Multi atlas segmentation of rat leg muscles

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Introduction

Accurate and reliable muscle size quantification is essential to investigate muscle function related to exercise adaptation, ageing, neuromuscular pathologies… Currently, MRI muscle volume quantification is the gold standard; however this technique requires a tedious and very time-consuming manual delineation of the muscle structures of interest. A strategy commonly used to ease the post processing is the reduction of the number of slices to manually segment associated with geometrical assumption to interpolate missing data [1].

Little work has been done so far on automated segmentation of muscle images especially when only specific muscles have to be distinguished. In this work we propose a fully-automated method to segment region of interest on limb muscle images. We evaluated this method for the segmentation of gastrocnemius and plantaris muscles on rat leg images.

Method

Our method is based on multi-atlas segmentation. An image is segmented by a set of atlases; the segmentations produced are then combined by a voting procedure. To further enhance the process, we propose to generate artificial atlases by shifting the atlases along Z before the non-rigid registration and adding their segmentation in the vote.

The background is first removed by segmenting images in two classes using FAST [2]. The biggest connected component of the class of highest intensity is kept as the leg mask.

Each atlas is then **linearly realigned** on the subject image using FLIRT [3] and **non-linearly registered** using the method described in [4]. The segmentations given by each atlas are then combined using the **weighted voting** procedure described in [5]

The "cylindrical" shape of the leg make the rigid registration unreliable along Z, we propose to add artificial atlases by shifting the atlas of +/- one slice along Z before of the non rigid registration. The number of atlas participating in the vote is *de facto* tripled without the need to manually segment them.

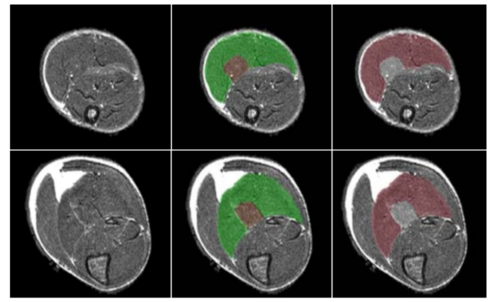

Figure 1*: Rat leg transverse images (left column), the manual segmentation (middle column) and the automatic segmentation (right column) on two different slices.*

Results and discussion

The method has been evaluated for the gastrocnemius and plantaris segmentation of the rat leg (2 months old wistar Han rat) (see Fig. 1). The method has been tested on a set of 12 rat leg images from the ankle to the knee, (Rare sequence, TR=2000ms TE=16ms, FOV=30x32mm, 256x192 pixel, 18 slices). The images of five other rats (same acquisition parameters) are used has atlases. The method has been tested using 1, 3 and 5 atlases, with and without the Z-shifting step. Segmentation quality is measured by reporting the relative overlap (RO) of three structures: the gastrocnemius, the plantaris and the two grouped together (see Fig. 2). The percentage error of the muscle volume measured with automated compared to manual segmentation is also reported in Table 1.

Table 1: Muscle volume error

	n atlas	Gastrocnemius %	Plantaris %	Gastroc + plant %
no shift	1	3.94 ± 2.93	7.18 ± 4.43	3.86 ± 3.04
	3	3.24 ± 2.29	5.42 ± 4.60	3.16 ± 2.07
	5	3.37 ± 2.28	5.54 ± 3.64	3.22 ± 2.17
shift	1	3.69 ± 2.46	7.18 ± 4.22	3.66 ± 2.62
	3	3.17 ± 2.38	5.74 ± 4.26	3.07 ± 1.94
	5	3.49 ± 1.94	5.76 ± 3.63	3.05 ± 2.12

Volume error is presented in percentage (mean ± sd) for each structures of interest using different numbers of atlas when the shift procedure along Z is used or not.

Looking at Fig. 2, one can first note that the standard, one atlas segmentation, gives good results on the three structures. Even the plantaris, for which contrast with surrounding structures is poor, has an RO of more than 0.7. One can also see that the Z-shifting procedure provides an important improvement. Roughly, RO obtained using Z-shift and 1 atlas are equivalent to RO obtained with 3 atlas and no Z-shift (similarly, Z-shift, 3 atlas ≈ no Z-shift, 5 atlas). The use of Z-shift can consequently be useful to reduce the number of atlas to manually segment to build a dataset.

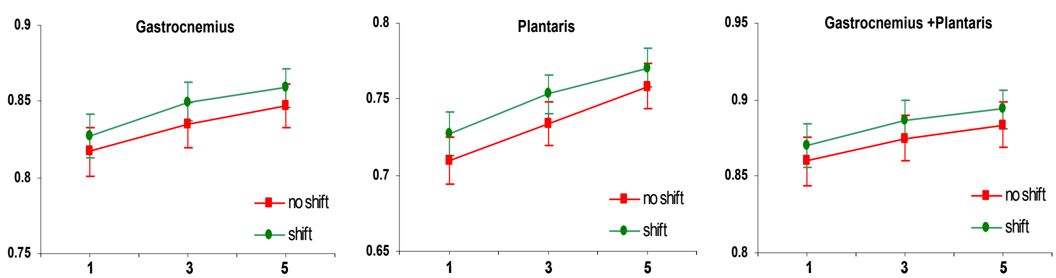

Figure 2*: relative overlap with standard error of the segmentation for the different structures using different numbers of atlas when the shift procedure is used or not.*

Table 1 shows that the volume error is relatively low, especially for gastrocnemius. Surprisingly, the benefit of the Z-shift procedure is not clearly visible when considering the relative volume error. However one can note that almost no improvement is obtained when 5 atlases are used instead of 3.

Conclusion

We proposed a method to automatically segment limb muscles which alleviate tedious manual work done so far to analyze MRI data. As this method is fully automated no intra- and inter-operator variability is introduce during the processing. The Z-shift procedure introduced in this work enable a further improvement which allows a very low number of atlases in the manual database.

Using this method, it is possible to increase the spatial resolution along Z, in other words to have a very accurate description of the whole muscles of interest.

References

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