Robust Window Detection from 3D Laser Scanner Data

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Abstract

In this paper we propose a robust system for window detection using popular descriptive statistics and image based methods, making use of 3D information from a laser scanner. The scanner generates 3D point clouds containing intensity and distance information in a spherical co-ordinate system, with optional additional RGB texture information. The applied descriptive statistical method exploits basic local features such as mean, variance and standard deviation of the distance measurement data. The laser distance information shows high variability in windows region, due to specular reflections on window screens on one hand, and screen penetration on the other hand. Therefore we determine an adaptive threshold on the basis of local absolute differences of adjacent laser-measured distances in the image formed by the angular co-ordinate system of the scanner. For window segmentation the image is binarized using the derived threshold, and morphological operations such as closing using adaptive (i.e. distance - dependent) structural elements are performed. After contour analysis the resulting bounding rectangles are used to retrieve the positions and global shapes of windows in the image. The system provides a sufficient windows detection rate for direct application in a deformation measurement system.

Keywords: *Urban laser scanning, windows detection, descriptive statistics, deformation analysis*

1 INTRODUCTION

3D facade models are becoming popular in urban deformation measurement systems supported by computer vision techniques. There are many approaches to generate such models from 3D point clouds obtained from a laser scanner as well as from multi-view 2D camera images. Wang et al. [10] presented a set of algorithms that recovers detailed building surface structure from large sets of urban images containing severe occlusions and illumination variations. An iterative weighted average algorithm is introduced to recover high-quality consensus facade texture. They combined 2D and 3D methods to extract micro structures facilitating urban model refinement and visualization. Frueh et al. [2] developed a system which consists of data processing algorithms for generating textured 3D building facade meshes from laser scans and camera images. It uses data acquired from digital cameras and a laser scanner while driving on public roads under normal traffic conditions. The process detects and classifies dominant building structures on the basis of foreground and background layers. It was evaluated on a large data set of downtown Berkeley with several million 3D points in order to obtain texture-mapped 3D models. Similarly, Pnard et al. [6] presented a system for 3D building facade reconstruction from multiple wide-angle views. They developed an algorithm which automatically generates textured meshes of building facades from a set of multi-overlapping calibrated and oriented images. Main objective was to obtain high geometric accuracy while trying to create 3D point clouds. They gained

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accurate representations of the facade surfaces for visualization purposes. Mayer and Reznik [5] proposed a system for Building facade interpretation from uncalibrated wide-baseline image sequences. Their system is based on novel features and Markov Chain Monte Carlo (MCMC). The system provides fully automotive facade interpretation from wide-baseline image sequences with the basic idea to construct the whole building from different parts e.g facades and windows. Schindler and Bauer [8] presented a model-based method to reconstruct buildings from close-range images. The 3D points are segmented with robust regression algorithms and the geometry of this model is defined by 3D shape templates. The system identifies rectangular features from projected outliers on a rectified wall-plane for window detection, requiring multiple images for plane-estimation. Lerma and Biosca [3] developed a system for architectural modeling which obtains the surfaces of the object after reducing the data volume. Pu and Vosselman [7] proposed a semi-automatic system for reconstruction of buildings from range data. Another system presented by Thiemann and Sester [9] obtains a recursive segmentation of buildings based on feature analysis. It directly operates on 3D data generated by large distance laser scanner and provides robust detection of the windows in the facades.

The system introduced in this paper works directly on the laser-scanner provided image in a spherical co-ordinate system. Its workflow is depicted on Figure 2. The distribution of local distance changes is analysed to obtain a global threshold for window pixel candidates. Dedicated morphological operations and contour analysis of segments lead to rectangular window segments further usable for the respective application.

