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MODELLING OF THE IRS-1C SATELLITE PAN STEREO-IMAGERY USING THE DLT APPROACH

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ABSTRACT

In view of the new high resolution satellites, images from the PAN camera of the Indian Remote Sensing satellite IRS-1C were evaluated for mapping applications at the Centre for Topographic Information, Geomatics Canada. The capability for 3D determination of individual points was investigated using in-house available systems. The orientation of the images was performed using the Direct Linear Transformation (DLT) method. The results obtained demonstrated the viability of this approach for 3D data extraction for topographic mapping within the limitations of the geometric configuration of the available stereo pair and the poor radiometric quality of one of the images.

1 INTRODUCTION

The stereo-compilation from aerial photographs was and is still the most popular method for 3D topographic data acquisition for production of new and the revision of old inaccurate databases and maps. The situation for updating existing topographic databases is different. For the Canadian context, studies conducted at Geomatics Canada have shown that a suitable method can be the monoscopic updating from ortho-images (Armenakis and al., 1995; Savopol, 1994). The data source for the ortho-images can be either digitized aerial photography or satellite imagery with ground resolution of 10m or less, depending on the location of the area of interest, the density of information, the desired content and accuracy of the updated data, and the availability of DEM data.

However, data collection in stereo mode for updating is sometimes the best solution or even the only possible solution especially in areas with only older poor cartographic base and in areas with significant high elevation differences and without accurate existing DEMs. Stereoscopy offers some important advantages in facilitating the identification of features.

The new high resolution commercial satellites will provide more choices for data sources. This paper describes an investigation conducted at the Centre for Topographic Information (CTI), Geomatics Canada, on the use of the Indian Remote Sensing satellite IRS-1C PAN images for national topographic mapping. For the stereoscopic evaluation of 3D data extraction, two CCD overlapping scenes were restituted using the Direct Linear Transformation (DLT) method.

2 SATELLITE STEREO-COVERAGE

Depending on the design of its sensors, a remote sensing satellite with stereo capability is able to capture images in stereo mode using one of two possible configurations: across track or along track.

In across track configuration, the pointing of the imaging sensor is oriented off-nadir in the across track direction. The stereo coverage is obtained by recording the same area from one of the neighboring tracks after the sensor orientation has changed for an across track angle in the opposite direction (or for a nadir view). This configuration was used for the design of the SPOT series of satellites and for the two IRS-1 C and D satellites. The across track configuration was adopted for the design of this two series of satellites probably aiming to increase the ground coverage, as well. In fact, the off-nadir view capability allows a “revisit period” about 4 to 5 times shorter than the repeatability cycle. The “revisit period” is the average time between two possible “visits” of the same site using all across track available angles of view. The repeatability cycle is the time between two passes over the same site. For a satellite using only a nadir angle of view, the revisit and the repeatability periods are equal. In the case of the IRC-1C satellite, the repeatability cycle is 24 days and the average revisit period is approximate 5 days.

In the along track configuration, stereo-coverage is obtained during the flight along the same orbit either by using at least two sensors oriented off-nadir in the along track direction with different angles of view, i.e. fore and aft, or by changing the pointing angle of one sensor along the orbit. The time between the recording of the two images is very short, as in traditional aerial photogrammetry. The illumination conditions are identical, the radiometry of the two images is similar and the stereo observation should be easy.

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That is an important advantage over the across track configuration, where the delay between the two images can be some days in the best case, but most of the time is some weeks or months. The German MOMS-2P camera (three line sensor) uses an along track configuration.

Although no commercial satellite is offering such a capability today, the two design configurations could be combined in order to obtain the advantages of each. For example, a two sensor system with along track configuration could be installed aboard a satellite offering the capability of pointing the entire along track sensors system in the across track direction. Such a system could offer the quality of a stereo pair with similar radiometry (good image correlation) obtained from the along track sensor system with the higher coverage capability of the across track orientation.

