Paraspinal Muscle Segmentation in CT Images using a Single Atlas

Submitted to Faculty Research Day 2015 at University of North Georgia

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Abstract

Paraspinal muscles support spine and are the source of movement force. The cross section area (CSA) size, shape, density and volume are affected by many factors, such as surgery, age, health condition, exercise, and low back pain. Manual measurements of paraspinal muscle CSA and volume in CT images is inaccurate and time consuming.

Minimally invasive spine surgery (MISS) was introduced to provide less muscle tissue injury, less postoperative pain and earlier mobilization than traditional open back surgery. Physicians can use the computed tomography (CT) images to estimate volume of muscles surrounding the spine before and after the MISS operation. The thickness of reconstruction of CT slices is determined during scanning. If the size of muscle region in CT images can be measured, the volumetric estimation of muscle tissues surrounding the spine can be obtained by calculating the sum of the products of the slice thickness and the muscle region size of each CT slice. Hence, segmenting the muscle region in CT images becomes the key step in the procedure of estimating paraspinal muscle volume. The results can be used to evaluate tissue injury and postoperative back muscle atrophy of MISS patients. The results can also help to optimize patient rehabilitation management and monitor its effectiveness.

Automatic paraspinal muscle segmentation in CT images is challenging because the variability of anatomical muscle shape is large among images, and the range of Hounsfield units of muscle overlaps with that of other nearby soft tissues. There is no clearly defined relationship between interested muscle regions and voxel intensities. To make the task even more difficult, parts of the boundaries of the interested muscle groups are very close to those of the spine and other organs, making region growing-based algorithms ineffective.

This work proposes an atlas-based algorithm to segment paraspinal muscle regions in CT images. It consists of three main steps: (1) global image alignment; (2) local contour optimization; and (3) local deformation. In step 1, the affine transformation T from spine contours in atlas and target is estimated after points in the two contours are registered. During step 2, to overcome anatomical region shape and size variations, especially the changes of relative spatial relation of spine and paraspinal muscles among the reference atlas and target images, intensity difference list (IDI) along the normal line of a contour point p is used to optimize the contour of region of interest in the target images. In step 3, a GVF snake deformation algorithm refines the boundary contour of paraspinal muscles. Intensity Space Map (ISM) is used in this step to generate a muscle shape prior.

Experimental results show that the atlas-based algorithm combined with local optimization and intensity space map effectively segment paraspinal muscle regions. A single atlas is needed to processing a sequence images, making it efficient to process a sequence of CT images. It provides

a solid foundation for muscle volume estimation for physicians to evaluate muscle damage due to spine surgery and monitor the progress of patient recovery.
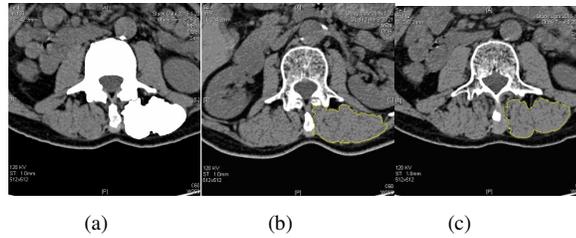
Some experimental results

Fig. 1. (a) Atlas: image number 63, Slice thickness is 1.0mm. (b) Segmentation result: target image number 22. (c) Segmentation result: target image number 72.