Evaluation of Rapid Semi-Orthorectification of Low Cost Small Format Aerial Photogrammetry

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Abstract

Orthophoto is photogrammetric product which has been widely used for various application. Orthorectification process need cameras' interior orientation parameter (IOP), exterior orientation parameter (EOP) of each photo, and digital terrain model (DTM). Operationally, IOP is obtained using camera calibration, EOP from space resection or aerial triangulation, and DTM data from external sources (for instances: terrestrial survey or LiDAR). This procedure usually is used for metric camera which has very good precision. Unfortunatelly, each stage is independent, so there is a delay between stage.

This paper elaborates rapid processing of semi-orthophoto derived from Low Cost Small Format Aerial Photogrammetry (SFAPm). Semi-orthophoto refers to product of orthorectification which its terrain's height is set to constant. Low cost SFAPm refers to SFAPm technology which utilized non metric digital camera and ultralight aeroplane. Rapid processing refers to bundle 3 stages of orthorectification in one workflow. To compensate of unknown camera's IOP and its stability, in-flight camera calibration is performed. EOP are computed using aerial triangulation. Based on IOP and EOP values, semi-orthorectification can be performed in one workflow.

The result of this research is semi-orthophoto derived from SPAPm and its mosaic. Quality of semi-orthophoto is indicated from its seamless of mosaic. Mosaic of semi-orthophoto of flat area has seamless mosaic, but mosaic semi-orthophotos of mountainous is not seamless. Interpretabilty objects on semi-orthophoto of SPAPm can be done clearly if minimal size of the object is 3 pixels.

Key words: Small Format Aerial Photogrammetry (SFAPm), non metric digital camera, camera calibration, semi-orthophoto, IOP, EOP.

1. INTRODUCTION

Various applications which related to utilization of spatial information, such as construction work, land valuation and development, land use and cadastral, need various large scale map, high spatial resolution satellite image, or aerial photograph. A kind of representation of spatial data which has informative, complete, and reliable accuracy is orthophoto. Orthophoto which has orthogonal projection usually can be used as basic data for mapping work. Unfortunatelly, orthophoto has limited area coverage, so it need to be merge to produce large area coverage.

Small Format Aerial Photogrammetry (SFAPm) is a kind of low cost and rapid mapping technology which can be utilized to produce digital orthophoto. Main characteristic of SFAPm is utilized a non-metric digital camera equipped on an ultralight aeroplane. These equipments are widely available on market.

Utilization of non-metric digital camera causes a potential of large geometric distortion on photo due to imperfect of the lens. It is recognized as instrinsic parameter of the lens, or in photogrammetry community, it is known as interior orientation parameter (IOP). The IOP is obtained using camera calibration.

Utilization of ultralight aeroplane in aerial photography can caused variation of position and orientation of camera in a flight line. In photogrammetry community, position and orientation of camera are known as exterior orientation parameter (EOP). Variation of EOP in a flight line can caused irregular overlap, B/H ratio, and scale variation between successive photos.

2. METHODOLOGY

2.1. Theoretical Background

Orthophoto or orthorectification is a transformation from the central projection of the photograph into an orthogonal view of the ground, thereby removing the distorting effects of tilt and terrain relief (Habib, 2007). In oblique or tilted aerial photograph, relief displacements depend on flying height, distance the point from nadir point, earth curvature, and the terrain (Wolf, 1983). Operationally, orthorectification of aerial photo needs IOP, EOP, and DTM data. IOP is obtained from camera calibration, EOP from space resection or aerial triangulation computation using amount ground control points, and DTM from stereoplotting photos, terrestrial survey, or external sources.

Based on figure 1, relationship between photo coordinate system and ground coordinate system is represented by collinear equation (equation 1).

