DISASTER MONITORING AND MANAGEMENT BY THE UNMANNED AERIAL VEHICLE TECHNOLOGY

Tien-Yin Chou [a,], Mei-Ling Yeh [a,], Ying-Chih Chen [a], Yen-Hung Chen [a]

[a] Feng Chia University, Geographic Information System Research Center, No. 100 Wenhwa Rd., Seatwen, Taichung, Taiwan 40724 - (Jimmy, Milly, Joyce, Jasonchen)@gis.tw

Technical Commission VII Symposium 2010

KEY WORDS: Hazards, Landslides, Photogrammetry, Change Detection, Monitoring, Visualization

ABSTRACT:

In the local small densely populated Taiwan, the recent spates of serious natural disasters have caused loss of lives and property. In view of above, there is important to how to depend on a high flexibility remote sensing technology for disaster monitoring and management operations. According to the Unmanned Aerial Vehicle (UAV) technology advantages such as great mobility, real-time rapid and more flexible weather conditions, and this study used the UAV technology to get the real-time aerial photos. These photos can record and analyze the overall environmental change caused by the MORAKOT typhoon. And also after the process of Image Rectification, we could get the estimated data of new collapsed lands to become the useful references of emergency rescue.
On the other hand, digital photogrammetry can apply on the camera inside and outside position parameters to produce the Digital Elevation Model (DEM) data of 5m resolution. The DEM data can simulate the latest terrain environment and provide reference for disaster recovery in the future.

1. INTRODUCTION

The Unmanned Aerial Vehicle technology has developed over several years, and there is including fixed win vehicle and rotary wing vehicle. The characteristic of the UAV to the task of providing a good platform to replace the man was detected to ensure the security and the ability with visual images, allowing users to understand the actual situation. With advances in technology development, the functions of UAV are widely used for different purposes in recent years. These have included surveying the development of city infrastructure, researching agriculture, fishery and farming, monitoring environmental protection, highway driving, forestry management, and disaster prevention like floods or debris flow.
Since the earthquake 921 in 1999, there was have frequent natural disasters in Taiwan in recent years due to geology loose and huge changes of the global environment, it impacts people's livelihoods and security heavily. All government units in the pre-disaster preparedness, disaster response and post-disaster reconstruction in the emergency response to take various measures and contingency plans, the development of various policy ran really need to diversify information channels to provide assistance, in order to reduce people's lives property damage and to prevent the occurrence of secondary disasters.

The disaster areas are often located in difficult terrain with inconvenient and dangerous traffic; the officers are unable to get into there after the typhoon and earthquake. In emergency situations, the remote sensing technology can be used as real-time information gathering pipelines in order to provide real-time disaster information efficiently.

Therefore, in recent years for the land-use change and disaster detection, mostly aerial photographs or satellite images, and acquired by the interpretation of the information required; but satellite images because of the scope is too large, images of the small scale, in a small area or in the changing differences between small and require more detailed information on the occasion, often limitations and often can obviously see that although the overall changes in the region, but it can not be more precise differences between local area change. Although the aerial photographs of a large scale, but because each line of surveillance photographs, none fixed, doing image comparison, and overlap, the inevitably left beads of regret. UAV can work in dangerous and unreachable areas. While its small size, easy loading, with the better of the mobility, they can be used anytime, anywhere and in a relatively harsh climate of the mission.

So in this paper, there is introducing the technology and fly procedure of UAV and used the UAV technology to get the real-time aerial photos. These photos can record and analyze the overall environmental change caused by the MORAKOT typhoon. And also after the process of Image Rectification, we could get the estimated data of new collapsed lands to become the useful references of emergency rescue. On the other hand, digital photogrammetry can apply on the camera inside and outside position parameters to produce the Digital Elevation Model (DEM) data of 5m resolution. The DEM data can simulate the latest terrain environment and calculate the debris variation which can provide reference for disaster recovery in the future.

