CARTOGRAPHIC POTENTIAL OF IRS-1C DATA PRODUCTS

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ABSTRACT Indian Remote Sensing Satellite IRS-1C launched in December 1995 carries onboard pushbroom linear CCD scanner cameras capable of providing high resolution imagery of Earth's surface . This raises the issue of usefulness of this data for topographic mapping purposes. This paper provides a theoretical assessment of cartographic potential of IRS-1C imagery and describes planned experiments to assess the cartographic potential of IRS-1C imagery with actual data.

The following Data Products planned for IRS-1C mission can be used for Cartographic applications:

1. Radiometrically corrected raw geometry Basic stereo Pair of PAN data.

2. Geocoded Data Products. These products are provided in 1:250,000 and 1:50,000 scales for LISS-3 and additionally 1:25,000 scale for PAN.

3. Merged Products. These products are expected to allow better visual interpretation capability for linear features of interest in Cartographic applications.

Early results from first set of IRS-1C imagery show that the theoretical expectations are met.

1.0 Introduction

Indian Remote Sensing Satellite IRS-1C launched in December 1995 carries onboard pushbroom linear CCD scanner cameras capable of providing high resolution imagery of Earth's surface . It is expected that updating of topographic maps will be one of the major Remote Sensing applications to receive boost from IRS-1C imagery. The issue of usefulness of IRS-1C data for topographic mapping purposes is discussed in this paper from two angles viz.

1. a theoretical assessment of cartographic potential of IRS-1C imagery and

2. early results with available IRS-1C imagery .

Based on both theoretical possibilities and first cut assessment conclusions related to cartographic potential of IRS-1C imagery are drawn.

2.0 IRS-1C specifications related to Terrain Mapping

IRS-1C carries three cameras viz. multispectral LISS-3 camera, high resolution steerable Panchromatic Camera and Wide Field Sensor. Of these the first two provide such resolutions as to make them probable candidates for cartographic applications. Basic characteristics of these two sensors are as given in table 1.

The Panchromatic camera can be steered upto +/- 26 degrees. Thus by acquiring imagery over the same ground area from multiple orbits a stereoscopic coverage can be obtained. Consequently by applying appropriate models a terrain height profile can be determined. The IRS-1C mission is thus capable of providing both planimetric and elevation information.

Table 1

	PAN	LISS 3 VNIR	LISS 3 SWIR
Spatial Resolution (m)	5.8	23.6	70.8
Swath (km)	70	142	148
Spectral Bands (micron)	0.5-0.6	.52-.57 .62-.68 .77-.86	1.55-1.70
No. of gray levels	64	128	128

The following Data Products planned for IRS-1C mission can be used for Cartographic applications:

1. Radiometrically corrected raw geometry Basic stereo Pair of PAN data. This product is useful for stereoscopic viewing and terrain elevation determination.

2. Geocoded Data Products. These products are produced by mosaicing a number of data sets, if necessary, to give a toposheet compatible product in terms of format, resolution and layout. For IRS-1C these products are provided in 1:250,000 and 1:50,000 scales for LISS-3 and additionally 1:25,000 scale for PAN.

3. Merged Products prepared by artificially merging the contents of registered high resolution PAN and low resolution multispectral LISS-3 data to produce high resolution multispectral data. These products are expected to allow better visual interpretation capability for linear features of interest in Cartographic applications.

3.0 Issues in Terrain Mapping using Spaceborne Stereo Imagery

The information content of a topographical map compiled by photogrammetric methods is provided by the ground resolution of the images expressed in m/line pair for camera systems and m/pixel for electro optical systems. The average resolution of an aerial photographic imaging system which is a combined influence of lens, film and the forword motion can be taken as ranging from 40 lp/mm for systems not using forward motion compensation to 140 lp /mm for modern system using forward motion compensation (FMC). The resolution in m/lp is given by :

$$R_{m/lp} = \frac{\text{Photo scale}/1000}{R_{lp/mm}}$$

The values of $R_{m/lp}$ for aerial photographs at 1:50,000 scale photography is 1.25 and 0.357 for systems without FMC and with FMC respectively.

