AUTOMATIC DETECTION OF SHADOW POINTS IN DIGITAL IMAGES FOR AUTOMATIC TRIANGULATION

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ABSTRACT

This paper presents a novel method for automatic detection of shadow points in digital images in order to improve the reliability of automatic triangulation. The new method is based on the model of shadow points, which contains the radiometric and geometric properties of shadow in the image. The first is that there is a distinct contrast along the edge of a shadow in the image. The second is that the surface around a shadow is not a smooth surface and the points in the shadow area have smaller elevation than the objects casting the shadow, such as trees or buildings. The proposed method works in two steps: it first detects points with high contrast by image processing, and then finds points where the terrain slope changes sharply in its surrounding area by using a local digital surface model (DSM) which is generated by image matching. The proposed approach has been implemented within Z/I Imaging's automatic triangulation product – ISAT. The tests on different projects show that the proposed method can detect shadow points effectively and thus improve the reliability of the triangulation results.

1. INTRODUCTION

Shadow is a common phenomenon in digital images. Since the information in shadow area may be lost or is very difficult to be extracted, it often causes problems in many photogrammetric applications such as automatic extraction of buildings and roads, generation of orthophotos and automatic triangulation. In automatic triangulation, tie/pass points of images are extracted automatically by image matching and the exterior orientation (EO) parameters of images are computed by using the extracted image points. Thus, the quality of the obtained EO parameters of images largely depends on the quality of the automatically extracted tie/pass points and their distribution in the block. The existence of shadow points reduces the accuracy and reliability of the derived EO parameters of the images, especially when the flight line is long, photos are taken at a large sun azimuth, or images are taken in a bad weather condition, e.g., a windy day. Therefore, how to detect and remove shadow points in the image automatically is an important issue in automatic triangulation. There are different methods developed for detecting shadow points. Some of them use the sun azimuth of the image and DSM to compute the location of shadows in the image (Amhar et al, 1998; Rau et al, 2002). They work well when the sun azimuth and DSM in the image area are available. However, DSM is sometimes unavailable for some applications, for example, in automatic triangulation. Other approaches detect shadow area by simply performing thresholding operation (Gong et al, 2002). Since shadows usually have large intensity values in the image, most shadow points can be detected by thresholding operation of the image. But, some non-shadow objects may also have large intensity values in the image and thus be detected incorrectly. In this paper, a new method based on the model of shadow points is presented. The model contains two distinct properties of a shadow in the image. The first is that there is a distinct contrast along the edge of a shadow in the image. The second is that the surface around a shadow is not a smooth surface and the points in the shadow area have smaller elevation than the objects casting the shadow such as trees or buildings. The proposed method works in two steps: it first detects points with high contrast and then find points where the terrain slope changes sharply in its surrounding area by using a local DSM. It is assumed that terrain has a sharp change in slope when high objects such as trees and buildings occur. The slope change of terrain can be calculated by using a local DSM generated by image matching during the generation of tie/pass points. The proposed approach has been implemented within Z/I Imaging's automatic triangulation product – ISAT. In the following sections, the process of automatic generation of tie/pass points and detection of shadow points will be described and some examples of shadow point detection will be presented.

2. AUTOMATIC GENERATION OF IMAGE TIE AND PASS POINTS

In automatic triangulation, tie/pass points for computing EO parameters of images are generated automatically by image matching. Different matching techniques have been developed for finding corresponding image points in overlapping images in the last two decades. Feature-based matching (FBM) and area-based matching such as least-squares matching (LSM) are two widely used matching methods. Both of them have their advantages and disadvantages. LSM has very high matching accuracy, but needs good approximation of the position of the point to be matched while FBM doesn't need good approximate location of the corresponding point and has relatively low matching accuracy. To reduce mismatch points, and thus to increase the reliability of triangulation results, a combination of LBM and LSM is usually used in the automatic generation of tie/pass points since they can compensate to each other. In Z/I Imaging's ISAT, the tie/pass points in the image are generated by using LBM and LSM from coarse to fine (Tang et al, 1997; Madani et al, 2001). The following diagram shows a general procedure of the automatic generation of tie/pass points in Z/I Imaging's ISAT.