2. UAV PAYLOADS OF EQUIPMENT

UAV payloads of equipment, due to the different mission requirements to carry the applicable equipment with high flexibility in use; it can be used in various fields to carry out a variety of different tasks. Hereby will be used in this study the instruments and equipment, their characteristics and functions is set out in Table1.

Table 1 The Specification for UAV system

Weight	8.5kg
Payload	5.5kg
Engine	15 c.c. oil engine
Main Airfoil	680mm non-symmetry
Empennage	Standard Empennage
Operation Range	3000m / 10000ft
Operation Time	20 minutes
Operation Altitude	3000m / 10000ft

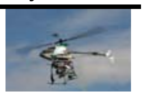


Table 2 The Specification for UAV Photographing System

Instrument	Model	specifications
Digital Camera	Canon EOS 5D Mark II	Effective Pixels: 21 million pixels Focal Distance: 1.8mm, Weight: 1.2kg Shutter Speed: 3.9fps
Digital Video Camera	Canon EOS 5D Mark II	Size: 1920 X 1080 pixels Focal Distance: 1.8 mm, Weight: 1.2kg Shutter Speed: 30fps
GPS System	SiRFStarIII Chip	Position Accuracy: ±3-5m Velocity Accuracy: 0.1 m/s RMS steady state Weight: 90g

3. OPERATION PROCEDURE

In order to improve the accuracy of UAV operation effectively, we collect the basic information of mission area, such as environmental information, flying plan (Figure 1) and weather factors. Then we choose the suitable weather to do the UAV operation procedure.

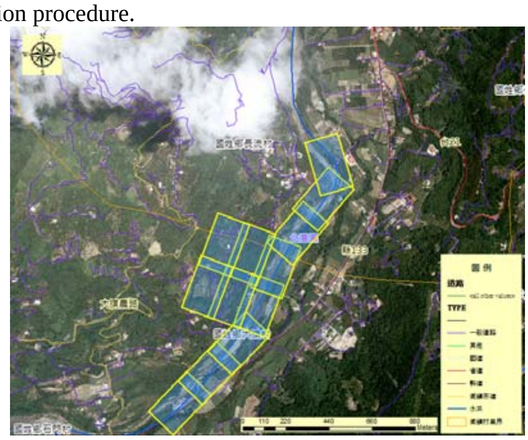


Figure1 The example of flying planning (pre-operation)

After the UAV operation procedure, we can get the different kind of images. These images are included nir-othor images and oblique shot images (Figure 2) which were are color correction and images mosaic. And in order to get the images with spatial coordinate system, we use the rubber sheeting method to collect these images. Finally, we can use these images to produce other application such like quantification of landslides or terrain simulation. Figure 3 is all the UAV operation procedure.

