

# Automatic Image Registration between Image and Object Spaces

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## Abstract

An ever-increasing number of remote sensors have necessitated data integration among different sensors. This is due to more gained benefits from differences in spectral resolution, acquisition time, and so on. With reference to primitive method of image registration, an image-to-image space is commonly mentioned for the process of registration when multiple images are considered, while image-to-object spaces is namely used as orthorectification, which is relied on DEM, camera parameters, and images configuration. This method is claimed as complex and needed for more carefully on processing. When the heterogeneous area is considered, it causes more problems on matching. Moreover, it is uncomfortable when the process is lacking of automatic procedure.

This paper, therefore, introduces improved model for automatic image registration with respect to image-to-object spaces based on edges and corners consideration. Polynomial transformation was mentioned as a major tool for transforming all tie points from image space to object space. Then accuracy was reported for whole area and for checked points. According to transformation, the RMS residual of whole area was approximately two pixels regarding systematic error, while efficiency index was about 0.99 at checked points. By improvement of procedure, edges and corners play an important role. Existing operators generated both features, then the redundancy of them was considered. Finally those redundant features are employed for improving output's accuracy.

*Keyword:* Image registration; edge and corner extraction and matching

## 1. Introduction

Remote Sensing is very useful technology particularly when it is applied to various fields such as natural resources management, urban study, and geography. 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. As developing research so far, many specific algorithms have been tested, but those algorithms could not fit for entire requirements especially when area interest is heterogeneous and when projections of integrated images are different. An appropriated solution has not been designed yet, due to the difficulties finding out matching features and complexity on transformation.

Actually, automatic image registration 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 problems are still occurrence such as delaying of processing time and the difficulties finding correctly matched features, so-called mismatching, where the heterogeneous area is involved. 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 polynomial transformation, edges, and corners.

## 2. Image registration

Conventionally, image registration is the process of geometrically transforming multiple images to the same referenced frame. In the case where that frame of reference is a local geodetic system (i.e. map projection), then the process is referred to as rectification. Although rectification removes the geometric effects of orientation from images, this is not the only type of distortion present in images. Other distortions are due to sensor anomalies, atmospheric refraction and terrain [2].

By human intervention, few tie points can be positioned, then transformation model is established. Finally, all tie points are transformed to the same referenced frame. However, by this transformation, some tiny errors still remain at those tie points and, of course, the area where is far from tie points, also represents substantial errors with higher degree. Dare and Dowman (2000) employed multiple features extraction algorithm relied on patches and edges in order to increase a number of tie points, but the processing time was a problem and, at the meantime a target area was recommended to homogeneous area only [2]. In fact, the thresholding recognizes features according to gray level (i.e. color), homogeneous patch extraction according to texture (or lack of it), and segmentation according to both gray level and texture cannot be applied by this algorithm, due to typical characteristic of area.

With the same projection of multiple images, the affine transformation is explicitly common to be applied for establishing the same space with high accuracy [3]. However, it has been seen that the geometrical errors still remain when different spaces of multiple images are being considered. The ever increasing of geometrical errors cannot be degraded when images are manipulated under an affine transformation as shown in Fig 1. The solution solving these errors are needed when the requirement of using integrated data is gradually incremented at the moment.

