PHOTOGRAMMETRIC PROCESSING OF HIGH MOUNTAINS IN NEPAL

Toya Nath Baral
Deputy Director General
Survey Department
HMG Nepal
Email:tnbaral@ntc.net.np
Tel: 977-1-4472963®

Abstract:

Application of traditional aerial survey technologies for topographic mapping purposes has a number of principal problems. The *growing worldwide acceptance of digital orthophotos has understood this need.*
Many trekking and expedition teams are expecting digital orthophoto and consequently 3D animation of the highest peaks and possible trekking routes, camping sites and information on how difficult the routes may be.
In recent years, inexpensive computers and advance of computer technologies contributed to the rapid development of digital photogrammetry (Dowman et al., 1992; Heipke, 1995). Successful implementation of digital photogrammetric workstations in mapping have been found in various disciplines (Chen et al., 1998; Skalet et al., 1992).
This paper highlights the results of the conventional photogrammetry and the possible advantages of digital photogrammetry over these and also the problems, issues and implications during digital Photogrammetric processing of high mountainous region in Asia.

Key words: Photogrammetry, Occlusions, Topography, Digital Terrain Model, Correlation

1. Introduction:

Physical isolation has excluded the mountains and their populations from development, resulting in political and economic marginality. Mountain people suffer from unemployment, poverty, poor health, and insufficient sanitation. Among the world's mountain areas, Asia contains the largest, highest, and most populated mountain systems. More than 250 million people live in mountain and upland areas. The loftiest peak in the world, **Mount Everest,** together with other high peaks, plus the presence of some exquisitely beautiful trekking routes, attract hundreds of thousands of people from all over the world to this lovely Himalayan destination.
Present need for planning and managing development activities for mountainous areas might be an accurate topographic database and an attempt has been made to prepare the same.
Advancement in digital Photogrammetric technique, lead to continuous growth of orthophoto production rather than the line maps. Here the tests were performed using both digital and classical Photogrammetric techniques in an area where the elevation varies extremely (more than 40% of the flying height above ground in a single model). This study was undertaken as a master thesis program in the Stuttgart University of Applied Sciences, in collaboration with Z/I imaging, GmbH, Germany. We will, mainly discuss the problems associated with height differences and lack of textures. The study area lies on south Asia region and in an antique mountainous country, Nepal. Curiosity, whether it is possible to perform digital aerial triangulation, automatic extraction of DTM and ortho-rectification of the study region, lead to formulate this program. We will address the automatic image matching problems arising from the poor textures in the images and high variation in radiometric resolution. Generation of tie points automatically will be the next issue to be discussed.
The Photogrammetric processing of photographs from high mountainous region requires not only identified ground control points, but also digital terrain models. This study project aims to varify how automatic triangulation, extraction of DTM, ortho-rectification and mosaicking can be accomplished automatically using the software from Image Station family. This paper starts discussing the data available for the study, methods to be used, problems encountered during operation, solutions so far found out and results. The study is limited to a high mountainous terrain in Nepal, relevance to all high mountainous range in Asia. This study could be an example to the high mountainous regions covering the northern belt of Afghanistan, Pakistan, India and Bhutan.
The vast Himalayan complex covers an area of about 594,400 sq km (about 229,500 sq mi) and extends in an arc of about 2410 km (about1500 mi). It stretches from the Indus River in northern Pakistan eastward across The Himalayas is a mountain system in Asia, comprising a series of parallel and converging ranges and forming the highest mountain region in the world. More than 30 peaks of the Himalayas rise to heights of7620 m (25,000 ft) or more, and one of these, Mount Everest (8848 m/ 29,028 ft), is the world's highest mountain.

Containing nine of the world's fourteen highest mountain peaks, Nepal is a true Himalayan kingdom. The Himalayas cover three fourths of the land in Nepal. *It is home to some of the highest, remotest, most rugged and most difficult terrain in the world*.

2. Data for study:

Data available are panchromatic aerial images at the scale of 1:50,000. The nature of terrain is of high irregular topography, from steep to very steep and most of the area is covered with snow. The variation of height within the project area is from 2500 meters to 8848 meters, creating extreme elevation differences of more than 45% of the relative flying height in individual models.