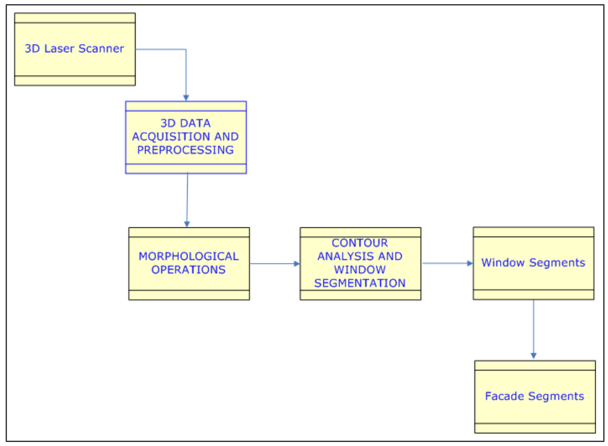

Figure 1. Pipeline for window detection from 3D laser scanner data

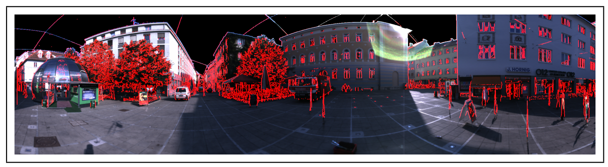

Figure 2. RGB image of urban scene in spherical laser scanner co-ordinates, overlaid by a binary mask from thresholding that resembles window candidate pixels

2 WINDOWS DETECTION

2.1 3D DATA ACQUISITION AND PREPROCESSING

Computer Vision systems are heavily focused on statistics, optimization and geometry. For the window segmentation proposed in this paper we rely on descriptive statistics which is an important tool of computer vision in the field of 3D data analysis. In our system we collect 3D data points using a highly accurate and long-range laser scanner. Data points with a distance up to 300 m are stored in a 3D structure containing individual spherical co-ordinates, distance from the laser scanner origin, as well as RGB texture values for each measured point. From the resulting distance image in spherical co-ordinates the basic parameters *distance mean, variance, standard deviation and co-officent of variation* as well as the distribution of local distance variations

$$D = dx_1 - dx_2 \tag{1}$$

are obtained with D the difference of the distance, dx_1 the distance at laser image coordinate(x_1, y), and dx_2 the distance at point$(x+1, y)$ for each laser image row y.

These are used to calculate an adaptive threshold T for the selection of window pixel candidates, given by 2:

$$T = Q_3 + Q_1 - 2M/Q_3 - Q_1 \tag{2}$$

where Q_3 and Q_1 are first and third designated quartiles, and M is the Median of the distances.

T can be directly used to binarize the image containing adjacent distance differences. An example for such a binarization is shown in Figure 2.

2.2 MORPHOLOGICAL OPERATIONS

Window Region of Interest (ROI) segmentation is performed by morphological operations. Closing on the binary image (dilation followed by erosion) with a $3*3$ structuring

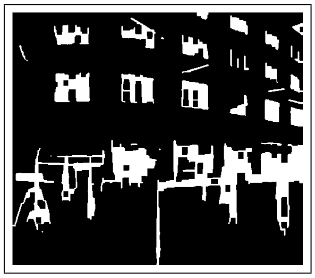

Figure 3. Closing joins separate portions of windows to be considered as single segments for further evaluation

element leads to connected components as shown in Figure 3.

2.3 CONTOUR ANALYSIS AND WINDOW SEGMENTATION

Window segmentation is done by connectivity-preserving contour analysis on the binary image. Contouring or *isoplething* disjoins regions and draws outlines of connected components in the image. In such way we retrieve contours and, in consequence, the up-right bounding rectangles of window segment candidates from the binary image. The area of the whole contour and the bounding rectangle are compared as given by Equation 3:

$$R = RA - CA < (0.5 * RA) \tag{3}$$

where R is the bounding rectangle, RA as the rectangle area and CA as the contour area.

3 EVALUATION AND RESULTS

To evaluate the windows detection system we have used images from a database obtained with a mobile mapping system [1] within the city of Graz, Austria. The database contains laser scan images of different viewpoints that were taken under different illumination conditions with a typical size of $2500 * 500$ pixels. Manual window segmentation served as ground truth. To evaluate the window detection rate we counted a *true positive*, if the window is detected in the data-analysis phase, *false negative* if an existing window was not detected, *true negative* if the window is present but not detected as a window and *false positive*, if a window was detected where there is actually no window present. There were a total of 196 windows calculated as ground truth, 135 of them were detected as true positives. Table 3 shows the detection results.

