Evaluation Of Topographic Mapping Possibilities From Cartosat High Resolution Data

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Keywords: *High-resolution satellite imagery, Satellite Photogrammetry, DEM, Orthoimage,Topographic Mapping.*

Abstract

Re-surveying or mapping is usually required when user needs for up-to-date maps at various scales are not met by existing maps. Generally, the requirements are for large scale mapping and the outputs may be in digital format or hardcopy or both. Data acquisition may be from field survey, aerial photographs or satellite imagery. Nowadays, due to availability of high resolution satellite imageries, scales 1:2,500 to 1:10,000 can be mapped for large areas as an alternative to field survey. Cartosat is producing stereo satellite imageries of 2.5m spatial resolution. This paper evaluates the possibilities of mapping at 1:10,000 from this Cartosat image. Evaluation of accuracy is done for both planimetric and height mapping. Also the optimum scales that can be derived from the Cartosat stereo-pair are suggested.

1. Introduction

Maps have been valuable tools for man from time immemorial. In the early ages maps were extensively used in travel and in navigation. Today maps have broader spectra of applications and have proven to be vital tools on decision making in many organizations like; government, engineering development, explorations and tourisms industry. The conventional topographic mapping method is a rather labor intensive, time consuming and expensive endeavor, hence an alternative for a faster and cheaper topographic mapping method should be sought for.

The new technology of high-resolution satellite imagery has demonstrated its immense potential for mapping. The IKONOS and Quickbird imaging systems offer ortho-image products meeting map accuracy specifications to scales as large as 1:10,000. The cost of acquiring such mapping products is, however, quite considerable and beyond the means of many prospective international users, especially in the developing world. Fortunately, there are methods available for users with photogrammetric capability to generate high-accuracy mapping from low-cost satellite images, with the possibility of achieving stereo models for accurate mapping. This paper summarizes an experiment of digital satellite photogrammetric approach for topographical mapping using stereo pair of high-resolution satellite imagery, Cartosat-I as a sample image.

2. Satellite Photogrammetry

Satellite photogrammetry has slight variations compared to photogrammetric applications associated with aerial frame cameras. This paper makes reference to the IRS-P5 Cartosat I satellite. The Cartosat I sensor provides 2.5 meter panchromatic imagery with stereo viewing capability.

"The IRS-P5 Cartosat-1 satellite carries Panchromatic cameras which are mounted such that one camera is looking at +26 deg. w.r.t. nadir and the other at -5 deg. w.r.t. nadir along the track. These two cameras combined provide stereoscopic image pairs in the same pass. The focal length of the camera optic is 1945 mm, which is very large relative to the length of the camera (78 mm). A polar sun synchronous orbit of altitude 618km with an inclination of 97.87 deg. and an equatorial cross-over local time of 10:30 hours and the descending node has been selected based on various considerations. The sun-synchronous orbit provides the imagery collection under near-constant illumination conditions throughout the life and repetitive coverage of the same area in a specified interval. In order to revisit the same place at a more frequent interval than the repetitive cycle, an off-nadir viewing capability is provided. Using this facility any area which could not be imaged on a given day due to cloud cover, etc. may be imaged on another day. The typical revisit cycle is 5 days with the off-nadir cross-track steering facility" [1].

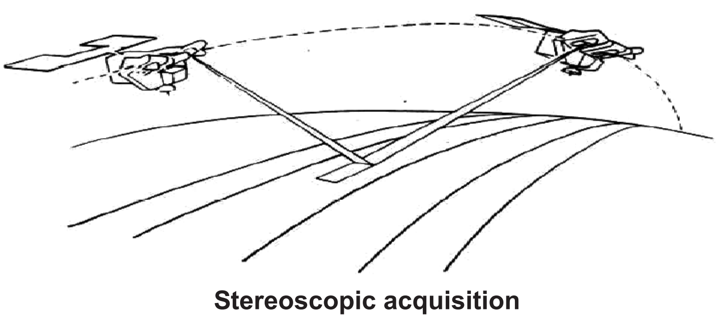
2.1 Key Parameters of the IRS-P5 Cartosat-1 Sensors [2]