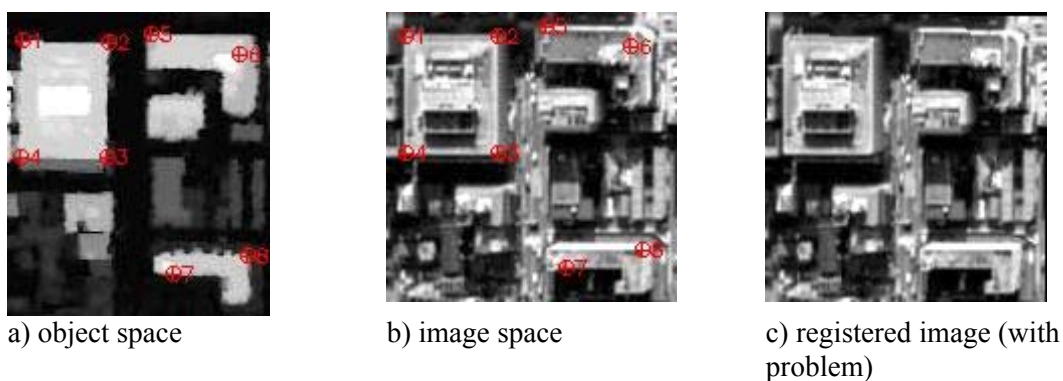


Figure 1. Affine transformation

Since last decade, many scientists have been developing algorithms for specific purposes based features of objects by relied on certain transformations. Goshtasby (1986) is a person who purposed a registration technique based polynomial function where patches were extracted as matching area [3]. Practically, difficulties of matching patched area are doubtful when the area interest is heterogeneous. In addition, Tipdecho and Chen (2001) performed an ability of polynomial function to be applied for image transformation between aerial photograph and airborne laser data. They found that polynomial function served for transforming images data between parallel and central projections [4].

With typical features of objects interest particularly edges, the developed process can extract those features through their shapes and then can provide substantial edges supporting to minimize degree of errors, due to transformation. Even it was claimed that edge could not serve enough tie points, edge still plays a key role for extraction and matching without typical characteristic of each area and limitation of map projection. With experiment of Tipdecho and

Chen (2001), edges extraction algorithm practically presented its capabilities and produced an acceptable result, that can be seen more details in [1]. There were Sobel and A'Trous Wavelet being employed for extracting edges. While matching algorithms commonly rely on either area or feature based matching particularly applied for automatic registration [5]. Dare and Dowman described that area based matching was only applicable to single source image registration. As feature based matching worked on points, lines, and patches of images. It always gives a good result with high accuracy when is applied for multi images with same map projections [2].

### 3. New approach

The new approach of image registration is mainly relied on edges and corners with respect to polynomial function. In case of edge extraction, the reliable algorithms are commonly available particularly in field of image processing. But, an obvious consequence is that even all-existing efficient algorithms are employed; the error caused by mismatching is still occurrence, due to heterogeneous area. In addition, it might also cause more problems if differences of map projection sources are considered. Generally, the potential to do manual matching is not practical when the larger size of study area is involved. Therefore, a new approach to automatic registration is purposed by employing edges, corners and modified polynomial function with respect to dynamic programming for overcoming all problems.

### 4. Methodology

Proposed automatic registration on different map projections is established. In order to eliminate the problem of matching tie points when heterogeneous area is considered. The following methodologies are defined for automatic registration.

- Manual tie points positioning
- Tie points selection
- Transformation model
- Automatic increasing tie points based on edge
- Accuracy improvement by corner
- Resampling

#### Manual tie points positioning:

First of all, manually positioning tie points is employed for images interest. Basically, this is a primitive method having been accepted for initial locating the tie points. For this study, extracted edge is set to be as a hint for positioning tie points. According to edge extraction, they are two operators to be applied for area interest: Sobel and A' trous wavelet. Sobel is a classical operator having high efficiency to extract edges especially for clear images. In the meantime, A'trous wavelet is also used for extracting edges. Theoretically it extracts only edge where performs in high reflectance. Road and edge could be extracted [4]. After all extracted edges are given, island noise filtering is employed. The closing algorithm with respect to mathematics morphology and thresholding are brought to produce meaningful results, and then clear edges are reproduced. The following kernel is established for closing.

```

-----
| 1 | 1 | 1 |
-----
| 1 | 1 | 1 |
-----
| 1 | 1 | 1 |
-----
kernel

```

Tie points Selection:

According to the number of tie points positioned, process of tie point's selection is initiated. Basically, this process is executed when transformation model is active. Transformation model here is relied on polynomial model proposed by Tipdecho, et.al [4]. By processing, all combinations of defined tie points are calculated as brute force method, and then accuracy at checked points for each combination are reported. By considering on efficiency index (EI), which is set as a measurement, finally the highest value of EI is selected accompanied with appropriate tie points.

