Adaptive Parameter Tuning for Morphological Segmentation of Building Facade Images

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1. Introduction

Automatic image analysis

Large scale urban modeling (e.g. Procedural modeling) → **Digital City Modeling** (Productivity + Faithfulness)

Applications:
- Urban planning
- Emergency response simulation
- Cultural heritage documentation
- Virtual tourism, etc.

Examples:
- Google Earth
- Microsoft Virtual Earth
- GeoPortail, etc.

- Hypothesis:
  - Images are rectified and cropped.
  - Facade elements are pseudo-regularly aligned (Haussmannian buildings).
- Our method is based on:
  - Accumulation of directional color gradients.
  - Morphological filters.

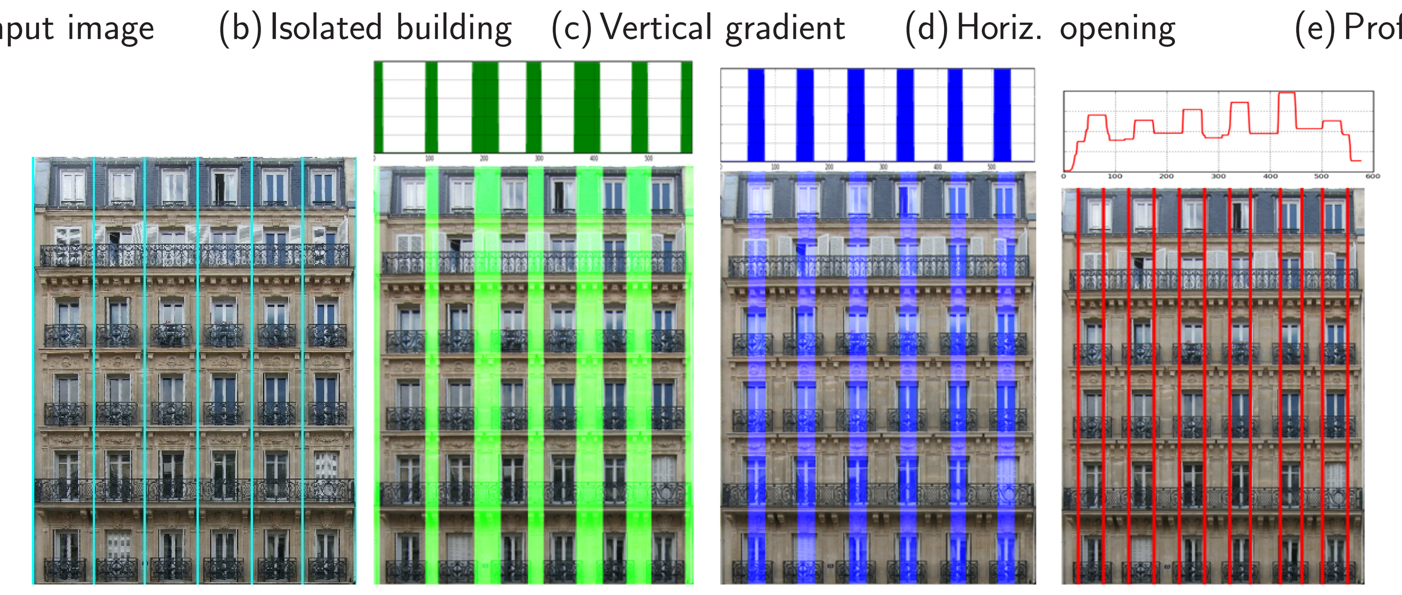
Morphological vertical gradient $G_y(x,y)$ → Horizontal opening $\gamma_{n_{op}}(x,y)$ → Gradient vertical projection $P_{G_y}(x)$ → Alternate Sequential Filter $ASF_n(x)$ → H-minima Filter h-min(x) → Facade divisions and Window detection

- We propose the adaptive tuning of morphological filters.

2. Method

- Input images (Fig. a) are assumed rectified and cropped (Fig. b).
- Morphological vertical gradient G_y detects horizontal contours (Fig. c).
- Opening $\gamma_{n_{op}}$ is applied to eliminate undesirable details (Fig. d).
- Accumulated vertical gradient P_{G_y} (Fig. e) contains peaks at window locations and valleys between them.
- ASF_n and **h-min** filters get a single maximum for each window (Fig. e).
- Watershed on the inverted profile computes facade divisions (Figs. e,f).
- In the filtered profile $\tilde{P}_{G_y}$, minima pass through the wall (Fig. g) while maxima pass through the windows (Fig. h).
- Constrained watershed on the projected horizontal gradient P_{G_x}, taking the extrema of $\tilde{P}_{G_y}$ as markers, determines the window line divisions (Fig. i).

