3D Building Reconstruction for 3D City Model Using UAV images

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Abstract

3-D reconstruction of buildings in urban areas is one of the highlighted issues in photogrammetry, remote sensing, computer vision, and computer graphic. It can be used in various fields such as urban planning, construction, disaster management, navigation system, and cyber city .This paper presents an approach for 3D reconstruction model of buildings from urban area for 3D visualization. The model is generated automatically from a single image taken by UAV (Unmanned aerial vehicles). Most methods used two or more images for 3D building reconstruction. The previous methods take much time to detect and match feature points in each image and consume more memory space for multiple images. The proposed system can extract 3D geometry information from a single image without knowing the priori parameters. The building features are extracted using modified building feature extraction algorithm and then reconstruct it 3D model using proposed 3D box method. The proposed method can reduce processing time and memory space by using a single image for 3D reconstruction.

Keywords: *UAV, 3D Box, 3D Surface Reconstruction*

1. Introduction

Digital Earth and Digital City have become the research focuses in geographic information system. High-resolution remote sensing images are the most important sources for the city 3D information acquisition, and there are increasing demands. The general remote sensing techniques by satellite and aircraft can get the geographic information of large area, but there are some limitations in detail information acquisition of city. So these techniques can't completely meet the need of subtle 3D information acquisition in city. Unmanned Aerial Vehicle, and the acronym is UAV, is a new platform of Remote Sensing. There is no man in UAV, and it is navigated by the telecontrol device. UAV has many good characteristics such as low cost, simple manipulation, high resolution, flexibility and etc. UAV can implement many tasks that traditional aircraft can't finish [2]. In the last few years, the usage of unmanned aerial vehicles (UAVs) has increased exponentially, involving a growing number of applications in different areas such as surveillance, monitoring and remote sensing applications, because of their capability of exploring areas inaccessible or dangerous for a human being. Among the various applications, the 3D model reconstruction of urban area plays a crucial role [1]. Our previous approaches have been done in [3], [4], [5] and [6] for 3D urban reconstruction using satellite images. These works are based on stereo image matching techniques and multiple images. Many techniques have been proposed in the literature for generating 3D building models.

K. Kyawt Kyawt Theint performed 3D urban reconstruction using satellite images. Firstly, preprocess the input satellite images, secondly building feature points are extracted using color segmentation and morphological processing, thirdly, calculate 3D dept map by modified factorization method of SVD and finally surface reconstruction is done using Delaunay triangulation method and wireframe[3].

H. Mayer, J. Bartelsen developed a 3D reconstruction model for image sequences taken from UAV. It is based on affine least squares matching (LSM). It stated that image sequences are particularly suitable for the reconstruction of 3D structures along linear objects such as roads [7].

W. Jizhou, LI Chengming implemented 3D reconstruction method of city building from single UAV image. It consist of four steps: firstly, check the camera to get inner elements including (x_0,y_0),f-focal length and len aberration parameter K. Secondly, divide parallel lines with X,Y and Z and compute three joint points .Thirdly, calculate three angle elements and finally, compute scale between reality and image using 2D GIS databases. The reconstruction accuracy depends on the correct choices of camera parameters [2]. The above methods have used multiple images to calculate the depth of object and to reconstruct 3D model. It takes time to process multiple images for 3D reconstruction. There is a challenging problem to calculate the depth or 3D cloud points from a single image.Unlike the above methods, the proposed system use single image without needing any camera parameters. It consists of three main parts: building extraction, calculation 3D cloud points and reconstruction of 3D building model. Firstly, we extract building features from complex urban environment using RGB color space and morphological processing. The 3D building model is successfully generated using proposed 3D box method without knowing the priori camera parameters.

This paper is organized as follow: the process of data acquisition is provided in section 2. The overview of proposed 3D reconstruction model is explained in section 3. The building feature extraction results are shown in section 4.Section 5 shows the computation of 3D cloud points using 3D box geometry. Theory of 3D surface reconstruction is provided in section 6. Experimental Results and performance evaluation result of proposed system are shown in section 7 and this paper is concluded in section 8.