oblique shot image	nir-othor image

Figure2 The types of UAV images

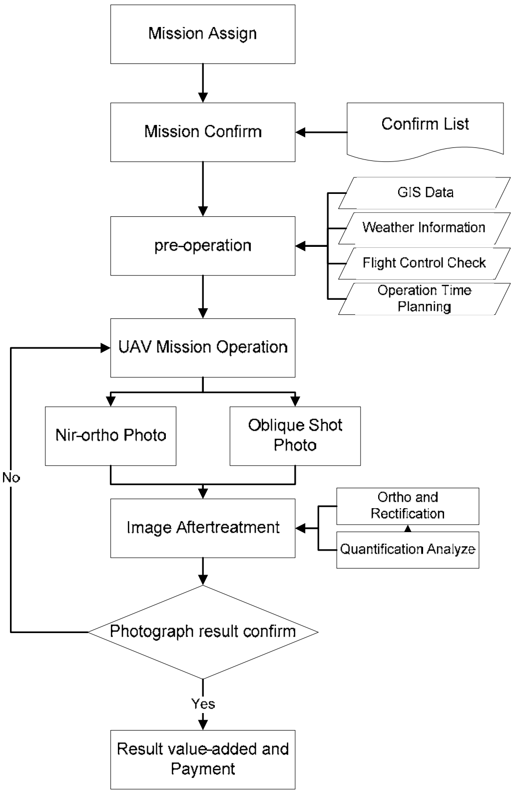


Figure 3 Operation procedure of UAV

4. EMERGENCY PHOTOGRAPHED RESULT AFTER TYPHOON MORAKOT

MORAKOT typhoon is the biggest natural disaster in Taiwan for fifty years. It brought different kinds of disasters, such like flood, dam failure, the broken of road and bridge, landslide, quake lakes, turbid water and driftwood. According to the data from Central Weather Bureau, there were total 673 people were killed and 26 were missing, more than NT 19.5 billion agricultural loss during the MORAKOT typhoon period. Because of many of these disasters were occurring simultaneously in the same place, the rescue were getting more difficult.

The obvious characteristic of MORAKOT typhoon is the huge rainfall. Even though the strength is medium, the rainfall is exceeded everyone's expectations. As Figure 4 is the cumulative rainfall of MORAKOT typhoon, it shows the rainfall center was located in the south area of Taiwan. And table 1(Shieh, etal. 2009) is the historic rainfall record; we can see the accumulation of rainfall depth of MORAKOT typhoon is reach 2583mm that gathering in 91 hours.

Figure 4 Isohyets of the cumulative rainfall of MORAKOT typhoon

Table3 The largest rainfall records of different typhoons

Typhoons	Year	Rainfall station	Accumulation of rainfall depth（mm）
MORAKOT	2009	Yu You Shan	2583
KALMAEGI	2008	Xin Fa	1043
AERE	2004	Guan Wu	1223
TORAJI	2001	Da Nong	433.5
WINNIE	1997	Wu Du	354
HERB	1996	A Li Shan	1986.5

Because of the heavy rainfall, the Typhoon MORAKOT backdrop of heavy rain hit southern Taiwan. Particularly the debris flow disasters were happened in Jiasian Township, Liouguei Township and Namasia Township, Kaohsiung County, Alishan Township, Meishan, Chiayi County, and Laiyi Township, Pingtung County, and Sandiman Township the most serious. Figure 5 is showed the most serious disaster locations.

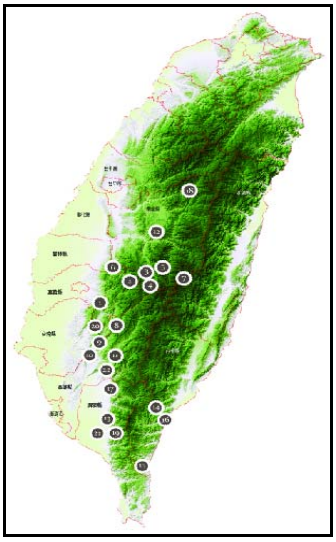
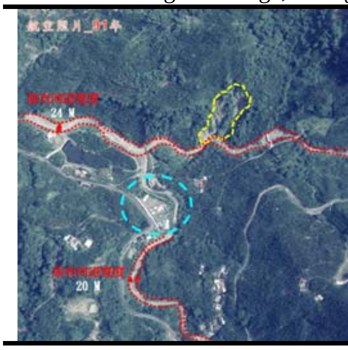
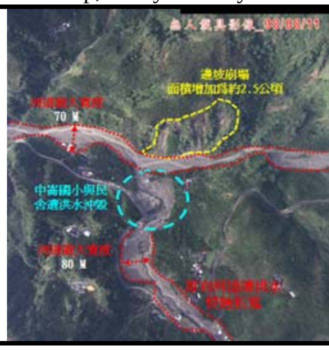
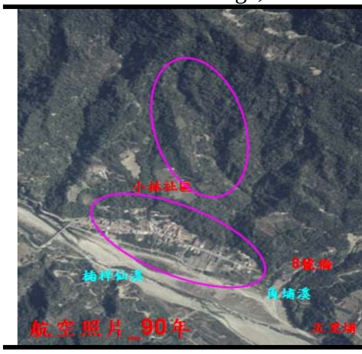
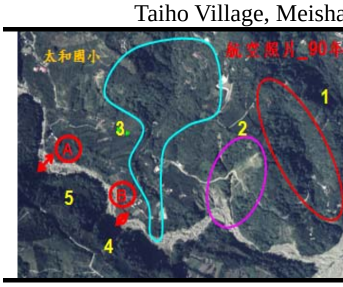
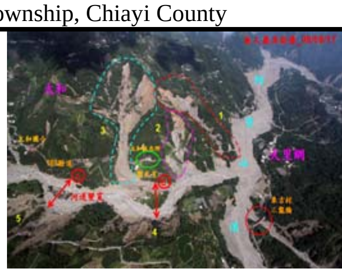
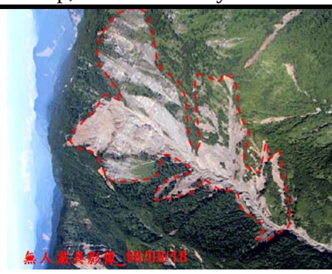


