Fingertip Motion Tracking with Ultrasound Analysis of Flexor Tendons

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Introduction: During a surgical procedure, it is often helpful to evaluate the surgeon's technical abilities by observing the movements of their hands, allowing experts to identify techniques that improve an operation's chances of success. Computer vision algorithms have been used to track the positions of the hands but become less effective when encountering poor lighting or obstructions [1]. We propose an alternative way of determining the positions of the fingers by monitoring the tendons that control their movement. The flexor digitorum tendons, located in the wrist, cause the index, middle, ring, and small fingers to flex. Using ultrasound imaging, the muscles attached to these tendons can be seen contracting when the fingers are curled, potentially allowing a computer program to calculate the position of the finger based on the width of the muscle at any point in time. By placing an ultrasound device on a surgeon's wrist, it would be possible to track the fingers with no dependence on lighting or obstruction conditions. Our group is taking the first step to developing this kind of device by simultaneously tracking the width of the muscle and the angle of the index finger and determining the relation between the two.

Materials and Methods: Imaging of the flexor tendons was accomplished using a Terason t3000 ultrasound system, which provided a real-time video feed from an ultrasound transducer imaging the wrist. The motion of the index finger was tracked to create a ground truth by means of three LEDs attached to the index finger. The LEDs were placed at the center of each phalanx, and their positions were tracked using a laptop webcam. OpenCV was used to capture video frames from both the Terason and the webcam, creating two concurrent video recordings in which the index finger was repeatedly flexed and extended. The videos were recorded for 89 frames. For each ultrasound frame, the flexor tendon was identified, and the width of the muscle was recorded. In each frame of the webcam video, the position of each LED was determined, and the angle between them was calculated.

Results and Discussion: Figure 1 shows the observed relationship between the width of the muscle and the angle of the finger. A negative correlation can be seen. Applying linear regression results in a slope of -0.0399 and an R^2 value of 0.6031. The scatter plot also appears to suggest a significant lag between the movement of the tendon and the movement of the finger. This is likely due to the Terason requiring a large processing time for displaying ultrasound images, while the laptop webcam can capture and display images much more quickly.

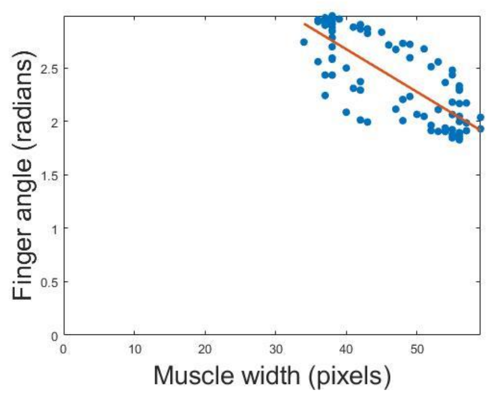

Figure 1. Relationship between muscle width and finger angle (n=98). Slope = -0.0399. R^2 = 0.6031

Conclusions: These results suggest that it may be possible to determine the position of a finger using only ultrasound imaging of the muscles in the wrist. We are encouraged to develop a portable ultrasound device to be worn on a surgeon's wrist to provide a non-invasive way of determining the movements of the surgeon's fingers. We are currently developing machine learning methods to more accurately predict finger position from ultrasound image sequences.

References:

[1] Zhang, Michael et al. "Using Computer Vision to Automate Hand Detection and Tracking of Surgeon Movements in Videos of Open Surgery." *AMIA ... Annual Symposium proceedings. AMIA Symposium* vol. 2020 1373-1382. 25 Jan. 2021