EXTRACTION OF MAN-MADE BUILDINGS IN MULTISPECTRAL STEREOSCOPIC IMAGES

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ABSTRACT

The objective of this investigation is to develop a scheme to extract man-made buildings from color aerial image pairs. The scheme consists of five stages of processing. In the first stage, an epipolar transformation is applied according to the predetermined orientation parameters. Second, segmentation for color image pairs is performed using 3-band region growing approach. In the third stage, we calculate edge strengths for 3-band image pairs. Fourth, the detection and location of precision corner points are performed. Two steps are included in this stage. The initial detection for corners is firstly performed according to the segments derived from stage two. Then, those initial corner points are refined according to the edge strengths as calculated in stage 3. In the final stage, a new matching idea is proposed to determine the disparities for each building in the stereopair. The proposed operator improves the matching results with respect to the traditional ones. Experimental results indicate that proposed scheme achieve (1) high precision for corner point location, (2) highly successful rate in image matching, and (3) high accuracy of disparity for buildings.

1 INTRODUCTION

Extraction of man-made buildings from aerial stereopair is an important task in topographic mapping and three dimensional city modeling. Automated extraction of such objects is also the major work in digital photogrammetry research. A large number of researches have been devoted to this area (Henricsson & Baltsvias, 1997; Gabet, et. al., 1997; Baillared, et. al., 1998; Kim & Muller, 1998; Sahar & Krupnic, 1999). Considering different shapes, environments, and image intensity for different buildings together with the occlusion and shadow effects, the automation is essentially an ill-posed problem (Sahar & Krupnic, 1999). In addition to developing better scheme, increasing higher information content is an essential way for the solution. Henricsson (1998) used multi-spectral images to improve the performance in roof determination and edge extraction. Spreeuwers, et. al.,(1997) and Gabet, et. al.,(1997) used multi-view images to reduce the effect of occlusion. Thus, high accuracy and reliability were achieved. From color image point of view, we will propose a scheme to extract man-made buildings from aerial stereopairs. The major works of the scheme include (1)generation of epipolar image pair, (2)segmentation by region growing, (3)computation of edge strength, (4)precision corner detection, and (5)precision image matching. A flowchart of the proposed scheme is show in fig.1.

2 THE PROPOSED SCHEME

The scheme consists of five stages of processing. In the first stage, an epipolar transformation is applied to the stereoscopic pair. Second, segmentation for color image pairs is performed using 3-band region growing. In the third stage, we calculate edge strengths for 3-band image pairs. Fourth, the detection and location of precision corner points is performed. Two steps are included in this stage. The initial detection for corners is firstly performed according to the segments derived from stage two. An algorithm will be provided for the initialization. Then, those initial corner points are refined according to the edge strengths as calculated in stage 3. In the final stage, a new matching idea is proposed to determine the disparities for each building in the stereopair. The proposed matching technique is call “CLR Matcher”. The matcher uses three-window approach to match image points along building edges.

