# AUTOMATIC PHOTO ORIENTATION VIA MATCHING WITH CONTROL PATCHES

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**ABSTRACT:**

Traditional aerial-triangulation has long relied on control points orientating the photo models into a ground-based coordinate system, reducing the distortion effect when tying photos by imperfect photo measurements, and calibrating camera inner parameters. Field surveying preparing for adequate number of control points and manual measurements of the control points afterwards on the photos cost considerably both in labour work and expense. During the past decade, digital photogrammetry by integrating the pros of image processing technique and rapid computation via the computer into photogrammetric discipline has made database-supplied control points as well as the automation of control point measurement truly possible. In this study, we employ the control patches, which have been created in previous photogrammetric projects with each feature point known in the object space as the centre of each patch, serving for the candidates of the control points that are likely to be found in the newly taken photos by utilizing image matching technique. Among others, the successful implementation of the above idea lies in the underlying factors: (1). The quantity and quality of control patches; (2). Predicting the control patches and projecting them onto new photos; (3). Alignment of control patches with respect to the new photos; (4). Generating the equivalent ground elements of control patches versus the new photos for the purpose of correlation; (5). Developing effective matching methods and matching strategy; (6). Refining the exterior orientation parameters. Furthermore, whenever at least three matched control patches succeed in a single photo, it follows that single photo orientation is applicable. The experiments under this work suggest the potential efficiency of automatic control point measurement from control patch database and photo orientation by the proposed workflow.

## 1. INTRODUCTION

Exterior orientation parameters are essential before any three dimensional object information can be photogrammetrically extracted and analyzed for various mapping purposes. Performing aerial triangulation has been commonly accepted as an economic way of fulfilling that goal. Traditional aerial-triangulation has long relied on control points orientating the photo models into a ground-based coordinate system, reducing the distortion effect when tying photos by imperfect measurements, and calibrating camera inner parameters . Field surveying preparing for adequate number of control points and manual measurements of the control points afterwards on the photos cost considerably both in labor work and expense. The advent of digital photogrammetry by integrating the pros of image processing technique and rapid computation via the computer into photogrammertric discipline has made database-supplied control entities as well as the automation of control entity measurements truly possible by utilizing the so-called "Control Entity Database". The realizable and useful control entities consist of point, linear, and area features. The most popularly associated sources that could be utilized in the database include control patch (or chip), vector map, orthophoto, and DTMs. A systematic effort of developing experiments implementing the above control entities can be referred to OEEPE (EUROPEAN ORGANIZATION FOR EXPERIMENTAL PHOTOGRAMMETRIC RESEARCH) test on "Automatic Orientation of Aerial Images on Database Information) which eventually appeared as part of report in official publication No. 36(Kirby, et al., 1999). Profound work in this research are illustrated by: AMOR(Läbe and Ellenbeck, 1996), developed at the Institute of Photogrammetry in university of Bonn, employs 3-D edges, such as 3D-wireframe models of buildings and road features, as ground control performing spatial resection; Perdersen (1999) performed orientation by hierarchical strategy in which road crossings and curve from digital maps are extracted and rasterized as matching templates in the upper pyramid levels, while manholes and drain gratings are searched and matched in the last two levels based on improved orientation parameters; Paszotta (1999) proposed determining exterior orientation parameters by minimizing the similarity measure between the old and new orthoimage generated by a new photo with approximate exterior orientation, obtained as per manual measurement for identifying some points in the old orthoimage onto the new photo, and a current height

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model; Shan (1999) matched orthoimage with new photo, but in an automatic fashion, by feature extraction and matching, and then performs bundle adjustment by integrating DTM data; Höhle(1998) implemented very same idea as Shan by solving exterior orientation with orthoimage and DTM, however, mainly employing road crossings found in the aerial photo and involving some manual measurements if good approximated orientations are intended. Inheriting the very similar idea of employing existing control entities, we try to employ control patches, which have been created in previous photogrammetric projects with each feature point known in the object space as the center of the patch serving for the candidates of the control points that are likely to be found in the newly taken photos by utilizing image matching techniques. Under the condition when more than three control patches are to be successfully matched in a single photo, it follows that single photo resection is applicable which would simplify photo orientation bypassing routine aerial triangulation (Shan, 1999).