3 DESCRIPTION OF IMAGE DATA

Two IRS-1C PAN images of the eastern Ottawa area and their individual CCD array images were acquired for this investigation. The availability of images at the time of image selection was limited. All images were of nadir view, that is, no stereoscopic coverage was available with the PAN camera tilted and thus resulted in weak convergent geometry. Selection of imagery was also limited due to cloud and snow coverage. The first scene, the 287/037, had been acquired on 25/11/96 and the shadow effect was obvious due to low sun elevation. The second scene, the 288/037, was taken on 15/06/96 and was from the neighboring orbit to provide basic stereoscopic coverage. Unfortunately, this image is of a poor radiometric quality but certain linear features, such as roads and road intersections can be distinguished for measurements. In this investigation for the determination of 3D coordinates, the left image of the stereo pair was CCD 3 from the 288/037 scene and the right image was CCD 2 from the 237/037 scene. The centre of the left image is at latitude 45^{o} 32’ 40”.56N and longitude of 75^{o} 19’ 32”.90W and the centre of the right image is at 45^{o} 22’ 03”.36N and 75^{o} 18’ 00”.35W respectively. This set-up has an unfavourable base-to height ratio of about 0.087. Despite the lack of ideal data it was decided to proceed with the testing of the images, the approach and the systems capabilities. Figure 1 illustrates a schematic diagram of the two images with the CCD sub-scenes and the overlapping area. The test area covers the upper part of the overlapping area with a width of 22km and a length of 24km.

4 MODELLING OF THE IRS-1C PAN WITH THE DIRECT LINEAR TRANSFORMATION

The georeferencing of the satellite images is based on two modelling approaches.

1) The algebraic type, which models strictly analytically the relationship between image and ground space and can be applied in two ways:

1-a) The relationship between image point coordinates (x, y) and ground point coordinates (X,Y) is expressed by polynomial functions assuming the image to earth projection as nearly orthographic due to the attitude of the satellite and does not consider the elevation of the earth points. The solution depends on the number and distribution of the control points and the degree of the polynomial.

2-a) The relationship between image space and ground space is expressed based on the perspective projection from a 3D to 2D space. In this case, the elevation of the ground points is taken into account, and thus is rigorous in each approach. The solution is based only on ground control points. An example of this approach is the Direct Linear Transformation (DLT) (Abdel-Aziz and Karara, 1971), which is an 11 parameter solution and requires a minimum of 6 points for the space resection.

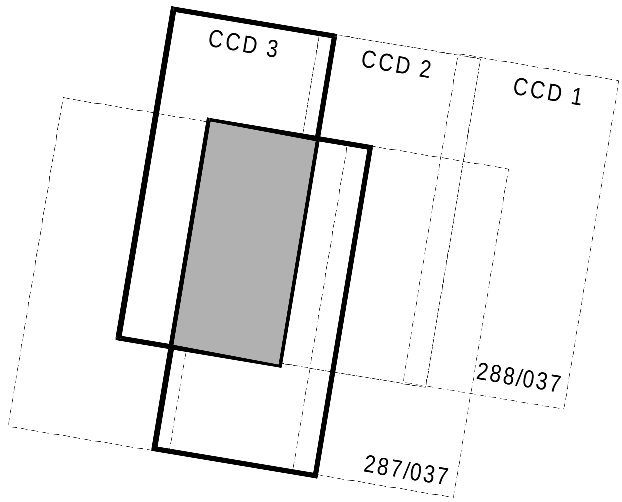

Figure 1: Overlap between the two IRS-1C PAN scens.

2) The physical type, which uses the collinearity equations to express the relationship between the 2D image points with their 3D corresponding ground points. It also accounts for the individual geometric elements affecting this relationship such as the interior and exterior orientation elements (that is, sensor geometry and calibration, orbital parameters), the rotation of the earth and other systematic error corrections.

The physical type of sensor modelling is a rigorous and more robust solution, requires fewer control points and the parameters involved are easier to understand. On the other hand, algebraic models are linear and have their merits when the sensor or its interior orientation are unknown and the accuracies achieved meet the requirements. For example (Edgardh, 1992), in the case of frame camera using 6 control points, the bundle solution was better in terms of precision and reliability that the DLT. However, with 13 control points both solutions are equivalent.

