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$J_{\min}$-image based color-texture segmentation using watershed and hierarchical clustering

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1. Introduction

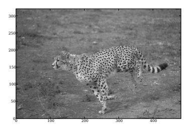
This work introduces $J_{\min}$-images as an alternative to gradient maps in watershed-based image segmentation algorithms. A $J_{\min}$-image is computed using J-images that are color-texture homogeneity maps based on Fisher's discriminant, introduced in [1]. The major advantage of using $J_{\min}$ is the elimination of the scale selection problem for texture segmentation. A filtered $J_{\min}$ is used as input for a watershed algorithm whose output is refined by a color histogram based hierarchical clustering step. Experimental results show good performance in the segmentation of natural images.

Hill *et al.* [5] present a recent watershed-based algorithm for texture segmentation. They introduce the concept of texture gradient that is computed using the non-decimated complex wavelet packet transform. The magnitude of the coefficients of each complex sub-band is used to characterize the texture content. Large texture gradient values correspond to texture transitions, while small values correspond to texture homogeneous regions. The $J_{\min}$ image share this property of enhancing texture transition boundaries, without the need of selecting several thresholds and over a wide range of scales.

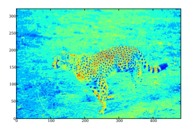
2. The JSEG algorithm

The JSEG algorithm was introduced by Deng and Manjunath in [1]. It uses *J-images* that are single channel images where the pixel intensity $J(x, y)$ is given by the J value computed over a window centered at (x, y). J is a value, based on the Fisher's discriminant [1,4], that measures an image color dispersion, which can be related to texture homogeneity. Figure 1 shows two J-images computed with different window sizes. Small values in J-images correspond to color-texture homogeneous regions while high values are seen near the transition boundaries between different color-texture surfaces.

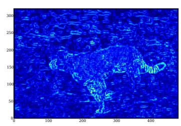
JSEG is a hierarchical coarse to fine region growing algorithm. At the beginning of each iteration, a J-image is computed. New segments are defined for groups of connected pixels presenting small values and appropriate size. Next, pixels presenting values smaller than the mean J-value of the unsegmented pixels are merged with adjacent existing segments. This step is repeated for a new J-image with smaller window size until a determined minimum size is reached. Finally, a post-processing segment merging step using histogram differences is performed to reduce over-segmentation.



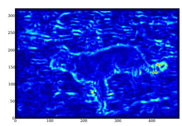
(a) Source image



(b) Quantized image



(c) J_9



(d) J_{17}

Figure 1. (a) Original image (481 × 321 pixels) from [3]. (b) Quantization using 16 codes (false colors used to better visualization). (c) J image computed using a disk window (diameter 9). (d) J image computed using a disk window (diameter 17).

3. $J_{\min}$-image based watershed

To compute the J-images, the input image is quantized to an appropriate level [1]. In our experiments, the most significant bits from the pixel luminance value are used to build a codebook (see Figure 1 (b)).

Window size selection depends on the texture to be segmented and the image resolution. Let $D = \{d_1, d_2, ..., d_n\}$ be the diameters of a set of circular windows. A *J_{min}-image* is defined as:

$$J_{\min}(x, y) = \min\{J_d(x, y) \mid d \in D\}. \quad (1)$$

The $J_{\min}$-image is filtered by an alternate sequential filter and then used as input for a watershed algorithm [2] (Figure 2). The watershed does not require marker selection.

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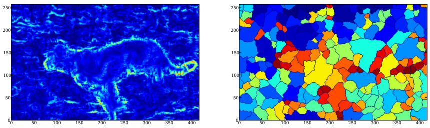


(a) $J_{\min}$ (b) Watershed

Figure 2. (a) $J_{\min}$ computed according Equation 1. (b) Watershed [2] applied over an filtered $J_{\min}$.

3.1 Segments merging

The output of the watershed is over-segmented and can be improved by a post-processing merging step. Let U and V be two adjacent segments gotten in the watershed procedure. In a first step, *J merging*, we compute J_U, J_V and the J value for the segments' union. If $J_{U \cup V} \leq \min(J_U, J_V)$, we merge the two segments. That means $U \cup V$ is as homogeneous as U or V and then we can assume merging is a secure choice.

Quantization differences and variations on texture's pattern cause over-segmentation problems that the previous step is unable to solve. In a second merging step, *color-based clustering*, we apply an agglomerative hierarchical clustering ([4], chapter 10) over the segments. The similarity measure adopted is the color histogram intersection in the HSI color space, given by

$$d_h(U,V) = \frac{1}{3} \sum_{c \in \{H,S,I\}} \sum_{i=1}^{L} \min(h_U^c[i], h_V^c[i]), \qquad (2)$$

where h^c is the normalized histogram with L bins in channel c, computed over the original image.

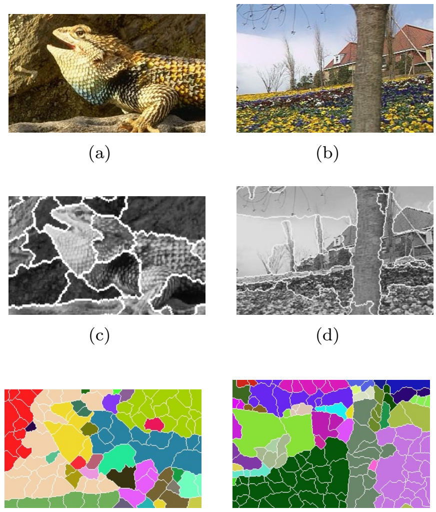
The J merging step provides bigger segments to the color-based clustering, letting better sampling in histogram computation and comparison.

4. Results and comments

Figure 3 presents results for two natural images, and the original results from [1]. Our experiments show that quantizing grey level images using 3 or 4 bits and just 3 window sizes to compute $J_{\min}$-images, produce good segmentation results.

In Figures 3(c) and 3(e), one can see the JSEG algorithm over-segments the background rock and the lizard back while our result shows larger homogeneous segments. Similar results are seen in the flower garden example in Figures 3(d) and 3(f).

We are currently exploring different approaches to image quantization, watershed markers selection and multi-scale analysis.



(a) (b) (c) (d) (e) (f)

Figure 3. Top row shows two natural images. The center row shows the results from [1] and the bottom row shows the results using $J_{\min}$-image.

Acknowledgments

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