Archives of Photogrammetry, Cartography and Remote Sensing, Vol. 22, 2011, pp. 285-296
ISSN 2083-2214

EVALUATION OF SEQUENTIAL IMAGES FOR PHOTOGRAMMETRICALLY POINT DETERMINATION

Michał Kowalczyk [1]

[1] Department of Photogrammetry Remote Sensing and Spatial Information Systems
Faculty of Geodesy and Cartography, Warsaw University of Technology
Pl. Politechniki 1, 00-661 Warszawa, Poland
mikowalczyk@wp.pl

KEYWORDS: Close Range Photogrammetry, Image Matching, Sequential Images

ABSTRACT: Close range photogrammetry encounters many problems with reconstruction of objects three-dimensional shape. Relative orientation parameters of taken photos makes usually key role leading to right solution of this problem. Automation of technology process is hardly performed due to recorded scene complexity and configuration of camera positions. This configuration makes the process of joining photos into one set usually impossible automatically.
Application of camcorder is the solution widely proposed in literature for support in 3D models creation. Main advantages of this tool are connected with large number of recorded images and camera positions. Exterior orientation changes barely between two neighboring frames. Those features of film sequence gives possibilities for creating models with basic algorithms, working faster and more robust, than with remotely taken photos.
The first part of this paper presents results of experiments determining interior orientation parameters of some sets of frames, presenting three-dimensional test field. This section describes calibration repeatability of film frames taken from camcorder. It is important due to stability of interior camera geometric parameters. Parametric model of systematical errors was applied for correcting images. Afterwards a short film of the same test field had been taken for determination of check points group. This part has been done for controlling purposes of camera application in measurement tasks.
Finally there are presented some results of experiments which compare determination of recorded object points in 3D space. In common digital photogrammetry, where separate photos are used, first levels of image pyramids are taken to connect with feature based matching. This complicated process creates a lot of emergencies, which can produce false detections of image similarities. In case of digital film camera, authors of publications avoid this dangerous step, going straightly to area based matching, aiming high degree of similarity for two corresponding film frames.
First approximation, in establishing connections between photos, comes from whole image distance. This image distance method can work with more than just two dimensions of translation vector. Scale and angles are also used for improving image matching. This operation creates more similar looking frames where corresponding characteristic points lays close to each other. Procedure searching for pairs of points works faster and more accurately, because analyzed areas can be reduced. Another proposed solution comes from image created by adding differences between particular frames, gives more rough results, but works much faster than standard matching.

1. ACCURACY AND REPEATABILITY

1.1 Interior Orientation Determination

First experiments have been performed for checking of repeatability of the interior orientation parameters. This is important due to accuracy of results and overall camera rating for photogrammetric applications. Digital film camera, used in this task, had a feature, which allowed for stabilizing of a camera constant, by avoiding movement of zoom and focusing at constant distance. 3D test field, used for this analysis, consisted of 52 points placed as small cylinders with different heights on flat plate, made of stable steel (figure 1). Coordinates of signalized points had been determined with accuracy of about 0.2 mm by special coordinate device. Computations have been accomplished for each image frame separately, basing on collinearity rule. Presented task aimed for determination of principal point of auto collimation, camera constant, radial, tangential distortion and affine factors. Recorded footage had images consisted of 1920x1080i pixels, with registration of odd end even numbered rows separately. Figures 2 and 3 present results of this experiment. All measurements have been performed with accuracy about ±1 pixel in image coordinate system.

