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Improving automated tracking of ultrasound muscle images by incorporating physiological variables

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Abstract— **Tracking the movement of the muscle-tendon junction is important for quantifying how muscles and tendons drive human movement. However, this remains an arduous task. Deep learning methods have recently shown promise for tracking, but there are limits to how well these networks generalize to novels subjects and tasks. Muscle-tendon junction movement is dependent upon muscle activation and joint-level motion. Therefore, we sought to determine if supplementing current networks with ankle angle and electromyographical (EMG) data would improve tracking. We observed a 20% increase in tracking accuracy for novel subjects when we incorporated EMG and ankle angle data into a current deep-learning network. Our results indicate that extending current methods to include data beyond the ultrasound image can significantly improve their accuracy.**

I. Introduction

Ultrasound imaging enables real-time quantification of muscle and tendon motions, an important tool for advancing our understanding of how muscles and tendons contribute to human movement. Unfortunately, processing ultrasound images remains time-intensive, creating a barrier to adopting this important tool. Deep learning methods have shown promise for fully automating this task [1, 2], but do not yet generalize well across novel subjects and tasks [1]. If deep learning methods are going to be widely implemented, they need to generalize. Many experimental paradigms that use ultrasound collect additional data such as joint motions and electromyograms (EMGs). Muscle and tendon motion is related to joint-level movement and the activation within the muscle. Extending existing deep learning methods with this non-image data may improve tracking results. Therefore, we sought to determine if adding ankle angle and EMG data to current networks would improve tracking accuracy.

II. Methods

The base network that we used is the VGG-Attention-3 network, which is one of the current networks used to track the muscle-tendon junction [2]. We extended this network to create two novel networks. The first had a fully connected layer for the ankle angle data, while the second had fully connected layers for both ankle angle and EMG data. The new layers processed ankle angle and EMG data from the current frame and the 4 frames before and after the current frame. Each network was trained on data from two subjects, with 30% of the data used for training and 70% for testing. Each network was then evaluated on 8 novel subjects. Network performance was assessed by quantifying the root mean squared error (RMSE).

B-mode ultrasound was used to track the distal medial gastrocnemius muscle-tendon junction as the subject's ankle was moved through a 20-degree sinusoidal motion at 0.5 Hz. Small pseudorandom perturbations were applied to the ankle to induce a random motion between frames. During the experiment, ankle angle and EMG recordings from the medial and lateral gastrocnemius and soleus were made. The mean EMG from the three muscles was used as the input to the network along with ankle angle and each frame from the ultrasound movie.

III. Results

Incorporating both EMG and ankle angle reduced the error when evaluating novel subjects. The base network had an RMSE of 3.8 ± 0.2 mm for novel subjects, whereas our new network that incorporated both ankle angle and EMG data had an RMSE of 3.1 ± 0.3 mm, a reduction of 20% ($p<0.001$). Surprisingly, incorporating only ankle angle data did not significantly decrease the RMSE (3.8 ± 0.4 mm, $p = 0.78$).

IV. Discussion & Conclusion

This work aimed to determine if adding physiological data to current deep learning methods improved the generalizability. By adding ankle angle and EMG data, we significantly improved tracking accuracy on novel subjects. Improving the generalization of automated ultrasound tracking will enable broader investigation into how muscles and tendons drive human movement.

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