## 2. METHODOLOGY

To implement a workable system for the underlying tasks in this study, the following missions must be taken into account:

### 2.1 The quantity and quality of control patches

A database for managing control patches is crucial for that the creating, updating, and utilizing control patches must be highly informative and efficient. The density and distribution of available control patches directly influence the pattern of control in the photos, a geometric factor towards the orientation solution.

### 2.2 Predicting and Projecting Control Patches onto New Photo

Based on the approximation of exterior orientation and ground coverage of photo, searching in the control patch database would lead to pick up the control patches that are likely to be found in the new photo. Back-projecting each control patch candidate onto new photo and evaluate the searching area where the conjugate point is situated.

### 2.3 Alignment of Control Patches

Since the flight direction of new photo is not necessary to be aligned with that of control patch, for fulfilling the requirement of area-based matching where target and searching windows need to be aligned to some extent, one has to check and decide the difference of flight directions between old patch and new photo, then rotate one of them for aligning purpose.

### 2.4 Generating the Equivalent Ground Elements

For satisfying the operational consideration of correlation, the pixels of target and searching window must refer to the same ground size. Therefore, it is a necessity to adjust and assure the equal scale for both windows.

### 2.5 Matching Methods and Matching Strategies

To increase the efficiency and reliability of image matching, the authors combine the normalized cross correlation (NCC) and least-squares matching (LSM) in an algorithmic fashion where NCC performs matching operation in all image pyramids while LSM only works in the highest resolution for achieving more accurate matching results. Furthermore, the matching in the last image level can be confirmed by comparing the NCC matching result with that of LSM.

### 2.6 Refining the Exterior Orientation Parameters

When applying image matching, the extension of searching area heavily depends on the uncertainty of exterior orientation. For too rough approximation of exterior orientation, image pyramids are arranged to ease the computational load by reducing the image scales, namely details. Due to going through degrading the feature significance, the signals in the original control patches may be weakened, leading to failure for image matching. Thus, it is crucial to identify the successfully matched control patches, even just few of them, by using collinearity condition and error detection solving for the orientation. Then based on the improved orientation parameters, if any, the prediction and back-projection of control patches and image matching can be run again with smaller searching area implying less signal degradation and hopefully more successfully matched control patches.

By taking the above six aspects into consideration, we implement a system via the following workflow, shown in figure 1.