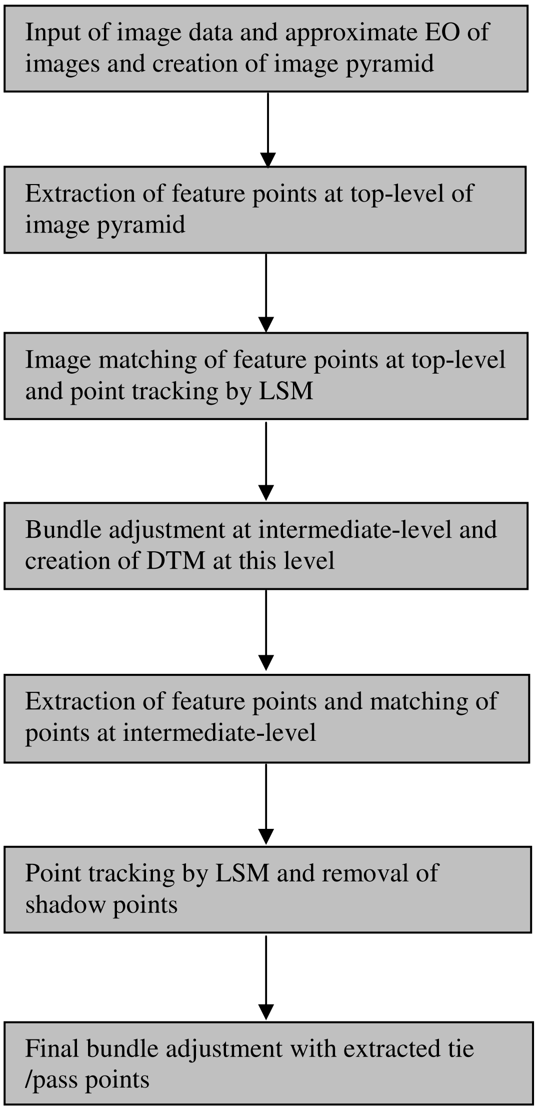


Figure 1. Automatic Generation of Tie/Pass Points in Z/I Imaging's ISAT

Automatic generation of image tie/pass points consists of three major steps: (a) feature extraction and matching at top-level of the image pyramid, (b) bundle adjustment at intermediate-level of the pyramid for obtaining better EO parameters of images and generation of a rough DTM, and (c) feature extraction and matching at intermediate-level with computed EO and DTM, and point tracking by LSM. The purpose of performing feature point matching at the top-level is to get better EO parameters of images and create a DTM for better image matching at the intermediate-level. The use of DTM created from the matched points can increase matching speed and improve the reliability of image matching at low levels of the pyramid, especially for mountainous areas. In ISAT, feature points are extracted by using the Förstner operator (Förstner and Gülch, 1987), a well-known interest operator in photogrammetry. It extracts points by examining the gradients of image intensity values around the points. By using the Förstner operator, most distinct points in the image, such as corners, can be extracted. Some shadow points may also be extracted at the same time. Some shadow points may survive from image matching and may reduce the reliability of final bundle adjustment, especially when strips in the block are very long. In order to improve the reliability of derived EO parameters of images, a process for removal of shadow points has been added in image point tracking in ISAT.

3. AUTOMATIC DETECTION OF SHADOW POINTS

Shadow points have some distinct properties in the image, which differentiate them from other features. The most distinctive properties are: (a) the image gradient around the shadow edge is usually large and (b) there is an abrupt change in elevation in the surrounding area since shadow is cast by high objects such as trees or buildings. A method for detecting shadow points in images has been developed based on these properties.

3.1 Generation of Candidates of Shadow Points

The shadow points are detected in two steps and the first is the selection of candidates of shadow points. Since shadow usually has larger intensity value than its neighbouring objects, points on the edge of shadow have large intensity gradients. The gradients in four different directions are computed as shown in Figure 2 and the maximum is chosen as the gradient of the point.

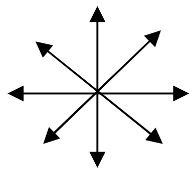


Figure 2. Intensity gradients in x, y and two diagonal directions

$$G = \max \{ G_i \},\ i = 1, 2, 3, 4. \qquad (1)$$

i in the above formula represents direction the intensity gradient is computed and includes x , y and two diagonal directions. Once the intensity gradient of a feature point is calculated, it is compared with the given threshold and the point is selected as a candidate of shadow points if it is larger than the threshold.

3.2 Detection of Shadow Points

Shadow is cast by high objects such as trees or buildings. There is an abrupt change in elevation around trees or buildings that cast the shadow. Thus, shadow points can be detected by detecting the change of terrain slope in a local area around the selected candidate points.