Table 1 Data for study

Project Name	High Mountain-GIS	Remarks
Scene Content	Open, snow covered	
Scene topography	Steep to very Steep	Most rugged terrain
Image Scale	1:50.000	Large variation in Scale
Camera	Wild RC 30	GPS onboard
Focal Length	153.19 mm	Calibrated
Flight Date	Nov-Dec, 1992	
Film Material	Panchromatic (B/W)	
Number of Images	93	3000 sq.km
Overlap	l=80%, q= 40%	
Scanner used	PhotoScan 2001	
Scanned pixel size	14 um and 12 bits depth	Per image=728MB
Scanned Material	Positive Film	
Scanned Channel	Panchromatic	
Scan Date	August 2001	
Source	Survey Department	

Image Orientation:

1. Aerial Triangulation:

All aerial images available in hard film copy were scanned using PhotoScan 2001.The results of scanning were 14um pixel size in resolution, 12 bits CCD data output with full set of overviews. The disk space occupied by one image data came to be 728 MB. These data were loaded to run automatic image matching process. A commercial software (ISAT) was used to perform the automatic orientation of the input images for ortho-rectification. The final results of this are exterior orientation parameters of the images to be rectified.

2. DTM extraction:

Next step is the automatic extraction of digital terrain model. A surface model is needed for true ortho-images. Input for the extraction of digital terrain model is the oriented images from **step-1**

3. Orthorectification:

Now we can use the results from **step 1 and 2** for the generation of single ortho-image using commercial software (OrthoPro). This is rather straightforward and can be done automatically, but the surface model should be edited precisely to eliminate blunders and outliers.

4. Production of Orthomosaic:

Finally creation of orthomosaic, tone balancing and seam line hiding is performed in order to end up with a nice looking mosaic. Manual editing is very important to get the optimal position for seam lines in Mountainous region.

5. Objective:

Objective of the whole Photogrammetric processing is the production of DTM, digital orthophoto and visualization of photo realistic 3-D textured model of high mountainous region in Nepal using available digital photogrammetric processing technology.

Problems encountered during automatic aerial triangulation:

Serious problems were encountered associated with extreme height and radiometric differences during the processing of automatic aerial triangulation. No tie points were generated in extreme bright and dark shadow area, because the automatic image matching algorithm could not resolve the problems associated with textures and contrasts in the images. The other main problem with height
differences was to create multi-ray tie points for the stability of the AT block. There is almost no connection between the different strips.

Table 2 Problems in automatic aerial triangulation due to height difference.

Strip No.	Max.H(m)	Min.H(m)	dH.(m)	Av.Gr.El.(m)	Hg. (m)	% dH/Hg
55	8383	5383	3000	6883	13500	45
54	8848	4848	4000	6848	13500	60
53	6700	4200	2500	5450	13500	31
52	7300	3200	4100	5250	13500	49
51	7100	2900	4200	5000	13500	49
50	5700	2500	3200	4100	12500	38
49	4200	2400	1800	3300	12500	20
48	4000	1500	2500	2750	12500	25
47	3500	2000	1500	2750	12500	15

Problems in matching:

Big problem was encountered in finding homologous patches for image matching due to the bright reflection of snow and dark shadows present in the images (lack of textures). No tie points were created in such an area. Algorithms for stereo matching have been developed over many years and comprise highly complex code, there are therefore, clearly inertia to be overcome. Still there exist some confusion of reliability of DEM produced by using automatic matching procedures. Iterative or automatic methods, with multipoint matching gives good results but that requires extra data and consequently costs. This is the area where most research is needed for the acquisition of reliable DEM/DTM/DSM.

Summarizing the specific problems we get:

- Large scale variation due to extreme height differences, created big matching problem and ended with high residuals.
- Variable overlap created problems to generate tie points in the start and end of the strips.
- Erroneous correspondence was established due to bright reflection of snow and dark shadow.
- Measurement of natural control points was found difficult where no signalized points exist.

How the problems were solved:

Matching problems are assigned to that the image can be relatively rotated, images can have different scale, occluded objects, and large variations on radiometric resolution.

Difference in scale means different resolutions and this gives a sharp image in one and the blurred in the other. Rotated image means that one has to resolve the geometrical relationship between images and if automatic procedures failed then the system allows us to measure manually. Blurred texture present in the image make the correlation almost impossible even in the manual measurement mode.The matching problem was solved after necessary interactive measurements were carried out and using a robust matching technique i.e FBM which use the technique of describing features to establish correspondence between two images within ISAT.