Transformation Model:

As mentioned in the process of tie point's selection, transformation model [6] plays an important role in that selection. The procedure of transformation is illustrated as

- (a) Input data (X, Y, Z, U, V) are set as equations. X, Y, and Z come from airborne laser with respect to position and height; meanwhile U and V are obtained from aerial photograph as column and row of pixel on corresponding positions. Thus, equations are defined as:

$$U = a_0 + a_1x + a_2y + a_3z + a_4x^2 + a_5y^2 + a_6z^2 + a_7xy \quad (\text{Equation 1})$$

$$V = a_0 + a_1x + a_2y + a_3z + a_4x^2 + a_5y^2 + a_6z^2 + a_7xy \quad (\text{Equation 2})$$

- (b) Based on Eq. 1, they are  $a_0, \dots, a_7$  being solved firstly by matrix and least square methods. Sample data is brought into testing process. Finally the results of  $a_0, \dots, a_7$  are yielded. At the same time, the best tie points are allocated by dynamic program. Here, for Eq.1 of U, group representatives are already defined. Then, according to those selected tie points, Eq.2 can be calculated and finally resulted the constant values of  $a_0, \dots, a_7$  of V.
- (c) Then it comes to the process of rechecking the values of proposed equations by replacing the value of X, Y, Z to both equations.
- (d) Finally U and V are yielded with EI value

Automatic increasing tie points based on edge:

Automatic positioning on tie points is the way to position tie points with few manual procedures. According to defined transformation model, here the relation between image space and object space is already established. In parallel, process of edge extraction is executed. Finally, relied on transformation model and extracted edges, the process of positioning additional tie points is initiated. By detail, when edge is detected in object space, the location in image space can also be allocated by considering on defined transformation model. Then local window is searching for corresponding edge in image space. In fact, the radius of searching can be adjusted. Finally all detected edges are presented and the center position is named as tie points.

By detail of local window searching, the step of programming is illustrated as follows: Basically it is a 3x3 grid represented as local window. The way of searching is allocated as Fig. 2 by giving a pixel of radius for searching.



Edges

(a)



Defined distance

```
0 0 0
0 1 0
1 0 1
```

Direction of node for selection

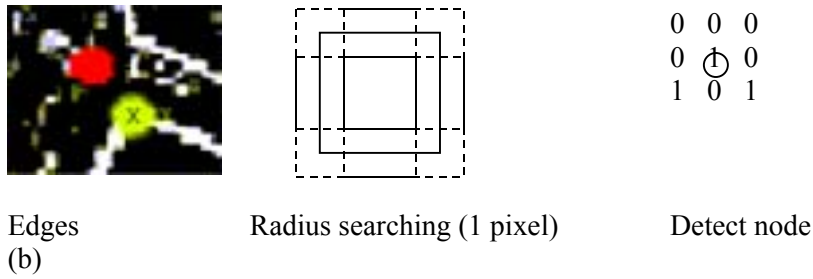


Figure 2 Process of local window searching

Practically typical behavior of local window searching performs as

- (a) 8-connected neighborhood is employed as 3x3 grid mask
- (b) Grid position of (1,1) is designed as center of grid, as well as matrix, and rank no. is also defined as shown in Fig. 3
- (c) Firstly local window searching is executed on object space by focusing on edge. Then, edge is detected and also allocated as chain code as shown in Fig. 4. This process is active until completing for whole area.
- (d) According to defined transformation model and detected edges in (c), corresponding edge in image space are allocated. If edge on image space is detected, then chain code is setup and compared with chain code in object space.
- (e) If the corresponding edge cannot be found at the first time, the local window searching is moved within one pixel of radius. However, if edge cannot be found again, local window searching is stopped, then go to another area.
- (f) By dynamic programming, this process is run automatically.
- (g) In case of chain code comparison, the center position is named as tie point, when the values of chain code present in same number as in Fig.4.