(a) Input image (b) Isolated building (c) Vertical gradient (d) Horiz. opening (e) Profiles



(f) Vertical splitting (g) Minima (h) Maxima (i) Window divisions

- Although a vertical splitting is explained, the same technique applies to horizontal splitting, just changing vertical by horizontal and vice versa.

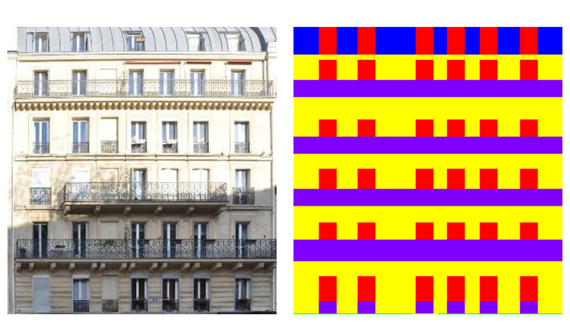
3. Some Segmentation Examples

- Our approach applies to pseudo-periodic structures and it is robust to different issues (Figs. j,k,l).
- Good results are obtained, but they depend on a correct parameter tuning.

(j) texture, noise (k) occlusions, shadows (l) rectification errors

4. Database

- 100 rectified and annotated images from the public database: `http://vision.mas.ecp.fr/Personnel/teboul/data.php`.

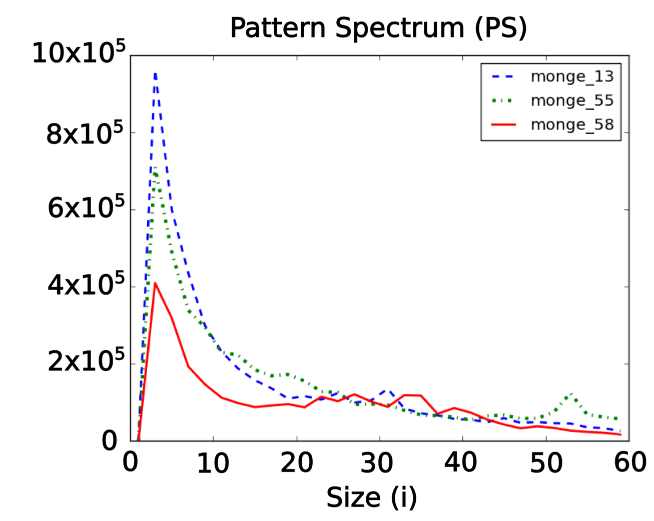


(m) monge 19 (n) Ground truth

5. Adaptive filter tuning

Opening filter ($\gamma_{n_{op}}$)

- $\gamma_{n_{op}}$ gets rid of noise from gradient images.
- Size distribution of the noise is characterized using $PS_i = \sum_{\forall pixel}(\gamma_{i-1} - \gamma_i)$.
- n_{op} is chosen as the value **i** for which **PS** falls down under 25% of its maximum.
- Robustness to image resolution changes.



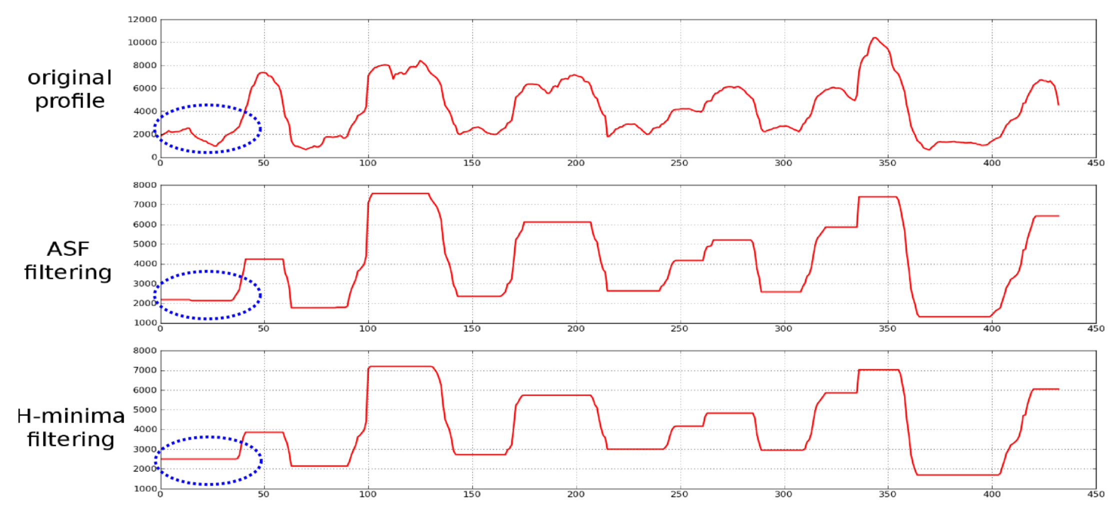
Alternate Sequential Filter (ASF_n)

