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International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies

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Unmanned Blimp Aerial Photography for Low-cost Mapping

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ARTICLEINFO

Article history:
Received 15 July 2015
Received in revised form
19 October 2015
Accepted 10 November 2015
Available online
12 November 2015

Keywords:
Photogrammetry;
UBAP;
topography;
auto-pilot;
ortho-rectification;
mosaic image;
cadastral;
GPS.

ABSTRACT

Traditional land surveying requires skilled surveyors and high resolution satellite imagery is costly and undated source. As a consequence, topographical and other spatial data is more or less lacking for rural and urban planning and development. Unmanned Blimp Aerial Photography (UBAP) with vertical color aerial images is an alternative way for land surveying and topographical mapping. This research project integrates UBAP system to provide a low-cost but quality efficient solution for producing aerial color photos on a high pixel resolution. The test site is in Chonburi province (Bangphra district) on Rajamangala University of Technology Tawan-ok, Bangphra Campus where results mosaic ortho-rectification images for updating cadastral map and generating Digital Elevation Model (DEM) for 3-D city modeling. The balloon altitude is at 150 meters with about 3-centimeter Ground Sampling Distance (GSD) by using auto-pilot system. Mapping accuracy is then compared with static positioning measurement from Global Positioning System (GPS).

1 Introduction

Airphotos are the most widely available and often used type of remote sensing data worldwide and constitute the standard by which all other types of remote sensing are judged for coverage, spatial and spectral resolution, cost, and suitability for a host of survey and mapping applications. For satellite-acquired remote sensing, aerial photography has become

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an important source of ancillary data for analysis and interpretation of space-based imagery (Aber and Aber, 2002).

Manned platforms employed for Small-format aerial photography (SFAP) include small airplanes and helicopters, ultra-light planes, and hot-air balloons. Unmanned platforms are model airplanes (Murden and Risenhoover, 2000; Planer-Friedrich et al., 2007) hot-air blimps (Marzolff and Poesen, 2009), helium blimps and balloons, and kites (Aber et al., 1999).

Low-cost Unmanned Blimp Aerial Photography (UBAP) was built by using some local materials and equipments that can be integrated at low cost (if we can produce as commercial product can cost down below 1 million Baht ($US30,000): excluded with operation cost). According to the Bangkok Post (2009), if we compare to Thai Royal Army used the two high-resolution surveillance cameras for the plane-shaped balloon at the cost of 350 Million Baht (US$10million). The system has autopilot for aerial photography, post-processing for Ortho-image and mosaic photos to produce 3D building model and topographic map and land survey.

Update land use information, cadastral mapping and infrastructure surveying are priority and crucial requirement for updating cadastral map. GIS database at the scale of 1:4,000 is being built and updated at provincial administrative organization, and the administrative authority of sub district in Thailand where high resolution of satellite imagery is very costly and aerial photograph is outdated and always not available, especially in the rural areas.

The idea is to provide a low-cost but quality efficient solution for producing aerial color photos on a high pixel resolution. Other high resolution images from advanced scanners like Quickbird, Ikonos or others are most likely unaffordable due to insufficient decentralized budget of Government offices. As a consequence topographical and other spatial data is more or less lacking in planning offices. Other problems involve lacking of sufficient overlap among the photo that make it impossible for geo-rectification and Digital Elevation Model (DEM) generation for the study area, lacking of integration of high accurate GPS data collection at the time of image capture, this leads to low map accuracy (El-Sheimy et al., 2005), as well as high cost of remote sensing digital image processing with a lot of unused function that makes users difficult to operate and hard for technology transfer.

Replacing conventional aerial photography, the new technology for Unmanned Blimp photography (UBAP) is developed for local administrative officers in Thailand for cadastral map updates. UBAP is vertical, oblique or panoramic aerial images; a unique method of low altitude aerial photography allows almost unlimited camera has best photograph the subjects.

This technology can produce land use map at the scale of 1:4,000 and update GIS data in district and sub-district level. The ortho-rectification images from this work can be used for factory, industrial land management, real estate, land development site for construction and road building. This low-cost surveying technology can be transferred to local administrative officers. As it is an easy technology, people with little knowledge on surveying and GIS can quickly grab the technology concept.

