AUTOMATIC REGISTRATION OF CCD IMAGES AND
INFRARED IMAGES OF HJ-1 BASED ON IN Variant
FEATURE AND MUTUAL-INFORMATION

Ni Xi-liang $^{1,2}$, Ding Lin $^1$, Jiang Tao $^2$, Hu Shun-shi$^3$

1) (Institute of Remote Sensing Applications, Chinese Academy of Sciences, Beijing 100101, China) 2) (Shan Dong University of Science and Technology, Qingdao, 26651, China) 3) (Hunan Normal University, Changsha, 410006, China)

E-mail: kaiven20080808@126.com

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ABSTRACT: With the great progress of obtaining multi-source remote sensing image from different sensors with different resolutions, a single kind of remote sensing image could not meet the requirement of applications in many fields and it needs various kinds of remote sensing images usually to be used together. So, the algorithm of registering multi-source remote sensing images has become a hot issue in today’s research. Environmental satellite-1 (HJ-1) includes a B Satellite—an optical satellite, providing information for the changing trends of the disasters and ecological environment within visible bands (30m) and infrared spectral bands (150m and 300m). The great differences in gray and resolution resulting from different imaging mechanism of IR and visible images make the fact that still no one method could effectively realize higher accurate registration for both IR and visible images. Through analyzing various remote sensing image registration algorithms, this paper proposes a registration approach based on SIFT and Mutual-Information (MI) according to the imaging characteristics of HJ-1 IR and visible images. First, the improved SIFT algorithm realizes the uniform distribution of feature points, and also speeds up the extraction rate of SIFT feature points. Then, the feature points are matched by using the MI method, which greatly improves the matching accuracy. Finally, some mismatched points are eliminated by using consistency checking, which further improved matching accuracy. Many experiments on HJ-1 visible images and different resolution IR images show that the algorithm proposed in this paper can quickly achieve accuracy registration between HJ-1 CCD images and IR images. So the algorithm has great practical values.

1 INTRODUCTION

Environmental satellite-1 (HJ-1) successfully launched at the second half of 2008, providing information for the changing trends of the disasters and ecological environment. In order to integrate useful information of visual and infrared satellite images, it is necessary for registration of HJ-1 CCD images and infrared images. In the field of image registration, the registration of CCD images and infrared images has been the top issue researched. But practical and effective algorithms have not yet been found. Because visible images and infrared images
respectively have different spectrum range, they have little correlation and different nonlinear distortion problem, which was proposed by JIANG Jing et al (2006). So it is difficult to obtained high precision registration by using the algorithm based gray scale. The registration algorithm based on features becomes more important. Bay’s research (2001) showed that it is very difficult to extract common features between CCD images and infrared images because of the low spatial resolution and margin blurred of infrared images. To solve the above problem, an improved registration algorithm based on invariant feature and MI is proposed in this paper, which realizes precision images matching between HJ-1 CCD images and infrared images.

2 ALGORITHM FRAMEWORK

The main framework of automatic registration algorithm of this paper includes four steps, as follows: (1) uniformly blocking the base image and wrap image respectively; (2) extracting SIFT feature points from every image block; (3) feature points matching; (4) obtaining transformation parameters and registration results with least square method. Among these steps, (2) and (3) are the key step of image registration based on feature points, which directly affects the registration precision. Step (4) is a general method, in which all the algorithm are almost same. So Step (1),(2) and (3) will be introduced concretely as follows.

2.1 UNIFORMLY BLOCKING THE IMAGES

SIFT( Scale Invariant Feature Transform) was proposed by David G. Lowe(1999) as key-point at first. However, when it is applied, SIFT algorithm has a high time complexity, which became registration bottleneck of large remote sensing images. Especially for multi-source remotely sensed images, the research of Kennedy B E et al (2003) and Bentoutou Y et al (2005) showed it is difficult that original SIFT algorithm realizes the one-to-one correspondence of image feature points for the complex imaging condition and scene, which caused serious mismatching. Meanwhile, non-uniform feature points may cause low local registration precision. In order to solve these problems, it is necessary to uniformly block the base image and wrap image. The number of blocks is decided by the size of two images. In general condition, images are uniformly blocked to 4×4 or 5×5 image blocks, and rank these image blocks to make image blocks within the similar region have the same ordinal number, denoted by \{A\}, \{B\}.

Supposed the size of image is M×N, and blocking the image by m×n blocks, then the size of every image blocks will be (M/m)×(N/n). Then feature points are extracted from every image blocks, which realizes uniform distribution of feature points.

2.2 SIFT FEATURE POINTS EXTRACTION

According to the scale-space theory, key-points in different scale space are detected, which will keep scale invariant. Then influence of rotation and illumination to image registration is eliminated. Follows are the three steps of this process:

2.2.1. Establishment of scale-space
The scale space of an image is defined as a function, \( L(x, y, \sigma) \), that is produced from the convolution of a variable-scale Gaussian, \( G(x, y, \sigma) \), with an input image, \( I(x, y) \)

\[
L(x, y, \sigma) = G(x, y, \sigma) * I(x, y) \quad (1) \quad \text{and} \quad G(x, y, \sigma) = \frac{1}{2\pi\sigma^2} e^{-\frac{(x^2+y^2)}{2\sigma^2}} \quad (2)
\]

difference-of-Gaussian scale space, \( G(x, y, \sigma) \), which can be computed from the difference of two nearby scales separated by a constant multiplicative factor \( k \):

\[
D(x, y, \sigma) = (G(x, y, k\sigma) - G(x, y, \sigma)) * I(x, y) = L(x, y, k\sigma) - L(x, y, \sigma) \quad (3)
\]

