Automated Registration with High to Medium Resolution Satellite Data

AUTOMATED REGISTRATION WITH HIGH TO MEDIUM RESOLUTION SATELLITE DATA

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ABSTRACT**:** This is an ongoing engineering need for precise geodetic measurements. Recent measurements could not precisely predict the failure events of civic structures and ground position of specific locations. Precise measurement could be an interesting field of study for geodetic surveyors and researchers. There are many applications which require highly accurate (± 0.25 meters) measurements for geodetic surveying even though precision measurement techniques are still at the research stage. By applying the method of least squares it is possible to match two images precisely using a predefined template function. Consequently, image to image geometric correction could be conducted to fetch registered output image products. The registration could be done from high resolution satellite data (IKONOS) to medium resolution satellite data (ASTER) or from high resolution to high resolution satellite data (ALOS). In the present research, rational polynomial coefficient (RPC) orthorectification with digital Surface model (DSM) and least squares image matching technique were assembled. The developed numerical algorithm will be resembled to automatic and robotic. Finally, an advanced and precise application system was developed. This process had very good output with the total residual error of 0.06 pixel in high to medium resolution satellite data registration. This advanced application will be applicable in the field of engineering and social management. In addition, recent research trends on this topic are examined and evaluated. Future directions for research are suggested in the last section of this paper.

KEYWORDS: GCPs, registration

1. INTRODUCTION

There is increased interest today in making scientific progress through the use of remotely sensed data in social science research (Ronald R. et al., 1998). Remote sensing is a not new technology. Aerial photographs have been in widespread use for a half-century (Carls, 1947) and satellite images for a quarter-century (e.g., Estes et al., 1980; Morain, in this volume). These images have been put to various socially useful purposes, including making landslide monitoring, infrastructure liability failure monitoring, crop forecasts, predicting serve storms, and planning land development. Despite the apparent usefulness of remotely sensed data for social purposes, however, remotely sensed images have not been a popular for social science research, for several reasons (Ronald R. et al., 1998).

First, the variables of greatest interest to many social scientists are not readily measured from the air. Many social scientists find visible human artifacts such as buildings, crop fields, and roads less interesting than the abstract variables that explain their appearance and transformations. Changing land use, road and building construction, and the like are regarded as manifestations of more important variables, such as government policies, land-tenure rules, distributions of wealth and power, market mechanisms, and social customs, none of which is directly reflected in the bands of the electromagnetic spectrum. Thus social scientists are likely to be skeptical that remote sensing can measure anything considered important in their fields of study (Turner, in press).

A related issue is that social science is generally more concerned with why things happen than where they happen (Turner, in press). Even areas of social science in which one might expect a spatial orientation are curiously a spatial. For example, while is seems almost self-evident that spatial propinquity must be a factor in the shaping of social networks, it is only recently that the spatial aspects of social networks have been receiving attention (Faust et al., 1997). Relatively few social scientists outside the field of geography value the spatial explicitness that remotely sensed data provide, nor do the typical social science data sets contain the geographic coordinates that would facilitate linking social science data and remotely sensed data.

Remotely sensed data in this case satellite images are spatially acquisition of ground surface data with measurement of specific spatial/temporal/spectral resolution. They are directionally and geometrically correct with regard to a planar frame of reference. Uncorrected satellite data have spatial distortion due to terrain elevation as well as geometric distortions due to inconsistencies in the attitude of the satellite position (roll, pitch and yaw). These limitations to accuracy are sometimes quantifiable in terms of scale, resolution and angular distortion but for the most part the "accuracy" of a satellite image registration is a function of the experience of the interpreter and availability of ancillary information.

Image registration is the art of locating digital pixel of the image with relative position of the ground. The geometry of an orthorectified high resolution satellite image (IKONOS) is fixed by RPC data. These RPC coefficients, along with measurements of the plane's three dimensional position relative to the ground, can be used to remove spatial distortions caused by topography, called ortho-rectification. By removing the geometric distortions and the topographic distortions satellite data can be used for very precise registration to other uncorrected satellite data.

Recently, there are several approach to register images to use in real world applications. The most attracting method was a method that combines the merits of area-based and edged-based matching was applied to photogrammetry by Foerstner (1982), Ackermann (1984), and Pertl (1984). The method was found to be of great potential for a variety of image and template matching problems. It is of particular value for some essential photogrammetric tasks such as automated detection and measurement of fiducial marks, reseau crosses, stereomodel (Gruber) points, control points, the transfer and measurement of tie points, and generation of digital terrain models (Gruen A., 1985). This interest will be future work in this research.

2. REGISTRATION

Registration is a process to register an input image (ASTER or ALOS) to geographic coordinates and correct them to match with reference image (IKONOS) geometry. The miss registration of pixels, (Figure 1) could be output erroneous result to conjugated images processing.