2. Data Acquisition

The usage of UAVs enables image acquisition of objects from different viewing positions, which are impossible to take up by earthbound vehicles. The input building area in urban region is acquired using UAV remote sensing system. By using UAV system for image acquisition, we can get high resolution input images for reconstruction. The input image is taken obliquely to get more information of building including top texture and side texture. The acquisition geometry is shown in figure 1.

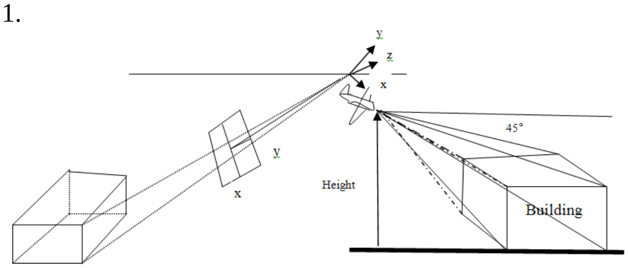


Figure1. Oblique Building Photo

3. Proposed 3D Reconstruction System

The new approach of 3D building reconstruction model is developed using efficient morphological processing and proposed 3D box geometry methods. The step by step processing of proposed system are the following:

Step 1: we acquired input building area from a UAV.

Step2: preprocess the input images such as image resizing, and noise removing.

Step 3: extracts building area using RGB (Red, Green, and Blue) color space and morphological operations.

Step 4: computes 3D cloud points of building object using proposed 3D box geometry method.

Step 5: triangulates the resulting 3D cloud points of building object.

Step6: reconstructs the 3D surface model using triangulated image and wireframe drawing.

Finally, the 3D building reconstruction model is display.

The overall processing of proposed 3D reconstruction system is shown in figure 2.

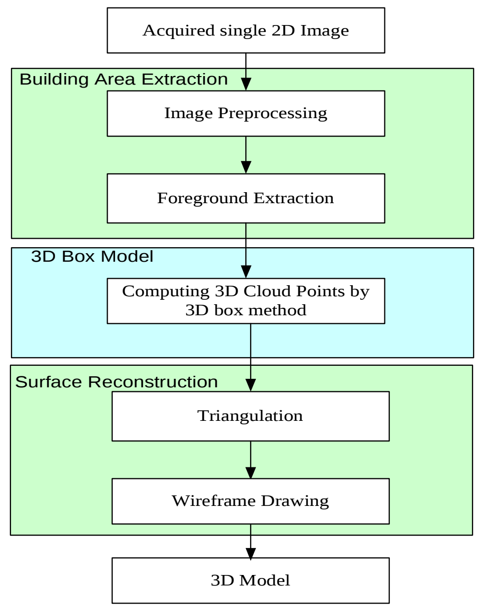


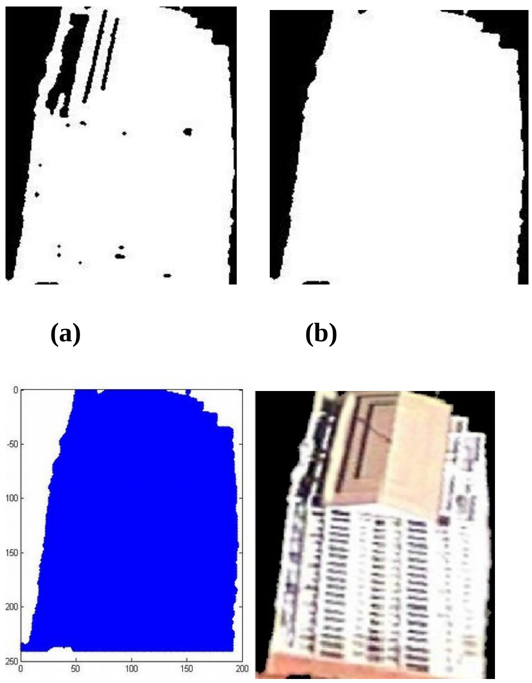
Figure2. Illustration of proposed system

4. Building Feature Extraction

The processing of proposed automated feature extraction method is shown in this section. The input image is resized to speed up the processing time. The mathematical morphology is applied to enhance the image and foreground object is obtained from the complex urban scene. Feature points are extracted from the detected building. The foreground object is retrieved based on the extracted feature points and RGB (Red, Green and Blue) color space. The extracted building area are not directly applied to model the three dimensional building. To generate the whole building features, the morphological operation has been developed. The results of building feature extraction are shown in figure 3, and figure 4.