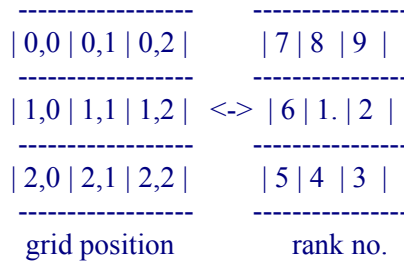


Figure 3 Searching design

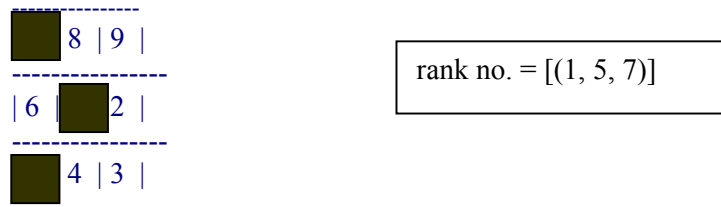


Figure 4 Chain code

Finally all additional tie points after applying local window searching are allocated automatically. Then, it comes to the process of improving an accuracy of all tie points. Corner is brought into the process of improvement accuracy of tie points.

Accuracy improvement by corners:

This stage considers on corners, which are relied on edges, in both master and slave images. The corner matching is defined by considering the similarity. Finally, the redundancy of corners is an indicator for matching.

First of all, corner is detected by defined template. Basically crossed lines are set as master kernel as shown in Fig.5. Then, the process of multiplication with defined crossed line is generated. By testing, sixteen types of corner are set as target group as shown in Fig. 6. So, if each of them is found on image, that position is mentioned as corner.

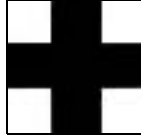


Figure 5 Master kernel

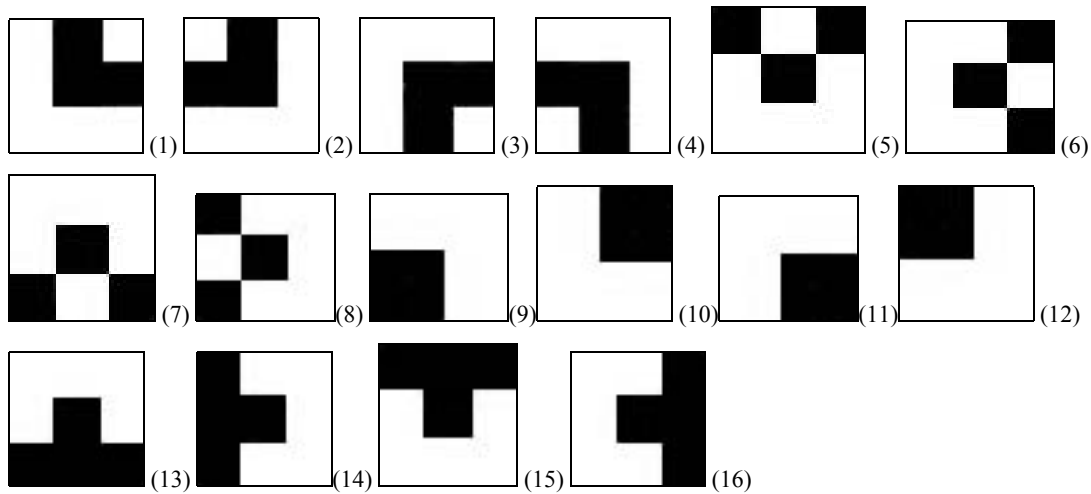


Figure 6. Corner templates

Secondly, it is a process of redundancy consideration. With the result of automatic increasing tie points relied on edges and corner extraction as mentioned above, both data are brought into this process. If the positions of edge and corner present at the same coordinate within designed radius, then those positions are recognized. On the other hand, if those points are not represented at the same position, so those points are eliminated. Finally they are only high accuracy on position of tie points to be selected for setup transformation model.

Resampling:

Here, when accurate tie points are allocated, then transformation model is executed. Finally, all pixels from aerial photograph are transformed to airborne laser data. At this place, the process of comparison, using  $R^2$ , between referenced U and V and calculated U and V are taken into account.

**5. Application to aerial photograph and airborne laser data**

The area interest was described with aerial photograph and airborne laser data. By typical characteristics of images, aerial photograph showed in central projection, while airborne laser presented as parallel projection as in Fig 7.

