GENERATION OF 3D BUILDING MODELS FROM COMMERCIAL IMAGE DATABASE THROUGH SAHDOW ANALYSIS

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ABSTRACT

Many people use a commercial image database such as Google Earth Image map from the internet. We propose a method by volumetric shadow analysis for generation of 3D building models from the commercial image database. The proposed method can extract building heights and building footprints using volumetric shadows analysis from a single image. No external control points are required. Instead, the proposed method needs the directions of the sun and the camera is needed. As the commercial image database does not provide them, we estimated them by simple image measurements and a known height of one reference building. For experiments, images extracted from Google Earth were used. For performance analysis of our method, building heights extracted by our method were compared with building heights extracted by stereo IKONOS images as reference. The Root Mean Square Errors (RMSE) calculated from the comparison were under 2 m. The experiment result shows 3D building models can be effectively generated from the commercial image database by the proposed method.

INTRODUCTION

In the last years, commercial image databases such as Google Earth, Virtual Earth and etc. and 3D building models attached to those databases have appeared and have been opened in the Internet. These commercial image databases have been popularized and interest about 3D building models has been increased. 3D building modeling from high resolution images is the important topics in photogrammetry and remote sensing, so many researchers have tried to extract 3D building information from high resolution images and many methods have been proposed. Among these methods, there are methods for building extraction from a single image. These approaches need clues such as shadow, vertical line and etc (Liow and Pavlidis, 1990; Shufelt and Mckeown, 1993; Kim and Muller, 1998; Lin and Nevata, 1998; Tao et al., 2008). The method by volumetric shadow analysis was proposed as one of shadow-based methods (Lee and Kim, 2005). This method extracts a building height and its footprint by repeatedly constructing 3D building wireframe and building shadow for an assumed building height in an arbitrary 3D space and by repeatedly projecting shadow and building wireframe constructed onto images until the shadow projected matches against the actual shadow on the image. The method can effectively extract building heights and its footprints in complex city. The method needs the ground sample distance (GSD) of the image and the information about the direction of the sun and the camera and however does not require any external control points.

The purpose of this paper is to propose an approach that extracts 3D building information and generates 3D building models from a single image of a commercial image database, which is without any meta information such as the GSD of the image and the direction of the sun and the camera. For this approach, the proposed method extends the volumetric shadow analysis previously proposed (Lee and Kim, 2005). The direction of the sun and the camera for volumetric shadow analysis can be estimated by simple measurements of the image and a known building height and proposed method does not need correct the GSD of the image. This paper shows 3D building models generated by the proposed method from a pushbroom image and a perspective image of Google Earth, the commercial image database.

3D BUILDING EXTRACTION BY VOLUMETRIC SHADOW ANALYSIS

As mentioned above, the proposed method is based on the volumetric shadow analysis. This section briefly introduces 3D building extraction method by volumetric shadow analysis and estimation of the direction of the sun and the camera from the image.

Algorithm for 3D Building Extraction by Volumetric Shadow Analysis

If we know a building height and the direction of a light source and a camera, we can construct the shadow and the wireframe of the building for an assumed building height in an arbitrary 3D space and project the model back to image space. The method by volumetric shadow analysis reconstructs the shadow and the wireframe of a building by the building height. However as the building height is unknown, the method increases or decreases the building height from initial value at regular intervals. As the building height is changed, the shadow and the wireframe of the building are reconstructed by the changed height and re-projected onto the image. Until the shadow projected matches against actual shadow on the image, the building height is changed, and the shadow and the wireframe reconstructed and re-projected onto the image. When the shadow projected matches against the actual shadow, the building height becomes the actual building height and the bottom boundary of the wireframe projected onto the image becomes the boundary of the building footprint.

This method can extract the height and footprint of the building with shadow blocked partially or with footprint blocked completely, because the method uses volumetric shadow analysis by reconstructing the building shadow and its wireframe. As mentioned before, the method needs the GSD of the image and the direction of the light source (sun) and the camera and the commercial image database such as Google Earth does not provide them. We can estimate the direction of the sun and the camera by simple measurement of the image and a known building height as below.

Estimation of the Direction of the Sun and the Camera

The direction of the sun and the camera can be explained by an azimuth angle and an elevation angle. In this paper, the azimuth angle is begun from Y axis of the image, so the azimuth angle of the sun and the camera can be estimated by the angle between shadow line and Y axis of the image and by the angle between vertical line of building and Y axis of the image. The elevation angle of the sun and the camera can be estimated by the length of shadow line or of vertical line of building, a known height and the equation (1). The equation (1) explains the relationship between a building height and the length of shadow line or of vertical line.

$$H = \overline{SahdowLine} \times GSD \times \tan\theta_{SE} = \overline{VerticalLine} \times GSD \times \tan\theta_{CE} \tag{1}$$

In the equation (1), H is a building height, θ_{SE} is the elevation angle of the sun and θ_{CE} is the elevation angle of the camera. If GSD is unknown value, the ratio ($GSD \times \tan\theta_E$) instead of the elevation angle (θ_E) can be estimated, so the proposed method can generate 3D building models without regard to the GSD of the image.

As mentioned above, for the elevation angle estimation, the height of one building selected by operator or user is needed. If the heights of all building are unknown, a height guessed by operator or user can be considered. In this case, building heights extracted by the proposed method will be scaled from the true values to the amount of the guessed height and its true height value.

