite remote sensing systems.

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