

## 3D VISUALIZATION OF BUILDING FROM LIDAR AND IKONOS IMAGE

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Commission II, WG II/6

**KEY WORDS:** LIDAR, IKONOS, projective transformation, strict geometric model, Laserscanning, Registration

### ABSTRACT:

Laser Scanner can measure the direct distance from the aircraft to the terrain surface by run-time emitting and reflecting laser pulse. DEM can be available with lower costs and sort period than other ways. IKONOS Satellite can get high resolution image. Combining DEM from Laser Scanning and texture from IKONOS image in the same region can provide a low-cost way to realize 3D-visualization to a certain extent. Registering IKONOS image and LIDAR image is the most important procedure. Two algorithms are adopted in the registration of IKONOS image as texture information and LIDAR image as three-dimensional spatial information.

### 1. INTRODUCTION

Airborne laser scanning is a kind of way to acquire fastly three-dimensional points, which are dense and well-distributed on the sensed surface. It has become the prime method for the acquisition of digital elevation models in several countries. Comparing to analytical or digital photogrammetry, Laser scanning can reduce the costs for DEM production and increase reliability, precision and completeness. Of course, it need detection and elimination of systematic errors. As the product of laser scanning LIDAR (Light Detecting And Ranging) image is provided. As gray-scale image LIDAR image can be processed by a series means of digital image processing and analysis and more information such as feature points, lines, edges, contours that can be used for integrating into other supplementary sources of information. Texture mapping is essential to get a realistical 3D visualization of building. IKONOS image can provide high-resolution texture images that can be mapped onto the digital surface model. Prerequisite for information fusion of LIDAR and IKONOS image is registering them and make them in a common coordinate system. Here two approaches are presented register the IKONOS image as texture corresponding to DEM. One is based on projective transformation, which only depend on the pixel coordinate of LIDAR image and IKONOS image without using of the height of ground points. It is not based on strict geometric model, but it needs not any other system parameter. It can reach approximately requirement of reality and accuracy and is a convenient way. The other way is strict geometric model based on affine transformation of the calculation for the position and orientation parameters of the remote-sensing image with higher resolution. (Jianqing Zhang, 2002) This way need several Satellite Both two algorithms need some control points to calculate transformation parameters. Projective transformation needs not less than 4 pairs of points. Affine transformation needs not less than 5 pairs of points. Difference of texture is great between LIDAR and IKONOS because two images are formed by different sensors. So these control points are chosen manually for test simplicity. Whereas the common shape information can still be extracted from them by image processing and analysis. Despite it is difficult to process entirely automatically semi-automatic processing is possible and feasible.

### 2. LIDAR IMAGE AND IKONOS IMAGE

LIDAR often uses laser as a source of a focused light beam. The higher the power of the laser, the stronger is the reflected signal and the more precise the measured range. Figure 1 shows a LIDAR image from laser scanning. It has been converted into 8-bit gray-level image, which the bright of each pixel can present the height of the corresponding terrain point. In the image, high buildings are most apparent, especially for which have regular shape. There are some irregular bright pixels like white noises, which are formed by the pulses reflected by trees and vegetables. In order to get real surface model these should be eliminated by image processing. The LIDAR has the same resolution  $1m \times 1m$  with the DEM. So it can give pixel coordinate as the ground points.

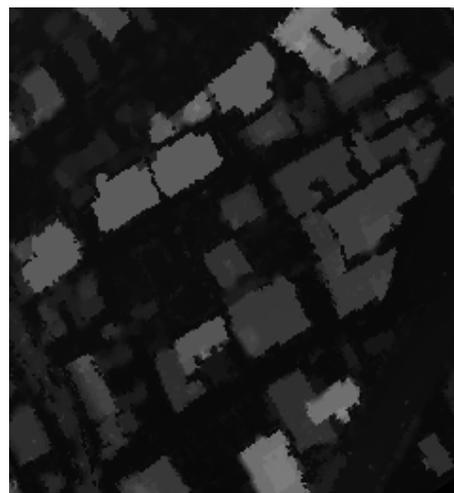


Figure 1. LIDAR image  $1m \times 1m$

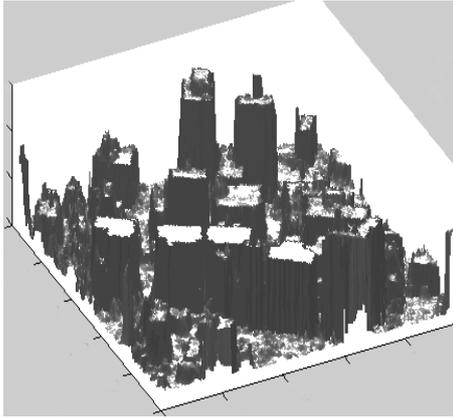


Figure 2. DEM visualization

The IKONOS-2, which can acquire the remote sensing image with 1-meter resolution for commercial application, had been launched successfully in September 1999. The QUICKBIRD, which can acquire the image with 0.62-meter resolution, had been launched successfully in 2001 too. Some other launch plan that can get more high resolution remote sensing image are being executed. Because of the low costing and short period it can meet the needs of more quick development of economy and society.

