A Novel Method to Automatically Segment the Pelvic Floor Muscles in MR Images

Zhen Ma, João Manuel R. S. Tavares & Renato Natal Jorge
Faculty of Engineering, University of Porto, Porto, Portugal

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1 INTRODUCATION

The high prevalence of pelvic floor disorders has raised increasing attentions on the study of pelvic cavity [1]. Thanks to the advances of imaging techniques doctors can obtain high resolution images of the pelvic cavity which considerably enhanced the accuracy of diagnosis. The usual first step of medical image processing is to segment the organs and structures presented in the image slices, among which a correct segmentation of pelvic floor muscles is crucial for the later 3D reconstruction and analysis. However, along with the changes of positions and viewpoints the appearances of pelvic floor muscles have large shape variations. Meanwhile these muscles are usually surrounded by fiber structures and are highly textured so that they have a poor resolution in the images acquired. All these factors make a correct segmentation hard to perform even when done manually by a well qualified technician. Given the considerations of improving the time efficiency, robustness and decreasing the intra-observer or inter-observer errors, an effective computer-aided algorithm is urgently needed. In this paper, magnetic resonance imaging (MRI) is chosen as the imaging modality of study, because MR images have better views of soft tissues when compared with other non-invasive modalities, and a novel method to automatically segment the pelvic muscles is proposed.

2 DEFORMABLE MODELS

Deformable models are popular techniques in the image segmentation area because they are flexible to be modified in order to meet the requirements of a concrete task and can easily incorporate a priori knowledge. As summarized in [2], the two types of deformable models: parametric deformable models and geometric models, have been intensively investigated in the recent few decades. Parametric deformable models have high computational efficiency and can easily incorporate a priori knowledge; Geometric deformable models have the advantage of naturally handling topological changes.

3 METHOD

Preliminary applications of deformable models to segment the organs and structures in MR images of pelvic cavity have been discussed in [2], from which the obstacles for a successful segmentation can be summarized as two main aspects. The first one is that the top part of the levator ani in a MR image only consists of few pixels and therefore the contour stops before it reaches to the correct position; The incompleteness is due to the smoothing effects of the speed function and lack of strong attraction forces that can lead the contour to the right position. The second aspect is that the partial volume effects diffuse the boundary of levator ani and obturator internus because muscles are usually surrounded by fiber tissues or fats which make a clear definition of their boundary hard to perform.

One of the advantages of designing a new algorithm to be used for a medical application is that the available priori knowledge can be considered to improve its performance. Given the main function of the pelvic floor is to support the organs in the pelvic cavity, locations of related organs and their pressures to pelvic floor muscles have direct influences with the appearances of muscles. Moreover, considering that under most cases the related organs, such as rectum and bladder, can be successfully automatically segmented, and that their biomechanical behavior and biological relationship with the pelvic floor muscles, we then are able to consider these important cues on organs shape and location in the design of a new method to automatically segment pelvic floor muscles in MR images.

To handle the first aspect of obstacles, the contrast of image intensity is used as a main part of external energy. This external force has been used in Chan-Vese's model which is a popular deformable model that does not rely on gradient magnitude and has less dependence on initial location [3]. However, the complex background in medical images requires careful utilization of this model. In our case, initial shape and location of the moving contour are defined based on the positions of the organs that have already been segmented. A region is formed to constrain the computational area so that the homogeneity of image intensity inside the moving contour and intensity contrast can be used as the external force. Under these premises, a shape influence field is formed basing on the boundary of segmented organs to identify an accurate boundary. Analysis on the necessity of inserting a shape influence field is to be made.

The boundary confusion due to the partial volume effects is solved in the proposed method by the shape influence fields and the constrained computational area. The regularity of the contour is guaranteed by the internal forces and the distances between the upper boundary and the lower boundary. A post-processing algorithm is made concerning the smoothness of the final contour. To test the effectiveness of the proposed methodology several experiments are going to be presented. Discussions on the effects of initial conditions and the influences of different choices of internal forces will also be presented.

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