

Application of Remotely Piloted Vehicle (RPV) in Monitoring and Detecting Watershed Land-Use Change and Problem Areas

Long-Ming Huang¹

Abstract.— Improper cultivation of steep mountainous areas in Taiwan contributes to serious erosion and landslides. Regular patrol, detection, and administration of these problem areas has been an extremely difficult due to the steep and dangerous terrain of many of the forested watersheds in Taiwan. A remotely piloted vehicle (RPV) has been developed for various civil and military applications. This paper reports the results of a preliminary application of RPV in monitoring and detecting land-use changes and problem areas in inaccessible watershed areas. Preliminary results indicated that RPV, with its small size, low price, easy operation, and high mobility, should be a safe, economic, quick, and efficient way of obtaining information in problem areas for identification and watershed management planning and administration.

Introduction

Taiwan is a mountainous island with a limited amount of plains. Slope lands are in demand for various agricultural and non-agricultural uses. Activities on these lands often increase erosion, landslides, debris flows, and other disasters to stream and reservoir sedimentation, which poses significant threat to life and property.

For disaster mitigation, illegal and improper over-farming on hill slopes must be effectively regulated and controlled. Therefore, monitoring the condition of the watersheds affected is a priority. However, regular patrol, detection, and administration of these problem areas has been difficult due to the steep and dangerous terrain of many forested watersheds in Taiwan. Aerial photographs or satellites images are often used to gather the necessary information.

Precise interpretation using satellite images in areas with small variations is impossible due to insufficient image resolution. Therefore, it is important to develop new surveying and monitoring technologies to efficiently monitor field conditions and to improve watershed management. This would promote the effectiveness and de-

pendability of disaster information and mitigate losses from disasters.

The Unmanned Aerial Vehicle (UAV) has numerous application possibilities. Besides military purposes, UAV can be used for field reconnaissance for urban development and construction projects, monitoring for environmental protection, highway detecting and searching, forest and hillside disaster prevention, coastal survey and control, pre-disaster monitoring and post disaster surveying. Because of its light weight, small size, high mobility, safety, easy maintenance, and low cost, UAV has been extensively used. Moreover, since there are no concerns about possible personnel casualty, UAV is capable of performing various weather missions in potentially dangerous locations. UAV's payload compartment can be designed for installing instruments of different weights and sizes and for surveying and monitoring applications in different fields. In comparison with traditional flying vehicles, UAV is economical, safe, mobile, and has extensive applications.

The purpose of this study was to use a color camera with charge coupled device (CCD) fitted on a vertical take-off/landing rotary-wing aircraft and horizontal take-off/landing fixed-wing aircraft for taking dynamic images. These images were instantly transmitted by coupling with radio transmission equipment (receiver/transmitter). Image processing and analysis was performed on the feed back data to acquire the relevant information. Sky remote surveying and instantaneous monitoring provides the necessary information to establish a policy for effective disaster warning, with adequate timing to reduce associated losses.

Principles

Charge Coupled Device (CCD) and Image Pick-up Principles

Images can be classified into 2 categories, analog image data and digital image data. All image data stored on a computer are digital, while the original formats for all the

¹ Associate Professor, Department of Soil and Water Conservation, National Chung-Hsing University, Taichung, Taiwan

available image data are analog. Therefore, it is necessary to transform the analog image data to digital image data through interface processing (figure 1).

The CCD is a state-of-the-art technology that uses a solid-state image element on the camera to produce images with different resolutions. Since only digital image data can be processed by a computer, these data are in discrete format (i.e., the images are composed of single frame images of specific time difference); therefore, image frames can be selected individually during post processing. The video signal specifications currently used in Taiwan have standard NTSC (National Television System Committee) specifications, so NTSC video signal was adopted as the input format. The relationship among various NTSC signal frequencies are:

Frame frequency $f_r = 29.97 \text{ Hz}$

Scanning line frequency $f_L = 15.734 \text{ KHz} = 525 f_r$

Color sub-carrier frequency $f_{sc} = 3579.545 \text{ KHz} = 227.5 f_L$

CCD images are input to the computer in standard NTSC video signals through a dynamic image capture card. The RGB color signals are not synthesized into a combined video signal, so a specific color system frequency zone can be intensified by using the image processing technique. While the images played can be recorded in standard AVI image play format using a dynamic image card, apart from CCD image resolution, the image capture card will also affect the pick-up speed and resolution. The image capture can be classified into static capture and dynamic capture. Each type of capture separates the video signals input from CCD into frames of images through the image capture card, which are then picked up and stored. Since memory capacity consumed by dynamic capture is large, image resolution is lower than that of static capture.