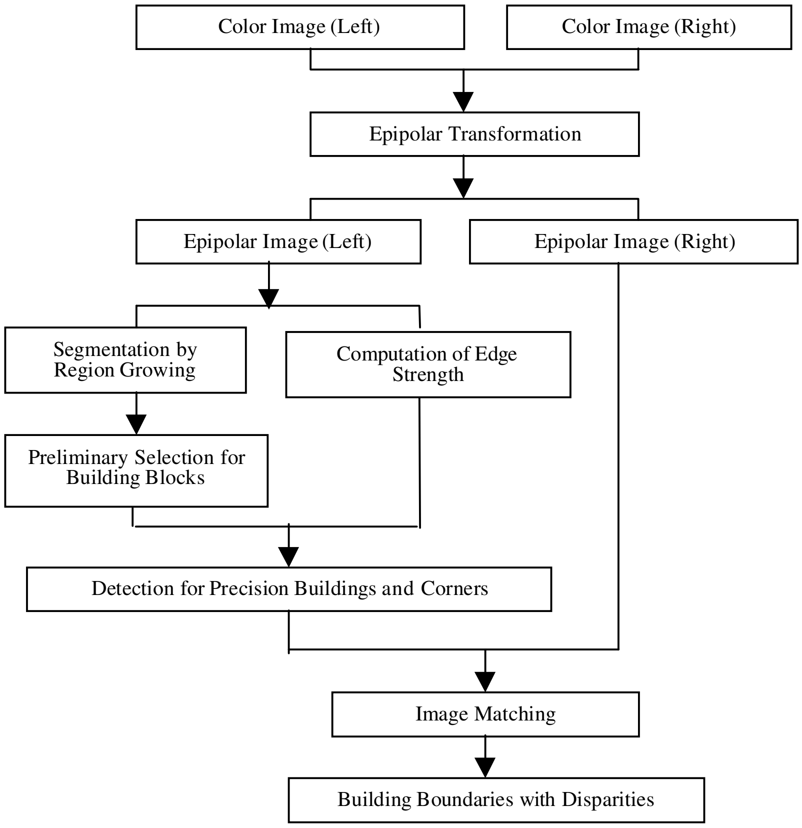


Figure 1. Flowchart of the Proposed Scheme

2.1 Epipolar Transformation

In order to exclude the vertical parallax to simplify the successive processing, we transform the image coordinates to an epipolar system. After the determination for orientation parameters we redefine the axis in coincidence with the flight direction. Then the epipolar images can be generated by an orthorectification procedure provided that a ground surface is available (Chen & Lee, 1993). Thus, the buildings will yield significant horizontal parallax.

2.2 Segmentation

In order to segment buildings from backgrounds in an image, one assumption of being made is that the roof of a building is radiometrically homogeneous. Two approaches are possible. The first is the classification (clustering) procedure. The second one is called region growing. The problems of using clustering approach encounter difficulties of selecting number of clusters and lack considerations of local features. Thus, region-growing approach is used in this investigation.

Referring to fig.2, the method of region growing used in this investigation is stated as follows (Dang, et. al., 1994). We first select a seed point then the following procedure will apply to the whole image. The grey value of point S is compared to its neighborhoods (P_1~P_8) band by band. If the grey value difference between S and P_i is less than a threshold for each band, then the two points are merged into a region. The region begins to grow until the stability. The growing procedure is then reapplied to the points which have not been treated. The method produces unique result when different sequences of seed points are selected.

P_1	P_2	P_3
P_8	S	P_4
P_7	P_6	P_5

Fig.2. Illustration of a Seed Point and Neighborhoods

2.3 Edge Strength Calculation

The proposed scheme combines segment information and edge strength to determine the accurate shape of buildings. A number of edge detectors such as Sobel operator (Gonzalez&Woods, 1992), LoG (Marr & Hildrith, 1980), Canny operator (Canny, 1986), and MEDT (Deok, et. al., 1995) have been reported. We select Sobel operator for computational simplicity. Combining the gradients convoluted by a horizontal and a vertical operators to each spectral band image. The one with the highest strength among the 3 band images will be considered as the final edge strength.

2.4 Detection for Buildings and Corners

The results of segmentation and edge detection are combined in this stage. Two steps are processed. The first is to detect the preliminary corner points. Then a refinement procedure follows.

2.4.1 Preliminary Corner Detection

For a given window with $n \times n$ pixels, it moves along the border of a region segmented from §2.2 (fig. 3.a). Then we calculate the angl θ between C and the outmost points E_1 and E_2 (fig. 3.b). If θ is in a reasonable range, the point is assumed to be a corner candidate. In general, several points would be retained around a real corner (fig. 3.c). Thus, we take average location for the preliminary corner points (fig.3.d).

