



## Practitioner's Guide:

### Low Cost Amateur Aerial Pictures with Balloon and Digital Camera



Bundesministerium für  
wirtschaftliche Zusammenarbeit  
und Entwicklung

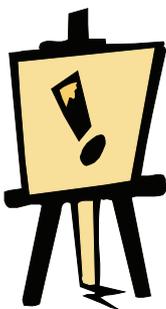
**ded**  
Deutscher  
Entwicklungsdienst



Centre for International  
Migration and Development  
a joint operation of GTZ and the  
German Federal Placement Agency

### Low Cost Amateur Aerial Pictures with Balloon and Digital Camera

#### Brief Description



“Low Cost Amateur Aerial Pictures with Balloon and Digital Camera” 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, which are either not available or not accessible in many developing countries.

Other high resolution images from advanced satellite scanners like Quickbird, Ikonos or others are unaffordable to many low budget projects as well as to sub-ordinate planning institutions. As a consequence, topographical and high-resolution spatial data is more or less unavailable in those planning offices. Because of this, planning is often based on out of date topographic and thematic maps, while the situation in the real world has considerably changed. Especially on lower planning levels (e.g. provincial, district, municipality or community planning) this method is an approach to generate a snapshot of the real situation on a low budget basis.

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 flat areas with rapid land use changes. Additionally, a digital camera is required, and some modifications have to be possibly made in order to remote control the camera, which, attached can reach a height of up to 1000 m above the ground.

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.

Further outcomes of this technique are up to date 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.

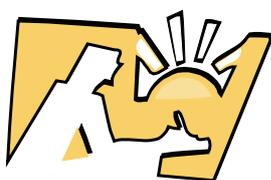
### Low Cost Amateur Aerial Pictures with Balloon and Digital Camera

#### Proposed Main Users

Provincial, District, Municipal and Community Planners or related development projects, local line departments, private sector, Natural Resource Mangement, Buffer Zone Management, Rural Development, Urban Land Valuation and related fields on a similar scale.



#### Purpose of the Method



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.

The aim of this methodology 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 many 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.

### Low Cost Amateur Aerial Pictures with Balloon and Digital Camera

#### Advantages



- ▶ The production of ortho-photos is cost efficient,
- ▶ Production of ortho-fotos can be done independently by purchasing its own equipment,
- ▶ The resolution of the pictures can be determined by the technical resolution of the camera and the altitude of the balloon (up to 1000 m above the ground),
- ▶ The production of ortho photos can be done repeatedly on an individual schedule (compared to aerial photography done by a private company), without tremendous costs (e.g. for ground monitoring),
- ▶ Specially modified cameras (without infrared filter) can also show infrared reflections for a more detailed analysis of vegetation.

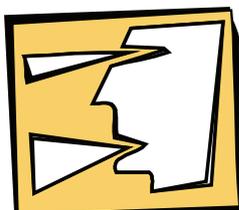
#### Limitations



- ▶ This methodology is not appropriate for surveying, land titling and cadastral applications below 1 m accuracy level,
- ▶ Areas with permanent winds or cloud coverage can not be covered,
- ▶ The rectification of made photos requires correctly rectified map material (e.g. for rubbersheeting),
- ▶ Mountainous areas are not accessible and the result will be more likely to have less accuracy,
- ▶ Starting of a balloon might require a permission from national aviation authorities,
- ▶ Electric power lines might interfere with the strings for positioning a balloon,
- ▶ Technical Expertise is required for the “rubber sheeting” of not rectified pictures.

### Low Cost Amateur Aerial Pictures with Balloon and Digital Camera

#### Principles & General Procedures



#### Why do we need quick and cheap Orthophotos

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. Geo-referenced or rectified aerial photo image maps are getting important due to its low cost and fast production. Recent spatial information of fast changing environments is crucial for several administrative, planning, observation and assessment reasons.

