ON OBJECT EXTRACTION USING AIRBORNE LASER SCANNER DATA AND DIGITAL IMAGES FOR 3D MODELLING

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ABSTRACT:

Airborne laser scanners are effective at extracting the micro topography or ground surface under trees, which cannot be detected by aerial photogrammetry, and are suitable for use in many applications, such as city modelling, DTM generation, monitoring electrical power lines, and detection of forest areas. The most remarkable aspect of these systems is their ability to acquire the 3D coordinates of huge object points in real-time. There are many studies on object extraction using point clouds from airborne laser scanner data, where the shape of an object depends on the density of a point. However, this is generally used for rough shapes or fitted geometric shapes. It is difficult to reconstruct detailed object shapes without many edge points, even if high-density point clouds are obtained. On the other hand, it is possible to acquire detailed object edges from digital camera images if the digital camera is equipped with an airborne laser scanner system. The procedures investigated in this paper for improving rough object shapes using airborne laser scanner data are as follows. Firstly, camera calibration is performed to integrate point clouds and digital images by simultaneous adjustment, such as by bundle adjustment with self-calibration using distance data taken directly from airborne laser scanner data. Secondly, the rough 3D object shape is extracted from the point cloud using normal vectors. Moreover, visualization of normal vectors is used for operator interpretation. Thirdly, the rough 3D object shape is converted into the image coordinates of multiple images by a collinearity condition. The 2D coordinates of detailed image shapes are acquired using characteristic image quantities from around the rough shape. Finally, the detailed 3D shape is computed using the spatial intersection of the 2D coordinates of detailed shapes and the orientation parameters. This paper describes fundamental studies for extracting object shapes for 3D modelling using airborne laser scanner data and digital images.

1. INTRODUCTION

Approximately 1200 GPS based control stations have been established by the Geospatial Information Authority of Japan (GSI). This infrastructure was utilized by various fields for the wide area crustal deformation caused by "The 2011 off the Pacific coast of Tohoku Earthquake" which occurred on March 11, 2011. Airborne laser scanner (ALS) systems are also used after disasters for topographic surveys using GPS based control stations. The ALS system has the advantage of acquiring detailed terrain data; however, objects such as buildings are generally represented as rough shapes by the discretely obtained point clouds. There are many studies using images to improve rough shapes. For example, Hu et al. (2004) demonstrated the extraction of buildings from LIDAR data and used edges extracted from high-resolution aerial images to refine laser data model accuracy. This approach is limited to buildings with primitive models. Chen et al. (2005) performed building reconstruction using aerial orthoimages and airborne laser scanner data; however, there were issues with the use and creation of orthoimages.

On the other hand, it is possible to acquire digital images if a digital camera is equipped with an ALS system. The digital camera is almost non-metric and needs camera calibration for accurate three-dimensional measurements. When a non-metric digital camera is used, its interior orientation parameters are generally computed beforehand using a test sheet or test target. However, if the digital camera is operated in severe conditions e.g. high-altitudes and low temperatures, camera calibration should be performed sequentially. The authors have been concentrating on developing a practical 3D measurement system for close range photogrammetry using consumer-grade digital cameras. The Image Based Integrated Measurement (IBIM) system is our photogrammetric system, which uses digital cameras and a hand-held laser distance meter (Nakano and Chikatsu, 2010). The orientation parameters of the triplet images are unknown and the pseudo-GCPs are simultaneously calculated by the collinearity condition, distance condition, and geometric constraint condition. It is possible to integrate point clouds and digital images by applying the concept of the IBIM system to ALS system camera calibration. With this motive, simultaneous adjustments, such as bundle adjustments with self-calibration, are proposed in this paper so that exterior

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orientation parameters obtained from the GNSS/IMU system, distances and 3D object coordinates acquired from the laser scanner, and the interior orientation parameters are simultaneously adjusted. Combined block adjustment orientations were proposed in the late 1900's (Ackermann et al., 1972, EL-Hakim & Faig, 1981, Chikatsu et al., 1988). The proposed adjustment is widely expected to enable the utilization of the airborne laser scanner in generating large-scale maps and efficient aerial photogrammetry should be accomplished, except for geodetic data such as ground control points and aerial triangulation. Therefore, this paper uses calibration of non-metric digital cameras to integrate point clouds and digital images.

The object extraction procedures using ALS data and digital images are performed in three steps.

1) A rough 3D object shape is extracted using a normal vector map that is created from TIN by point clouds. Visualization of normal vectors is useful for operator interpretation.

2) The rough object shapes are converted into multiple image coordinates by a collinearity condition. The 2D shape coordinates of detailed images are acquired using image characteristics from around the rough shape.

3) The detailed 3D shape is computed using the spatial intersection of detailed 2D shape coordinates and orientation parameters.

A flowchart of the object extraction procedure is shown in Figure 1.