### 2.2.2. Keypoints detection

In the DOG scale-space, each sample point is compared to its eight neighbors in the current image and nine neighbors in the scale above and below. It is selected only if it is larger than all of these neighbors or smaller than others. Then low contrast points and edge responses points will be rejected respectively by using the two functions.

\[
D(x) = D + \frac{\partial D}{\partial x} x + \frac{1}{2} \frac{\partial^2 D}{\partial x^2} x^2 \quad (4) \quad \text{and} \quad \frac{\text{Tr}(H)^2}{\text{Det}(H)} < \frac{(r+1)^2}{r} \quad (5)
\]

in which, \( H = \begin{bmatrix} D_{xx} & D_{xy} \\ D_{xy} & D_{yy} \end{bmatrix} \). When keypoints were detected, every keypoint consists of three information: location, \((x, y)\), scale, \(\sigma\), and orientation, \(\theta\).

### 2.2.3. Descriptor production

When keypoints were detected, the local image gradients are measured at the selected scale in the region around each keypoint. These are transformed into a representation that allows for local shape distortion and change in illumination. Finally, feature vectors with 128 dimensions are produced. The vectors can keep invariant to illumination change, scale change and rotation.

### 2.3 Feature points matching

The matching process of feature points consists of three steps in this paper: coarse matching using minimum distance method, precise matching using normalized mutual information and eliminating mismatch points.

#### 2.3.1. Coarse matching using minimum distance method

Assumption that \( A_i \) and \( B_i \) are two image blocks, from which \( T_A = \{f_j\}_i \) and \( T_B = \{g_j\}_i \) were vector sets respectively extracted. Nearest neighbor method of Euclidean distance was used as matching principle.

The best candidate match for each keypoint is found by identifying its nearest neighbor in the sets of keypoints. A more effective measure is obtained by computing the ratios between the closest neighbor distance and the second-closest neighbor distance, \( k_i \). Then the ratios are sorted from the smallest to biggest, and the matching points corresponding to the ratios which
are sorted in first N are regarded as the correct points, \( f_i, g_i \).

2.3.2. precise matching using normalized mutual information

Mutual information is sensitive to image feature change in overlap region, so normalized mutual information was used by DENG Xiao-lian (2006), which can reflect the change of registration function,

\[
I(A, B) = \frac{H(A) + H(B)}{H(A, B)} \tag{7}
\]

So, normalized mutual information function is selected as evaluation function, of which max value is 2. Then a suitable threshold is defined, homonymy points that were extracted after coarse matching using minimum distance method will be accepted if the value of normalized mutual information is greater than the threshold. Otherwise, the matching points will be omitted, which achieve precision matching.

2.3.3. eliminating mismatch points

The homonymy points selected by coarse matching and precise matching are correct in general. However, mismatched points may still exist, which makes consistency check more important to remove mismatched points. A book wrote by Morton J. Canty (2006) cited the fact that distances are preserved under a rigid transformation. Let \( A_i, A_j \) represent the distance between two points A1 and A2 in an image. For two sets of feature points, \( \{A_i| i = 1, 2, 3, \ldots\} \) and \( \{B_j| i = 1, 2, 3, \ldots\} \), in image 1 and 2, the ratios are computed and calculated. These should form a cluster,

\[
\overline{A_iA_j}/\overline{B_iB_j}, i = 1 \ldots m, j = i + 1 \ldots m \tag{8}
\]

so that indices associated with ratios scattered away from the cluster center can be rejected as mismatched points.

EXPERIMENT AND ANALYSIS

Automatic registration between HJ-1 visible images and infrared images was tested by using the algorithm proposed in this paper on standard PC hardware. Experimental images are intercepted from the same area images. Visible images were chosen from the second band images of HJ-1 CCD images, of which the size is \( 1500 \times 1000 \), and spatial resolution is 30 meters; infrared images were chosen from short infrared wave band images of HJ-1 satellite, of which the size is \( 300 \times 200 \), and spatial resolution is 150 meters. Because of the too big spatial resolution difference between HJ-1 visible images and infrared images, visible images should be down sampled to achieve the same spatial resolution as infrared images. At this time, visible image sampled should be regarded as base image, and infrared images should be regarded as warp image. Figure 1 shows the base image and warp image.
The base image and warp image were respectively uniformly blocked to $4 \times 4$, and every image block is ranked to make image blocks within the similar region between HJ-1 visible images and infrared images have the same ordinal number. Then, coarse matching points were extracted by using SIFT algorithm to visible image block and infrared image block which has same ordinal number. After precise matching using normalized mutual information and consistency check, the final matching result were obtained. The figure2 shows the final matching result obtained by the registration algorithm proposed in this paper.

For comparison, we used automatic registration function of ENVI to obtain registration result of experimental images, which is shown in figure3. From figure3, it can be seen obviously that there were serious mismatch points. So the automatic registration algorithm based on invariant feature and mutual-information proposed in this paper is effective.
CONCLUSIONS

Based on invariant feature and mutual-information, the algorithm in this paper achieves high accuracy of automatic registration to HJ-1 visible images and infrared images with great differences of gray and resolution. In this paper, uniformly blocking method not only speeds up the registration, but also greatly reduces the mismatching ratio through locally geometric restrain which narrows the searching scope. And with initial matching by minimum distance, precise matching by normalized mutual information and removing mismatched points by consistency detection, the matching can be more precise. Another advantage of this algorithm is that uniformly blocking and locally searching corresponding points make the control points evenly distributed in HJ-1 visible images and infrared images, which further improved the precision of geometric correction.

REFERENCES