Automatic Image Registration and Color Merging for SPOT5 Imagery

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Abstract- An automatic process for registering the panchromatic and multispectral SPOT5 imagery is presented. The registration process make used of edges and corner information to select informative image patches in the PAN image. A hierarchical local matching method is then used to find the best matched image patches in the XS image. The coordinates of the matched image patches are fitted to an affine transformation model. The merged high resolution color imagery is obtained by multiplying each spectral bands with a sharpening factor computed from the intensity values of the panchromatic image and the corresponding pixel values of the multispectral images.

I. INTRODUCTION

The SPOT5 satellite carries two High Resolution Geometric instruments (HRG) enabling it to map large area of the Earth (60km x 60km) in very high resolution of 2.5 meters to 5 meters in panchromatic (PAN) mode and 10 meters in multispectral (XS) mode. The objective of color merging is to produce a high resolution (2.5m or 5m) color/multispectral image by combining the high resolution (2.5m or 5m) panchromatic image with the lower resolution (10m) multispectral image. In this paper, we present an automatic process for registering the panchromatic and multispectral SPOT5 images and then merging the registered images to obtain a high resolution color image.

II. RELIEF CORRECTION

Each HRG instrument in SPOT5 images the ground with the panchromatic band pointing slightly backwards (-0.529°) and the multispectral bands slightly forward (+0.529°). This results in a slight relief displacement in opposite directions for the panchromatic and multispectral images. We need to correct for this relief displacement before registering the images with an affine transformation. Since the angle subtended is small, a coarse orthorectification of the images with the GLOBE 1km DEM of the world will be sufficient to correct for this relief displacement. No GCP needs to be used as the 50m rms positional accuracy of SPOT5 images is accurate enough that no significant degradation to the coarse orthorectification is introduced.

III. AUTOMATIC IMAGE MATCHING

A. Selection of Image Patches

After coarse orthorectification of both images, the next step is to find corresponding image points for registration. To do this automatically, we need to select and match image features with high information content. Our approach is to select image patches with edges and corners. We used Canny[1] filter to locate the edges in the image and then used Harris[3] corner detector to detect corners from the edges detected (in order to reduce unnecessary corners and to increase processing speed).

There are a few processing steps in the detailed Canny[1] detector: Gaussian smoothing, gradient computation, non-maximal suppression and hysteresis. We used a 11×11 Gaussian window with a standard deviation σ of 2.0 for the Guassian smoothing. A 3×3 Sobel filter is then used to derive the edge strength, i.e. the gradient of image intensity. In performing hysteresis, pixels with edge strength greater than 98.5 percent of all strength or any connected pixel with strength greater than 50 percent are marked as edge pixels. In Harris[3] corner detection, a 5×5 Gaussian window with a standard deviation σ of 1.0 is used as the gradient weight, and 0.04 is chosen as the constant value in the corner/edge response function.

The edges and corners detection are applied to the PAN image only. Image patches that contain one or more corner points are used as candidates to select the corresponding image patches in the XS image.

B. Hierarchical local matching

After corner detection, a hierarchical local matching approach is implemented to match the image patches. The PAN and XS images are scaled by various factors to create a few hierarchical layers, with the highest resolution layer having a pixel size equal to that of the PAN image. The matching of two patches at various layers is computed by maximising the normalized cross correlation

$$C(A,B) = \frac{\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}((A_{ij}-\overline{A})\times(B_{ij}-\overline{B}))}{\sqrt{\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}(A_{ij}-\overline{A})^2 \times \sum_{i=0}^{N-1}\sum_{j=0}^{N-1}(B_{ij}-\overline{B})^2}}$$

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where C(A, B) is the normalized cross correlation between the scaled PAN and XS image patches, N is window size of image patch, A_{ij} and B_{ij} are individual pixel values in the PAN and XS patches, respectively, $\overline{A}$ and $\overline{B}$ are average pixel values in the PAN and XS patches, respectively.

Image matching starts with the lowest resolution layer. The panchromatic patch that contains one or more detected corners is used as the reference. By shifting the multispectral patch around its initial position, the location where the normalised cross correlation of the two image patches is highest within a range of shifting is selected as the matched position. For each higher resolution layer, the matched position derived from the previous lower resolution layer is used as the initial position and matching is performed to improved the accuracy of the matched position. A threshold of 0.85 for the cross correlation coefficient of the highest resolution layer has been set to reject those image patches with poor matching.

C. *Affine Transformation*

An affine transformation model that incorporates shifting, rotation, scaling and shearing between two images is then used to fit the centre coordinates of the matched image patches. The affine model is represented by the matrix equation

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} a_1 & a_2 \\ b_1 & b_2 \end{bmatrix} \cdot \begin{bmatrix} x' \\ y' \end{bmatrix} + \begin{bmatrix} a_3 \\ b_3 \end{bmatrix}$$

where (x, y) and (x', y') are respectively the centre coordinates of the panchromatic and multispectral image patches, a_1, a_2, a_3 and b_1, b_2, b_3 are parameters to be derived.