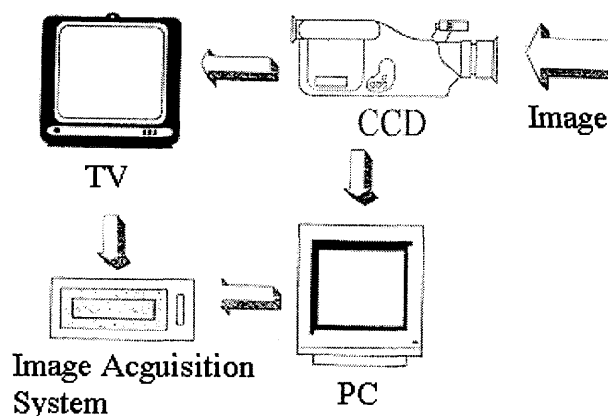


Figure 1. Flow chart for acquisition and storage images by the charge coupled device (CCD).

Equipment

Color CCD Camera

CD-5 color CCD camera with a 1/3" picture tube, resolution up to 410,000 pixels, power 5 VDC, weight 135g, transmission channels VHF 4ch to 12ch, luminous intensity 5 lux min.

FT-900 Type Microwave Image Transmitter

FT-900 type transmitter, using a transmitting frequency of 1.2 GHz, transmits signals using a frequency modulation with transmission power between 0.5 W and 2.0 W, power applied 12 VDC to 13.8 VDC, weight 580 g, bandwidth for transmitting images 27 MHz, TV output terminals of NTSC. FT-900 type receiver uses reception frequencies from 1.2 GHz to 1.3 GHz, at a voltage identical to that for the transmitter.

UPG-302 Dynamic Images Capture Card

Under NTSC specifications, 30 pictures of resolution 320 x 240 can be picked up per second; 24-bit full-color static images of resolution 640 x 480 pixels can also be picked up; 3 AVI image compression formats of Indeo 3.2, YUV 4:1:1, YUV 16:1:1 can be supported.

Working Platform for Aerial Photography

After repeated designs, tests, and improvements, a working platform for aerial photography with satisfactory balance was produced. This platform was made of aluminum alloy, carbon fiber compound material and was built with small hydraulic shock absorbers. FT-900 type microwave image transmitter and server, etc. were all fitted on the working platform. High-quality aerial images were obtained because of the shock absorbing systems installed on all XYZ axes.

Remotely Piloted Vehicle RPV

A remotely piloted fixed-wing aircraft and a helicopter were designed and built for this study to take aerial photographs in watersheds. The data were compared and evaluated for their applicability.

The specifications and functions were:

1. Horizontal Propeller Type RPV (fixed-wing aircraft) (figure 2 and photo 1)

Body length 2.35 m, breadth 3.12 m, height 0.7 m, total weight 8 kgs, maximum payload 6 kgs, fuel tank capacity 1,000 cc, engine capacity 20 cc, maximum cruising time 50 minutes, operation radius 2,000 m, runway length for taking off 20m to 25 m, for landing 25 m to 40 m, maximum flying altitude 1,500 m above ground.

2. Vertical Rotary-Wing RPV (non-fixed-wing aircraft, i.e., helicopter)

Body length 1.32 m, breadth 0.185 m, height 0.47 m, total weight 5 kgs, main rotary wing length 1.54 m, maximum payload 4 kgs, fuel tank 500 cc, engine capacity 9.8 cc, maximum cruising time 15 minutes, operation radius 800 m, take off/landing space 3 square m, maximum flying altitude 500 m above ground.

Methods

Before using RPV as the study vehicle, it was important to ensure that the total payload weight was smaller than the maximum payload of RPV. Electronic interference should be avoided and inside payload space of RPV should be considered.

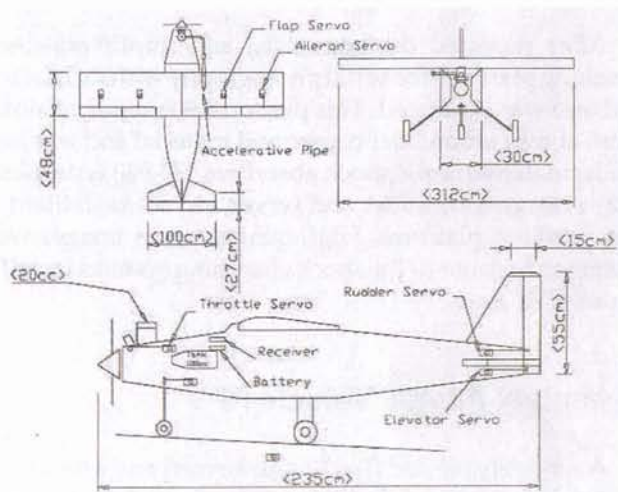


Figure 2. Three views of the remotely piloted fixed-wing aircraft.



