FACADE DETECTION IN OBLIQUE AERIAL IMAGE USING OBJECT BASED IMAGE ANAYLYSIS

Ya-Ching Hsu[a] , Jyun-Ping Jhan[b] and Jiann-Yeou Rau[c]

[a]Graduate Student , [b]Ph.D Student and [c]Assistant Professor,
Department of Geomatics, National Cheng Kung University,
No.1, University Road, Tainan 701, Taiwan;
Tel: (886) 6 -237-0876 ext.800;
E-mail: graaabcd@gmail.com, riddle0104@hotmail.com, jyrau@mail.ncku.edu.tw

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ABSTRACT: With the development of 3D city model and 3D Geographic Information Systems (GIS), the models of buildings provide many applications like urban planning, disaster assessment, virtual visualization, and others. For city models production, aerial images and photogrammetry are definitely important data source and technology for building reconstruction, since rich geometric and semantic information from images offer a rapid method on reconstructing numerous building models. Comparing with vertical aerial images (VAI), there are more advantages in oblique aerial images (OAI). Oblique images offer 3D information of ground objects from different views, and it can provide not only the top surface information but also the side, such as the building façade. The façade information is useful for building change detection, reconstruction and texture mapping. Thus, in this study we propose to utilize oblique aerial images for façade detection through object-based image analysis (OBIA) technique. At first, we segment the image into objects using multi-scale multi-resolution image segmentation by color information. Some auxiliary information might be useful for image segmentation also analyzed in this study, such as edge detection and image enhancement. In order to detect the façade area, several feature objects were be utilized. 3D information generated by two oblique images from similar view direction is the main index for finding façade in our research. Finally, performance assessment will be evaluated through visual interpretation of ground objects to find the optimal classification scheme.

1. INTRODUCTION

1.1 Motivation

Oblique aerial images (OAI) provide abounding ground objects information due to a large tilt angle of the camera. As shown in figure 1, OAI provides not only horizontal but also vertical information of ground objects like building façade and looks more intuitive than vertical aerial images (VAI). For this reason, it has been applied in many researches and purposes such as façade texture mapping, building model reconstruction, online digital map service, etc. There is also some image provider supply oblique images, such as Pictometry company (Pictometry, 2000) which provide imagery for the customer to apply on different purposes like measurements or decision making. For all these advantages of OAI and its wide applications, we decided to perform façade detection with object-based Image Analysis (OBIA) technique.

Figure 1: (a) Oblique aerial image; (b) Vertical aerial image of the same area as (a)

1.2 Object-based Image Analysis (OBIA)

In traditional, image analysis such as image classification is based on pixels. According to the spectral information of each pixel, we can perform some identification or classification algorithm on the image. However, the noise on the image always cause salt and pepper effect and induces inaccurate result. For this reason, object-based image analysis has been developed since 2000 (Blaschke, 2010). The objective of object oriented analysis (OOA) is segmenting and classifying the image as visual identification result by human eyes. In OBIA, image will be segmented into objects and the interpretation scheme is processed in object level. Object can provide not only spectral information but also shape and texture analysis for the following classification and detection scheme and reach the result close to visual interpretation.

In this study, we perform multiresolution segmentation algorithm for image segmentation. Image will be segmented into objects by merging adjacent pixels with homogeneity. Homogeneity means the similarity of features such as colors, texture or brightness. It is a hierarchically bottom-up method, adjacent objects will be merged into a larger one continuously by the given homogeneity criteria such as shape, compactness, and scale (Benz et al., 2004). It will induce larger objects when scale becomes higher.

Usually, we need not only one segmentation step to get the best result. Refer to Jhan (Jhan and Rau, 2012), there are three stages for acquiring more precise and reliable result in landslide detection based on OBIA. The three stages are initial segmentation, region grow and down scale segmentation, respectively. In order to improve the accuracy, we also utilize the same concept in our façade detection scheme.