3.2.1 Generation of Local Digital Surface Model (DSM): Before the generation of a local DSM, an area around the point should be defined on the overlapping images. The area should be big enough to cover the object casting the shadow. Once the area is defined, all image points in the area are matched by image matching. Since the feature points in the area may not be dense enough, an area-based image matching is used. The elevation of the matched points is then computed by forward intersection with the EO parameters of the images from first bundle adjustment.

3.2.2 Fitting A Surface to Local DSM: After a local DSM is created around a feature point, a surface is fitted to the created DSM. It is assumed that the terrain surface in a small area is a smooth surface in most cases and there is an abrupt change in elevation in the area where breaklines, trees, buildings, etc. occur, as shown in Figure 3. In this study, a first-order surface is fitted to the local DSM by using the least-squares method.

The standard deviation of elevation difference between points and the fitted surface is then computed, which represents the change of terrain slope in the area. When the standard deviation is larger than the given threshold, it can be determined that there is probably a tree or a building in the area and point is removed as a shadow point.

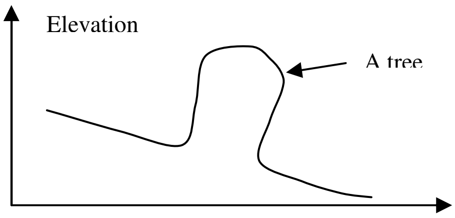


Figure 3. Slope Change in the Area with Trees

4. SOME EXAMPLES

The developed approach has been tested within Z/I Imaging's ISAT and some test results are presented in this section. The project presented in this paper consists of 4 strips and each strip has 7 images, taken with analog aerial camera. The images have a scale of 1:6800 and were scanned at 14µm. There are a lot of trees and shadows in the project area. The project was run with and without the function of removing shadow points. Figures 4(a) and 4(b) show the tie/pass points of an image in the project generated by ISAT before and after removal of shadow points respectively. It can be seen that plenty of tie/pass were created cross the image before removal of shadow points, among which some are good points, such as corners of sidewalks. But, many shadow points and points on top of trees were generated at the same time since the main features in this area are houses, large buildings, trees and shadows cast by these objects. With the function of removal of shadow points, most shadow points were removed successfully. Figures 4(c) and 4(d) show the points in a small area (black boxes) before and after removal of shadow points. Totally there were 12 tie/pass points generated in this area, seven of which are shadow points. After removal of shadow points, all shadow points were removed and there were eight points generated, as shown in Figure 4(d). Almost all of these points are new points since the algorithm removed some non-shadow points incorrectly and added some good points automatically. Another example is shown in Figure 5.