Fig. 1. Reference 3D test field

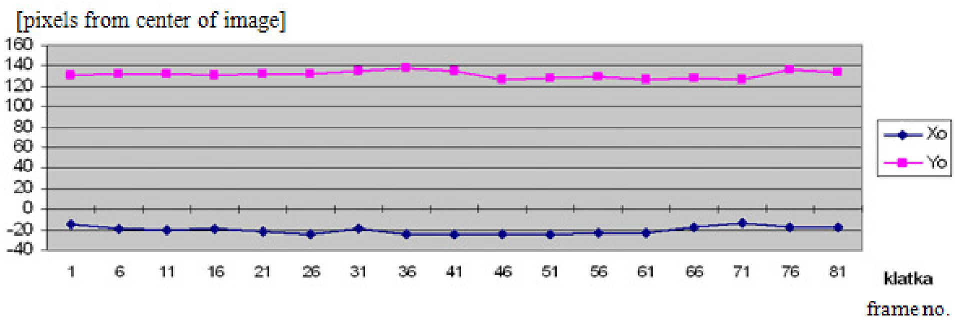


Fig. 2. Results for principal point of auto collimation determination

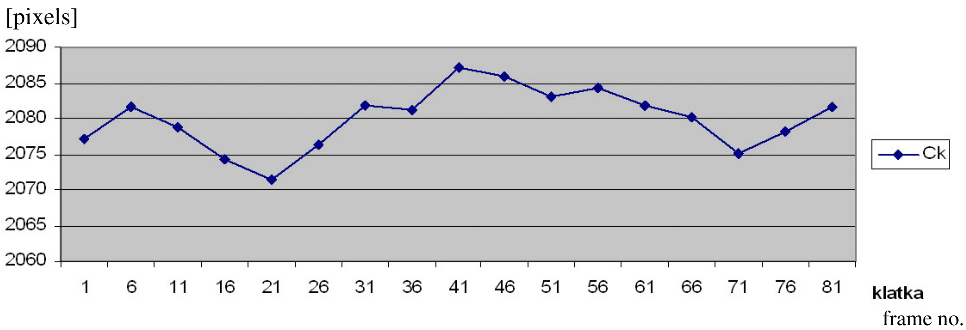


Fig. 3. Results for camera constant determination taken from different film frames

As shown in figures 2 and 3 repetitiveness of principal point determination reaches about ±1.9% in comparison to vertical frame dimension, and camera constant about ±0.8% in relation to its value. During registration of the successive frames the camera was positioned horizontally on small wheel toy vehicle.

1.2 Spatial Intersection

The same frames of film were applied for determination of three dimensional coordinates of the test points. Some of them were used as the reference control points and remaining ones as the check points. Camera positions are presented in figure 4. Base length to object distance ratio approximated 1/52 for neighboring frames. The distance between the camera stations and the object amounted to about 1.250 m, while base length for the successive centers of projection was about 24 mm.

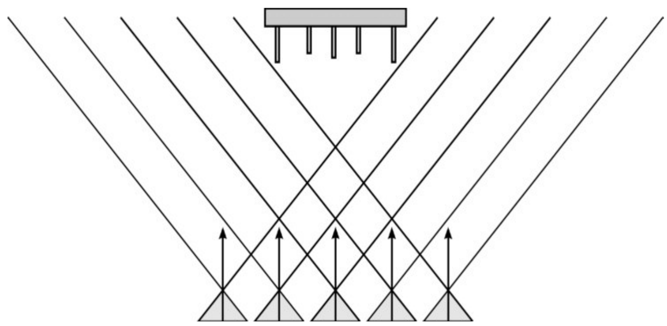


Fig. 4. Camera positions in respect to test field

The experiment included several combinations of images which have been used for the final adjustment. The sets of images, which included from 2 to 12 frames, with base to distance ratio accounted from 1/52 to ¼, gave mean deviations for check points from 0.8 mm to 1.3 mm for X,Y, and from 5.4 mm to 9.6 mm for Z (figures 5 and 6).