Taking 1.25m/lp as the resolution of aerial photograph and if the content of the image are to be as much as that of a 1:50,000 aerial photograph then the pixel size of the satellite image should be 0.5m as given by the Kell's factor of $2^{3/2}$ as pixel given by :

$$R_{m/lp} = 2^{3/2} * R_{m/pixel}$$

Even though the information content or features that can be extracted from any given imagery is determined by photographic resolution and scale or more directly by the resolved distance on the ground it is difficult to establish a linear relationship between map scale and resolution required as some features like roads , rail, canals etc. have to be depicted on a map irrespective of the scale. The smallest feature that can be depicted on a map is assumed to have a least dimension of 0.25 mm. In order that an object be identifiable on the imagery in medium contrast conditions, it must be imaged by at least 5 resolution elements. It follows then that resolution required for imagery can be estimated as :-

$$\text{Ground resolution} = 0.2 \times 0.25\ \text{mm} \times \text{map scale number}$$

$$= 5 \times 10^{-5} \times \text{map scale number}$$

For 1:50,000 scale map product the required ground resolution = 2.5 m.

However for detection of features in good radiometric contrast condition it is sufficient to image the object in 2-3 resolution elements. In such cases a pixel resolution of 5-6 m is sufficient. Thus IRS-1C resolution is sufficient for identification of features required for 1: 50,000 scale mapping.

Pixel size from Photogrammetric criteria The measurement of reliable terrain height from digital stereo data recorded by tilting camera are heavily influenced by geometric principles involving B/H ratio , sensor attitude , pixel size and correlation accuracy . The photogrammetric approach assumes sufficient transformation capability for bringing corresponding images in approximate congruence. The error p_x expected in image parallax removal when employing digital correlation technique is given by

$$p_x < K * (\text{pixel size}),$$

where values $0.2 < K < 1.5$ shows the degree of correlation.

The parallax error may be converted into the height error (h) through the use of base to height ratio inherent in the parallax equation, when the Y-parallax is 0.

$$h = \frac{H}{f} \cdot \frac{H \cdot \sigma p_x}{B}$$

and analogous to digital sensor

$$\Delta H = \frac{\Delta P . SF}{2 \tan\alpha}$$

where

σ px or Δ p is the total error in parallax measurement in the image plane,

SF is the scale factor = H/f,

f is the focal length,

H is the flying height of sensor above the average terrain elevation,

B is the base distance between exposure stations,

α is the half angle between intersecting rays, referenced to local vertical ($H/B = 1/2 * \tan \alpha$).

Scale factor (H/F) multiplied by parallax (σp_x) in the image plane yields the pixel size on the ground:

$$\frac{H}{F} * \sigma p = \sigma Px = K * (\text{Pixel size})(\text{m on ground})$$

Therefore, Pixel size = $1/K * B/H * \sigma h$

The relationship between the closest relative contour interval meeting the 90 percent criteria and the precision of instruments (σ) for relative spot heights

$$C.I. = 3.3 \sigma h$$

or

$$s h = 0.3 * C.I.$$

Pixel size $Ps = 1/K * B/H * 0.3 * C.I.$

Assuming B/H =0.6 and the desired contour interval for 1:50,000 mapping is 20 m we get

$$Ps = 0.83 \times 0.6 \times 20 \text{ m}$$

= 10 m for 1:50,000 scale maps.

The accuracy of spot heights referenced to a recognised datum is largely determined by factors which create geometric displacements in the sensor data and produce correlation or measurement errors in the along track direction. These displacements or errors (ΔX) may be expressed in fractions of pixel at the ground or in arc seconds.

From a comparison of the mapping standards and the standards of IRS-1C Data Products it can be concluded that

- It is possible to obtain point height and contour information compatible with 1:50,000 and 1:25,000 scale topo maps from IRS-1C PAN stereo pairs.

-Most of the spatial land cover information required for updating of topographic maps at 1:50,000 scale can be obtained from IRS-1C PAN and LISS-3 data. Certain features may require field verification. At 1:25,000 scale a larger component of field verification and complementation may be required.

4.0 Description of a software system for Terrain Mapping Using IRS-1C Imagery

The software system developed at Space Applications Centre (ISRO) for terrain mapping using IRS-1C imagery was used for analysis of IRS-1C capabilities. This system consists of the following basic elements:

(i) Ground Control Point (GCP) tools
(ii) Digital Elevation Model (DEM) generation and editing
(iii) Orthoimage generation
(iv) Quality Evaluation and
(v) Mapping using GIS

All these are additionally supported by image processing and graphics libraries. The hardware consists of an Indigo-2 R-4000 based softcopy photogrammetry workstation with stereo display monitor, crystal eye glasses for stereo view, a scanner and a plotter. The details of the software system are explained in the subsequent sections.

