MONO-IMAGE INTERSECTION FOR ORTHOIMAGE REVISION

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ABSTRACT

This research addresses the problem of revising existing orthoimages using updated information that are captured from single aerial imagery. The proposed revising approach applies image resection followed by mono-image intersection employing a DEM for the imaged area. The data used in the research experimentation consists of a high resolution aerial image captured recently with the digital aerial camera UltraCam-D, a photogrammetrically generated DEM, and an orthoimage. The image format is 7500 pixels along track by 11500 pixels across track and the pixel size is 9 μm by 9 μm. It has a 10-cm ground sample distance. The DEM and the orthoimage have 1-m and 20-cm ground sample distances, respectively. Fifty four common points, which appear distinctly in both the test image and orthoimage, are selected and measured interactively. They are employed in the image resection, mono-image intersection, as well as accuracy evaluation of the approach. The yielded accuracy figures, which are smaller than the ground sample distance of the orthoimage, confirm its validity for updating orthoimagry.

Keywords: Image Matching, Digital Elevation Model, Orthoimagery, Space Resection, Mono Intersection.

1. INTRODUCTION

Orthoimage is one of the crucial components of geographic information system. An orthoimage is an image that is based on an orthographic projection. They combine the rich information content of images with the geometric properties of maps. Having a digital elevation model (DEM) of the area, orthoimage is created from the perspective image of known exterior orientation parameters through a reprojection process. Both DEM and orthoimage are typically generated in a digital photogrammetric environment [1, 2, 3].

Revision of orthoimages is a fundamental procedure to keep the database of a GIS updated. They have a revision cycle ranging normally from four to five years [5]. For the purpose of their revision, aerial imagery and high-resolution satellite imagery are the most valuable data sources. This is due to the economic and high-quality data they could offer. However, new technologies like laser scanning can help to speed up the revision process [6,7]. Several revision strategies are proposed in the literature. They are based on imagery data as well as data from other sources. However, reaching a high accuracy in the revision process utilizing such data is a main concern.

In this paper, a simple approach of updating orthoimage is presented. It utilizes only a single aerial image and a DEM, regardless of its source. The image provides the feature points required for revision, whereas the DEM enables generating 3-D object coordinates of those points using mono image intersection. Section 2 presents the mathematics and implementation of the approach. Section 3 includes description of the data used and experiments made. Experimentation results are exhibited in Section 4. Finally, conclusions are drawn and an outlook on potential work is given in Section 5.

2. APPROACH

The presented approach points toward revising an existing orthoimage with updated information from a recently-captured aerial image provided that a DEM is available. The approach starts with selecting a number of points that appear in both the image and the orthoimage. The positions of selected points are measured on the image in the pixel coordinate system and transformed into the image coordinate system, centered at the image principal point. The X and Y object coordinates of the points are determined on the orthoimage, whereas the Z coordinates are obtained by interpolating the DEM using an appropriate interpolation technique. Nearest-neighbor interpolation, bilinear interpolation, and bicubic interpolation are the most common techniques in this regard.

The image coordinates as well as the object coordinates of selected points are employed in a space resection process to determine the exterior orientation parameters of the image [4]. The space resection is mathematically based on the well-known model of collinearity, which assumes that the camera perspective center, the image point and corresponding object point are collinear. The formulated collinearity conditions are resolved utilizing least-squares estimation. Precision figures of estimated orientation elements can be extracted from the covariance matrix resulted by the estimation process.

