HYBRID MATCHING BASED ON POLYNOMIAL TRANSFORMATION

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ABSTRACT:

A new approach for hybrid matching based on polynomial models is proposed. Polynomial plays a key role in matching process; while the Efficiency Index measures the accuracy of the matching result. Airborne laser and aerial photograph are two data sources for this study. Even those sources perform in different projections, one can be transformed to another projection based on purposed transformation model and finally represented in the same projection as parallel. Both manual and automatic functions were employed to assist and improve modes of gathering and increasing number of tie points. Apart from edges and corners, height constraint and buildings configuration are employed. By result of this study, it was found that an accuracy of matching at checked points, when polynomial transformation was executed, was 0.99 of EI, and in the meantime the correlation (R^2) of resampling was about 0.99. Furthermore, height constraint was very important when various height of buildings were involved. It was found that dense buildings area with homogeneous height gave the highest accuracy of matching when polynomial transformation was applied.

1.INTRODUCTION

Remote Sensing is very useful technology particularly when it is applied to various fields such as natural resource applications. By ever increasing the number of sensors, the requirements of integrations among different sensors have been arisen, once is due to more gained benefits considering on differences of spectral, time, and etc., including its applications. As developing so far, specific algorithms have been tested, yet those algorithms could not fit entire requirements especially when area interest is heterogeneous and when projections are different. An appropriated solution has not been designed, due to the difficulties finding out matching features. With primitive manual procedure, e.g. registration is unwise to be taken into account; even manual process provides an easier way to allocate whole tie points than automatic process.

Actually, automatic matching has been explicitly requested for long time, but it is just an ideal solution in the past. Nowadays, some algorithms are designed and employed to result with acceptable accuracy. The single and multiple automatic feature extraction are efficient tools, which perform good consequence, when they are brought into the process of image registration [1]. However, when do observing in detail, some blunders are still occurrence such as delaying of processing time and the difficulties finding correctly matched features, so-called mismatching, where the heterogeneous area is pursued. All problems described above are still doubtful for explicit solving in practical. This paper is, therefore, going to overcome these problems and performing with robust procedure relied on height constraint and block configuration to serve for matching.

2.IMAGE MATCHING

In general there are many matching models having been developed. Focusing on digital photogrammetry, matching is the establishment of correspondence between the same points in two or more images or between a point on an image and its corresponding representation. Basically, two types of matching are considered: area based matching and features based matching. Area based matching considers only intensity of the pixels. The simplest area based technique is cross correlation, which compares only the intensity of patches from the two images [2]. Feature based matching uses symbolic descriptions of the images for establishing correspondence. DEM generation from matched points is a common technique to be applied for matching. The points are extracted by using of an interest operator and then points without a match are eliminated.

It is due to crossed platforms and projections are employed for this matching, so transformation model is another parameter that is concerned. Theoretically, transformation model is a technique, which is used to simulate both the movement and the manipulation of objects in two-dimensional (2D) and three-dimensional (3D) spaces. These processes involve translations, rotations, scalings, and reflections, which is called affine transformation. Generally, transformation model can operate either in rigorous or in non-rigorous forms. However, with the increasing number, and greater complexity of sensors becoming available, the need for standard transformation, polynomials, has been requested by considering on less complexity of mathematic function [3].

Practically, polynomials are applied for various data sources. Kratky (1989) used polynomials to transform from object co-ordinates to image co-ordinates of SPOT data in the real time loop of an analytical plotter by fitting spatial grid through a least square solution. Madani (1999) reported on the use of rational functions (ratios of polynomials) based on a rigorous analytical triangulation adjustment, photogrammetry techniques, and simulating stereo-image geometry respectively [4]. At the turn of the century, the rational functions is introduced by fitting the rational functions both to image and object-grids positioned at different elevations using rigorous image geometry model and least square adjustment [2]. It is also applied for digital photogrammetric workstations. Then, it can be concluded that the uses of polynomials are quite suited to be used for many sensors and provide an efficient and accurate way of using data [3]. However, the combination between different sources of tested data has not been experimented. Attempt so far have used single data source by experimenting in stereo pair platforms. This kind of experiments may have a limitation of losing some information for improvement of polynomials.