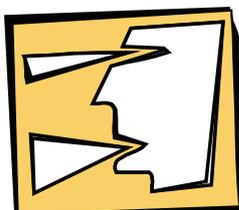
In many developing countries, recent aerial photos with detailed ground resolution of their environments is sometimes problematic or even impossible to access for non official or non administrative purposes as well as international cooperation projects.

Several aerial photos missions have been carried out by contracted international remote sensing companies funded by different international grants and loans in most countries. However, most of this spatial data is collected in some ministries while a transparent and controlled access or exchange to remote sensing data, even among different ministries is often not yet established. In contrast, Interpretation of these high resolution remote sensing data is necessary in the field of 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 nearly on everyone's disposal, even in developing countries, has provided a change in scale with more detailed information being sought through the means of digital image analysis. 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. This results in an image accuracy of approximately 0.7 - 1.5 m and a ground resolution of 0.4 to 0.8 m per pixel, depending on platform altitude. Currently several remarkable attempts in balloon born amateur digital photogrammetry have been applied during the last five years. Since two years this technology has been applied in a number of projects on different scale levels in Cambodia in urban as well as rural areas. The production of amateur aerial photographs is a highly efficient aerial balloon photo technique, which makes them affordable at a price of 0.10 – 0.35 US cents per hectare, even for low budget projects in developing countries.

### Low Cost Amateur Aerial Pictures with Balloon and Digital Camera

#### Principles & General Procedures



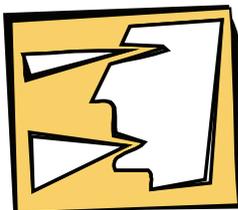
#### Processing amateur digital aerial pictures

In most cases mosaic images were produced based on several single pictures using standard remote sensing mosaic production techniques. Firstly, an atmospheric correction had to be carried out, a step which can be skipped in low altitudes. Secondly, images were enhanced before mosaicing.

Geo-referenced digital images are transformed to the local co-ordinate system, by warping the digital images to fit either to a base map or other ortho-images. Ortho-rectified pictures 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 GPS. Using two GPS with post processing an accuracy rate of less than 1.0 m can be achieved. 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 50 m grid which 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, which is much more cost effective and requires higher statistical and remote sensing software capacities.

### Low Cost Amateur Aerial Pictures with Balloon and Digital Camera

#### Principles & General Procedures



#### Types amateur digital aerial pictures

Geo-referenced digital images are transformed to the local co-ordinate system, by warping the digital images to fit either to a base map or other ortho-images.

Ortho-rectified pictures are processed and shifted to an air triangulation model using the method of surveyed ground control points.

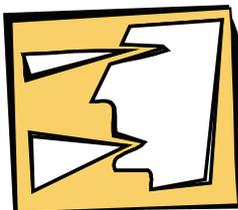
For real ortho rectified images require a fully calibrated camera, which costs about five times more than a non-professional one. Ortho-rectified photos based on digital elevation model techniques are considered to offer higher applicable precision as the accuracy level of simple handheld Garmin GPS 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.

Photo 1: Digital Camera with GPS receiver



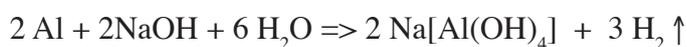
### Low Cost Amateur Aerial Pictures with Balloon and Digital Camera

#### Principles & General Procedures



#### Hydrogen balloon technique

The normally used balloon is made of light PE material with a maximum size of inflation of about 2.5 m. 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 can be produced locally. 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 (see Photo 2). 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:



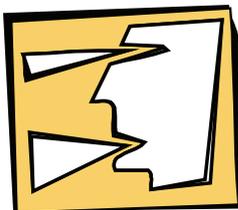
A non calibrated simple 7 megapixel (or better) digital camera is fixed in a light plastic holder together with the infrared remote control and a GPS receiver. The camera is activated by a special electronic clock and is set to take pictures every 10 seconds synchronized with a GPS receiver (see Photo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

