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Original Research Article

DEVELOPING AND FILED TEST OF A LOW-COST UNMANNED AERIAL VEHICLE FOR USING THE DIGITAL IMAGE CORRELATION METHOD

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Abstract: Taiwan is located on Pacific seismic belt. Otherwise, global warming causes climate change to induce heavy precipitation and typhoons in summer. Therefore, people in Taiwan experience earthquakes and typhoons many times every year. Unfortunately, geological conditions in Taiwan can not suffer these kind nature hits to cause natural disasters, affected the life and property of people seriously. In order to rescue people's life and protect property of citizens, disaster areas need to be investigated as soon as possible to provide more information for national rescue teams to adopted policy to integrate national emergency relief resources. Thus, unmanned aerial vehicle (UAV) is provided with characteristics of quick deploy and reconnaissance. But, UAV is very expensive. Therefore, in this research, the concept of fixed wing airship, embedded simple microcontroller board, such as GPS, 3-axis Gyroscope, Gravity-sensor and Magnetometer, is used to construct a low-cost unmanned aerial vehicle (UAV). Otherwise, the digital image correlation (DIC) method, applied digital camera, a non-contact optical measurement and computational capability of computer, has been developed by our research team. In this study, this developed UAV combines with developed digital image correlation (DIC) method and the remote sensing technology to expand as an automatic investigation device of cruise to monitor the possible occurrence of distressed area. The field test of this developed UAV combined with camera, installed with the developed DIC method, has been test and verified at mountain in central Taiwan. The analysis results of these tests reveal that this UAV with DIC can automatic flied through the preestablished positions to detect digital images. The practicability and mobility of this UAV with DIC method have been verified in this study.

Keywords: Digital Image Correlation Method (DIC), Auto-Pilot, Open Source, unmanned aerial vehicle (UAV)

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1. Introduction

Global warming to cause climate change, there are many heavy precipitation, typhoons and strong earthquakes, happened around the world. These natural disasters affect life and property

of people. Two strong earthquakes caused the terror-stricken tsunami disaster caused by the earthquake in Indonesian and Japan with Richter scale of 9 in 2005 and 2011 respectively. Especially, Japan Earthquake 2011 caused complex disasters, included Fukushima nuclear disaster. This nuclear disaster resulted in radiation hazard to affect people's life and safety of rescue team. Therefore, how to survey disaster area to provide disaster relief are very important affairs for government. Rapid reconnaissance and rescue are needed to be executed as soon as possible. Unfortunately, there are many uncertain and unsafe conditions around these disaster areas. These indeterminate situations caused some tragedies for rescues teams and affected life of relief workers (Taiwan News report, 2009). Therefore, new technology can be applied to investigate the real situations of disaster areas to protect the safety of rescue team.

The technologies of Unmanned Aerial Vehicle (UAV) have been widely applied to this kind issue. But, the price of UAV is very expensive to restrict the application of this technology. In this research, three open sources with the global positioning system (GPS), 3-axis Gyroscope and Magnetometer are applied to develop a Low-Cost Unmanned Aerial Vehicle (UAV). Otherwise, the technologies of digital image correlation method (DIC) (Tung et al. 2014; Shih and Sung 2013; Tung et al. 2012; Sung et al. 2012) are combined with this developed UAV to detect the digital images from set positions. Field test of this developed UAV with DIC is executed to verify the practicability and feasibility of this proposed method in this research.

2. Methodology

Recently, some of open source projects have been announced to develop unmanned aerial vehicle such as: OpenPilot, Paparazzi and ArduPilot (Liu et al 2012; Jama and Schinstock, 2011; AI-Tahir, and Arthur, 2012). These projects provide with the flight module program or hardware structure as open source. These projects reduce research obstacles. Therefore, in this research, these three open sources have been applied to develop unmanned aerial vehicle. Otherwise, our research team has been developed Digital Image Correlation (DIC) method many years (Tung et al. 2014; Shih and Sung 2013; Tung et al. 2012; Sung et al. 2012). Therefore, this DIC method is applied to combine with this developed UAV.

2.1 Auto Pilot Control Hardware

Open Pilot is one of the most famous Open Source UAV autopilot, it is not a commercial venture but an Open Source community project. The control board is designed for tiny and low-cost control autopilot platforms. It is a capable platform for multi-rotor craft, helicopters and fixed wing aircraft as well.