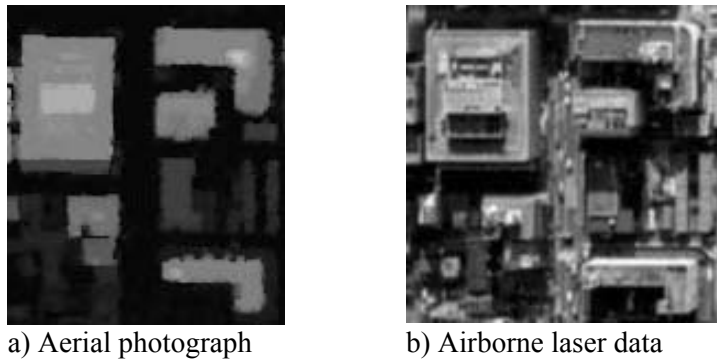


Figure 7. Experimented area

As mentioned in the process of manual tie points positioning, edge-extraction operators were applied for area interest in both aerial photograph and airborne laser data as shown in Fig. 8. Then, the tie points were defined manually. Table 1 showed list of tie points.

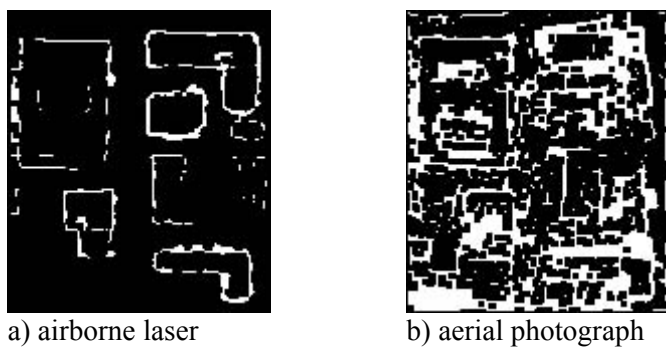


Figure 8. Mathematic morphology (MM) application

Table 1. Data list shown as manual selected tie points

Row (x)	AIRBORNE LASER		AERIAL PHOTOGRAPH	
	Column (y)	Height (z)	Column (u)	Row (v)
49	15	133	54	11
5	72	110	9	70
71	27	110	80	23
117	13	125	122	9
122	47	100	130	43
51	91	108	57	87
29	107	102	35	104
74	122	129	82	118
106	130	128	117	126

Next, the process of tie point's selection was implemented by considering on transformation model. By experimenting, accuracy at checked point was illustrated in terms of EI that performed 0.99 (out of 1.00) with respect to eight tie points. It was also found that, however, substantial error was arisen where away area was involved. The correlation of EI represented as 0.90 and 0.99 respectively for entire area when was applied for 19,749 pixels. Fig. 9(a) and (b) delineated graphically coordinated pairs distributing over whole image with its correlations. By testing, when tie point was increased to ten points, the correlation performed with higher result: 0.996 and 0.999, as shown in Fig. 9(c) and (d). Apart from correlation results, image output was presented as in Fig. 10.

