Automatic Building Outline Reconstruction Using 2D Building Data and Stereo Images

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ABSTRACT: In this paper, we proposed an automatic procedure to reconstruct building outline using building data and stereo aerial images. Our methods focused on the outline of building, excluding the inner structure of roof surface. This procedure includes five steps, 1) to produce the edge gradient images by Canny Detector, 2) to defined the valid workspace in object space and image space by building data, 3) to detect line segments using grayscale Hough Transform, 4) to obtain 3D line candidates under epipolar geometric constraint and in valid workspace, 5) to reconstruct the building outline from candidates by shortest route decision. The reconstruction results of six buildings with plane roof and nine buildings with gable roof showed that this procedure was quite reasonable.

1. INTRODUCTION

The building data as a main product of photogrammetry developed from 2D maps to 3D city models, following the progression of computer technology and the requirement of users in this decade. Some researches [Halla and Brenner, 1997] [Hernricsson, 1996] [Lammi, 1997] used the existent building data to reconstruct building model but not available for variety of types. Some practical technologies are available for semi-automatic reconstruction of buildings, for example, CC-Modeler [Gruen, 1998], CSG [Veldhuis, 1999] and SMS [Rau, 2001] without using this data. However many researches for fully automatic building reconstruction are still in progress [Zimmermann, 2000] [Brenner et al, 2001] and prefer to fuse with many different data like existent building data, multi-view aerial images, multi-spectral images, DTM, DSM and so on. In this paper, we proposed a procedure to reconstruct the building outline automatically. In fact, our original motivation was to perform change detection of buildings, and which should be detected their locations first and whether changing before to be reconstructed. In our experiment, there were six buildings with plane roof and nine buildings with gable roof to be

reconstructed, and the results showed that our proposed procedure was quite reasonable.

2. THE PROPOSED PROCEDURE

Our basic assumption for building outline reconstruction was that there would be the shortest route to connect the building edges from all the lines in object space. For this assumption, the building edges must be in correct positions and enough to be connected for each other. Thereby we tried to extract correct and enough edge features through our procedure. There were five steps in our proposed procedure. At first, we produced edge gradient image by Canny Detector. Second, valid workspace in object space and image space was defined by building data. Third, linear features were segmented by grayscale Hough Transform on gradient image for each eave. Fourth, candidates of 3D line were acquired under epipolar geometric constrain and eliminate from valid workspace check. At Last, we grouped the optimal lines for building outline by shortest route decision whose rules were reasonably designed.

2.1 EDGE MAGNITUDE IMAGE

Edge features are the basic elements of building model. There are many methods for edge detection like LoG, Sobel Operator, Canny Detector [Canny, 1986], Foerstner Operator [Foerstner, 1994], MEDT method [Deok et al, 1995] and so on. However the optimal results from these different technologies are quite approximate. Unfortunately edge features as building eaves might not be easy to be detect, that is because radial features of image are not always equal to geometric features of building.

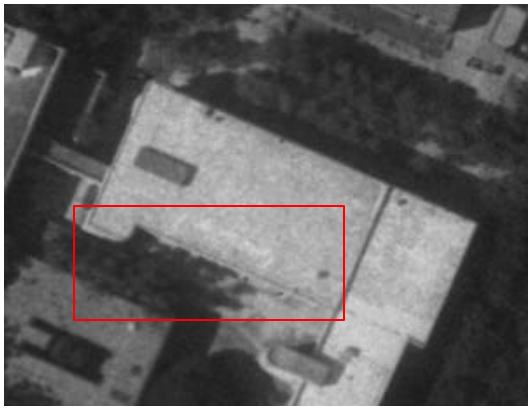

Fig.1 Building with blurred edge

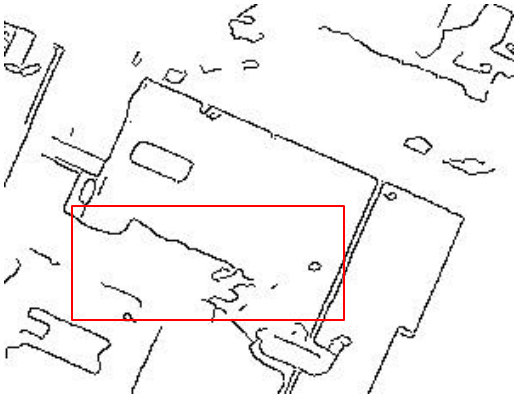

Fig.2 Edge detection by Canny Detector

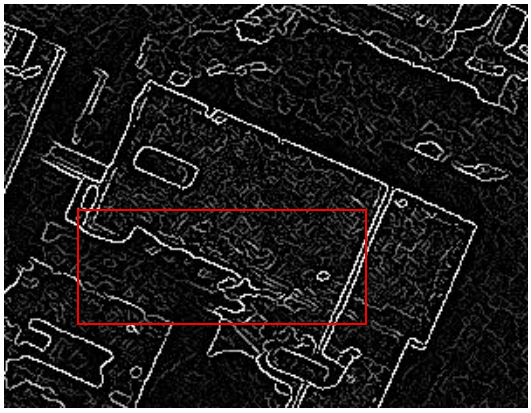

Fig. 3 Edge gradient image

Fig. 4 Linear features by grayscale Hough Transform

Fig.1 and fig.2 indicate that edge features yielded by Canny Detector with optimum parameters don't include the blurred eaves. That is because the gradient magnitude of eave pixels is too low to be detected. For this reason, we used the former product – edge gradient image to detect the exact edges instead of binary edge image. An edge gradient image showed in figure 3 still contains the exact eaves with low magnitude. Later we detect the linear features in step 3 with grayscale Hough Transform.