	PAN Fore Camera	PAN Aft Camera
Tilt Along Track	+26 deg	-5 deg
Spatial Resolution	2.5 m	2.5 m
Swath-width	30 km	27 km
Radiometric Resolution, Quantization	10 bit	10 bit
Spectral Coverage	500-850 nm	500-850 nm
Focal Length	1945 mm	1945 mm
CCD Arrays (no. of arrays * no. of elements)	1 * 12000	1 * 12000
CCD Size	7 µm x 7 µm	7 µm x 7 µm
Integration Time	0.336 ms	0.336 ms

2.2 Stereo Imaging

The concept of stereo pair images is that two images are acquired at two different angles, left viewing and right viewing, and preferably at same time or within short time interval in order to have same features and illumination on both images. These images can be viewed stereoscopically to obtain relief impression using optical instruments, and of lately using soft photogrammetric stations. Pushbroom sensors like SPOT sensors have the capability of off nadir viewing. This means they can be pointed towards left or right of the orbit track or pointed forward or behind along satellite track. This characteristic has a number of advantages which include reduction of revisit time by observing areas not on satellite path, areas not covered by clouds can be imaged at that particular moment, and most importantly this characteristic provides good opportunity for stereo imaging. Stereo imaging with such satellites can be done across track (images taken from different satellite paths) or along track, where the second image is taken in quick succession of the first image by the same sensor along the same track. The figure below shows stereo acquisition by a satellite.

Imaging with enlarged swath width



Stereoscopic acquisition

3. Dataset Used

Cartosat Stereo images of Barcelona (provided by Nepasoft) (Copyright reserved to ERDAS Imagine India)

Spatial Resolution: 2.5m

Scene Coverage: 30km X 30km

RPC file of the sat image

- Ground Control Points:

Planimetric: extracted from the sample orthoimage of the same area

Altimetric: extracted from the sample DEM of the same area

Where, R is the incidence angle of the right image and L is the incidence angle of the left image.

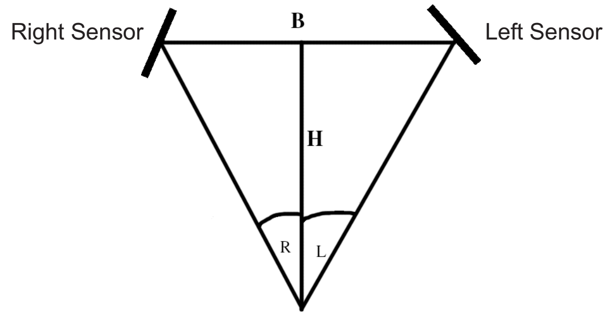


Figure : View Geometry

Backward Image

```
ProductID=055056200501
SatID=CARTOSAT-1
Sensor=PAN_AFT
GenAgency=NRSA
Path=0117
Row=0208
DateOfPass=19JUL05
PassType=SSN
OrbitNo=1116
SceneSequenceNumber=01
BytesPerPixel=2
GenerationDateTime=27AUG05
ProductCode=STUC00GOJ
ProductType=ORTHOKIT
ResolutionAlong=2.5000000
ResolutionAcross=2.5000000
Season=JUL
ImageFormat=GeoTIFF
ProcessingLevel=STD
ResampCode=CC
NoScans=12000
NoPixels=12000
MapProjection=NONE
Ellipsoid=WGS_84
Datum=WGS_84
```

Forward Image

```
ProductID=055056200601
SatID=CARTOSAT-1
Sensor=PAN_FORE
GenAgency=NRSA
Path=0117
Row=0208
DateOfPass=19JUL05
PassType=SSN
OrbitNo=1116
SceneSequenceNumber=01
BytesPerPixel=2
GenerationDateTime=27AUG05
ProductCode=STUC00GOJ
ProductType=ORTHOKIT
ResolutionAlong=2.5000000
ResolutionAcross=2.5000000
Season=JUL
ImageFormat=GeoTIFF
ProcessingLevel=STD
ResampCode=CC
NoScans=12000
NoPixels=12000
MapProjection=NONE
Ellipsoid=WGS_84
Datum=WGS_84
```

3.1 Suitability for DEM generation

There are three main factors to consider if the two images are capable of forming a stereo pair:

i. The Base Height, B/H, ratio.

ii. Date of acquisition

iii. The degree of overlap.

