Digital Surface Model based Image Matching for Image Registration

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Abstract: Image registration technique is the basic need of digital image processing. Image matching process should be done before image registration. This study could be conducted image registration by matching two images, the reference and satellite images. The reference image could be simulated from Digital Surface Model. The satellite image will be any type of image with same location. Firstly, the shadow image and shaded relief image were calculated from elevation data using acquisition parameters of satellite image; secondly, the reference image was simulated by adding shade and shadow images. The simulated image was match with input satellite images; after all, the registration was carryout. The result gives 2 pixels RMS error.

Keyword: Ground Control Points, RMS, Digital Surface Model, Least Square Matching

1 Introduction

Image registration task is a basic requirement of digital image processing in remote sensing and photogrammetry. Registered images could be applied in many applications; support that study on land-use/land-cover change in forestry and agriculture; investigation of land movement in infrastructure engineering, civil work, and oil/gas exploration. All those image analyzing applications should be respected to prior registration. Traditionally, images are register using manual selected ground control points (GCPs). GCP points could be lat/long values of respected earth location or x, y position in another map of the earth. The selection of GCP points is tricky work when the interested area has not included the remarkable features. Some of interest areas could be dense forest, hilly area without river indicator, or planed-flat land. It is very difficult to find GCP points on that homogenous area; in regarding to this, there is a way to register images by least square method, A. Gruen (1984). It is a powerful and an adaptive technique to register images by matching the template (searching patch) with input images. The research work is applied this matching method using simulated satellite image. Initially, a satellite image was simulated from the digital surface model (DSM) with high spatial resolution; afterwards, the searching patches are defined on the simulated image. Subsequently, the matching method was applied to the input image with related template.

1.1 Problems of interest

The problems of interest in this research are:

- Accurately registration to the satellite images using digital surface model data
- Efficient used of DSM data to solve the problem affect different satellite images by sun direction

1.2 Objectives

The objectives of this study are:

- To simulate satellite image from DSM
- To match images for image registration purpose
- To investigate the use of simulated DSM image in image processing as reference

2 Methodology of Image Matching

Initially, shadow was extracted from the elevation data, applying with input image's acquisition parameters. Firstly, sun elevation angle and sun azimuth angle were calculated from the acquisition time and study area coordinate; afterwards, the values are input to calculate shadow and shade relief. A simulated image was produced by adding the shade and shadow data. The simulated image should be resample as the size of input image. Secondly, templates (15×15 pixels) were selected from the simulated image. The selected patches could be matched with input image by giving initial value to each patch. The least squares matching method was used in the matching process. Overall methodology was shown in the figure (1).

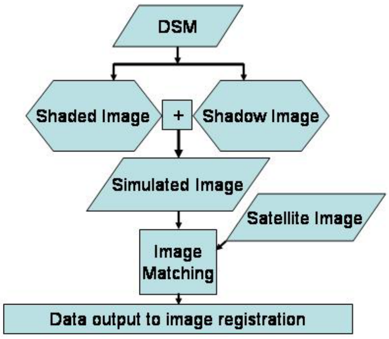

Figure 1: overall flow

At last, the result will be evaluated by comparing visually selected values.

2.1 Data used

There are two type of data is using in this work. Those are elevation data as reference and ASTER image as raw image.

2.1.1 Digital Surface Model (DSM)

DSM (RaMSE: Kokusai Kogyo CO., LTD.) is the acronym of digital surface model. It has 1 meter spatial resolution; including the actual surface high of buildings, trees, bushes and houses from the sea level line. The left upper corner of data low land with dark appearance, and the other side was covered by hilly area. There are some buildings and agriculture land in the middle part of the data.

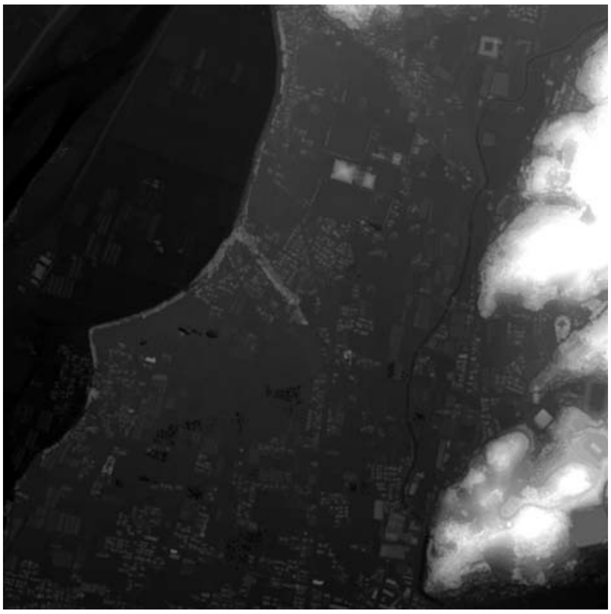
Figure 2: Digital Surface Model (DSM)

2.1.2 ASTER image

The input data is a subset of a satellite image acquired by ASTER sensor. It has medium spatial resolution (15 meters). The image has three spectral; bands red, green and blue. The RGB color was transformed to hue, saturation, lighting (intensity). The intensity band was extracted to match with reference patches.