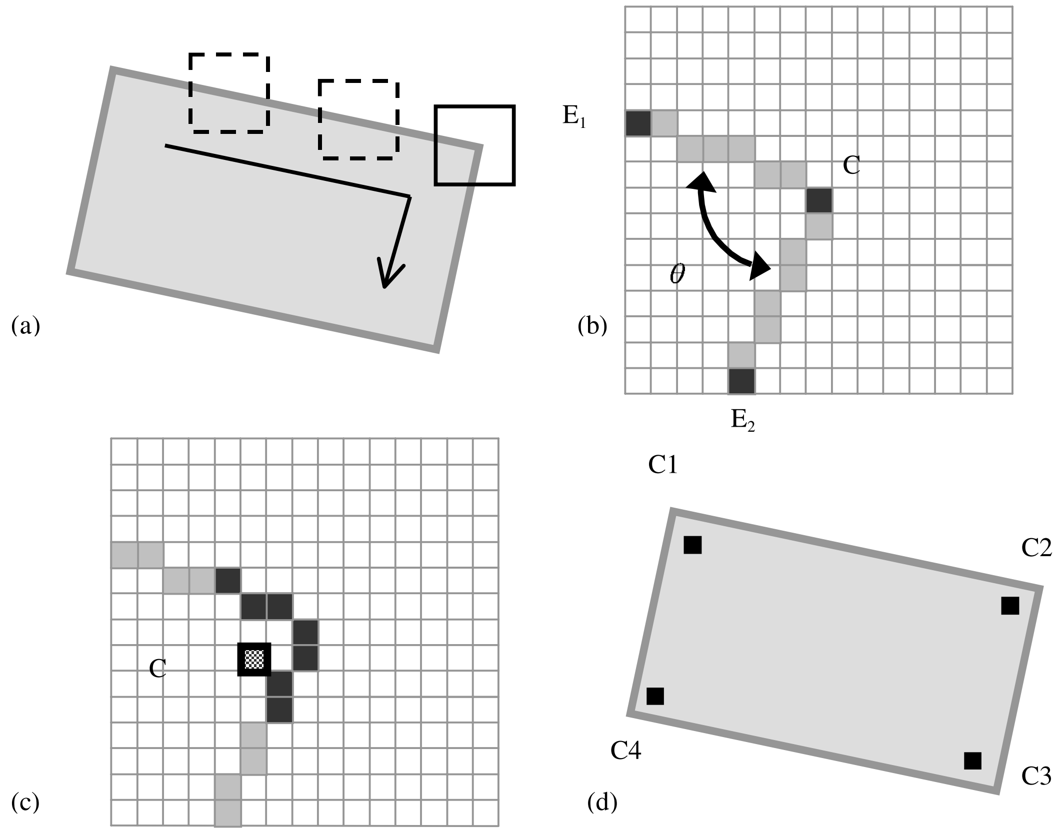


Fig.3. An Illustration of Preliminary Corner Detection

2.4.2 Detection for Precision Buildings and Corners

We search for the edge line with the highest strength in the buffer zones for the possible lines connected by preliminary corners. Starting from the preliminary corners C_1 and C_2, a window is selected (fig.4.a). Then the edge strengths of all the line combinations of the points in window C1 and window C2 are computed. The two linking points with the largest strength are remained. The procedure is recursively performed until no changes are detected. Meanwhile, if an angle between two connecting lines is not in a reasonable range, the boundary is ignored. Then we determine the intersection of remained edge lines as corner points for a building (fig.4.b). Connecting final corner points, a building is extracted (fig.4.c).

