An Approach for Sub-pixel Level Registration for Multispectral Data – Special Emphasis on the High Resolution Data from IRS P6 LISS 4 Sensor

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Abstract

The IRS P6 satellite to be launched during the first quarter of 2003 is a continuation of IRS 1C/1D satellites with some additional features. Being a continuation mission, none of the features of IRS 1C/1D have been dropped, but some enhancements have been made. All the bands of LISS 3 are of 7 bits. In IRS 1C/1D SWIR band of LISS 3 sensor had a spatial resolution of 70.5 m, as compared to 23.5 m in the other bands. However, in IRS P6, all the bands of LISS 3 sensor have a spatial resolution of 23.5 m. The Panchromatic camera of IRS 1C/1D has been replaced by a multispectral LISS 4 sensor, which has got the same spatial resolution of 5.8 m in the three spectral bands of green, red and near infrared. There will be option of acquiring the data in either the multispecral mode, in which case the swath will be 23 km, or in single band mode, when the swath will be 70 km . Unlike IRS 1C/1D, when the 70 km product called for mosaicking data from three heads, in this case, no such mosaicking will be needed. The data will be of 7 bits. Besides these two payloads, there will be one more payload the AWiFS, in four bands and of 10 bit data. The resolution of this payload will be about 60 m. There will be two cameras in this payload, AWiFS A and AWiFS B, each having a swath of about 350 km. The mosaic of data from these two sensors will give a swath of about 700 km, corresponding to that of WiFS data from IRS 1C/1D. Thus, IRS P6 data will be available over a wide range of spatial resolutions from about 6 m multispectral to about 60 m multispectral data. The LISS 4 payload has besides tilting capability, and hence we can expect stereo coverage in multispectral mode. All these payload configurations suggest that the data from this new satellite will be of immense use for all kinds of applications from cartography to agricultural output estimation.

LISS 4 payload has a staggered payload configuration – the bands are not registered onboard. Besides, in each of the bands, the odd and even pixels are staggered. These need to be corrected for before the data is useful. The staggered arrangement of the different bands in the payload calls for a new approach of ground based registration of the data. The usefulness of the high resolution data will be enhanced only if registration is achieved to sub-pixel level. This will be done at the Data Products level and this paper addresses this issue.

Overview

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1. Introduction

Band to band registration is a major problem for any satellite data. This problem is accentuated and is more critical for high-resolution data. LISS-4 camera of IRS-P6 operates in three different spectral bands and has a spatial resolution of about five metres. The spectral band details are given in Table 1. There are three arrays of detectors, corresponding to the three spectral bands. These three arrays are physically separated in the camera – the distance between the two extreme arrays corresponding to a ground distance equivalent of 2.1 seconds. The arrays have a common optics. Besides, in each of the arrays, the odd and even detectors are staggered by about five lines in the focal plane.

Table-1
Spectral band information of IRS P6 LISS 4

Band-2	0.52 μ - 0.59 μ	GREEN
Band-3	0.62 μ - 0.68 μ	RED
Band-4	0.77 μ - 0.86 μ	NIR

Let us consider any one line imaged by a particular band. All the odd pixels of this line will correspond to one line on the ground. The even pixels of the same ground line will be imaged later. However, by the time the even pixels are imaged, the earth would have rotated, albeit by a small amount. Thus, a normal imaging mode will give rise to gaps at the even pixel locations. This gap in one line of image can be removed if the relative motion of the earth and the satellite during the time interval between the odd and even pixel imaging is reduced to zero. This is proposed to be done by giving a yaw steering, which compensates the earth rotation effect. The yaw steering is a continuous process, and depends on the geodetic position of the sub-satellite point.

In view of the geometric configuration mentioned above, a line on the ground will be imaged by the three detectors (bands) at different times. The earth rotation compensation due to the continuous yaw steering will render the different bands also to be registered. However, any error in the attitude determination, or the attitude rate error being beyond specification, will lead to misregistration among the different bands. Since this misregistration will depend on the attitude rate, this parameter might even vary within one scene. In this note, a method of finding the registration parameters between the different bands of a scene, particularly with reference to IRS P6, is presented. The method developed in this note has been tested on an IKONOS False Colour Composite (FCC) image shown in Fig 1.

2. Methodology

Digital image registration is done using some similarity measures between two images. The similarity measure gives a quantitative measure of the match between a point in the reference image with a point in the target image. Generally, area correlation or sum of squares of differences (SSD) is the popular similarity measures used. If the points P and Q in the two images are match points, then this similarity measure attains a local extremum. In case of area correlation the value is a maximum, while in the case of SSD, the value is a minimum. The similarity measure computation is done using a window of size WxW in the target image and a search area of size SxS in the reference image. The window area is slided in the search area, and for each location of the window area, the similarity measure between the window area and the corresponding area in the search area is found out. This way, a total of $(S-W+1)^2$ similarity measures are calculated. Out of these similarity measures, the point at which the measure is an extremum is the match point. Similarity measure will give correct match points if the spectral bands of the two images are correlated, so that the spectral response for any feature is similar in the two bands.