2 Literature Review

Conventional, large-format aerial photographs, taken from heights of several 1,000 meters and at scales of 1:20,000 to 1:40,000 have resolution on the range of 1- 4 m. Similar resolutions are achieved by high resolution Ikonos satellite imagery. Most other satellite sensors, such as Landsat 7 ETM and SPOT, provide moderate resolutions of 15 to 30 m. In order to achieve sub-meter resolution, a variety of small-format techniques have been developed for aerial photography (Lillesand et al., 2004). Small-format aerial photography (SFAP) has experienced rapid development during the past quarter century, spurred by innovations in platforms and camera systems as well as increasing demand for high-resolution, large-scale imagery in diverse applications (Light, 2001). SFAP is typically acquired at low height (few 100 m), which results in high-resolution and large-scale images while sacrificing broad areal coverage. Thus, SFAP is well suited for detailed investigations of relatively small ground targets and selected objects.

Seang and Mund (2006) researched on Balloon Based Geo-Referenced Digital Photo Technique. Their utilized balloon is made of light PE material with a maximum size of inflation of about 2.5m. It is fixed and controlled via 6-8 non flexible offshore fishing lines adjusted at special fixation tongues on the bottom of the balloon. As inflation gas helium or hydrogen can be used.

None of the above reviews are feasible in the context of Thailand due to the image coverage is small and not sufficient for cadastral mapping. Those incompatible systems are pointed as following:

- Altitude of kite is low and not sufficient to capture a large area that results a lot of works for mosaic the photos.

- Angle of view of the camera lens is limited at 50 to 32 degree (38 mm to 114 mm on a 35 mm camera). This causes small captured coverage of imaging and labor consumption to map a large area.

3 Study Method

3.1 Equipment and Tools

3.1.1 Unmanned Blimp

Unmanned Blimp (16 meter length and 2.4 m diameter) is an aerial photography flight platform which formed by air capsule, power devices and helm as illustrated in Figure 1. Material of the balloon is double layers PVC tarpaulin, thickness heavy-duty, laminated and coated pvc fabric. Our materials are puncture-proof, fire-resistant and comply with American Society for Testing and Materials (SGS & ASTM) safety standards.

Figure 1: The Unmanned Blimp used in this research.

The unmanned blimp aerial photography system with balloon, flight control and digital remote sensing device are described in Figure 2.

3.1.2 Flight Control System

Blimp flight control system are designed for autonomous flight control, it can control the blimp in accordance with the planned routes and altitudes. Meanwhile it incorporated with the integrated digital camera control and three-axis stabilized platform.

- Control the helm rotation

- Control the engine speed and power output
- Control the digital camera's exposure
- Control the rotation
- Blimp working status acquisition
- Digital cameras working status acquisition

3.1.3 Digital Remote Sensing Device

Digital Camera: System Application using SLR digital camera as aerial imaging equipment, the main parameters are affective pixels (16.68 million pixels), maximum resolution (4,592 x 3,448), sensor type MOS, sensor size (20 mm) and storage media Security Digital memory cards. Cost of equipment and tools is summarized in Table 1.

Equipment and Tools	Quantity	Value (Baht)
Unmanned Blimp System		
Unmanned Blimp	1	200,000 (US$6250)
Flight Remote Control System	1	200,000 (US$6250)
Autopilot Control System	1	200,000 (US$6250)
Aerial Photography System		
Digital Remote Sensing Device	1	100,000 (US$3125)
Stabilizing Platform	1	100,000 (US$3125)
Data Acquisition	1	100,000 (US$3125)
Post-Processing Software	1	100,000 (US$3125)
Total		1,000,000 (US$31250)

3.2 Energy and power consumption

The energy and power consumption mainly use for the system are Liquid helium for filling the balloon and gasoline gasohol 91 for engine operation and transformed Alternating Current (AC) 15 voltage for helm rotation.

3.2.1 Liquid helium

Liquid helium is used in cryogenics and has been filled to the balloon. Helium is the second lightest gas, thus good for lifting as well. A major advantage is that this gas is noncombustible. Helium, which has a mass of 4.00 g/mol, has a density of 0.164 g/l. Thus, a one-liter balloon of helium can lift a mass of (1.18-0.164) = 1.02 g. Of course, this would include the mass of the balloon skin itself, and we are assuming that the pressure inside the balloon is not significantly greater than the surrounding pressure of 1 atm. (http://web.physics.ucsb.edu/~lecturedemonstrations/ Composer/Pages/36.39.html)

3.2.2 Gasohol 91

Power module provides the power for blimp's flight. Power module is an integrated

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installation for two 62 CC engines used Gasohol 91 (a mixture of gasoline 91 and ethanol,). The engine is installed on both sides of the blimp, equipped with tanks, tilt rotor, engine and other related equipment. Propeller engine protected by glass fiber reinforced plastic protective cover (ducted).