Problem: Locating error

- Sample point location on based image:

16652.85E, 59893.97N

- Sample point location on input image: 16646.05E, 59890.73N

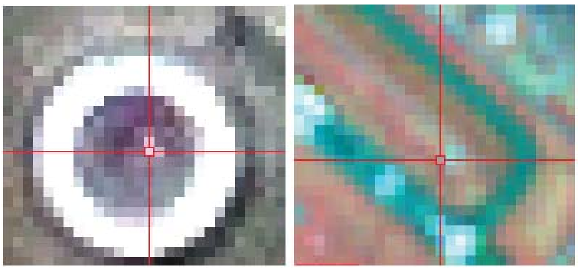

Figure 1: Locating error conjugated image pair.

In this experiment, the original image is roughly registered ASTER image with the easting error 6.8 meters and northing error 3.24 in the specific place. It was still needed to get precise registration to include in the social research analysis.

Selecting ground control points (GCPs), warping input image with reference one and resampling to new output image are serial processes of image registration.

2.1 Selecting GCPs, Least Squares estimation/RMS error calculation

Image matching is the prior method to register images by selecting match point pairs or tie points (GCPs) between reference and input images. The reference image sometime can be called based image and the warp image is raw or input image.

The total root mean squares (RMS) error can be calculated using (Equation 1) and (Equation 2) by inputting selected GCPs points.

The RMS for a collection of N values x_1, x_2, ..., x_n is:

$$X_{rms} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} x_i^2} = \sqrt{\frac{x_1^2 + x_2^2 + ... + x_N^2}{N}} \quad (1)$$

$$TotalRMSerror = \sqrt{(x_{rms}^2 + y_{rms}^2)} \quad (2)$$

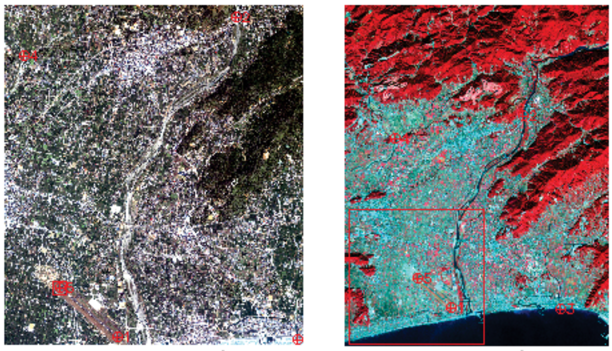

Figure 2: Full images with GCP Points.

In this study, the IKONOS image was used as reference image and assumed it was orthorectified image with precise location. The ASTER image was as an input image to correct. It could be raw images or pre roughly registered image.

Ground control points (GCPs) is a type of tie points. It can be acquired from the GPS or vector data or registered reference image. In this study, GCPs points are selected from orthorectified high resolution satellite image (IKONOS). Selection of the GCPs is identification of the GCPs in the displayed images by locating pixels. Selecting subpixel positions are supplied to provide higher accuracy in selecting GCPs. The following facts are used to produce accurate results, when selecting corresponding control points:

- Select numerous control points. A warping transformation based on many control points produces a more accurate result than one based on only a few control points.

