# CONTOUR LINE REGION SEGMENTATION

*(Extended Abstract)*

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*ABSTRACT*

In images such as of contour maps, fingerprints, and electric fields, regions of contour lines can be distinguished, and these regions are often used for image understanding. In this work, such images are collectively termed contour line images. The objectives are to determine the properties by which contour line regions are characterized, and to develop an approach using these properties to automatically determine regions. An algorithm is proposed to group lines into regions. This is based in part on the parallel-adjacency criterion which is defined here. The algorithm has been applied to several contour line images, and the resultant regions are shown.

KEYWORDS: contour line regions, image segmentation, pattern recognition

## 1. Introduction

It is a simple matter for a person to locate a knot in wood grain, or to recognize a pattern in marble. Patterns on contour maps can be recognized as locations of rivers or steep grades. Other constant-value plots such as flux line fields in electromagnetics and isobar maps in meteorology are interpreted by the *pattern* of lines (rather than by individual lines) to understand global information in the image. Differences in the shape of contour patterns in fingerprint images can be used, even by non-experts, to distinguish different prints. All these examples involve images of contour lines in which regions of line patterns are discerned by human viewers, and from which interpretation or recognition is performed. Although human recognition of these patterns seems trivial, it is no trivial task for a computer. In this paper, we examine properties which characterize regions in contour line images, and propose an approach for performing automatic determination of these regions.

We wish to deal with contour line images, irrespective of what the contour lines represent. The expression *contour line image* will refer to an image made up of lines (where lines can be curved) which run approximately parallel to adjacent lines, at least over short distances. The spacing between adjacent lines is often small, and the lines may be densely packed. Therefore, groups of lines appear as regions rather than boundaries. Examine Figure 1, and determine the number of contour line regions in each diagram based on the "similarity of pattern" within each region. Our experience shows that there is a general consensus in the number of regions perceived for each. It is this response that we desire to emulate by machine. (Our informal examination of the human perception of these regions is inadequate to claim that this is a universal response, however this does not lessen the interest in proposing a method for emulating what we have found to be a common response.) The common responses given for the number of regions in each diagram of Figure 1 are shown in Figure 2.

## 2. Method

Our objectives are to determine the properties which characterize contour line regions, and to describe an approach which utilizes these properties in order to segment regions. It is necessary to clarify some terminology before describing the properties and approach. A *contour line*, or *line*, is a straight or curved sequence of contiguous points between two endpoints. A *segment* is a straight line fit to a portion of a line. We will refer to *regions* of lines, and *groups* of segments.

First, we combine descriptions of some of the properties of contour line images into the expression **parallel-adjacency**. The parallel-adjacency criterion specifies that if a pair of segments are:

1. adjacent (i.e. not separated by other lines),
2. close in distance,
3. approximately parallel, and
4. overlap by a specified amount,

then the lines to which the segments belong are potentially in the same region. In the algorithm to be described below, pairs of segments are first compared for parallel-adjacency, and groups of line segments are built by these pairwise comparisons. Then, in the same manner, adjacent lines are compared pairwise to determine if they are similarly comprised of segments of the same parallel-adjacency groups. In this way, lines are combined into *contour line regions*.

The main steps of the algorithm are listed below:

1. Split lines at all junctions (bifurcations and crosses in lines).
2. Perform piecewise straight-line fitting so that each line is comprised of straight line segments.
3. Construct an adjacency list of the straight-line segments. This segment adjacency list (SAL) contains, for each segment, all other segments meeting criteria for distance proximity, approximate parallelism, and non-zero overlap with respect to that segment.
4. Merge the segments of the SAL into groups on the basis of pairwise similarity of line segments due to the parallel-adjacency criterion. The result is the segment group list (SGL).
5. Consider each line in its entirety (made up of the straight line segments), and group the lines, again in pairwise fashion, based on line adjacency and similar composition of line segments from the SGL. The result is the line region list (LRL) containing line composition of each contour line region.

### 3. Results

The algorithm was applied to each of the diagrams in Figure 1. The results are shown in Figure 2. For these synthesized images, which contain no noise, the regions found by the algorithm are consistent with our expectation and approach. Figure 3 shows the results of the algorithm as applied to a thinned fingerprint image which contains broken, short, and isolated lines. The 3 largest regions (in terms of number of lines per region) which are found by the algorithm are shown. We are currently working to better establish the relationships of the algorithm parameters to the image characteristics — especially for images containing noise.

### 4. Summary

The objectives addressed in this work are to determine properties which characterize contour line regions, and to automatically distinguish those regions. In the context of this work, contour line images consist of a large number of lines, where adjacent lines are closely spaced, overlap, and are approximately parallel. From these properties, the parallel-adjacency criterion is defined and used to associate piecewise segments of different lines into groups. Contour line regions are then found by pairwise merging of lines which are similarly comprised of groups of segments. Experiments have shown that the regions determined by the algorithm as applied to both synthetic and real images are consistent for our approach.