As new sensors become operational with the new high resolution satellites, their sensor modelling may still not be available immediately. For this reason, during this investigation the capabilities of the existing systems were tested using the Direct Linear Transformation model. The rigorous DLT approach has also been used for the geometric modelling of SPOT imagery (El-Manadili and

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Novak, 1996). The DLT transformation model between image space (x, y) and ground space (X, Y, Z) is expressed as:

$$x = \frac{P_1X + P_2Y + P_3Z + P_4}{P_9X + P_{10}Y + P_{11}Z + 1}$$

$$y = \frac{P_5X + P_6Y + P_7Z + P_8}{P_9X + P_{10}Y + P_{11}Z + 1}$$

where P_i are the parameters of the DLT transformation.

Using the Helava/Leica DPW 770 system, monoscopic measurements of 9 control points were performed on split screen mode for both array images. The ground coordinates of the control and check points were derived from aerotriangulated points, and from digital orthophotos and their DEM in monoscopic mode. Their distribution within the test area is shown in Fig. 2. Examples of the image points are illustrated in Figure 3, where the difference in season, sun illumination and poor radiometry of the left image are visible. The difficulties in cross identification of the points have been also reported by Jacobsen, 1997, where a two month delay in image acquisition resulted in a failure to measure 62% of the points.

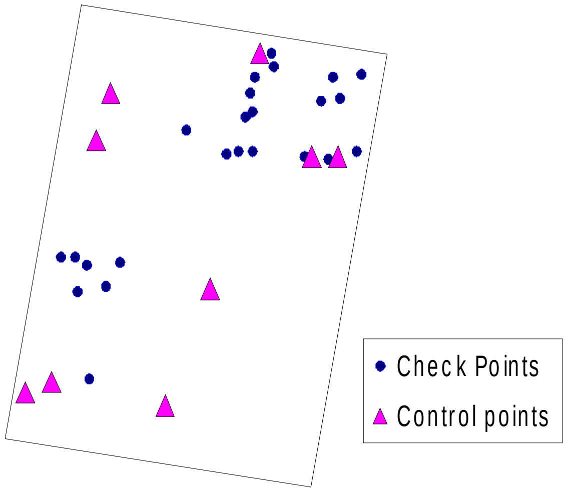

Figure 2: Distribution of control and check points within the test area.

Figure 3: Examples of images of ground points.

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The DLT solution was applied using the image measurements and the full ground coordinates of the points. The RMS errors of the image residuals were under 1 pixel for both images. Using the estimated DLT parameters to relate each image to the ground, the ground coordinates of 22 check points were measured in the virtual stereo-model. These stereoscopically determined values were compared with their photogrammetrically derived “true” ground values. Table 1 summarizes the results of the coordinate differences.

	DX(m)	DY(m)	DZ(m)
Bias	-2.8	5.7	19.9
Standard Deviation	6.0	6.4	29.8

Table 1: Ground errors at the stereoscopically measured check points.

While the horizontal accuracy is slightly over one pixel, the determination of the elevation is very weak due to the B/H ratio of about 0.087. The results can be further improved if the image pixels are corrected for systematic.errors.

5 CONCLUSIONS

Despite the fact that satellite imagery is almost an orthographic projection at nadir view due to its very high attitude, the stereoscopic 3D determination of topographic features can meet many mapping requirements. The upcoming high resolution satellites will be on lower orbits and will provide along track stereo coverage. Thus, stereo (and even multi-scene) determination of points is expected to increase. In addition, either the sensor geometry may not be available or the sensor model may not be fully developed for immediate use with the image data. In this investigation both the unknown sensor model and the stereo-point determination were addressed using the existing digital photogrammetric workstation at CTI with the rigorous Direct Linear Transformation for the orientation of the IRS-1C scenes. Initial results obtained with this approach showed that the planimetric accuracy of the stereo-compiled data is in the order of 1 pixel, while the vertical accuracy (about 30m with a very small B/H) depends on the stereoscopic acuity (existence or not of residual y-parallax) and, of course, on the base-to-height ratio. It is anticipated that the results obtained can be further improved if the image pixels are corrected for systematic errors caused by the across track off-nadir viewing and the rotation of the earth before the application of the DLT transformation. Work also continues towards the automatic extraction of control information required for the satellite imagery from digital orthophotos.

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