- ASF_n is a sequence of openings (γ_i) and closings (φ_i) of increasing sizes: $ASF_n(P_{G_y}) = \gamma_n\varphi_n \ldots \gamma_2\varphi_2\gamma_1\varphi_1(P_{G_y})$.
- The **n** leading to the most regular result is selected.
- Regularity: standard deviation $\sigma(n)$ of the segmented facade division sizes.

(o) $\sigma(n=0)=7.7$ (p) $\sigma(n=1)=14.0$ (q) $\sigma(n=7)=6.2$ (r) $\sigma(n=11)=68.9$

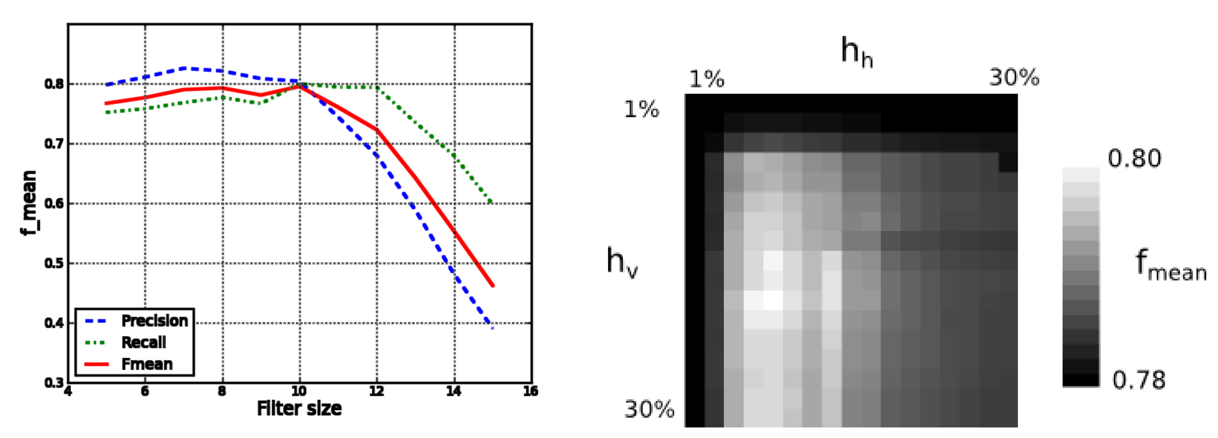
H-minima filter (**h-min**)

- **h-min** removes remaining low contrasted extrema (lower than **h**).
- **h** is chosen depending on the extrema dynamic: $h \propto range(ASF_n(P_{G_y}))$



6. Results

- We evaluate window localization using **Precision**, **Recall**, f_{mean}.
- An exhaustive test for **n** shows that our tuning method offers the best possible score f_{mean}=0.79 (Fig. s).
- For **h**, the best possible f_{mean} corresponds to h_v=14% and h_h=2.5% in vertical and horizontal profiles, respectively (Fig. t).



(s) ASF size (t) H-minima thresholds

- Overall performances: Precision=0.82, Recall=0.79 and f_{mean}=0.80

(u) monge 34 (v) monge 58 (w) monge 63 (x) monge 13 (y) monge 55 (z) monge 85

7. Conclusions

- Our adaptive segmentation method offers robustness to texture, noise, image resolution changes, occlusions, shadows and rectification errors.
- It fails if pseudo-periodic hypothesis is not fulfilled.
- Good performances on Teboul's public database.
- In the future, ultimate opening will be studied. This operator automatically adapts its size to image structures based on a contrast criterion.

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