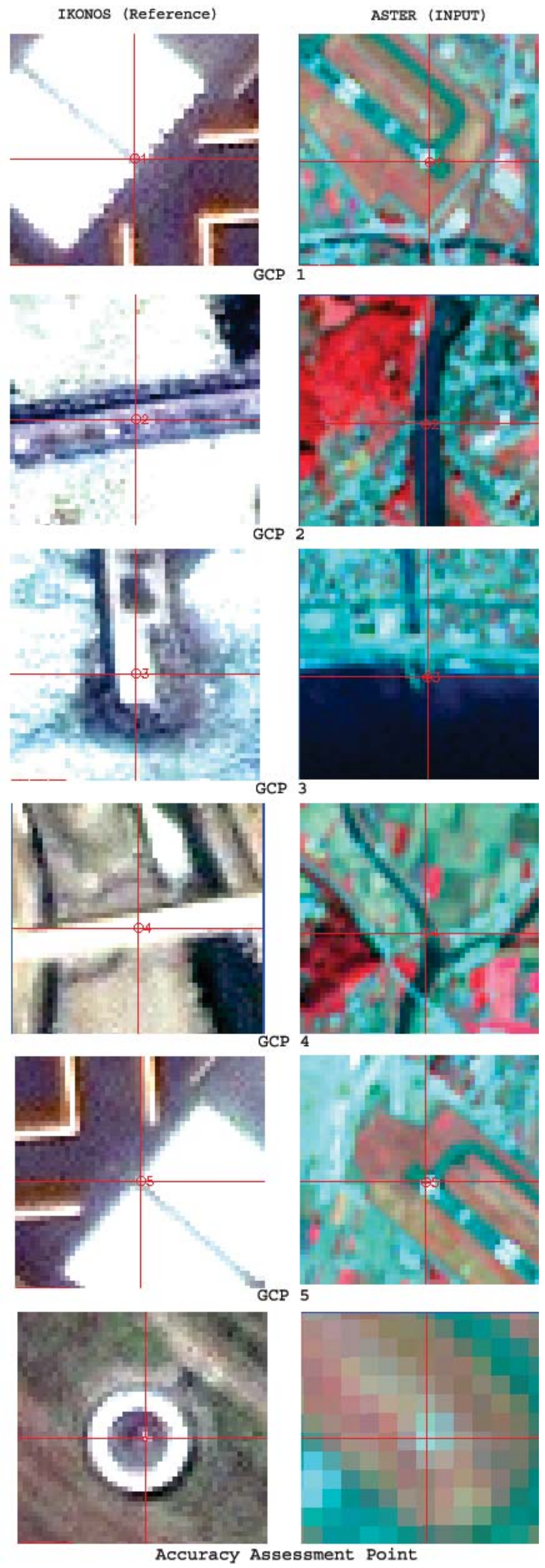

Figure 3: Selected GCP Points.

- Select control points near the edges of the image in addition to control points near the center of the image.
- Select a higher density of control points in irregular or highly varying areas of the image.
- Select points in which there are more confident. Including points with poor accuracy may generate worse results then a warp model with fewer points.

In this study, total selected ground control point is 5 pairs and it is match $(\text{degree}+1)^2$ polynomial degree 1's requirement. It is a possible approach in situations with more than three pairs of fitted points. The total residual error is 0.06 for this GCPs selection. Based on selected GCPs, the degree of polynomial (in this case degree is 1 because GCPs= 5 we have according to $(\text{degree}+1)^2$) and polynomial coefficient can be calculated. Using least squares estimation, determines the coefficients $Kx_{i,j}$ and $Ky_{i,j}$ of the polynomial functions by (Equation 3) and (Equation 4).

$$X_i = \sum_{i,j} Kx_{i,j} X_o^j Y_o^i \qquad (3)$$

$$Y_i = \sum_{i,j} Ky_{i,j} X_o^j Y_o^i \qquad (4)$$

where Kx and Ky used as inputs P and Q to the next process. This coordinate transformation was then used to map from X_o, Y_o coordinates into X_i, Y_i coordinates. X_i, Y_i are vectors of X and Y coordinates to be fit as a function of X_o, Y_o. X_o, Y_o are vectors of X and Y dependent coordinates. These must have the same number of elements as X_i, Y_i. K_x is a named variable that will contain the array of coefficients for X_i as a function of (X_o, Y_o). This parameter is returned as a (Degree+1) by (Degree+1) element array. Ky is a named variable that will contain the array of coefficients for Yi.

The calculated values of those coefficients matrix from this sample are presenting below:

k_x00=2327.0883466 k_y00=3586.4158528
k_x01=0.0001432187 k_y01=0.0666028563
k_x10=0.0668108705 k_y10=0.0000844610
k_x11=-0.0000000113 k_y11=0.0000000051

k_x, k_y contains the array of coefficients for Xi, Yi as a function of (Xo, Yo). This parameter is returned as a (Degree+1) by (Degree+1) element array.

2.2 Polynomial warping / Geometric transformation

Warping could be performed using polynomial functions, Delaunay triangulation, or rotation, scaling, and translation (RST). The geometrical transformation formula:

$$g[x,y] = f[x',y'] = f[a[x,y], b[x,y]] \qquad (5)$$

where g[x, y] represents the pixel in the output image at coordinate (x, y), and f [x', y'] is the pixel at (x', y') in the input image that is used to derive g[x, y]. The functions a (x, y) and b (x, y) are polynomials in x and y of degree N, whose coefficients are given by P and Q, and specify the spatial transformation.

2.3 Spatial transformation / image resampling

There are several methods for spatial resampling such as include nearest neighbor, bilinear, and cubic convolution. Nearest neighbor method was applied in this study restraint to selected GCPs.

- Nearest Neighbor

  Nearest neighbor interpolation method was selected to perform this process. This resampling uses the nearest pixel without any interpolation to create the warped image. Using following spatial transformation function, the nearest neighbor interpolation method could be applied.