1.3 Façade Detection

In the past, façade detection and interpretation often performed in close range photos or 3D models from robot visualization or mobile mapping systems. The applications of detected façade can be utilized in visual interpretation, façade mapping, building verification and structure detection for further purposes, etc. Usually, building façade is detected by image data, 3D information or both of them. 3D information can obtained from LiDAR data, photogrammetry technique or disparity map of two images.

In recent years, with the development of aerial image and image matching technique, OAI shows the advantage that it can acquire a great number of façades and reconstruct the 3D building models rapidly, especially in urban area. This also improved the technique in façade texture mapping and building extraction scheme. With Pix4UAV© software provided by Pix4D, we can even acquire the 3D point cloud full automatically by only using aerial image data. Following this concept, there was a pixel-based façade detection method provided by Xiao (Xiao et al., 2012), in order to extract buildings from utilizing oblique aerial images only, building façade were detected preliminary for generating 3D hypothesis. In their study, facades were decided by texture evidence map and height gradient map. Texture evidence map verified the feature lines on façade like window's outline and height gradient map indicated façade would located on larger gradient area since it is assumed vertical to the ground. Height information was acquired from 3D point cloud by dense matching technique and projected into the source image. In our research, we also utilize height information to extract façade area. Differ from their assumption that building façade has larger height gradient, we perform another assumption due to the segmented objects are almost not located at specific height on one facade. The objects are segmented by multiresolution segmentation algorithm, so the segmented result is depending on feature's homogeneity.

1.4 Study Area and Material

Oblique aerial images are acquired from an Aerial Multi-Camera Imaging System (AMCIS) which contains five cameras. This system can provide four oblique images with four opposite looking directions and one vertical image at the same exposure time as shown in figure 2. We can acquire abundant ground information efficiently and rapidly by using this system. The study area is located at Taichung City, one of the major cities in Taiwan. This city contains different types of buildings including low-height departments and new-build tall buildings that are suitable for our research. The interior and exterior orientation parameters of each image are acquired from camera calibration and aerial triangulation result. Table 1 shows the specification of the used AMCIS.

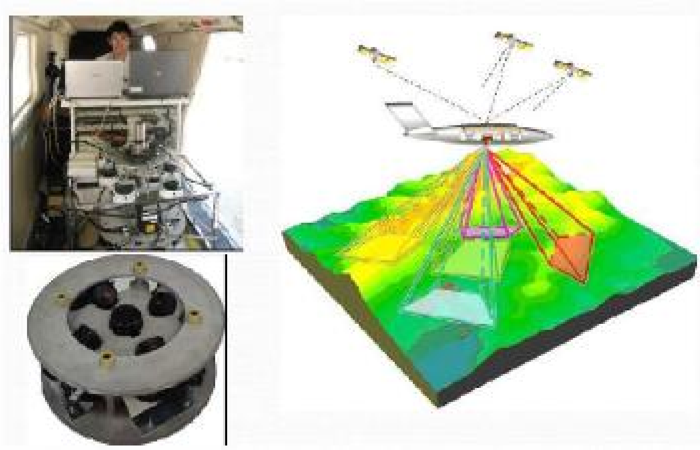

Figure 2: NCKU-Aerial Multi-Camera Imaging System (AMCIS)

Table 1: Information of the AMCIS system

Camera	Sony Alpha DSLR-A850
Sensor type	CMOS
Image size	6048 x 4032
Focal length and ground sampling distance (Vertical)	20mm, 25~35cm
Focal length and ground sampling distance (Oblique)	50mm, 11~25cm
Tilt angles	40°~45°
Flight height	800m

2. METHODOLOGY

For finding façade area on oblique aerial image by Object-Based Image Analysis, we utilize the Trimble eCognition© software to realize our idea. Figure 3 shows the flowchart of this study. First, the enhanced image is segmented into objects on pixel level with edge map and classified by the façade index as façade seeds. Next, we adopt region growing on façade seeds to include the undetected facade area. The growing result is then segmented and classified again with down sampling scale as precise façade seeds. Finally, we merge the detected objects and remove non-façade area by considering the objects' size and brightness. The detecting result is compared with ground truth generated by visual interpretation.

