AUTOMATIC BUILDING HEIGHT EXTRACTION BY MONOSCOPIC SHADOW ANALYSIS

Tsend-Ayush Javzandulam
Department of Geoinformatic Engineering, Inha University
253 Yonghyun-dong, Nam-gu, Incheon, 402-751, ROK
javzaa@inha.ac.kr

Taejung Kim
Department of Geoinformatic Engineering, Inha University
253 Yonghyun-dong, Nam-gu, Incheon, 402-751, ROK
tezid@inha.ac.kr

Kyung-Ok Kim
Spatial Information Research Team, Electronics and Telecommunications Research Institute
161 Gajeong-Dong, Yuseong-Gu, Daejeon, 305-350, ROK

ABSTRACT: An attempt has been made in this study to develop an automatic algorithm to determine building height from monoscopic high-resolution satellite data. The algorithm is based on analysis of projected shadow and actual shadow of the building. The algorithm estimates building height automatically by projecting building shadow onto the image for given building heights, counting overlapping pixels between the projected shadow and actual shadow, and fining the height that maximizes the number of overlapping pixels. A panchromatic IKONOS image over Deajeon area is used to test proposed algorithm. The result is compared with building height by stereo analysis and the accuracy of the building height extraction is examined using standard error of estimate. It was found that standard error (SE) is 1.66 m.

KEY WORDS: Building extraction, shadow analysis, IKONOS

1. INTRODUCTION

The 3D city model has been an increasing interest for recent several years because its significant role in many application areas, like communication industry, urban microclimate and pollution control analysis, transportation navigation, landscape planning and visualization, etc. One of essential issues for the 3D city models generation is building extraction. Most of previous approaches on building extraction are used light detection and ranging (LIDAR) and stereo analysis. Recently, high-resolution satellite imagery has become available, and this shows an opportunity for so-called urban remote sensing to challenge the topic of urban details mapping.

The objective of this research is to develop an algorithm to extract height of building automatically. Basic idea is to get a correlation between building height and pixel number of the intersection of actual shadow and projected shadow. We hypothesized that the peak point of the correlation curve may give a building height. The developed algorithm works as follows. First, we select four corners of a building roof manually, then we define region of interest(ROI). After defined region of interest, we extract actual shadow region applying simple threshold into ROI. The common methods for detecting shadow are based on their low value level in all spectral bands. A simple threshold of histogram makes it possible to discriminate the zones of shade. After that we draw the shadow of the building and count overlapping pixels between projected shadow and actual shadow. The shadow direction cast by buildings can be determined by the azimuth angle of the sun and the satellite. The information of the azimuth angle of the sun and satellite are provided in metadata of satellite image.

In this study we considered that buildings have uniform height generally descriptive of flat roofs on top of rectangular solids. Walls are considered to be vertical and each building casts its shadow on a surface that is locally flat.

2. PROPOSED ALGORITHM

The proposed algorithm works by providing corner points of building roof. First, we select four corners (rx_i^0, ry_i^0) $i=\overline{1,4}$ of a building roof manually. We then define a region of interest (ROI) as a square region of $\max\{\max(x_i)-\min(x_i), \max(y_i)-\min(y_i)\}$ $i=\overline{1,4}$.

In order to extract actual shadow of building, we apply the simple threshold to subset image. Let *AC* denote the set of actual shadow pixels.

Using the provided roof corner points we can delineate whole boundaries of building roof. Let (rx_i^o, ry_i^o) $i=1,2,\ldots, BL$ denote boundaries points. Where, *BL* is boundary length. The initial height of the building is selected as h=1m or 1 pixels. Since the roof boundaries and height are known, building footprint boundaries can be defined by the azimuth angle and elevation angle of satellite as follows:

$$\begin{cases} px_i^h = rx_i^o + \Delta x_v \\ py_i^h = ry_i^o + \Delta y_v \end{cases} \quad i=\overline{1,BL}$$

$$\Delta y_v = \frac{h}{\tan(El)} \times \sin(Az) \tag{1}$$

$$\Delta x_v = \frac{h}{\tan(El)} \times \cos(Az)$$

where (px_i^h, py_i^h) $i=1,2,\ldots, BL$ are the points of the building footprint boundaries, h is building height, *Az, El* are azimuth angle, elevation of satellite respectively.

After determined footprint boundaries, the points of shadow lines (sx_i^h, sy_i^h) $i=1,2,\ldots,BL$ can be determined by the azimuth angle and elevation angle of sun and it is defined as follows:

$$\begin{cases} sx_i^h = px_i^h + \Delta x_S \\ sy_i^h = py_i^h + \Delta y_S \end{cases} \quad i=\overline{1,BL}$$

$$\Delta x_S = \frac{h}{\tan(SEl)} \times \cos(SAz) \tag{2}$$

$$\Delta y_S = \frac{h}{\tan(SEl)} \times \sin(SAz)$$

where h is building height, *SAz, SEl* are azimuth angle, elevation of sun respectively. Figure1 show diagram of roof, footprint and shadow points.