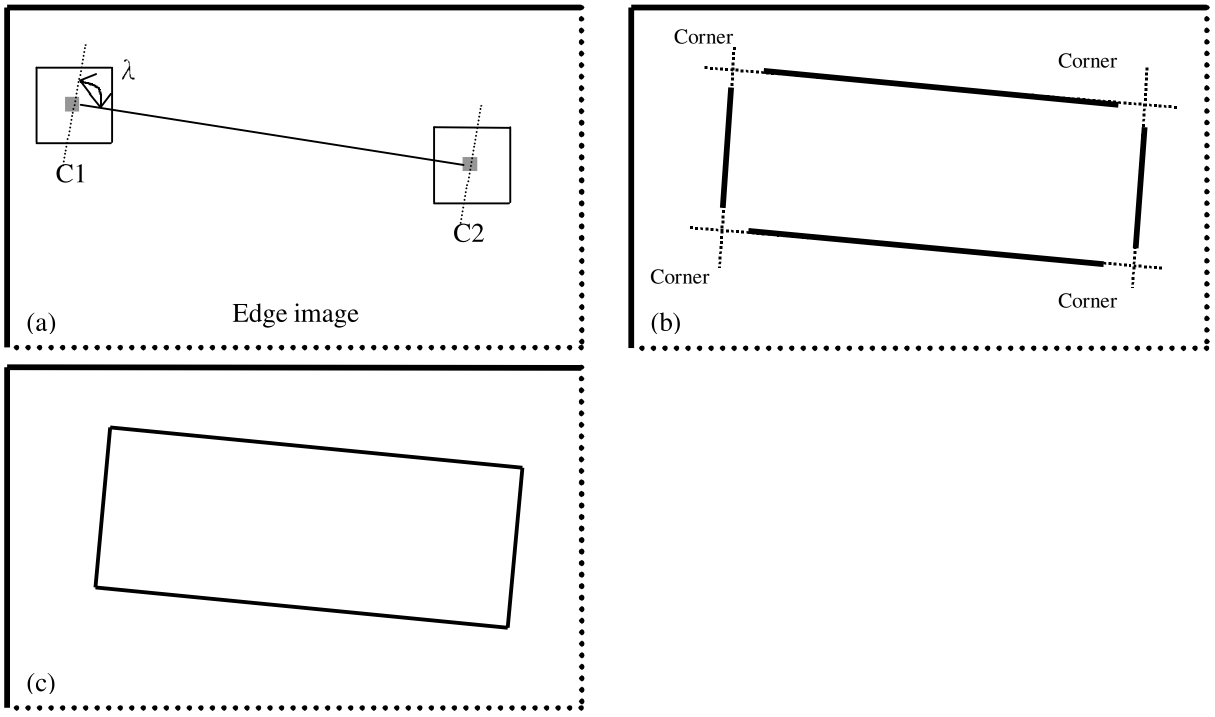


Fig.4. Detection of Precision Building and Corners
(a)Edge Strength Calculation for Possible Combination,
(b)Determination of Building Corners,
(c)Extracted Building.

2.5 Image Matching

Considering the surface discontinuity around a building, we propose a multi-window method for image matching. The method is called "CLR Matcher". We use three windows (fig.5) for each edge point to move along the epipolar lines. The grey values are used to compute the correlation coefficients. The one which has the highest correlation coefficient and is larger than a threshold is kept. An illustration in fig. 6 compares the traditional single window matching (a) with respect to CLR Matcher (b). In the case of traditional approach, point A, B and C could not be successfully and reliably matched. On the other hand, for CLR Matcher, the matching would be successful by windows R for points A and C and by window L for point B.