3.2.3 Transformed electricity AC15 Voltage

Transformed electricity AC 15 Voltage is supplied for Control the helm rotation. Control the engine speed and power output Wire wound potentiometer. (High power wire wound pots are referred to as "rheostats".) Because the characteristics of resistance wire can be very closely controlled, wire wound pots can be made very precisely and very linear. The HS-815BB was designed primarily as a flight servo but is great for all types of applications. A 140° rotation means that it operates 50° more than a standard servo. This larger angle of operation is taken advantage of by the extra long 4.5” arm that comes standard with the HS-815BB servo. Hem includes Rudder and the elevator are composed of light processed wood material, using frame type construction to ensure strength (Figure 3.9). They are installed in the blimp astern, to control the blimp's flight direction and height.

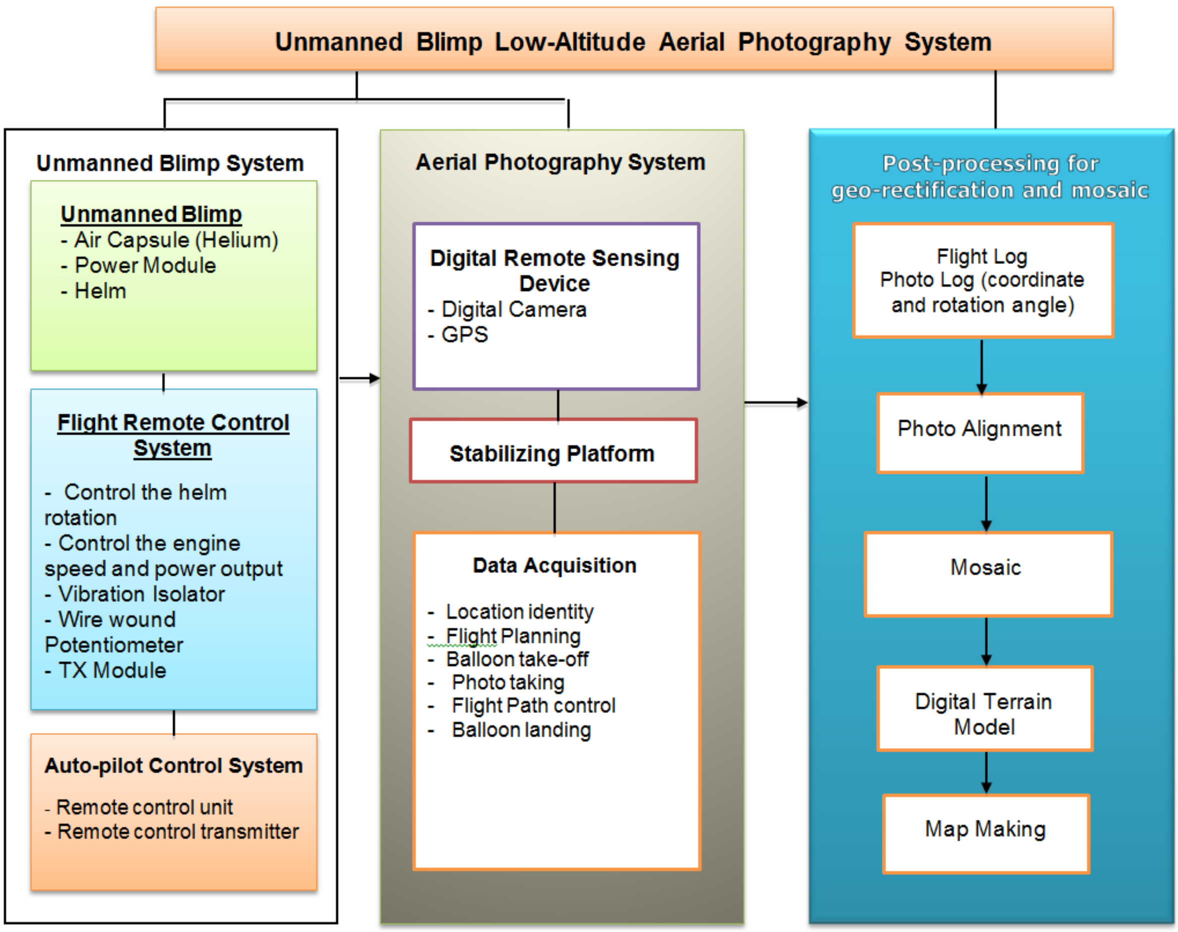

Figure 2: System configuration.

3.3 Study area

Bang Phra in Si Racha district is a in Chonburi province, Thailand. 80 kilometer apart to South East of Bangkok, Bang Phra is located at the Gulf of Thailand, about halfway between Chonburi and Pattaya as shown in Figure 3. It is in a heavily industrial zone consisting of manufacturing and shipping industries, supported by the