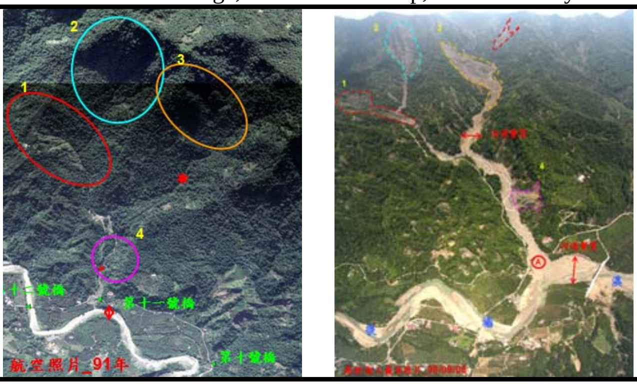
Figure 5. Disaster Areas After Typhoon MORAKOT

Soil and Water Conservation Bureau to assist this study, the use of UAV technologies to overcome transport barriers to quickly acquire all the major affected areas of the real-time disaster information, disaster follow-up analysis, disaster restoration and reconstruction work and the importance of reference information.

Table 3 The Achievement Images of Emergency Photographed After Typhoon MORAKOT

Before	After
Zhonglun Village, Zhongpu Township, Chiayi County	
	
Siaolin Village, Jiaxian Township, Kaohsiung County	
	
Taiho Village, Meishan Township, Chiayi County	
	
Shenmu Village, Xinyi Township, Nantou County	
	
Singlong Village, Liugui Township, Kaohsiung County	
	

Before	After
Guanshan Village, Nanhua Township, Tainan County	



5. USING UAV TECHNOLOGY TO PRODUCE THE DIGITAL TERRAIN MODEL DATA

UAV is also a part of aerial remote sensing, over the years the collection of information on the environment plays a very successful role. Because of their high mobility and high revisit rate, therefore, the use of remote unmanned vehicles in a similar way the traditional aerial surveys produced digital elevation data can be master of environmental information and analysis, providing important analysis is available.
Digital Terrain Model (DEM) data is the important basic environmental information, and the data is usually used for spatial analysis research. In this study, we would use the UAV technology to produce the 5m resolution DEM data. The study area is located in HuaShan River of YunLin County. The produce was included camera calibrating, terrestrial photogrammetry, aerial photograph, and simple aerial triangulation and finally gets the DEM data.

