

COREST: A MEASURE OF COLOR AND SPACE STABILITY TO DETECT SALIENT REGIONS ACCORDING TO HUMAN CRITERIA

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Keywords: Region of interest, Region detector, Color stability, Space scale.

Abstract: In this paper we present a novel method to obtain regions of interest in color images. The strategy consists in the evaluation of the stability of a region according to its properties of color and spatial arrangement. We propose a fusion of the classical color image segmentation with the space scale analysis. An image can be decomposed in a set of regions that describe the whole image content. Using a set of manual labelled images we have evaluated the properties of the detector according to the human perception. The proposed region detector has a potential application in the field of the content based image retrieval by sketch.

1 INTRODUCTION

Many Computer Vision applications use region detection procedures as a first step to extract relevant information from images. Sometimes this relevant information needs to fit the human perception of the image content. This constraint is usually required in the content based image retrieval field (CBIR). Several commercial systems incorporate drawing interfaces to allow users to create their own queries (Veltkamp and Tanase, 2000). Sketch based search engines are very attractive because overcome language limitations and allow to adapt the queries to the user needs. But, can these queries fit the preprocessed information of the database images?

CBIR systems use to rely on a previous segmentation of the images. The goal of segmentation is to group together similar pixels in order to separate them into regions. Nevertheless, some experiments like the Berkeley segmentation data set demonstrate that does not exist a unique way in which humans select the relevant information of an image. The Berkeley database collects the hand labelled segmentations from several human subjects (Martin et al., 2001). In the Figure 1 we show an example where we can observe that different users describe the same image with a very different set of regions. This high variability suggests that CBIR systems could benefit of region detectors that go beyond the classical segmentation algorithms. Classical segmentation procedures provide a unique and disjoint decomposition of the

image into a set of regions (Cheng et al., 2001). However, the set of regions that humans perceive as meaningful can be even overlapped or self-contained.

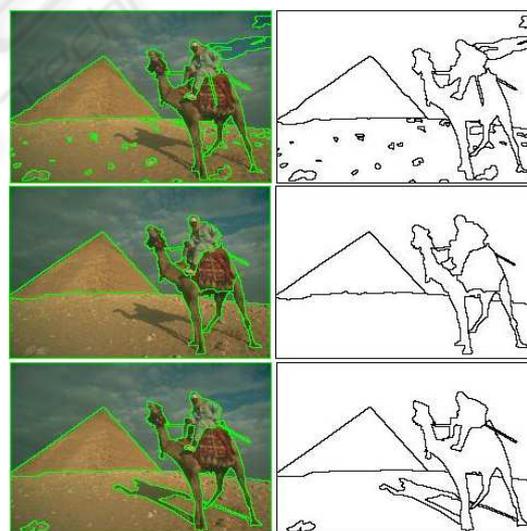


Figure 1: Examples of the Berkeley data set. Manual segmentations provided by different users on the same image.

In the last years some works to detect regions of interest have incorporated the multiscale analysis of the image content. Lindeberg observed that humans identify real-world objects depending on the scale of observation (Lindeberg, 1993). He illustrates this phenomena with the example of the a tree: at

close scales human identify the leaves as objects but the concept of the forest only has sense from large distances. The main idea of the multiscale analysis consists in selection local image structures at specific scales. The specific scales are those for which a given function attains an extremum. Techniques such as the Laplacian of Gaussian (LoG) or the determinant of Hessian (DoH) have obtained excellent results in matching applications where two images contain instances of the same real object (Mikolajczyk et al., 2005).

In this paper we propose a system to detect regions of interest according to the human perception. The main strategy of our proposal is to mix the classical color segmentation with the scale space analysis. On the one hand we make a region detection from the homogeneity properties of the color pixels. On the other hand we propose a perceptual grouping of the pixels being or not connected according to their spatial arrangement.

The paper organization is as follows. In the section 2 we explain the main idea and the implementation of our proposal. Then, in section 3, we present some results involving a set of human based synthetic images. Finally, the section 4 exposes the conclusions and future work.

