DEM GENERATION FROM HIGH RESOLUTION MULTI-VIEW DATA PRODUCT

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ABSTRACT:

High resolution space-borne remote sensing image data show a high level of detail and provide many opportunities to be integrated into remote sensing applications. In particular, surface mapping from multi-view and stereo data sets becomes feasible with height accuracy in the meter range. Cartosat-1 and Cartosat-2 are the two Indian satellites which provide the high resolution images. Cartosat-1 is a unique satellite having along track stereo imaging capability with 2.5 m resolution. Cartosat-2 is the second satellite in the Cartosat series which was launched during January 2007 by PSLV. Cartosat-2 is a high agility advanced satellite with a high spatial resolution of better than 1m in panchromatic band with an operational life of 5 years. Cartosat-2 provides standard multiple scene product called as Multi-view with an overlap of more than 80 percent. Stereo image viewing has been the most common method of elevation modelling used by the mapping, photogrammetry, and remote sensing communities. Multi-view Image contains radiometrically corrected images with rational polynomial coefficients. Maximum three multi-view images are possible in a single pass of the satellite. In this study Multi-view Images have been treated as stereo image pairs to obtain stereoscopy. Generating DEMs from stereo data normally requires the use of a geometric model and ground control points (GCPs). The collection of GCPs presents a significant problem in many practical applications due to non availability of GCPs. A DEM generation method which requires no GCPs would therefore be of significant interest to users of stereo data. The RPC model was computed for each image. A pair of quasi-epipolar image is generated from the stereo images to retain elevation parallax in the X-direction. An automated image matching procedure is then used to produce the DEM. In this study, automatic DEM extraction of Cartosat-2 multi-View data without the use of GCPs has been evaluated, as well as the improvement of extracted DEM quality by applying horizontal shift on reference DEMs from the available Global DEMs or other source DEMs. High quality DEM has been generated at 2 m grid spacing which will be of immense use for producing digital city model (DCMs).

1. INTRODUCTION

High resolution space-borne remote sensing image data show a high level of detail and provide many opportunities to be integrated into remote sensing applications. In particular, surface mapping from multi-view and stereo data sets becomes feasible with height accuracy in the meter range. Cartosat-1 and Cartosat-2 are the two Indian satellites which provide the high resolution images. Cartosat-1 is a unique satellite having along track stereo imaging capability with 2.5 m resolution. Cartosat-2 is the second satellite in the Cartosat series which was launched during January 2007 by PSLV. Cartosat-2 is a high agility advanced satellite with a high spatial resolution of better than 1m in panchromatic band with an operational life of 5 years. Cartosat-2 provides standard multiple scene product called as multi-view with an overlap of more than 80 percent. Stereo image viewing has been the most common method of elevation modeling used by the mapping, photogrammetry, and remote sensing communities. In this mode of imaging, strips on either side of the track in the North-South or South-North direction are considered and one strip selected can be imaged maximum three times with different look angles with a specified strip length. Multi-view Image contains radiometrically corrected images with rational polynomial coefficients. Maximum three multi-view images are possible in a single pass of the satellite. In this study Multi-View Images have been treated as stereo image pairs to obtain stereoscopy.

Digital elevation models (DEM) are generated by traditional photogrammetry with aerial photos, by airborne laser scanning, with stereo images from space called stereogrammetry, or with interferometric synthetic aperture radar (InSAR) [Jacobsen, 2004]. Stereogrammetry involves the extraction of elevation information from stereo overlapping images, typically airphotos, satellite imagery, or radar. To obtain stereoscopy with images from satellite scanners, two methods are possible: along-track stereoscopy from the same orbit, using fore and aft images, and across-track stereoscopy from two adjacent orbits.

DEM gives the information about the shape of earth surface which can be used for various tasks like map creation, urban planning, flood control, resource management, telecommunication planning, military mapping etc. Elevation data, integrated with imagery is also used for generating perspective views, useful for tourism, route planning to optimize views for developments and to lessen visibility of forest clearcuts from major transportation routes.

The manual method of DEM generation is a time consuming job, so the most of the data processing is done by automatic/semi-automatic methods. With the help of remote sensing methods, one can generate DSM (Digital Surface model) which is the height on the earth surface over canopy cover (Vegetation & man made structures). The conversion of a DSM into a DEM is another task of research in remote sensing [Baltsavias, 1999].

In this study, we have examined the automatic DEM generation from Cartosat-2 multi-view images without the use of GCPs, as well as improvement of extracted DEMs using the Shuttle Radar Topographic Mission (SRTM) DEMs. Available data sets of Cartosat-2 multi-view sensors are used for DSM generation with very high resolution (1 m) for this study.