In order to update the orthoimage with new features existing in the recently-captured image, each feature is digitized into a set of discrete points. The object coordinates of each of those image points are to be determined using the available DEM through a mono-intersection process. For a digitized point having x, y image coordinate, their X, Y object coordinates can be determined using the inverse form of collinearity condition equations:

$$X - X_C = (Z - Z_C).\frac{r_{11}(x - x_o) + r_{12}(y - y_o) + r_{13}(-c)}{r_{31}(x - x_o) + r_{32}(y - y_o) + r_{33}(-c)} \quad \ldots\ldots\ldots\ldots\ldots(1)$$

$$Y - Y_C = (Z - Z_C).\frac{r_{21}(x - x_o) + r_{22}(y - y_o) + r_{23}(-c)}{r_{31}(x - x_o) + r_{32}(y - y_o) + r_{33}(-c)} \quad \ldots\ldots\ldots\ldots\ldots(2)$$

where x_o and y_o are the principal point coordinates; c the camera principal distance; X_C, Y_C, Z_C the perspective center coordinates in the object coordinate system; Z is the elevation of the object point; and r_{11}, r_{12}, … r_{33} the elements of rotation matrix, transforming from the image coordinate system to the object coordinate system.

An initial value of the elevation Z of the point is necessary as an input to Equation 1 and 2 to get coarse estimates of its X,Y object coordinates. The average elevation of the terrain of the photographed area can be a valid initial value. Updated Z value is obtained from those coarse estimates by interpolating the DEM. It is then used in the two equations to compute updated X,Y object coordinates. This process is iterated until the differences between two successive values of X,Y estimates are negligible.

In order to assess the accuracy of object coordinates estimated by mono intersection, a check analysis is to be performed employing a set of check points that exist in the orthoimage. At this point, the accuracy is indicated by the root mean square (RMS) of the differences between X,Y object coordinates estimated by mono intersection and their corresponding values determined directly from the orthoimage.

3. EXPERIMENTION

The data used in this research are shown in Figures 1-3. Figure 1 exhibits the test image. It is captured in 2005 with the panchromatic digital aerial camera UltraCam-D from Vexcel Imaging. The image shows part of the baida city that is located in the East North of Libya. The image format is 7500 pixels along track by 11500 pixels across track. Given that the pixel size is 9 μm by 9 μm, the format is 67.5 mm by 103.5 mm. The focal length of the camera lens is 101.400 mm. The flying height is nearly 1700 m and the average elevation of the imaged area is 620 m. This yields a ground sample distance of nearly 10 cm. The elevation range of the area is about 40 m.

The DEM that correspond to the test Image is illustrated in Figure 2. It is generated in a digital photogrammetric environment with 1-m ground sample distance from a strip of digital images including the test image. The orthoimage related to the test image (see Figure 3) has a 20-cm ground sample distance. It is resulted by a digital orthorectification process utilizing the DEM of Figure 2. This process reduces the geometric distortions of image content due to camera tilt as well as relief displacement.

In order to carry out the experimental work, 54 points are selected interactively in the test image and their image coordinates are measured to a fraction of a pixel. Measured pixel coordinates are converted to the corresponding coordinates in the image coordinate system centered at the principal point. Those points are also identified in the orthoimage and their X,Y coordinates are determined consequently, whereas the Z coordinates are interpolated from the DEM using the nearest neighbor interpolation.

A number of 22 points, out of the selected points, are utilized as control points (see Figure 4) in a space resection process to resolve the exterior orientation parameters of the test image. The other 32 points (see Figure 5) are employed as check points in a check point analysis for the accuracy assessment of the approach. The process of mono-image intersection is performed for the control as well as the check points utilizing the exterior orientation parameters estimated by the resection process. Computations are carried out using prototype programs developed in MATLAB environment.

4. RESULTS

Two computation phases are carried out in this research; space resection and mono-image intersection. Regarding the first phase, the estimated standard error of unit weight (σ_o) is 5.8 μm. It is an indication to the global precision of the resection process. Table 1 lists the standard errors of estimated exterior orientation parameters resulted by the space resection.

Results of the second computation phase are the coordinates of control and check points as computed from their measured image coordinates and the orientation parameters estimated in the first phase. Table 2 gives statistics of the absolute differences among control point coordinates found by mono-image intersection and their counterparts derived directly from the orthoimage.

Specifically, the average, RMS, Minimum and maximum of the absolute differences are displayed in the Table.

