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A Criterion for Circumscribed Contour Determination for Image Segmentation

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Abstract

The aim of the work presented in this paper is to explore the concept of *Circumscribed Contour (CC)* and the development of a methodology for its obtention. These contours correspond to significant borders between the perceptive regions of the scene. The extraction of the CC is based on the obtention of a contours image generated from the integration of the contours obtained from the Hue, Intensity and Saturation components of the scene, and their further processing.

The image of Circumscribed Contours can constitute a significant step towards image segmentation, providing a simplified scene representation.

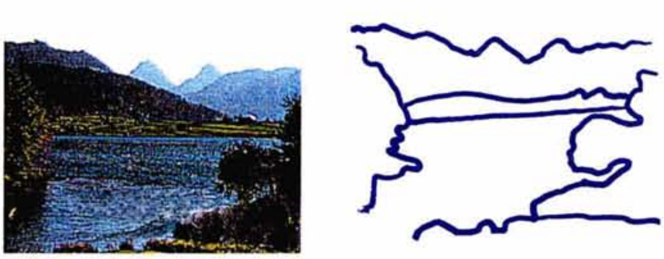

Figure 1: 1a Original Image. 1b Circumscribed Contours(CC)

1 Introduction

Russ in [1] considers the ability of the eye to respond to cartoons and line drawings. This author comments that the cartoon provides the eye with the minimum information it would have to extract from the scene itself to transmit up to higher levels of processing in the brain, such as scene interpretation.

This paper describes a method to obtain the most significant (perceptive) contours of an image that can constitute a schematic and simplified representation of the scene. We will name them Circumscribed Contours (CC). These contours will make easier the posterior image segmentation process.

The system proposed integrates the information coming from different processed subimages derived from the original one, which are: magnitude and orientation of the local edges obtained from the intensity (I), hue (H) and saturation (S) components; as well as the textural information achieved from these components, in a similar conceptual way which is proposed in [4].

The basic properties that the CC present are: 1) They are contours of an important length inside the setting of the scene. 2) The regions separated by the CC, present some appreciable differences in chromatic features (H,S,I) and textural features (density of edge points, blurryness, discontinuity, granularity, straightness, ...)

Some exemples of CC of different scenes, are: the external contour of a wooded zone, the track limits of the road, the skyline of a landscape image, the outline of a house or a zone of buildings, the line that surrounds a large object or a set of superimposed objects in an industrial scene, etc. Figure 1 shows the Circumscribed Contours concept.

Some researchers have been working in extracting specific contour lines to achieve some determinated objectives. These contours could be considered low level specific circumscribed contours. For instance, in the paper of [2] the skyline is extracted with the purpose to locate a vehicle in a suburban area. In the paper of [3] the detection and classification of the roads and tracks limits are carried out as a support to the traffic scene interpretation.

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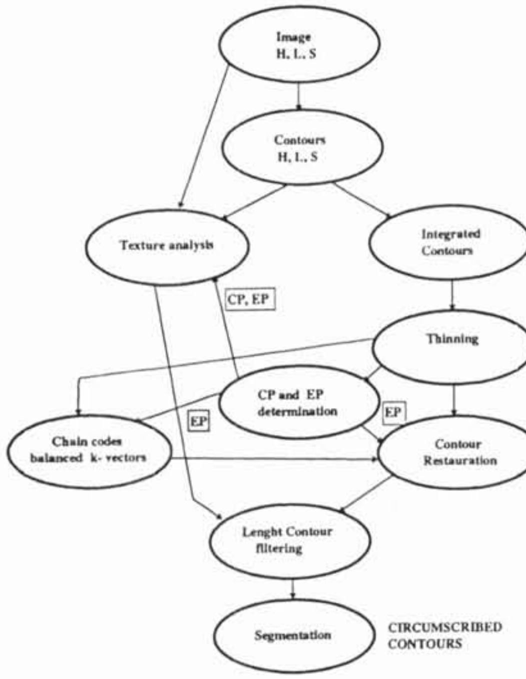

Figure 2: Processes for Circumscribed Contour obtention

2 Process to obtain the Circumscribed Contours

The process followed to obtain the Circumscribed Contours is shown in the figure 2. The stages of processing are: 1) Obtention of local contours from H, S and I components of the original image. 2) Integrated Contours Image generation. 3) Integrated Contours Image thinning. 4) Obtention of the crossing points (CP), endpoints (EP) and orientation of the contour pieces (V). 5) Contour restoration process. 6) Texture parameters obtention from the differents stages previously cited. The texture analysis is used to help the contour obtention in some specific zones of the image, where the chromatic contours has low continuity. 7) To consider the chromatic and textural contours that presents a value of length large enough. This depends on the type of scene analyzed.

