# MATCHING OF ARTIFICIAL TARGET POINTS BASED ON SPACE INTERSECTION

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**ABSTRACT:**

Aiming to the fast automatic matching of artificial target points in digital close range photogrammetry, a new matching method basing on two-image space intersection is presented in this paper, thinking over the epipolar line constraint in object space. Firstly, a set of initially matched image points is found by calibrating the shortest distance between two image rays. Secondly, the coordinate of corresponding object point is calculated through two-image space intersection, and these points are grouped according to distances between each other. Finally, eliminate those image points whose coordinate errors are too great and who are in the same image, and find out homologous image points by numbers of image points corresponding with object points. Both experiences prove the advantages of the matching method, which are high speed, high matching quotient and low miss matching quotient. It can also provide precise initial values for the following bundle adjustment.

## 1. INTRODUCTION

In digital industrial photogrammetry, artificial target points with regular geometry Figure are usually used as points to be measured to improve the precision of measurement. Auto matching of artificial target points is one of key techniques in digital industrial photogrammetry. The matching method discussed mostly now is perhaps matching based on epipolar line constraint, which means that homologous points must be on the corresponding epipolar lines (H. -G Maas, 1992; J. Dold and H. -G Maas, 1994; ZHAO Meifang et al., 2003). As known to all, epipolar line constraint is in image plane, in which the three dimension information of object points in object space can't be presented, since the imaging is a projection from the 3D space to a 2D plane (Zhang Zuxun and Zhang Jianqing, 1996; Feng Wenhao, 2002). Therefore, the matching will be difficult if it is carried out based only on the image plane. To improve the matching based on the epipolar line constraint, a new method based on space intersection is presented in the paper.

## 2. PRINCIPLE OF MATCHING

### 2.1 Epipolar line constraint in the object space

From the point of object space, the epipolar line principle can be described as follow: if two image points are homologous, their image rays must intersect each other at one point in object space (Figure 1 a). However, two image rays can't intersect strictly due to the errors of camera, stations and the coordinate measurements of image points, and there is a short distance between them (Figure 1 b). According to this principle, the paper presents a new matching method of artificial target points, which is proved effective. The process calculating coordinates of object point with its corresponding image points is space intersection, so the matching method is called matching of artificial target points based on space intersection.

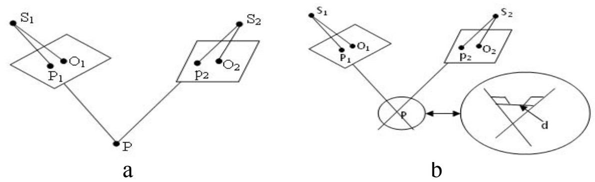


Figure 1. Epipolar line constraint in the object space

### 2.2 Matching of a given image point

The matching of a given image point is a phase-out process. Firstly we get a set of initially matched image points by calculating distances from image rays of target image point to that of image points in other images. Secondly, two images space intersection is carried out with target image point and initially matched image points one by one, and a set of potential object points is obtained at the same time. These object points are then grouped according to distances between each other. Thirdly, calculate corresponding image points coordinates of each potential object points. Eliminate those image points whose coordinate error is too great and who are in the same image. Finally, take statistics of corresponding image point numbers of each object points. The object point with most corresponding image points are the corresponding object point of the given image point, and its corresponding image points are homologous with the given image point.
Threshold values are given in advance:

$\varepsilon_1$ : The maximum distance between two image rays

$\varepsilon_2$ : The maximum distance between two potential object points

$\varepsilon_3$ : The maximum residuals

$\varepsilon_4$ : The maximum distance between two corresponding object points

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$N$ : The minimum number of corresponding image points

The matching is carried out as follow:

(1) Distances from image ray of the given image point $p_0$ to that of image points in other images, which are signed as $d_1$, are calculated one by one. The image points is an initially matched image point if $d_1 < \varepsilon_1$. After this step we get a set of initially matched image points $G(p)$. In Figure 2 we get 10 initially matched image points $p_i$ ( $i = 1, 2, \cdots, 10$ ).