We then draw shadow region while increase the building height by one pixel or one meter. For every step height, we count points of projected shadow lines if all points of line are in actual shadow region. Let us denote those number of counted points at h step height as PN^h. Then this process continues until PN^h reaches 0

$$PN^h = \sum_{i=1}^{BL} Temp_i$$

$$Temp_i = \begin{cases} \sum_{k=1}^{SL} k & if \quad \forall k : (sx_{i_k}^h, sy_{i_k}^h) \in AS \\ 0 & otherwise \end{cases} \quad (3)$$

$$SL = \frac{h}{\tan(SEl)}$$

where *SL* is length of projected shadow line.
Here, before PN^h reaches 0 if the project shadow surpasses size of subset image we expand the subset image by 100x100pixels. When PN^h reaches 0 the building height is accepted as *H* which is maximum value of *PN* for all *h*. $H : PN^H = \max_h PN^h$

3. RESULT

To assess the performance of the proposed algorithm, we used the 1 m resolution Ikonos image over the Deajon city of Korea. Employing the proposed algorithm, we extracted 30 building height from 7 sub-regions in the image. Here, we extracted the building height if whole actual shadow of building is visible and not blocked. Figure2 shows examples of building height extraction. The upper part of figure shows buildings on image before drawing 3D building structure and lower part of image shows drawn structure of building and shadow region. To verify the result of the proposed algorithm, using Ikonos stereo pair image we manually calculated building height by measuring tie points on the building and on the ground, by calculating 3D coordinates for the tie points and by calculating the difference between the two. We assumed that building height by stereo analysis is true building height and the extracted building height is compared with building height by stereo analysis. The difference error of extracted building height and measured building height are shown in Table 1. The accuracy of the building height extraction is examined using standard error of estimate. The standard error is calculated by following equation.

$$SE = \sqrt{\frac{1}{N-2} \sum_{i=1}^{N} (\hat{y}_i - y_i)^2} \quad (4)$$

where $\hat{y}_i$ and y_i are the extracted and measured height of building, and *N* the number of extracted building. It is found that standard error from result of stereo analysis is 1.66 m.

4. CONCLUSIONS

In this study, we proposed an algorithm for building height extraction from high-resolution satellite image. The algorithm is based on shadow analysis therefore it is well applicable to extract building height if building shadow is not blocked.

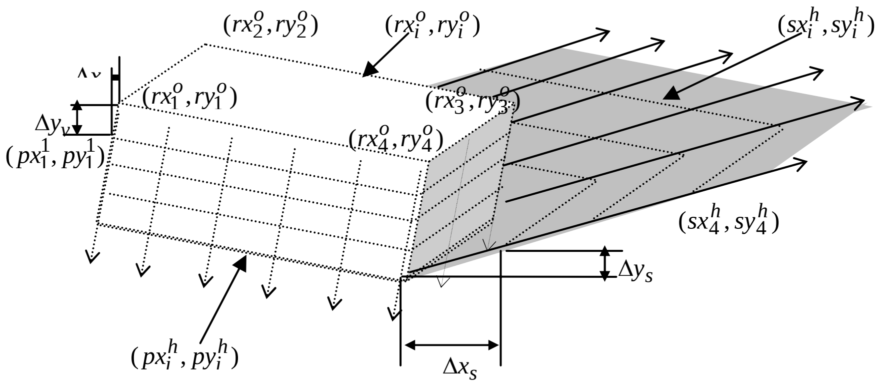

Figure1. Diagram of roof, footprint and shadow points

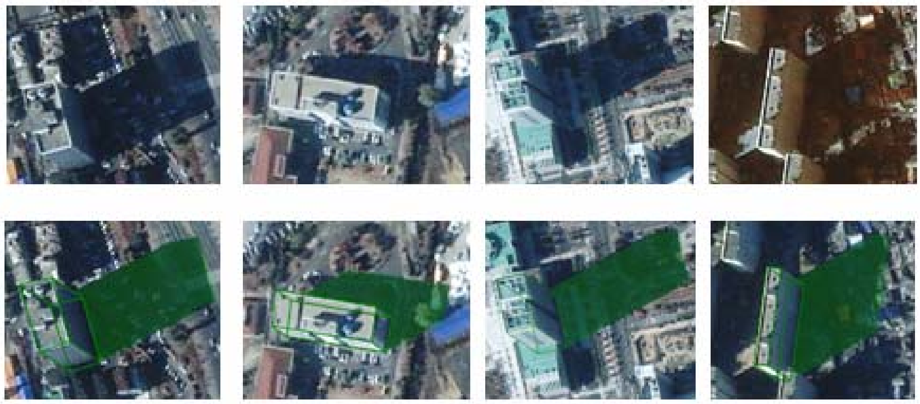

Figure2. Examples of extracted building height

Sub-region ID	No of extracted building	Difference error between extracted and measured building height (m)
A	5	1.31
B	4	0.90
C	3	1.40
D	3	2.20
E	2	0.60
F	3	1.46
G	10	1.39

Table1. Result of comparison of extracted and measured building height.

5. REFERENCES

Lee, D. S., J. Shan Behal, 2003, Class-Guided Building Extraction from Ikonos imagery, Photogrammetric Engineering & Remote Sensing, 69(2), pp 143-150

Shan,J, and S.Lee 2002, Generalization if building Polygons extracted for Ikonos imagery, International arcives of Photogrammetry Remote Sensing and Spatial Information Sceineces, 34(1), oo 286-290

Segl, K. and H. Kaufmann, 2001, Detection of Small Objects from High-resolution Panchromatic Satellite Imagery Based on Supervised Image Segmentation, IEEE Transactions on geoscience and remote sensing, 39(9) pp20880-2083.