Since we are interested in finding the misregistration parameters in the different bands, the method of similarity measure will not be successful. Hence, before initiating any process, we have to find the *Points of Interest* (POI), which are expected to give similar response in any of the bands. In our approach, we have considered the edges as POI. An edge image is formed corresponding to each of the band images before the similarity measure technique is adopted.

As mentioned earlier, the misregistration between the different bands might not be a single value, and hence, it is necessary to find out this parameter at various locations. To do this, the given band images are divided into small segment images as shown in Fig 2. The misregistration parameters between corresponding small segment images will be found out. In view of the continuous yaw steering, the corresponding segments of the different bands will be registered at a gross level.

Let us consider any one pair of corresponding segments in the two band images. To find the POIs, an edge detection filter is applied. In our method, we have used the simple variance filter. This yields the edges corresponding to the two segments. In general, these edges have a thickness of about three to five pixels, shown in Fig 3. The intermediate pixels in these thick edges are removed to get the final POIs - Fig 4. Since any image will contain a very large number of edges, finding the similarity measure at each of these POIs is very time consuming. Hence, similarity measure calculation is done only at 100 POIs selected at random. In this work, we have used area correlation as the similarity measure.

At each of these 100 POIs, the area correlation between the two bands is calculated, by using suitable window and search areas centred at the POI. As mentioned earlier, the window area is slided across the search area and the point at which the correlation value is maximum is the match point. This match point is good up to integer level. However, for accurate colour image composition, it is necessary to get registration up to sub-pixel accuracy.

With the integer level match point as reference, sub-pixel level registration can be accomplished in the following ways:

1. Surface fitting
2. Zoom correlation

2.1 Surface fitting: In this case, around the point of integer level match, a correlation surface is fitted. This surface gives the functional dependence of the correlation values on pixel and scanline, which is valid even for fractional values. The point at which this surface attains a maximum gives the location of the exact match. The surface fitting can be effected in the following ways:

a) Least Square correlation Surface Fitting

The correlation surface can be described by

$$\mathrm{Surf}(x,y) = a_0 + a_1x + a_2y + a_3xy + a_4x^2 + a_5y^2 + a_6x^2y + a_7xy^2 + a_8x^3 + a_9y^3 + a_{10}xy^3 + a_{11}x^2y^2 + a_{12}x^3y + a_{13}x^4 + a_{14}y^4$$

We shall consider only surface of degree 4, and hence this polynomial will have 15 coefficients. However, a square patch of 5 x 5 correlation values around the integer match point, will give 25 data points. Hence, the surface fitting is done using the method of least squares.

b) Correlation surface fitting using thin plate splines

In this case, the surface is represented by

$$\mathrm{Surf}(x,y) = a_0 + a_1x + a_2y + \Sigma F_i r_i^2 \log(r_i^2)$$

where

$$r_i^2 = (x-x_i)^2 + (y-y_i)^2$$

$$\Sigma F_i = 0$$

$$\Sigma x_i F_i = 0 \text{ and } \Sigma y_i F_i = 0$$

The advantage of thin plate spline method is that the surface passes through all the tie points unlike the least square surface fitting method.

2.2 Zoom correlation: In this method, small patches in the reference and target segments around the integer level match points are zoomed. These zoomed images are then matched using the area correlation technique described above. The integer level match of these zoomed images will correspond to fractional level match of the original segments. The accuracy of the match depends upon the zoom factor.

The zooming can be accomplished in two ways – using bilinear interpolation or by using FFT. In the former case, the zooming is inferior compared to the FFT method. However, in this case, the zoom factor can be any arbitrary value, and hence we can achieve any level of fractional accuracy of registration. In the case of FFT zooming, the zoom factor should always be a power of 2, and hence the accuracy of sub-pixel level registration will be negative powers of 2. Besides, the computation is more in the FFT method.

Using any of the methods mentioned above, we can obtain the misregistration parameters at each of the POIs in the segments considered. The misregistration parameters at the different POIs will in general not be same. However, since the segment is small, the spectral variation in the two segments will not be abrupt, and hence there cannot be drastic difference in the misregistration parameters within one segment. Hence, out of these 100 misregistrtaion parameters, we calculate only one for this segment by filtering these values. The filtering is done on the basis of the modal value of these parameters. The method when applied to different segments will give misregistration parameters corresponding to those segments.

Using these misregistration parameters obtained at well-distributed segments, the two images can be registered by using a warping polynomial (Anon., 2000).

3. Results and discussion

Of all the methods mentioned above, we have selected the area-correlation method with least square surface fitting for sub-pixel level registration.