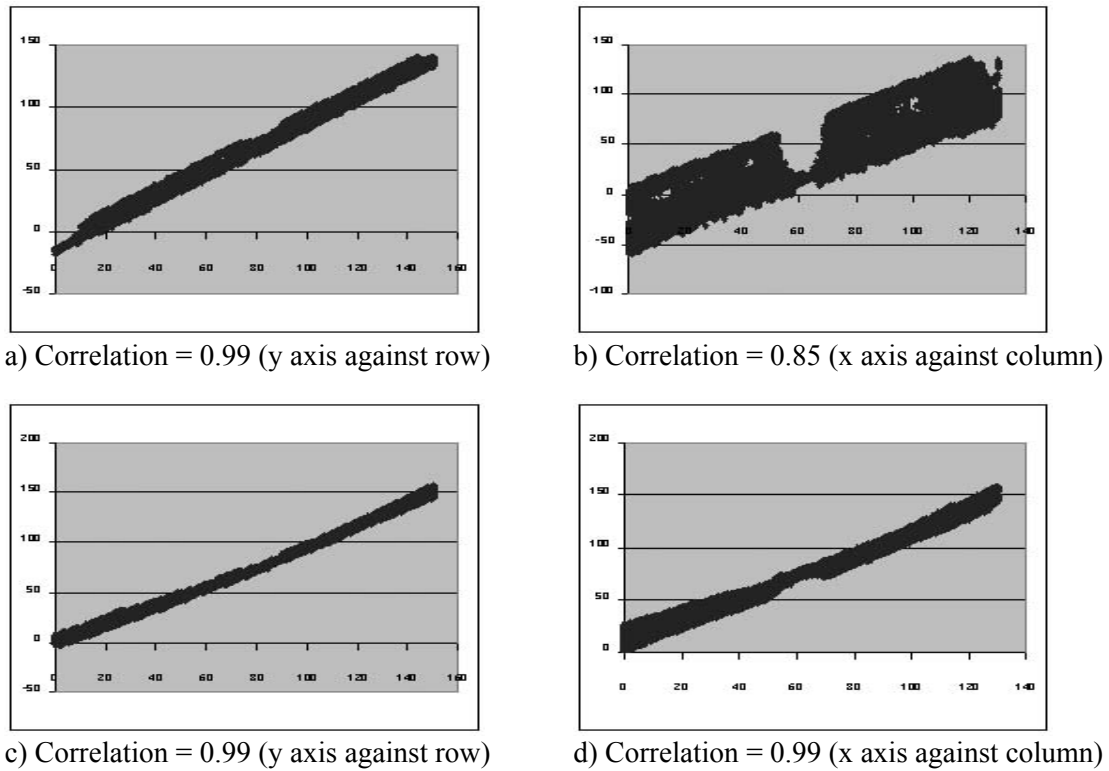


Figure 9. Pair of coordinates distribution

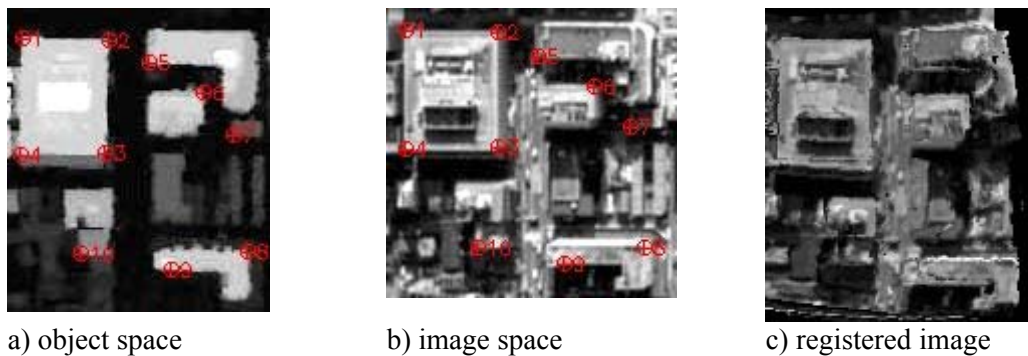


Figure 10. Image-to-object space registration

As mentioned, when the number of tie points was increased, the correlation also incremented. With this reason, the automatic increasing tie points based on edge was applied, then corner was considered for improving an accuracy of them. For this paper, the radius of searching was defined into three distances: 1, 2, and 3 pixels respectively. Fig.11 showed all results, which were selected by considering on redundancy.