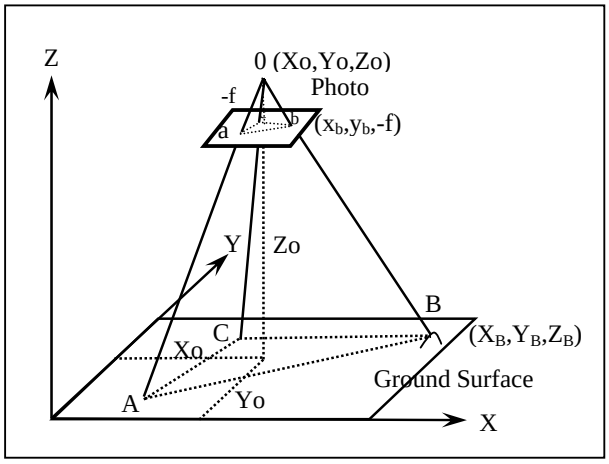

Figure 1. Relationship between photo coordinate system with ground coordinate system.

$$x_i = x_o - f\frac{(r_{11}(X_i - Xo) + r_{21}(Y_i - Yo) + r_{31}(Z_i - Zo)}{(r_{13}(X_i - Xo) + r_{23}(Y_i - Yo) + r_{33}(Z_i - Zo)}$$
$$y_i = y_o - f\frac{(r_{12}(X_i - Xo) + r_{21}(Y_i - Yo) + r_{31}(Z_i - Zo)}{(r_{13}(X_i - Xo) + r_{23}(Y_i - Yo) + r_{33}(Z_i - Zo)} \quad (1)$$

where,

x, y	: photo coordinate system
x_o, y_o	: exposure center in photo coordinate system
f	: length of focus
X, Y, Z	: ground coordinate system
X_o, Y_o, Z_o	: exposure center in ground coordinate system
r_{ij}	: element of matrix rotation

Projection of any pixel on DTM data is utilized to correct relief displacement due to terrain variation. This process causes pixel position is not in right place, so it needs a resampling process. There are 3 methods of resampling, nearest neighbour (NN) interpolation, bilinear interpolation, and cubic convolution. NN interpolation has several superiority, i.e. fast computation and unchanging brightness value of the pixel in the process.

2.2. Data

This research utilized 99 photos which divided into 5 flight paths or runs. Figure 2 shows a block of original SFAPm photos. These photos was acquired using Nixon D2X non-metric digital camera. Study area is located at Central Java, Indonesia. This research also utilized 34 Premark Points as Ground Control Point or GCP which observed using high precision Total Station equipment.

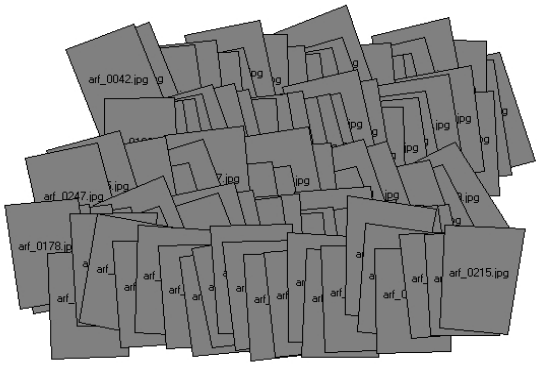

Figure 2. A block of original SFAPm photos

2.3. Research Method

Figure 3 showed flow chart of the research. Research was begun by establishment of premark points on study area. Distribution of premark points were designed well spread entire area. Premark points were located in open space so they could be well identified on photos. Coordinate premark points were determined by Total Station observation. Most of premark points had function as ground control points (GCP) and the rest were set as independent check point (ICP).

Prior to limited study area, aerial photograph was caried out in a day. In the same day, in-flight camera calibration was performed. The process is intended to determine camera IOP. The reason for implementation of in-flight camera calibration was considering characteristic of non metric digital camera which could be lack of stability.

Based on achieved IOP, interior orientation for each photo was performed. Principle of interior orientation was transformation from image coordinate system into photo coordinate system using two dimensional affine transformation. Any instrinsic lens distortions were corrected in this stage.

To determine EOP for each photo, space resection or aerial triangulation was performed. This stage involved identification GCP on photo and determination tie points (TP) on overlap area on adjacent photos. This process could be done automatic or manual. Automatic identification of TP had to be verified manually at the end of the process. Manual identification of TP utilized visual interpretation. This process was accurate, but it was time consuming.

Production of orthophoto needs accurate IOP, EOP, and DTM. But, availability of DTM which appropriate to photo resolution is not easy to be found. So, development of semi-orthophoto was a promising alternative. Semi-orthophoto is a product of orthorectification which DTM is initialled as constant.

