REGION GROWTH BASED ON COLOR GRADIENTS

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Abstract

This paper presents an algorithm of regions growth. The growth takes place as consequence of the establishment of a homogeneity approach, which use a distance measure in a space of color representation of the type HSI. The main idea is to use seeds that will appear located in a not supervised way on detected contours; being used the information of the map of gradients of the image to spread its growth.

1. INTRODUCCIÓN.

In computer vision an image segmentation process is a basic mechanism of *information condensation*. This transformation process applied directly to image pixels will produce a group of primitives (regions, contours, etc), which are obtained starting from pixels cluster using a defined approach of homogeneity. Those primitives describe and model the contents of the images to be used in a later stage of scene understanding.

Based on the carried out treatment is possible to classify the image's segmentation algorithms in three main categories:

- **Edge detection.** In [7][4][3] is possible find methods based on local detection of level variations of the image signal.
- **Segmentation in parametric spaces.** In [12][10][2] are described concrete implementations of these methods, which are more global methods of clustering. These techniques regroup the pixels with a similar level of gray / color, without consider any neighborhood that can exist among the same ones.

- **Growth of regions** [11]. It is a local method of segmentation based on the selection of one or several image pixels (denominated seeds), in relation to which will go adding pixels until forming a region. The main inconvenience this technique presents is the location of the seed to use; it is possible to use a random location of the same ones among the pixels contained in another region or to use some algorithm of the type split and merge [9][8]. The adjacent areas will be merged to form an only region if they satisfy some similarity approach.

In [2][13][14] some algorithms are presented that make use of the techniques mentioned previously.

The Section 2 describes the color space we have defined, in which an algorithm of detection of discontinuities has been generalized (Section 2.1). In the Section 3 the outline of proposed regions growth is shown and the obtained results are presented in the Section 4. Finally in the Section 5 the conclusions of the carried out work are presented.

2. PERCEPTUAL COLOR SPACES.

With the objective of adapting the most possible to the way in which the human eye perceives the colors were developed the *perceptual color spaces* or *spaces of uniform chromaticy scale (UCS)*.

Here has been used as representation space the HSI space, upon which a technique of regions growth has been developed. Nevertheless, the presented algorithm could be valid in any other representation. In [5] is described a more extensive development to an approach to this space.

2.1. Contours detection in color images.

To determine the local variations of image color, it will become necessary to define a distance and an order inside the space of elected color.

2.1.1. Distances in space of representations.

The color space used is inscribed inside a cylinder, then the distance between two points (colors) of the same one $P_1 = (H_1, S_1, I_1)$, $P_2 = (H_2, S_2, I_2)$ is given by:

$$d = ((d_I)^2 + (d_C)^2)^{1/2} \tag{1}$$

where

$$d_I = |I_1 - I_2| \tag{2}$$

and

$$d_C = \begin{cases} ((S_1)^2 + (S_2)^2 - 2S_1 S_2 \cos\phi)^{1/2} & \text{, if } P_1 \text{ y } P_2 \text{ are chromatics} \\ 0 & \text{, if } P_1 \text{ y } P_2 \text{ are achromatics} \\ S_1 - \Omega_{I_2} & \text{, if } P_1 \text{ is chromatic and } P_2 \text{ is achromatic} \end{cases} \tag{3}$$

being

$$\Omega_{I_2} = \text{Chromaticity threshold for } I_2 \tag{4}$$

$$\phi = \begin{cases} |H_1 - H_2| & \text{, if } |H_1 - H_2| < \pi \\ 2\pi - |H_1 - H_2| & \text{, if } |H_1 - H_2| > \pi \end{cases} \tag{5}$$

The value d_I is the intensity difference between the two points, d_C is the distance among the projections of the points in a chromaticy plane, and ϕ is the less angle that separates H_1 and H_2. The threshold of chromaticy Ω establishes the separation of the space of color representation in two areas: the *chromatic area* and the *achromatic area*. This separation responds to the necessity perceptual of using the information of intensity or saturation and tone when determining frontiers assisting to the analyzed color points. In [6] appear an empiric approach to their calculation.

2.1.2. Order in color representation space.

Since does not exist a natural form, universally accepted, of colors ordering, here was defined our order in an arbitrary way. A simple technique that gives good results consists on evaluating one of the components in the two elements to order and hereafter to choose as the bigger element the one that possesses the big value in this component. In case of equality we would pass to the following component, and so forth. In our case given two pixels (H_1, S_1, I_1) and (H_2, S_2, I_2), we compare the I values first, then those of S and finally those of H. To compare this last component the used approach is the following one: if the angle of smaller module to pass from H_1 to H_2 is positive, we choose (H_2, S_2, I_2) and otherwise we stay with (H_1, S_1, I_1).