Photo 2: Balloon filling with Hydrogen Gas



### Low Cost Amateur Aerial Pictures with Balloon and Digital Camera

#### Principles & General Procedures



#### Field data acquisition

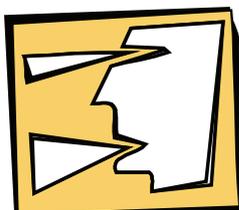
For photo orientation and precise image mosaics ground control points have been measured using post processing differential GPS in comparison to simple hand held GPS measurement. Additionally, a combination of Ground Control Points in combination with image to image rectification technique based on a geo referenced Spot satellite image is considered to provide relative accuracy below average handheld GPS errors.

Overlapping aerial photos with 30-40% stereoscopic zones along transects are taken across the target area using a non calibrated digital camera at a high image resolution of around 3000 x 4000 pixels or better. 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.

The resulting image nadir points (the point of the celestial sphere directly under the place where balloon is placed) 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. Photo files are converted from the Camera TIFF format into World-TIFF format using a six to ten parameter transformation (geo-referencing and rubber-sheeting) followed by re-sampling of the image using raster image processing software.

### Low Cost Amateur Aerial Pictures with Balloon and Digital Camera

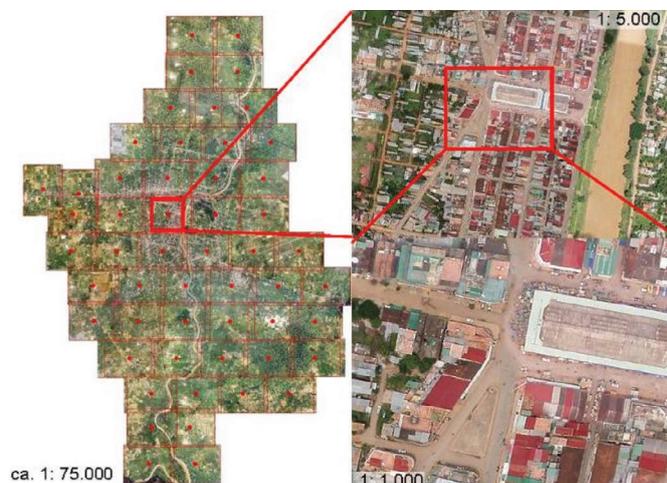
#### Principles & General Procedures



#### Photo geo-referencing

Photo geo-referencing rotates and stretches images to match the balloon nadir position, corrects further positioning errors and minimises image distortions. A first 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 second 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 third 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 ground control point links are poorly aligned after rotation. The majority of balloon images were transformed and re-sampled with 25 to 40 ground control points and a third 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 (see Figure 2 and 3). 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 neighbouring images.