2.1 Colour Transformation and Contours Obtention

This step consists mainly of a RGB to HSI colour coordinates transformation. This is considered by many authors [5], [6] a working space of colour more suitable to extract useful parameters for image segmentation. In this stage a low pass filter is applied to each one of the chromatic components to minimize the noise efect. In [5], the authors considers that the hue component is very noisy or unstable and irrelevant in the parts of the image where saturation is low (near the acromatic axis). If the value of saturation is high, then the hue component is relevant and its sensitivity to image noise is lower than that of the intensity component.

In our work, we attempt to obtain the most important contours of an image, considering the relevance of the gradient value for each chromatic component, using a neighbourhood analysis for each pixel of the whole original image.

From the subimages of hue, intensity and saturation, we obtain the local contours (magnitude and orientation) that are represented as $C^H(M^H, O^H)$, $C^I(M^I, O^I)$ and $C^S(M^S, O^S)$ respectively.

2.2 Integrated Contour Image

The integration of the edge images previously obtained enables the selective extraction of the most relevant contour information from each of them. A new contour image is generated: $f(C^H, C^I, C^S)$. We can define a function $f(C) = \max(\gamma_1 C^H, \gamma_2 C^I, \gamma_3 C^S)$ where $\gamma_i(M^i, O^i)$ are weigthing factors for every chromatic component used. These factors depends on the local properties of the contours in the neighbourdhood of the pixel considerated. Similarly, in [7] a combined gradient magnitude map is generated also by taking the maximum of the gradient magnitudes computed in the three colour bands: r, g and b.

2.3 Contour Thinning and Restoration

The determination of the CC requires to operate from thin and continuous contours. The thinning algorithm uses the integrated contour image $f(C)$ as input image.

Some classical thinning algorithms produce undesirable effects in specific zones of the image; for instance, the appearance of small circular formations surrounding the crossing points of the contours.

In order to avoid the addicional processing that would suppose the resolution of these problems, we propose the elimination of a small area around the crossing points (CP). The result is a set of thinned contour segments that present end points (EP) in their extremes.

Contour restoration is a problem widely treated in papers such those [8] and [9].The scheme implemented in this work takes into account the image parameters obtained from chromatic components (H,S,I) and the contour images $(C^H, C^I, C^S, f(C))$. For each one of the endpoints detected, we extract the direction of the contour piece V (considering k pixels from the EP) using the Freeman chain code (v_i) and the expression of the balanced k-vectors from [10], is:

$$V_i = \sum_{j=1}^{k} n_j v_{i-j} \tag{1}$$

where n_j are the weighted factors, which present values inversely proportional to the distance between the contour pixel and the EP.

The restoration process is carried out among the EP from different contour pieces. We propose in this work, a distance function in the multidimensional space of parameters, where each component of the expression is weighted with a factor α_i:

$$d^2(EP_a, EP_b) = \alpha_1(x_a - x_b)^2 + \alpha_1(y_a - y_b)^2 + \alpha_2(M(H_a) - M(H_b))^2 + \alpha_3(M(I_a) - M(I_b))^2 + \alpha_4(M(S_a) - M(S_b))^2 + \alpha_5(O(H_a) - O(H_b))^2 + \alpha_6(O(I_a) - O(I_b))^2 + \alpha_7(O(S_a) - O(S_b))^2 + \alpha_8\beta_{ab}(V_a - V_b)^2 \quad (2)$$

where the β parameter is related to colinearity of the two contour pieces.

Considering a set of endpoints EP_i neat to EP_a. If the distance between EP_a and EP_b of the contour pieces to be restored is small enough, and $d(EP_a, EP_b) = \min(d(EP_a, EP_i)), \forall i$, then the contour pieces are joined.

2.4 Texture Analysis

When we use local contours obtained from the chromatic components (H,S,I), the segmentation process has a poor performance in some specific elements of a natural images, such as: wooded zones, a group of trees, rivers, lakes, and so on. In these cases the use of textural features, in conjunction with the contours obtained from the chromatic components, could be the main idea to obtain the Circumscribed Contours for natural images.

The Figure 3 shows the integrated contours image obtained from the original mountains scene. The wooden zones in the image presents a very fragmented contour (high density of crossing points) due possibly to their textural nature. The obtention of the contours for these highly textured zones is a very important process to obtain a good segmentation.

Some of the textural features used, inspired in the work described in [11], are : homogeneity in some of the components (H, S, I), blurryness of some components in any direction, density of contour points considering $(C^H, C^I, C^S, f(C))$, density of edge points with a determinated direction, discontinuity (EP density), granularity (density of small closed shapes), etc. Other textural features are obtained from simple statistical parameters such as the mean or the variance of energy measures. These energy measures are obtained from the convolution of some center-weighted vector masks named Level, Edge, Spot, Wave and Ripple [12]:

$$\begin{array}{lcl} L5 & = & [\;1 \quad 4 \quad 6 \quad 4 \quad 1] \\ E5 & = & [\;-1 \quad -2 \quad 0 \quad 2 \quad 1] \\ S5 & = & [\;-1 \quad 0 \quad 2 \quad 0 \quad -1] \\ W5 & = & [\;-1 \quad 2 \quad 0 \quad -2 \quad 1] \\ R5 & = & [\;1 \quad -4 \quad 6 \quad -4 \quad 1] \end{array} \quad (3)$$

For instance, E5L5 is a horitzontal edge mask, R5R5 is a high frequency spot detector and L5S5 is a vertical line detector.