2.1.3. Computing gradient vector.

One of the classic methods of detection of discontinuities accepted by the bibliography is the gradient vector method (magnitude and address). In view of the color representation space elected in the work the use of masks of first order has been generalized based on the gaussian mask, like of Canny's filter[1] makes, from monochrome images to color images.

In the digital case, the image convolution with one mask first derived partially of the gaussian can be carry out by means of the successive image convolution with two one-dimensional perpendicular mask expressed in the following way:

$$\sum_k m_k(x_{i+k} - x_{i-k}) = \sum_k m_k c(x_{i+k}, x_{i-k}) d(x_{i+k}, x_{i-k}) \qquad (6)$$

being $d(x_i, x_j)$ the distance between pixels colors of x_i and x_j and

$$c(x_i, x_j) = \begin{cases} 1 & \text{if } x_i > x_j \\ -1 & \text{if } x_i \leq x_j \end{cases} \qquad (7)$$

an order function like the defined one in the previous point.

3. GROWTH REGIONS PROPOSED ALGORITHM.

An edge can be defined as a transition among adjacent regions that are homogeneous intrinsically by a side and in another side they are different from the rest assisting to some approach of homogeneity. A frontier is a reduced area, in which the image presents an abrupt change in color characteristics of pixels present in that region. This is based upon the idea that the objects and the areas that they occupy can be represented by their frontiers (contours), using some segmentation methods (at least ideally) to describe the frontiers, which define those objects and therefore to themselves.

The growth algorithm proposed here will try to join both advantages of the segmentation algorithms previously exposed: the information contributed by the gradient and the non-supervision present in regions growth.

3.1. Seed location.

The map of gradients allows us to define the component objects of a scene as is shown in Figure 1. Here is possible to observe both the gradient magnitude and a three-dimensional representation of the same one. Clearly is observed as the surfaces that appear in both a) and b) shown a mountainous system on which is possible to distinguish maximum picks that are unite forming a cordillera corresponding to what would be a frontier, and valleys corresponding to the areas that appear among the frontiers of an object.

The regions growth algorithm proposed will extend the initially placed seeds using an approach of homogeneity for pixels grouping and the gradient's image information to propagate the same ones, using the determined frontiers as *contention walls* of the same ones growth. To save the problem of the location of the seeds in the scene and their later growth, two solutions have been adopted:

- To locate the seeds along the detected frontiers.

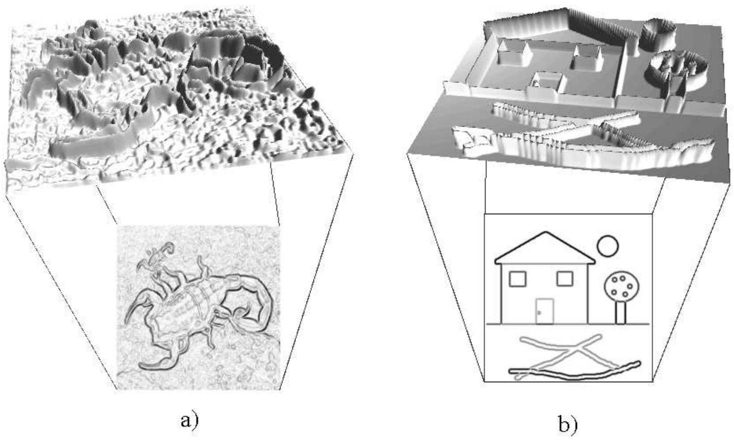

Figure 1: Map of magnitude and three-dimensional representation of the same one obtained as a result of the application of Canny's algorithm with a mask 9x9, $\sigma = 1.0$, a superior threshold of 0.9 and an inferior threshold of 0.5. The original images are given in the Figures 3.b and 3.d.

- To use the information contributed by the gradient, which definitively mark the slope in the three-dimensional structure shown in the Figure 2, to carry out the propagation of the located seeds.

The main problems to reach the correct situation of the seeds along the frontiers are basically two: the absence of the frontiers continuity in the segments (that would make two segments that belong to the same frontier are not united), and the presence of ramifications on a segment (what would hinder the process of pursuit of the same one).

Taking into account the previous considerations, and to avoid that regions already calculated surpass the frontiers, it will be place for each frontier segment, along all their journey, two different seeds, one coinciding with the same frontier and another to their right in such way that a related journey takes place for $4-$neighbors.

3.2. Regions growth.

Our regions growth algorithm is based on a controlled descent through the slopes of the image gradients. It necessary to remember our seeds are in fact placed in the image frontiers that correspond with the maximum (or crests) that present the image of gradients.