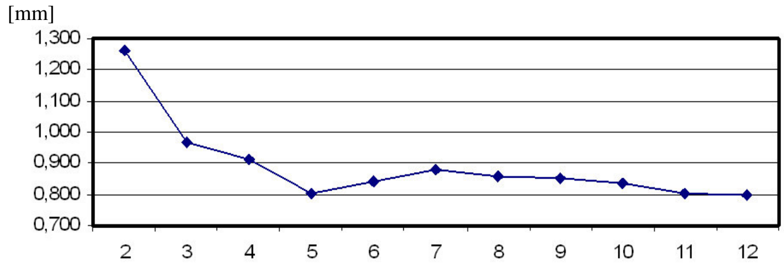


Fig. 5. Mean deviation in plane XY for check points

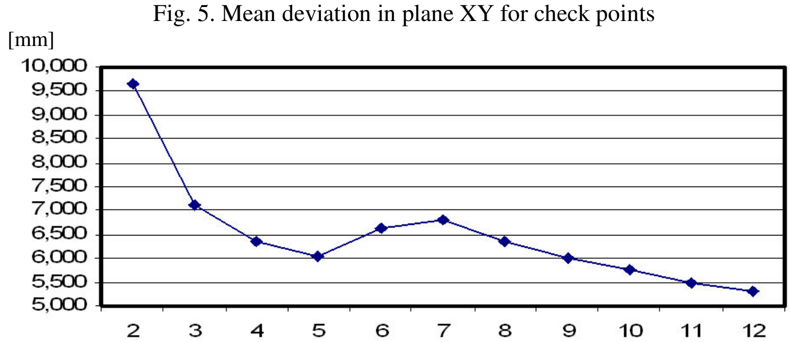


Fig. 6. Mean deviation in coordinate Z for check points

As we can see in these figures, accuracy of XY and Z determination, stabilizes when 5 frames are used. Base length to object distance ratio has value about 1/13 in this case. Decrease of Z determination is caused by relatively small value of B/D ratio and also by stability of camera constant.

Interior orientation and check points determination with many variants of frames configuration, had been performed as part of a master degree diploma work written by Daniel Wiszowaty at Warsaw University of Technology. Used software included Image Station Digital Mensuration, made by Intergraph, Kalib and locally made programs.

2. AUTOMATION OF MODEL EXTRACTION

Main goal which digital photogrammetry can reach is full automation of technology process. Moreover comparing to other geodetic approaches, digital photos deliver a lot of possibilities. As opposed to the conventional photogrammetric technologies, where the photos are taken from distant stations of camera, in case of the sequential film images, the successive frames have similar locations of perspective centers, and therefore can be potentially utilized in very simply way. Similar geometry of images allows applying not complicated procedures for their connection, which are supposed to be fast and robust.

On base of literature review concerning this topic, it has been found, that the following procedures were usually used by other authors: filtering images, finding characteristic points, creating pairs from corresponding points, making model from detected pairs and finally producing dense model. Such approach has some weaknesses, like for example creating pairs of points correctly.

2.1 Characteristic points for joining photos

Searching for characteristic points is described in many publications as common solution for connecting different photos. This is realized by well known operators like SUSAN lately SIFT (Scale Invariant Feature Transform) and SURF (Speeded Up Robust Features). Experience in this domain is systematically increasing. Methods became faster and more robust than at the beginning. In figure 7 the example of characteristic point detection for two frames from digital film sequence is presented.

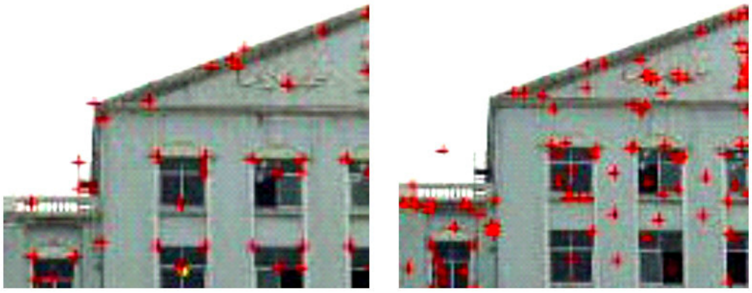


Fig. 7. Detected characteristic points in two corresponding images (Ding *et al.* 2008)

Figure 8 presents detection of more complicated features like lines. As shown, there are many disparities which probably lead to improperly tied point pairs. Problem occurs especially when frames differ because of some unnecessary objects (for example cars). Process of joining point pairs is usually based on FBM (Feature Based Matching) or ABM (Area Based Matching) performed with marked points or lines.

Fig. 8. Detection of points and basic features (Tian *et al.* 2008)

2.2 Creation of photogrammetric model

After selection correctly the point pairs, in the next step the three-dimensional model is created. Information about interior parameters of images is necessary. Each pair has coordinates in model space, taken by previously determined relative orientation parameters of corresponding images. Robustness of this process is improved by RANSAC (RANdom

SAmple Consensus) procedure (Fischler *et al.* 1981), which chooses and checks right configuration of points for stability of adjustment.

This model has geometrical conditions for setting up search lines for the remaining points in images. These points densify model to make surface around the whole stereogram. Usually to reach high accuracy, there is applied subpixel measurement, or images are oversampled and called super resolution images (Gerke 2008). These techniques allow reaching better accuracy for point determination (fig. 9), which descends along with distance from camera positions.