The base/ height ratio can be calculated using the two incidence angles provided with each scene and applying the formula:

$$B/H = \tan(R) + \tan(L)$$ [3]

The B/H ratio can be chosen from the following values:

1.0 - (high value, applicable particularly for analog processing)

0.8 - (optimal value, applicable for all application types)

0.6 - (low value, useable in digital processing)

In the case of the dataset used:

B/H ratio: 0.62 [1]

Date of acquisition of satellite image: same day

This shows a good possibility of stereo restitution of satellite image pair.

4. Orientation and Triangulation

Pushbroom sensors acquire images line by line. Every scan line has different time instance and hence different perspective projection model, but orientations of neighboring lines are strongly correlated. The exterior orientation parameters; which are the attitude angles of roll, pitch and yaw and the perspective centre change from scan line to scan line. The interior orientation parameters which comprise focal length, principal point location, lens distortion coefficients, and other parameters directly related to the physical design of the sensor are the same for the entire image. For the geo-referencing of imagery acquired by pushbroom sensors many different geometric models of varying complexity, rigor and accuracy have been developed. The main approaches include rigorous models, rational polynomial models, Direct Linear Transformations (DLT) and affine projections.

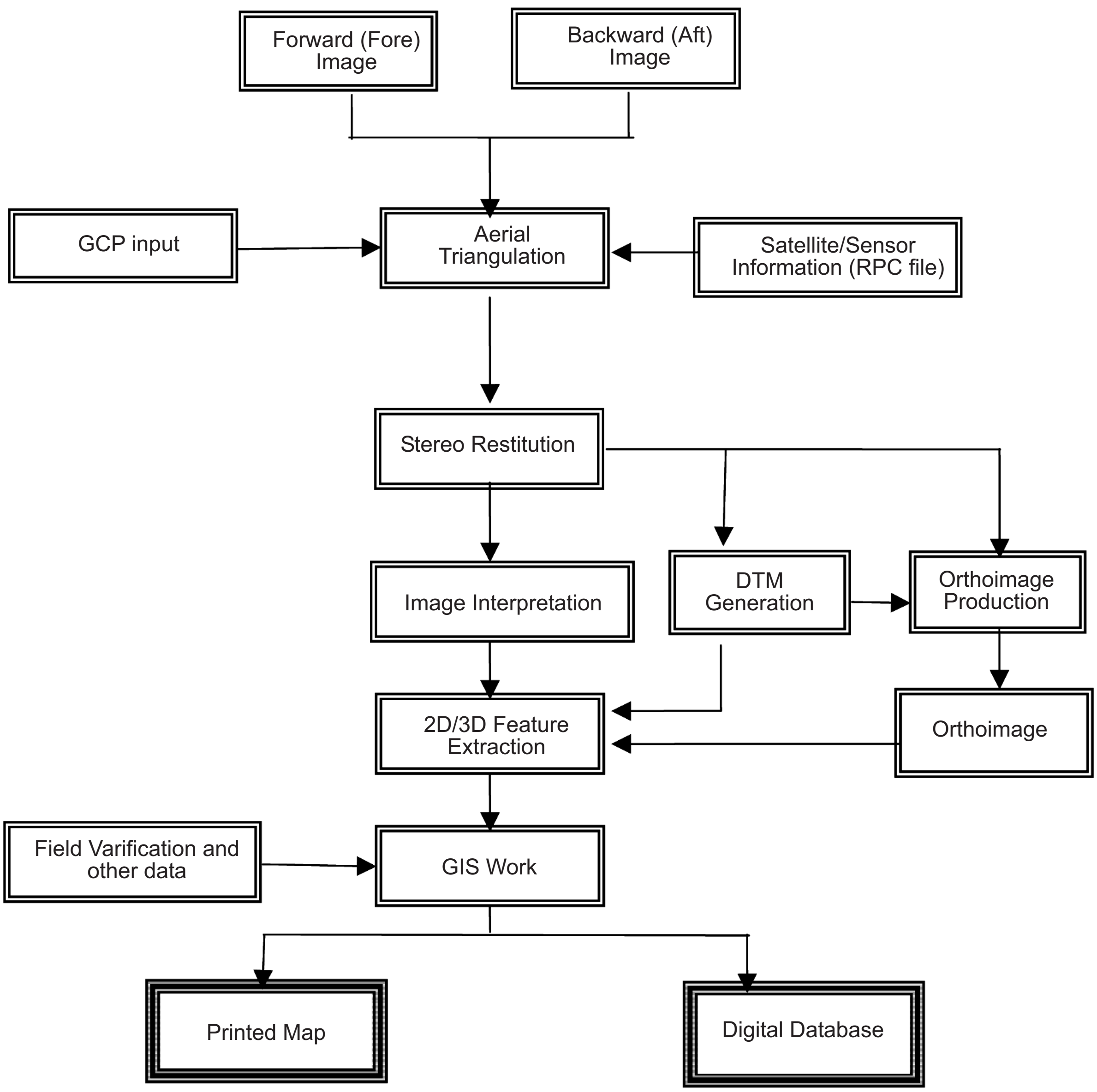
The procedure followed for the geometric processing was performed in LPS-Orthobase and the steps include automatic interior orientation, measurement of ground control points, after GCPs measurement an image matching technique which automatically identifies , transfers and measure image tie points between the two images making stereo pair was run, and finally the triangulation was run to obtain exterior orientation. From the triangulation model Digital Elevation Model was generated which was used for ortho-rectification of the images.