Figure 3: part of ASTER image

2.2 Image simulation

A satellite image was simulated from DSM by combining shadow and shade relief of elevation data. Initially, Shadow image and shaded relief image should be calculated.

2.2.1 Shadow

The movement of the shadow of the sun was able to be calculated as show in figure (4). Firstly, solar direction (sun elevation angle **φ**, sun azimuth angle **θ**) was calculated from local coordinate of study area and acquired time of input image. The ground coordinate (L, M, N) are calculate from solar direction.

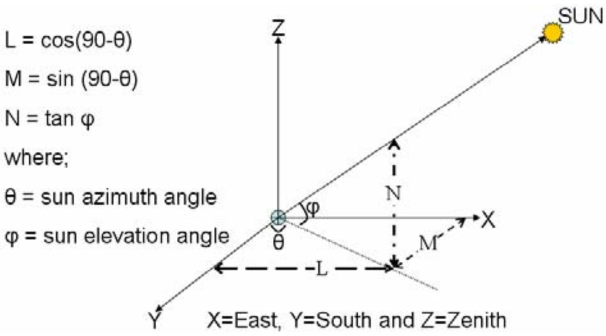

Figure 4: solar direction

2.2.2 Shade relief

The calculated sun elevation angle and sun azimuth angle are entered into the shaded relief image creation process using image processing software.

Figure 5: simulated image

2.3 Matching

The simulated image and input image were matched by least squares matching.

$$g_t(x,y)=h_0+h_1+g_s\,[(a_0+a_1x+a_2y),(b_0+b_1x+b_2y)]$$

where; g_t: target window

g_s: template window

h_0, h_1: unknown coefficients for brightness adjustment

a_0, a_1, a_2, b_0, b_1, b_2: unknown coefficients for geometric transformation

The equation is nonlinear equation; hence the equation was linearized by Taylor series. Initial values for unknowns were input to the linearized equation, and then iterative calculation carried out until the correction of the initial input minimized to be fall in global optimization. The selected template patches and its locations are shown in the figure (5) and figure (6).