(a) (b)

Figure3. Results of Building Feature Extraction (a) input image (b) binary image



(a) (b)

(c) (d)

Figure4. Results of Building Feature Extraction (a) Removal of Unwanted Small Parts (b) Extracted the Whole Building (c) Feature Points of Extracted Object and (d) Foreground Object

5. Computing 3D Cloud Points based on 3D Box Geometry

As initialize, the origin point is located at P_1 (0, 0, 0) in a 3D box. 3D box is shown in (Figure 5) and other points of 3D box get automatically. The 3-D box vertices are used to obtain the estimate of position and scale occupied by the object in the area of interest.

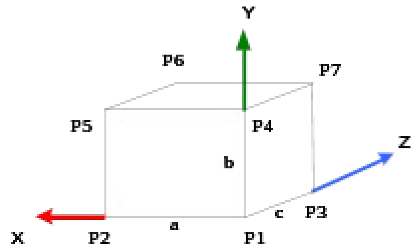


Figure5. The graphical representation of 3D box

The location of the model in the 3D space can be determined by specifying the positions of the anchor point on the object plane. 3D bounding box is around an object is constructed by getting the feature points from the object. 3D box calculates the other 3d image points according to the distance of the edge and location of the pixel on the image plane. The imaging geometry is shown in figure (6).

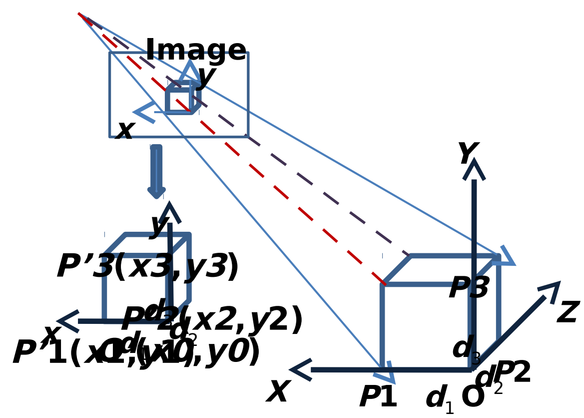


Figure6. Geometry of a Box in 3D Scene

The nonlinear equation is derived for the estimation of the structure of the object by using the edges of a box in a 3D scene. The lengths of each edge of the box d_1,d_2, and d_3 can be expressed by three points $P_1(X_1, Y_1, Z_1)$, $P_2(X_2, Y_2, Z_2)$, *and* $P_3(X_3, Y_3, Z_3)$, as

$$d_1 = |X_1 - X_2, Y_1 - Y_2, Z_1 - Z_2|$$
$$d_2 = |X_2 - X_1, Y_2 - Y_1, Z_2 - Z_1|$$
$$d_3 = |X_3 - X_1, Y_3 - Y_1, Z_3 - Z_1|$$

Align the origin of the image coordinate system and the origin of the 3D box coordinated system. The aligned coordinates newx and newy is calculated using Equation (1) and (2).

newx = pixel location of image width – x (1).

newy = pixel location of image height –y (2).

After aligning the coordinates, the coordinate transformation from the image coordinates system to the 3D box coordinate system can be represent in Equation 3.

$$P' T = P \quad (3)$$

Where P' is the image plane, T is the transformation matrix and P is the 3D coordinates. According to Equation (3), the relation between image points and corresponding 3D points are obtained.

