CONNECTED COMPONENT LABELING USING MODIFIED LINEAR QUADTREES

Xiaoning Wang and Wayne A. Davis

Department of Computing Science
The University of Alberta
Edmonton, Alberta, Canada T6G 2H1

Abstract[1]

Using the modified linear quadtree proposed in [1,9], this paper presents an $O(n \cdot N)$ algorithm for labeling connected components of a region consisting of N BLACK nodes in a 2^n by 2^n binary image. As a direct application of the algorithm, a method for computing the perimeter of a region is also described.

1. INTRODUCTION

The identification of all connected components of a region is a fundamental operation in image processing and geographic systems [4, 5]. Samet [6] presents an algorithm for labeling all connected components of a region represented by a quadtree, and shows that its average execution time is $O(T + N \cdot \log N)$, where T and N are the total number of nodes and the number of BLACK nodes in the quadtree, respectively. That algorithm outperforms the traditional method which has an execution time proportional to the number of pixels of the image [5]. Gargantini [3] also describes an entirely different algorithm using a linear quadtree [2]; however, that algorithm has limited power as it is only applicable to regions with very special configurations.

In this paper, an algorithm adopting a novel approach for labeling all connected components of a region using a Modified Linear Quadtree (MLQ) is presented. It is capable of handling regions with arbitrary configurations. Furthermore, the algorithm is of time complexity $O(n \cdot N)$, and hence compares favorably to Samet's algorithm [6]. As an application of the algorithm, this paper will show that, with the same time complexity, the perimeter of a region can also be computed.

2. DEFINITIONS AND NOTATION

This section contains some basic definitions and terminology for region representations that are fundamental for the remainder of this paper.

[1]This research was supported in part by the Natural Sciences and Engineering Research Council of Canada under Grant NSERC A7634.

Definition 1: An *image* is a 2^n by 2^n array of unit square pixels each of which can assume one of 2^k values, where n is called the *resolution parameter* of the image.

Definition 2: An image is called a *binary image* when its pixels assume either 1 or 0 values. A pixel is BLACK if it has the value of 1, otherwise it is WHITE.

Without loss of generality, only binary images will be considered in this paper since all of the algorithms can be extended to nonbinary images.

Definition 3: The *region* of a binary image is composed of all BLACK pixels, and the *background* of the region is composed of all WHITE pixels.

Definition 4: Let (i, j) represent the location of a pixel p in a given image, where i and j are the column and row positions respectively. Then p has four horizontal and vertical neighbors located at: (i-1, j), (i, j-1), (i, j+1) and (i+1, j). These pixels are called the *4-neighbors* of p, and are said to be *4-adjacent* to p.

Definition 5: For two BLACK pixels, p and q, of a region, p is said to be *connected* to q if there is a path from p to q consisting entirely of pixels of the region.

Definition 6: For any BLACK pixel p, the set of pixels connected to p is called a *connected component* of the region. If a region has only one component, then it is called "connected".

Based on the principle of recursive decomposition, an image is decomposed in the following manner to separate a region from its background[10]. If the region does not cover the entire binary array, the array will be subdivided into four equal-sized square blocks. This process will be applied recursively, until blocks are obtained that are either totally contained in the region or totally disjoint from it. The recursive decomposition of an image produces blocks that must have standard sizes (powers of 2) and positions. Similar definitions can now be formulated in terms of blocks.