TEXTURE MAPPING FOR BUILDING FAÇ ADES USING TERRESTRIAL LIDAR POINT CLOUDS AND CLOSE RANGE IMAGES

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ABSTRACT

Façade texture mapping for building models has been widely studied to meet the needs of photorealistic building models for more than fifteen years. Except from using texture library, spectral information from images is needed to realize photorealistic visualization. Close range imagery is a preferable material because it provides information of the building façade from human perspective. However, in many situations, textures would not be proper to directly drape due to image occlusions on a single building façade. With accurate depth information, terrestrial lidar data can be used to distinguish occlusions from target façade. On the other hand, images taken from different directions help each other to compensate the occluded parts. To strike a balance between reality and visualization, we assume that one façade image patch is able to substitute other façade patches provided that they have the same texture. Therefore, texture analysis is used to recognize and classify the façade textures. Experimental results show that the proposed method may reach high fidelity, provided that the detailed building models are available.

INTRODUCTION

In recent years, 3D building model is popular in fields like urban planning, cultural heritage maintenance, reality navigation, etc. In order to reach immersive experiences, photorealistic building models are needed to emulate the real situation. There are two major parts in generating a photorealistic building model. One is to build a geometric model, and another is to map the texture. To generate the geometric model, image and lidar point clouds are the important data sources [Baltsavias, 1999]. On the other hand, aerial and ground images are two possible materials to generate the photorealistic façade texture. Façade textures from aerial images are often incomplete or leaned to low resolution [Rau and Chu, 2011]. Close range images provide façade textures, which is straightforward for users to recognize the building. With the material of model and images, for the purpose of mapping textures, the 3D geometry between these materials have to be connected. In the consideration of realistic and accuracy, the level of details on building models should be taken into account when solving the joints.

Building façades are frequently blocked by self-occlusion or foreground elements, like trees, street lamps or benches [Bénitez et al., 2010]. Using terrestrial lidar data with accurate three-dimensional information [Beck and Haala, 2007], it is possible to distinguish foreground elements and building structures. To detect and remove occlusions, three-dimensional point clouds of the foreground elements should be back-projected on images. Nevertheless, texture mapping might be refractory due to the different illuminations among images. Mosaicking is a normally used solution to splice images [Kang et al., 2010]. When the building model is rough, mosaicking is a practical method to map a small number of façades. However, when it comes to more detailed model with a large number of façades, it might be inappropriate. In this research, our goal is to strike a balance between reality and visualization. There are often similar structures on building façades. Each structure provide one unique texture. When mapping the texture, we assumed that if similar façade textures can be categorized, we can map same texture on similar façades to reach consistency. A more complete process will be narrated in the next section.

METHODOLOGY

We combined three kinds of data, building models in different level of details, terrestrial lidar points, and close range images. Building model is simplified by point clouds. It provides self-defined coordinate system and building façade information. Terrestrial lidar points with accurate 3D coordinate are capable of distinguishing occlusions from building structures. Close range images come with spectral information and the texture characters are used to identify façades. There are three parts in our method: (1) data registration, (2) occlusion detection and (3) façade texture selection.

Data Registration

A working coordinate system is defined in which the X axis is perpendicular to the façade, Z axis is perpendicular to the ground and the coordinate system conforms to the right-hand rule. The origin of the coordinate system is on the roof corner of the building façades, as shown in Figure 1.

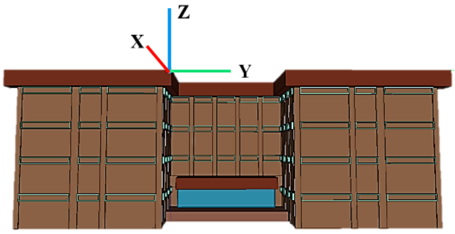

Figure 1 The coordinate system of the building model

The original coordinate system of the terrestrial lidar scan depends on the location of the scanner. Thus, three-dimensional conformal coordinate transformation is used with three rotation parameters and three translation parameters. On the other hand, each image has its own coordinate system in object space, where the origin of the coordinate system is the perspective center. Through the bundle adjustment, we determine exterior orientation parameters (EOPs) in the defined coordinate system.

Occlusion Detection

Occlusions on images may be caused by foreground elements and self-occluded parts, i.e., the building itself. Foreground elements, as literally suggested, must be objects in front of the façade. Terrestrial lidar data with three-dimensional information helps us to find foreground elements. Since, the X axis is perpendicular to the façade, we can examine the X value in the determination. Then, we can simply back-project those points onto each image through collinearity condition equations using the three-dimensional coordinate of the foreground elements and the EOPs of each image.

For self-occluded parts, a range buffer approach is applied. The building model helps us to make an index map having the same size as the image. The pixel will be recorded only if the distance between the façade and the perspective center is the shortest. Yet, the elements we back-projected is just points with infinitesimal size. Therefore, we buffer the point with a reasonable range. And we project each image on a plane to generate orthoimages and compensate occluded parts with conjugate pixel on the other images.

Façade Texture Selection

There are often similar structures on façades of a building. In this stage, our objective is to categorize the similar façade textures into individual groups. We start from two aspects: the geometry from model space and the texture from image space. For the model space, we extract 3D coordinates and the shape as façade information. Recognizing the shape and the size of each façade, we classify them into categories.

With the compactness determination in shape and size, image patches from the same model location will not be in different category. However, façades in the same shape with different textures will be grouped together in the previous step. In addition, with different shooting directions, the hue of images may be different. We should not only rely on RGB images to determine. In order to focus on its texture, we apply grey level co-occurrence matrix (GLCM) [Haralick et al., 1973] to compute the disparity between pixel and its surrounding neighbour pixels. Once the matrix of all façades in the same category is generated, we observe the distribution of values and compute its expected value. Comparing the GLCM results and intensity images, in the last step, we assume that there are only one texture pattern in a category. Then, we calculate the average value for each group. Ultimately, the optimal façade texture is selected based on the closest result to the majority.

EXPERIMENTAL RESULTS

The experimental result shows the texture mapping results with different level of details on building model (Figure). The model in Figure 2(c) is more complete than model in Figure 2(a). As a result, we get a better mapping result in Figure 2(d). Figure 3 shows the texture mapping results in different stages. Figure 3(a) shows the results before occlusion removal. Figure 3(b) is the results after occlusion removal but without façade texture selection. And Figure 3(c) is the outcome after façade texture selection.

(a) (b) (c) (d)

Figure 2 (a) (b) Less detailed model with its façade texture (c) (d) More detailed model with its façade texture

(a) (b) (c)

Figure 3 (a) Texture before occlusion removal (b) Texture before selection (c) Texture after selection

CONCLUSIONS

In this research, we have proposed a façade texture mapping approach by combing TLS data and close range images. We use terrestrial lidar points to detect occlusions on images, compute the compactness between façades using the information from building model, and analyze images to obtain texture characterization. The results show that this is an applicable approach to categorized façade patches and determined the optimal texture. It is also concluded that the proposed method may reach high fidelity, provided that the detailed building models are available.

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