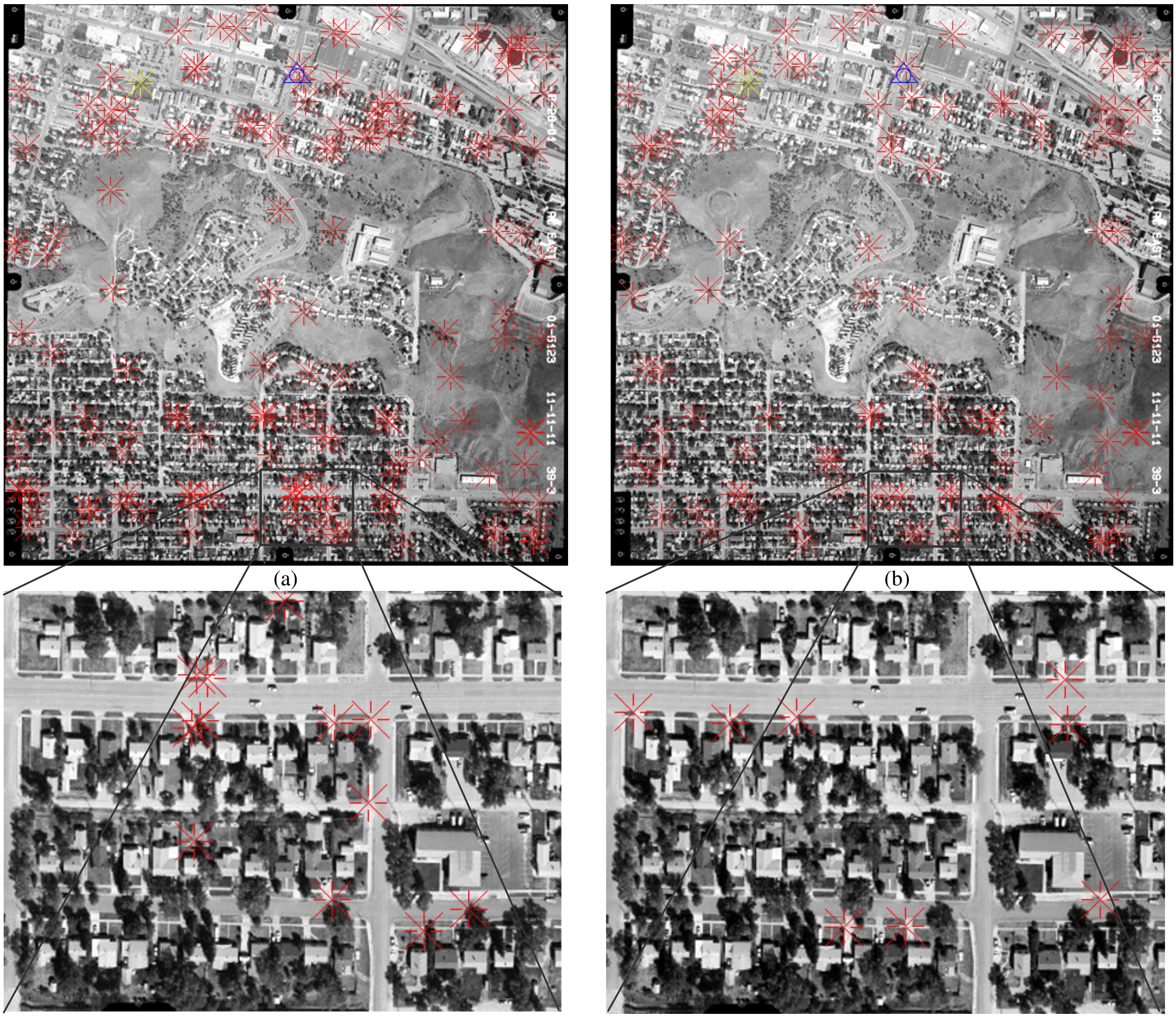


Figure 4. Automatically generated Tie/Pass Points (a), (c) extracted tie/pass points before removal of shadow points, (b), (d) extracted tie/pass points after removal of shadow points