Photo 1. Appearance and physical condition of the remotely piloted fixed-wing aircraft.

Set-up of Instantaneous Monitoring System

The instantaneous monitoring system was divided into RPV payload and ground reception station. RPV-carried CCD image signals were transmitted back to the ground through the transmitter. They were then received and decoded via reversed procedure and further monitored and recorded through a computer monitoring system.

Ground Simulation

An automobile was used as the substitute vehicle for RPV because of its high safety record. The integrity of the system and the loss rate of the data transmitted were tested in advance.

Procedures

1. Establish a mobile station: Install the CCD outside of a car with the lens facing the car's right side, feed the CCD images into the FT-900 type microwave image transmitter via a video signal cable, fit the antenna on top of the car, regularly check the transmitting condition.
2. Erect a ground station: Enter the image signals received from the FT-900 type microwave image receiver into a computer for monitoring through the instantaneous monitoring system.
3. When RPV moves, the main station receives and saves the data synchronously.



Photo 2. Payload flying test for the remotely piloted fixed-wing aircraft.



Photo 3. Silting condition of the check dam upstream of Feng Chiu bridge No.1 after repair.

RPV-Bound Experiment

As required by RPV experiment, a large, open area was used as the flying site. Photo 2 is a remotely piloted fixed-wing aircraft used to perform real-time image transmission and take-off, landing, and flying tests. The experiment procedure follows.

1. Establish a mobile station: Install the CCD under RPV with lens facing downward, feed the CCD images into the FT-900 type microwave image transmitter through a video signal cable, fit the antenna beneath RPV, regularly check the transmitting condition.
2. Erect a ground station: Enter the image signals received from the FT-900 type microwave image receiver into a computer for monitoring through the instantaneous monitoring system.
3. When RPV moves, the main station receives and saves the data synchronously.

Test Site Condition

The on-site aerial photographing location for this project was in the Feng Chiu area of Nan Tou County in central Taiwan. The watershed is 174 ha with an average grade of 6%, which occupies about 75% of the watershed. The slopes run mainly west and southwest. A majority of the collapses and erosion ditches in this area are approximately 1.6 km long and are concentrated in the forestland around the ridgeline. Because of the steep gradient, heavy rains generate surface run-offs. Any landslide has a high possibility of causing large debris flows. The devastating



Photo 4. Stream regulation and drainage ditch condition after repair downstream of Feng Chiu bridge No. 1.

earth and sand disasters and loss of dwellings and lives caused by Typhoon Hope was the result of a large debris flow.

Mud and gravel flow disasters triggered during Typhoon Wayne in 1986, initiated construction of a gravity-type sand dam at the erosion ditch outlet near the upstream side to block or retard the flow. During Typhoon Herb in 1996, the main body of the dam remained intact, however, the dam wing on the left was damaged and the flow rectification work and drainage ditches downstream were either damaged or buried due to inadequate cross-sections or insufficient gradients. All damage has been fully repaired as shown in photos 3 and 4.

Results and Discussion

Ground Monitoring System

The ground software monitoring program can perform real-time display of the down-transmitted image pictures taken by RPV-bound CCD camera. The image pictures are then monitored and recorded using the computer monitoring system.

The CCD camera and the transmitter are fitted on the working platform for aerial photography. The cloud platform is installed in a capsule under the fuselage to prevent blurred CCD images from engine shocking. Since the real-time images taken are down-transmitted to the ground monitoring station by a FT-900 microwave image transmitter, the transmitted video and audio signals are subject to noise interference that would produce lines on the images. Interference can be minimized using a boosted-signal and a segregated-signal reception port.

Photos 5 through 9 are real-time CCD aerial pictures taken at different locations over Feng Chiu village in Nan Tou, Taiwan, when this system was being used for monitoring.

On-Site Aerial Image Evaluation

Evaluation of the on-site serial images (photos 5 and 6) reveals that the mud and gravel flows at this site were caused by extensive amounts of earth and rock collapses adjacent to the ridge line. Because this site experienced early stage collapses, the land was stratified and broken

sandstone covered it in the form of a thick layer of earth and gravel. The topography is U shaped, with 3 sides surrounded by mountains and one side remaining open. The ground surface water and seepage water from the mountain top and the boundary merge at this site. During heavy rains, the broken sandstone pours down as a mud and gravel flow then bursts free. Because the river valley is quite steep and the earth mass was huge, a large area downstream was affected.