Figure 3. IKONOS image  $1m \times 1m$ 

### 3. REGISTRATION BASED ON PROJECTIVE TRANSFORMATION

Registration is an application of geometric operation. Because of different way of image formation, an image has translation, rotation or more other complex distortions comparing with the other image. One such image can be taken as standard of reference and the other distorted to match it. In general, geometric operation includes two steps: spatial transformation, which specify mathematically the spatial relationship between input image and output image, gray-level interpolation, which specify value relationship between two image. Here two separate algorithms are adopted for the geometric operation.

#### 3.1 Projective Transformation for Spatial Transformation

$$\begin{aligned} X_i &= \frac{a_0 x_i + a_1 y_i + a_2}{a_6 x_i + a_7 y_i + 1} \\ Y_i &= \frac{a_3 x_i + a_4 y_i + a_5}{a_6 x_i + a_7 y_i + 1} \end{aligned} \quad (1)$$

In equation (1),  $(X_i, Y_i)$  is pixel coordinate in the IKONOS image and  $(x_i, y_i)$  is pixel coordinate in the LIDAR. The equation determines the 2D spatial relationship of LIDAR image and IKONOS image. Because 8 parameters need to be worked out at least 4 pairs of points should be given. In general, more than 4 pairs of points are given, and least square method is applied to resolute equation.

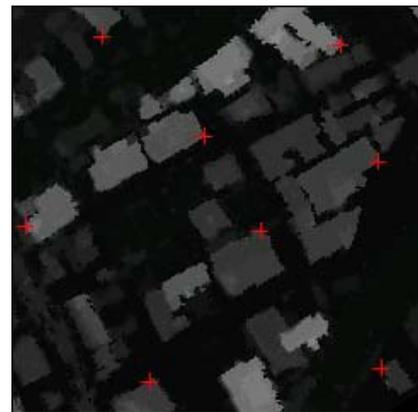
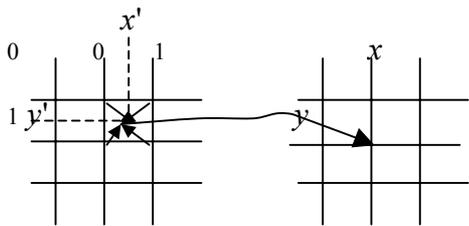


Figure 4. image with control points

#### 3.2 Bilinear Interpolation for Gray-level Interpolation

*Bilinear interpolation* can get more desirable result than does *nearest interpolation*, with only a slight increase in programming complexity and execution time.



$f(x', y')$  is gray-value of fractional pixel position of  $(x', y')$ .  $g(x, y)$  is gray-value of pixel  $(x, y)$ .  $f(x', y')$  is determined by the value of corner points of unit square  $(0,0),(0,1),(1,0),(1,1)$ .

$$f(x', y') = [f(1,0) - f(0,0)]x + [f(0,1) - f(0,0)]y + [f(1,1) + f(0,0) - f(0,1) - f(1,0)]xy + f(0,0)$$

**3.3 Result of Experiment**

Rectified texture image being mapped to DEM can produce 3D visualization of the region.