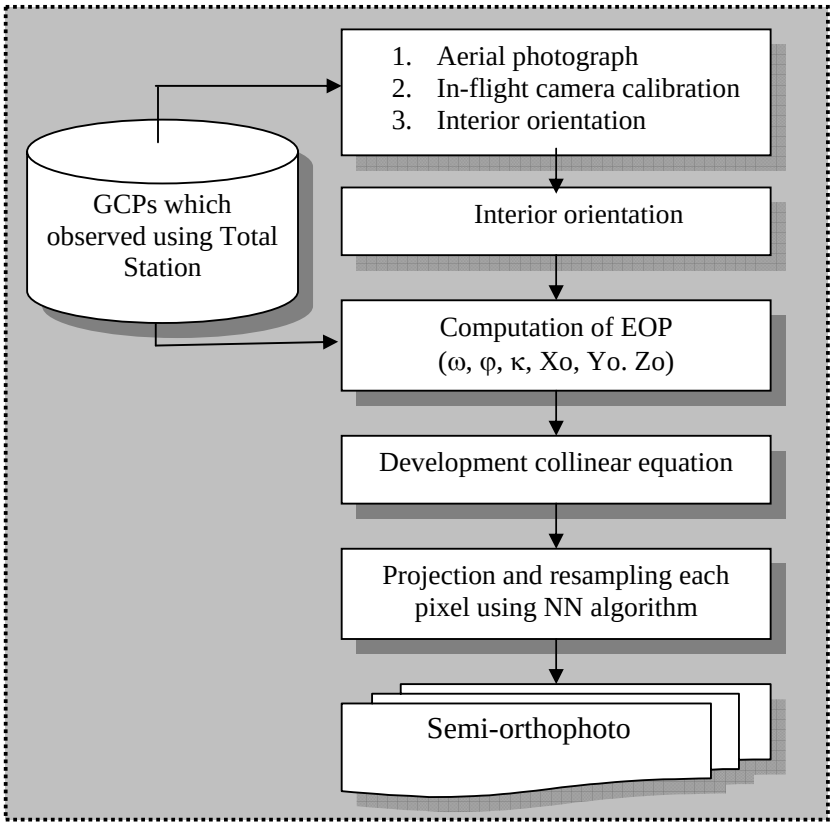

Figure 3. Flow chart of the research.

3. RESULT AND DISCUSSION

Figure 4 shows a block of semi-orthopoto processed from original photos (Figure 2). Height variation and tilt caused by aircraft movement of all original photos have been corrected, so entire semi-orthophotos as seen on Figure 4 have orthogonal projection and become vertical photos. In this process, scaling and rotating have been performed on all photos. As seen on Figure 8, deformation on building (left image) due to tilt has been corrected (right image).

A block of semi-orthopoto is consist of 5 flight paths or runs. First and last flight paths covered mountainous area. Run 1 on Figure 6 is an example of mountainous area. Second, third, and fourth flight paths covered flat area. Run 4 on Figure 7 is an example of flat area.

Mosaic of semi-orthophotos of flat area, as seen on right image on Figure 7, has seamless mosaic. On the contrary, as seen on right image on Figure 6, the semi-orthophotos mosaic is not seamless.

Non-metric digital camera used in this research is Nixon D2x which the effective photo size is 2.845 x 4.288 pixels. The CMOS cell is equal to 5.5 micrometre. Computation shows, 1 pixel of relief displacement on edge photo occurs if terrain variation is vary from 0.5 m to 1.0 m. It is obvious that photo covered mountainous area needs DTM in orthorectification process.

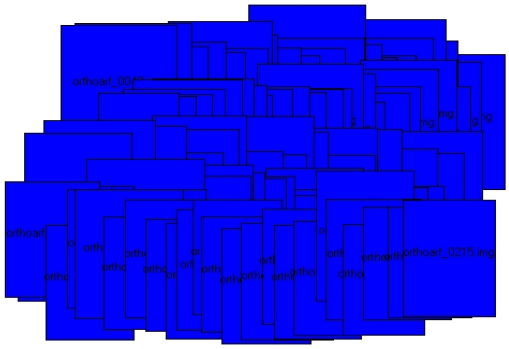

Figure 4. A block of semi-orthophoto

Figure 5. Sample of uncorrected photo (left) and semi-orthophoto extracted (right)