By matching 8 to 12 pairs of image patches, a residue of less than one pixel size of the panchromatic image is achieved.

IV. COLOR MERGING

Merging of the high resolution color imagery is performed by multiplying each spectral band with a sharpening factor computed from the intensity values of the panchromatic image and the corresponding pixels of the multispectral images. The detailed merging method is described by the equation

$$I_{i_{merge}} = \frac{I_{pan}}{I_{xs}} \cdot I_{i_{xs}}$$

where i is the band index of SPOT5 imagery, I_{pan} and I_{xs} are intensity of panchromatic and multispectral imagery, respectively, $I_{i_{xs}}$ and $I_{i_{merge}}$ are grey value of each band in multispectral and merged imagery, respectively. The factor (I_{pan} / I_{xs}) is referred to as the sharpening factor.

Since the spectral range of the PAN image overlaps only the RED and GREEN bands of the XS image, we compute the $I_{i_{xs}}$ by taking averaging of pixel values of only the RED and GREEN bands. The non-overlapping bands (NIR band and SWIR band) can either be sharpened with the same sharpening factor or merely resampled to the resolution of the panchromatic imagery. The pseudo-natural colour SPOT 5 imagery can also be merged with the panchromatic imagery in the same way.

V. TEST IMAGERY AND RESULTS

To demonstrate the method, a pair of 2.5m PAN and 10m XS SPOT 5 images taken from the same instrument were selected. Fig, 1 and fig 2 show the coarse orthorectified PAN and XS images respectively. A part of the full resolution images are shown in fig. 3 and fig. 4. The edges of PAN imagery detected by Canny detector are shown in fig. 5 in grey colour, while the corners detected by Harris corner detector are shown in white colour. The total residual after matching and fitting to the affine transformation model is 0.8 PAN pixel. The final merged 2.5m/pixel pseudo-natural color imagery is show in fig. 6 in overview and fig. 7 in full resolution.

VI. CONCLUSION

An automatic image registration method based on feature information and hierarchical local image matching is described. The affine transformation model used is able to register the coarse orthorectified images to an accuracy of less than one PAN pixel. After registration, the merged high resolution multispectral image is generated. The method has been tested on a few SPOT5 PAN and XS image pairs of various incidence angles. The results so far are consistent.

We expect the automatic matching method to have problems in imagery where there are too much clouds or water. In such situations, the program may not be able to find enough image patches with good edges and corners content. An option has been provided to manually provide the corresponding image registration points and these need only be approximately located. The hierarchical image matching, affine model fitting and colour merging can still be applied in the same way.

REFERENCE

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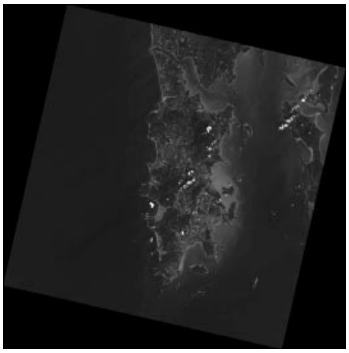

Figure 1. Overview of SPOT5 panchromatic image.

Figure 3. Part of SPOT5 panchromatic image in full resolution 2.5m/pixel.

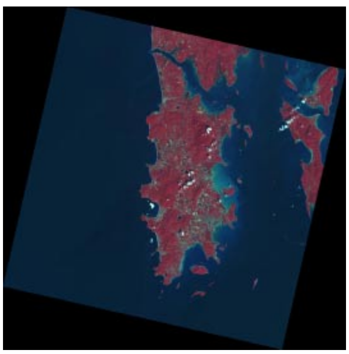

Figure 2. Overview of SPOT5 multispectral image.

Figure 4. Part of SPOT5 multispectral image in full resolution 10m/pixel.

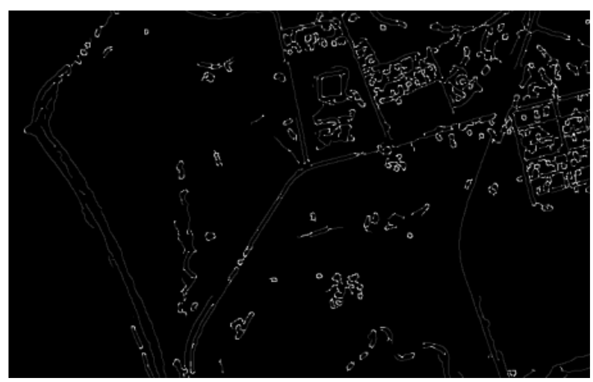

Figure 5. The edges and corners of PAN imagery are shown in grey and white color, respectively

Figure 6. Overview of merged pseudo-natural color image.

Figure 7. Part of merged pseudo-natural color image in full resolution 2.5m/pixel.