Balloon Based Geo-Referenced Digital Photo Technique a Low Cost High-Resolution Option for Developing Countries

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Key words: Geo-referenced balloon photos, remote sensing technology for developing countries

SUMMARY

The paper introduces and assesses the highly efficient amateur aerial balloon photo technique which makes aerial photos affordable at a price of 0.10 – 0.35 US cents per hectare. The idea is to provide an inexpensive but quality efficient solution for recent aerial color photos on a high pixel resolution as orthophotos are not always accessible in Cambodia. Other high resolution images from advanced scanners like Quickbird, Ikonos or others are most likely unaffordable due to insufficient decentralized budget in Cambodia. As a consequence topographical and other spatial data is more or less lacking in planning offices. Enhancement and modifications basically are not easy to integrate into smaller scaled planning resources. This modern technique is based on a simple plastic balloon (r=3m), inflated with hydrogen gas, chemically produced on the site and adapted to the conditions in developing countries especially for areas with rapid land use changes. In Cambodia, it is offered by a private geo-spatial company, the Phnom Penh Geoinformatics Education Centre (PGEC) in collaboration with the Faculty of Land Management and Land Administration at the Royal University of Agriculture.

The rectified, merged and geo-referenced aerial balloon-photos with a surface resolution per pixel of 20m to 0.4m, depending on altitude of the platform and camera capacity, can be enlarged up to a scale of 1:800 without any loss in optical and spatial quality. Methodologically the approach uses typical image processing, enhancement and geo-referencing techniques like haze elimination, merging and mosaic procedures, mostly provided by ERDAS IMAGINE software. The aerial photo collection follows standard aerial photo measures like flight line preparation, synchronization of camera and GPS clocks as well as ground truth samples.

The balloon based digital aerial photos from a non calibrated digital camera (Olympus C-70) are already integrated in decentralized regional and urban planning processes in Cambodia as well as geospatial education, data trainings. Further outcomes of this technique are lately renewable detailed land use maps as well as other planning sources for real estate validation and environmental protection strategies i.e. buffer zoning concepts. Besides, they are expected to be useful for other "small area" projects like village based land use planning, technical implementations or (eco-) tourism projects at specific locations and retakes of the same photos within a high-level time resolution of one or two years.

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1. INTRODUCTION

Digital aerial images provide multi-scale, multi-temporal, and multi-spectral properties thus production of the images becomes a main trend in the field of GIS and photogrammetry (Hofmann, et al., 1984). Geo-referenced or rectified aerial photo image maps are getting important due to its low cost and fast production (Jiann &Liang 1999). Accessibility of recent aerial photos with detailed ground resolution of Cambodian environments is sometimes problematic or even impossible for non official or non administrative purposes as well as international collaboration projects. Since 1992 several aerial photos missions have been carried out by contracted international remote sensing companies funded by different international grants and loans. However, most of this spatial data is collected in some Cambodian ministries while a transparent and controlled access or exchange to remote sensing data, even among different ministries is not yet established in Cambodia. In contrast, recent spatial information of fast changing environments is crucial for several administrative, planning, observation and assessment reasons. Interpretation of these high resolution remote sensing data is tempting in the frame of land titling, land use classification, degradation assessments, urban and infrastructure planning as well as monitoring of rapid land cover changes in any kind of environment.

Digital high resolution imagery together with up to date computing power now at everyone's disposal has provided a change in scale with more detailed information being sought through the means of digital image analysis (Jiann &Liang 1999). For example, it is noticed that highly sophisticated and expensive analog devices are no longer required in photogrammetry if amateur digital camera devices are connected with GPS and GIS image enhancements and geo-rectification techniques (Celikoyahan et al 2003). Currently several remarkable attempts in balloon born amateur digital photogrammetry have been applied during the last five years (Pivnicka & Kemper 2004). Since two years this technology has been applied in a number of projects on different scale levels in Cambodia (Mund et al 2005). This paper introduces and assesses the highly efficient amateur aerial balloon photo technique, which makes aerial photos affordable at a price of 0.10 – 0.35 US cents per hectare, even for low budget projects in developing countries.