4.1 DEM Generation and Orthoimage Production

Stereo model was generated after aerial triangulation which was used for feature extraction, DTM generation and Orthoimage production. Satellite Images were orthorectified using the DTM to produce orthoimages.

5. Methodology

The figure below shows the workflow of the whole mapping work.



6. Feature Extraction

The topographical features extracted in different layers are:

Transportation – (lines/polygon)
Hydrographical features (polygon)
Land cover – (polygon)
Buildings – (polygon) and Built-up area – (polygon)

6.1 2D Feature Extraction

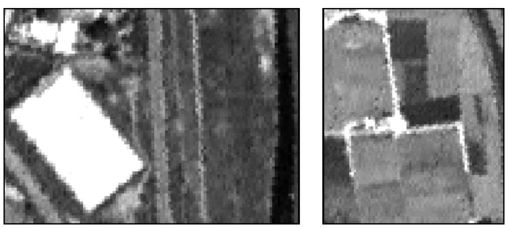
The parameters for feature extraction in 2D were as follows:

Tone, Shape, Pattern, Texture, Size, Association, Site

Tone

- Relative brightness of a black/white image
- Tonal variations depend on energy reflected

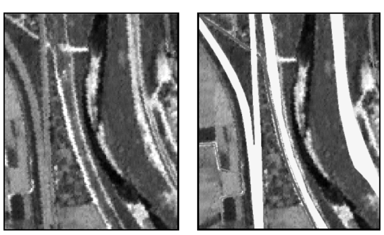
Spectral characteristics of an image - expressed as 0-255 grey levels



Tonal variations in two portions of the image

Shape

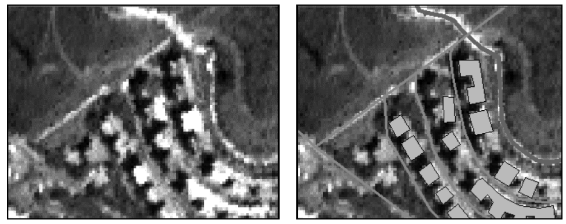
- Shape or form characterizes terrain objects
- In 3D it relates to height differences
- Useful for identifying roads, railway tracks, built-up areas, agriculture fields etc.



Linear shape assists in identifying roads

Pattern

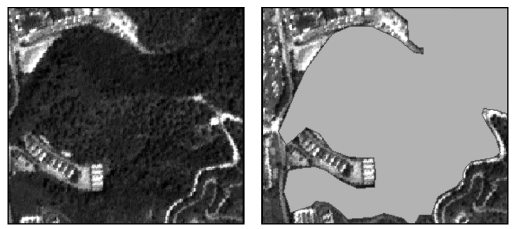
- Spatial arrangement of objects
- Repetition of certain form of relationships
- Useful for identifying man-made features like built-up ares etc, hydrological systems, geological patterns etc



Regular pattern helped to identify individual buildings

Texture

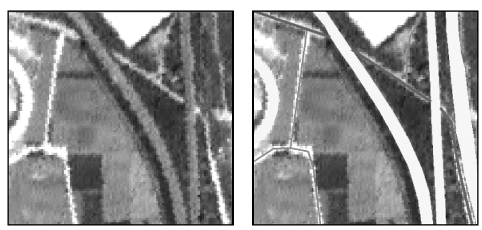
- Frequency of tonal change
- May be coarse or fine, smooth or rough, even or uneven, mottled, speckled, granular, linear etc
- Terrain roughness or smoothness
- Strongly related to spatial resolution