2.2 WORKSPACE DEFINITION

The form of conventional map for buildings was 2D line art with remark of floors rather than digital type of 3D building models. Since there are quite a lot of existent building data, they can be the good initial locations for automatic reconstruction, and change detection should be performed before that also.

Here we used the building data to define the approximate location of eaves from the coordinate of corners with possible error. For example, distance error of 0.6 meter was appended to the plane coordinate and a range from 3.3 meter to 4 meter defined the height of each floor. Then the valid workspace for each eave was defined in object space and projected to image space for next process.

2.3 LINES SEGMENTAION

In section 2.1, we produced edge gradient image by Canny Detector but not detect the exact edges yet. Before lines segmentation process, the gradient magnitude was reduced to 4 levels, which meant to weight for edge pixels. Then grayscale Hough Transform was performed within the valid workspace on image to segment linear features. Though magnitude of some edge pixels was weak, they still accumulated to a larger number in Hough Space and could be detected as a same line. Figure 3 shows the edge gradient image and figure 4 shows the result of linear features with 4 lines for each eave. One can find the blurred eaves are detected now.

2.4 CANDIDATES FOR BUILDING EAVES

Since edge features were detected, lines matching were always performed next to acquire 3D lines in object space. Unfortunately either area-based or feature-based matching methods rarely succeeded for eaves because of interferences as shadows, low contrast, repeated texture, obstruction and so on. Therefore we skipped matching step and computed every possible line pairs under epipolar geometry constrain. Though this result with greed lines showed in figure 5 is quite cluttered, most incorrect lines would be filtering out through check of valid workspace, which was defined on step 2. Figure 6 shows the lines in valid workspace, they are few and could be candidates of eaves.

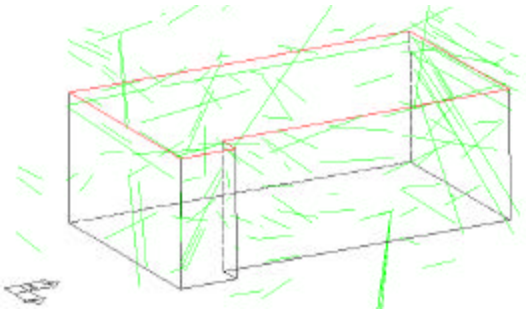

Fig. 5 All possible line pairs for eaves

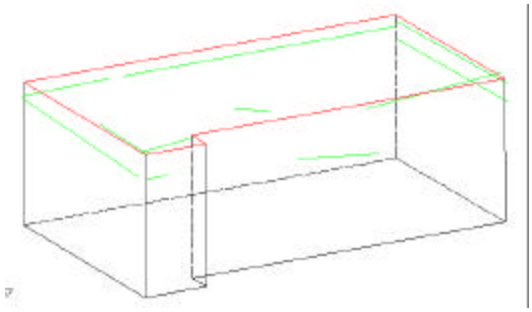

Fig. 6 The candidates within valid workspace

2.5 BUILDING OUTLINE RECONSTRUCTION

Our basic assumption for building outline reconstruction was that the perpendicular distance between connected lines on the same side and the height difference of intersectional lines for connected eaves should be smallest than any others. Since there were candidates for each eave, some of them could be grouped into an optimum outline by shortest route decision. We designed some reasonable rules to search the edges for building outline. For example, while searching edges on the same side, the perpendicular distance on XY-plane between the connected edges should be smallest and less than 1 meter, neglecting the height value. Under this rule, the slopes of gable roof would be

included.

And based our observation, longer lines were much more likely to be correct edges, so for connected eaves they were given much weight than the shorter. Then the possibility for two connected eaves was computed by dH/L1+dH/L2, here the dH was the height difference on intersection point and the Ln were the length of edges on connected side. In this process, every candidate would be the first edge and start to find the next connect edge on the same side or next side, and after forming a close outline they would assign a possibility through our rules. Then the smallest value just like shortest route should be the optimal building outline. Blue lines showed in figure 7 are grouped into the optimal edges for the outline from candidates through our rules.