sprawling port of Laem Chabang (20th largest in the world, see List of world's busiest container ports). With Chonburi city to the north and Pattaya, Bang Lamung township, Laem Chabang to the south, it forms the economic zone of the Eastern Seaboard of Thailand, a fast growing zone that is second to only Greater Bangkok in population and wealth. Due to the strong infrastructure, Laem Chabang and the Eastern Seaboard in general is the major hub for international exports.

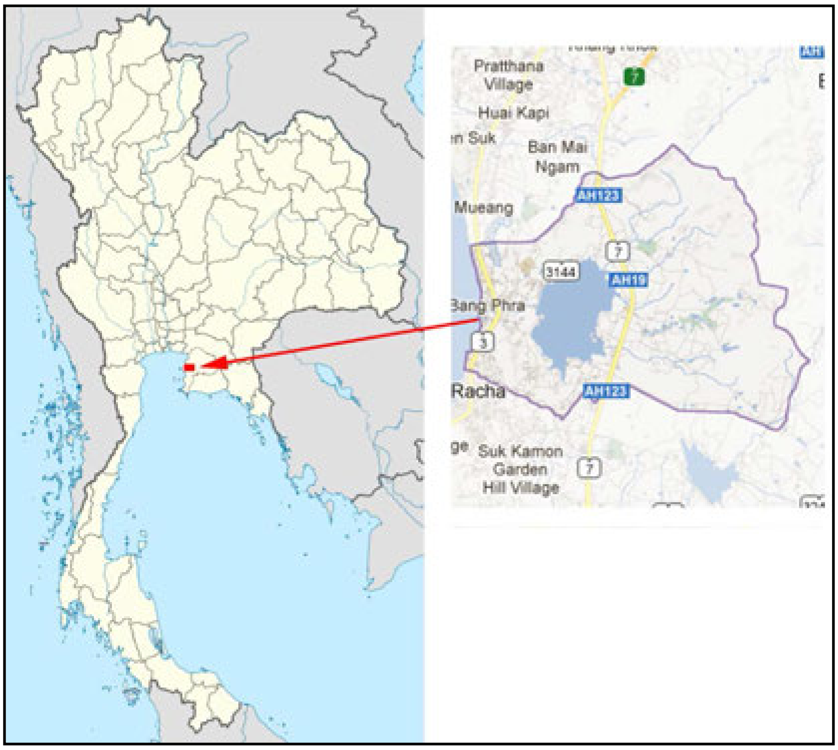

Figure 3: Bang Phra in Si Racha district, Chonburi province, Thailand (Source: OpenStreet Map)

Rajamangala University of Technology at Bang Phra Campus has civilian airfield that is an ideal for the study area because the open space for Blimp taking off and landing. The testing flight was conducted during 13:00 – 16:00 pm in May 17, 2013 with 180 hectare (1.8 square kilometer that covers the whole campus area.

4 Results and Accuracy Assessment

4.1 Acquired data and processing

New technology for Unmanned Blimp photography for replacing conventional aerial

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photography is developed for local administrative officers in Thailand for updating cadastral map and generating Digital Elevation Model (DEM) for mapping and local utility planning.

Table 2: Flight parameters.