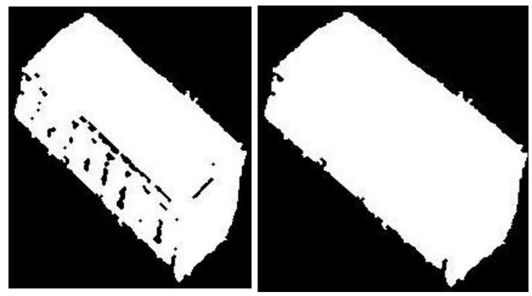
6. Surface Reconstruction

The well-known method is used to reconstruct the topology surface from points in three dimensional spaces. The surface reconstruction is done by constructing Voroni diagram and Delaunay triangulation form the obtained 3D points set. The triangle is build using the three nodal points which are projected from a planar surface in the 3D scene. The complete 3D building model is obtained by integrating the triangulated 3D points and voronoi topology. The results of triangulated surface of building object and 3D building model is shown in figure 9.

7. Experimental Results

The results of proposed system are shown in this section. The proposed system is tested with a single image taken by UAV. In figure 7, (a) and (b) shows the input image and binary image respectively. The removing of unwanted parts and region filling is shown in figure7 (c) and figure7 (d).

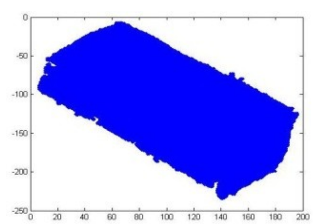
(a) (b)



(c) (d)

Figure7. Experimental results of building area extraction (a) input image (b) binary image (c) Removal of Unwanted Small Parts (d) Extracted the whole Building Area

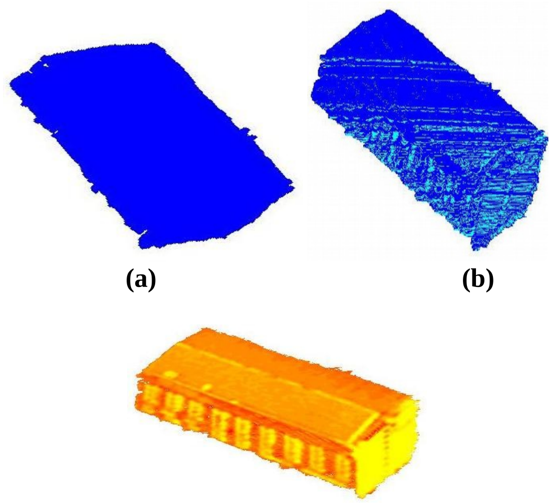
The extracted feature points of the object and foreground object are depicted in figure 8,



(a) (b)

Figure8. Experimental results of building area extraction (a) Extracted 2D Feature Points (b) Foreground object

Figure 9(a) depicted the plotted 3D cloud points of experiment result. The triangle patch of the 3D cloud points of the object is shown in Figure 9(b) and the reconstructed 3D building model is shown in Figure 9(c).



(a) **(b)**

(c)

Figure9. Results of Reconstruction 3D Model (a) Calculated 3D Cloud Points (b) Triangulated Surface of Building Object and (c) Reconstructed 3D Model

7.1 Performance Evaluation

The proposed method has been tested on different kinds of buildings. The processing time depends on the number of feature points and number of triangle patch. The reconstruction method can be confirmed with the number of 2D and 3D points without losing the original raw data. The computation time result of proposed 3D reconstruction system is shown figure 11.

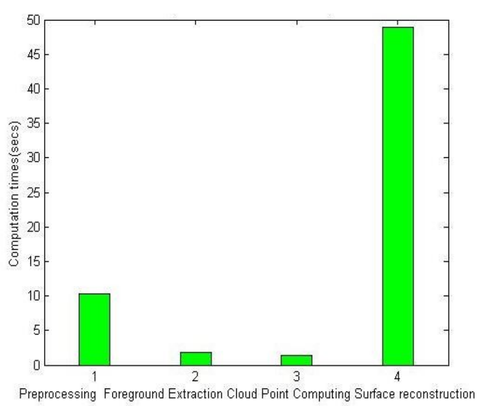


Figure11. Computation time result for proposed method

8. Conclusion

In this paper, we have design a 3D building reconstruction method for 3D city model from single UAV image. 3D city model is developed using proposed 3D box method without knowing the camera parameters within the shorter time. In future, the system aims to generate the whole 3D urban views including multiple buildings for geographic information system and construct the complete 3D urban modeling using UAV images.

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