Horizontal lines in figure 17 b represent results of Z distance allocation for integer values of coordinates measured in image space, where subpixel measurement hasn't been performed. This is the reason why this kind of complicated calculations should be done for getting satisfactory results. In case of sequence images improvement can also be attained by using multiple images and accordingly better conditions of spatial intersection.

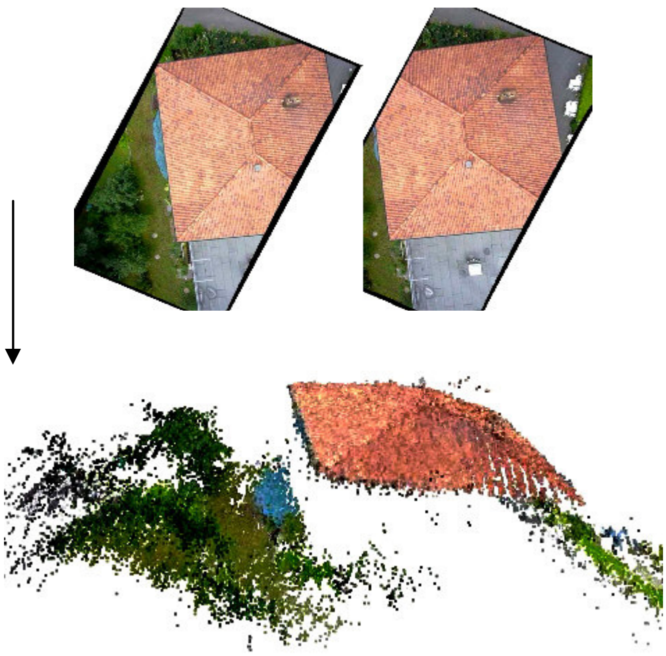


Fig. 9. Model created from two oversampled images (Gerke 2008)

2.3 Initial image shift

First step of joining images in sequence has key role for any further performed determinations. This is the vector of translation between two neighboring frames. Better and more robust way to attain it, is working on whole image than groups of points.

Common solution is delivered by image pyramid. Matching works fine, but time of computations, especially for small computers can be unacceptable. In case of disparities in images, when detected points do not fit for both images from stereogram, ABM made for whole image can save technology process. Certainly it is applied for one of the higher levels from image pyramid.

2.3.1 Many degrees of freedom: Proposed calculations are connected with increasing degree of freedom for second image. That is beside translation in three-dimensional space also three angles around three axes like those for relative orientation (figure 10).

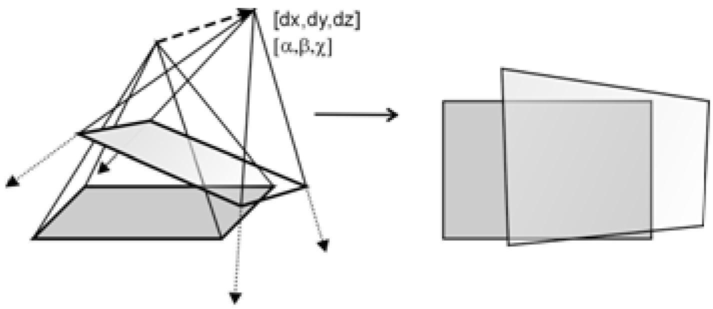


Fig. 10. Proposed movement of second image of pair for determination image distance in ABM

This operation brings second image much closer to first one comparing to translation applied only. Approximation of image regions from both frames is better and more useful for further actions.

In this experiment the film taken from hand held camera while walking is assumed. The results present robustness of this method also for images taken with remote camera positions (not neighboring). In this procedure, while going through levels of image pyramids, the image shift map for each pixel is generated. This map is presented in figures 11 and 12 separately for horizontal and vertical displacement.

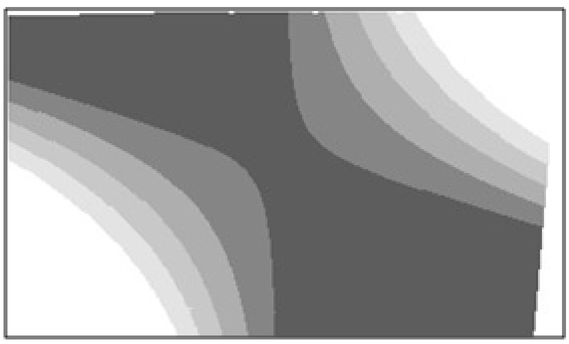


Fig. 11. Horizontal shift between images, brightness shows value of displacement.