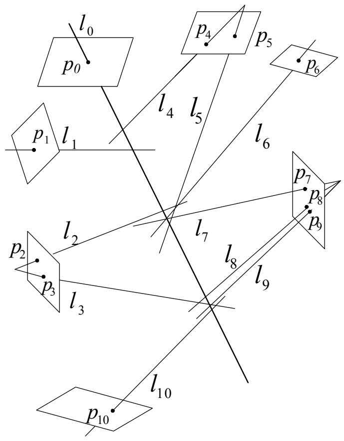



Figure 2. Initially matched image points

(2) Two images space intersection is carried out with the given image point $p_0$ and image points in $G(p)$ one by one, and a set of potential object points is obtained at the same time. In Figure 3 we get 10 object points $P_i$ ( $i = 1, 2, \cdots, 10$ ).

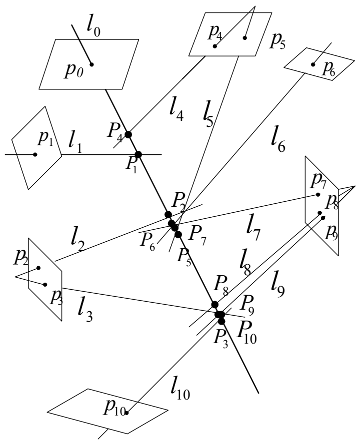



Figure 3. Two images intersection

(3) Distance $d_2$ between each other object points in $G(p)$ is calculated, and they are signed as one if $d_2 < \varepsilon_2$. The set of potential object points after this step is signed as $G(Q)$. In Figure 4 $P_2$ 、$P_5$ 、$P_6$ and $P_7$ are grouped as $Q_1$ , $P_3$ 、$P_8$ 、$P_9$ 、$P_{10}$ are grouped as $Q_2$ .

(4) If two image points corresponding to any point in $G(Q)$ are in the same image, they should be eliminated, and then the number $n$ of image points corresponding to each point is calculated. The object point will be eliminated if $n < N$ , and those rest points are signed $G'(Q)$ . In Figure 5, image points $p_8$ 、 $p_9$ corresponding to $Q_2$ in the same image are eliminated (Figure 5 a). If $N = 3$, object points $P_1$ 、 $P_4$ with 2 image points should be eliminated(Figure 5 b).

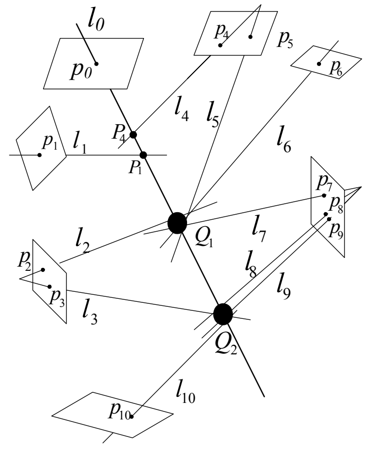
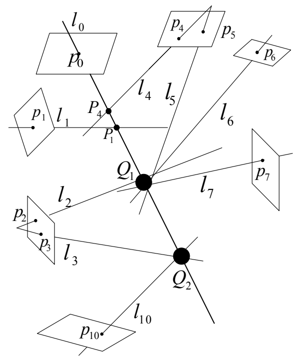
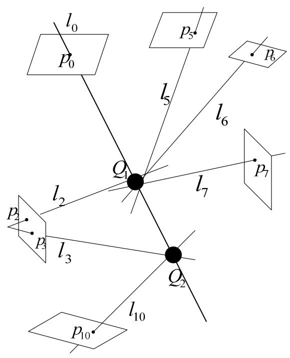



Figure 4. Grouping object points




a




b

Figure 5. Checking image points in the same image

(5)The coordinates of every object points in $G'(Q)$ are calculated by space intersection, and then coordinates and residual error $d_3$ of their corresponding image points are calculated too. The image point should be eliminated if $d_3 > \varepsilon_3$. Similar to step (4), the object point with few image points will be eliminated, and those rest points are signed $G''(Q)$, as showed in Figure 6.