Earth and gravel deposited at this site came from collapsed earth and gravel in the forestland. Large particles rolled down to the erosion ditch triggering mud and gravel flows. The steep hillside upstream and the left bank of the erosion ditch are covered with forest. The areas on the right bank of the erosion ditch are developed. Approximately 40% of the watershed is developed, with 42 ha of farmed area at a gradient greater than 55%. The major crop on the downstream slope of the watershed is betel nuts (photo 7). The lower part of the steep slope land on right bank of the erosion ditch is Feng Chiu village (photo 8). Photo 9 shows new farm land on the left bank slope.

Evaluation of the Applicability of RPV

On-site aerial photographs illustrate that due to the geographical location and the weather of Taiwan, there is a relatively large variation of wind direction and air flow at 100 m to 800 m above ground compared to wind direction and air flow at 800 m to 1,500 m above ground. Because the elevation of the Feng Chiu area is between 600 m and 1,500 m, with unstable air flows at low altitude, a fixed-wing aircraft is more suitable. A non-fixed-wing aircraft (helicopter) is more suitable for special terrain, areas without a runway, or where the objects to be observed



Photo 5. Present condition of debris flow tracks site in Feng Chiu by aerial image (1).



Photo 6. Present condition of debris flow tracks site in Feng Chiu by aerial image (2).



Photo 7. Present condition of debris flow tracks site in Feng Chiu by aerial image (3).

move in irregular curves, etc. If still pictures or data, or low altitude and high-angle surveying is required, then a non-fixed-wing aircraft provides better flexibility.

types of aircraft perform differently depending on flying altitude, airstrip availability, and mission requirements.

Conclusions and Suggestions

Conclusions

1. The blurring of CCD images due to engine shocking can be improved through repeated designs and tests for higher quality aerial images.
2. A video-signal system has been successfully integrated and installed on RPV. Several aerial photography tests have been performed, which indicate the feasibility of employing RPV for surveying and monitoring in water collecting zones.
3. Remotely controlled aerial surveying for debris flow tracks in Feng Chiu has been completed with comprehensive video tapes recorded by aerial photographing.
4. Instantaneous transmitting of dynamic image data has been achieved and will serve as valuable reference material for watershed management.
5. Both fixed-wing and non-fixed-wing aircraft can produce aerial image data. However, each of these

Suggestions

1. For conducting the relevant studies, other instruments such as GPS, approach angle indicator, drift angle indicator, fuel gauge, etc., on board RPV should be integrated to learn more about RPV condition. If inertia navigating instruments of gyroscope and accelerometer, etc. are added, then RPV attitude can be obtained. These data can be used as the advance operation for RPV automatic piloting.
2. Air flows in mountainous areas of Taiwan are extremely unstable. On-site flights have proved that fixed-wing aircraft have high applicability for unstable air-flow space at low altitudes if a runway can be provided on site.
3. Application of RPV has become a topic of great interest for studies in various fields. However, control skill and maintenance expertise can not be obtained quickly. Therefore, when these tests and studies are performed in the future, besides careful planning, organizing a cross-field study group is proposed.



Photo 8. Present condition of debris flow tracks site in Feng Chiu by aerial image (4).



Photo 9. Present condition of debris flow tracks site in Feng Chiu by aerial image (5).

Acknowledgments

The authors wish to thank Peter F. Ffolliott, University of Arizona, Tucson, Arizona, and Malchus B. Baker, Jr. for their technical reviews of this paper.

Literature Cited

- AW&ST and AUVSI, (1997). "1997-98 International Guide to Unmanned Vehicles" A Publish of The McGraw-Hill Companies, ISBN 007-607102-2, May.
- Goodhue, J., (1997). "Experiments Aloft: Balloon Born Payloads Reach Near Space" GPS World, pp34-42, September.
- Barrows, A. K., Enge, P., Parkinson, B.W. and Powell, J.D., (1995). "Flight Tests of a 3-D Perspective-View Glass-Cockpit Display for General Aviation Using GPS" Proceedings of ION GPS-95, Palm Springs, California, USA, September 12-15.
- Barrows, A. K., Enge, P., Parkinson, B.W. and Powell, J.D., (1996). "Flying Curved Approaches and Missed Approaches: 3-D Display Trails Onboard a Light Aircraft" Proceedings of ION GPS-96, Kansas City, Missouri, USA, September 17-20.
- Clavet, D., (1993). "GPS Control for 1:50,000-Scale Topographic Mapping from Satellite Images." Photogram. Eng. And Rem. Sens., 59(1), pp. 107-111.
- Guan, W.L., Hsiao, F.B. and Ho C.S., (1997). "Developing a GPS Navigation System for Remotely Piloted Vehicle", AIAA Guidance, Navigation and Control Conference, New Orleans, LA Aug. 11-13.