4.1 GCP Generation

Basically this consists of a scanner system, wherein the desired maps are scanned in an appropriate resolution. The digital image is properly thresholded, so that all the linear features are clearly identifiable. The scanned image is then transferred to the main system for GCP identification along with the stereo pair images.
Co-ordinates of a point in terms of latitude and longitude is obtained by a projective transformation on the surrounding known grid points of the map. The height of the point is interpolated from the nearest elevation contour lines. The image co-ordinates of the control points are identified parallelly on the display device.

4.2 DEM generation and editing

A DEM is regarded as a numerical description of the surface of an object on measured or derived co-ordinates of numerous scattered points. With the advent of digital phtogrammetry workstations with high computation power, DEMs can be derived by purely digital approach, from the satellite stereo pairs. The digital mode of DEM generation from a satellite stereo pair consists of the following steps

(i) Automatic identification of conjugate points
(ii) Determination of satellite orientation using a model based on orbit and attitude parameters
(iii) Three dimensional co-ordinate determination by the method of space intersection
(iv) Bundle Adjustment
(v) Height interpolation to compute heights at regularly spaced grid points and
(vi) Point editing to remove the spurious height points and reinterpolation

4.3 Orthoimage Generation

Basically a precise ground to image relation along with the DEM and the raw data are the requirements to generate an Orthoimage. This is a geocoded product corrected for all the geometric errors including terrain relief and the camera tilt, which can be directly used for topographic mapping. The Orthoimage can directly go into a GIS. For an output grid of latitude and longitude and height (obtained from DEM) time and pixel of the input image can be calculated by an iterative way using equations (2),(3) using the updated orientation of the image. And the gray value for this point is generated by resampling the input image. The DEM can be the one derived from the same stereo pair or it is digitised/derived from map. In case of map DEM GCPs are also required additionally, to get mapping between ground and image.

4.4 Quality Evaluation

One of the most critical component of the mapping is the accuracy of the product used in terms of its tickmarks and the internal distortion. The system contains accuracy checks at every process level. i.e. the model accuracy on GCPs and on check points, is given immediately after space resection and intersection. In addtion to this the Orthoimage evaluation with respect to its tickmarks is done on checkpoints within the system. The checkpoints are identified on the Orthoimage manually, and their estimated positions w.r.t the tickmarks are compared with the actual values. The RMS of these errors are quoted as the location accuracy and the standard deviation represents the internal distortion. Apart from this quantitative approach, Orthoimage is evaluated qualitatively by overlaying map features either digitally or photographically. The DEM can be qualitatively evaluated by (i) draping the Orthoimage on the derived DEM and comparing this with the draping of Orthoimage over map derived DEM and (ii) comparing the contours obtained from both image derived DEM and map derived DEM.

4.5 Mapping using GIS

For better visual interpretation of linear features in conjunction with their back ground texture, merging of pan data with that of LISS-3 is found helpful.

Terrain mapping needs derivation of cultural features, elevation changes and thematic information from the derived DEM and Orthoimage. This task can be better achieved by using a GIS. Basic tools required for terrain mapping are slopes, surface area, volume, line of sight coverage, draping, perspective view etc., can be efficiently derived/obtained in the GIS environment.

5.0 Early results from IRS-1C Data Evaluation for Cartographic purposes

The first sets of cloud free stereo pairs from IRS-1C Panchromatic data were taken for generating DEM and Orthoimage. The data specifications are given in Table-2. The stereo pairs were generated at National Remote Sensing Agency (NRSA), Hyderabad,. using an operational software developed by SAC. The data has undergone only radiometric corrections, no geometric corrections are applied. Three mapsheet areas (47M/13/SE, 56A/1/NW and 53K/13/SW) are considered. Since the overlap between stereo images is only 60%, full map sheet area is not available for any of these map sheets. Hence an area of 7.5" X 7.5" is selected nearer to the above map sheets (80% of total map sheet area is covered), through corner co-ordinates. Ground control points are selected from each stereo pair, and they are digitised from available 1: 25,000 and 1: 50,000 scale mapsheets. Out of these four/five are used as control points and remaining five/six are used as check points. Table-3 gives the RMS values of accuracy obtained from the model on check points. This clearly shows, the model accuracy depends on the input GCP accuracy. GCPs collected from 1: 25,000 scale map resulted a better DEM accuracy than the GCPs collected from 1: 50,000 scale, as expected.