(6) If there is only one point in $G''(Q)$, its corresponding image points are the matching result; else the point with most corresponding image points is selected. If there are 2 (or more) points selected the matching of the given image point is fail. In Figure 6, if $Q_1$ has 4 corresponding image points and $Q_2$ has 3, $Q_1$、$p_5$、$p_6$、$p_7$ are corresponding to $p_0$ (Figure 6 a); Else if both of them have 3 corresponding image points, the matching of $p_0$ is fail.

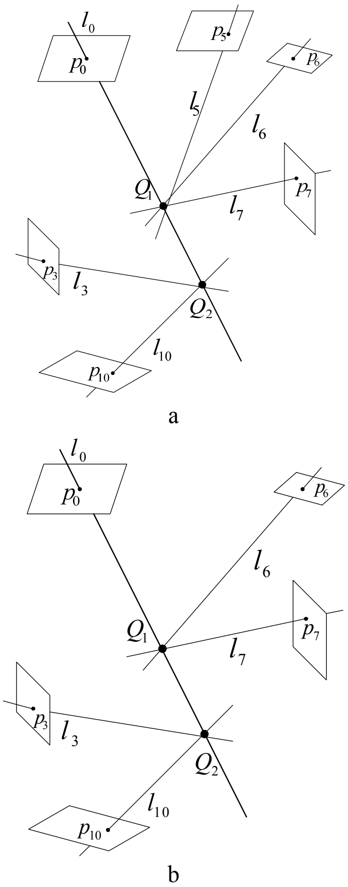



Figure 6. Checking the residual error of image points

### 2.3 Matching in practice

The matching progress above is for one given image points. For the speed and accuracy some problems should be paid attention to in practice.

(1) In practice the numbers of artificial target points and images are both great and image rays crisscross. In this condition, if the initial parameters are not accurate enough, the matching will not be carried out successfully. Therefore, it is essential to match those image points with more correspondence and carry out bundle adjustment with a few matched points to enhance the accuracy of the initial parameters.

(2) The threshold $\varepsilon_1$ could not be set to a great value; else there will be many false image points found. With small $\varepsilon_1$ the image points corresponding to one object point may be matched to several groups, as showed in Figure 7. To solve this problem, the bundle adjustment should be carried out again after the matching, and the distance $d_4$ between every 2 object points is calculated then. If $d_4 < \varepsilon_4$, the 2 object points are merged.

(3) Some corresponding image points may be missed unavoidably due to the limited accuracy of parameters, although it can be enhanced by the bundle adjustment. They should be searched according to the residual error after the last bundle adjustment.

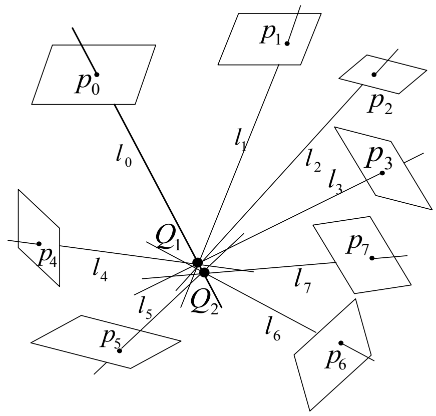


Figure 7. Corresponding image points are divided to several groups

Considering the problems above, the whole matching progress in practice is as follow:

(1) Set thresholds $\varepsilon_1$、$\varepsilon_2$、$\varepsilon_3$、$\varepsilon_4$、$N$ (if there are more than3 images, then $N = 4$; else $N = 3$), and match a few object points. For example, match 10 image points in every image.