2 THE COLOR REGION STABILITY (CoReSt)

We have developed a region detector inspired in the work of Matas that defines the concept of maximally stable extremal regions (MSER) (Matas et al., 2002). Matas informally explained this concept as follows. Imagine all possible thresholdings of a gray-level image. Then, we can see the thresholded images as a movie where we start with the lowest threshold and we gradually increase it. Thus, the first image is white and subsequently black spots begin to appear and grow. This spots correspond to local intensity minima, so they continue merging until reaching a whole black image in the last movie frame. To evaluate this evolution, a stability function between regions of consecutive frames is defined. This function consists in the rate of change of the region areas. This way, threshold levels that are local minima of this rate change are selected to produce the maximally stable extremal regions. The MSER has been exported to color images by Forssén (Forssén, 2007) applying the same idea of stability by looking at successive time-steps of an agglomerative clustering of image pixels. Following the movie example, imagine that we have a color image instead of a grayscale one. Then, we

have a threshold related to the color distance of two pixels. We begin with an image where every pixel is an independent region. As we increase the threshold the connected pixels which distance is lower than this value begin to fuse. Finally, all the pixels form a single region in the last frame. This way, the more distant the color of a region is respect from the color of the surrounding pixels, the more the stable the region is.

The color analysis takes into account the structures formed by connected pixels but does not analyze the emerging structures according to the scale of observation. Going back to the human perception, it seems a natural process to group similar color regions if they are close enough. The space scale analysis is the tool that allows to perform this kind of region association. The process takes an important role to identify objects in real images when they suffer from partial occlusions or they present a textured patterns. This way, we propose to export the stability measure to the spatial arrangement of the pixels. To illustrate the spatial stability, imagine that we have an image with a set of segmented regions. Then we also have a threshold related to the spatial distance of the region centroids. Our movie starts with this set of regions being independent and, as we increase the threshold, the regions are progressively joined. In the last frame they are all joined in a single one. Then, the more isolated a region is, the more stable the region is.

Finally, we quantify the saliency of a region mixing the stability measures of color and space. In the next section we present a region detector based in this measure that we have called CoReSt (Color Region Stability).

2.1 The Region Detector Implementation

From an implementation viewpoint we propose to detect regions of interest using the mean shift algorithm (Comaniciu and Meer, 1999). A pixel is understood like a point in a 5D space where its first three dimensions are related to the color values in the Luv space the other two represent the (x,y) coordinates of the normalized image size. We use an implementation of the mean shift clustering that depends on two thresholds, hc and hs , that control respectively the similarity constraints on the color and the space (Christoudias et al., 2002). We analyze the segmentation stability according to the variation of these two thresholds. To illustrate the process we can construct a bidimensional grid filled up with the clustered images (see Figure 2). Let us name MSS the mean shift function and HC and HS the two sets of thresholds we evaluate related to the color and space respectively. Further-

more, we define NC and NS the amount of parameters that each set contains.

$$HC(x) = \{hc\} \quad x = 1..NC$$

$$HS(y) = \{hs\} \quad y = 1..NS$$

Then, the grid that contains the segmented regions is denoted G and has dimension $[NS \times NC]$.

$$G^{(x,y)} = MSS(I, HC(x), HS(y))$$

For every region of image in the grid, we can find the analogous regions along the two dimensions. Using the movie example, the analogous regions are those that maximize the overlapping area when we increment and decrement the HC and HS thresholds. Let us define the OAR the function that computes the rate of overlapping area between two regions.

$$OAR(R_1, R_2) = \frac{Area(R_1 \cap R_2)}{\max(Area(R_1), Area(R_2))}$$

We denote $R_i^{(x,y)}$ the i region of the grid cell (x, y) and $AR_{(x,y)_i}^{(x,y)'}$ its analogous region of another cell $(x, y)'$.

$$AR_{(x,y)_i}^{(x,y)' } = R_j^{(x,y)' } \mid \max OAR(R_i^{(x,y)}, R_k^{(x,y)'}) \\ \forall k = 1..#R^{(x,y)'}$$

Once we have the segmentation evolution along the color and the space dimensions, we need a function to evaluate the stability of the regions. Matas (Matas et al., 2002) used the relative area between the regions, but notice that we also work in the space domain considering strong changes when the regions from disconnected components. This way, we add the values of the second central moments to provide a more robust measure of stability. These moments can be understood as the lengths of the axis of the ellipse that encloses a region. The similarity rate between two length values L_1 and L_2 is computed using the function LR .

$$LR(L_1, L_2) = \min(L_1, L_2) / \max(L_1, L_2)$$

We name mAL and MAL to the lengths of the minor axis and major axis of an ellipse. Given two regions R_1 and R_2 we define the ratio of the axis lengths as:

$$ALR(R_1, R_2) = \max(LR(mAL_1, mAL_2), \\ LR(MAL_1, MAL_2))$$

Then, given a region $R_i^{(x,y)}$ and another analogous one $AR_{(x,y)_i}^{(x,y)'}$ we compute the stability S as the mean of the area rate and the axis rate.

