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MORPHOLOGICAL FAÇADE IMAGE ANALYSIS FOR BUILDING MODELING

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ABSTRACT

In this paper, we describe a novel method for morphological façade analysis. The analysis consists of two parts: façade division and localization of windows. The façade division is based on the façade alignment hypothesis. We accumulate directional color gradients and we analyze the generated profile. Our approach introduces several morphological filters to augment the robustness to problems such as: low perspective distortion, textured images and small obstacles in images. The localization of windows uses the profiles and the façade division information.

Index Terms— Mathematical morphology, Façade analysis, Façade division

1. INTRODUCTION

3D urban environment modeling becomes a fundamental part in a growing number of geo-applications as e.g Google Earth, Microsoft Virtual Earth, IGN - Geoportail 3D, etc. The main approaches to model cities are based on coarse modeling, for instance: polyhedral representation, main walls, roof planes and ground planes. Nevertheless, last research frameworks try to analyze building façade in real images. This analysis extracts and reconstructs windows, doors and ornaments to provide rich information of the buildings and to add visual realism. Furthermore, the reconstruction of façades is a hard problem, given the large variety in their appearances and structures [1, 2]. Our goal is façade interpretation from real images as automatically as possible; especially to facilitate the extraction of semantic/grammatical information. We focus on ortho-façade image analysis. The first step in façade analysis is its division in columns and rows by exploiting horizontal and vertical alignment of façade structures(windows, doors, balconies). Façade division constitutes relevant information for semantic interpretation.

This paper is organized as follows. Section 2 describes our method for façade division and window location. Section 3 presents conclusions.

2. FAÇADE ANALYSIS

2.1. Façade division based on gradient projection

We propose a method to divide façades on rectified images or with low perspective to facilitate the extraction of semantic information. In order to detect façade division we use a hypothesis that façade structures are horizontally and vertically aligned [3]. For that reason, our approach is based on gradient projection analysis. Vertical gradient (G_v) is generated by using a horizontal structuring element (SE) and horizontal gradient (G_h) is generated by using a vertical SE. Figure 1 illustrates both gradients.

(a) (b) G_v (c) G_h (d) Profile

Fig. 1. **(a)** Original Image, **(b)** and **(c)** vertical and horizontal color gradients, **(d)** vertical $P_v\left(G_v\right)$ and Horizontal $P_h\left(G_h\right)$ profile

To make more robust our approach to textured façade images and balcony balusters, we applied a viscous leveling filter before projection step. Viscous leveling [4] is an extended version of leveling [5] introduced by Meyer. The viscous leveling reduces leakage problem produced by narrow bridges [6]. In order to avoid narrow connections between dark objects, viscous upper leveling reconstructs marker g in a dilated version of f. The result is then eroded in order to retrieve the original size of the reconstructed objects. As result we have eliminated the dark balconies, reduced the texture and kept the contours of windows (Figure 2(c)).

(a) f (b) $g = \varphi f$ (c) Viscous leveling

Fig. 2. **(a)** f Original image, **(b)** g Marker: a closing image by using 13×13 square as structuring element, **(c)** g Directional upper viscous leveling: size of vertical and horizontal operators is 2 and 6 respectively

Afterward, we accumulate on rows vertical gradient, providing horizontal projection $P_h\left(G_v\right)$. Similarity vertical projection $P_v\left(G_h\right)$ is created using horizontal gradient. These projections contain peaks at windows locations and valleys within the wall. Figure 1(d) shows projections of a "rectified" façade image. In $P_v\left(G_h\right)$ profile, the three first peaks are not easily separable; because of tree occlusion. In $P_h\left(G_v\right)$ profile, the biggest peaks are created by balconies variations by