A short description of the method has been given in this extended abstract. Continuing work will give a better understanding of the performance of the algorithm for different conditions and types of images, and a more detailed description will be given in a future paper.

### Relevant Literature


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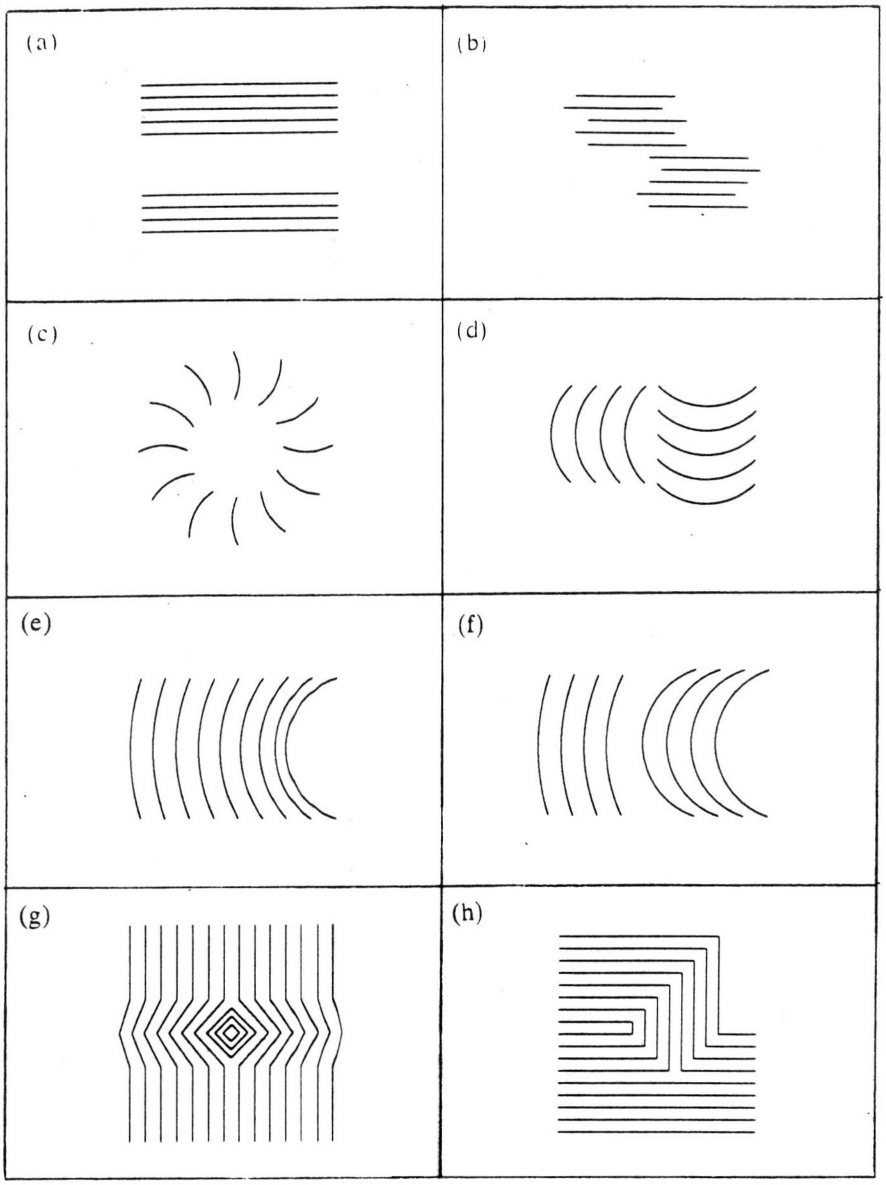