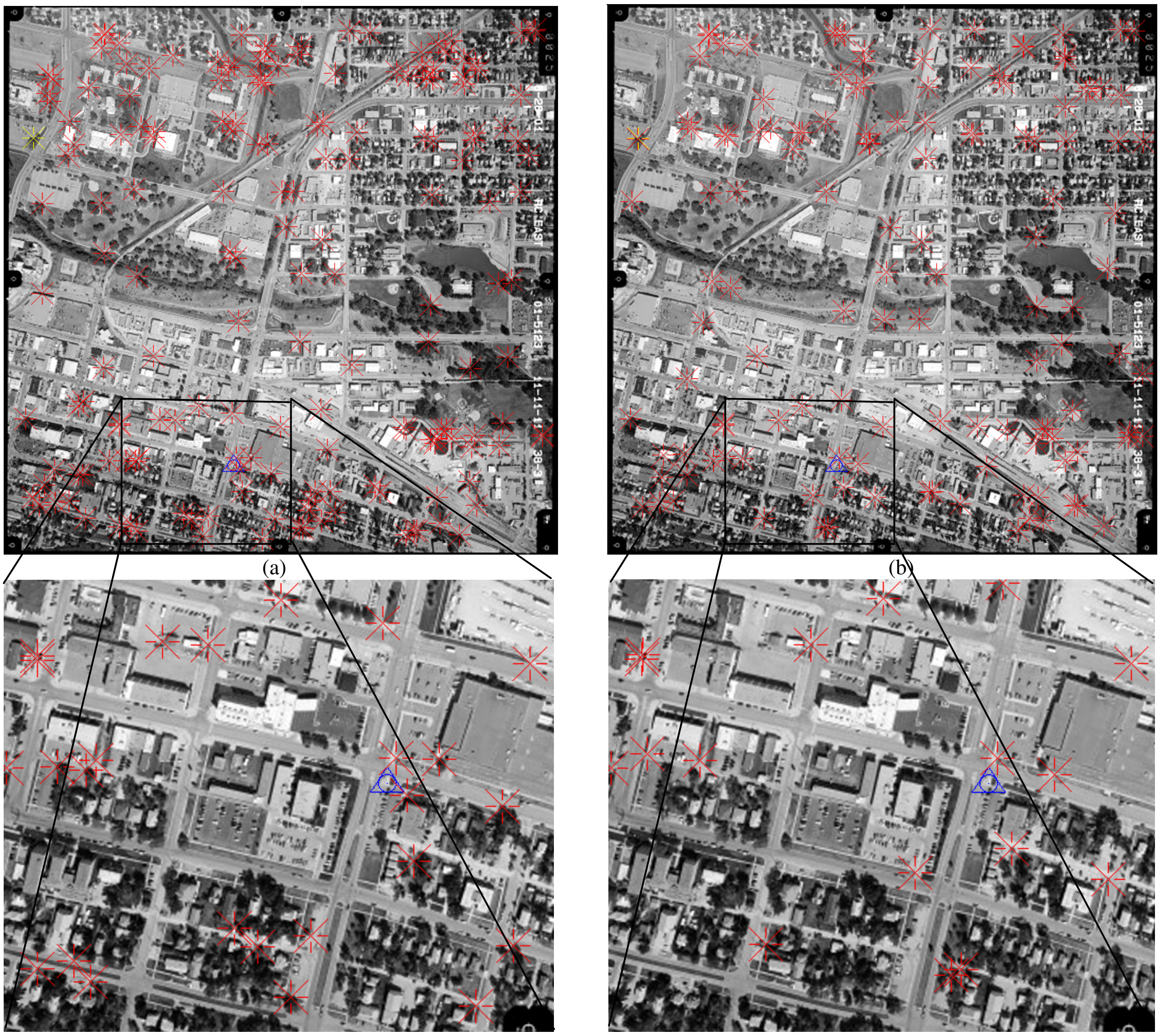


Figure 5. Automatically generated Tie/Pass Points (a), (c) extracted tie/pass points before removal of shadow points, (b), (d) extracted tie/pass points after removal of shadow points

A visual check of the generated tie/pass points by ISAT reveals that more than 80% shadow/tree points were removed in this project. About 20% non-shadow points were treated as shadow points and removed incorrectly. But the algorithm created some other tie/pass points automatically to replace them and there is no effect to the final results of bundle adjustment. Figure 6 shows the distribution of tie/pass points generated by ISAT before and after removal of shadow points. It can be seen that plenty of well-distributed tie/pass points were generated after removal of shadow points although the total number of tie/pass points is reduced slightly.

4. CONCLUSIONS

In automatic triangulation, generation of good tie/pass points is crucial to the final results of bundle adjustment. The existence of shadow points may reduce the accuracy and reliability of triangulation, especially when the block is very large, the sun azimuth is large or photos are taken in bad weather conditions. In this paper, a new method based on the properties of shadow points is presented. The method detects shadow points in two steps. First, it produces the candidates of shadow points by checking the image gradient and then determines shadow points by checking slope change in a local area around the selected candidates. The test results have shown that shadow points can be removed effectively by the proposed approach during automatic generation of tie/pass points.

REFERENCES

Amhar, F., J. Josef and C. Ries (1998). The generation of true orthphotos using a 3D building model in conjunction with a conventional DTM. *International Archives of Photogrammetry and Remote Sensing*, 32(part 4): pp. 16-22.

Förstner, W. and E. Gülch (1987). A fast operator for detection and precise location of distinct points, corners and centres of circular features. In: *Proceeding of Intercommission Workshop on Fast Processing of Photogrammetric Data*, Interlaken, Switzerland, pp. 281-305.