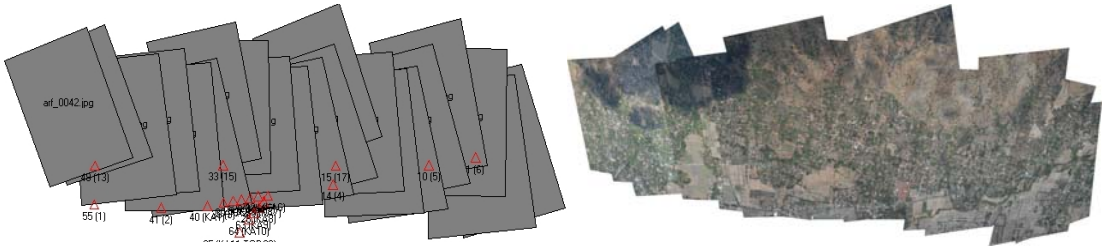

Figure 6. Small format aerial photos in run 1 (left) and the mosaic (right) on mountainous area

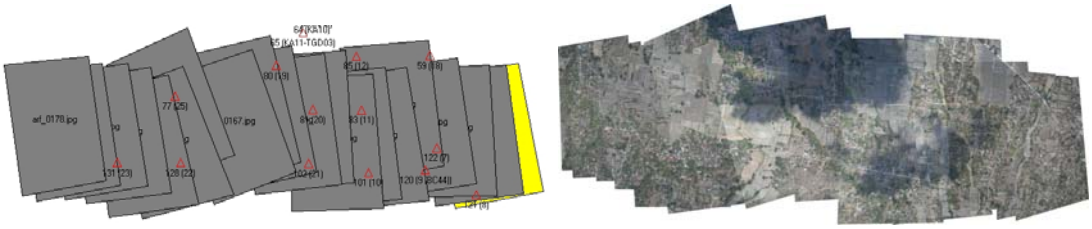

Figure 7. Small format aerial photos in run 4 (left) and the mosaic (right) on flat area

A method to verify geometric condition and quality is overlay mosaic of semi-orthophotos on appropriate DTM data. Good mosaic semi-orthophoto covers DTM data exactly. Figure 8 shows overlay mosaic of semi-orthophoto of run 5 on appropriate DTM data. Exploration into the data can be accomplished virtually. Panning and zooming can be conducted in order to interpret and recognize the objects. Object's identification on the semi-orthophoto will succeed if the minimal size of the expected object is 3 pixels and the photo has good contrast.

Non-metric digital camera Nixon D2x used in this research has 24 mm of lenght of focus and the CMOS size is 5.5 micron. Practically, flying height is about 800 – 1.000 m, so the SFAPm has scale about 1:33.000 - 1:41.000. Based on the scale, accuracy of identification object is about 10 m – 12 m. On the contrary, size of ground sample distance (GSD) is approximately 20 cm, so the zoom is about 50 – 62 times.

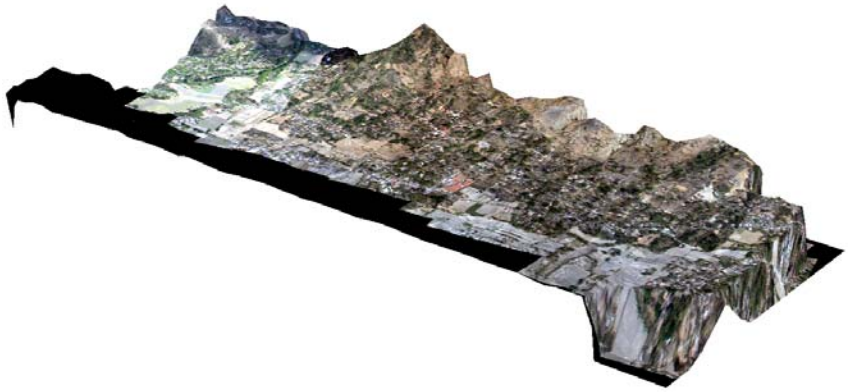

Figure 8. Overlay semi-orthophoto mosaic on DTM data

4. CONCLUSION

From the result of the experiment, it can be concluded that mosaic of semi-orthophoto of flat area has seamless mosaic, but mosaic semi-orthophotos of mountainous is not seamless. Interpretabilty objects on semi-orthophoto of SPAPm can be done clearly if minimal size of the object is 3 pixels.

5. REFERENCES

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