Matching quality was found much better within ISAT, after exterior orientation parameters were imported, but that did not helped much in adjustment to provide a stable block automatically. However, interactive measurement was necessary for the stability of the block. System finds erroneous correspondence between images with cloud patches, bright reflection of snow and dark shadow. There is robust estimation algorithm to detect the blunders and eliminate within ISAT, still in this extreme condition of poor textures and big height differences, manual editing is found very effective.

Summarizing the solution, we have

•Interactive measurements of additional tie points and robust matching within ISAT.

•Alternative to that is to import the exterior orientation and or GPS/INS data.

•Measurements of redundant ground control points.

Discussion of the Results:

Different tests were performed to evaluate the efficiency of software in image matching to generate tie points using 12bits and 8 bits images, but both having 14um of resolution. The result above shows a very few or no tie points in 8bits images and considerably more tie points in 12 bits images though they are not well distributed because of the poor texture present in the images**.** Correlation based sterio-correspondence algorithms use the assumption that pixels in correspondence have very similar intensities (photometric compatibility constraint).

System generated tie points on the snow and cloud having erroneous correspondence which were found undetected blunders and that could only be corrected by editing manually. 12 bits images finds considerably sufficient tie points where as 8 bits images could not find any tie points in areas having snow and shadow coverage. Human interventions and well thought weak areas handling provisions should be present in the systems to handle such an areas. In automatic digital aerial triangulation software of tomorrow it would be convenient if the program could handle user controlled matching, additional geometric data and a data base to store natural control points. User control matching is suitable where the terrain is extremely varying in elevation and having poor texture on it. It is for instance not practical to have the same matching strategy in built-up areas, open cultivated fields, forest areas and high mountainous areas like in Nepal. Digital orthophoto production provided – compared to analogue production techniques – a larger flexibility taking mainly advantage of digital image processing techniques. Furthermore, the digital output opened a larger variety of applications, e.g. in a GIS environment. Both aspects influenced the production workflow changing from analogue to digital, and thus, allowing to take advantage of the inherent capabilities for automation.

Some of the examples of final output are listed below for explanations.

Vendor	System	Av. Correct T.P.per image	Eliminated Blunders		No. of multi ray points in object space						
			No.	%	Total	2ray	3ray	4ray	5ray	6ray	7ray
ZI Imaging	ISAT 2001	63	92	3.11	2955	1398	985	552	15	3	2

Table 3 Automatic Tie Point Generation (weak geometry)

Sigma	Degree of Freedom	Control Points Used	Image Points Used	Photo Used	Average points/image
4.9um	**1717**	**58**	**2077**	**47**	**45**

Table 4 Sigma Accuracy of the AT Block

Parameters	X/Omega	Y/Phi	Z/Kappa	XY-Combination
RMS-Control	0.400m	0.257m	0.126m	0.337m
RMS-Limit	1.000m	1.000m	1.500m	
Mean.std.dev. Object	1.816m	2.161m	2.737m	
Max.Residual	1.282m	0.562m	0.323m	
Residual Limit	1.500m	1.500m	3.000m	
Mean std photo Position	3.136m	3.832m	2.088m	
Mean std photo Attitude	0.027m	0.022m	0.008m	

Table 5 Block Adjustment Result

Photo Triangulation Results

Summary Stats | Photo Stats | Object Stats | Point Stats | Exterior Orientation | GPS | INS | Self-Calibration

Parameter	X/Omega	Y/Phi	Z/Kappa	XY
MS Control	9.941	12.495	10.001	11.2
MS Check	0.000	0.000	0.000	0.00
MS Limits	20.000	20.000	25.000	
lean Std Dev Object	2.932	3.009	6.823	
lax Residual	14.281	21.028	15.760	
esidual Limits	30.000	30.000	40.000	
lean Std Dev Photo Pos	3.760	5.288	6.476	
lean Std Dev Photo Att	0.039	0.021	0.009	
MS Photo Pos	0.000	0.000	0.000	
MS Photo Att	0.000	0.000	0.000	

Key Statistics

Sigma: 4.6 um
RMS Image (x, y): 2.8, 3.1 um
Number of iterations: 5
Degrees of Freedom: 1648
Number Image Blunders: 19

Solution Successful.

