

BOUNDARY DETECTION OF TEXTURED REGIONS

Masahiko Yachida, Motozo Ikeda and Saburo Tsuji
Department of Control Engineering, Osaka University
Toyonaka, Osaka 560, Japan

It is not easy to find exact locations of boundaries of textural regions since statistical properties around the boundary show mixed properties of two neighboring regions. This paper presents a method to detect exact locations of boundaries of textural regions in the scene. We first propose 'a measure of boundary' which shows large value on the boundary and very small value in other locations. Then we propose a method to find globally good boundaries with respect to the defined measure of boundary using the optimization procedure.

The initial segmentation is performed on the reduced version of the input image using multiple textural properties by the recursive thresholding method. This segmentation result on the reduced image is then utilized as a plan for detecting exact locations of textural boundaries in full size image by the proposed textural boundary detector. The proposed method has been applied to a number of textured images, and some of the results will be given in the paper.

1. INTRODUCTION

Texture is an important property for segmentation of input pictures into regions in scene analysis. Many methods have been proposed to extract meaningful textural properties of local regions such as coarseness or orientation [1]; however, few attempts have been made for detection of exact textural boundaries. Usual methods apply local operators sensitive to some statistical properties of local regions, and then the textural boundary is obtained as the boundary of regions having homogeneous textural properties.

However, such a simple method cannot find correct location of textural boundaries. The reason is that statistical properties do not change abruptly on the boundary, but gradually change from one region to another region. Therefore, there are relatively broad regions having mixed properties of two neighboring regions around the boundary. Thus, existing methods find a boundary somewhere in this broad region around the true boundary. In this paper, we propose a good measure of textural boundary and a method to find a globally good boundary with respect to the defined measure of boundary.

2. MEASURE OF TEXTURAL BOUNDARY

For the sake of simplicity, let us first consider the problem of finding the boundaries of two textural regions R_1 and R_2 that are known to have homogeneous properties P_1 and P_2 respectively. As shown in Fig. 1, the boundary exists in the region S between two homogeneous regions R_1 and R_2 and the local properties of the region S are not homogeneous and have some mixed properties of two regions. Let us define a local operator that has two regions r_1 and r_2 on both sides of a center line L as shown in Fig. 2, and denote the local properties of r_1 and r_2 as p_1 and

p_2 respectively. Then, if the operator lies on the boundary, the following conditions must be satisfied:

- 1) p_1 is similar to P_1 and different from P_2 .
- 2) p_2 is similar to P_2 and different from P_1 .

Let us define the similarity of textural properties of p_1 , p_2 , P_1 and P_2 as

$$\begin{aligned} D_{11} &= p_1 - P_1 \\ D_{12} &= p_1 - P_2 \\ D_{21} &= p_2 - P_1 \\ D_{22} &= p_2 - P_2 \end{aligned}$$

Then the above conditions can be stated as:

- 1) $D_{12} > D_{11}$, and 2) $D_{21} > D_{22}$

Therefore, we define the measure of textural

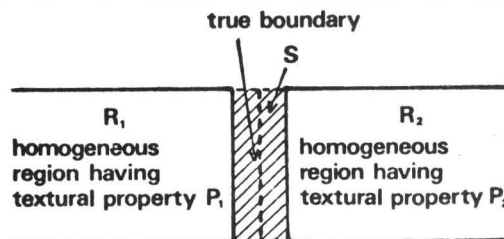


Fig. 1. Textural boundary exist somewhere between two homogeneous regions R_1 and R_2 .

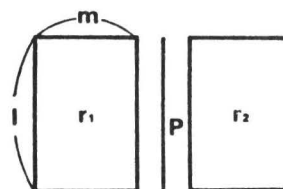


Fig. 2. A local operator.

boundary M as:

$$M = (D_{12} + D_{21}) - (D_{11} + D_{22}) \quad (1)$$

The value of the measure M is large when the operator is on the boundary and is very small in other places. Fig. 3 shows the values of D_{11} , D_{12} , D_{21} , D_{22} and M when the operator is on the right of the boundary.

Then, the boundary can be found by searching the region S for points having large value of M. However, local decisions such as finding points having local maximum of M cannot produce a good boundary since noise causes many false boundary points and gaps on the true boundary. We utilize the optimization method to find a globally good boundary with respect to the measure M in the region S.