2.2 Paparazzi Project

Paparazzo is a free and Open Source hardware and software project. The key feature of the paparazzi autopilot is its unique combination of inertial measurement and infrared thermopiles for attitude sensing, providing a robust and accurate attitude estimate that requires no ground calibration and can recover from any launch attitude.

2.3 ArduPilot

ArduPilot is a full-featured autopilot based on the Arduino Open Source hardware platform, and it is based on a 16 MHz Atmega328 processor for processing the control commands. ArduPilot is free open source firmware for different versions of control boards:

These three open sources have been applied to develop the fixed wing UAV. The prototype of this developed UAV is shown in Fig. 1.

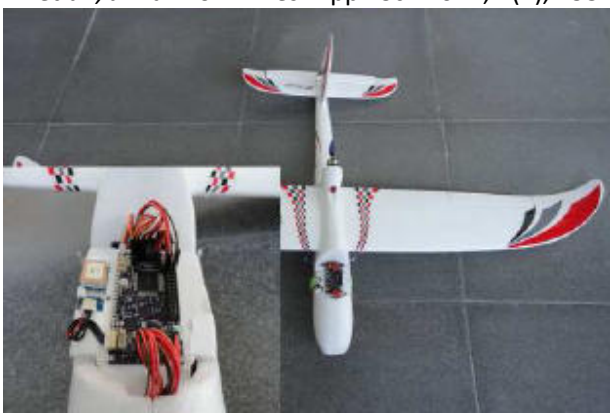

Fig. 1: the prototype of this developed UAV based on these three open sources

2.4 Digital Image Correlation Method

Digital Image Correlation method is basically taken as the foundation of "search to perform mathematical calculations ", comparing the partial relativity of two images and judging the image towards reflection before and after transformation. This concept, which makes use of finite element method, will transform in-front and back. It attempts to divide the image body up into a small mesh, being called as sub-image. Assuming the one point of sub-image, shown as Fig.2, which transforms an in-front and back bit in a displacement function:

$$x^* = x + u(x, y)$$
$$y^* = y + v(x, y) \qquad (1)$$

The relativity analysis related to transforming in-front and back is in accordance with the Digital Image Correlation method that judges the degree of transforming the image in-front and back. This makes the sum of the gray scale inside image equal to the total amount. The Digital Image Correlation method is defined as follows:

$$COF = \frac{\Sigma g_{ij} \tilde{g}_{\bar{i}\bar{j}}}{\sqrt{\Sigma g_{ij}^2 \cdot \Sigma \tilde{g}_{\bar{i}\bar{j}}^2}} \qquad (2)$$

Where, g_{ij} *and* $\tilde{g}_{\bar{i}\bar{j}}$ *are grey scale of image A on coordinate (*i, j*) and image B on coordinate* $(\bar{i}, \bar{j})$*, respectively. And coordinate* $(\bar{i}, \bar{j})$ *of image B corresponds to coordinate (*i,j*) of image A.*

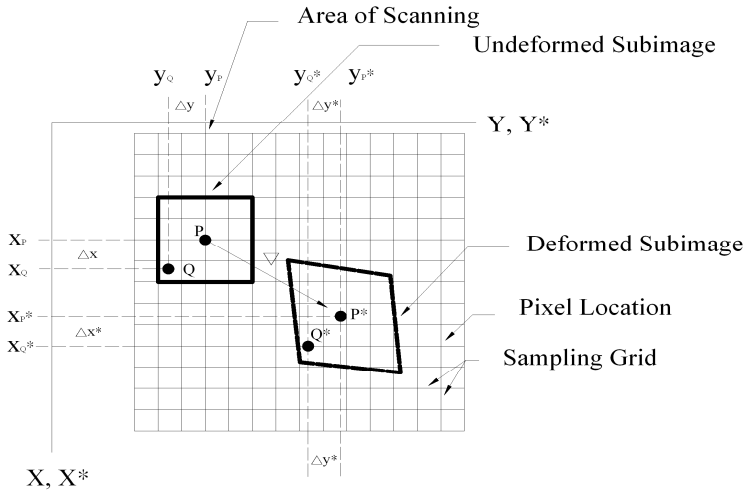

Fig. 2: Schematic drawing of relative location of sub-images of deformed and un-deformed images on surface

3. Test Results

Field test of this developed UAV with DIC is executed at height of 650 meter in central Taiwan. All the flight paths of this UAV were steered by the set path in advances. Otherwise, the flight control of UAV flight altitude was under control of global positioning system (GPS). This GPS is applied to control the Latitude, Longitude, Ground speed and Coordinated Universal Time (UTC) time of this UAV. Then, 3-axis Gyroscope can measure or maintain its flight orientation. Gravity-sensor can measure the angle of UAV with respect to ground. Magnetometer can judge the azimuth angle of UAV easily. Then, digital camera is installed at the bottom of UAV to detect the digital images automatically. The original digital images photos detected by this installed digital camera are shown in Fig. 3.