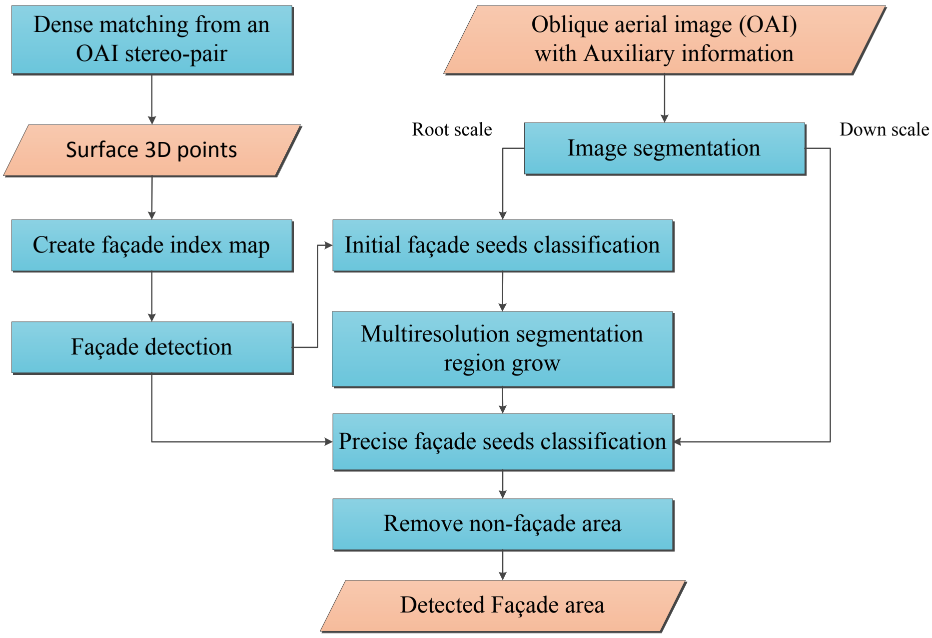

Figure 3: Flowchart of façade detection based on object oriented method

2.1 Image Segmentation and Region grow

We use multiresolution segmentation and multiresolution segmentation region grow in image segmentation and region grow steps. As mentioned is 1.2, image will be segmented into objects by homogeneity criteria. In the study case, we defined the shape, compactness, and scale parameter by visual verification. There are two segmentation steps performed during processing, both of their weight are set as (R, G, B, edge) = (1, 1, 1, 2). Here, we use enhanced images and edge map to assist segmentation. The comparison of these auxiliary information is described in the following section. Furthermore, shape and compactness parameters are set as 0.1 and 0.9. Scale is set to be 60 as root scale in the first segmentation step and 40 as down sample scale in the second segmentation step. In multiresolution segmentation region grow stage, the feature's weight is the same as segmentation and the scale is defined as 100.

2.1.1 Auxiliary information: In image segmentation step, we compared the segmentation result with two auxiliary information extracted from the original image. Figure 4 shows the original image, enhanced image and edge map generated from the original image. Image after enhancement is more clearly and different objects can be identified easier. Edge map can not only provide the structural line of the buildings but the features on the façade such as windows. Figure 5 shows the segmentation result in different situations. Compared with non-auxiliary information result, it's clearly to see the image is segmented along the structural line with edge map (blue rectangle). However, we can see the edge also is segmented into individual object on the vertical structural line of this building (yellow circle), because the edge also contains some pixels. Figure 5 (c) shows the segmentation result after image enhancement, we found that the building and ground can be separated successfully in this case (red circle). Combining the advantages of (b) and (c), we utilize both auxiliary information and set their weight as (R, G, B, edge) = (1, 1, 1, 2) in our research after trials for getting better segmentation result. In (c) and (d), green rectangle shows the improvement with considering the edge. We found that the roof is separated into two objects and include upper building without using the edge map. The polygon's outline in (d) is also smoother than (c).