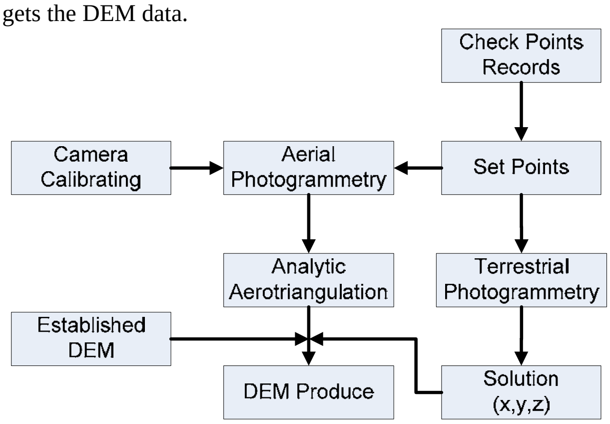
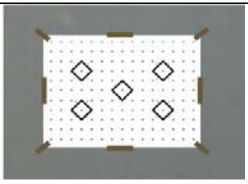


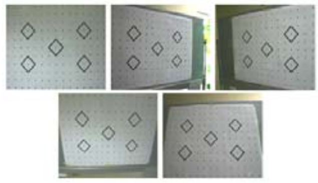
Figure 6 The Procedure of DEM Data Product

5.1 Camera Calibrating

Before using the UAV technology to execute the aerial photogrammetry, we must do the camera calibrating. The camera type is the Canon 500D. First we did the pattern sheet in the calibrated place, and then we used the camera to take positive direction, about 45 degrees up and down the images. Finally we took all the angles of images into the operational programs to get the calibrated parameters to be the reference of producing DEM data. Figure 7 is showed the images of camera calibrating procedure.

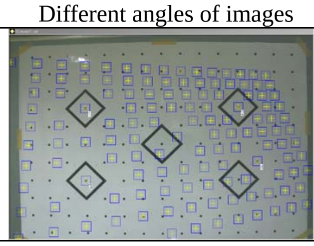


Patter Sheet



Different angles of images

Mathematical operation



Patter Sheet Detection

28.032958 // Focal Length
10.957661 // Xp
7.422567 // Yp
2 // Distortion Model
4 // Number of Distortion Parameters
1.336398e-004 // k1
-2.108462e-007 // k2
-2.991114e-005 // p1
-1.278623e-005 // p2
0.004600 // X Resolution
0.004600 // Y Resolution
0 // Number of Fiducial Marks

Parameters of camera calibrating

Figure 7. The images of camera calibrating procedure

5.2 Terrestrial Photogrammetry

In order to confirm the location of control points, the study area must set some aerophotography survey marks. These marks record important information about control points, such like sizes, shapes, colors, materials and positions.

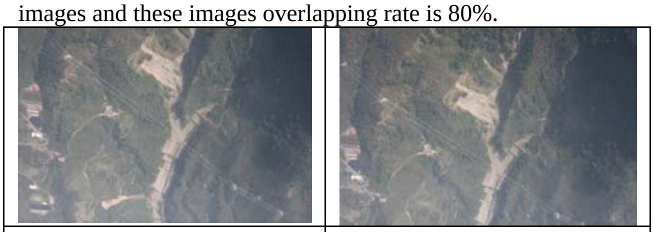
Figure8 aerophotography survey marks

Besides, we executed terrestrial photogrammetry to get the control points which from aerophotography survey marks. The survey information would be the useful reference of image rectification.

Figure 9 Terrestrial Photogrammetry

5.3 Aerial Photogrammetry

In this procedure, we use the UAV to get the aerial photos and take the aerial photogrammetry rules for example. The photogrammetry must do the vertical continuous photography. Photo-axis tilt required less than 4 degrees, Air angle less than 10 degrees, the route should be more proactive at both ends of two relative images. Figure 10 is showed the photogrammetric images and these images overlapping rate is 80%.

