EFFICIENT IMPLEMENTATION OF THE LOCALLY CONSTRAINED WATERSHED TRANSFORM AND SEEDED REGION GROWING

Richard Beare

CSIRO MIS
Locked Bag 17, North Ryde, Australia, 1670
Richard.Beare@csiro.au

Abstract The watershed transform and seeded region growing are well known tools for image segmentation. They are members of a class of greedy region growing algorithms that are simple, fast and largely parameter free. The main control over these algorithms come from the selection of the marker image, which defines the number of regions and a starting position for each region.

Recently a number of alternative region segmentation approaches have been introduced that allow other types of constraints to be imposed on growing regions, such as limitations on border curvature. Examples of this type of algorithm include the geodesic active contour and classical PDEs.

This paper introduces an approach that allows similar sorts of border constraints to be applied to the watershed transform and seeded region growing. These constraints are imposed at all stages of the growing process and can therefore be used to restrict region leakage.

Keywords: watershed transform, region growing, constrained regions.

Introduction

Image segmentation aims to partition images into a number of disjoint regions according to some criterion, like color, edges or texture. The watershed transform [5] is a popular tool for performing region based segmentation of images. It is fast, flexible and parameter free. Seeded region growing [1] is a closely related approach that is usually applied to the raw image rather than the gradient image. Prior knowledge is usually provided to the watershed transform and seeded region growing algorithms by using a marker image [9] which defines the number of regions and the starting points for the growing process. However it is sometimes desirable to be able to impose additional constraints.

This paper will introduce a mechanism that can easily be included in the well known *hill-climbing* watershed transform implementation and the closely

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related seeded region growing implementation. The modification allows constraints to be applied to the curvature of region borders at all stages of the growing process. This makes some of the useful properties of other region segmentation approaches, like geodesic active contours and classical PDEs, available in more traditional region based segmentation frameworks. The modified algorithms are called *locally constrained* watershed transform and *locally constrained* seeded region growing.

Cost based frameworks for the modification have been developed elsewhere [4]. This paper will develop the modification from the point of view of a physical model and an efficient implementation of the algorithm.

The paper is structured as follows. Sections 1 and 2 introduce the watershed transform and previous work on constrained region growing. Sections 3 and 4 introduce the leakage problem that we are trying to correct and the physical model we are using to address it. Implementation, results and performance are discussed in Sections 5, 6 and 7.

1. Brief history of the watershed transform

A detailed description of the watershed transform's heritage is given in [12, 7]. Only a brief summary will be given here.

The watershed transform was first proposed as a segmentation method that modeled the progressive immersion of a topographical relief (an image) in a fluid [5]. Each regional minimum [1] in the surface corresponds to a different lake. Neighboring lakes meet at watershed lines as the level of flooding increases. Flooding continues until the entire relief is immersed.

An algorithmic definition of this model that allowed an efficient implementation employing priority queues was proposed by Vincent and Soille [14]. The algorithm defined a recursive relationship between gray levels of the image.

Meyer [8] defined the watershed in terms of a distance function called the topographical distance. This distance was defined in terms of the *lower slope* of *lower complete* images. images).

The catchment basin of a regional minimum is the set of pixels that are closer (in terms of the sum of value of regional minimum and the topographical distance) to that regional minimum than any other. The topographical distance watershed is the complement of the union of catchment basins.

These definitions produce a cost of zero in flat zones of an image, leading to a watershed that may be thicker than one pixel on a plateau. The usual solution to this problem is to transform images so that they are *lower complete*. This guarantees that there are no plateaus and that the watershed zones are thin.

More recent work by Nguyen, Worring and van den Boomgaard builds on the topographical distance framework and establishes the relationship between the watershed transform and energy-based minimization [11].