AUTOMATED MEASUREMENT OF MUSCLE ARCHITECTURE FROM ULTRASOUND IMAGES

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INTRODUCTION
Ultrasound can be used to measure muscle architecture in vivo [1]. Unfortunately, this can be time consuming when dealing with dynamic muscle contractions which has led to the development of automated techniques for architecture measurement [2]. Many algorithms track a limited number of points or are difficult to implement for different muscles. Identifying multiple fascicles in ultrasound images allows for assessment of average pennation angle in each frame and does not constrain the algorithm to following one specific object through the entire movement. The purpose of this study is to describe an algorithm that is based on object detection methods to measure average pennation angle and calculate average fascicle length in ultrasound images.

METHODS
The algorithm was implemented in MATLAB (The MathWorks Natick, USA) using the Image Processing Toolbox. A region of interest was defined by the user and for each frame that region of interest was converted from grayscale to black and white. Superficial and deep aponeuroses were located by calculating the sum of each pixel value in each row in an image. The row with the highest sum in the top half and bottom half of the image were identified as the superficial and deep aponeuroses. The distance between aponeuroses was defined as muscle thickness.

After aponeurosis detection, the original grayscale image was further cropped to remove the aponeuroses from the image. The image was converted to black and white but this time the contrast of the image could be manually adjusted to account for varying gain settings on the ultrasound machine. This adjustment allowed the user to produce an ideal image for fascicle detection.

An object detection approach was used to detect fascicles within the ultrasound frames. Fascicles were identified as objects that had fascicle-like attributes (correct orientation, above a minimum size, and line-like quality). The “regionprops” function in MATLAB was used to determine the pennation angle of the fascicle with respect to the horizontal. The average of all the measured pennation angles was assumed to be the pennation angle for the image. Using this average pennation angle and the muscle thickness, average fascicle length was calculated [3].

To validate this algorithm two methods were used, a computer generated video and a physical model. A video was created with “fascicles” that rotated through 20°. A random amount of rotation (0 – 0.5°) was added to each fascicle for each frame to represent the uneven movement seen in ultrasound. Extraneous objects were added to the video to represent artifacts seen in ultrasound videos. Superficial and deep aponeuroses were also added. Noise was added to the image by blurring the entire image (Figure 1).

In some of the images not all the “fascicles” were detected by the algorithm which is typical for in vivo ultrasound. The average angle of the “fascicles” detected by the algorithm was compared to the known average.
In the physical model, rubber bands were placed along a string which moved the bands in the same manner as fascicles. Rubber bands were chosen due to their similar appearance on ultrasound when compared to muscle fascicles (Figure 2).

The movement of the bands was captured using a video camera and PC-based ultrasound system (Echoblaster 128, Telemed, Lithuania) simultaneously. Pennation angles were compared between the algorithm and digitization of the video.

RESULTS AND DISCUSSION
The results of the computer generated video tracking indicated no differences between the known and measured angles (p < 0.05). Results of the physical tracking model indicated the algorithm produced results that were within the results determined using manual digitization for both length and angle (Figure 3).

CONCLUSIONS
The results indicate that the algorithm is accurate for measuring the orientation and length of fascicle-like structures automatically. The validation methods strived to mimic in vivo images by adding noise, random motion, or similar image quality. Automated imaging methods for ultrasound are important for assessing movement of muscles. Many algorithms focus on a single point [4, 5] which can be difficult when points move in and out of the imaging plane.

Limitations did exist in this study. All detected objects have equal weight in the average pennation angle calculation. Non-fascicle objects can be ignored using selection criteria to identify only the most likely objects as fascicles. Another limitation is the ability to generalize these findings to in vivo images. The validation methods were selected to mimic in vivo images but more research is needed to fully accept this algorithm for automatically measuring fascicles from in vivo images.

REFERENCES