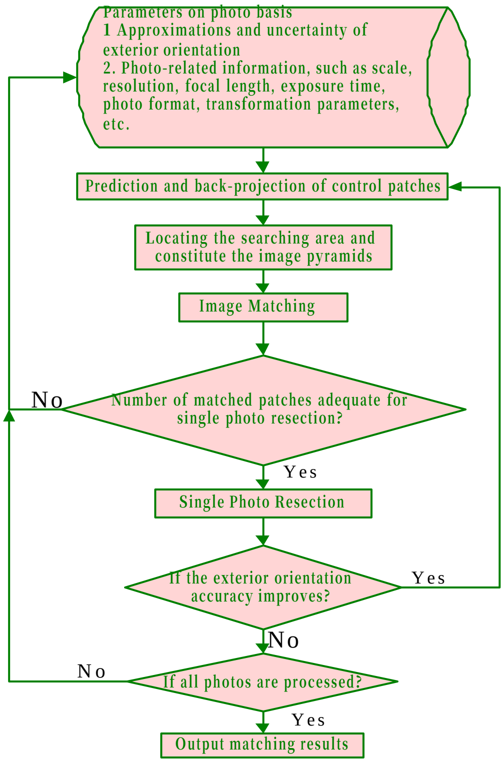


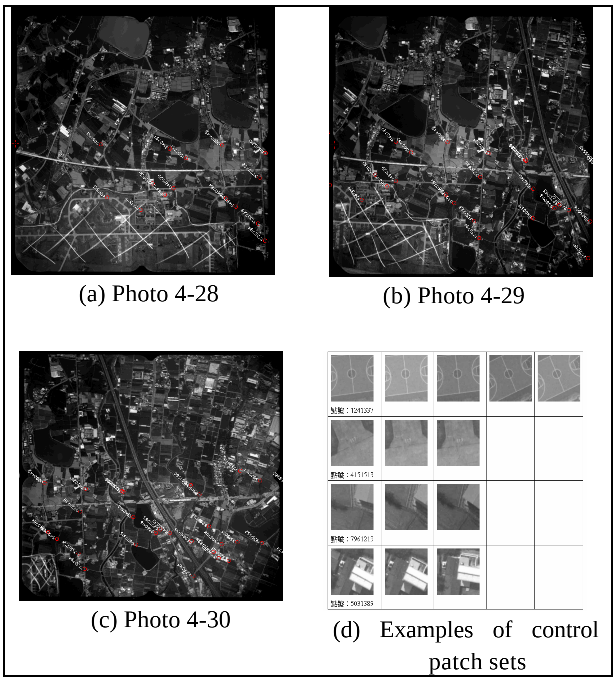

Figure 1. System workflow

## 3. EXPERIMENTS

To illustrate how the proposed workflow is realized in real applications, two photogrammetric cases covering mostly rural area for experimental purposes are chosen and demonstrated as follows :

### 3.1 Case1

Three successive aerial photos, shows as (a),(b), and (c) in figure 2., are treated as new taken photos. On the other hand, within the area covered by above three photos, control patch data sets had been collected from previous photogrammetric missions and saved in control patch database in the system. Part of employed control patch sets can be seen in figure 2.(d) as examples. The configuration of case1 is summarized in table 1.1.



(a) Photo 4-28 (b) Photo 4-29 (c) Photo 4-30 (d) Examples of control patch sets

Figure 2. Photos and examples of control patch in case1

| | Scale | Ground pixel resolution | Exposure date | No. of patch set |
|---|---|---|---|---|
| New photo | 1/10000 | 25cm x 25cm | 2002.10.19 | |
| Control Patch | 1/5000 | 7.5cm x 7.5cm | 2000.06.30 | 38 |

Table 1.1 Configuration of case1

To demonstrate the influence of quality of orientation approximation towards the solution, different sets of initial approximation, from coarse to fine, seen as group1, group3, and group4 in table1.2, have been tested using system workflow but without involving in refining the orientation parameters. On the other hand, with the coarsest approximation in this case, a complete run of proposed system chain, shown as figure 1, has been gone through. The matching results including the successful ratio of matching and relative time cost for all four groups are listed in table1.3. Notice that denominator in table 1.3 indicates the number of total involved control patches while the nominator represents the number of successful matched control patches through cautious visual confirmation in the photo.

| | Group1 | Group2* | Group3 | Group4 |
|---|---|---|---|---|
| Accuracy of position | 10m | 10m | 5m | 1m |
| Accuracy of pose | 3 degree | 3 degree | 1 degree | 1 minute |

Group2* applies refining the exterior orientation while other groups do not.

Table 1.2 Case1: Groups of given exterior orientation

| | Group1 | Group2* | Group3 | Group4 |
|---|---|---|---|---|
| Photo 4-28 | 4/16 | 9/16 | 7/16 | 10/16 |
| Photo 4-29 | 5/24 | 12/24 | 12/24 | 16/24 |
| Photo 4-30 | 5/26 | 14/26 | 11/26 | 14/26 |
| Relative time cost | | 1 | 0.55 | 0.46 |

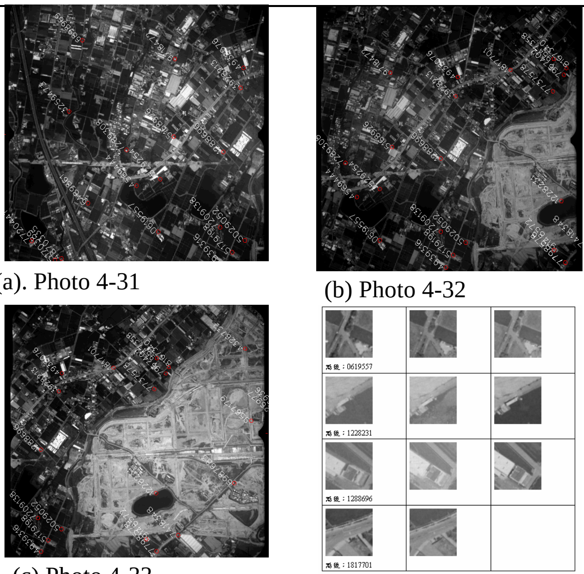
Table 1.3 Case1: Successful ratio of matching (Number of successful matched patches/total involving patches) and time cost

