AUTOMATED METHOD FOR TRACKING CHANGE IN MUSCLE FASCICLE LENGTH FOR ULTRASOUND IMAGES

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INTRODUCTION

Amongst the main factors that determine the functional properties of a muscle are muscle architecture, muscle strain and strain rate. During concentric contraction fascicle length shortens and pennation angle increases. Ultrasonography can be used to directly visualize in vivo skeletal muscle. Real time images of muscles can be obtained using B-mode ultrasound during any dynamic activity. To date there are no reliable methods to automatically track the fascicle orientations or strain from ultrasound images. The purpose of this study was to find an automated method to track change in length of muscle fascicles.

METHODS AND PROCEDURES

Ultrasound images (Echoblaster, Telemed; LT) were obtained from distal part of vastus lateralis close to knee from left leg of a subject during cycling. Images were extracted per frame from the video sequence (fig.1).Each image was segmented to obtain muscle fascicles. Methods used to find length change of fascicles are described below.

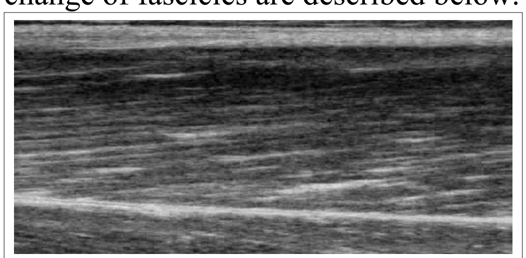


Figure 1 Image obtained from ultrasound

Multiscale vessel enhancement filtering was used to enhance tube like structure of muscle fascicles [Frangi et al].The image was first convolved with Gaussian of a particular scale (which is same as standard deviation of Gauss Function) and then a Hessian matrix was obtained at each pixel. Eigen values of the Hessian matrix were used to define vesselness function (*Vo*(s)) as follows:

$$V_o(s) = \begin{cases} 0 & if\lambda_2 > o \\ \exp\left(-\frac{R_\beta^2}{2\beta^2}\right)\left(1-\exp\left(\frac{-S}{2c^2}\right)\right) & \end{cases}$$

where λ_1 and λ_2 are Eigen values of Hessian such that$|\lambda_1|>|\lambda_2|$, $R_\beta=|\lambda_1|/|\lambda_2|$ is measure of line like structure and S= Frobenius norm of Hessian is low in background. β and c are arbitrary contants depending on image and in this case both are 0.5.

The whole process was repeated at each pixel for different scales and then the one giving maximum vesselness value was used. The image after vessel enhancement is shown in fig.2.

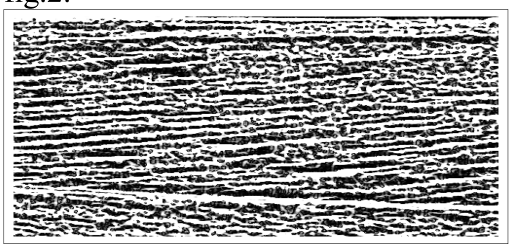


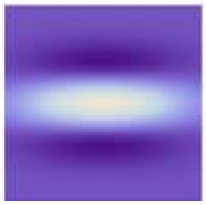
Figure 2 Image after vessel enhancement filtering

Mean orientation of fascicles was obtained by two methods.

1. Radon Transform (Khouzani, Zadeh) was used to obtain to obtain mean orientation of fascicles.
2. Muscle fascicle orientation at each pixel was by using anisotropic wavelet analysis. The image was convolved with anisotropic wavelets at different orientations to obtain local orientations at each pixel. Eq. Of wavelet used

$$\omega = \frac{\exp(-\frac{x_s^2}{2}+\frac{1}{90}(-x^2-y^2))Cos(2\Pi v x_s)}{2\Pi}$$

$$x_s = \frac{\Pi(xCos\theta - ySin\theta)}{2f}$$



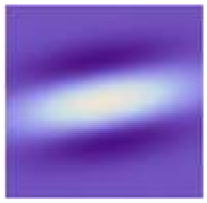


Figure 2 for θ=0^o **Figure 3** for θ=10^o

Fascicle directions were found by tracking through the vector field found from method 2...

RESULTS

Fig. 2 was convolved with anisotropic wavelets to obtain local orientation at each pixel. The computed fascicle trajectories (shown in red dots) matched those visible by eye, and followed local curvature that occurred naturally within each fascicle (fig. 5 and fig. 6).

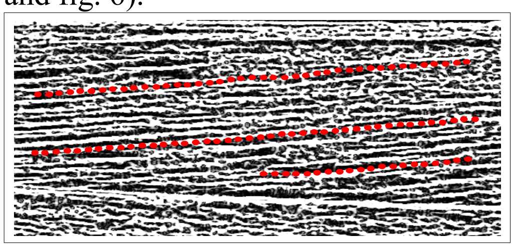


Figure 5 Orientations obtained after convolving fig4 with wavelets

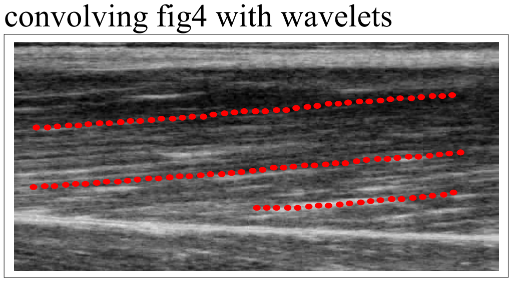


Figure 6 Orientations shown on original ultrasound image

DISCUSSION

The results obtained depend on the factors *f* and *v* in the wavelet expression. Results are best at some optimal value (f = 6.5 and v =0.3) in a sequence so seems to be determined by muscle structure and resolution of image).This is very effective method for automatic tracking of muscle fascicle length change. The methods will be validated by extracting orientation of parallel lines at some known angle or comparing to physical phantoms.

SUMMARY

Images of muscle obtained using ultrasonography were filtered using multiscale vessel enhancement filtering to enhance muscle fascicle structure. Orientation of the fascicles was obtained using both Radon Transform and anisotropic wavelet. Muscle fascicle strains can be quantified by this information tracked through the vector field of their orientations.

REFERENCES

A.F. Frangi, W.J. Niessen, K.L. Vincken, M.A. Viergever (1998). Multiscale vessel enhancement filtering. In Medical Image Computing and Computer-Assisted Intervention - MICCAI'98, W.M. Wells, A. Colchester and S.L. Delp (Eds.), Lec.notes in Comp Sc1496,30-137.

K.J Khouzani and H.S Zadeh, (2005) Radon Transform Orientation estimation for rotation invariant texture analysis.