1.1 Purpose

Geo-referenced or ortho-rectified aerial photo image maps are getting important due to its low cost and fast production. The aim of this project is to incorporate and geo-reference unregistered data from a balloon or ultra light born aerial photography to a coordinate system topographical map. The resolution quality of low-altitude aerial photography far exceeds that of other surface imagery such as Spot or even Ikonos satellite imagery, making it a valuable tool for urban planners, environmental scientists and nature protectionists. Detailed spatial information below 1m pixel resolution such as vegetation associations or housing types is not detectable on inexpensive but larger airborne imagery while high resolution Quickbird images are often not available or cloud covered for Cambodian regions. Detailed construction types and multi-temporal spatial features such as vegetation vitality and small scale clearings are not easily to detect on conventional satellite imagery. Due to geo-referenced aerial photos these features could easily be digitized into separate layers using GIS mapping techniques. However, amateur aerial photos do not generate compass orientation nor any spatial reference information or exact scale. Geo-referencing or ortho-referencing methods needs to be applied, i. e. using referencing tools in ArcMap which allows the user to align geographically unregistered data to data that exists in geographical coordinates.

1.2 Digital aerial balloon, ultra light or kite images

Airborne photography and photogrammetry has been a platform for technological improvements and innovations ever since and it was just a question of time to combine balloons, ultra lights and other flying objects such as kites with digital remote observation technology. Major differences between traditional airborne photogrammetry and digital amateur orthophoto gathering technique are the utilization of low budget technology which is easy to transport and handle as well as appropriate under many circumstances with suitable calm weather conditions. Balloon or kite aerial photography and the practice of low-altitude aerial photographs have a surprisingly long history since the late 19th century. The Frenchman Arthur Batut is credited as the first person to attach a camera to a kit in 1888 (Haefner, 2004) and some 20 years later low altitude photography was frequently used on the battle fields of the first world war. Due to the invention of airborne plane photography balloon photography was not considered for much of the 20th century. But with the digital revolution high resolution camera equipment became affordable for everyone. However, with the advent and link to GIS and GPS technology, balloon photography has been resurrected again and currently a growing base of new practitioners develops suitable application for architecture, archeology and many other observation issues which demands high resolution imagery. The application of this enhanced amateur technique shows promise of improving airborne mapping technique and photogrammetry but has also presented unique challenges all its own.

2. APPLIED TECHNOLOGY

2.1 Types of exercised amateur digital aerial pictures

Two types and various scales of digital aerial photos below 1m pixel resolution are used within the program: geo-referenced and ortho-rectified ones. In most cases mosaic images were produced based on several single pictures using standard remote sensing mosaic production techniques previous to enhancing and referencing the final image. Geo-referenced digital images are transformed to the local co-ordinate system, by warping the digital images

to fit either to abase map or other ortho-images. Ortho-rectified picture are processed and shifted to an air triangulation model using the method of surveyed ground control points.
Ortho-rectified photos based on digital elevation model techniques are considered to offer higher applicable precision as the accuracy level of simple handheld Garmin GPS 76 can only be improved up to +/- 2m applying post processing differential GPS measurements.
There are significant benefits in ortho-rectified photography over simple geo-rectified images used here, but there are also significant variations in cost. Ortho-rectified photography has the potential to be more accurate while the photographic image is draped over a digital terrain model based on land survey control. The main benefits are of improved accuracy in horizontal as well as vertical plan shape, particularly where there is high relief across the area. But this accuracy again is strongly dependant upon the accuracy of the DTM used as base model. The most accurate acquirable DTM for Cambodia is the SRTM 50m grid with provides high spatial resolution with a grid of interpolated levels at 1m intervals. Unfortunately, it has got some significant miscalculations in huge flat lowland areas like the Cambodian floodplain or the Tonle Sap Lake and its tributaries. Only photogrammetrically derived detailed DTM or air triangulation models would provide higher precision and better resolution. This may allow orthophotos to be produced with a plan position accuracy of approx. +/-1m, but was not applied due to limited data processing capacity.

2.2 Hydrogen balloon technique

The 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. While helium is still very expensive and problematical to acquire in developing countries, hydrogen was chosen for this application in Cambodia. The advantage of hydrogen is its uncomplicated production on the test site based on aluminum cans, water and a special salt which are easy to transport and assembly just beforehand its application. The critical danger of hydrogen is its chemical unstable reaction prone to dangerous explosion and inflammation. The chemical reaction formula with the resulting hydrogen gas and Natriumalbumiat is given as follows: $AL+NaOH+3H_2O= Na[AL(OH)_4]+1,5H_2O$.