Figure 5. IKONOS matched LIDAR

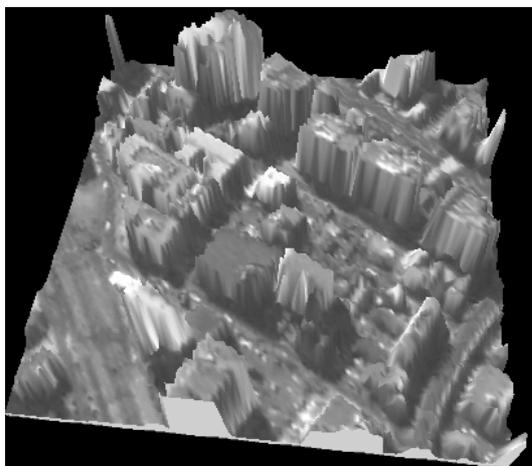


Figure 6. 3D Visualization of block

**4. REGISTRATION BASED ON STRICT GEOMETRIC MODEL**

The strict geometric model of the calculation for the position and orientation parameters of the remote-sensing image with higher resolution, (proposed Jianqing Zhang, Zuxun Zhang, 2002, being published) adopts the method with three steps of transformations. IKONOS image is similar as SPOT image, which is imaging by pushbrooming ahead with the linear array CCD. That is, it is central projection in the scanning direction, and parallel projection in the flight direction. The first step of the strict geometric model is reducing the three dimensional space to the image space by the similar transformation. Then, the small space is projected to the level plane, which passes the center of the image plane, by parallel rays ( Affine transformation ). Finally, the level image is transformed to the original declining image. Every step of the new method is the strict, and the map function of each transformation is the first order polynomials and other simple function. The final calculation of the parameters is for the linear equations with good status. As a result, the problem of the relativity of image parameter calculation is solved completely.

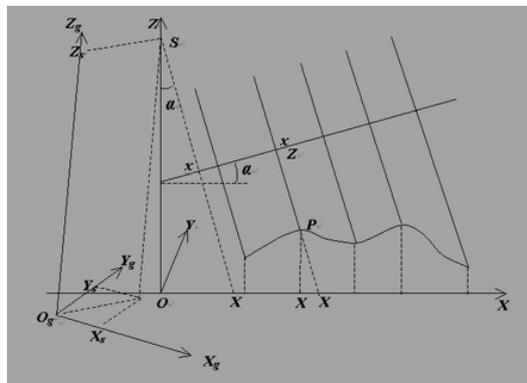


Figure 7. Image Geometry of Parallel Ray Projection

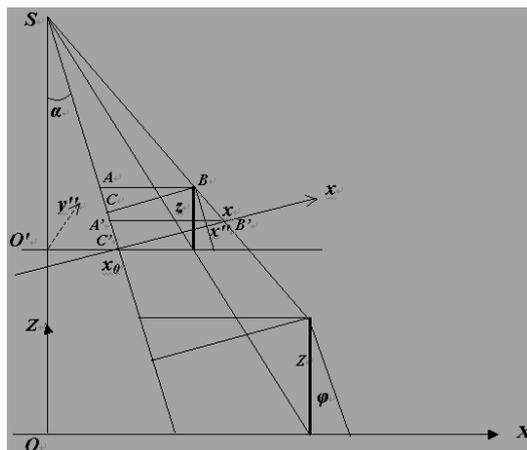


Figure 8. Image Profile

$$\frac{f - \frac{Z}{m \cos \alpha}}{f - x \operatorname{tg} \alpha} (x - x_0) = a_0 + a_1 X + a_2 Y + a_3 Z$$

$$(y - y_0) = b_0 + b_1 X + b_2 Y + b_3 Z$$

The equation show the strict mathematical relationship of the image coordinates  $(x, y)$  and the space coordinates  $(X_g, Y_g, Z_g)$ . More than 5 pairs of control points being given, the parameters can be computed stably. Subsequent operations is the same as that of the front algorithm.

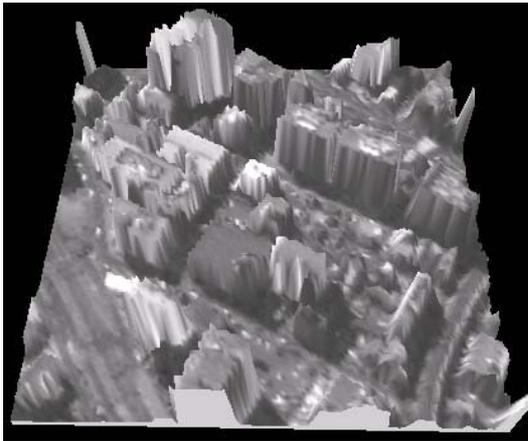


Figure 9. 3D visualization of block from strict geometric model

## 5. CONCLUSION

Two algorithms are adopted in the registration of IKONOS image as texture information and LIDAR image as three-dimensional spatial information. One is based on projective transformation, which is only based on 2D image coordinate, is convenient and fast. The other is based on strict geometric model, which is based on relationship of 2D image coordinate and 3D space coordinate, is stable. So 3D visualization can be realized approximately from data of IKONOS satellite and laserscanners, which both are fast and low cost means of acquisition of geo-information.

## ACKNOWLEDGE

Thanks Gene Dial of SPACEIMAGE for supporting the IKONOS data and materials.

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