Database	CityScanner
True Positive	135
False Negative	21
True Negative	27
False Positive	13

Table 1. Windows Detection Evaluation Results for CityScanner database

Figure 4. (a) Original Image in laser scanner spherical geometry (b) Candidates for window sub-segments (binary, overlaid on (a). (c) Detected Window rectangular outlines

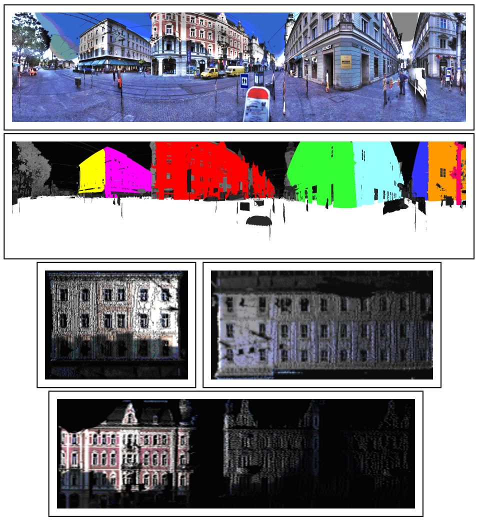

Figure 5. Top: Laser RGB texture (shading corrected) in spherical co-ordinate system. Middle: Plane (colored) segmentation using RANSAC. Bottom: RGB texture projected on respective planar patches

Figure 4 shows images containing the window patterns and the corresponding window detection results. The extraction of windows is required for object recognition as a pre-processing step in a deformation analysis system [4]. The deformation analysis systems relies on the detection of frontal windows mainly perpendicular to the laser scanner up to $25°$ of maximum angular deviation. The windows which fall above the defined percentage were discarded while calculating the ground truth for the evaluation, although many of them were detected in the first phase of the algorithm.

4 CONCLUSION AND OUTLOOK

In this paper we have presented a robust window detection system usable as pre-processing tool for urban deformation measurement systems. The deformation analysis system gathers accurate 3D measurements on unique points of the building surface in different epochs and compares them across various time spans. It is therefore fed with 3D co-ordinates (i.e. bounding boxes) of the detected windows. Possible extensions of the laser-based method are manifold. One approach is automatic plane detection, followed by texture reconstruction on the detected planes, which avoids the image distortions caused by the spherical laser scan geometry (Figure 5).

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References

[1] H. U. et al. Mobile mapping for the environment. In *3rd Int. Workshop on Mobile Mapping Technology*, Cairo, Egypt, 2001.

[2] C. Frueh, S. Jain, and A. Zakhor. Data processing algorithms for generating textured 3d building facade meshes from laser scans and camera images. volume 61, pages 159–184, Hingham, MA, USA, 2005. Kluwer Academic Publishers.

[3] J. B. J.L Lerma. Segmentation and filtering of laser scanner data for cultural heritage. In *CIPA*, page 896, Torino, Italy, 2005.

[4] H. K. M. Lehmann, A. Reiterer. Deformation classification in high density point clouds. In *International Conference on Optical 3-D Measurement Techniques VIII*, pages 234–240, Zurich, 2007.

[5] H. Mayer and S. Reznik. Building facade interpretation from uncalibrated wide-baseline image sequences. volume 61, pages 371–380, February 2007.

[6] L. Pnard, N. Paparoditis, and M. Pierrot-Deseilligny. 3d building facade reconstruction under mesh form from multiple wide angle views. In *Proceedings of the ISPRS Working Group V/4 Workshop, Venice, Italy*. ACM Press, 2005.

[7] S. Pu and G. Vosselman. Automatic extraction of building features from terrestrial laserscanning. In *IEVM06*, 2006.

[8] K. Schindler and J. Bauer. A model-based method for building reconstruction. In *HLK '03: Proceedings of the First IEEE International Workshop on Higher-Level Knowledge in 3D Modeling and Motion Analysis*, page 74, Washington, DC, USA, 2003. IEEE Computer Society.

[9] M. S. Thiemann Frank. Segmentation of buildings for 3d generalisation. In *ICA2004*, Leicester, UK, 2004.

[10] X. Wang, S. Totaro, F. Taillandier, A. Hanson, and S. Teller. Recovering facade texture and microstructure from real-world images. page A: 381, 2002.