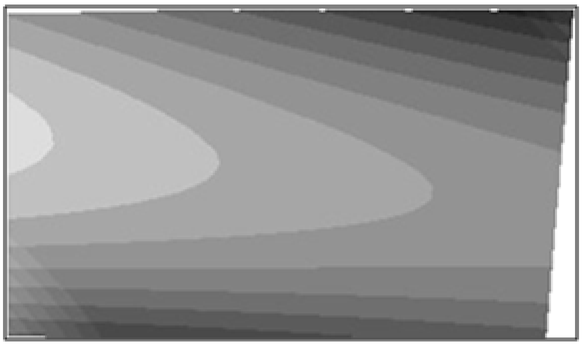


Fig. 12. Vertical shift between images, brightness shows value of displacement.

Afterwards the set of characteristic points for both images is generated. They are linked together. Figure 13 shows effectiveness of image joining without previously performed approximation of image projection.

Fig. 13. Image linking without initial approximation of image shift

There are some point disparities which can cause problems with model generation. For comparison, in figure 14 the results with application of initial approximation of image movement are demonstrated.

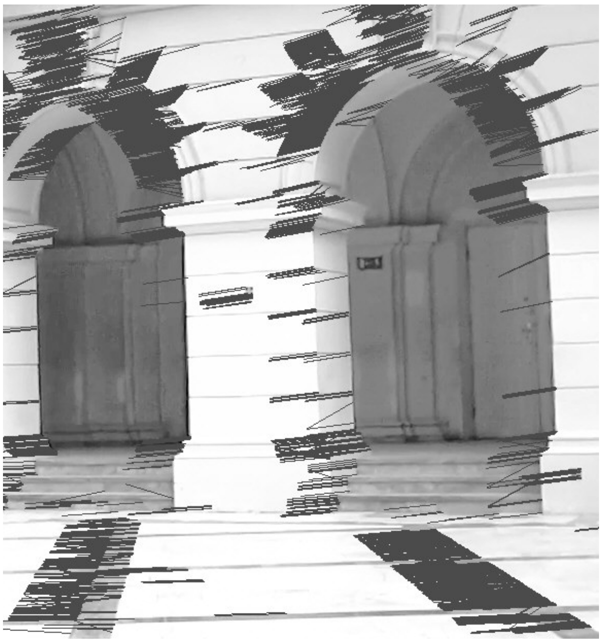


Fig. 14. Image linking with performed initial approximation of image shift

As can be observed, there is a large improvement in stabilization of point pairs detection after initial preparation. Unfortunately and certainly in this second case calculations are much more time consuming.

2.3.2 Many images: Next experiment has been undertaken with assumption that camera moves along an object, the images are taken perpendicularly to trajectory and parallel to each other, like in figure 4. Initially vector of shift between images is determined from large group of frames. Procedure takes advantage from image created by combination of several frames (fig. 16). The office building presented in figure 15 has been recorded from a tram.

Fig. 15. Object recorded from a tram.

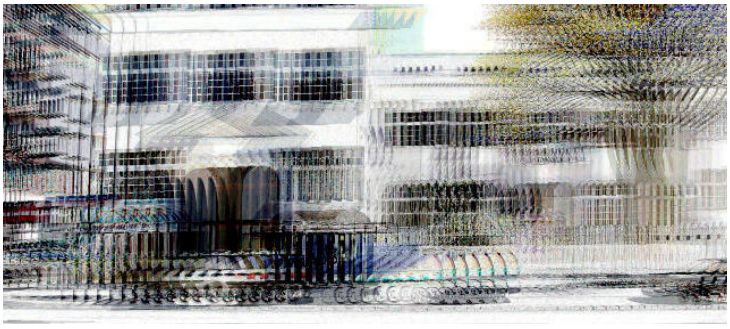
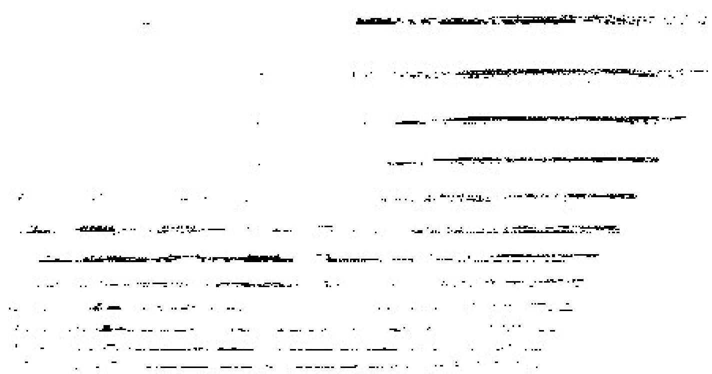