Figure 1: Image acquisition plan and detailed image of Battambang, Cambodia



## Low Cost Amateur Aerial Pictures with Balloon and Digital Camera

### Principles & General Procedures

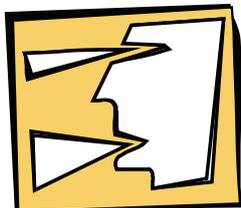
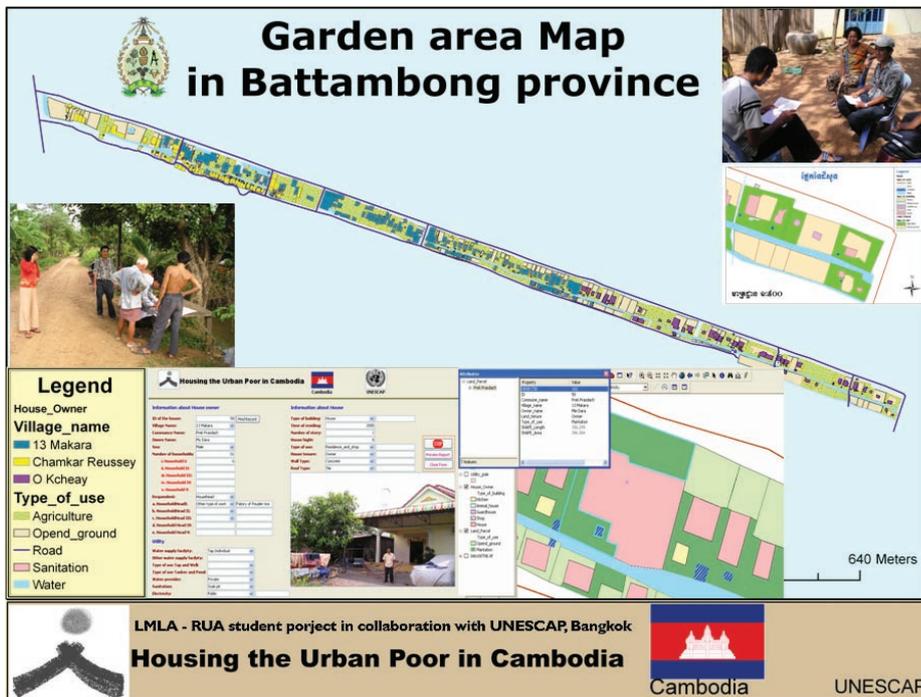
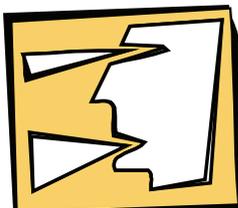