Fig 1: Hydrogen production

Fig 2: Balloon filling with Hydrogen Gas

A non calibrated simple 7 Megapixel digital camera (Olympus C70) is fixed in a light plastic holder together with the infrared remote control and a GPS receiver. The camera is activated by a special electronic clock and is set to take pictures every 10 seconds synchronized with a GPS receiver. Resulting pictures will have a ground resolution below 1m up to 5-10cm. Balloon levels of 50 to 400m above ground with different resulting ground resolution are possible with decreasing positioning accuracy of picture nadir points in higher altitudes. The price of the complete photo acquisition bundle add together around 2500 $ including camera and GPS receiver. Problematic are the balloon sensitivity to wind speed over 3m/sec and explosive inflation gas.

Fig 3: Camera and GPS holder

Fig 4: Balloon fixation and control

2.3 Field data acquisition

For photo orientation and precise image mosaics ground control points have been measured using post processing differential GPS in comparison to simple hand held GPS measurement. Additionally, a combination of Ground Control Points in combination with image to image rectification technique based on a geo referenced Spot satellite image is considered to provide relative accuracy below average handheld GPS errors. Image orientation and rectification of images and mosaics comparing the two referencing models mentioned above is currently underway. Overlapping aerial photos with 30-40% stereoscopic zones along transects are taken across the target area using a non calibrated digital camera (Olympus C-70) at a high resolution of around 3000 x 4000 pixels (7.2 megapixels). With a flight altitude of 500-1200m this translates to a ground resolution of about 40 x 40 cm or even 10 x 10 cm per pixel or about 5 to 25 times the resolution of a typical Spot image or aerial photo, which was only available beforehand. The resulting image nadir points are corrected with calculated image centers beforehand using the positioning data from GPS receivers and a calculation of real image nadir points and calculated GCPs based on topographical maps of 1:50.000 scale. Plan position accuracy achieved varies according to the variability of ground surface elevation, altitude and the tilt of the camera holder during photography. Plan position is usually found to lie within 2-3m with raw images but, with full rectification, the expected accuracy ranges in between 0,2m to 0,5m in horizontal distance to the topographical reference while the vertical accuracy was not yet calculated.

2.4 Photo geo-referencing

Photo files are converted from the Camera TIFF format into World-TIFF format using a six to ten parameter transformation followed by re-sampling of the image using ERDAS software.