Fig. 16. Image created by combination of frames

First model has been created from just two frames lied next to each other in film footage. Figure 17 clearly shows that accuracy is limited due to the distance between each part of the object and center of projection.

a)

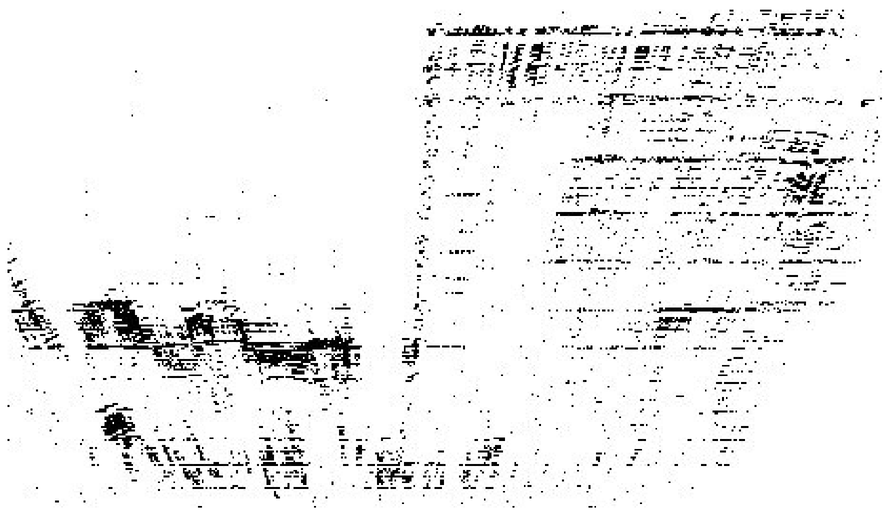


b)

Fig 17. 3D model created from two, nearly located, camera positions.
a) View from front, b) View from top

Second model was prepared with seven images (fig. 18). Possibly accuracy along Z axis has been improved after increasing parameters of spatial intersection. The tree in right part of the model has been reduced, which gives chance for elevation of the building represented more precisely.

a)



b)

Fig. 18. 3D model created from seven camera positions. a) View from front, b) View from top

The results represent good basis for preparation of dense 3D model. However, still large number of wrongly recognized points should be eliminated.

Second part of experiments, connected with image matching and researching into right point determination, has been realized with Delphi compiler by author.

3. CONCLUSIONS AND FURTHER WORK

Summarizing results of the presented experiments give the evidence of a great potential of the camera registering digital film. Instead of low resolution in comparison to standard photo devices, a large number of observations increases robustness of the technology. Very important for that scope is well performed preparation for creation of 3D model. This task makes search area for corresponding points smaller and more accurate. Further experiments ought to prepare the models with more universal conditions. Elimination of distracting objects like treetops and cars is also a prominent issue.

REFERENCES

Ding Y., Zhang J. Q., 2008, Architectural Scene Rapid Reconstruction Based on Features. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*. Vol. XXXVII. Part B3b. Beijing 2008

Fischler, M, A, Bolles, R, C, 1981: "Random sample consensus: a paradigm for model fitting with applications to image analysis and automated cartography", *Commun. ACM, vol. 24, no. 6, pp. 381-395, June 1981.*

Gerke M., 2008, Dense Image Matching In Airborne Video Sequences. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*. Vol. XXXVII. Part B3b. Beijing 2008

Tian Y., Gerke M., Vosselman G., Zhu Q., 2008, Automatic Edge Matching Across an Image Sequence Based on Reliable Points *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*. Vol. XXXVII. Part B3b. Beijing 2008