The propagation algorithm is simple: *for each labeled pixel to spread their label toward those not labeled neighbors that have a value of gradient magnitude near to his.*

This growth mechanism alone is insufficient; due to it makes grow the regions in a non-homogeneous way, independently of the real differences of gradient magnitude. In this way a region presenting a marked slope in the image of gradient magnitudes would grow the same as another with little or any slope. To avoid this the minimum value of the pixel's gradient magnitude is limited so that the label spreads to him. When the propagation step does not make any change is decremented the value of the gradient magnitude and it continues spreading. The growth algorithm is the following:

```
G(x,y): Image of gradient magnitude
E(x,y): Image labels
M=max(G)
m=min(G)
k=M
Repeat while k>=m
   Repeat while E(x,y) is changing
       For all E(x,y), E(x',y') is a non label neighbor
           E(x',y')=E(x,y) iif |G(x,y)-G(x',y')| is minimum
               and G(x',y')>=k
       End For
   End Repeat
   k=k-dk
End Repeat
```

where `dk` represents an increment of value magnitude of used gradient.

The simplification of frontier segments cut the ramifications of the same ones based on elimination of edges map of the points considered as triples and quadruple, as well as to their $8-$eighbors. After the application of the previous algorithm the image will be recovered from regions to exception of those areas, for what in a later phase the remaining pixels would be labeled, assigning them to the region that more times appear of how many surrounds it.

In the Figure 2 is possible to observe the process of growth of regions starting from the map of edges of the original image 3.b, on which the seeds have been located.

The process of simplification of the frontier segments assisting to the location of the seeds can cause that different recovered regions appear on oneself object. To avoid that redundancy of regions is inserted, in a last step, a fused of the

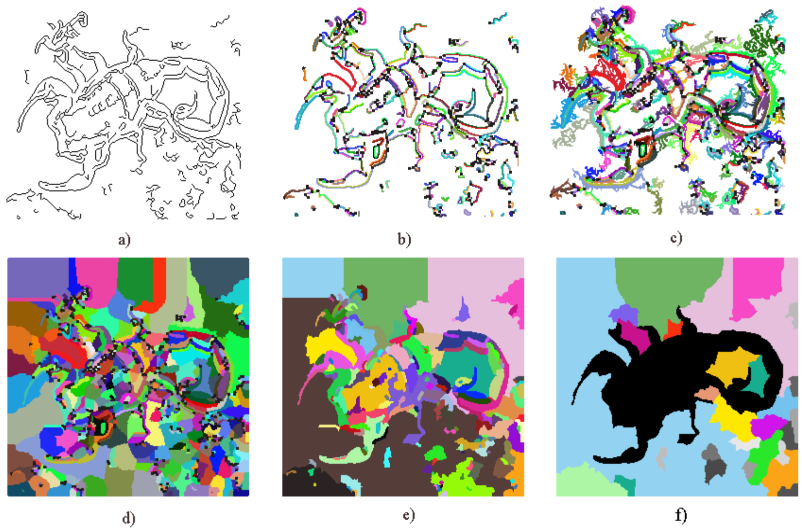

Figure 2: a) Edges map obtained after the application of the discontinuities detection algorithm proposed (mask of size 9x9, $\sigma = 1.0$, upper threshold $= 0.9$ and lower threshold $= 0.5$), b) Results of growth regions process after the first iteration, c) after the seventh iteration, d) after the tenth iteration, e) Final filler of not labeled areas, f) Final grouping of regions assisting to of minimum distance approach among the middle colors on considered regions.

same ones. The approach of merge is simple: if the frontier of union of two adjacent regions does not appear in the map of edges they unite both to form a bigger one.

The fusion process also allows recovered regions considered as small can be absorbed by their neighboring regions. The Figure 2.f show (a label of black color has been chosen for its best visualization) the final grouping of regions assisting to an approach of minimum distance among the colors means of the considered regions.

3.3. Regions interpolation.

After having extended the recovered regions of scenes, it is possible to substitute the associate labels by means of a simple interpolation of the values (H, S,

I) to allow a better visualization of the information of contextual dependences of patches or certain regions. To be able to carry out the interpolation we will calculate the stocking of the values (H, S, I) of the pixels in the original image for each region. The mechanism used to calculate this average is the following one:

$$x = \frac{1}{n}\sum_{i=1}^{n} S_i \cos(H_i) \quad y = \frac{1}{n}\sum_{i=1}^{n} S_i \sin(H_i) \tag{8}$$

$$\bar{H} = \arctan\left(\frac{y}{x}\right) \quad \bar{S} = \sqrt{x^2 + y^2} \quad \bar{I} = \frac{1}{n}\sum_{i=1}^{n} I_i \tag{9}$$

4. RESULTS OBTAINED.

In the Figure 4 are shown the final results obtained after to apply the regions growth algorithm proposed.