GENERATION OF 3D BUILDING MODELS

Overall Process

The Figure 1 shows the overall process for generation of 3D building models. This process includes the method by volumetric shadow analysis. For generation of 3D building models, first of all, the direction of the sun and the camera has to be estimated by simple measurement of the image of the commercial image database. After estimating the direction of the sun and the camera, the height of buildings and its footprints are extracted by the method based on volumetric shadow analysis. At the same time, a 3D building model is generated by the 3D building information extracted. The proposed method manually extracts 3D building information, so the accuracy of the height and footprint boundary extracted by proposed method is influenced by the measurement of an operator or a user.

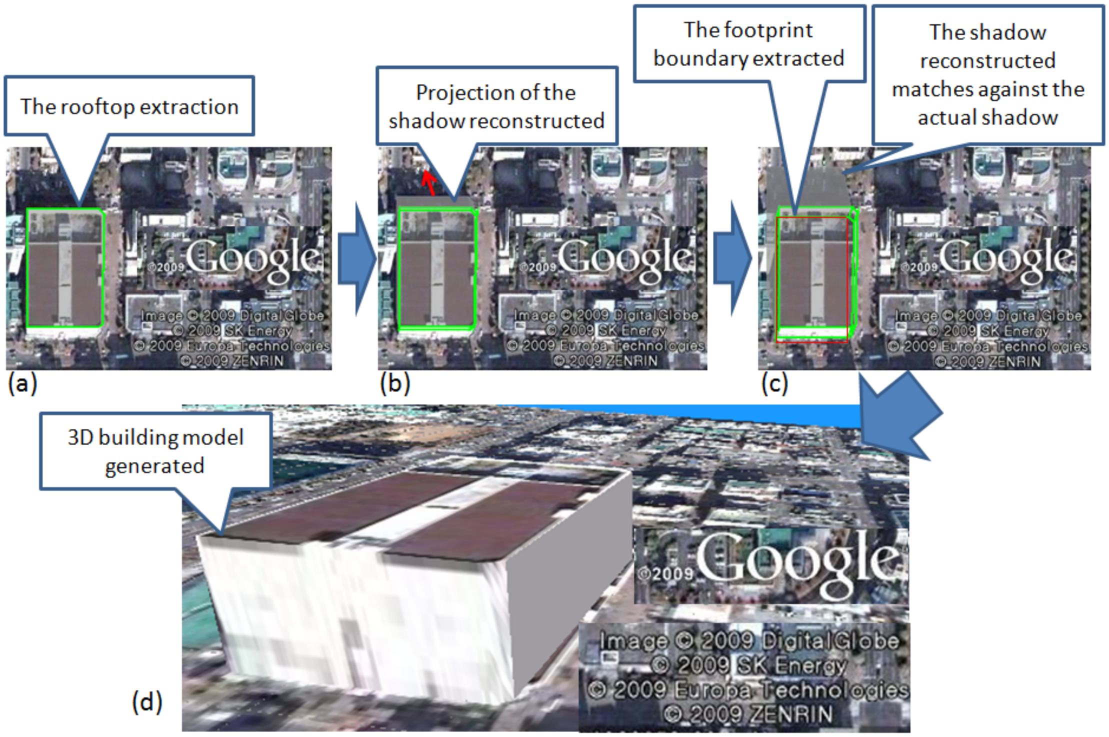

Figure 1. The overall process of the proposed method.

Result and Performance

For performance analysis of the proposed method, the building heights extracted by proposed method were compared with the building heights extracted by stereo IKONOS images over the same region as reference. In this paper, the building heights extracted from the pushbroom image (Figure 2 (a)) were just compared with reference. Table 1 shows the result of the height comparison.

Table 1. The accuracy of building heights extracted by the proposed method

ID	Reference Building Heights (R)	Building Heights extracted (E)	R-E
1	19.0	19	0
2	28.5	27	1.5
3	88.8	88	0.8
4	42.5	43	-0.5
5	40.5	44	-3.5
6	36.3	35	1.3
7	89.3	89	0.3
8	46.7	45	1.7
9	28.1	29	-0.9
10	95.5	94	1.5
11	81.1	82	-0.9
12	25.3	23	2.3
13	15.3	14	1.3
14	42.5	44	-1.5
15	17.1	18	-0.9
16	15.7	18	-2.3
17	43.9	43	0.9
RMSE (m)			1.6

In Table 1, "Building Heights extracted (E)" indicates the building heights extracted by the proposed method from the image of Google Earth. For estimation of the direction of the sun and the camera, one known height, which was found from the Internet, was used. As shown in Table 1, RMSE about 17 buildings is under 2 m.

Figure 2 shows 3D building models generated by the proposed method from the image of Google Earth, the commercial image database. The 3D building models were generated from the pushbroom image (Figure 2 (a)) and the perspective image (Figure 2 (b)) of Google Earth. In Figure 2, the Google Earth image as texture was mapped to 3D building models generated. For generation of 3D building models, OpenGL and visual c++, 2008 were used.

Figure 2. 3D building models generated by the proposed method from the image of Google Earth

CONCLUSION

This paper proposes the method based on volumetric shadow analysis for generation of 3D building models from the commercial image database. For performance analysis, 3D building models were generated by the proposed method from the pushbroom image and perspective image of Google Earth, the commercial image database, and the building heights extracted by the proposed method were compared with reference heights. The result shows RMSE about 17 building is under 2 m. We believe this result indicates that the accuracy of the proposed method is suitable to applications with moderate accuracy requirements. 3D building models generated by the proposed method shows that they do not have detailed shapes. However the all results show the proposed method can effectively and simply generate 3D building models from the pushbroom image and the perspective image of the commercial image database.

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