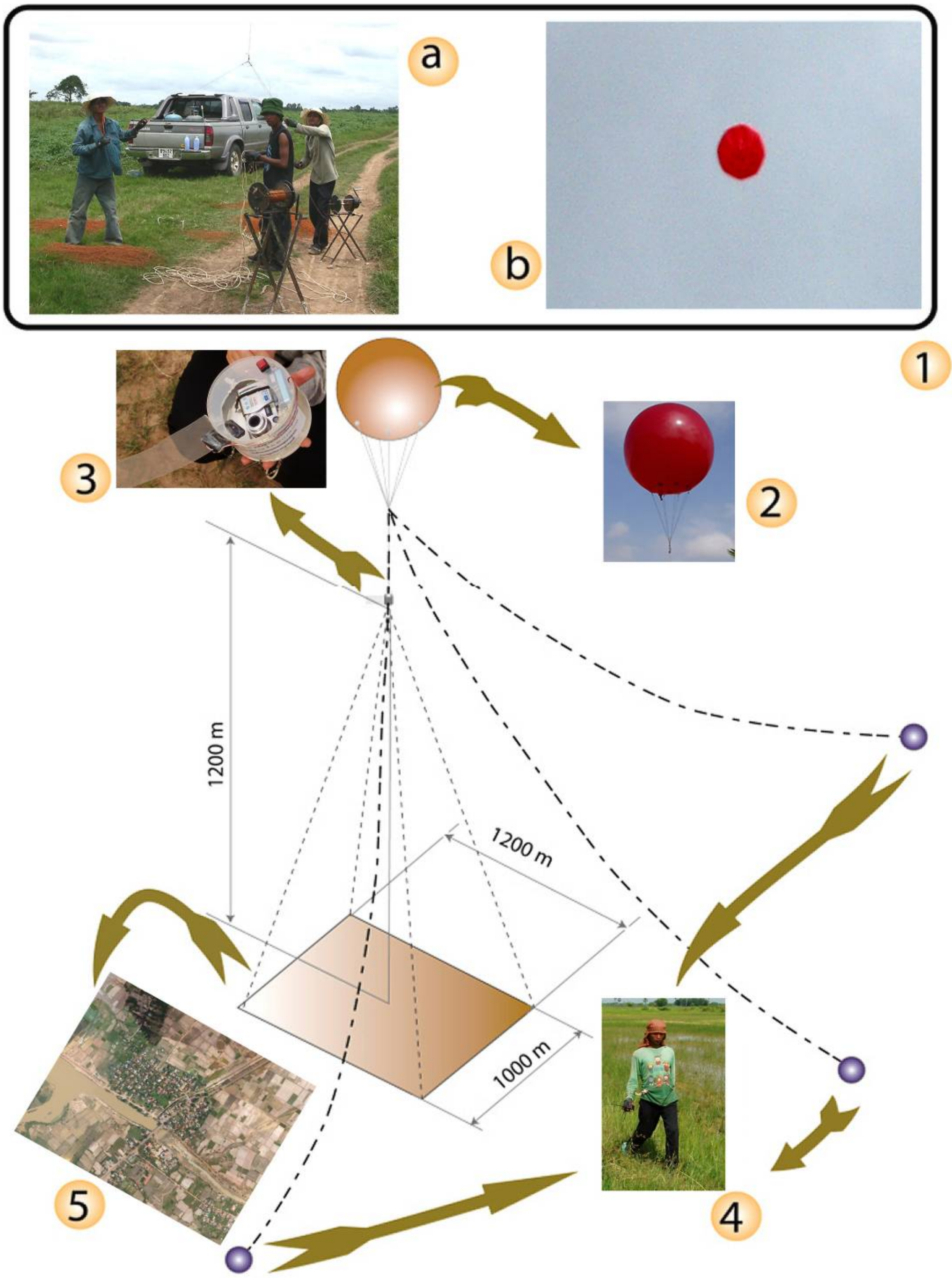

Fig 5: Model of image acquisition technique (Seang 2005)

This rotates and stretch images to match balloon nadir position and corrects for further positioning errors and image distortion. A 1st order transformation will allow the unregistered image to be rotated, shifted, or scaled, but will not deform the image to best match the links. The 2nd Order polynomial transformation allows some distortion of the unregistered image, and should be used if the unregistered image does not quite align with the existing registered map. A 3rd order polynomial transformation is only applied to maximum distortion, or "rubber sheeting", of the unregistered image to match the ground control points. This is necessary for images with larger deformation and where GCP links are poorly aligned after rotation. The majority of balloon images where transformed and re-sampled with 25 to 40 GCPs and a 3rd order transformation method. Transformed and geo-referenced images are then joined into mosaics and ready to be used in further interpretation, mapping and classification processes. Mosaic tiles produced in TIFF files, have been found to produce the most versatile images for manipulation within GIS. During mosaic joining cloud areas are masked or extracted and substituted with overlapping areas of neighboring images.

2.5 Picture scales and mapping techniques

Geo-referenced aerial balloon pictures can be viewed or plotted within a GIS, at scales of better than 1:800 to 1:5000, without any significant loss of image quality. Although a higher level of urban architecture plan shape accuracy can be achieved by mapping from even higher resolutions, the resulting image quality exceeds existing and available conventional aerial photos. Pictures could be even used to count the number of umbrellas of temporary market sellers around market areas. Especially in remote open forest regions the achieved data quality offers new opportunities for inventories and detailed degradation studies. Image data management techniques are applied as follows:

- Photo acquisition and image preparation
- GPS-Data acquisition and post-processing
- Photo mosaics and geo-referencing
- Accuracy assessment
- Final image re-sampling and map production or on screen digitizing

Fig 6: Market Area I Battambang in 1:1.000

Fig 7: Degraded open forest area 1:5.000

This photo-scale appears to be optimal, for production of geo-rectified images for use in urban and regional planning as well as environmental observations. It produces reliable plan shape data and horizontal resolution for analytical remote sensing data interpretation and on screen digitizing for operational purposes. Even though detailed vegetation or environmental change detection based upon this method is limited, this accuracy is acceptable at all levels of urban planning and change detection of any kind of construction in the urban environment like spontaneous settlements as well as informal construction. Therefore, it is proved to be an appropriate technology for urban planning and construction verification in cities with small to limited budgets.