As presented in Table 2, the values of RMS are 4.5 cm in the *X*-direction and 5.9 cm in the *Y*-direction. They indicate an accuracy of nearly one fourth of the ground sample distance of the orthoimage. The maximum values of the absolute differences are 11.5 cm in the *X*-direction and 12.8 cm in the *Y*-direction, which are equivalent to nearly two thirds of the ground sample distance of the orthoimage. This level of accuracy suggests that interpolating point elevation using nearest neighbor technique is reasonable for mono-image intersection.

Regarding check points, Table 3 shows the statistics of the absolute differences among their coordinates found by mono-image intersection and their corresponding values derived directly from the orthoimage. The listed values of RMS of those differences are 12.1 cm in the *X*-direction and 13.3 cm in the *Y*-direction. This means an accuracy of about two thirds of the ground sample distance of the orthoimage. The maximum values of the absolute differences are 25.3 cm in the *X*-direction and 25.2 cm in the *Y*-direction, which correspond to about one and one fourth of the ground sample distance of the orthoimage. In view of those accuracy figures, mono-image intersection can be utilized satisfactorily for the revision of orthoimages.

Finally, the computed differences, or errors yielded by applying the presented approach, are exhibited graphically in Figure 6. It can be seen from the figure that resulted errors at the check points located near the image borders are larger than the errors obtained at the check points lying close to the image centre.

5. CONCLUSIONS

An approach of revising existing orthoimages is presented. The revision process is based on the availability of recently-captured imagery as well as the related DEM. The approach starts with the computation of exterior orientation parameters of the considered image through space resection utilizing a set of common points in the image and the orthoimage. Next, the object coordinates of image features required for the orthoimage update are found by mono-image intersection. In line with the acquired results, the following conclusions can be drawn:

- Space resection of imagery using object coordinates extracted from the orthoimage and related DEM gives acceptable precision figures.
- Mono-image intersection yields accuracy figures that are within the ground sample distance of the orthoimage to be revised.
- The nearest neighbor interpolation is satisfactory for interpolating point elevations required for mono-image intersection.

- The resection phase of the approach can be executed automatically by generating the common points using an interest operator and matching them employing one of the well-known matching techniques.
- It is suggested to try interpolating point elevations using other techniques for the sake of yielding better accuracy figures.