The original IKONOS images are perfectly registered and our method also gives the same result. To test the efficacy of our method, we have shifted the NIR band with respect to the other two bands. The shift is not just an offset, but varying over the entire image. This shift between the two bands was also detected by our method. This is shown in Table-2. The FCC image of the IKONOS data set is given in Fig 1. Fig 5 shows the full resolution image from a portion where there is no misregistration. The full resolution image of the portion where misregistration was deliberately introduced is shown in Fig 6.

Since the images are captured line by line, there is a possibility of a yaw between the arrays, and hence on the ground. This case has also been handled by this method, so long as the inter array yaw is less than 3°.

The method gives satisfactory results when tested on IRS-1D LISS-3 data as well as the CCD data of INSAT-2E. Hence, the method is quite rugged and proven to work over a range of resolutions – from about 5 m to about 1 km.

Table-2 Misregistration parameters at the different segments of IKONOS data set

RED-NIR					GREEN-RED				
SegNo	MisRegPix		MisRegScan		SegNo	MisRegPix		MisRegScan	
	Val	Std	Val	Std		Val	Std	Val	Std
00_00	-0.04	0.06	0.0301	0.06	00_00	-0.01	0.04	-0.01	0.05
00_01	-0.018	0.06	0.014	0.07	01_00	-0.2	0.05	-0.002	0.05
03_01	-2.4	0.0	0.4	0.15	03_01	-0.01	0.06	-0.004	0.06
04_03	0.0	0.0	-0.03	0.04	04_03	-0.04	0.07	0.00	0.00

Fig 1 IKONOS FCC test data

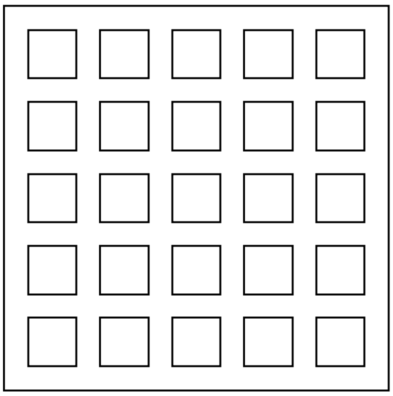

Fig 2 The band scene divided Into small segments

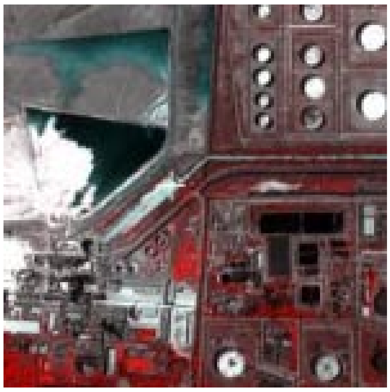

Fig 5 Full resolution segment of a portion where there is no misregistration

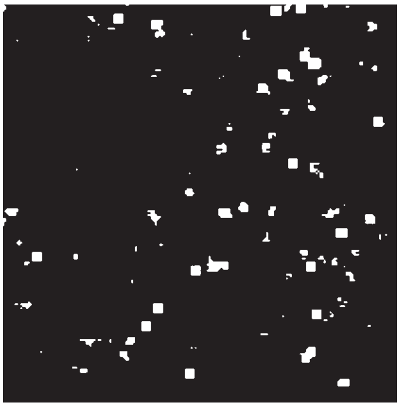

Fig 3 Edges detected by variance filter

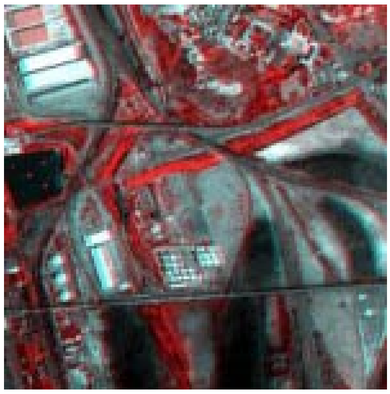

Fig 6 Full resolution segment of a portion where misregistration was deliberately introduced

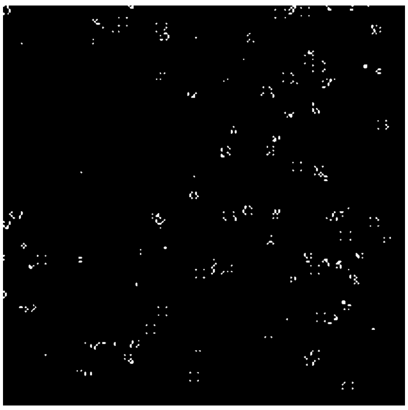

Fig 4 Edges of Fig 3 with in between pixels removed

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5. Reference

[1] Anon., 2000, Geocoded Product generation of India and its environs from INSAT-2E CCD data, SAC/SIIPA/SIPG/DPSD/TN14/May 2000.