Commun. Comput. Phys.
doi: 10.4208/cicp.2009.09.026

Vol. **7**, No. 4, pp. 759-778
April 2010

Image Selective Segmentation under Geometrical Constraints Using an Active Contour Approach

Noor Badshah and Ke Chen*

Centre for Mathematical Imaging Techniques (CMIT), Department of Mathematical Sciences, The University of Liverpool, Liverpool L69 7ZL, United Kingdom.

Received 3 February 2009; Accepted (in revised version) 10 September 2009

Available online 3 November 2009

Abstract. In this paper we propose a new model for segmentation of an image under some geometrical constraints in order to detect special regions of interest. Our work is based on the recent work by Gout et al. [Numer. Algorithms, 39 (2005), pp. 155-173 and 48 (2008), pp. 105-133] using geodesic active contours models, by combining it with the idea of a piecewise constant Mumford-Shah model as with the non-selective Chan-Vese segmentation. Numerical tests show that our method is more robust than the previous works.

AMS subject classifications: 62H35, 65N22, 65N55, 74G65, 74G75

Key words: Active contours, energy minimization, partial differential equations, segmentation, level sets, geometric constraints.

1 Introduction

An important problem in image processing is the segmentation of a picture representing a real scene, into classes or categories, corresponding to different objects and the background in the image. In the end, each pixel should belong to one class and only one. In other words, we look for a partition of the image into distinct segments each having some features in common, e.g., intensities, colour or texture. A variety of different techniques have been developed to solve the problem of image segmentation, such as region growing and emerging [1], watershed algorithms [31], minimum description length criteria [21], and Mumford-Shah energy minimization [22]. Recently, PDE-based active contour models [20, 29] for curve evolution have been popular for image segmentation. In our recent work [4–6], we have developed effective multilevel algorithms for the Chan-Vese [14] approach for implementing active contours without edges. In [7,11] the authors discussed the global minimizers of the snake models.

*Corresponding author. *Email addresses:* `noor.badshah@liv.ac.uk` (N. Badshah), `k.chen@liv.ac.uk` (K. Chen)

While the above segmentation models are useful for various applications, however, other imaging problems require the functionality of selectivity, i.e., only segment a particular part among those objects that have the same feature. Such situations are ubiquitous in medical imaging especially in CT images where most objects (organs) have similar intensities. For example, we might like to segment the left kidney only whilst the above methods will give both kidneys mixed other organs. For the simple example in Fig. 3, it is fairly easy to segment the image to obtain 4 objects together but not separately because these four objects belong to the same intensities-based class. The task of a selective segmentation is how to detect only one of them, given additional information. Following Gout et al. [18], we consider the case of geometric constraints in terms of a list of given points near the interested objects to aid segmentation.

We remark that geometric constraints are also necessary for normal segmentation methods whenever the interface between objects is not 'clearly' visible due to poor image quality or some occultation. Curve evolution means to evolve deformable contours subject to constraints towards the boundary of the object to be detected. This deformation is made trying to minimize a functional depending on the curve and defined so that a local minimum is obtained at the boundary of the object. Casselles et al. [8] have shown, for example, that setting one of the regularization parameters to zero in the classical active contour model is equivalent to finding a geodesic curve in a Riemann space whose metric depends on the image content [18], because an edge in an image is the locus of points for which the image gradient rapidly varies. However when data acquisition cannot be performed in an ideal manner, this criterion can no longer be applied. This is the case when two objects, having similar homogeneous intensity or texture etc, are very close to each other. Then it is hard to clearly identify the interface without additional information. Here we consider geometrical constraints consisting of a set of points belonging to the contour of interest. For a medical image, practically, the expert needs to click on the organ under consideration a couple of times.

To proceed, let $z(x,y)$ be the given image defined on a rectangular domain Ω. The geometrical constraints in terms of a set of n_1 points near the boundary of object to be detected are defined by $A=\{(x_i,y_i)\in\Omega,\ 1\le i\le n_1\}\subset\Omega$. The aim is to find an optimal contour $\Gamma\subset\Omega$ that best approaches the points from the set A while detecting the desire object in an image.

Recently Gout et al. [18] proposed a model based on geodesic active contours for solving this problem. Their model uses image gradient information $|\nabla z|$, to stop the contour evolution. If the given image z is very noisy, then the isotropic smoothing Gaussian has to be used, which will smooth the edges in an undesirable manner. While this model can detect objects correctly for many examples, we found that it is sensitive to parameter choice and hence it can fail to work for some images. Here to increase robustness, we modify their model by combining it with the idea from Chan-Vese model [14], which helps in segmenting noisy images without an isotropic smoothing Gaussian and also helps to segment images with fuzzy boundaries, as verified later.

This paper is organized in the following way. Section 2 contains a review of the ex-