Current Count

Control Points Used: 5
Check Points Used: 0
Photos Used: 47
Photos Not Used: 0
Image Points Used: 2036

Cameras used: (1).

Camera Id	Lens Distortion
RC_20_Nepal	On

Project Settings

Linear Units: Meters
Angular Units: Grads

Atm Refraction: On
Earth Curvature: On

Table 6 Photo Triangulation Results

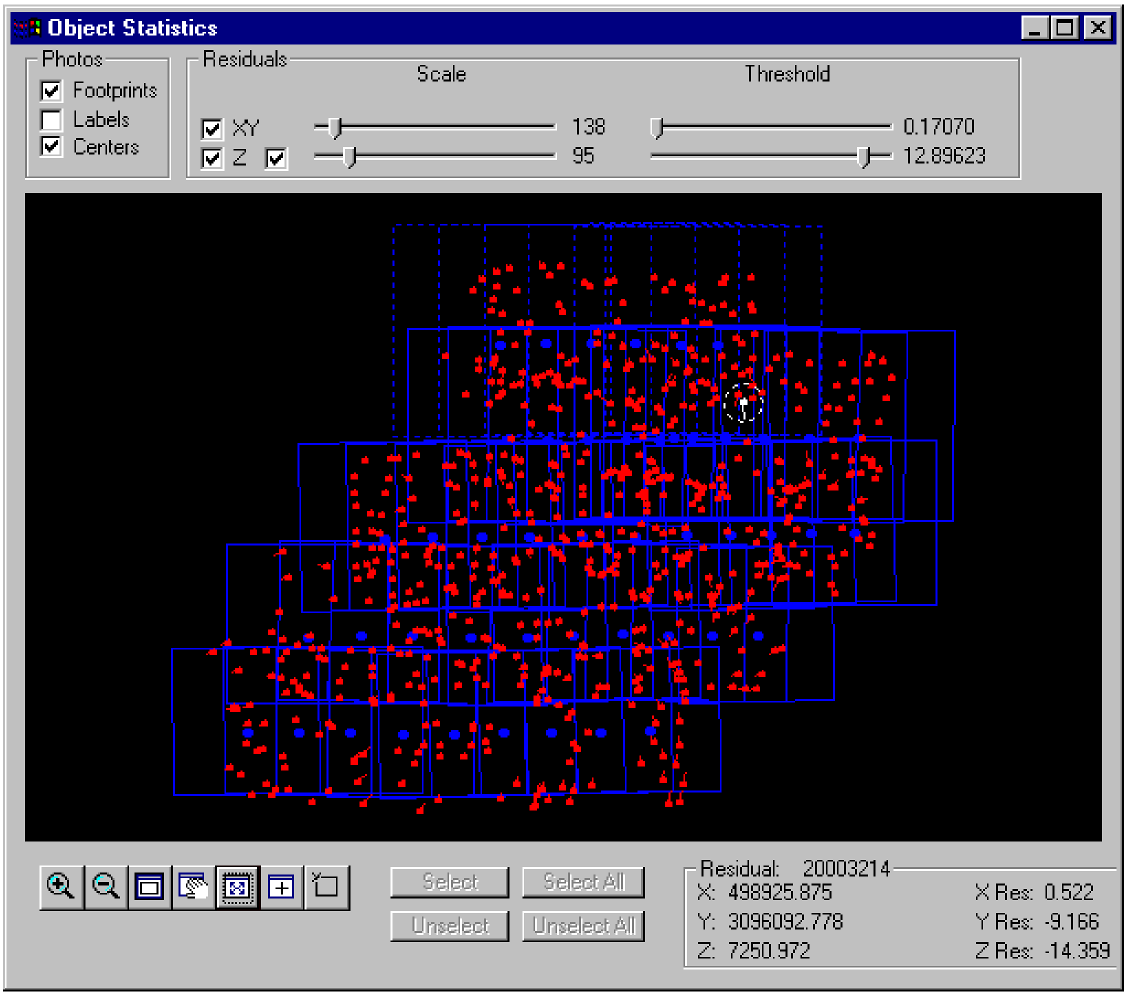

Figure 1 Tie points distribution in a block (no tie points in snow, shadow and occluded areas)