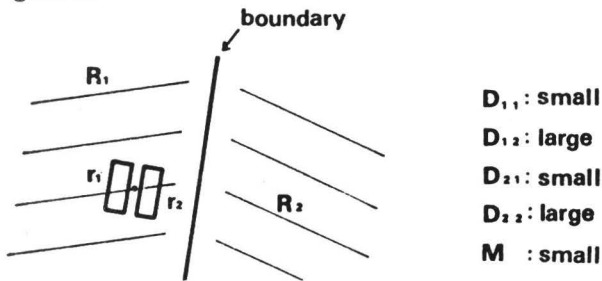


Fig. 3. The values of D_{11} , D_{12} , D_{21} and D_{22} when the operator is on the right of the boundary.

3. GLOBAL DETECTION OF BOUNDARY

Let us represent a line by any sequence of connected linear segments $L_1, L_2, \dots, L_N$ of length ℓ , and define a merit function ϕ of the line $(L_1, L_2, \dots, L_N)$ as

$$\phi(L_1, L_2, \dots, L_N) = M(L_1) + M(L_2) + \dots + M(L_N) \quad (2)$$

Where $M(L_i)$ is the measure of the boundary of the linear segment L_i computed by the local operator parallel to the linear segment L_i , as shown in Fig. 4.

Then, the sequence of linear segments $L_1, \dots, L_N$ having the maximum value in the region S can be considered as the globally good boundary. Therefore, the problem of finding the globally good boundary becomes the problem of finding the sequence of linear segments $L_1, \dots, L_N$ which maximizes the merit function ϕ given in (2). This problem can be solved by the multistage optimization procedure. An efficient method for solving this problem is described by the authors[2]. We may embed shape information such as smoothness into the merit function ϕ as

$$\begin{aligned} \phi(L_1, \dots, L_N) = & \sum_{i=1}^N M(L_i) \\ & - k \sum_{i=1}^{N-1} |\theta(L_i) - \theta(L_{i+1})| \end{aligned} \quad (3)$$

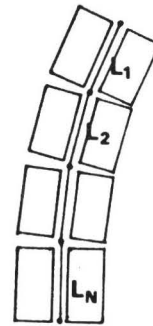


Fig. 4. Representation of a line by a sequence of linear segments $L_1, L_2, \dots, L_N$. A local operator is set parallel to each linear segment.

Where $\theta(L_i)$ is the slope of the line L_i and k is a constant. This merit function find a boundary having large value of M and low-curvatures.

4. INITIAL SEGMENTATION OF PICTURES

We have described a global method to find exact location of boundaries in the region S. In this section, we will briefly describe a method of the initial segmentation of a picture into regions having homogeneous textural properties. Fig. 5 shows a flowchart of the initial segmentation procedure. First, the input picture is averaged to obtain the reduced version of the image. The initial segmentation is performed on this reduced image and the segmentation results are used as a plan for detecting exact locations of textural boundaries in the full size image. We use not only a single textural property but also multiple textural properties such as gray-level distribution, edges per unit area or edge direction for segmentation. After obtaining these textural properties in the image, a non-linear averaging operator proposed by Tomita and Tsuji[3] is applied to smooth textural properties of each point in the image. Then, the recursive thresholding method proposed by Tomita et al[4] is applied to segment the image using multiple textural properties.

First, the histograms of the entire image are computed for all textural properties. Then, by analyzing these histograms, the most promising property for partitioning the image is selected. That is, the property whose histogram has deep valleys between two prominent peaks is selected as the promising property for partitioning and the threshold is determined as the value of the bottom of the valley. Then, the image is segmented by the selected threshold of the selected property. For each of the segmented regions, we apply the same procedure as described above until each region has only one prominent peak in the histograms.

These segmented regions of the reduced image are utilized as the plan for detecting exact locations of the boundaries of textural regions in the full size

image by the textural boundary detector described before. The plan gives the textural boundary detector the following two things: 1) search region of the boundary, and 2) textural properties of two neighboring regions to be utilized in finding the boundary.