DEM and Orthoimages are generated for the map sheet areas using the software system described in the previous section and detailed evaluation is carried out. Results are shown in Table 4. This error is a result of all the errors namely, DEM error, interpolation error and model error.

A qualitative evaluation of Orthoimage for set 1 is done by

(a) overlaying all linear features of map, with the help of a tracing at 1:25000 scale, which almost sits onto the Orthoimage with the above accuracy. Further, Orthoimage showed the recent information like new roads/constructions and other elevation changes like quarrying etc., which can be used for updating.

(b) Comparing the draping of (i) the Orthoimage over derived DEM from the stereo pair and (ii) Orthoimage over map derived DEM. Draping from map derived DEM showed blocky effect/discontinuties, because of lack of continuous information of elevation, whereas the other draping showed smooth variation of the terrain, since it has the continuous information of terrain elevations. The map DEM is generated by digitising the 10m contours from the 25000 scale map.

(c) Comparison of elevation contours, showed a good match of peaks and valleys of elevation, from both DEMs derived from image and map.

6.0 Conclusions and Recommendations

The early results described in section 5.0 can be categorised in three classes:

1. The reconstruction of terrain profile. This is related to the precision of height determination for various terrain conditions viz. highly undulating, moderately undulating and flat. It is shown that in case of moderately undulating terrain conditions with moderate contrast the terrain model can be automatically reconstructed to meet requirements of 1:25,000 scale mapping. The experiments described in 5.0 were conducted with stereo pairs acquired with approx. 0.5 base to height ratio. It can be concluded that for regions having moderate radiometric contrast the elevation information derived from IRS-1C imagery is sufficient for 1:25,000 scale mapping. For other types of terrain this conclusion comes from the capability of achieving any base to height ratio upto 1.1.

It has been seen that the breaklines and breakpoints can be identified with high confidence in manual mode. Identification of breaklines and breakpoints in automatic mode is a subject of further research.

2. Availability of standard map features in imagery. It is concluded that the linear features available in the 1:50,000 and 1:25,000 scale topographic maps could be reidentified an registered on the corresponding imagery. This wa achieved in part due to good Orthoimage quality.

3. Identification of new features for mappin at 1:50,000 and 1:25,000 scale. A large number linear features having similar texture and contras as classified features from map were available i the Panchromatic imagery. These could be easi transferred to the base map. A positive identificatio of these features into various classes could not b carried out due to mixed spectral response. Th situation can be rectified by registerin panchromatic high resolution imagery with mediu resolution multispectral imagery. This as well a field verification of alignments and identification planned to be carried out in near future.

It is known that the day to day capability for cartographic applications may be different from the theoretical assessment due to factors like atmospheric conditions, mosaicing related problems etc. In order to get realistic capabilities of IRS-1C for Cartographic applications it is planned to conduct map updating exercise over a test site undergoing fast development. This will be followed by field verification and assessment of % of various map features at 1:50,000 and 1:25,000 scale available from given set of imagery.

Table - 2 : Details of Input Data Sets used for testing

097/058	D7	15/01/96	-14.5
097/058	C8	19/01/96	+12.8
097/058	D4	15/01/96	-14.5
097/058	C5	19/01/96	+12.8
097/050	B9	07/02/96	+18.88
097/050	B7	13/02/96	-18.03

Table - 3

Model accuracy (in meters)on GCPs and Check points

	Set 1*	Set 2**	Set 3**
No. of GCPs	5	4	5
No. of check points	5	6	14
GCP Easting	1.2	3.0	9.8
GCP Northing	3.0	4.5	11.3
GCP Elevation	8.5	6.7	9.9
CPS Easting	10.5	18.3	27.1
CPS Northing	27.5	36.3	32.4
CPS Elevation	13.6	28.9	26.6

* Points are collected from 1:25000 scale toposheets of SOI.

** Points are collected from 1:50000 scale SOI toposheets

Table 4: Results of evaluation of Orthoimage

	Map No	Error in Easting	Error in Northing
1.	47M/13/SE	14 m	20 m
2.	56A/01/NW	24 m	36 m
3.	53K/13/SW	30 m	24 m

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