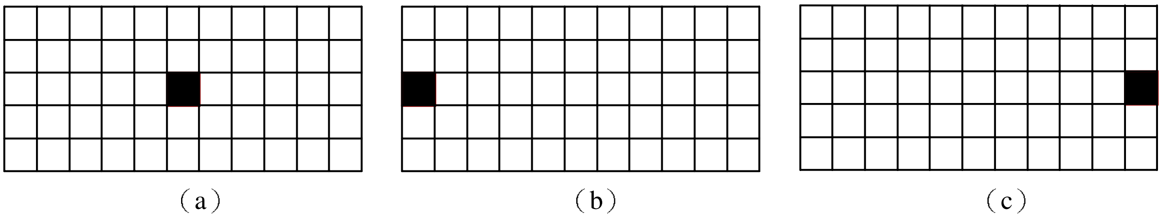
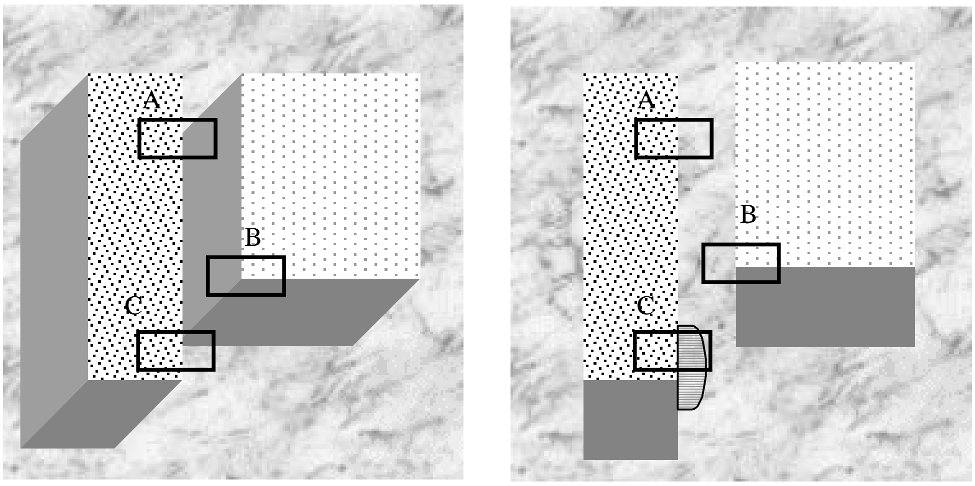
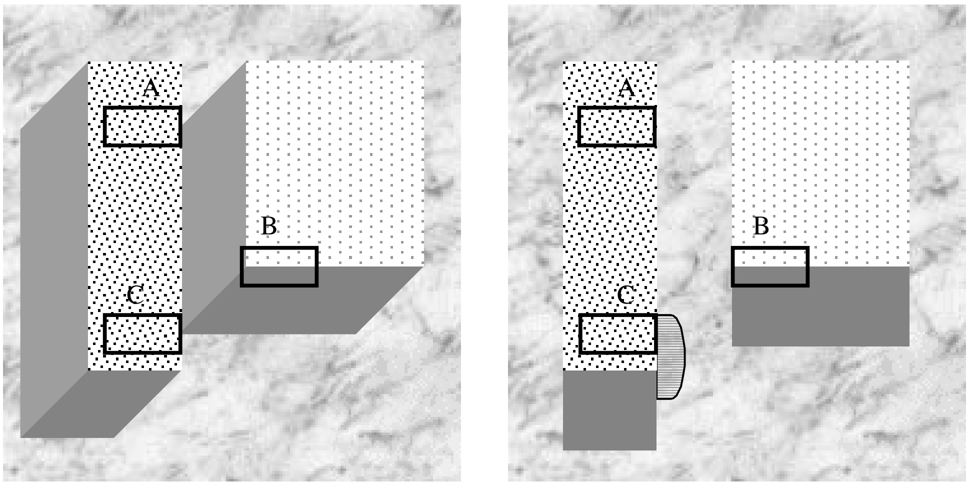


Fig. 5 A Illustration of CLR Matcher (a) Center (b) Left (c) Right



(a)



(b)

Fig.6 Comparison of Traditional Window Matching and CLR Matcher

(a) Single Window, (b) CLR Windows

3 EXPERIMENTAL RESULTS

The experiment includes the testing of the proposed scheme for building detection from a pair of color aerial image pairs. Test images were scanned from a pair of aerial photos with a scale of 1 to 9800. Scanning at 22.5 μm pixel spacing, the pixel coverage in the object space is about 20 cm. The images of the test area are shown in fig. 7. The result of segmentation using region growing for the left image is shown in fig. 8. Fig. 9 shows the building blocks manually selected from the segmented regions. This is considering the semi-automatic approach and is the only manual input in the whole process. Fig. 10 is an edge strength map. The results of detected building corners are illustrated in fig. 11. In which, a partial enlargement is shown in fig. 11 (b). Finally, the detected buildings are shown in fig. 12.

(a) (b).