Figure 4: (a) Original image; (b) Image after enhancement; (c) Edge map extracted from the original image

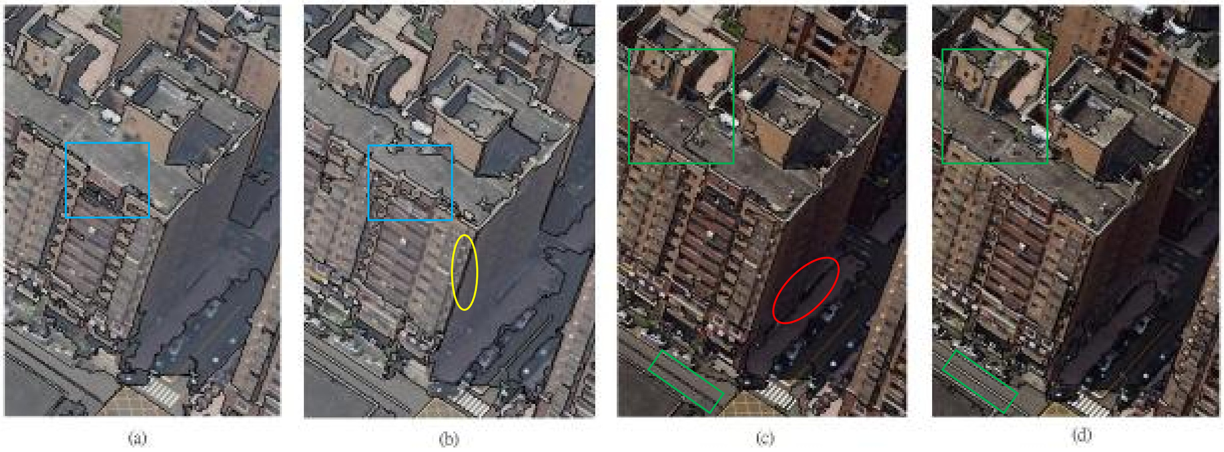

Figure 5: (a) Image segmentation without edge map, (R, G, B) = (1, 1, 1); (b) Segment in same scale as (a) but with edge map, (R, G, B, edge) = (1, 1, 1, 1); (c) Segmentation after image enhancement, (R, G, B) = (1, 1, 1); (d) Segmentation after image enhancement with edge map, (R, G, B, edge) = (1, 1, 1, 2)

2.2 Façade Detection

After image segmentation, pixels are segmented into objects. Every object is view as a basic unit in classification and we can find which object feature is appropriate for finding area of interest. In our study, façade area is classified by the façade index mentioned following.

2.2.2 Façade index map: Decided by our trial, there are three steps for acquiring the façade index map. First, dense 3D points are generated from two stereo images by a dense image matching technique (Rau & Yeh, 2012). Then, the generated 3D surface points) will be interpolated by Kriging method for producing high dense surface points. This step induces more dense points on the horizontal plane than the vertical direction due to the interpolation is based on object space X-Y plane. Based on the assumption that building facades are vertical to the ground, we can find out that there are seldom points on the facade after 3D interpolation. Finally the points' Z coordinate are back projected to the original stereo images, then we assign the index value as 255 when Z is larger than 0 and the others kept as 0. It means if there is no point project on the image the index value will be 0, then we can get the façade index map as shown in figure 6. In the end, combining the image segmentation results we can estimate the object's mean facade index value and by means of a pre-defined threshold we can detect the façade seeds. That means, during façade detection if an object's mean façade index value is lower than a threshold, it is considered as a possible façade.