By complexities of polynomials when higher degree is mentioned, it causes such barrier for computation and sometimes affects to accuracy degradation. Universal Sensor Model, USM, regarding on rational function [5] provides

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dynamic rational function polynomial allowing for the selection of minimum number of rational function polynomial coefficients in order to meet a desired fit accuracy relative to rigorous sensor model of complex sensor [5]. However, it occurred some disadvantages of complexities of polynomials, which represented to the fifth power of the two horizontal co-ordinates and up to third power for elevation [9][3]. Obviously the polynomials become more complexities with higher power of polynomial function.

Considering the accuracy of polynomials, it is experiment on the geometric accuracy of polynomial mapping functions with a SPOT's stereo pair. It was found that the accuracy represented with 1m in object and 1μm in image space [1]. Madani (1999) resulted RMS accuracy on checkpoints with 8.5m in planimetric and 6.8m in elevation [4]. In 1999, USM is applied to fix the problem of accuracy limitation in fitting to the rigorous image geometry model and a complex non-linear fitting process [5]. By many papers, finally it is reported that polynomials could improve geopositioning performance and could yield the product with acceptable accuracy [3].

However, even reviewed methods separately fulfill in each part. It has not had a specific solution achieving for all requirements. Some methods are not rigorous and could lead to errors. On the other hand, it shows some complexities of defining function and number of points required including complexities of polynomial functions.

3.PROBLEM OF MATCHING

Basically the problems of image matching on different types of data source are classified into two types, those arising from object's appearance on the different images and those arising from difference of scale and the projection problem. With the first type, obvious examples are the difference between optical images and microwave images, and between images and maps. The possibility of different tilt or a large time difference can cause significant difficulties. For the second type, Tilt causes scale change and both illumination condition and land cover can have changed over a period of time [2].

4. NEW APPROACH

The purposed way to do image matching is firstly relied on polynomial transformation model that is brought into eliminating the problem of object's appearance in the different projections. Secondly, the purposed approach is relied on edges and corners. This approach helps to avoid a problem of different illumination condition. By details of extraction, the reliable algorithms are commonly available particularly in field of image processing that each algorithm has own efficiency to extract edges in different aspects [5], meanwhile matching presents in feature based matching.

According to the process of matching, Tipdecho, et.al (2001) found that even all-existing efficient algorithms were pursued; the error caused by mismatching was still occurrence [8]. Thus, in order to avoid this problem, layering on height is conducted and then each layer is executed for matching. In the meantime, area interested is defined into groups by considering the building configuration. This consideration is pursued to answer, which defined group is appropriate for purposed matching. The answer of this experiment would report in specific area with its accuracy.

Therefore, a new approach to automatic matching is the use of edges and corners based on proposed polynomial function, including height constraint and building configuration are major factors to be considered in this study.

5. STUDY AREA

The study area is a part of Kyoto city, Japan. Figure 1 shows an interest area.

(a) aerial photograph (b) airborne laser data

Figure 1 The study area

6. METHODOLOGY

For this study, building configuration is considered on dense and height of building. According to typical behavior of city area, the following classes are defined.

Class 1: Non buildings
Class 2: Sparse buildings
Class 3: Dense buildings with heterogeneous height
Class 4: Dense building with homogeneous height

<u>Non buildings</u>
The area, where consists of less than 50 % of buildings, is defined as non buildings

<u>Sparse buildings</u>
It means that area present buildings about 50% within its boundary, meanwhile the rest are area without buildings.

<u>Dense buildings with heterogeneous height</u>
The area that represents various heights of buildings is named in this group. Some areas especially in central business district (CBD) are also classified into this group.

<u>Dense buildings with homogeneous height</u>
The area that represents similar heights of buildings is defined in this group. Some areas especially in residential area are classified into this group.

According to corner and edges, edge is the first thing to be extracted by using Sobel and A'Trous wavelet operator, and then corners are detected by defined template of corners as see in Fig.2. This method is initiated on master image, and then grouped into each class and each level of height.

