Field Observation using Flying Platforms for Remote Sensing Education

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ABSTRACT:

Field data are not only essential for calibration of satellite data but also very important for supplementing those satellite data. For the very local remote sensing application, satellite data is sometimes limited because of its recurrence, expensive cost and the weather including insufficient resolution. Now at the Space Technology Applications and Research (STAR) program of AIT, simple, low-cost, light weight and easily transportable platform technologies are under investigation. Several field experiments have been performed in one of STAR's classes, as a part of remote sensing education. In March 2001, a test was conducted using ultralight plane in Chonburi City. In March 2002, a test was conducted using Kite-Balloon (Kitoon) in Ayutthaya City. Radio-controlled unmanned air vehicles (UAV) or flying robots will be planned for future test. These kinds of filed observation are not only suitable for educational purpose, but also useful for real time disaster monitoring, environmental monitoring, military operation, cartography, etc. and for getting in-situ local ground truth data to calibrate or compensate satellite data, by upgrading the systems with flight control and navigation subsystems, camera pointing control subsystems as well as command and telemetry subsystems.

INTRODUCTION:

It is more than thirty years since the first artificial satellite of remote sensing was launched into orbit. Remote sensing, as a part of space technology, has achieved tremendous progress and has greatly contributed toward managing the earth's natural resources, observing and predicting natural phenomena, and helping users to monitor and mitigate disasters. However, for the local or continuous real time remote sensing application, sometimes satellite data are insufficient because of its recurrence and limit in resolution. To overcome these problems, other platforms for land observation have been developed to get in-situ ground truth data which can calibrate and compensate satellite data and have become a complementary and important part of field observation technique. For example, the stratosphere airship, which can stay at the fixed point in the stratosphere in spite of strong wind stream, has been studied. The recent progress of rescue robot is remarkable due to highly speeded evolution of AI technology. Aerial photometry by surveillance aircraft or helicopter has been fully matured. But usually such system is quite expensive and cannot be used for developing countries or rural regions due to lack of suitable airfield etc. The authors think that simple, low-cost and easily transportable flying platform system is a powerful alternative means to augment the weakness of satellite remote sensing systems. In this paper, several flying platform systems we have studied and results of field experiments we conducted by using a few of them are introduced. And also, the educational meaning of platform design is evaluated.

FIELD OBSERVATION:

For a global and long time-duration changes, satellite visual image or spectral data will provide useful and sufficient data for analyses. Meanwhile for the local or continuous real time remote sensing applications such as disaster monitoring and emergency rescue mission, satellite data itself is not sufficient to conduct detailed analyses. Visible data for some area tend to miss because of a cumulus. Tropical southern islands are usually covered by thick cloud for a long time of period. To cope with this problem, new remote sensing techniques like microwave SAR or INSAR have been developed. But no satellite can always exist over the specific area but satellites on the geo-stationary orbit. To get quasi real-time data of the specific area for every time, multi-satellite constellation is required. Even if the size of satellite can be smaller, it is very expensive to launch and maintain a large number of satellites forming a constellation network. Satellite image also has the limit in resolution for the case of a small satellite. The authors think that simple, low-cost and easily transportable flying platform system is a powerful alternative means to augment the weakness of satellite remote sensing systems. Now at the STAR program in AIT, sky-sport plane like ultralight or parasail, tethered system like balloon, blimp or kite, radio-controlled UAV or a new type of flying robot, either of which can take a series of aerial photographs on demand in real time, are under investigation and researches are going on. Some of them have been tested in the field already and had shown excellent performance.