Figure 2: Garden-strip in Battambang with 10 cm ground resolution



## Low Cost Amateur Aerial Pictures with Balloon and Digital Camera

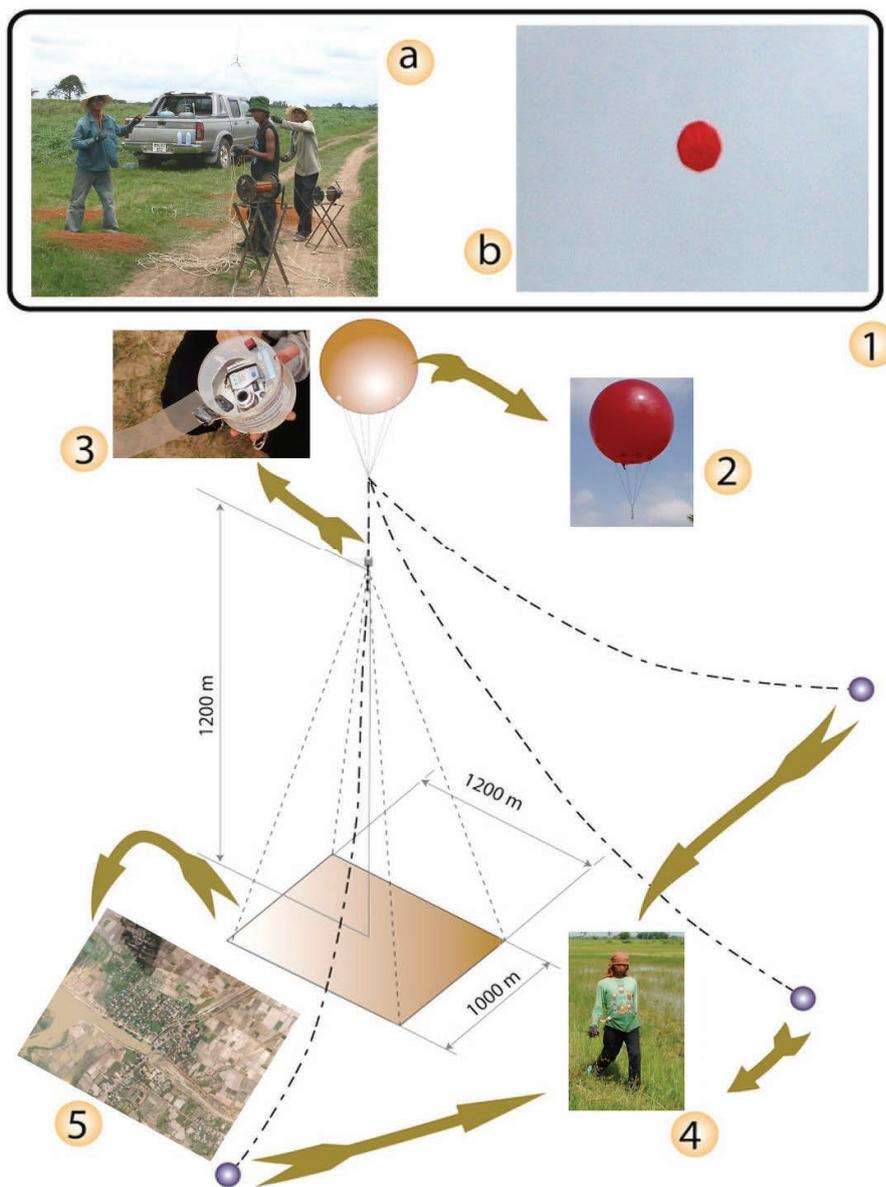
### Principles & General Procedures



### Picture scales and mapping techniques

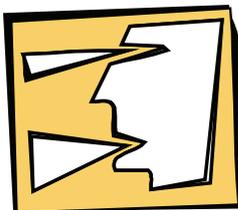
Geo-referenced aerial balloon pictures can be viewed or plotted within a GIS, at scales of 1:5000 to 1:10.000 without any significant loss of image quality. Although a higher level of urban architecture plan shape accuracy can be achieved by mapping from even higher resolutions, the resulting image quality exceeds existing and available conventional aerial photos.

Figure 3: Model of image acquisition technique



### Low Cost Amateur Aerial Pictures with Balloon and Digital Camera

#### Principles & General Procedures



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.

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 an appropriate technology for urban planning and construction verification in cities with small to limited budgets.

Figure 4. Result of the orthophoto mosaic / map after identification and classification