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Figure 1: The test image

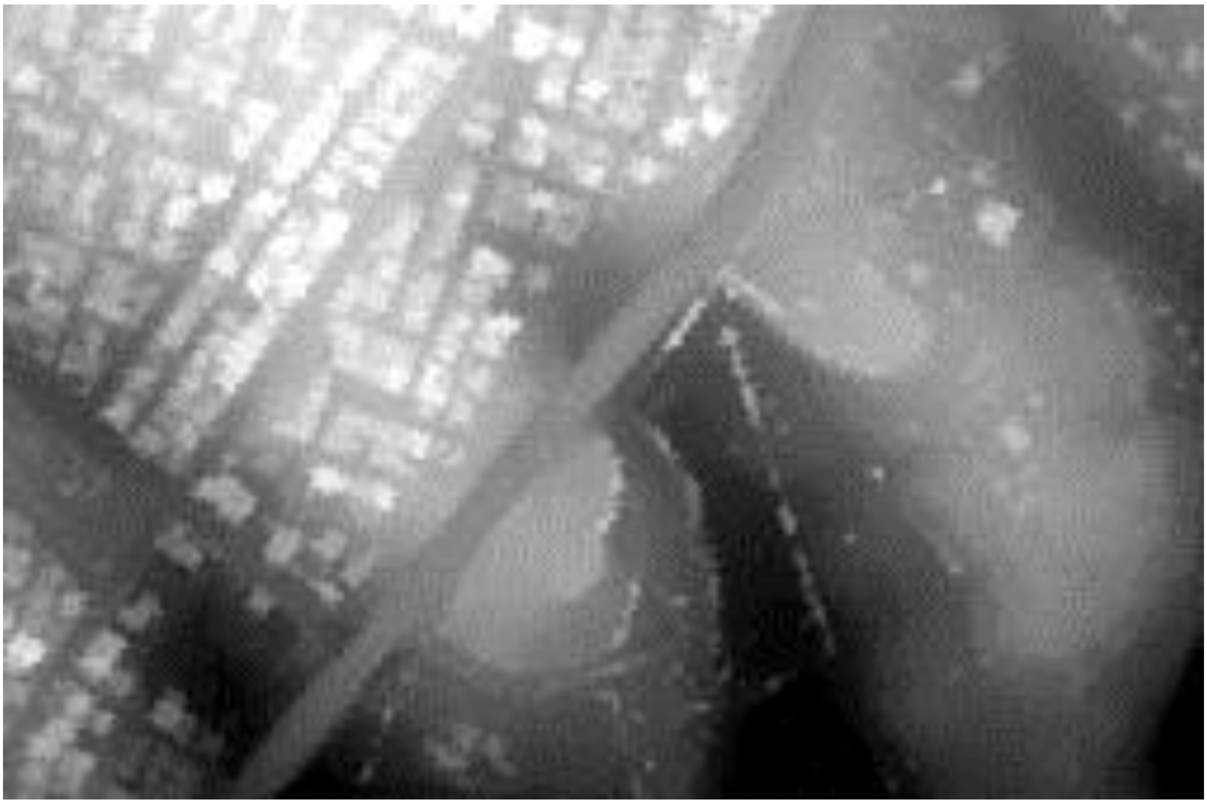

Figure 2: The DEM Corresponding to the Test Image

Figure 3: The Orthoimage Corresponding to the Test Image

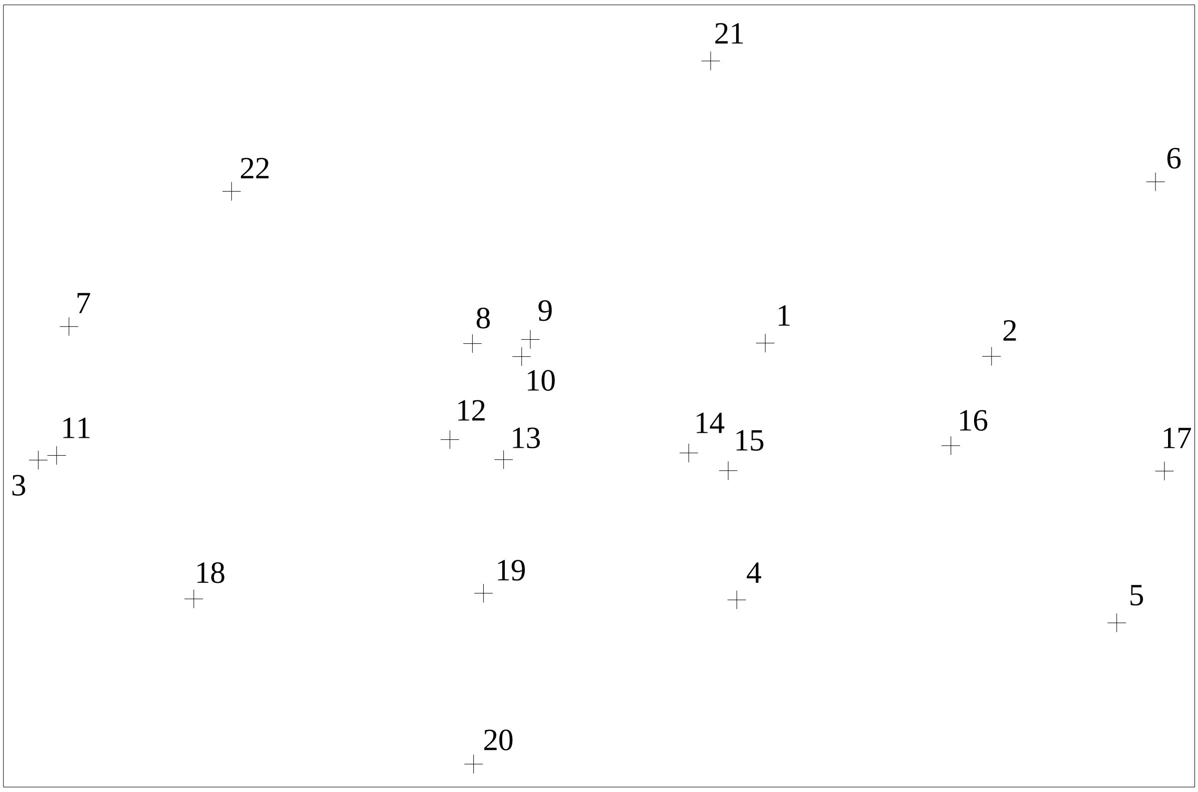

Figure 4: Configuration of Selected Control Points