FLYING OBSERVATION PLATFORMS:

The most powerful measure next to or even exceeding in some sense to the Earth Observation Satellite is the aerial photometry by surveillance aircraft or helicopter. The system has been fully matured but it is a little expensive and has less mobility and maneuverability. Utilization of airships is suited for continuous long duration observations over specified area. Recently, it was reported that Kasetsart University had designed an unmanned airship that would be beneficial in many fields (Siribodhi, 2001). Sky sport light plane is also available as a very mobile and inexpensive platform. A parasail plane has advantage in its cost, transportability and smaller space for take off and landing, though a little sensitive to winds. An ultralight plane also has similar performance. Further explanation of ultralight plane system with some results is given in the next paragraph. For more local area, much more challenging systems are obtained by using radio-controlled unmanned helicopters (Tsutsui, et al., 1999).

Another system with further inexpensive and yet longer mission time is obtainable by using tethered system such as balloon, blimp and kite. These are needed for fixed-point observations or low-altitude observations in situations where aircraft could not operate effectively because of its flight envelope performance. Further explanation of kite-balloon system with some results is also given in the following paragraph.

From the practical and operational point of view, continuous monitoring over all weather condition is desired especially for disaster monitoring or military operations. Next generation satellite for earth observation might give answer to this challenging problem. However, the most practical and feasible approach under existing technology is the selection of an appropriate platform from various ones including satellites, flying platforms and ground platforms according to users' observation purpose. Common to each system are the mobile ground data-handling terminal for quasi real time data evaluation and transmittance.

AERIAL PHOTOGRAPHY SYSTEM USING ULTLALIGHT PLANE:

Figure 1: tested ultralight platform

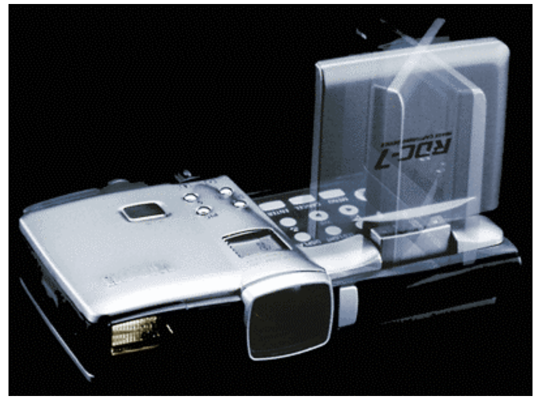


Figure 2: a test digital CCD camera

In March 2001, a test was conducted using a two-sheeter ultralight "Quick Silver MX-II Sprint" (Figure 1) of CMT Flying Club of Chonburi. The City of Chonburi, the eastern coastal province of Thailand was selected as the study area because of the location of ultralight plane flying club and its variety of land cover, etc.

As an image capture device, Ricoh RDC-7 color digital CCD camera (Figure 2) was mounted on the left side strut just below the sheet with shock absorbing material. Flight was about 60 minutes over the out skirts of Chonburi City on the cloudy day at the height of about 500 meter with the speed of around 45 km/hr. The picture was taken every 30 seconds. Although focus was not as sharp as a picture on ground, the quality of pictures recorded above the city were fine as shown in the Figure 3 and sufficient for most applications with the resolution of 0.5 meter or less. Noise existed in some images because of cloud over the vegetation area (Figure 4). With a constant altitude and horizontal flight, most of the images recorded by RDC-7 color camera were nearly vertical images excluding images during the plane take-off, landing, and turning. Each image has 640-pixel by 480-pixel size in the form of jpeg.

The system has proven to be fully operable, frequently usable and able to expand its application area if it meets the local flight regulations. In spite of using a low-cost platform and a commercial digital camera, a series of aerial images is sufficiently qualified for further processing with the standard resolution and size, in terms of the image processing for the visualization and animation.