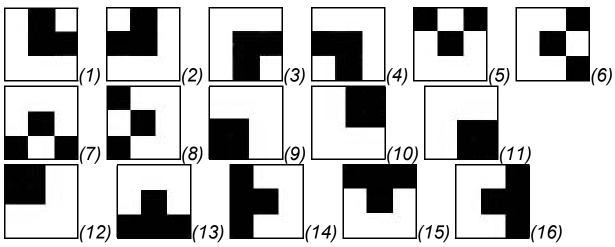

Figure 2 Template of corner

Here, it comes to the process of similarity. As mentioned that detected corners on master image are listed; then the process of transforming all corners from master image to slave image are executed. The transformation model as shown in Eq.1 is applied for this transformation, then all calculated position on slave image are reported [7].

$$U = a_0 + a_1x + a_2y + a_3z + a_4x^2 + a_5y^2+a_6z^2+ a_7xy$$
$$V = a_0 + a_1x + a_2y + a_3z + a_4x^2 + a_5y^2+a_6z^2+ a_7xy \quad (1)$$

where U, V = column and row of aerial photograph
x,y = airborne laser coordinates
z = height of buildings in airborne laser data
$a_0,..,a_7$ = constants

According to this report, some positions are eliminated, due to out of range. Only exactly and almost exactly positions are taken into account. Then, 5x5 window grid is employed for checking the similarity. It is only greater than 75 percents to be selected. For the rest, they are eliminated.

After application on similarity, those corners are transformed as local transformation in each block. Then, result of matching is generated.

7. EXPERIMENT

When airborne laser data was considered, the area interest regarding on building configuration was classified as Fig 3.

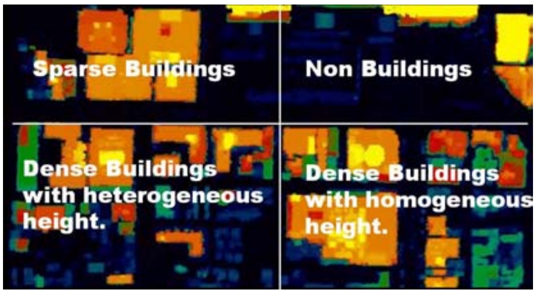

Figure 3 Building configurations

Then, the corner was firstly detected by defined template as shown in Fig 2. As we were known that edges were extracted by Soble and A'trous wavelet operators. Then closing, that was mathematic morphology, was applied for making clearer edges. Finally thresholding was brought to clarify a unique of intensity values. Figure 4 showed the result of edge extraction on airborne laser data, while Fig 5 presented data from aerial photograph.

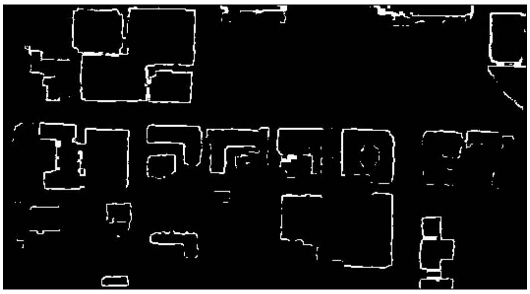
Figure 4 Result after applying Sobel on airborne laser data

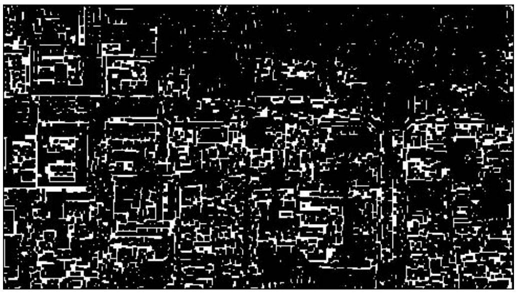
Figure 5 Result after applying A'Trous wavelet on aerial photograph

Then, the process of detecting corners was employed. By dynamic programming, templates of corner were brought into the process of detecting corner. Finally, the result was yielded as shown in Fig 6.

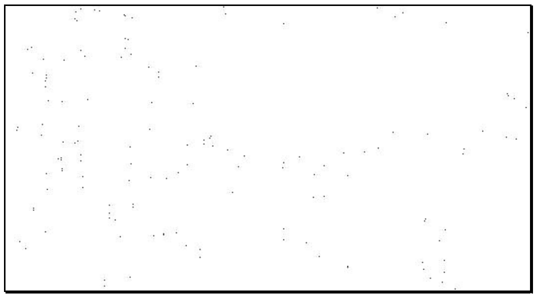
Figure 6 Result of corners

According to Fig 6, they were 140 corners to be positioned by applied templates. However, based on proposed procedure, all corners here were set into each class. Then, it came to the process of transformation regarding on layering on height. Basically, they were two layers: roof and ground. By computation trough Eq.1, the constant values of transformation model were shown as tables 1 and 2. Here, they were named as global transformation model.