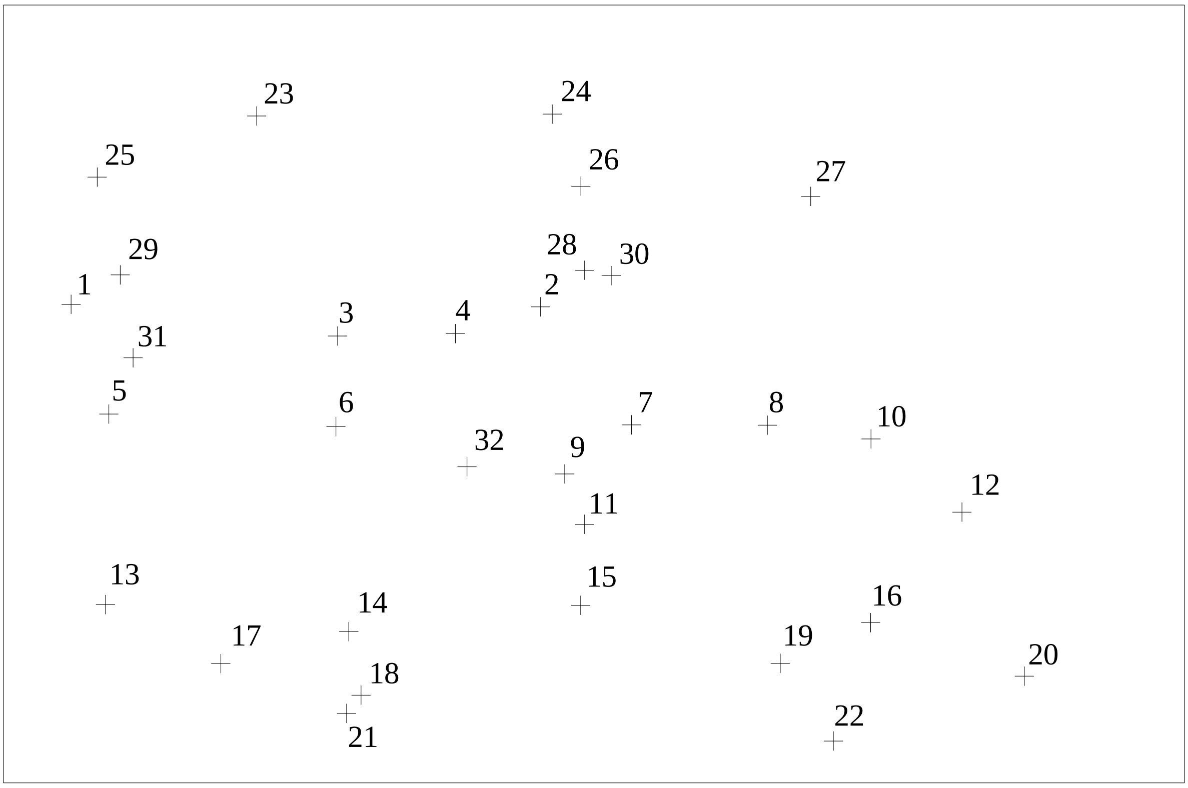

Figure 5: Configuration of Selected Check Points

Table 1: Standard Errors of Estimated Exterior Orientation Parameters

Element	ω	φ	K	X_L	Y_L	Z_L
Std. Error	0.0079	0.0145	0.0020	0.270	0.154	0.037

Units: Degrees for ω, φ, and κ; and meters for X_L, Y_L, and Z_L.