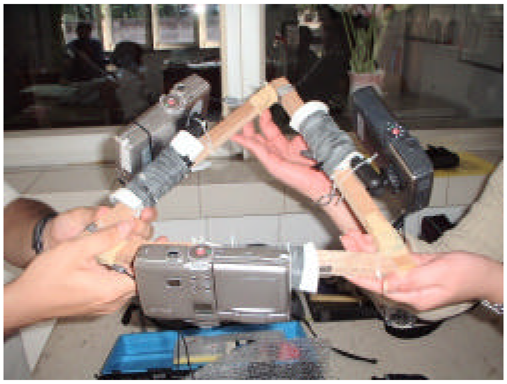
Figure 3: the images of Chonburi city, taken by ultralight plane

Figure 4: noised and non-noised images above the same area during the test flight

AERIAL PHOTOGRAPHY SYSTEM USING KITE-BALLOON:

In March 2002, a test was conducted using a kite-balloon (so-called "Kitoon") lent from Keio University, Japan. The city of Ayutthaya was selected as the study area. Ayutthaya is one of ancient capitals of the Kingdom of Thailand, and there are many historical sites and temples in this city. The Kitoon has approximately 2 meters width and 5 meters length, so its volume is about 21m^3. The Kitoon filled with helium gas was launched by using a boat to pull it by tethers along the river surrounding the city.

We used three Ricoh RDC-7 color digital CCD cameras (Figure 2) as image capture devices. A tripod structure with the triangle frame connected with rubber bands and plastic tiers was adopted for camera-mount system. Each camera was fixed to the tripod with a screw at its backside (Figure 5). When mounting each camera, the look-angles of different cameras had to be calculated so that the cameras were able to take photograph of a large area. Proposed look-angles were off-nadir for all the cameras, as illustrated in Figure 6. Wind drag and balloon drifting force were considered to take a great effect on the camera positioning system. However, this three-tier tripod system always tended to be straight downward to the ground due to the gravitational force. As the first tier was linked to the hook near the top of the balloon, it kept the system safe from pitch angle variation. The other two tiers were hooked on the left and right sides of the balloon, which kept the camera system stable from changes in roll and yaw angles.



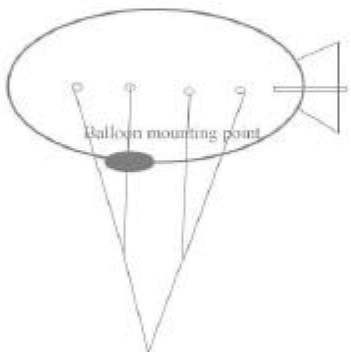


Figure 5: tripod camera-mount system

Figure 6: camera mount system with off-nadir looks angles

The real experiment and field survey have shown the advantage of this system. Moreover, keeping the system stable, this three-tier system can easily be adjusted to change the look angles of the cameras. The pitch tier can be adjusted to rise up or lower down the head of the triangle, thus it can change the look angles by one movement. Flight was about 90 minutes over Ayutthaya's historical heritage along the river on the fine day at the height of about 150 meter with the boat speed of around 5 to 10 km/hr. The picture of each camera was taken every 30 seconds (Figure 7). Each image has 640-pixel by 480-pixel size in the form of jpeg.

The camera mount system and balloon altitude & attitude stabilizer have to be improved to get better aerial pictures to be useful for field study. Higher altitude around 1 km will have to be realized for wider area coverage. For future study, an unmanned radio-controlled airship or blimp, which is not tethered by ground operators, will be designed in STAR program.

Figure 7: the images of Ayutthaya city, taken by kite-balloon

EDUCATIONAL PURPOSE OF FIELD EXPERIMENTS

Design of flying platforms and flight tests discussed above were made in the framework of the STAR program course study “Aerospace Technology – Basics to Applications”, as a part of remote sensing education. Not so many opportunities to design a total engineering system or to verify its feasibility and versatility through the field experiments have been given to graduate students, although they are very useful for engineering education. For the design and field experiment of aerial photography mission using flying platforms, many engineering topics such as aeronautics, flight dynamics, image processing, control engineering, mechanical engineering, etc. have to be considered. The synthetic and systematic way of thinking like the design of flying platforms is very important for engineers to create new ideas.