(2) Bundle adjustment is carried out with these object points matched to enhance the accuracy of parameters.

(3) Sign the image points matched as unmatched, and match all the image points again.

(4) Bundle adjustment is carried out again.

(5) Search the missed image points corresponding to every object point.

(6) Set $N = 3$, and match the rest image points.

(7) Merge object points according to the threshold $\varepsilon_4$.

## 3. EXPERIMENT AND CONCLUSION

To validate the performance of the matching method based on the space intersection, two experiments with a control frame indoor and a satellite antenna are carried out. The result is showed in table 1.

Statistic in the matching progress is showed in table 2. Figure 8 shows the matching result of 3 images in control frame indoor experiment.

From the result of experiments above it can be concluded:

(1) All of image points in both experiments were matched correctly, which proved that the matching method had a high matching rate and low miss-matching rate.

(2) Less than 30 seconds were consumed by matching more than 7,000 image points, which was quick enough for treating with data in digital industrial photogrammetry on the spot.

(3) The bundle adjustment can enhance the accuracy of parameters and the matching rate effectively, though it costs little time.

(4) Coordinate residual error RMS of image points homologous with matched object points was less than 2 microns(one fifth pixels), thus, these coordinates of matched object points and improved elements of exterior orientation could be used as precise initial value for the following bundle adjustment.

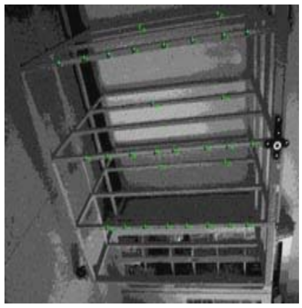
| Statistic | | Control frame indoor | | Satellite antenna | |
|---|---|---|---|---|---|
| | | Data | Result | Data | Result |
| Number of images | | 9 | 9 | 19 | 19 |
| Number of object points | | 30 | 30 | 674 | 674 |
| Number of image | | 269 | 269 | 7084 | 7080 |
| Threshold | $\varepsilon_1(mm)$ | 50 | | 20 | |
| | $\varepsilon_2(mm)$ | 50 | | 20 | |
| | $\varepsilon_3(\mu m)$ | 40 | | 30 | |
| | $\varepsilon_4(mm)$ | 50 | | 20 | |
| Number of rest image points | | 0 | | 4 | |
| Time(*s*) | | 0.41 | | 26.05 | |
| Number of image points mismatched | | 0 | | 0 | |

Table 1. Matching result

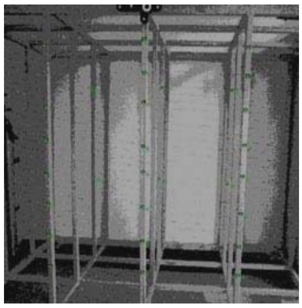
| Experiment | Statistic | Step 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Control frame | Matched image points | 189 | 189 | 267 | 267 | 269 | 269 | 269 |
| | Rms(*um*) | 32.1 | 0.6 | 0.8 | 0.6 | 0.6 | 0.6 | 0.6 |
| | Matched object points | 23 | 23 | 30 | 30 | 30 | 30 | 30 |
| | Time(*s*) | 0.10 | 0.3 | 0.35 | 0.41 | 0.41 | 0.41 | 0.41 |
| Satellite antenna | Matched image points | 467 | 467 | 7032 | 7032 | 7071 | 7080 | 7080 |
| | Rms(*um*) | 12.3 | 1.4 | 3.5 | 1.50 | 1.51 | 1.51 | 1.51 |
| | Matched object points | 56 | 56 | 672 | 672 | 672 | 675 | 674 |
| | Time(*s*) | 4.1 | 4.7 | 20.3 | 25.7 | 25.7 | 25.7 | 26.1 |

Table 2. Statistic in the matching progress

a image 1



b image 2



c image 3

Figure 8. Parts of matching result

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