$$S(R_i^{(x,y)}, AR_{(x,y)_i}^{(x,y)'}) = OAR(R_i^{(x,y)}, AR_{(x,y)_i}^{(x,y)'}) * 0.5 + \\ ALR(R_i^{(x,y)}, AR_{(x,y)_i}^{(x,y)'}) * 0.5$$

Treating separately the analogous regions of the two dimensions, we name SC to the function that measures the stability along the color, and SS its equivalent in the space.

$$SC(R_i^{(x,y)}) = \sum_{x=1}^{NC} \frac{S(R_i^{(x,y)}, AR_{(x,y)_i}^{(x,y)'})}{NC} \\ SS(R_i^{(x,y)}) = \sum_{y=1}^{NS} \frac{S(R_i^{(x,y)}, AR_{(x,y)_i}^{(x,y)'})}{NS}$$

At this point we have two measures of stability in the range $[0, 1]$ for all the regions of the images in the grid. Next we select those that describe best an image.

2.1.1 Maximum Selection Response

Among the whole set of segmented regions we select those that present a maximum response of the stability measure. Let us name PC and PS the functions that evaluates the presence of a peak in the response of the functions SC and SS . These regions are called $ROIS$.

$$ROI_i^{(x,y)} = R_i^{(x,y)} \mid PC(R_i^{(x,y)}) \text{ or } PS(R_i^{(x,y)})$$

$$PC(R_i^{(x,y)}) = SC(AR_{(x,y)_i}^{(x-1,y)_i}) \leq \dots$$

$$SC(R_i^{(x,y)}) > SC(AR_{(x,y)_i}^{(x+1,y)_i})$$

$$PS(R_i^{(x,y)}) = SS(AR_{(x,y)_i}^{(x,y-1)_i}) \leq \dots$$

$$SS(R_i^{(x,y)}) > SS(AR_{(x,y)_i}^{(x,y+1)_i})$$

A global measure of saliency GS can also be computed for each each selected ROI .

$$GS(ROI_i^{(x,y)}) = \frac{SS(ROI_i^{(x,y)}) + SC(ROI_i^{(x,y)})}{2}$$

This value combines the stability of color and space allowing to rank the regions by its meaningfulness. This can be useful to weight the matching of the $ROIS$ in a retrieval process.

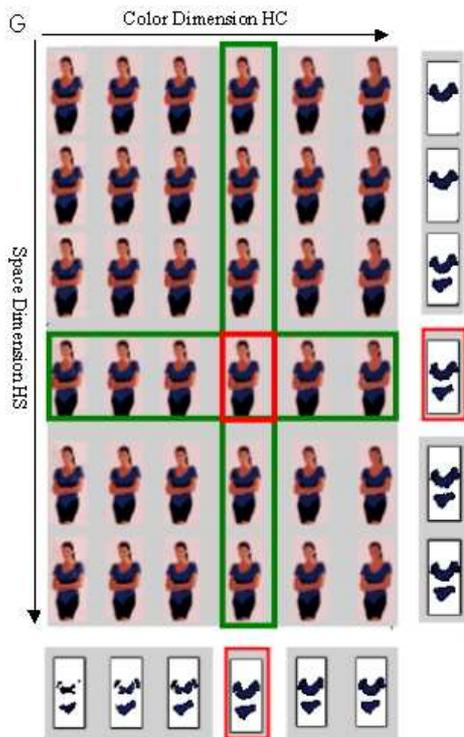


Figure 2: Grid of segmented images using the *MSS* according to the parameters of color *HC* and space *HS*. We show an example of a region and their analogous regions. From them we compute its stability measure. Observe how it grows through the scale, fusing with regions of the same color, and how it grows through color fusing with similar colored pixels.

3 EXPERIMENTS AND RESULTS

We have made a set of experiments to study the performance of the stability measure according to the human perception. As a ground truth of our test, we have used 100 images of the Berkeley database with their corresponding manually labelled regions (Martin et al., 2001). We have compared the performance of the proposed region detector (COREST) with its two most related algorithms: the Mean Shift Segmentation (MSS) and the Maximal Color Stable Regions (MCSR).