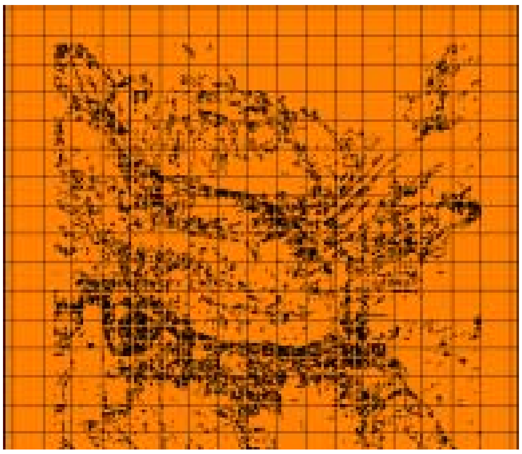

Figure 2 Automatic DTM Extraction

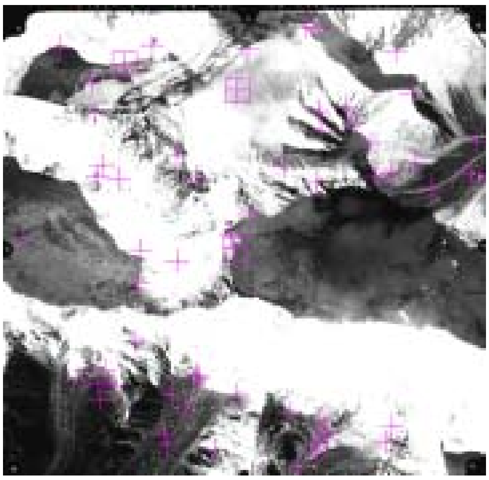

Figure 3 Rectified Aerial Photograph

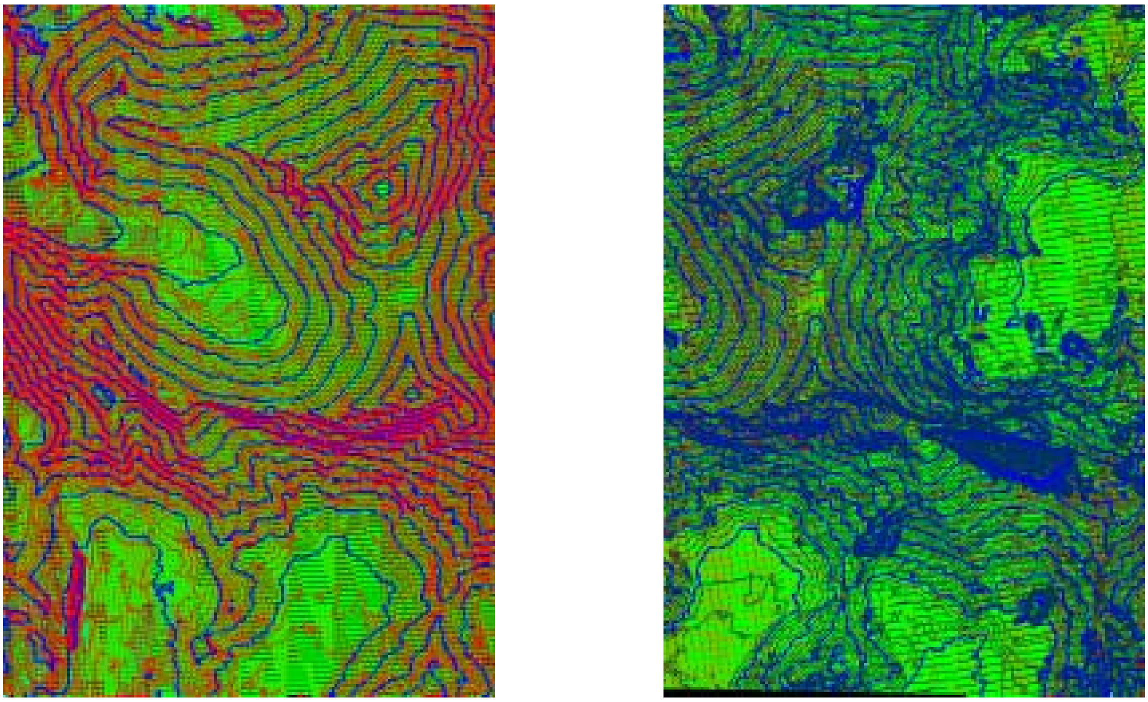

Figure 4 Comparison of DTM (low resolution/fairly good and high resolution/noisy)