Flight information	Parameter
Flying altitude	349 m
GSD	5.8 cm
Coverage area	180 ha
Flying time	30 min
No. of image	748
Photo resolution	4,592 x 3,448
Camera Focal length	20 mm

The Balloon flown at the altitude of 349 meters to cover 180 hectare (1.8 sq. km) of Rajamangala University of Technology at Bangphra Campus and the flight parameter is shown in Table 2. The result for data acquisition and flight configuration parameter is shown in Figure 4.

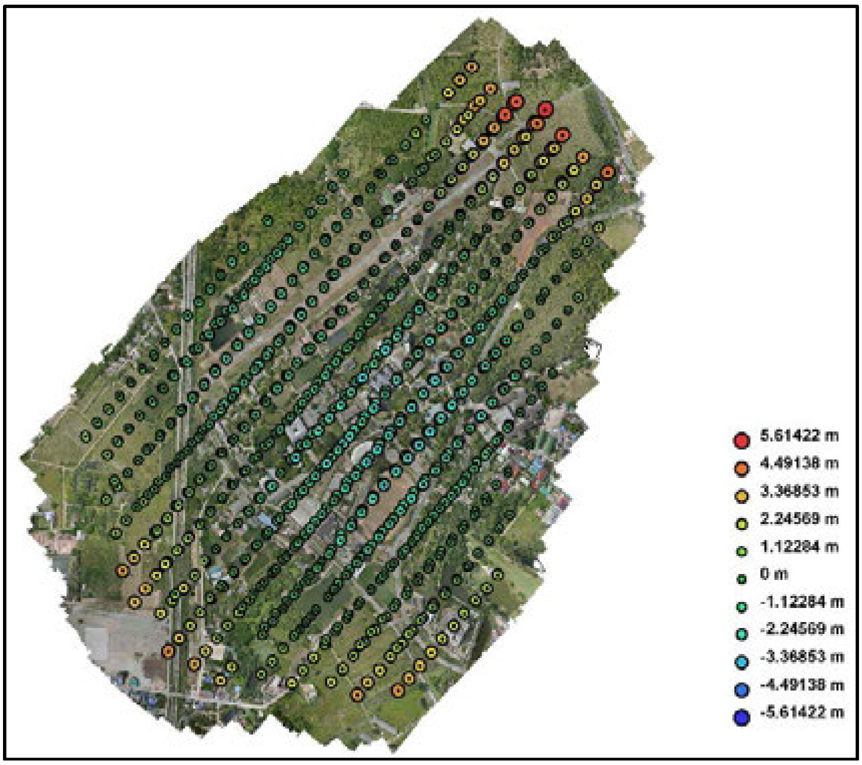

Figure 4: Total of 748 camera station and their position accuracy.

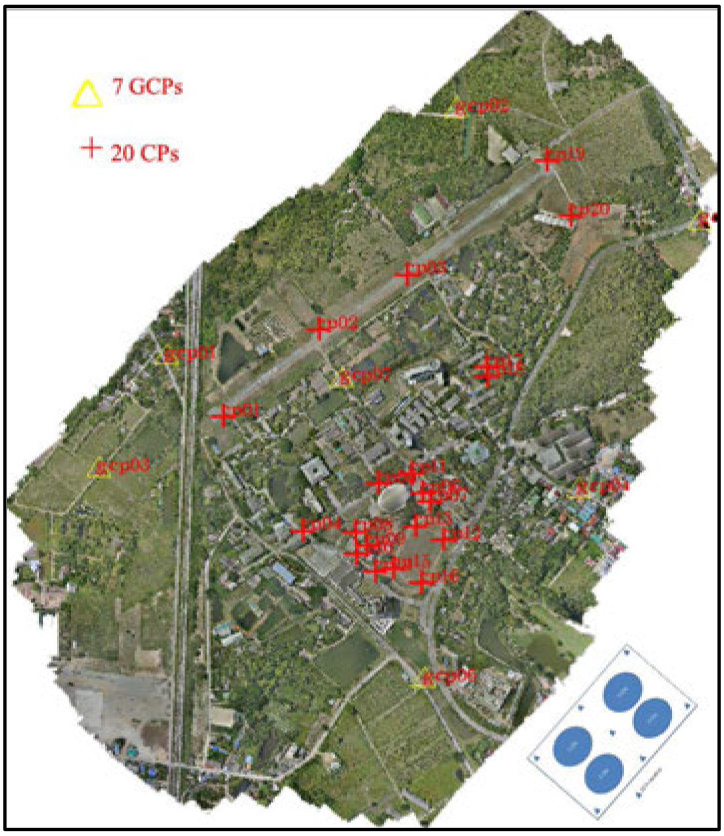

Figure 5: Allocation of 7 GCPs and 20 CPs for accuracy assessment.