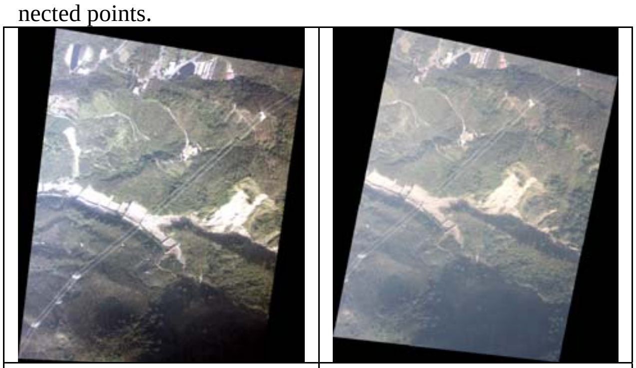


Left Image | Right Image

Figure 10 The photogrammetric images

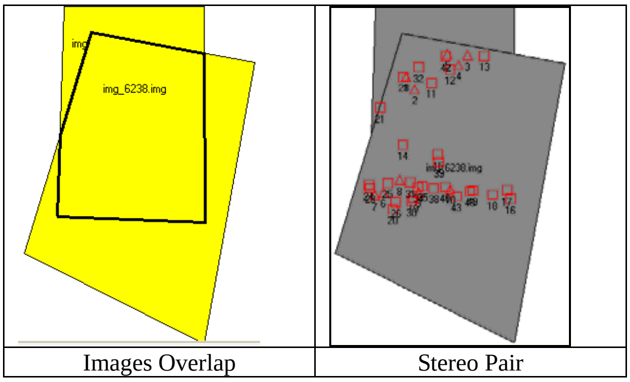
5.4 Analytic Aerotriangulation and Orthorectification

In order to eliminate errors associated with the process of aerial photogrammerty, we used the Pixel by Pixel Rectification Method to do the images orthorectification. The results are showed as Figure 11. Figure 12 are showed the images after interior orientation and exterior orientation procedure operation. The triangles are control points and the square are the connected points.



Left Images | Right Images

Figure 11 Orthorectificated Images



Images Overlap | Stereo Pair

Figure 12 Images Overlap and Stereo Pair

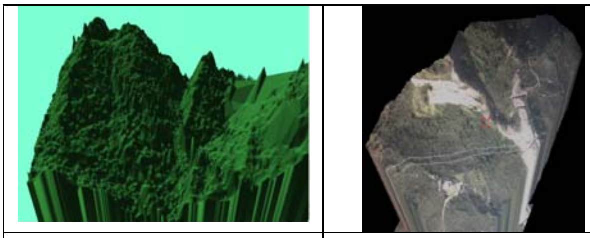
5.5 DEM calculation results and accuracy check

After the above procedures and measured solution, we produced the 5m resolution DEM data. And the data accuracy was checked by 10 points, there is showed as Figure 13. And Figure 14 is the DEM result.

The residuals of the check points

Point ID	rX	rY	rZ
6	-6.0546	2.2757	0.2877
27	0.1115	-0.0374	0.3052
34	-0.0072	0.0094	-0.1572
38	0.0054	0.0299	-0.1849
51	0.0000	-0.0013	-0.1788
66	-0.0052	0.0048	-0.1507
83	0.0167	-0.0263	0.0978
115	-0.0190	-0.0014	-0.0633
122	0.0938	-0.0660	0.2953
133	-0.0980	-0.0560	-0.2192
	aX	aY	aZ
	-0.5956	0.2131	0.0032
	mX	mY	mZ
	1.9155	**0.7204**	**0.2094**

Figure 13 The accuracy of DEM data



DEM Model | DEM overlap Aerial photo

Figure 14 DEM result

6. ADD-VALUE APPLICATION OF DEM RESULT

The use of UAV produced DEM data, remote sensing information can be carried out with related sets of overlapping, and the use of value-added multimedia technology to carry out target areas show environmental change. So we can build the 3D simulation that can display the surface details and reserving time, thus reducing the overall cost. So, this study integrated updated high resolution of aerial photos and high precision DEM data to simulate the 3D environment. The simulation result shows as Figure 15.