5. EXPERIMENTAL RESULTS

To show the ability of detecting exact locations of textural boundaries, we tested the proposed method on the image shown in Fig. 6. Fig. 7 shows the initial segmentation procedure obtained for this image. Fig. 8 shows the boundaries detected by the textural boundary detector.

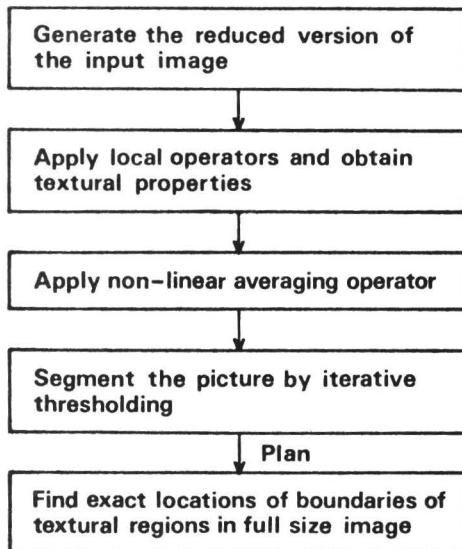


Fig. 5. A flowchart of the initial segmentation procedure.

REFERENCE

- [1] R. M. Haralick : *Statistical and Structural Approaches to Texture*, 4th IJCPR, pp. 45-69, 1978.
- [2] M. Yachida, M. Ikeda and S. Tsuji : *A Knowledge Directed Line Finder for Analysis of Complex Scenes*, 6th IJCAI.
- [3] F. Tomita and S. Tsuji : *Extraction of Multiple Regions by Smoothing in Selected Neighborhoods*, IEEE Trans. SMC-7, pp. 107-109, 1977.
- [4] F. Tomita, M. Yachida and S. Tsuji : *Detection of Homogeneous Regions by Structural Analysis*, 3rd IJCAI, pp. 564-571, 1973.

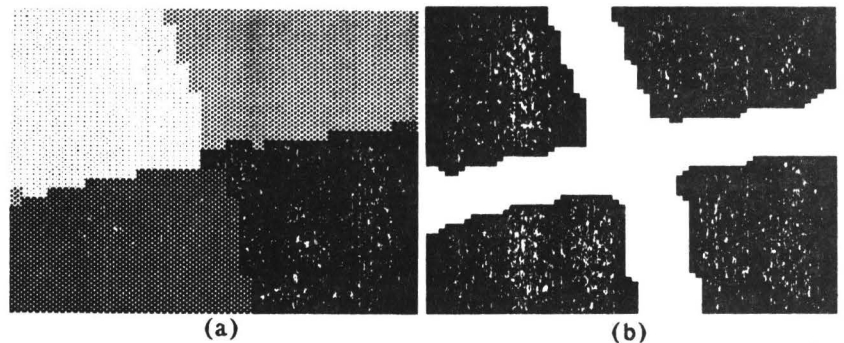


Fig. 7. Initial segmentation procedure for the input picture shown in Fig. 6. (a) Result of applying the non-linear averaging operator to the reduced image of Fig. 6. Picture size is 64 by 64 points. (b) Plan region for the exact detection of boundaries.



Fig. 6. Picture containing four regions. Picture size is 256 by 256 points.

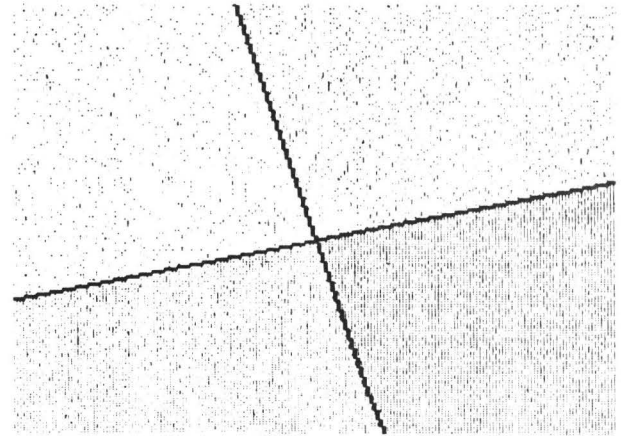


Fig. 8. Boundaries obtained by the textural boundary detector.