COMPUTER METHODS AND PROGRAMS IN BIOMEDICINE 84 (2006) 114–123

journal homepage: www.intl.elsevierhealth.com/journals/cmpb

Segmentation of kidney from ultrasound B-mode images with texture-based classification

*Chia-Hsiang Wu, Yung-Nien Sun**

Department of Computer Science and Information Engineering, National Cheng Kung University, Tainan 701, Taiwan, ROC

ARTICLE INFO

Article history:
Received 2 May 2006
Received in revised form
18 September 2006
Accepted 18 September 2006

Keywords:
Boundary extraction
Texture features
Classification
Dynamic programming
Ultrasound images

ABSTRACT

The segmentation of anatomical structures from sonograms can help physicians evaluate organ morphology and realize quantitative measurement. It is an important but difficult issue in medical image analysis. In this paper, we propose a new method based on Laws' microtexture energies and maximum a posteriori (MAP) estimation to construct a probabilistic deformable model for kidney segmentation. First, using texture image features and MAP estimation, we classify each image pixel as inside or outside the boundary. Then, we design a deformable model to locate the actual boundary and maintain the smooth nature of the organ. Using gradient information subject to a smoothness constraint, the optimal contour is obtained by the dynamic programming technique. Experiments on different datasets are described. We find this method to be an effective approach.

1. Introduction

Many applications in medical imaging rely on a segmentation process to define object contours. Tracing the contours in medical images allows the computation of clinical measures and important quantitative interpretation. Numerous methods have been developed to segment anatomical structures and delineate object contours in various kinds of biomedical images, including MR [1–5], CT [6], scintigram [7], DNA [8], biopsy [9], histopathological [10], X-ray [11], and ultrasound images. The non-invasive and real-time characteristics of ultrasound have enabled its wide use in hospitals, and even the Internet [12]. However, among all medical imaging modalities, segmentation from ultrasound images is one of the most challenging tasks, because ultrasound images are characterized by weak edge information, and it is difficult to locate an object's contour accurately within a fuzzy ultrasound image.

Object contour definition from ultrasound images can be accomplished in a number of ways. Manual contour definition is a popular but time-consuming process and suffers from a very low degree of reproducibility [13]. Some methods have proposed to use an image's gray level information to identify the object borders [14]. However, it is difficult to automatically detect the object by using gray level information only. Snake-based deformable models are better solutions for image segmentation and various applications have been found for medical image analysis [15]. A deformable model typically consists of a geometric representation of the target and a set of energy functions that control the evolution of a contour model. Because the image segmentation problem is formulated as an energy minimization problem in deformable models, the improvement often focuses on initialization, energy definitions, and optimization.

Texture features, which represent the variation (or pattern) in intensity of a particular region of an image, are capable of capturing soft-tissue characteristics appearing in images [16]; therefore, they have been proven to be useful in medical image segmentation [17,18] and analysis [19–23]. Texture fea-

* *Corresponding author*. Tel.: +886 6 2757575x62526; fax: +886 6 2747076.
E-mail address: ynsun@mail.ncku.edu.tw (Y.-N. Sun).
0169-2607/$ – see front matter
doi:10.1016/j.cmpb.2006.09.009

tures provide important and useful clues for the identification of organs and tissue, but with additional computational costs, especially when multiple features are needed. As mentioned, weak edge information is a serious problem in ultrasound image segmentation. This is also the reason why snake-based deformable models do not work effectively because of the lack of a strong intensity gradient. Nevertheless, edges are usually the interfaces between different tissue types in ultrasound images, so texture features should be a more reliable factor in detecting edges. Thus, the proposed algorithm combines a deformable model and texture classification for kidney segmentation, and this approach does help to alleviate the weak edge problem in our experiments.