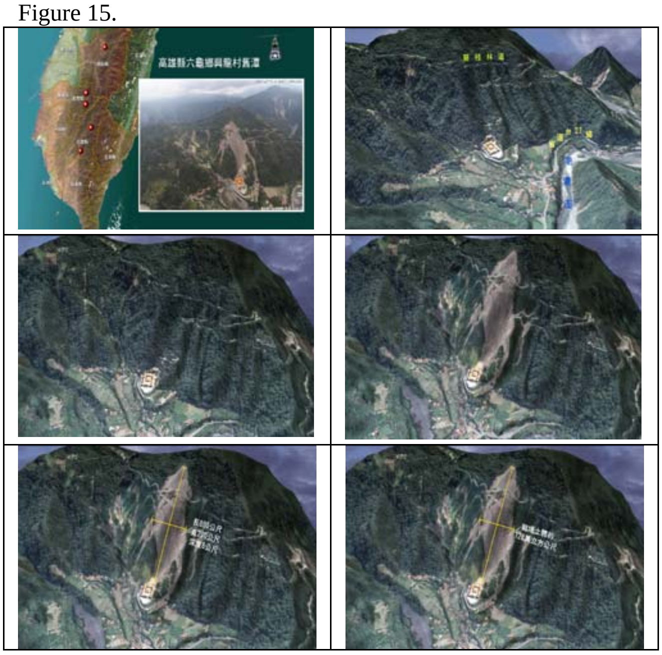


Figure 15 The Achievement Images of Photographed Image Add-value Application

7. CONCLUSIONS

The rain of typhoon is a large area, high-intensity, long the pattern, resulting in increase landslides and debris flow, and the type of disaster is no longer a local area of the flood or sediment disaster hurricane events in the MORAKOT presented for large-scale floods, landslides, debris flow, avalanches, and other barrier lake complex disasters. And a large number of earth and rock entrainment flooding upstream migration, the downstream simultaneously super-heavy rain again, so to make the amount of surge flooding downstream areas, and thus downstream river-crossing bridges, coastal highway facilities, water facilities, causing a major impact, but also in turn affect the resumption of the follow-up disaster relief construction work limitation.

So using the UAV technology is providing applicable information and assistance, therefore we need to build a procedure of disaster information collection and build. Base on this we can get effective information at appropriate time and provide the reference for the phases of disaster-preparedness, response and return. This study used the high mobility, high time-resolution and high image resolution and other features of unmanned vehicles to provide government important reference information in planning for disaster response and return.

References from Journals:

Long-Ming Huang, Wen-Fu Chen, Sheng-Jie Wu, Chang-Hang Wu,2006, Application of Geometric Correction Method to Remotely Piloted Vehicle (RPV) Airspace Image for Surveying and Analysis of Disaster Areas, Journal of Chinese Soil and Water Conservation, 37(2):111-124.

Afzal Ahmed, Dr. Masahiko Nagai, Dr. Chen Tianen, Prof. Ryosuke SHIBASAKI, 2008, UAV Based Monitoring System and Object Detection Technique Development for a Disaster Area, The International Archives of the Photogrametry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B8. Beijing.

U. Coppa, A. Guarnieri , F. Pirotti , A. Vettore, 2008, Accuracy Enhancement of Unmanned Helicopter Positioning With Low Cost System, The International Archives of the Photogrametry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B5. Beijing.

C.L. Shieh, C.M. Wang, W.C. Lai, Y.C. Tsang,S.P. Lee, 2009,"The composite hazard resulted from Typhoon Morakot in Taiwan,"Journal of the Japan Society of Erosion Control Engineering, Vol. 62, No.4, pp. 61-65.

Chun-Ming Wang, Shin-Ping Lee, Chen-Chian Li, Yun-Chung Tsang, Chjeng-Lun Shieh, 2010, Disaster caused by typhoon Morakot, Journal of the Taiwan Disaster Prevention Society, vol.2,NO.1.

ACKNOWLEDGEMENTS

Thanks for the Soil and Water Conservation Bureau to provide the funds to assist the project.