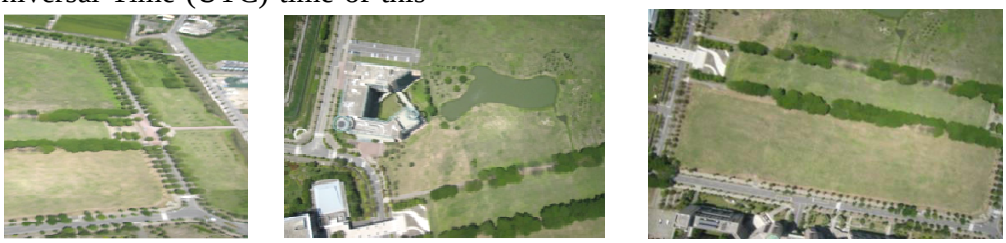

Fig. 3: The original digital image photos detected by digital camera

Actually, there are some errors are happed at these detected photos, caused by the rotation of camera lens and detected angle of camera. Therefore, Georeferencer GDAL is applied to decorate these photos. This GDAL not only corrected the tilt deformation of aerial photographs, using the GPS coordinates of the reference point on the aerial photographs to identify with known geographic coordinates information and also these aerial photographs can be placed in the correct position on the coordinates to correct the deformation cause by UAV vehicle is tilting when the moment of capture original image. This corrected, edited and mapinterlinking photo, detected from DIC camera, is shown in Fig. 4.

Fig. 4: The corrected, edited and mapinterlinking photo from camera installed in UAV

Then, the aerial photography published by government is applied to compare with the analysis results of this proposed method. The similarity degree of these two photos is about 96.7%.

4. Conclusions

The open sources are applied to develop unmanned aerial vehicle (UAV), embedded with GPS, 3-axis Gyroscope, Gravity-sensor and Magnetometer, is feasibility. The test results can obtain the following comments:

1. All embedded devices can bring their functions to control and reach the set flight requirement. The flight path can follow all set flight path and altitude.
2. The digital camera can detect the digital photos, followed the set requirement. But, some of photos need to be corrected, edited and mapinterlinking photo.
3. The mapinterlinking photo of this proposed device compared with the aerial photography is about 96.7%. The precision degree and practicability of this developed UAV with DIC camera has been proved in this study.

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References

1. http://big5.cri.cn/gate/big5/gb.cri.cn/27824/2009/08/12/2225s2589481.htm
2. S. H. Tung, M. H. Shih and W. P. Sung, 2014, “Applying the Digital-Image-Correlation Technique to Measure the Deformation of an Old Building’s Column Retrofitted with Steel Plate in an In-situ Pushover Test” , Sadhana - Academy Proceedings in Engineering Science, *Vol. 39, No.3, pp.699-711.*
3. M. H. Shih, and W. P. Sung, 2013, “Application of Digital Image Correlation Method for Analyzing Crack Variation of Reinforced Concrete Beams”, Sadhana - Academy Proceedings in Engineering Science, *Vol. 38, No. 4, pp. 723-741.*
4. Shih-Heng Tung, Ming-Hsiang Shih, W. P. Sung, Meng-Chia Weng, 2012, “Applying Digital Image Correlation Method to Detect Deformation of Abamurus”, Disaster Advances (SCI), Vol. 5 (4),pp. 202-208.
5. W.P. Sung, Shih, Ming-Hsiang, 2012,“Applying Spine-Type Prism to Improve Three Dimensional Dynamic Digital Image Techniques”, Advanced Science Letters,Vol. 13, No.1, pp. 879-883(5).
6. C. Liu, et al, 2012, “Path following for small UAVs in the presence of wind disturbance,” in Proceedings of 2012 United Kingdom Automatic Control Council(UKACC), pp. 613-618.
7. M. Jama, and D. Schinstock, 2011, “Parallel Tracking and Mapping for Controlling VTOL Airframe,” Journal of Control Science and Engineering, Volume 2011, Article ID 413074, 10 pages.
8. R. AI-Tahir, and M. Arthur, 2012, “Unmanned Aerial Mapping Solution for Small Island Developing States,” in Proceedings of Global Geospatial Conference 2012.