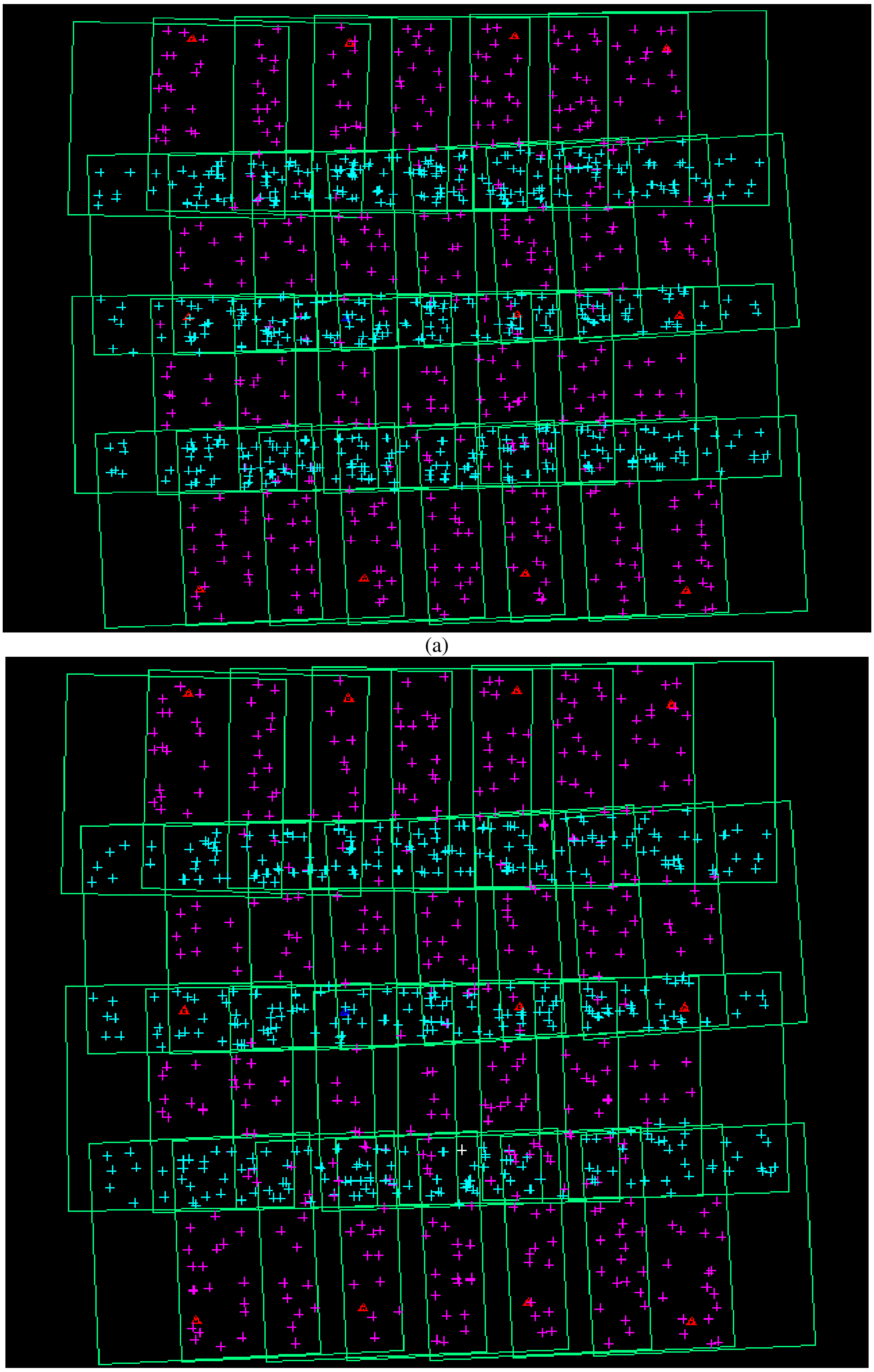
Gong P., X. Mei, G. Biging and Z. Zhang (2002). Improvement of an oak canopy model extracted from digital photogrammetry

. *Photogrammetric Engineering and Remote Sensing*, Vol. 68, No. 919-924.

Madani, M., C. Dörstel, W. Zeitler and L. Tang (2001). Z/I Imaging's new automatic aerial triangulation system. In: *Proceedings of 2001 Annual Conference of American Society of Photogrammetry and Remote Sensing*, (CD ROM).

Rau, J., N. Chen and L. Chen (2002). True orthophoto generation of built-up areas using multi-view images. *Photogrammetric Engineering and Remote Sensing*, Vol. 68, No. 6, 581-588.

Tang, L., J. Braun and R. Debitsch (1997). Automatic triangulation – concept, realization and results. *ISPRS Journal of Photogrammetry &Rremote Sensing*, **52** (1997) 122-131.



(a)

(b)

Figure 6. Distribution of Automatically Generated Tie Points Before and After Removal of Shadow Points (+ represents pass points within strips, + denotes tie points cross strips) (a) before removal of shadow points, (b) after removal of shadow points