

Using Orthophoto for Building Boundary Sharpening in the Digital Surface Model

Xiaohu Lu, Rongjun Qin, and Xu Huang

INTRODUCTION

Dense stereo matching has become one of the dominant tools in 3D reconstruction of urban. However, state-of-the-art semi-global matching (SGM) strategy normally imposes smooth penalty to deal with non-texture or repeating texture areas, which leads to smoothing on depth discontinuities, particularly for densely built areas with narrow streets.

Post-processing is generally utilized to solve this problem. Pixel based methods use neighboring pixels in a support window to refine the disparity of boundary pixels. Contour/line based methods extract building boundaries or line segments first, and then use plane function to refine the disparity of these boundaries.

In this work, we proposed and compared a graph-cut based and a line based DSM boundary refinement methods.

METHODS

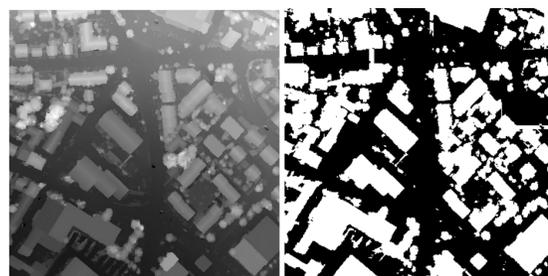
Inputs: DSM and corresponding orthophoto

Outputs: Adjusted DSM and orthophoto

Step1: Pre-processing

(1) DSM Building Boundary Extraction

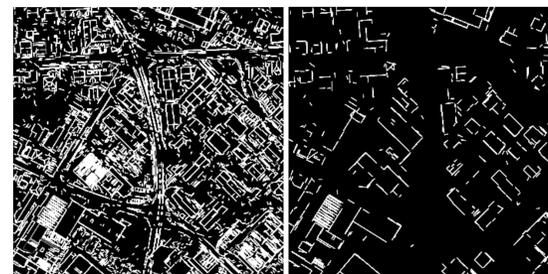
- Robust morphological top-hat operation with of structuring element range [10, 400] with an interval of 10 pixels.



(a) DSM (b) Tophat result

(2) Orthophoto Building Line Extraction

- LSD to extract line segments
- Building boundary buffer zone to filter non-building line segments



(a) LSD line segments (b) filtered line segments

Step2: Boundary Adjustment

(1) Graph-cut Based Boundary Adjustment

- Energy function

$$E(l) = \sum_p D(p, l_p) + \sum_{p,q} V_{pq}(l_p, l_q)$$

P: data points L: set of labels

$D(p, l_p)$: data term $V_{pq}(l_p, l_q)$: smooth term

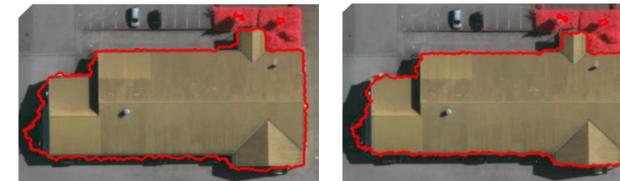
- L is defined as the offset of contour pixels

(-5, -5)	(-4, -5)	...	(4, -5)	(5, -5)
(-5, -4)	(-4, -4)	...	(4, -4)	(5, -4)
...		(0, 0)		
(-5, 4)	(-4, 4)	...	(4, 4)	(5, 4)
(-5, 5)	(-4, 5)	...	(4, 5)	(5, 5)

$$D(p, l_p) = \begin{cases} 0, & \text{if } (x_p + x_l, y_p + y_l) \text{ in line buffer} \\ 10, & \text{otherwise} \end{cases}$$

$$V_{pq}(l_p, l_q) = \begin{cases} 2, & \text{if } \|l_p - l_q\| < 5.0 \\ 100, & \text{otherwise} \end{cases}$$

- The running time of this process is in seconds level for a normal computer



(a) Original boundary (b) Graph-cut boundary

(2) Line Based Boundary Adjustment

- Fit a plane for each side of buffer zone of line segment
- Adaptive buffer zone width: $\min(3 \times \text{line width}, 30)$
- Plane fitting:

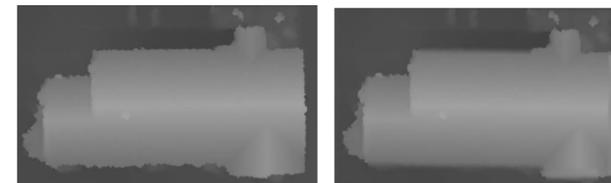
$$h_1 = ax_1 + by_1 + c$$

$$\vdots$$

$$h_n = ax_n + by_n + c$$

Solving: least square

- Adjust DSM boundary pixel values via fitted plane function.



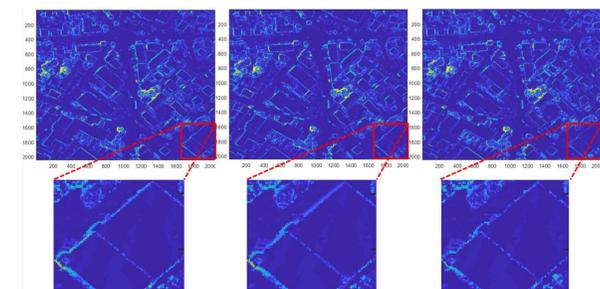
(a) Original DSM (b) Adjusted DSM

RESULTS

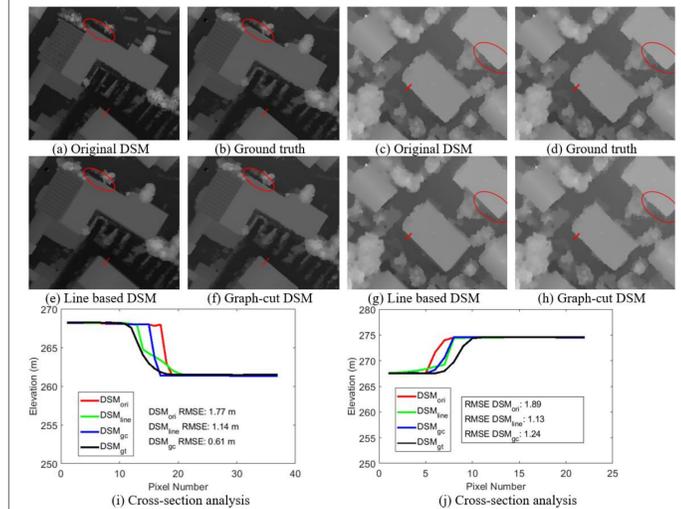
(1) Dataset

ISPRS dataset on urban classification and 3D building reconstruction. 9 cm Lidar DSM as ground truth. Three patches with size 2048x2048 in pixels, 184x184 m².

(2) Overall Result: 2.3% and 3.2% improvement



(2) Boundary Result: 1.77m to 1.14m and 0.61, 1.89m to 1.13m and 1.24m



CONCLUSIONS

Two methods using line segments from orthophoto are proposed and compared for DSM boundary refinement. The overall RMSE has been improved 2.3% and 3.2% for line based and graph-cut based methods, respectively. While the RMSE on building boundaries is improved from 1.77m to 1.14m and 0.61m for one case, from 1.89m to 1.13m and 1.24m for the other case.

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