**Figure 1.** How many contour line regions are there in each image?

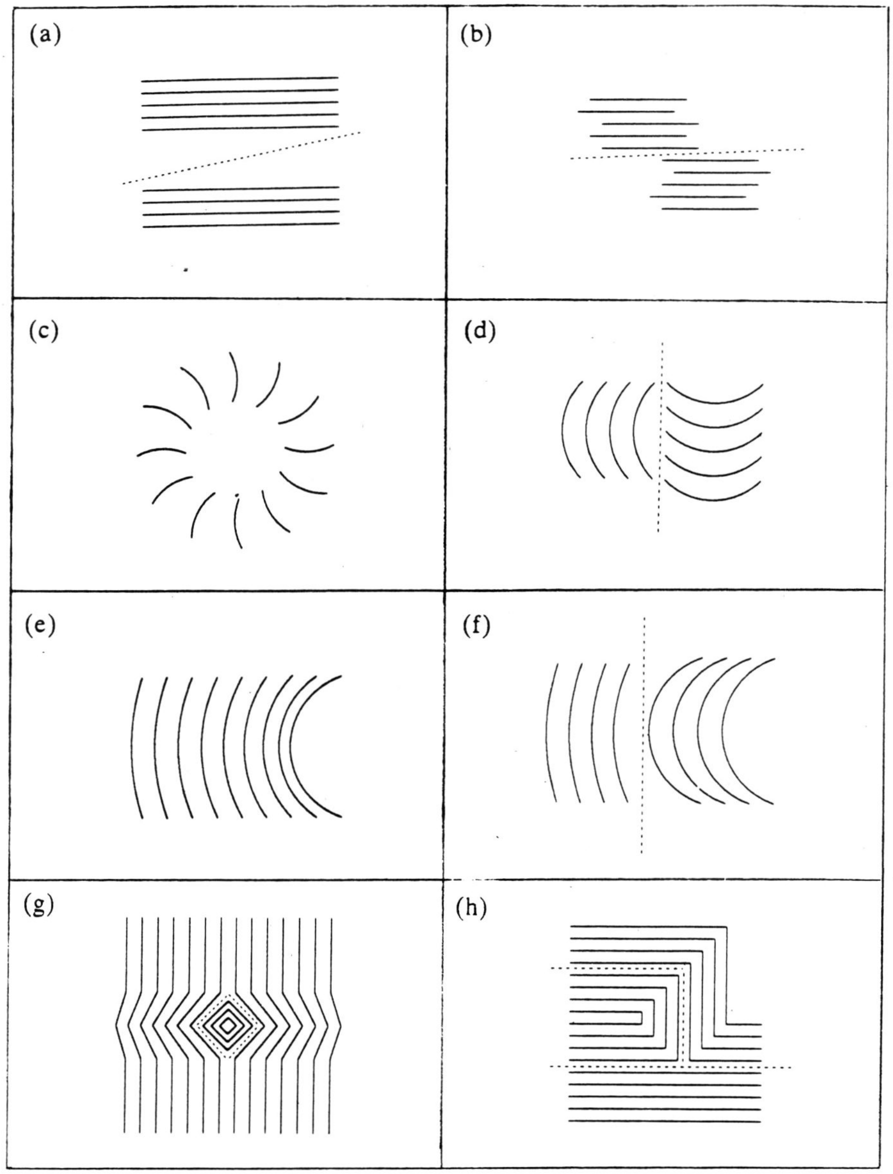


**Figure 2.** Contour line regions found by the algorithm for the images in Figure 1. Number of regions: (a) 2, (b) 2, (c) 1, (d) 2, (e) 1, (f) 2, (g) 2, (h) 3.

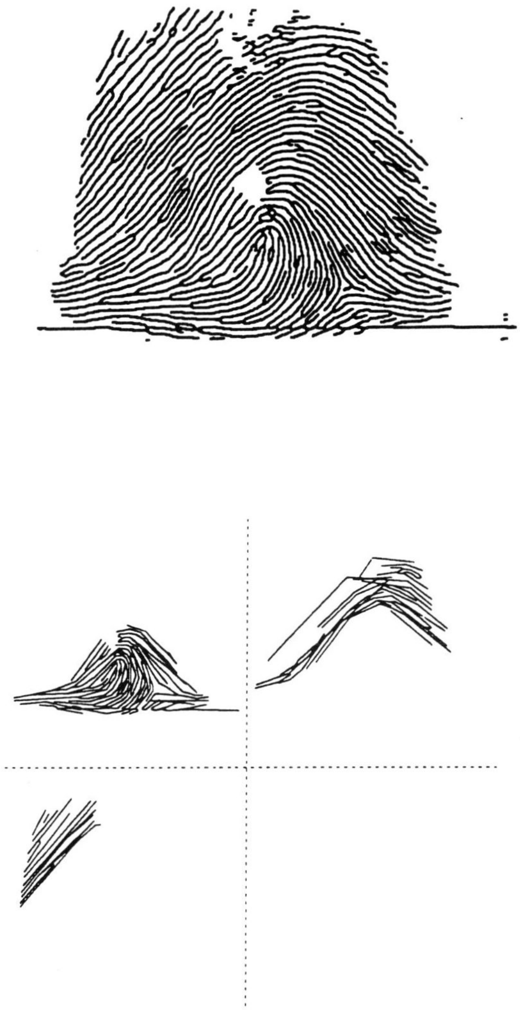

Figure 3. Fingerprint image, and the regions found.