2.5 Circumscribed Contour Determination

The threshold value for the minimum length is related to the object dimensions that appear in the image and therefore it depends on the type of scene considered. It is necessary to take into consideration the possibility to have a very wavy contour, that presents enough length. If this type of contours take up a small region of the image, their have poor significance. It will be necessary to balance their length with a penalty factor.

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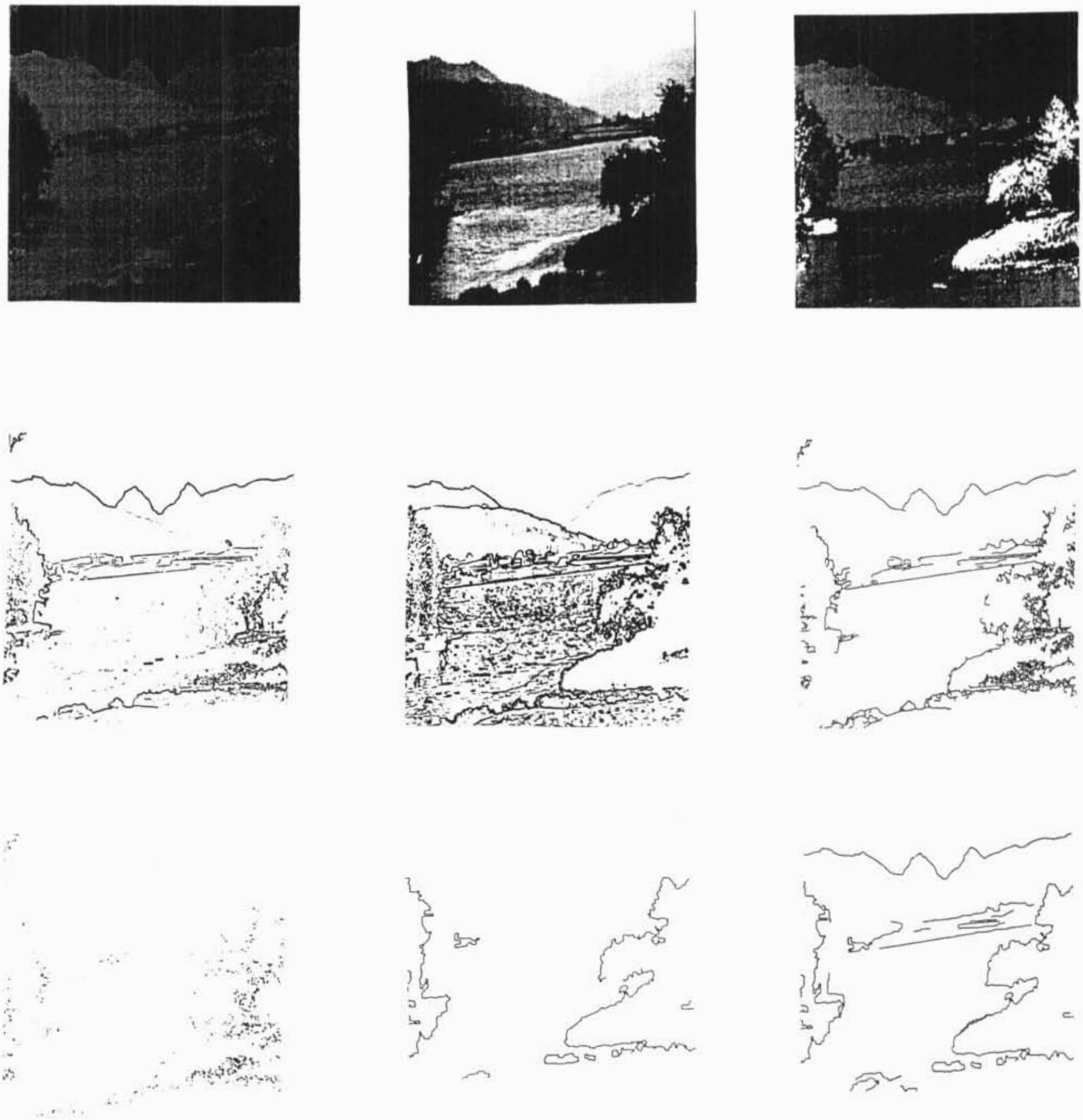

Figure 3: From left to right and top to bottom: Hue, intensity and saturation of the original image. Local contours obtained from the hue and intensity components. Integrated contours image. Density of crossing points of the integrated contours image. Texture contours for the wooded zone (based on homogeneity criteria on intensity component). Circumscribed contours obtained.