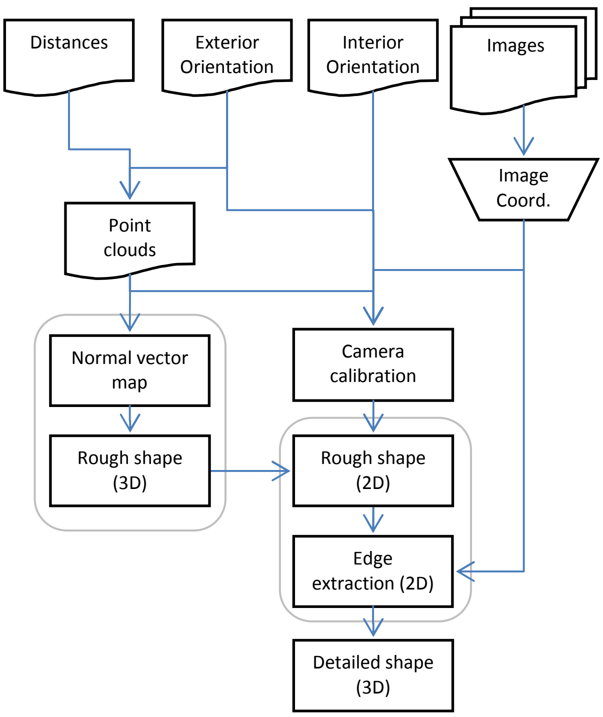

Figure 1. Object extraction flowchart

2. CAMERA CALIBRATION

The authors have been concentrating on developing a close range measurement system for consumer grade digital cameras using triplet images (Chikatsu et al., 2006). The measurement system was adopted into digital aerial photogrammetry in this paper because triplet images have following characteristics.

- Triplet images have advantages in generating stereo pairs.
- Triplet images have the flexibility for multiple images.
- Triplet images have the ability to increase geometric restriction.

Moreover, the IBIM system of the basic camera calibration concept has distance condition characteristics and also uses pseudo ground control points (GCPs), which are virtual points. Figure 2 shows the measurement concept used in this paper.

On the other hand, lens distortion is the most important interior orientation parameter, and many distortion models have been proposed (Brown, 1971, Murai, Matsuoka, Okuda, 1984). This paper uses Brown's 1971 model, which takes the 7th degree of the radial polynomial equation and the tangential distortion into account, and has been widely used in close range photogrammetric fields.

$$
\begin{aligned}
x &= x' + \frac{x'}{r}\left(K_1 r^3 + K_2 r^5 + K_3 r^7\right) + P_1\left(r^2 + 2x'^2\right) + 2P_2 x'y' \\
y &= y' + \frac{y'}{r}\left(K_1 r^3 + K_2 r^5 + K_3 r^7\right) + 2P_1 x'y' + P_2\left(r^2 + 2y'^2\right)
\end{aligned} \tag{1}
$$

where $r = \sqrt{x'^2 + y'^2}$ = the radial distance from the principal points

x, y = corrected image coordinates

x', y' = image coordinates

K_1, K_2, K_3 = radial distortion coefficients

P_1, P_2 = tangential distortion coefficients

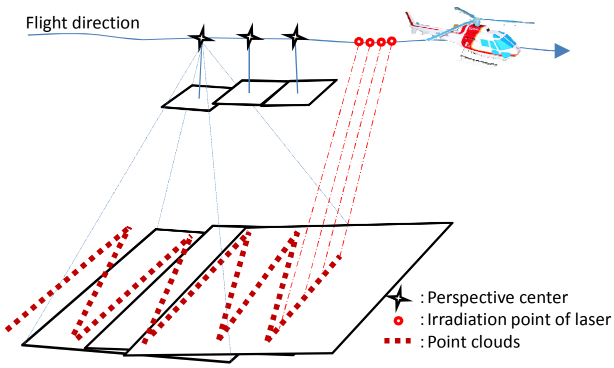

Figure 2. Measurement concept

The exterior parameters (X_0, Y_0, Z_0, ω, φ, κ) and the interior parameters (f [focal length], u_0, v_0 [principal points], a, b [scale factor, shear factor], K_1, K_2, K_3, P_1, P_2 [lens distortion]) are unknown parameters of the multiple images and the pseudo-GCPs (X_i, Y_i, Z_i), respectively. These unknown parameters are simultaneously calculated by the collinearity condition, distance condition, and geometric constraint condition under the local coordinate system. Here, the collinearity condition is shown as Equation (2) and the distance condition is shown as Equation (3).

$$
\begin{aligned}
x &= -f\,\frac{m_{11}(X - X_0) + m_{12}(Y - Y_0) + m_{13}(Z - Z_0)}{m_{31}(X - X_0) + m_{32}(Y - Y_0) + m_{33}(Z - Z_0)} \\
y &= -f\,\frac{m_{21}(X - X_0) + m_{22}(Y - Y_0) + m_{23}(Z - Z_0)}{m_{31}(X - X_0) + m_{32}(Y - Y_0) + m_{33}(Z - Z_0)}
\end{aligned} \tag{2}
$$

where x, y = corrected image coordinates

f = focal length

X, Y, Z = pseudo-GCP object coordinates

X_0, Y_0, Z_0 = perspective center

m_{ij} = rotation matrix elements