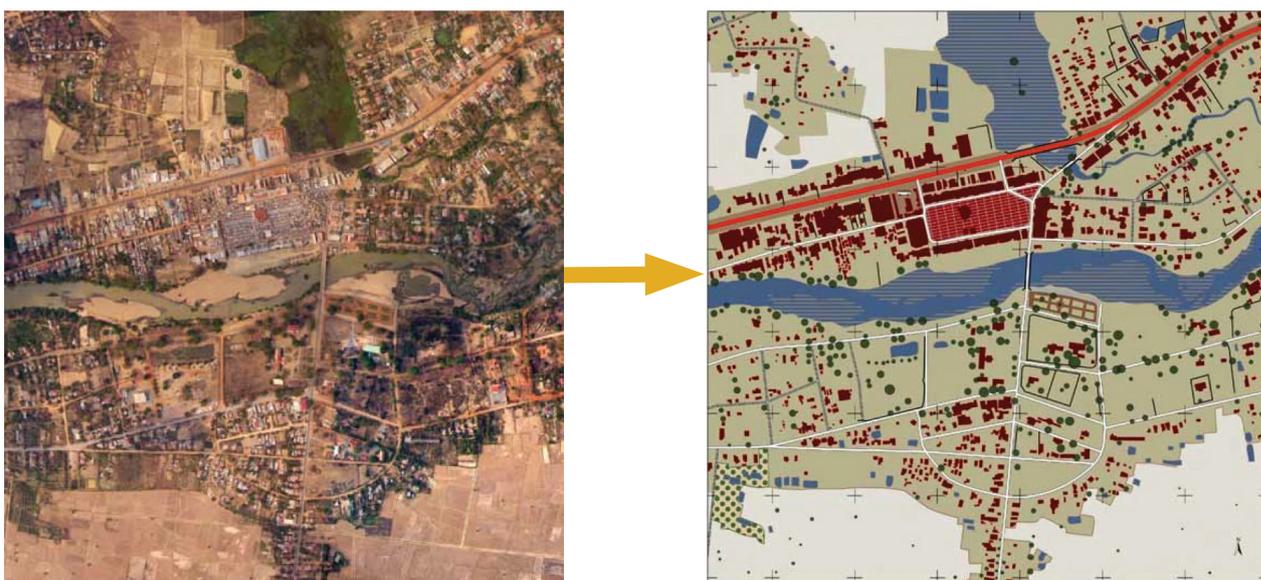


Figure 4 courtesy of MLMUPC GD LMUP

### Low Cost Amateur Aerial Pictures with Balloon and Digital Camera

#### References and Sources Used



- CELIKOYAHAN, M., O. ALTAN, G. KEMPER and G. TOZ. 2003. **Calibrating and using an Olympus camera for balloon-photogrammetry; new perspectives to save cultural heritage.** In: CIPA 2003 international conference proceedings.
- CELIKOYAHAN, M., O. ALTAN, G. KEMPER and G. TOZ. 2003. **Evaluation of a theatre by using low altitude aerial and terrestrial photogrammetry; new perspectives to save cultural heritage.** In: CIPA 2003 international conference proceedings.
- CHEN, L.C. and J.Y. RAU. 1993. **A Unified Solution for Digital Terrain Model and Orthoimage Generation from SPOT Stereopairs.** IEEE Trans. on Geoscience and Remote Sensing, Vol. 31, No. 6, pp. 1243-1252.
- HAEFNER, S. 2004. **The Art of Kite Aerial Photography.** In: **Photo Techniques USA Magazine**, Issue: July / August 2004.
- ILKKA KORPELA. 1999. **Tree detection from digital aerial photos. An experiment with varying photo and object characteristics.** In: proceedings of: workshop on image analysis and spatial statistics in forestry on November 2, 1999 at KVL, Frederiksberg, Denmark.
- JIANN. Y. R. and C.C. LIANG. 1999. **Digital Ortho-image Generation from Large-Scale Aerial Photography.** In: GISdevelopment.net
- KEMPER, G. 2003. **Avionic Systems for application in forestry and agriculture.** In: 9th conference about Information system for Agriculture and Forestry, proceedings. Prague, CZ.
- KEMPER, G. 2006: **Spezialapplikationen in der luftgestützten Fernerkundung – preiswerte Systeme, Plattformen und Trägersysteme.** In: Angewandte Geoinformatik 2006 – AGIT Proceedings 18. Wichmann Verlag, Heidelberg.
- KEMPER, G., M. CELIKOYAHAN, O. ALTAN, and G. TOZ. 2003. **Ballonluftbild- und GIS basierte photogrammetrische Auswertung kulturhistorischer Objekte in Patara/Türkei.** In: Angewandte Geographische Informationsverarbeitung IX – AGIT 2003, Wichmann Verlag, Heidelberg.
- MUND, J.-P., N. RATTANAK and T. P. SEANG. 2005. **Urban and Peri-urban Land Management examples from provincial Cambodian cities.** In: Proceedings of the FIG SEASC conference in Brunei Daru Salam, November 2005.
- SYMANN, RALF, DED, GD LMUP (MLMUPC): **Balloon Report - Taking an Aerial Photo of Kompong Speu Town.** Cambodia 2004.

[http://kambodscha.ded.de/cipp/ded/lib/all/lob/return\\_download,ticket,g\\_u\\_e\\_s\\_t/bid,2225/no\\_mime\\_type,0/~/Balloonreport.pdf](http://kambodscha.ded.de/cipp/ded/lib/all/lob/return_download,ticket,g_u_e_s_t/bid,2225/no_mime_type,0/~/Balloonreport.pdf)