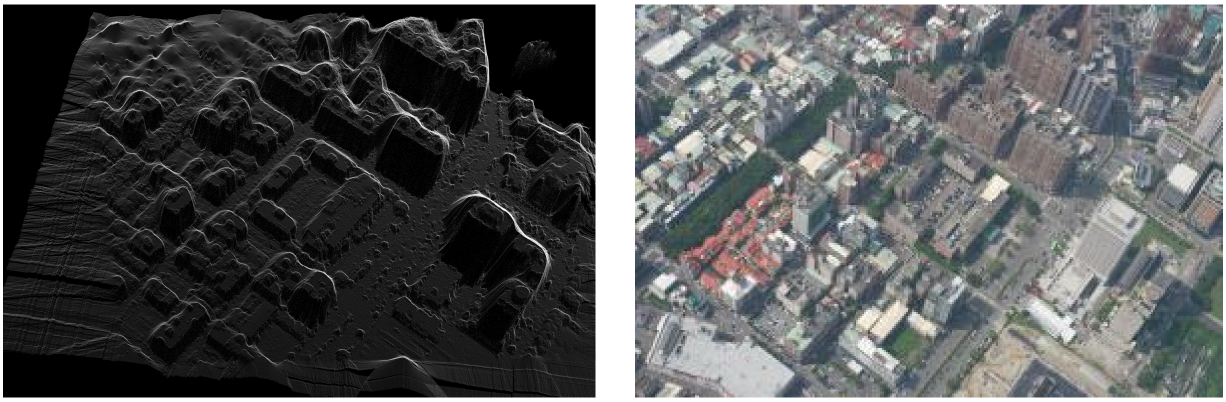

Figure 6: Façade index map (left) and original image (right)

2.3 Removal of Non-facade Area

Two feature indices are created for removing non-façade area and let the experiment result more reliable and accurate. The first feature index is the object size, we assume the facades are larger than a specific size on the image, not only to remove the small wrong patches but keep complete façade for other applications in the future. The other index is brightness which means the average value of all spectrums. In order to avoid some shadow area and vegetation, we will remove the patches with low brightness.

3. RESULTS

Figure 7 and 8 shows the experimental results, green patches on the right image represents the ground truth selected by visual verification and purple patches on left image represents the detecting results by our method. Black area means no overlap on the stereo-image, so we can't obtain the façade index map. After visual assessment, we find that most of the façade can be classified correctly. Nevertheless, there is still some undetected or incorrect classification area. In figure 7 and 8, the yellow rectangles show the building facades at the boundary of the image are undetected due to its façade is incomplete in one of the stereo images. In green rectangles, the façade detection is failed due to the high density residential area didn't generate correct 3D building points by image matching. Red rectangle shows the unclearly edges of detected façade which is induced by incorrect interpolation result as discussed in the following section. Figure 10 shows the consequence of removing small patches (green area) and vegetation (purple area) by object size and low brightness respectively. We can find the detected trees were filtered effectively.