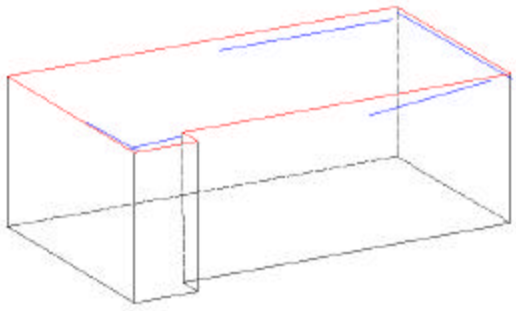

Fig. 7 The optimal lines by shortest route decision

3. EXPERIMENTAL RESULT

There were two test data for our experiment. NCU area with stereo images of scale about 1:12000, B/H 0.55 and pixel size 25um provided 6 buildings with plane roof and 3 buildings with gable roof. And Yang-Mei area with stereo images of scale about 1:7500, B/H 0.45 and pixel size 22.5um provided 6 buildings with gable roof. Figure 8 and 9 show successful edge groups in blue for building outline, and the green lines as candidates are excluded through reconstruction process.

Figure 10a and 10b indicate a possibility to form a slope or a horizontal line on gable roof, because they were easy to be detected as straight lines by Hough Transform. And Figure 11a and 11b show a failed one because of serious occlusion and shadows. Multiple images could provide many correct edges to solve the problems occurred in figure 10 and 11.

For preliminary accuracy estimation, we computed the difference of corners between manual measurement and reconstruction results without refining the outline by geometric constrain like parallel, perpendicular and coplanar conditions. The mean error, RMSE and maximum error for plane were 0.51m, 0.61m and 1.19m respectively. The maximum was caused by intersection of short and aslant edges. The mean error, RMSE and maximum error for height were –0.27m, 0.86m and +1.38/-1.79m respectively. The maximum were caused by edges approximately parallel to epipolar line direction and this situation exaggerated the error.

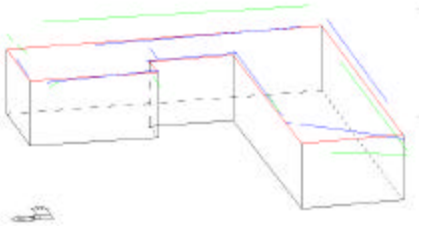

Fig.8 Detected lines for outline of plane roof

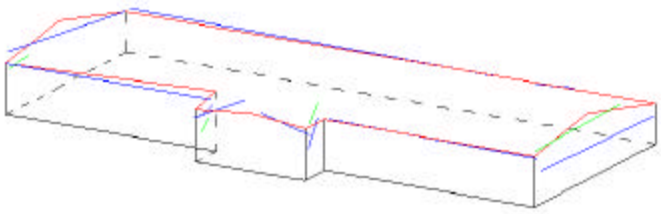

Fig.9 Detected Lines for outline of gable roof

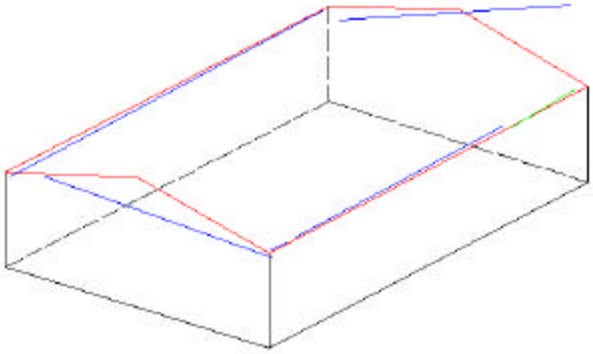

Fig. 10a and 10b the possible error lines of gable roof caused by Hough Transform

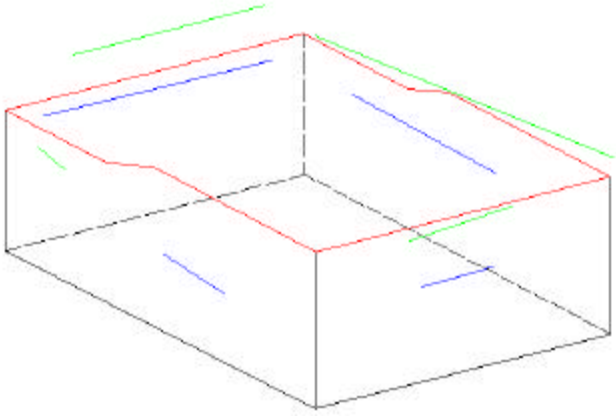

Fig. 11a and 11b the incorrect edges for outline due to occlusion and shadows

4. CONCLUDSIONS AND FURTURE WORKS

The experimental result indicated that the proposed procedure was able to reconstruct the outline of buildings with plane roof or gable roof. The rules of shortest route decision for building outline

reconstruction seemed enough for our data, but might need more tests to improve them. Though there was one building failed to be reconstructed due to serious occlusion and shadows, multiple images could solve this problem.

Based on the correct line group, we could refine the building shape with geometric constrain as parallel, perpendicular and coplanar conditions, and further more to reconstruct the inner structure like ridge. Anyway, our original motivation is to detect the change of building, and the decision machine for this purpose doesn't developed yet and still need further works.

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