There exists many strategies to quantify the agreement of a segmented region with a ground truth reference (Unnikrishnan et al., 2007). Nevertheless, these strategies do not match our region detector output since one pixel of an image can be assigned to more than one region of interest. This way, to provide a numerical evaluation we have used the repeatability measure proposed by Mikolajczyk (Mikolajczyk et al., 2005). The repeatability computes the percent-

age of manual regions that can be matched with any of the regions that the automatic detector provides. To simplify the matching step we have approximated the regions with ellipses according to their moments. Then, two regions are considered to match if its overlapping area is greater than a given percentage. To illustrate the overlapping rate we show some examples on the Figure 3 extracted from (Mikolajczyk et al., 2005).

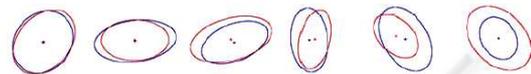


Figure 3: Examples of the overlapping error rate between two ellipses. From top left to bottom right: 10 to 60%.

We have tested the repeatability of the three detectors (COREST, MSS and MCSR) with the overlapping error threshold varying from 10 to 60%. The graph of the Figure 4 presents the mean of the repeatability for the whole set of test images. We have tested the algorithms with the default parameters of the available source code (Christoudias et al., 2002) (Forssén, 2007). Thus, every detector can provide a different amount of ROIS in the same image. The mean number of manual segmented regions per image is 26 and the mean number of ROIS per image detected with the COREST, MSS and MCSR are of 275, 388 and 990 respectively. We observe that the repeatability of the test with the COREST method is higher than the other two through all the overlapping thresholds. We can deduce that even though it detects a lower amount of regions per image, the stability criteria allows to match a higher percentage of the ground truth regions. This way, relaxing the overlapping parameter to a 60% it reaches a repeatability of 68.6%, despite the complexity of the natural scenes and the subjectivity of the human based ground truth.

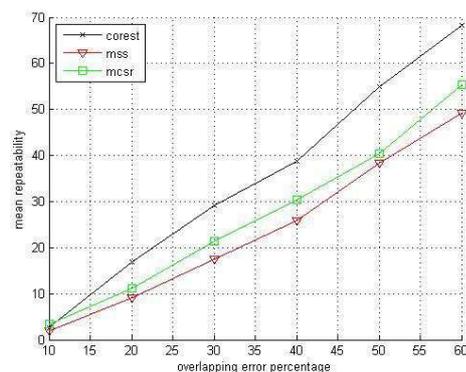


Figure 4: Mean repeatability for the test set.

The Figure 5 presents the COREST detector re-

sults with some examples. For every example we show the ROIS of the real images that fit best the manual ones. In other words, we show the detected ROIs that maximize the overlapping area of the ground truth regions.

The COREST detector has selected the image regions according to the stability measures in the color and in the space features. Then, the contrasted regions and isolated regions are detected as meaningful according to the human perception. As we have introduced in the section 2 the analysis of the space properties plays an important role in identifying objects in real images. Then, it makes possible to group a set of disjoint regions that belong to an object that is partially occluded. This phenomena can be illustrated with the image *a*) of the Figure 5. Thus, if we look at the palm picture we realize that the sand area is occluded by a shadow that the user has omitted. Being the shadow so contrasted with the color of the sand, a classical segmentation could never join the two parts. The same occurs in the detection of the background region in the fireman scene *f*). The region belonging to the wall is occluded by a picture and it is broken into a set of parts. The space scale analysis has also effect in the presence of textures. Then, the system is able to group similar color regions. Natural scenes have plenty of textures such as trees *a*), clouds *h*), waves *e*), or the leopard skin *d*). Moreover, images that contain man made objects can also present repetitive patterns that a human perceive as belonging to the same object. This is the case of the white and red striped bars of the figure *c*) or clothing garments of the image *b*).

4 CONCLUSIONS

We have presented a novel region detector on color images that combines a classical color segmentation approach with a space scale analysis. We have used the mean shift algorithm to measure the stability of the regions on the color and the space domains. The detector gives a very high degree of freedom about the shape of the output regions making it suitable to describe any image content. Moreover, the multiscale approach allows the system to detect ROIS composed by disjoint regions that can come from partial overlapped elements or textured areas. We have made some experiments to evaluate the regions of interest of manual labelled image vs. the regions of interest of a real scene. Using a human based benchmark we have demonstrated that exist enough correlation to use this region detector in applications where the information has to be matched according to the human represen-

tation. One of the potentially applications could be found in the content based retrieval systems that allow sketch based queries. dfafd

ACKNOWLEDGEMENTS

This work has been partially supported by the project TIC2003-09291 and the grant 2002FI-00724.