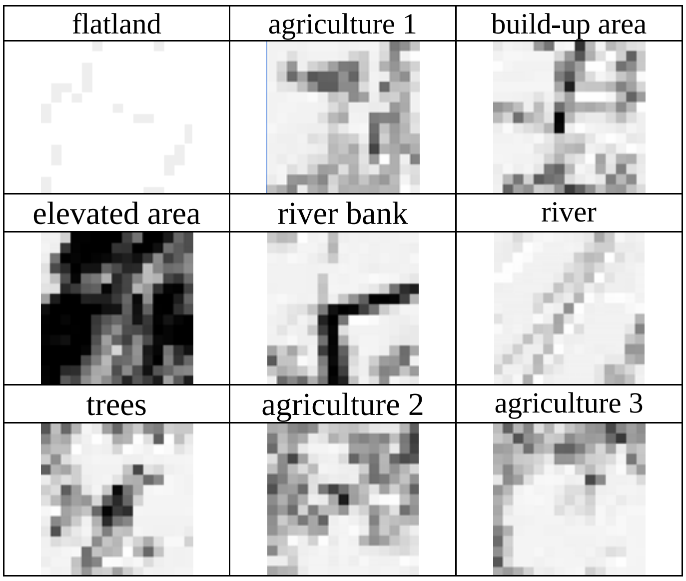

Figure 5: templates patches

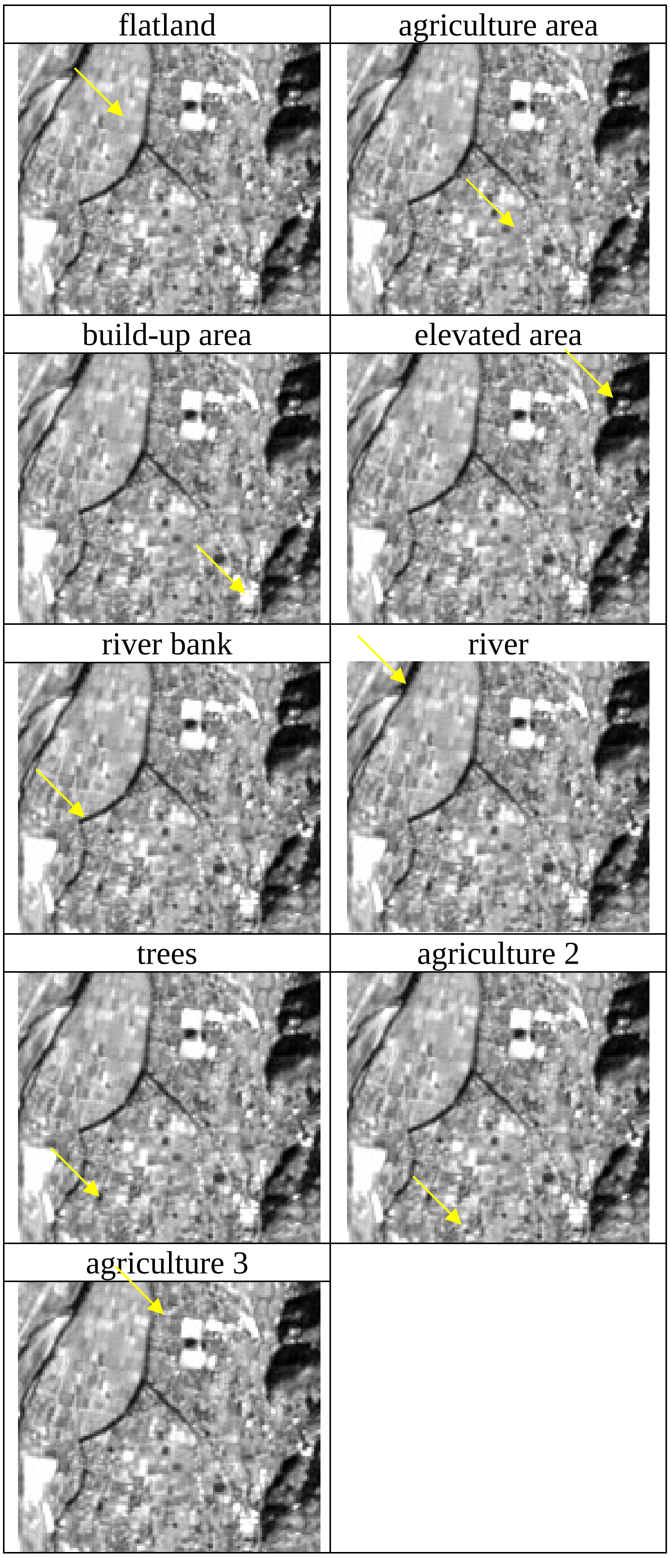

Figure 6: template location on ASTER image

3 Result of Image Matching

Evaluation of this work was done by comparing between two results of visual or least squares matching approach.

3.1 Initial Coordinate

GCP points were visually observed and extracted the coordinate of its point from the input image; moreover, they are use in the calculation of image matching as initial values (table 1). The selection of initial values is an important task in the LSM technique; adjusting initial condition the result can be improved. The initial values were adjusted in until the acceptable output.

Table 1: initial value from visual selection (unit in pixel)

	Initial	
	GCP_x	GCP_y
Flat land	45	28
Agriculture 1	76	81
Build-up area	99	105
Elevevated area	121	18
River bank	29	70
River	25	10
Trees	36	100
Agriculture 2	53	116
Agriculture 3	68	12

3.2 Least Squares Matching

Least squares matching method was used to select GCP points. The selected points are represented in the (table 2). It could be applied in the image registration process.

Table 2: LSM method GCPs result (unit in pixel)

	Result	
	LSM_x	LSM_y
Flat land	44.11	27.23
Agriculture 1	78.64	87.39
Build-up area	101.85	105.67
Elevevated area	121.08	17.89
River bank	31.41	68.93
River	26.90	9.70
Trees	34.20	99.60
Agriculture 2	53.30	115.60
Agriculture 3	67.90	12.50

The result GCPs shows that there are some variations between initial values and calculated values.

4 Result of Registration

Image registration was carryout using calculated GCPs. The RMSE for a collection of N values $x_1, x_2, \ldots, x_1$ (x: residual) is:

$$X_{rms} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} x_i^2}$$

Total RMS error $= \sqrt{(x_{rms}^2 + y_{rms}^2)}$

The registration result has total residual error 2.15.

Table 3: residual in registration (unit in pixel)

	Residual		RMSE
GCP	X	Y	
#1	1.81	1.16	2.15
#2	-1.49	-4.58	4.82
#3	0.42	1.88	1.92
#4	-0.31	0.83	0.88
#5	-2.21	0.75	2.33
#6	-0.51	0	0.51
#7	1.42	-0.07	1.42
#8	0.38	0.78	0.87
#9	0.49	-0.73	0.88
	Total RMSE		**2.15**

5 Conclusions

Based on the results comparison, we could conclude that the land-covered reflectance spectra are respectively affected to the satellite image especially on the flatland, forest, and build-up area. It could be maintained by adding spectral values of ASTER spectral library. On the other hand, elevated area and some crop land were issued good response It says that simulated satellite images from elevation data could be applied to register satellite images; moreover, it could be improved by adding spectra reflectance value.

6 Future works

The future works:

- will be investigated the selection of initial value
- will be removed shadow and shade disturbance from high resolution satellite data
- will be added land surface reflectance spectra to simulated image

References:

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