2. IMAGE ORIENTATION

Generating DEMs from stereo data normally requires the use of a geometric model (rigorous physical sensor model) and ground control points (GCPs). The collection of GCPs presents a significant problem in many practical applications, as an existing source of GCPs may not be available. A DEM generation method which requires no GCPs would therefore be of significant interest to users of stereo data. The RPC model was computed for each image and supplied in a text format with the Cartosat-2 datasets.

Rational Polynomial satellite sensor models are simpler empirical mathematical models relating image space (line and column position) to latitude, longitude, and surface elevation. The name Rational Polynomial derives from the fact that the model is expressed as the ratio of two cubic polynomial expressions. Actually, a single image involves two such rational polynomials, one for computing line position and one for the column position. The coefficients of these two rational polynomials are derived from the satellite's orbital position, orientation and the rigorous physical sensor model. The RPC method is a useful method to avoid the development of 3D physical models. The RPC method computes the polynomial adjustment model for each image [P Cheng, March 2006].

$$\Delta P = Ao + AS \times Sample + AL \times Line + ASL \times Sample \times Line + \ldots \quad (1)$$

$$\Delta R = Bo + BS \times Sample + BL \times Line + BSL \times Sample \times Line + \ldots \quad (2)$$

Ao,AS,AL,ASL,….. and Bo,BS,BL,BSL,….. are the image adjustment parameters, Line and Sample are the line and sample coordinates of an image, and ΔP and ΔR are the adjustable functions expressing the differences between the measured and the nominal line and sample coordinates.

3. DEM GENERATION

Leica Photogrammetry suite Software has been used for modeling and DEM generation. The software supports reading of data, manual or automatic GCP/tie points (TP) collection and geometric modeling of different satellites including RPC model. It is also capable of automatic DEM generation, DEM editing, ortho rectification and mosaicking. This RPC method of the software is based on the block adjustment method developed by Grodecki and Dial. LPS software supports zero order, a first order and second order RPC polynomial adjustments. To generate DEM a project has been created inside the software. The RPC model was computed for each image as per equations (1) and (2). Since no ground control point was used (they are not available for this area), a zero order polynomial adjustment has been considered. A pair of quasi-epipolar image is generated from the stereo images to retain elevation parallax in the X-direction. An automated image matching procedure is then employed to produce the tie points (conjugate points) through a comparison of the respective grey values of these images. The matching method finds the corresponding pixels in the left and right quasi-epipolar images by a hierarchical sub-pixel mean normalized cross correlation matching method. Correlation coefficients are generated between 0 and 1 by this matching technique. For each matched pixel, 0 represents a total mismatch while 1 represents a perfect match. The points having correlation coefficient more than 0.80 have been selected for the computation of parallax. The parallax then converted into irregular height points which had been converted into regular DEM by tin linking and a second order surface fitting. The generated Cartosat-2 DEM and the orthoimage of the corresponding area are shown in Figure-1.

The accuracy of the DEM has been checked with SRTM 3-arc second DEMs. SRTM is an international project spearheaded by National Geospatial Intelligence Agency (NGA) and NASA. Since only tie points could be collected between each stereo pair, the horizontal positions of the extracted DEM will include errors caused by uncorrected biases and errors in the RPCs. These errors have been reduced by comparing similar features between the extracted DEM and the SRTM DEM, and applying offset values in X and Y to the extracted DEM to match the SRTM DEM horizontal positions. It has been observed that there was a constant shift of 90 m in X and 112 m in Y direction. This has been compensated by applying bias in the X and Y direction. The Cartosat-2 DEM and the SRTM DEM of same area are shown in Figure-2. It can easily be observed that the details generated by Cartosat-2 multi-view DEM are much better, due to its capability of extraction of finer details of elevation from its high resolution data. SRTM DEM was in vertical datum EGM 96. So it has been converted into WGS 84 by applying a bias of 46 m for this area. After applying the shift in Longitude and Latitude direction the image difference statistics between the two DEMs shows a constant bias of 34 m in height. The DEM difference statistics is summarized in Table-1. Currently the technique establishes generation of relative DEMs in a better grid interval. The capability of this technique in terms of the final achievable accuracy is to be further assessed with the use of high accuracy GCPs for modelling and precision DEM for evaluation. Figure 3 gives Cartosat-2 orthoimage drapped over DEM generated from muliti-view imagery

Figure-1 (a): Cartosat-2 DEM sub-sampled at 2 m pixel size

Figure-1(b): Orthoimage of the same urban area as in fig-1(a) sub sampled at 2 m

Height Difference	Cumulative difference Percentage (SRTM – Cartosat 2 DEM)
Within 2 m	45.17
Within 4 m	68.71
Within 6 m	87.23
Within 8 m	91.11