Ultrasound imaging has been widely applied to various kinds of examinations and treatments. In this research, the focus is to segment the kidney contour from a B-mode ultrasound image which is used to assist the evaluation and diagnosis of acute pyelonephritis. For children, acute pyelonephritis is a serious disease that may result in irreversible renal scarring [32], and it can also occur in adults, especially adult women [33]. If left untreated or unresolved over a period of months or years, acute pyelonephritis will lead to scarring and the possible loss of kidney function. The sequelae of pyelonephritic scarring include but are not limited to hyposthenuria, proteinuria, and hypertension. For the diagnosis of renal diseases, kidney contour information is useful for physicians to evaluate the diseased kidney and is also an important feature used in the data fusion from different image modalities. In this study, we design a deformable model with texture-based classification to locate kidney contours. We use texture features and MAP estimation to classify pixels. A deformable model is used to locate the object based on this classification. This model is then optimized by dynamic programming along with a smoothness constraint. Because kidney ultrasound images are usually contaminated with noises and sometimes with weak edges that make contour detection a difficult task, our idea is to combine the deformable model with texture classification to make the segmentation algorithm of kidney ultrasound more reliable. In fact, most of the deformable models rely only on minimizing a cost function defined by a weighted sum of conventional energy terms, whereas the proposed deformable model adopts Laws' texture energy measures representing kidney texture in an ultrasound image and an ellipse model approximating the kidney shape in the model initialization.

This paper is organized as follows. The overview of the proposed model is described in Section 2. Section 3 describes the model initialization. Section 4 details the approaches for pixel classification. The procedure for optimal contour finding is presented in Section 5. The experimental results and relevant discussion are given in Section 6. Section 7 contains our conclusions and plans for future development.

2. Overview

In order to overcome the difficulties of segmentation in ultrasound images, we design a generic model capable of capturing the anatomical characteristics of sonograms. The proposed model consists of two stages as described in Fig. 1.

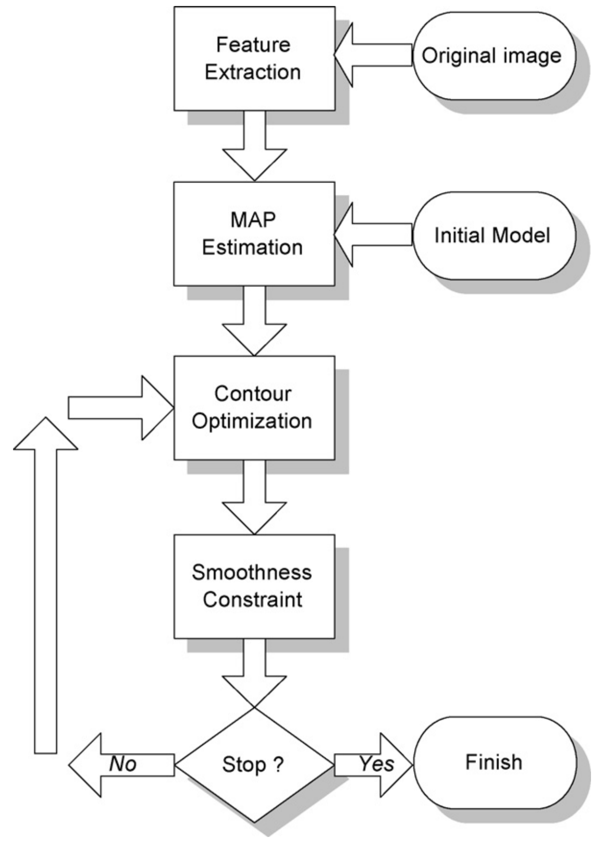

Fig. 1 – Flowchart of the proposed method.

In the first stage, pixel classification is carried out by MAP estimation and texture features. The MAP estimation classifies image pixels into two classes, inside or outside the organ. In the second stage, the contour is obtained by a dynamic programming approach subject to a smoothness constraint. The deformation process is stopped if the resultant contour is kept unchanged from the last iteration.

3. Model initialization

The aim of model initialization is to provide a general approximation of the boundary location. The shape approximation selected here is an ellipse, since the shape of a kidney in a two-dimensional image is close to an ellipse. It is simple enough to be generated by using only four parameters x_0, y_0, a, and b by:

$$\frac{(x-x_0)^2}{a^2}+\frac{(y-y_0)^2}{b^2}=1 \quad (1)$$

where x_0 and y_0 represent the ellipse's center, and a, b are the half lengths of the long and short axes, respectively.

For better performance on matching the geometrical model to the given data on images, a fifth parameter θ is used for rotating the standard model in (1) about the model's centroid. Supposing that the four apex points of the ellipse are given, an initial model is represented by a parametric ellipse $e(t) =$