Table 3: Accuracy assessment using GPS and field check.

D	Image Coordinate UTM Zone 47 P			DGPS Static - Post Process UTM Zone 47 P			Accuracy assessment Unit: meter		
	Easting	Northing	Ortho H	Easting	Northing	Ortho H	East Err	North Err	Height Err
cp01	711734	1463426	14.625	711734.6	1463426	16.24	0.534	0.218	1.615
cp02	711944	1463622	18.795	711942.8	1463622	20.181	1.233	0.341	1.386
cp03	712140	1463745	22.367	712138.7	1463746	23.901	1.234	1.056	1.534
cp04	711910.1	1463171	15.935	711911.1	1463172	16.662	1.045	1.033	0.727
cp05	712079.1	1463278	15.963	712078.1	1463278	18.72	0.937	0.514	2.757
cp06	712175.5	1463256	18.786	712175.4	1463258	20.277	0.154	1.349	1.491
cp07	712193.4	1463237	18.635	712192.3	1463238	20.28	1.077	1.304	1.645
cp08	712025.7	1463169	15.369	712026	1463170	18.09	0.321	0.895	2.721
cp09	712053.3	1463138	16.064	712053.7	1463139	17.911	0.373	1.159	1.847
cp10	712029.2	1463119	15.897	712030.1	1463120	17.58	0.872	0.677	1.683
cp11	712151.8	1463301	19.576	712151.6	1463302	20.035	0.186	1.11	0.459
cp12	712224.5	1463153	17.542	712223.3	1463153	18.66	1.217	0.442	1.118
cp13	712161	1463183	16.744	712160.6	1463184	18.469	0.348	0.99	1.725
cp14	712072.9	1463081	16.151	712073.3	1463082	17.255	0.441	1.167	1.104
cp15	712112.9	1463088	17.339	712112.8	1463089	18.468	0.122	0.52	1.129
cp16	712176.1	1463056	18.05	712175.5	1463057	18.497	0.61	0.854	0.447
cp17	712315.3	1463540	23.237	712314.1	1463541	25.409	1.216	0.952	2.172
cp18	712317.7	1463520	23.367	712316.6	1463521	25.372	1.116	0.779	2.005
cp19	712445.1	1464003	32.574	712444.7	1464005	29.685	0.423	1.527	2.889
cp20	712497.6	1463880	30.701	712496.4	1463881	29.946	1.203	1.221	0.755
						Mean	**0.733**	**0.905**	**1.56**
						Max	**1.234**	**1.527**	**2.889**
						Min	**0.122**	**0.218**	**0.447**

4.2 Accuracy Assessment

The accuracy assessment was conducted by using seven Ground Control Points (GCPs)

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and twenty Check Points (CPs) that was well covered the study area as shown in Figure 5.

The accuracy assessment is illustrated in Table 3 as the average accuracy for East as 0.733 m and for North is 0.905 m, with 3D mean error less than 2meters. The minimum errors are 0.122 and 0.218 in East and North respectively. The average elevation accuracy can be achieved at 1.560 m with the minimum error at 0.447 and maximum error at 2.889 due to wind speed and unstable balloon altitude.

5 Conclusion

The Unmanned Blimp Aerial Photography (UBAP) was designed and assembled by using low cost and local material. Under the normal weather condition, the Balloon can fly up to the altitude of 150 m and the autopilot system can automatically control the flight path for acquiring standard aerial photograph for land surveying and topographical mapping. The Ground Sampling Distance (GSD) of collected data is about 3cm that presents a very detailed terrain feature as houses, trees, garden, road, cars, electric pole and other facilities. The mosaics of ortho-rectification image provide valuable land information for updating cadastral map and generating 3D Digital Elevation Model (DEM). Accuracy assessment with GPS and field check, this study found average 2D and 3D ground accuracy at about 1m and 2m, respectively. Also, maximum 2D and 3D ground accuracy almost 2m and 3m, respectively.

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