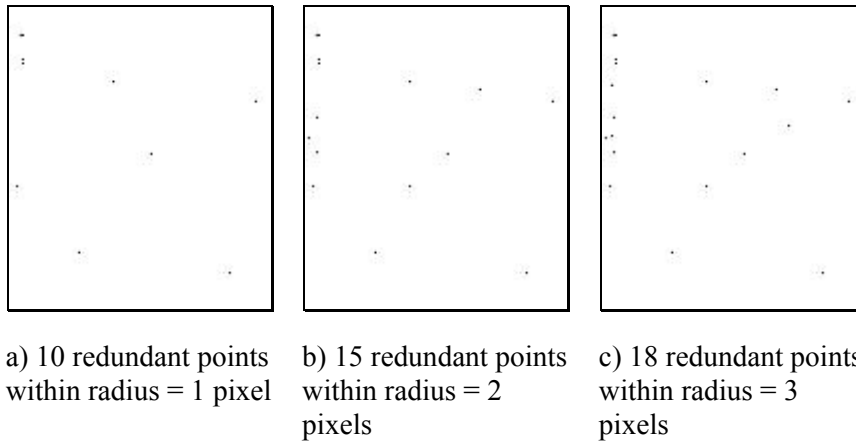


Figure 11. Result of redundancy in different radius

Next, it was resampling process. By result of experimenting as shown in Fig. 11, they were 10, 16 and 18 ties points having been selected automatically by redundancy consideration. Then, correlations were answered as 0.985, 0.993, and 0.993 of x-col and 0.996, 0.997, and 0.997 of y-row (see in Fig. 12) respectively. According to Fig. 12, it was concluded that output accuracy might reach the saturated points when tie points are positioned enough.

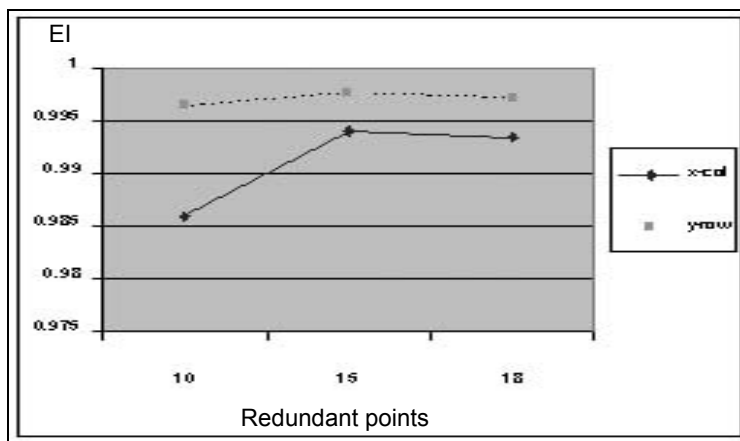


Figure 12. Correlation of different numbers of tie points

With an accuracy of output, figure 11(a) showed an overlay's result between airborne laser data and aerial photograph. In the meantime, an systematic error around the roof of building was shown in Fig. 11(b). By evidence, it was found that RMS residual of this output is set to two pixels. This was an accuracy of this method to be applied for image registration.

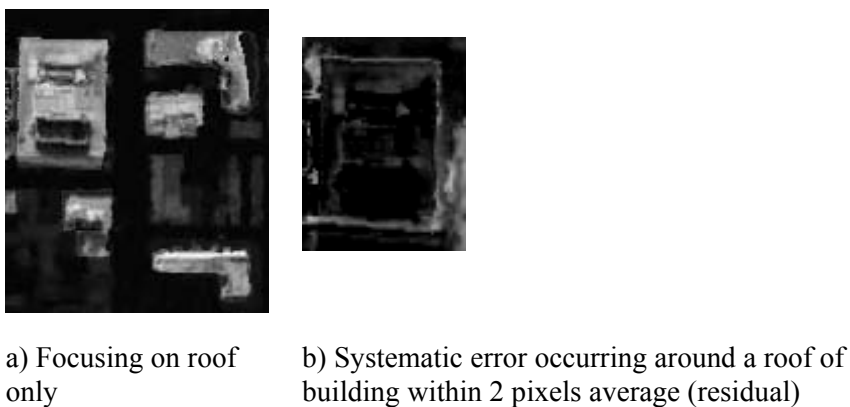


Figure 13. Accuracy of image registration

## 6. Discussion and results

The proposed method of image registration here is named as originality when different sources of image's projections are considered. This method produces an output with high accuracy regarding on 2 pixel of RMS residual by avoiding primitive procedures. Moreover when output's accuracy is compared with research in the past. It is found that it gives better accuracy than some primitive processes. However, this method should be tested on another kind of laser data for example ground-based laser scan. If this proposed method could maintain in the same standard with this paper, it should be benefit for some works in close-ranged photogrammetry.

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