For each image has been calculated the map of gradients and magnitude using the proposed algorithm of discontinuities detection, with a mask of size 9x9, $\sigma = 1.0$, an upper threshold equal to 0.9 and an lower threshold equal to 0.5. Hereafter the seeds are put to grow in both frontiers sides and finally the labels associated to each region have been substituted by means of the interpolation in the original image of the HIS pixels values placed in the obtained regions, to achieve a better results view.

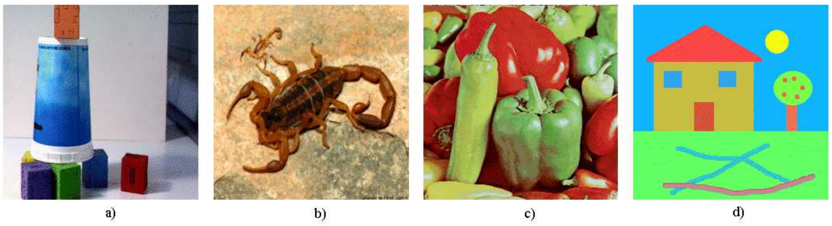

Figure 3: Original images.

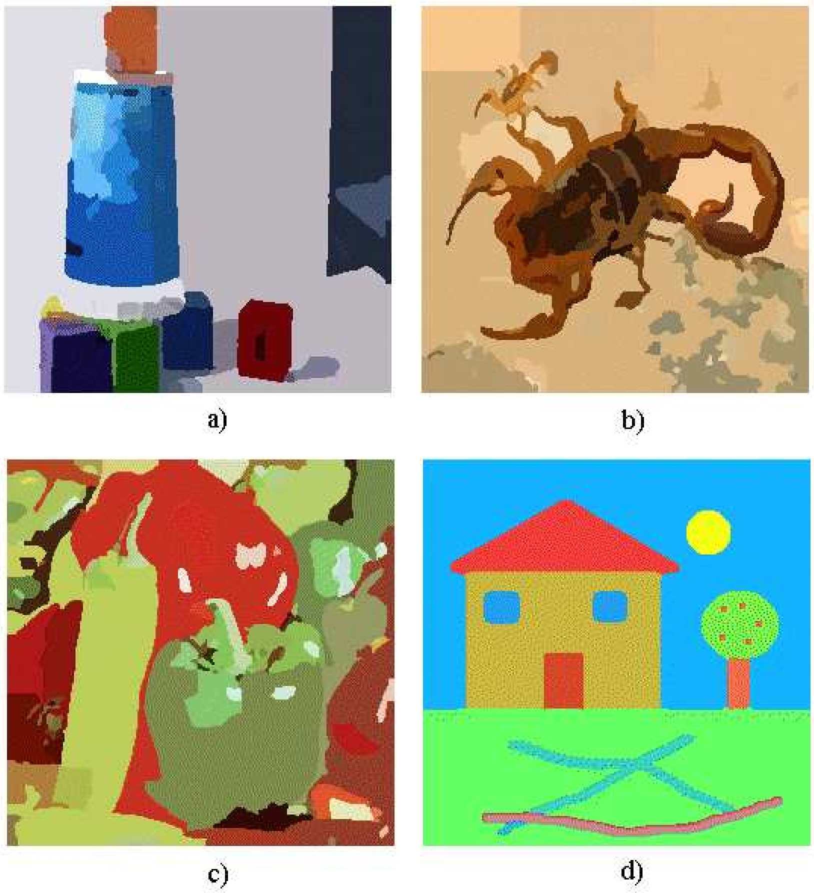

Figure 4: Result of interpolation of the regions generated starting from the growth of the seeds located on the maps of discontinuities of different images of the Figure 3.

5. CONCLUSIONS.

The presented work proposes a technique of regions growth on color images. Starting on a color representation space the Canny's algorithm is generalized to detect discontinuities on these images. The map of discontinuities determines the location of seeds in the images, while the map of gradients directs the growth of the same ones.

Compare with classic algorithms of regions growth [9], the one proposed presents two clear advantages *a priori*:

- It does not require of a supervised phase of seeds location in the scenes to segment. Different seeds are located automatically to a side and another of the frontier segments found in the scenes.
- The map of images discontinuities stops the process of seeds growth. The election of an inadequate approach of homogeneity won't lead to seeds growth without control.
- The technique of discontinuities detection defined allows choosing an appropriate scale of representation of the information. The convolution of the original sign with to kernel of the first derived of to gaussian function allows to control, starting from the used variance, the smoothing level considered in each one of them.

The obtained results show that the technique proposed generalizes to images in color the algorithm of regions growth. Also we can conclude starting from the four results shown in the Figure 4 that in images with a high relationship sign/noise, the proposed algorithm is able to simplify the scenes and to guide in a homogeneous way the growth of the seeds in the scenes.

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