Fig.7. Test Images (a) Left (b) Right

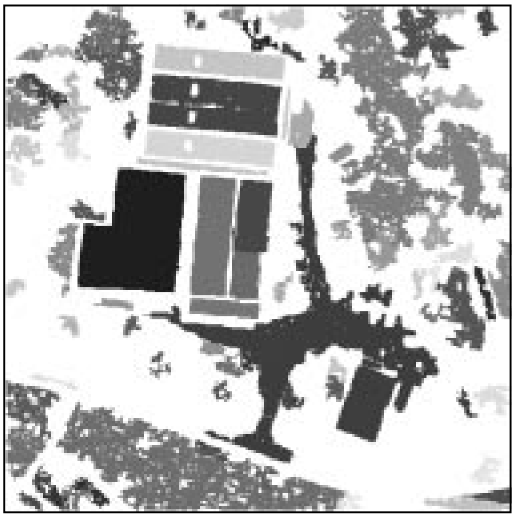


Fig.8. Results of Region Growing

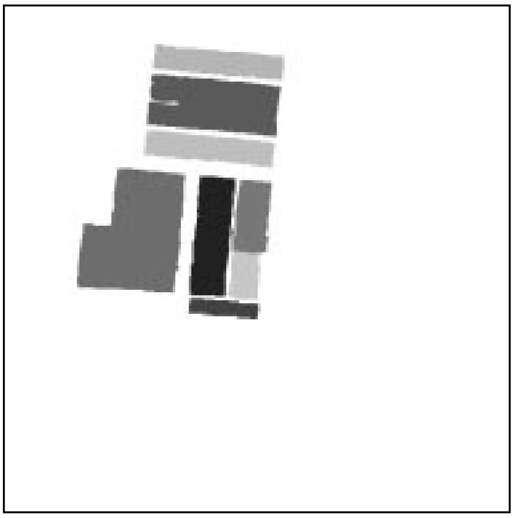


Fig.9. Selected Building Blocks

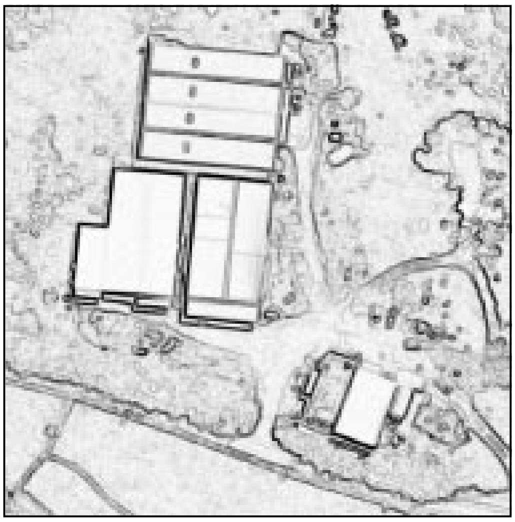
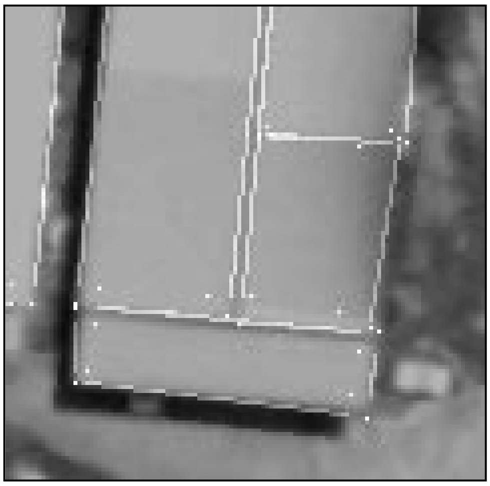


Fig.10. Calculated Edge Strength Map

(a)



(b)