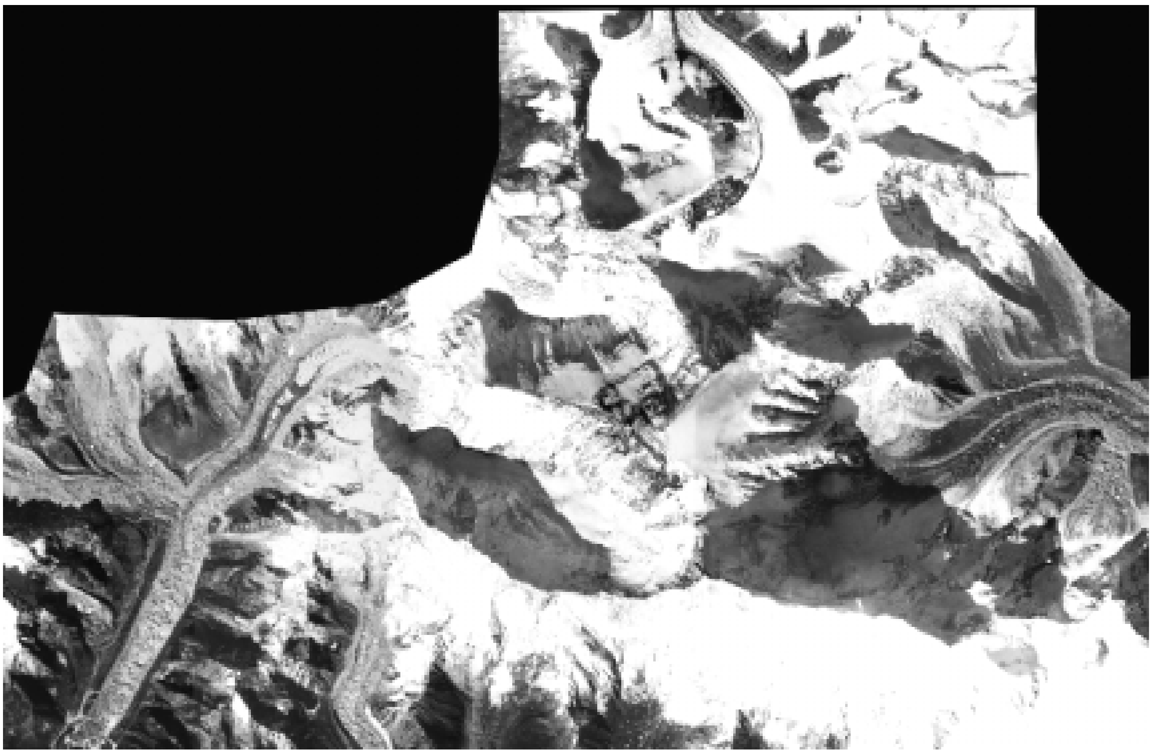

Figure 5 Ortho mosaic

Conclusion:

Application of traditional aerial survey technologies for topographic purposes has a number of principal problems. The most serious problem is definitely impossibility of automatic use of classical stereo photogrammetric methods in cases of complex terrain, the areas with no visual texture and so on.

Photogrammetry has the advantages of acquiring information about a large area very efficiently and cost effectively. Especially for inaccessible areas, photogrammetry is far more superior than traditional ground survey.

It is recommended to inspect and edit the resulting TPCs using Point Measurement facility in case of large relief displacements and imprecise projection center. The pull in range of the matching algorithms is approximately 10x10 pixels and if the positions of theTPCs are out of this range, the computation will fail. Due to the extreme relief problem the computation failed for many test blocks.

Note: Final products were DTM, Orthophotos and its Mosaic and the visualization of photo realistic 3-D textured model that will only be demonstrated during ACRS 2003. Due to the large volume of image data present in my paper even after compressing, I am unable to send it through online system or via email.