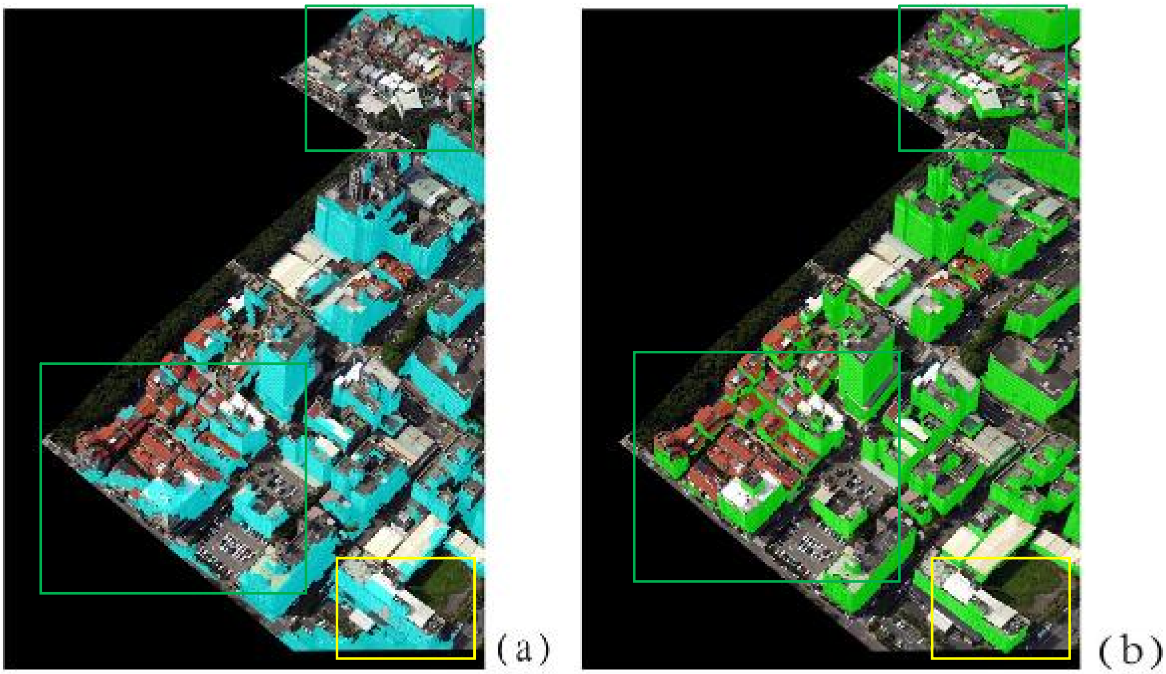

Figure 7: (a) Experiment result of left part image; (b) Ground truth of left part image

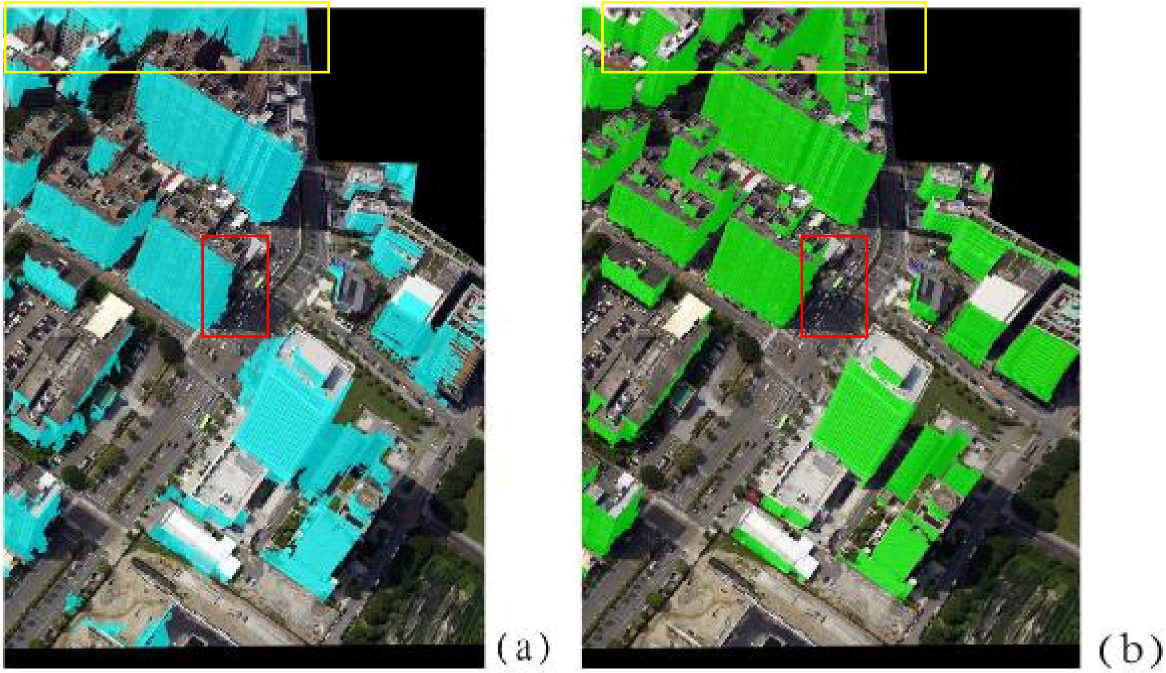

Figure 8: (a) Experiment result of right part image; (b) Ground truth of right part image

