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Analysis of Specific Rotational Movements of Muscle Fibers by Ultrasound Imaging

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1. Introduction

Amyotrophic lateral sclerosis (ALS) is a disease that causes muscle atrophy and weakness due to the degeneration of the nervous system, eventually leading to difficulty in moving on one's own. The symptoms are not well recognized in the early stage of the disease and are often felt only after the disease has progressed. The existing method of diagnosis is needle electromyography. However, needle electromyography is invasive and requires multiple tests on multiple muscles [1]. In comparison, ultrasonography has the advantage of being non-invasive.

One of the most important bases for making a diagnosis of ALS is fasciculation. Fasciculation is a random spontaneous contraction of a group of muscle fibers and is the most abundant symptom of ALS [2]. Recent studies have shown that although fasciculations can occur in non-ALS patients, they are more frequent in ALS patients than in non-ALS patients, and are widely distributed throughout the muscles of the body rather than locally [3]. Further research on the detection of fasciculation by ultrasound imaging has been reported to have the potential to alleviate some of the burden of ALS diagnosis for clinicians [1].

On ultrasound images in the direction of the cross-sectional view of muscle fibers, the movement of fasciculation is seen as rotational movement. In this study, we processed ultrasound images of ALS patients and analyzed the rotational motion for the purpose of future automated diagnosis using ultrasound images.

2. Method

Ultrasound videos taken from the direction of cutting muscle fibers are analyzed by optical flow. The optical flow is a vector representing the motion of an object between frames in a moving image. There are several methods to calculate the optical flow, such as the Lucas-Kanade method, which detects a feature point and calculates the movement of the feature point, but in this study, we use the method developed by Farneback [4]. Farneback method is a dense optical flow that calculates the motion between two frames for every pixel in the video.

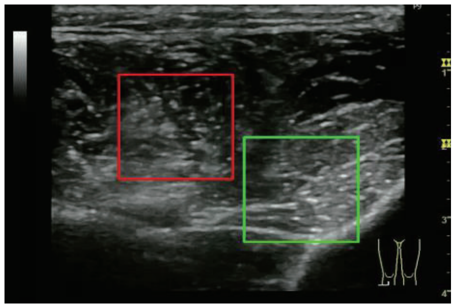


Fig.1 Screenshot of ultrasound image of ALS patient used for analysis.

This allows us to express the motion of each pixel between frames as v_x and v_y.

In this analysis, we used ultrasound images of the muscle fibers of an ALS patient. **Figure 1** is a screenshot of the ultrasound image we used. We calculated the optical flow for each frame of the video at 23 fps for 20 seconds, including this frame. In Fig. 1, the area circled by a red frame is the region where fasciculation occurred multiple times, and the area circled by a green frame is the region where the muscle fibers only moved in parallel without fasciculation. In the present study, the area of fasciculation was specified manually in advance, and the rotational motion was analyzed. In the same way, we also analyzed the motion in the range of parallel movement only, and used it 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:

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

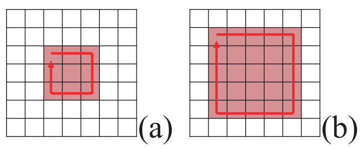
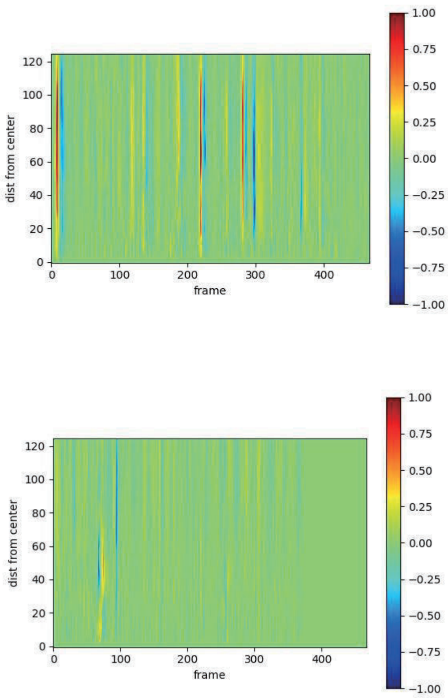


Fig.2 Images of OF line integral computed by Green's theorem. (a) Distance 1 from the center pixel, (b) Distance 2 from the center pixel.

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**). Within the red box in Fig.1, the line integral of the optical flow on the closed curve is obtained for each distance from the center. The line integrals of the optical flows are also obtained for the range of parallel shifts as a comparison.

The line integral of the calculated optical flow is shown in **Fig. 3**. The vertical axis is the distance from the center (pixels) and the horizontal axis is the time (frames). The color of the 2D map indicates the direction and the velocity of rotation, where the + component indicates clockwise rotation and the - component indicates counterclockwise rotation. (a) shows the areas where fasciculation occurs (red box in Fig.1), and Fig.3(b) shows the areas where fasciculation occurs only in parallel (green box in Fig.1). **Figure 4** shows the 2D map of Fig.3(a), cut at dist=30, 50, 70, and 90, to make it easier to understand the change of rotation components with time. The vertical and horizontal axes are the integrated values and frames, respectively.



(a)

(b)

Fig.3 Line integrals of optical flow. (a) The range where fasciculation occurs, (b) The range where only parallel movement occurs.

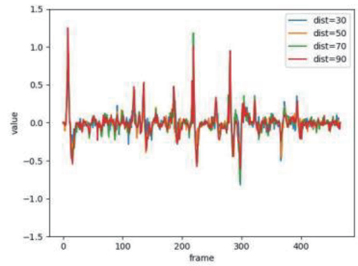


Fig.4 OF line integrals in time at dist=30, 50, 70, 90

4. Discussion

Looking at Fig. 3(a) and Fig. 4, we see that, first of all, negative rotation often occurs after positive rotation. In other words, it is considered that the negative rotation occurs to return to the original position after the positive rotation. In addition, there is a mixture of positive and negative rotations in one frame. This indicates that the inner and outer diameters of the muscle fibers may have different movements.

Next, comparing Figs. 3(a) and (b), we can clearly see that the integrated value of rotation in Fig. 3(a) is larger than that in Fig. 3(b). Therefore, as a result of the analysis of optical flow using Green's theorem, we can clearly detect the difference between the areas where rotation occurs and those where rotation does not occur.

5. Conclusion and Future Work

Using Green's theorem, we analyzed the optical flow of ultrasound images and investigated the characteristics of the fasciculation motion observed in ALS patients. In addition to obtaining the characteristics of the motion, we were able to quantitatively express the difference between the areas in which rotation occurred and those in which it did not.

In this study, the analysis range was set manually by identifying the center of rotation, but in future studies, we will work on the automation of finding the center of rotation as an issue to be addressed.

References

1) Sonoko Misawa, Clin Neurol **53**, 1206-1207 (2013) [in Japanese].
2) Masahiro Sonoo, J Jpn Soc Int Med, **89**, 623-628 (2000) [in Japanese].
3) Yukiko Tsuji, Yu-ichi Noto, Kensuke Shiga, Satoshi Teramukai, Masanori Nakagawa, Toshiki Mizuno, Clin Neurol **128**, 1069-1074 (2017).
4) Gunnar Farnebäck, LNCS **2749** (2003)