U equation	V equation
a_0 = -64.381509	a_0 = -42.421665
a_1 = 1.047134	a_1 = 0.027375
a_2 = 0.030980	a_2 = 1.060494
a_3 = 0.098172	a_3 = 0.272149
a_4 = -0.000053	a_4 = -0.000085
a_5 = -0.000045	a_5 = -0.000202
a_6 = -0.000423	a_6 = -0.000652
a_7 = 0.000033	a_7 = 0.000008

Table 1 Constant values of roof equation

U equation	V equation
a_0 = -54.696421	a_0 = -5.242039
a_1 = 1.041311	a_1 = -0.026450
a_2 = 0.017469	a_2 = 1.000859
a_3 = 0.247429	a_3 = -0.250012
a_4 = -0.000048	a_4 = 0.000019
a_5 = -0.000010	a_5 = -0.000053
a_6 = -0.002604	a_6 = 0.002514
a_7 = -0.000020	a_7 = 0.000013

Table 2 Constant values of ground equation

Next, according to transformation model above, all corners were transformed from aerial photograph to airborne laser data. Then, the process of checking matched tie points was involved.

Here, it came to the process of similarity based on positioned corners. This topic encounters on similarity of edge to be considered within 5x5-window grid at each corner. The result was reported in percentage (%) by counting number of matched pixels within 5x5-window grid. For this study, 75% of similarity was defined as level of acceptance. By dynamic programming, finally the accepted result was generated and then all corners were presented as tie points for transformation. Table 3 showed the accuracy of output after applying transformation.

Corner	Correlation		Resampling points
	xu	yv	
Similarity			
Class: 1			
roof (9 pts)	0.977888	0.996102	14346
ground (17pts)	0.964454	0.994570	24044
Class 2:			
roof (3 pts)	-	-	
ground (9 pts)	0.999359	0.990515	31647
Class 3:			
roof (8 pts)	0.953081	0.991958	6542
ground (16pts)	0.977600	0.999822	32336
Class 4:			
roof (13 pts)	0.999812	0.999448	11761
ground (13pts)	0.999689	0.999368	27431

Table 3 Result after similarity checking

As mentioned, transformation finally generated values as table 3. Here it was named as local transformation model. However, when considering on table 3, it was found that Class 4 gave better result than result shown in tables 1 and 2. It was able to conclude that local transformation model generated the matched result with higher accuracy than global transformation model when dense building with homogeneous height was employed. On the other hand, they were non-buildings area, sparse buildings area, and dense buildings with heterogeneous area to be best fit for global transformation model.

Finally, the result of matching was produced with the accuracy at checked points of 0.99, meanwhile the correlation of resampling was 0.99. Figure 7 showed the result of matching based edges, corners, and polynomial model. All factors were considered under height constraint and building configuration.

Figure 7 Result of matching

8. DISCUSSION AND CONCLUSION

The building configuration based on its density and height was investigated. It was found that density and height served a lot in terms of area classification. Even this method did not divide area by land cover of city, this purposed idea can serve very much attention particularly its output's accuracy. The simplicity of dividing into four classes means that complicated land cover seems unnecessary. Therefore, it was proposed that this purposed building configuration can be employed.

Corner extraction procedures were successful in yielding a number of tie points automatically. The quantity and distribution of corners were sufficient to allow the full scene images to be transformed and at the same time residuals could be calculated. But in case of insufficient corners, it caused an output's accuracy. The extraction described in this section highlights the principal advantage of using full scene image. This is the fact that not all of the corners have to be extracted, due to percentage of similarity; this means that the volume of processing can be greatly reduced.

Similarity based on edge relation was employed. It was found that percentage of similarity can limit the number of required corner as precisely as possible. The volume of selected corner was reduced, when the defined percentage was higher. Finally the appropriate corners can be delineated. Here the similarity was set up as 75%. This is the fact that more precise corner can be allow for the process of transformation. Therefore, it was purposed that similarity is quite useful when the high accuracy of output is requested. Therefore, it can be concluded that purposed method is sufficient for matching. At the same time, output was also produced with higher accuracy without the problems of projection's difference and illumination condition. By the way, accuracy reported here is higher than an experiment in the past for example Madani (1999).

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