Figure 10: Result without vegetation and small patches

4. DISCUSSION

For façade detection, 3D information is a strong index to verify if it is façade or not, but it also cause some problem for this scheme. The most considerable factor is the occlusion effect in back projection. Nevertheless, in our case study we only use two images with similar viewing direction, so we doesn't need to deal with this problem. Second, usually we can identify the facade through its height variation on vertical direction, but during our experiment, most of the roofs didn't have much matched points due to fewer features presented on the roof. Consequently, we interpolate the original matching points based on X-Y plane and defined the façade index map which introduce seldom points on the façade.

Comparing our experimental result with the ground truth, we still find some errors that shown in figures 7 & 8. (1) The dense and low residential areas did not generate correct 3D points by image matching. During our test with other case, we find this problem may cause by fewer features on small façade patches. (2) Without adding building structure line as break lines in interpolating matched points by Kriging, the output points will have some problem. The point cloud shows the smooth effect on building's edge, as shown in figure 9, the edge of the building cannot be separated clearly on the façade index map. That's why we utilize auxiliary information in image segmentation but the detected façade area still can't show the correct outline. As a result, we realize that individual building with specific height will achieve better detecting result with the proposed method since it has large façade and could be identified more easily.

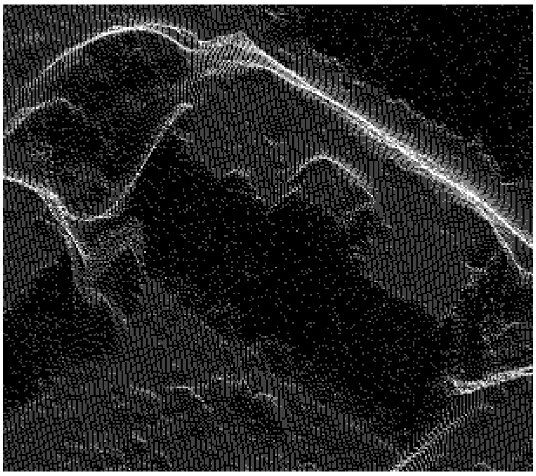

Figure 9: Smooth effect on building's outline induced by Kriging

5. CONCLUSIONS & RECOMMENDATIONS

This study proposes the use of OBIA technique and oblique aerial image for façade detection. There are some factors should be considered for utilizing object-based image classification in this scheme. For example, considering the original image only contains spectral information, the utilization of auxiliary information such as edge map in image segmentation step is suggested. We proposed a hierarchical approach to detect the façade. First, the oblique aerial image is segmented into objects. After classification by façade index map, we can get initial façade seeds. Then, we adopt region growing and down scale segmentation to acquire precise façade seeds. Finally, the façade areas are identified by filtering patches with small area and low brightness on precise façade seeds.

In our study case, we did not use any renowned methods of classification. During visual assessment, we found that most of the façade can be detected by the proposed method. However, some of the detected façade areas are incomplete due to the edge problem of interpolated 3D points. Nevertheless, there still some considerations we should notice in this scheme which discovered during our experiment. We conclude three conditions limited by our method: (1) the façade should be vertical to the ground; (2) façade detection could be failure in dense residential area; (3) the façade's outline can't be identified clearly due to rough interpolation. In the future, we will optimize the façade detection procedure and quantified object geometry accuracy by tools such as LIST (Landscape Interpretation Support Tool) (Schöpfer and Lang, 2006) or CI (Comparison Index) (Möller et al., 2007) to verify our result effectively and reliably.

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