FUTURE STUDY: TOWARD UNMANNED REMOTE-CONTROLLED FLYING PLATFORMS

In STAR program, radio-controlled unmanned air vehicles (UAV) like RC helicopters, airships or airplanes will be planned for future experiment. These kinds of field observation using unmanned, durable and stable flying platforms with higher maneuverability and mobility are not only suitable for educational purpose, but also very useful for missions requiring rapidity or emergency, such as disaster monitoring, forest fire monitoring, environmental monitoring, etc. and for dangerous missions such as military operations, drug smuggling operations, etc.

In designing unmanned flying platform with good performance, we have to design and integrate sub-systems as follows.

- Gyro stabilizer which can always orient the camera or video into the inertial coordinate, in spite of various disturbances like turbulence
- Camera pointing angle control which can orient the camera rapidly into the specific direction
- Flight control and guidance using GPS/INS/altimeter combined navigation techniques
- Remote control techniques for flight maneuver
- Telemetry and command system handling with online image data relay

- Light weight and long-time usable fuel engine
- Data processing function which can calibrate or compensate existing data obtained by satellite or GIS data base, with local ground truth data obtained by flying platforms

A new type of flying robot with inflatable rubber trusses filled with lighter-than-air gas that can change their shape and buoyancy as well as several movable propellers that can change their thrust vectors according to its flight mode is also now under study. Micro flying robots utilizing the flight dynamics principle of birds or flying insects will also be studied (Kawachi, 2001). Such small flying robots must be more effective for fixed-point observations, low-altitude detailed observations, hovering, etc. than existing UAVs. If we can use such small flying robots in a formation, they may be very useful for specific missions like forest fire and disaster monitoring, tropical jungle observation, military operations or drug smuggling operations, which need time-continuous surveillance as well as detailed observation from low altitude.

CONCLUSIONS:

The new way to improve the weak point of the satellite image has been developed with a lower cost. Flying platform system using an ultralight plane and a kite-balloon was designed and experimented in the field. The system has proven to be fully operable, frequently usable and able to expand its application area. These two platforms are the starting point to design and develop the new, low-cost, light weight, easily transportable field survey flying platform with integrated multi-functional sensors such as gyro-stabilizer, GPS, altimeter, OBC (onboard micro-computers), digital camera, digital video, etc. In the near future, we would like to apply our new flying platform system to geodesy, land survey, cartography, environmental monitoring, traffic monitoring, 3D digital image reconstruction of world heritages, etc. Further, after intensive feasibility study of flying platforms, we would like to take challenge in development of radio-controlled unmanned air vehicles (UAV) and flying robots with higher maneuverability, which may be very useful for real time disaster monitoring, military operations and crime surveillance, etc.

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REFERENCES:

Kawachi, K., 2001. Fixed and Flapping Wing Aerodynamics for Micro Air Vehicle Applications. In: Progress in Astronautics and Aeronautics, published by AIAA, Vol.195, Chap.14, pp.275-285.

Siribodhi, P., 2001. Come Fly with Me: New Thai Airship Unveiled. In: Newsletter of Kasetsart University International Affairs Division, October 2001, Vol.7, No.10.

Kusanagi, M. 2000. Fields Observations and Data Center Concept for the South East Asia. IAF-00-B.6.08, 51st International Astronautical Congress, October 2000, Rio de Janeiro.

Kusanagi, M., 2000. Remote Sensing, Geographic Information System and Global Positioning System Training Delivery System. RESAP Remote Sensing Specialist Meeting, March 2000, UN-ESCAP, Bangkok.

Tsutsui, M., Iizuka, K., Kajiwara, K. and Honda, Y., 1999. Ground Truth Measurement System Using RC Helicopter. 20th Asian Conference on Remote Sensing, November 1999, Hong Kong.

Murai, S., Samarakoon, L., and Honda, K., 1998. Activities of Education, Training and Research at Asian Institute of Technology. 19th Asian Conference on Remote Sensing, November 1998, Manila.