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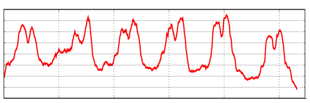
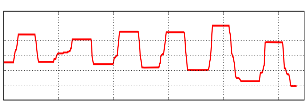
producing false valleys between balconies and windows. In textured or/and occluded façades, the gradient accumulation presents two important problems in projections $P_v(G_h)$ and $P_h(G_v)$: the creation of false peaks and false valleys and the reduction of dynamic between them. These problems produce an erroneous façade division. To solve this problem a filtering operation is included, before the gradient projection. We apply a directional morphological opening of λ size. The directional opening is applied in the same direction of gradient, i.e horizontal opening for G_h image and vice versa. The opening size is estimated using the smallest window size. The filtered gradients ($\widetilde{G_h}$ and $\widetilde{G_v}$) permit the reduction of noise caused by tree occlusion and other small structures. Then, we project each directional filtered gradient on its correspondent direction to create two new projections ($P_v\left(\widetilde{G_h}\right)$ and $P_h\left(\widetilde{G_v}\right)$).

$P_v\left(\widetilde{G_h}\right)$ and $P_h\left(\widetilde{G_h}\right)$ profiles contain peaks at windows locations and valleys within the wall. The profiles are filtered by using an alternate sequential filter (ASF) to allow an easy detection of the most representative maxima and minima of $P_v\left(\widetilde{G_h}\right)$. Finally, to find the façade division we use watershed (WS) segmentation of inverted $ASF\left(P_v\left(\widetilde{G_h}\right)\right)$. The cost of this segmentation is very low thanks to the fact that operation is applied to profiles (1D images). Vertical division process is illustrated in Figure 3. This process is equally applied on horizontal projection given as result Figure 3(c).



(a) $P_v\left(\widetilde{G_h}\right)$



(b) $ASF\left(P_v\left(\widetilde{G_h}\right)\right)$

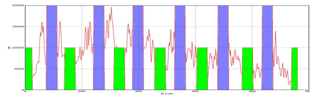
(c)

Fig. 3. **(a)** $P_v\left(\widetilde{G_h}\right)$ profile using filtered gradient, **(b)** ASF of $P_v\left(\widetilde{G_h}\right)$ profile 3(a), **(c)** Façade division

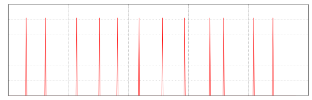
2.2. Localization of Windows

After having found façade division, we continue with localization of each window. The border information of a window is located on the biggest gradient value on its respective direction. If all windows are aligned, these values will generate large peaks after an accumulation process. Using the same technique of profile, we accumulate on rows $\widetilde{G_h}$, by obtaining a horizontal projection $P_h\left(\widetilde{G_h}\right)$ (vertical projection $P_v\left(\widetilde{G_v}\right)$ by duality). Nevertheless, these profiles are highly noisy. To solve this problem, we suppose there is a window by division. By using maxima and minima detection of filtered $P_v\left(\widetilde{G_h}\right)$ and $P_h\left(\widetilde{G_v}\right)$, we obtain good markers of windows and wall. A constrained watershed by markers is used to segment the new profiles and the position of windows is located by intersecting the vertical and horizontal segmentation that belongs to the marker windows.

In Figure 4, the localization of windows is shown. Figure 4(a) presents $P_v\left(\widetilde{G_v}\right)$ profile and its marker. The marker is extracted from maxima and minima of ASF$\left(P_v\left(\widetilde{G_v}\right)\right)$ profile. In this case, we can see that the image is not completely rectified because of a bad position of detected windows in the two last columns, even if the façade division was correct.



(a) $P_h\left(\widetilde{G_v}\right)$ profile + Marker



(b) WS constrained of V_h profile + Marker

(c) Intersection of segmentations

Fig. 4. **(a)** $P_h\left(\widetilde{G_v}\right)$ profile using filtered gradient and marker, **(b)** WS segmentation, **(c)** Windows position

3. CONCLUSIONS

In this paper, a morphological method for façade analysis has been presented. Two frameworks are analyzed: façade division and localization of windows. The façade division is based on profile analysis. The profiles are created by projection of directional color gradients. Several filters are added through the process, by increasing the robustness of method. We obtain good results on façade images with low perspective distortion, textured images and small obstacles.

4. ACKNOWLEDGES

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