Fig.11. Result of Corner Detection (a) Original Picture (b) Local Enlargement

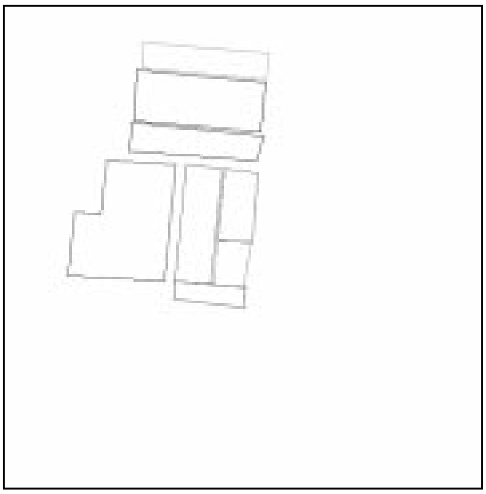


Fig.12. Detected Building Boundaries

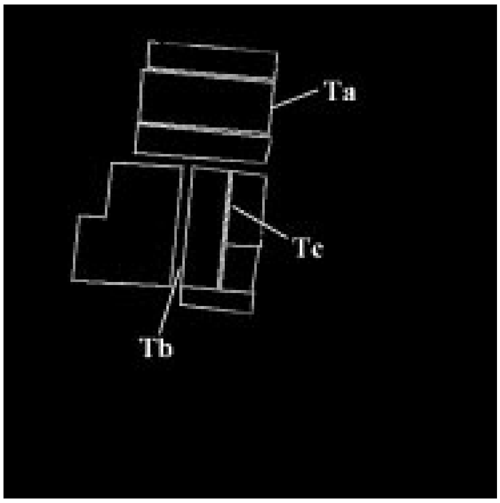


Fig. 13. Evaluation for CLR Matcher

In order to evaluate the precision of extracted building boundaries, we generate a set of reference data for the eight blocks as shown in fig. 9 by manual digitization. It is found that the preliminary corners have a mean error of 6.8 pixels and 2.1 pixel standard deviation. On the other hand, the corners refined by the edges have a mean error of 1.2 pixels and 0.6 pixel standard deviation.

To analyze the performance of CLR Matcher, we select three areas Ta, Tb, Tc, as shown in fig. 13. Then we compare the matching results with respect to the reference derived by manual digitization (Table 1). It is obvious that CLR Matcher performed much better than the one using "Center" only. The RMS of the differences is 2.2 pixels.

	Line	Sample			Correlation Coefficient			Successful Matching window
		Manual	Matched	Difference	C	L	R	
Ta	92	279	282	3	0.4826	-0.6151	0.8875	R
	93	279	282	3	0.4149	-0.6617	0.8966	R
	94	279	282	3	0.3536	-0.6821	0.9000	R
	95	279	282	3	0.2834	-0.6888	0.9010	R
	96	279	281	2	0.3224	-0.4274	0.9250	R
Tb	272	186	188	2	0.6639	0.9903	0.2981	L
	273	186	188	2	0.6503	0.9971	0.2758	L
	274	186	188	2	0.6522	0.9966	0.2638	L
	275	186	188	2	0.6743	0.9962	0.2640	L
	276	186	188	2	0.7080	0.9957	0.2649	L
Tc	192	235	236	1	0.9245	0.8980	0.9582	R
	193	235	236	1	0.9266	0.8882	0.9573	R
	208	234	236	2	0.8643	0.8351	0.5984	C
	209	234	236	2	0.8549	0.8241	0.6263	C
	210	234	236	2	0.8438	0.8471	0.6820	L
	211	234	236	2	0.8456	0.8996	0.7592	L
	212	234	236	2	0.8599	0.9104	0.8236	L
RMSE				2.2				

Table 1. Quantitative Analysis for CLR Matcher

4 CONCLUDING REMARKS

A scheme for building extraction from a pair of aerial images is given. The scheme is essentially a semi-automatic approach. The only manual intervention is the rough selection of potential building from segmented blocks. Experimental results indicate that the extracted building boundary may reach an accuracy of 1.2 pixels. The RMSE of the matched disparities may reach an accuracy of 2.2 pixels.

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