Grainy texture helped identify forest area

Size

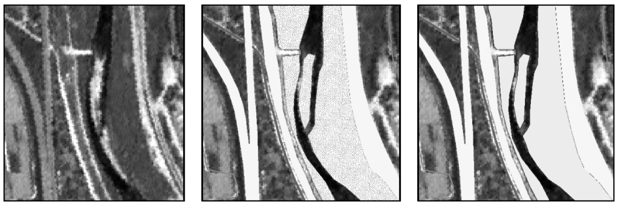
- Can be relative or absolute
- Relative size can be inferred from absolute
- Relative size can assist in classifying different features (e.g. highway-district road etc)



Relative size helped to classify roads

Association/Site

- Relates to geographic location
- Combination of objects used to identify a feature


Proximity to river means either sand or marsh land

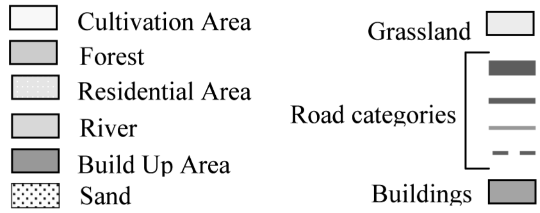
All features excluding buildings were extracted from orthoimage. Buildings were extracted from Stereo model. It is more user-friendly to extract feature from orthoimage by simply digitizing the features in the image. Uncertainties in image interpretation in orthoimage can be resolved by extracting in 3D mode i.e. feature extraction in stereo model. Stereo digitizing is more powerful to extract the topographical information since it provides the 3D view of the terrain although it is time consuming and needs expert knowledge.

Figure above shows the stereo model of the Cartosat -1 image of the study area.

Feature extraction of a small sample area of the above shown image is done. Most of the features were extracted in 2D digitization. The features which were difficult to classify like buildings were verified from stereo model. Field verification should be done to make the map complete.


Small part of the whole image


Digitization of the sample area



7. Suitability for mapping at 1:10,000

The Survey Department of Nepal has a specification of maximum Permissible error in planimetric plotting (PE) = 0.25mm * Mapping Scale

So for a scale of 1:10,000 mapping the permissible error PE = 0.25mm * 10,000 = 2.5m
Since the spatial resolution of the image is 2.5m, so theoretically the image is suitable for mapping at 1:10,000.

From the extracted features above, the line and polygon features were within the permissible error in 2D plotting. The features to be plotted as point in 1:10,000 scale can be viewed in 3D, but this particular sample image contained no such features, so the analyses was not performed for point features.

7.1 Suitability for mapping at other scales

Mapping at other scales will depend on the following:

- Permissible error (may be different from Survey Department of Nepal specifications)
- Purpose (e.g. only linear features may be needed)
- 2D or 3D (e.g. planimetric features are more accurately and easily plotted than contours)

So, if the permissible error for planimetric plotting is more than the Survey Department of Nepal specifications then it is possible to plot at larger scales. For example, since the spatial resolution of Cartosat image is 2.5m, if an organization has a planimetric PE of 0.5mm*Mapping Scale, then the scale for which it can plot is 1:5,000 (0.5mm * 5000 = 2.5m)

8. Limitation of the work

The main limitation of the work was the dataset to be used. Because of the unavailability of the satellite image of Cartosat -1 of Nepal, sample image from Barcelona was to be used. This caused limitation of control points.

Horizontal coordinates of the Ground Control points were taken from orthoimage and the vertical coordinate Z-value, was taken from sample DEM of the same area. This reason limited us from the field verification for validation of the work and to collect the incomplete information in the image.

9. Conclusion

Digital photogrammetry method was used for extraction of geo-information from Cartosat-1 image. Digital elevation model and orthoimage were produced. Distinct line and polygon features were extracted from the orthoimage. Features that were not clear in orthoimage were extracted from stereo model. Validation of the work in the ground was not possible. The image was found suitable for mapping at scale 1:10,000 using Survey Department of Nepal specifications.

Reference

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Jean-Paul DARTEYRE, DEM Stereoscopic aspects of SPOT, tutorials by GDTA, GDTA, 1995.