Table-1: Comparison of Cartosat-2 DEM and SRTM DEM

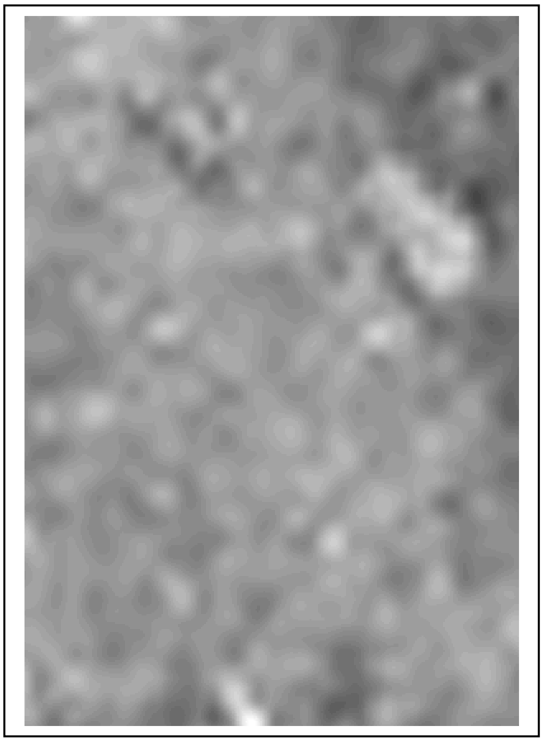

Figure-2 (a): SRTM DEM interpolated at 10 m Pixel Size

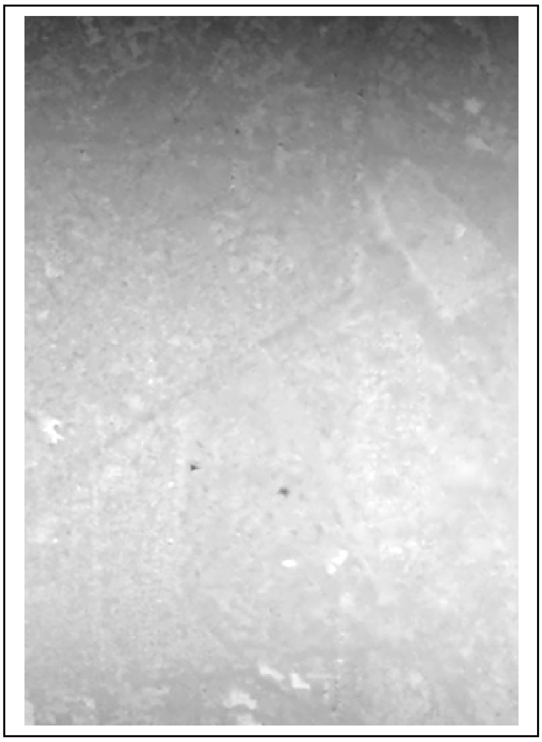

Figure-2 (b): Carto-2 Multi-view DEM corresponding to the same area as in fig 2(a) sub-sampled at 10 m pixel size

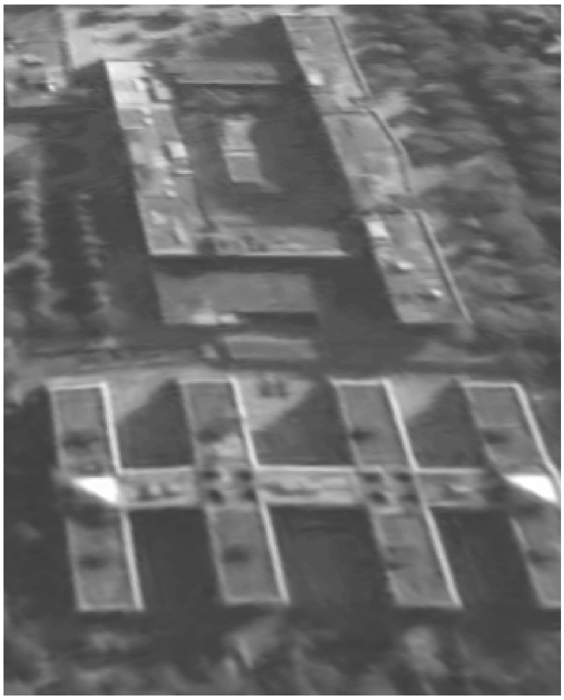

Figure-3.: Cartosat-2 Ortho-image draped over DEM generated from Cartosat-2 Multi-view images.

4. RESULTS & CONCLUSION

This study proves that it is possible to extract DEMs from Cartosat-2 multi-view images without GCPs. Only tie points have been used for the generation of DEMs. In this study, automatic DEM extraction of Cartosat-2 multi-view data without the use of GCPs has been evaluated, as well as studied the improvement of extracted DEMs quality by applying horizontal shift on reference DEMs from the available Global DEMs or other source DEMs. High quality DEM has been generated at 2 m grid spacing which will be of immense use for producing digital city model (DCMs). The accuracy of the DEM generated from multi-view images can be further improved with the use of high quality GCPs for modelling. Assessment of generated DEM with a reference including GCP modelling is the future scope of this study.

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