Table 2: Statistics of the Absolute Differences of Control Points

Statistic	ΔX (m)	ΔY (m)
Average	0.037	0.049
RMS	0.045	0.059
Minimum	0.001	0.002
Maximum	0.115	0.128

Table 3: Statistics of the Absolute Differences of Check Points

Statistic	ΔX (m)	ΔY (m)
Average	0.104	0.114
RMS	0.121	0.133
Minimum	0.003	0.004
Maximum	0.253	0.252

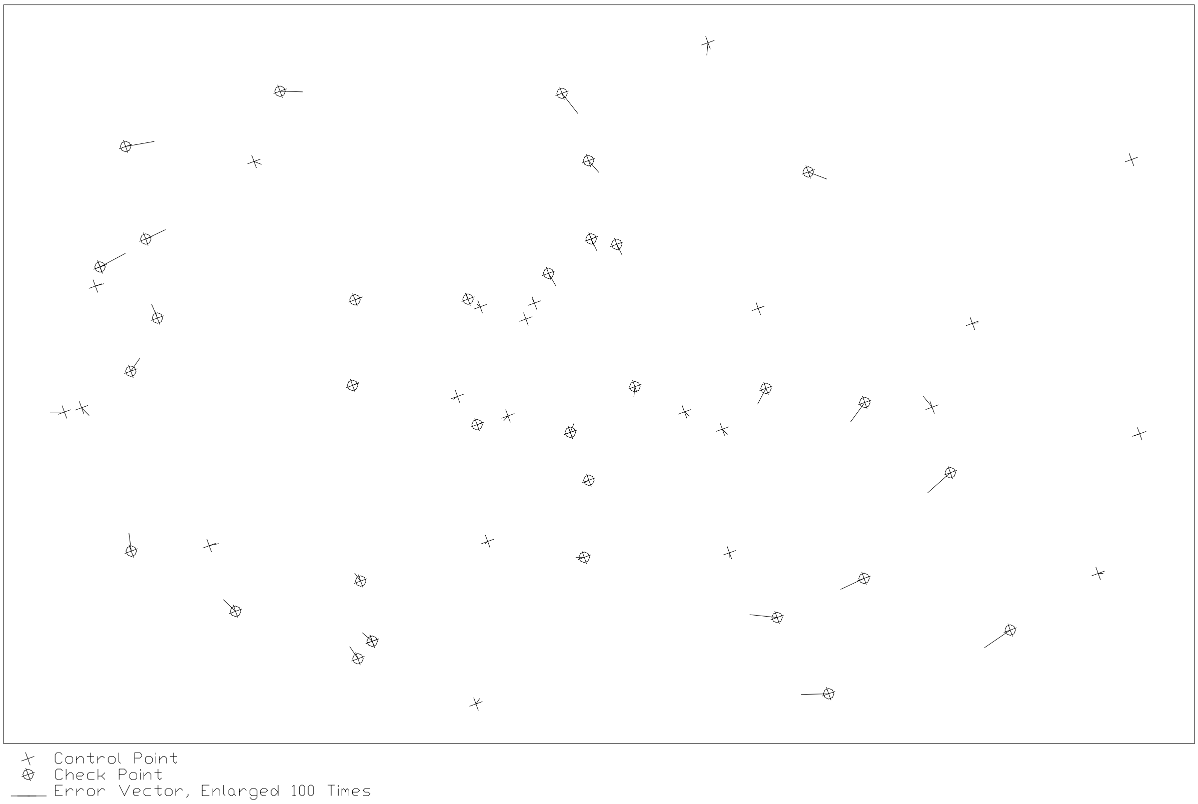

Figure 6: Resulted Differences (Errors) at Control and Check Points