**Analysis:**

1. The matching results, referring to table1.3, reveal that refining the exterior orientation, when applicable, does increase the matching performance by collecting more successfully matched patches, comparing the group1 with group2 in table1.3.
2. The more accurate exterior orientation, the better matching results can be expected, comparing group1, group3, and group4 in table1.3.
3. The failure cases of matching point to several factors including geometric distortion effect, weakened feature due to employing image pyramids, radiometric difference between old and new photos, and scene change(Wu,2003).

### 3.2 Case2

Another three photos taken from the same strip as case1 are matched with different sets of control patches with different scale as those used in case1. The ground pixel size of photo and that of employed control patch are the same in this case, however. The configurations of case2 are summarized in table 2.1.



(a). Photo 4-31 (b) Photo 4-32 (c) Photo 4-33 (d) Examples of control patch sets

Figure 3. Photos and examples of control patch in case2

| | Scale | Ground pixel resolution | Exposure date | No. of patch set |
|---|---|---|---|---|
| New photo | 1/10000 | 25cm x 25cm | 2002.10.19 | |
| Control Patches | 1/10000 | 25cm x 25cm | 2002.07.23 | 39 |

Table 2.1 Configuration of case2

Again, without and with refining orientation parameters along the matching processes are arranged by providing with the same initial approximations, as shown in table2.2, group1 and group, respectively. The matching results regarding the successful ratio are listed in table2.3, while the positioning accuracies checked in the object space via single photo and stereo-pair after solving for orientation are reported in table2.4.

| | Group1 | Group2* |
|---|---|---|
| Accuracy of position | 10m | 10m |
| Accuracy of pose | 3 degree | 3 degree |

Group2* applies refining the exterior orientation while group1 does not.

Table2.2 Case2: Groups of given exterior orientation

| | Group1 | Group2 |
|---|---|---|
| Photo 4-31 | 6/19 | 13/19 |
| Photo 4-32 | 5/21 | 15/21 |
| Photo 4-33 | 4/19 | 14/19 |

Table 2.3 Case2: Successful ratio of matching

| | Horizontal error | Vertical error |
|---|---|---|
| Single Photo | 10~15cm | 15~20cm |
| Stereo pair | 11~13cm | 16cm |

Table 2.4 Case2: Positioning accuracy in the object space

**Analysis:**

1. Comparing group1 with group2 in table2.3, it is confirmed again that refining the exterior orientation parameters does improve the matching performance.
2. Scene change and radiometric difference contribute most of failure cases that disapprove the matching (Wu, 2003).

## 4. CONCLUSIONS AND FUTURE WORK

### 4.1 Conclusions

To conclude this study, we have the following observations about the proposed system:

1. Automation : The proposed workflow performs highly automatic operation by reading into the parameter file and run in a batch fashion until reaching the final output without human intervention.
2. Flexibility : The variations between old and new photos, such as scales, flight direction, can be accommodated by the system and are proven to be reliable.
3. Intelligence: Refining the exterior orientation via matched patches that satisfy the collinearity conditions shows the system with learning mechanism towards better predicting control patches and consequently promoting matching performance.

It is also found that the surface objects like building are not suitable matching candidates due to perspective geometric distortion. In addition, features with thinner texture, such as the end of road lane segment, are not likely to well preserve the original signal strength when going through image pyramids processing. Features of these kind need to be further analyzed with more cautious treatment for being control patches.

### 4.2 Future Work

The further work immediately follows this study would consider testing the matching efficiency in mountainous areas which characterize the topography of Taiwan island. Besides, an interactive system allowing human intervention for providing approximation or checking results whenever necessary may much more secure the whole operation chain.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