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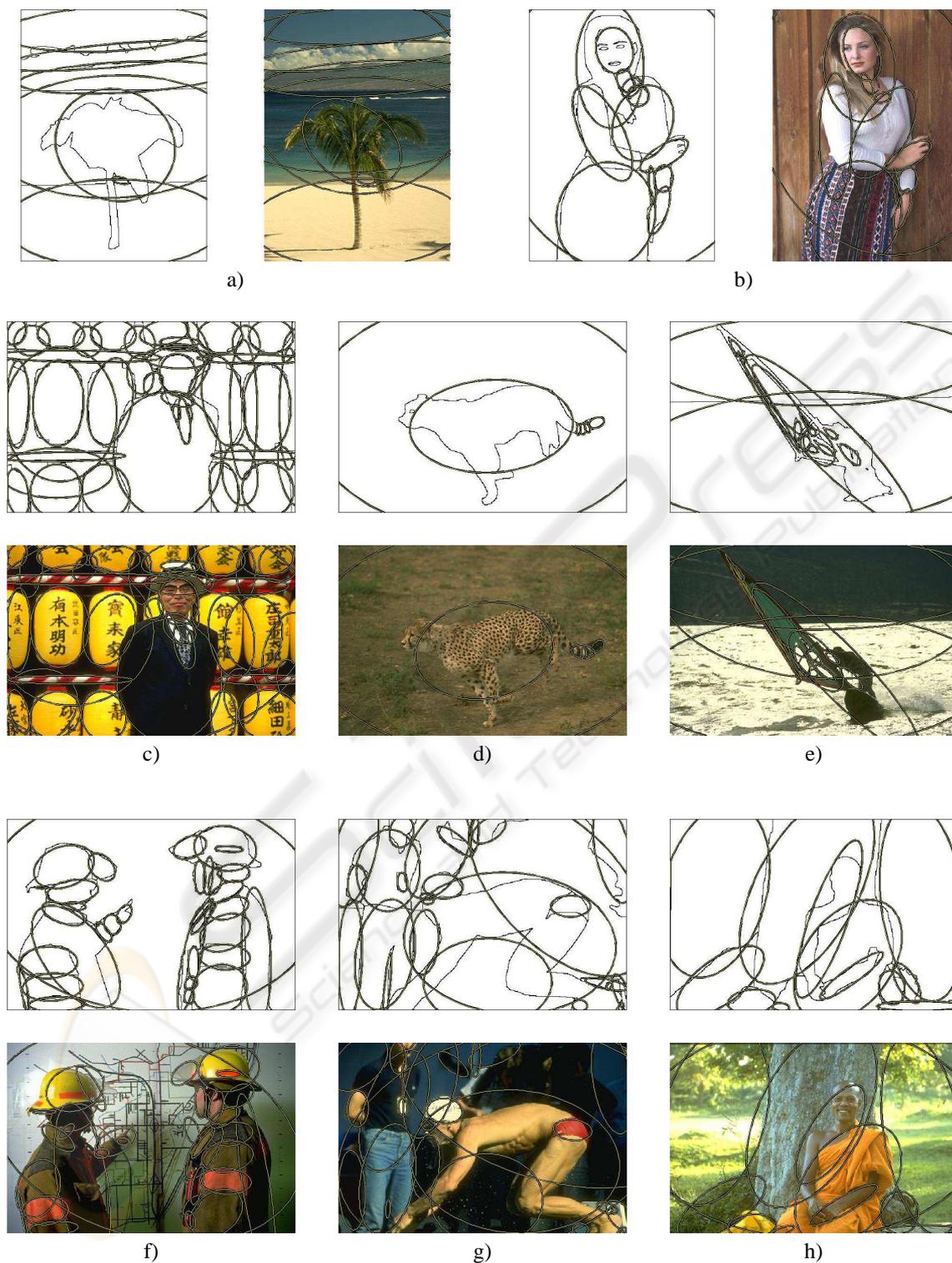


Figure 5: Some examples of the Berkeley data set. We show the ROIS of the manual segmentations and the ROIS of the real images that maximize their overlapping rate. We highlight the obtained ROIS with the ellipses that approximate their area.