P and Q are arrays containing the polynomial coefficients. Each array must contain $(N+1)^2$ elements (where N is the degree of the polynomial). According to this study, for a linear transformation, P and Q contain four elements and can be a 2 x 2 array or a 4-element vector. $P_{i,j}$ contains the coefficient used to determine x', and is the weight of the term $x^j y^i$. This P and Q polynomial coefficients matrices are written in the following format:

P[0,0]	Q[0,0]
P[0,1]	Q[0,1]
P[1,0]	Q[1,0]
P[1,1]	Q[1,1]

$$x' = a(x,y) = \sum_{i=0}^{N} \sum_{j=0}^{N} P_{i,j} x^j y^i \qquad (6)$$

$$y' = b(x,y) = \sum_{i=0}^{N} \sum_{j=0}^{N} Q_{i,j} x^j y^i \qquad (7)$$

where x' and y' are the locations in the base image, x and y are the locations in the input image (in this case ASTER), N is the polynomial degree (degree=1), and P and Q are the polynomial coefficients. This coordinate transformation then used to map from Xo, Yo coordinates into Xi, Yi coordinates.

3. RESULT

The accuracy checked was done by overlaid two images. Based on this assessment, the output image has satisfied result and it could be used for future social management analysis works.

The following (Figure 4) is represented that the accuracy of cross checking by images overlay.

Figure 4: Result Overlay.

Each residual errors and total residual error are listed in the following table.

Table 1: Resedual error.

GCP	Reference X	Reference Y	Input X	Input Y	Predict X	Predict Y	Residual X	Residual Y	$\sqrt{x^2+y^2}$
1	4459	11088	2626.87	4326.53	2626.96	4326.47	0.0883	-0.0609	0.1072
2	7631	2589	2838	3760.53	2838	3760.53	0.0019	-0.0013	0.0023
3	9265	11154	2947.47	4331.53	2947.45	4331.54	-0.0207	0.0143	0.0252
4	1984	3624	2461	3828.93	2461.01	3828.92	0.0117	-0.0081	0.0142
5	2947	9799	2526.07	4240.33	2525.99	4240.39	-0.0811	0.0560	0.0985
						Total RMS Error:			0.066406

Table 1: GCP points and RMS errors.

For the best results, GCPs should be widely scatter in the images and attempt to minimize the RMS error by refining the positions of the pixels with largest errors or by removing them. Errors can be reduced by using more points.

The selected tie points are calculated by using least squares estimation and the residual total error is 0.06 pixels.

The miss locating error problem mention in the beginning of this paper was corrected by image registration method. The output corrected location can be found in following (Figure 5).

- Sample point location on based image: 16652.85 E, 59893.97 N
- Sample point location on output image: 16653.75 E, 59893.98 N

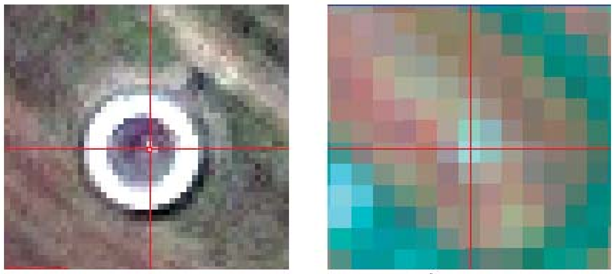

Figure 5: Output Precision.

After registration was conducted, the result shows that the two sample images have easting uncertainty 0.9 and northing uncertainty 0.01 meter.

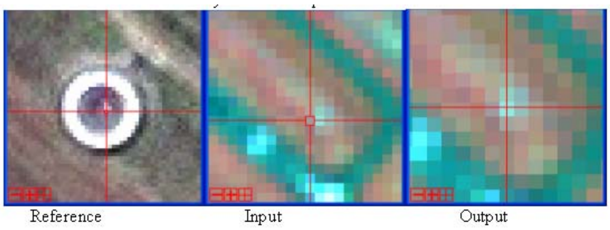

Figure 6: Input and Output Comparison.

- A landmark on runway of Kochi airport

The above image comparison (Figure 6) represented that the acceptable accuracy of image registration. It could be possible to improve accuracy by iterating registration. But it is impossible to remove uncertainty error.

4. FUTURE WORK

The method is tagged as "automated" because it could be possible to execute itself when the input data were available in specific folder and the program will automatically execute using predefine parameters for respected area.

Automated registration can be applied to a variety of location miss pointing problems. It shows numbers of attractive features to engineers and social scientists, such as locating specific pixels to detect the temporal based changed of socio related features, monitoring ground movement to forecast landslide disasters, and so on.

It is proved that image to image registration is successful approach to issue high accurate location for professional used. It also could be possible to extend the registration between orthorectified satellite image and existing GIS data. Then it is could be cross check by collected GPS data. It could be benefited to GIS data updating using available high resolution satellite data after registration.

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