2.6 Projects using this technique in Cambodia:

Digital geo-referenced images of Battambang town (NW Cambodia) were already produced for the district department of urban planning and construction. In 2004 and 2006 aerial balloon surveys were flown on different scales of 40cm and 10 cm ground resolution for urban master plan purposes, for regional development as well as change detection in the urban environment with regards to housing and infrastructure measures for informal settlements in the urban areas. For a second project, pictures of a scale of 1: 10.000–1:15.000 were taken in in remote rural areas with degraded open forest vegetation in NW Kampong Speu province. The topic is a seasonal to 5 years change detection observation of a degraded open forest environment for a special observation site of forest re-growth and vegetation recovering. Further images were taken for simple area observation and base maps of two national universities in Cambodia (Royal University of Agriculture and Preak Leap National School of Agriculture) in the surrounding of Phnom Penh. But one of the most advantageous applications of this method is the production of base maps for medium scale infrastructure projects like bridge and road construction, hydraulic engineering and irrigation projects in the Cambodian lowlands.

Fig 8: Infrastructure project (Seang 2005)

Fig 9: Detailed University picture

2.7 Discussion

Aerial balloon or ultra-light geo-referenced digital raster aerial photos offer a number of remarkable advantages, when compared with conventional large scale aerial photos and high resolution satellite scanner images. When correctly geo-referenced, these data sets can be used within GIS in combination with vector map data, typically from the topographical maps or field surveying for many planning and observation as well as management applications.

Furthermore, digital geo-referenced aerial photographs provide an excellent analytical medium, which can be used conveniently in combination with other types of geo-referenced survey information. In particular, the images provide the opportunity for valuable interpretation of cover changes in vegetation as well as urban land use types by reference to geo-referenced profile data in combination with field surveys. Balloon or ultra-light images offer the following additional detail, relative to conventional orthophoto mapping:

- Urban structure
- Urban infrastructure type an quality
- Detailed land use types in urban and peri-urban area
- Construction plan for medium scale infrastructure projects
- Vegetation classes and vegetation coverage
- Tree density per ha
- Tree types or morphological vegetation structure
- Seasonal and intra seasonal change detection

Geo-referenced balloon borne aerial digital photos can be an effective replacement for the traditional cost expensive orthophoto images in land cover analysis and urban planning projects and practical for field verification surveys as well. With a non-metric, small, relatively inexpensive digital camera, and inexpensive portable balloon or ultra-light solutions large digital aerial photography is now a suitable technique for developing countries to acquire inexpensive planning information. There is no inevitable requirement for an expensive camera equipment and high-level camera calibration. Once they are geo-referenced, they can be used as a map layers in any GIS and remote sensing application. They can be directly geo-referenced and viewed like maps without extra software for orthophoto re-sampling or other sophisticated image rectification and image enhancement technique. The major advantages of digital aerial photography are that digital images often have much higher resolution than conventional aerial photos. As a result they are efficient both in terms of time and cost.

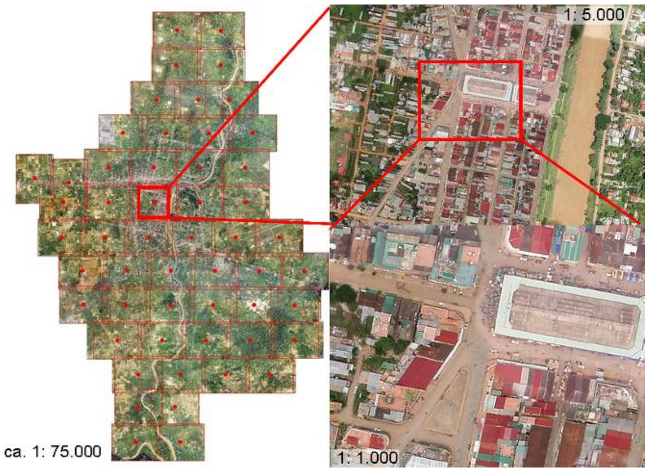

Fig 10: Image acquisition plan for and detailed Battambang images

However, there are several issues to consider before using digital aerial photography like the storage and image representation capacities as well as much higher number of photos for large-scale projects. We acquired more than 84 photos for a quite small region of Battambang town with 2.4 GB of raw data. The technical camera and GPS capacity is even though important for a successful project design as well as GIS and GPS trained staff for ground surveys and data handling. But future digital improvements will further offer enhanced GPS and picture resolution capacity while reducing size and weight of receivers like the new Sony GPS stick. The most challenging issues for digital balloon, ultra-light or kite imagery still remain camera calibration, exact flight management, exact GCP surveys as well as detailed high resolution DTM for ortho-rectification with higher accuracy of processed imagery.

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