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Fasciculation Detection Using Ultrasound Images for Early Diagnosis of ALS

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1. Introduction

Amyotrophic lateral sclerosis (ALS) ALS, also known as Lou Gehrig's disease, is a devastating neurodegenerative condition that affects motor neurons in the cerebral cortex, brainstem, and spinal cord. [1]

The early symptoms of ALS are not obvious, making early accurate diagnosis extremely difficult. ALS is a severe disease that progresses rapidly. If the disease is detected late, it not only limits the available treatment options but also narrows the range of life planning choices. The existing method of diagnosis is needle electromyography. However, needle electromyography is invasive and requires multiple tests on multiple muscles [3]. In comparison, ultrasonography has the advantage of being painless and non-invasive.

One of the important bases for ALS diagnosis is fasciculation. Fasciculation is a random spontaneous contraction of a group of muscle fibers and is one of the most common symptoms in ALS patients [4]. Recent studies have shown that although fasciculations can also occur in non-ALS patients, they are more frequent in ALS patients and are widely distributed throughout the muscles of the body rather than being localized [5]. In the preview study, one of the characteristics of fasciculation we observe is that negative rotation often occurs after positive rotation.. In addition, there is a mixture of positive and negative rotations in one frame [2].

Further research has indicated that detecting fasciculations using ultrasound imaging has the potential to alleviate some of the burden on clinicians in diagnosing ALS [3]. In ultrasound images of the cross-sectional view of muscle fibers, the movement of fasciculations is characterized by rotational motion. In this study, based on previous research, we further analyzed the rotational motion in ultrasound images of ALS patients, focusing on the goal of enabling automated diagnosis using ultrasound images in the future.

2. Method

Ultrasound videos taken from the direction of cutting muscle fibers were analyzed using the optical flow method. Optical flow is a vector that represents the movement of an object between frames in a motion image. There are various methods to calculate optical flow, but in this study, we adopted the Farneback method [6] as used in previous research. The Farneback method is a dense optical flow algorithm that calculates the motion of each pixel between two frames in a video.

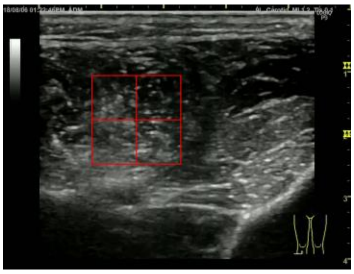

Fig.1 Screenshot of ultrasound image of ALS patient used for analysis.

This allows us to represent the movement of each pixel between frames as v_x and v_y.

Figure 1 is a screenshot of the ultrasound image of the muscle fibers of an ALS patient that we used. The optical flow was calculated for each frame in a 23 frames per second (fps) video over 20 seconds. In Fig. 1, the entire area circled by the red frame is where multiple instances of fasciculation occurred. The fasciculation area was manually identified by visual inspection, and the large red frame was evenly divided into four regions, each of which was analyzed for rotational motion. Subsequently, the sum of the rotational values and the corresponding angular velocity ω for the four smaller red frame regions were calculated. We also analyzed the overall rotational motion and angular velocity within the undivided large red frame area for comparison.

3. Results

The obtained optical flows v_x and v_y are processed. In this case, Green's theorem is used to analyze the rotational component. Green's theorem is expressed by the following equation:

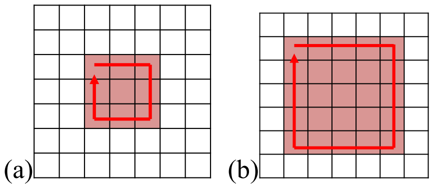

Fig.2 Images of OF line integral computed by Green's theorem. (a) Distance 1 from the center pixel, (b) Distance 2 from the center pixel.

$$\oint_C (P\mathrm{d}x + Q\mathrm{d}y) = \iint_D \left(\frac{\partial Q}{\partial x} - \frac{\partial P}{\partial y}\right) \mathrm{d}x\mathrm{d}y\,.\ (1)$$

Considering a region D bounded by a closed curve C, the line integral on the curve C coincides with the double integral on the region D. In this case, if $\boldsymbol{F} = (P, Q)$, the non-integral function on the right-hand side is represented by the rotation equation $\mathrm{rot}(\boldsymbol{F})$. Therefore, the integral on a plane curve is the sum of rotational components in the region. Using Green's theorem, the line integrals of the optical flow on the line can be obtained by adding up the rot of each pixel in the range of the line to be obtained (**Fig. 2**).

In each small red box in Fig. 1, the line integral of the optical flow on the closed curve was calculated based on the maximum distance from the center. The calculated line integrals of the optical flow are shown in **Fig. 3**. The vertical axis represents the rotation intensity, and the horizontal axis represents time (frames). The + component indicates clockwise rotation, while the - component indicates counterclockwise rotation. Figure 3 shows the results for the four small red box regions. **Figure 4(a)** illustrates the changes in angular velocity calculated by summing the rotational values of the small red boxes, while **Fig. 4(b)** shows the angular velocity calculated directly for the large red box.

4. Discussion

Looking at Fig. 3, we first observe that t there are intense positive and negative rotations in all four

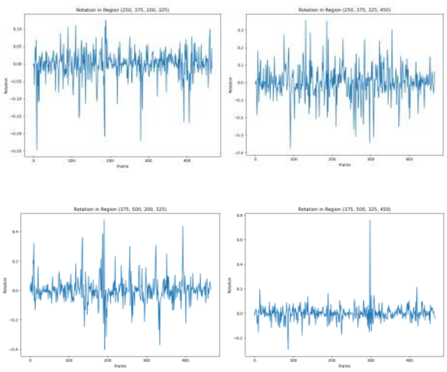

Fig.3 OF line integrals in time of four small red boxes.

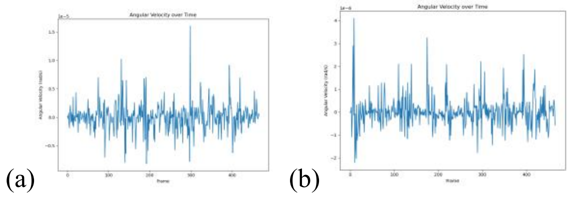

Fig.4 Angular velocity. (a) The angular velocity of the sum of rotational values in the small red boxes., (b) The angular velocity in the large red box.

small red box regions, with (Region in (375, 500, 325, 450)) showing a significant peak in rotation (approximately 0.8). This sharp change may be due to this region being closer to the center of fasciculation rotation, indicating that fasciculation phenomena are often accompanied by larger local rotational movements.

Next, comparing Figs. 4(a) and 4(b), we can clearly see that the rotational motion in Fig. 4(a) is more intense than in Fig. 4(b).

5. Conclusion and Future Work

We analyzed the optical flow of ultrasound images and further investigated the characteristics of fasciculation motion based on previous research. When the rotation threshold exceeds 0.4 and the angular velocity reaches a value of 1e-5, it can be determined that fasciculation is present. Subsequently, the candidate areas for fasciculation are identified within the overall range.

In future research, we will continue our efforts to achieve the automation of identifying the center of rotation.

References

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