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A Study on Disease Diagnosis by Tremor Analysis

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***Abstract*— Tremor is a symptom in which a part of the body (hands, feet, head, etc.) trembles involuntarily. Essential tremor and cerebellar disorders are examples of diseases with tremor, but it is sometime difficult to accurately diagnose these diseases by only physical examination, and there is no indicator to quantitatively evaluate the tremor. In this study, we analyzed the Finger-Nose-Finger (FNF) test, which is a physical examination for detecting patients' tremor, using image processing technology, and proposed an index to discriminate between essential tremor and cerebellar disorders.**

***Index Terms*—Abnormal Tremor, Cerebellar Disorders, Essential Tremor, Finger Nose Finger test, Root-Mean-Square Deviation**

I. Introduction

TREMOR is a symptom in which a part of the body (hands, feet, head, etc.) trembles involuntarily, and various diseases develop tremor. In the case of abnormal tremor, the tremors are fast, there is a high frequency of tremor occurs, there are features such as occur at rest and when taking a specific position [1]. Frequency of abnormal tremor is variable, 3-12Hz, and it occurred at rest or during taking a specific position [1]. Today, when diagnosing the disease with tremor from its characteristics of the movement, much experience and skills of experts are needed. Essential Tremor (ET) and Cerebellar Disorders (CD) are examples of tremulous diseases, and distinguishing both diseases is important because ET does not require emergent treatment while CD is often caused by emergent condition such as stroke [2]. However, it is sometimes difficult to diagnose these diseases accurately by only physical examination in outpatient setting. In addition, there is no indicator for quantitatively evaluating the tremor. Therefore, many doctors have risks to misdiagnose these diseases.

In this study, we propose an index to discriminate between ET and CD by analyzing the movement of tremor during the FNF test, which the patient's finger goes back and forth between his/her nose and the examiner's finger.

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In this paper, we propose a method of processing for finger region extraction from a moving picture and a feature quantity for disease name diagnosis in chapter 2. In chapter 3, we describe experimental environment, experimental method, and experimental results. Finally, we summarize the discussion, conclusion and future works in Chapter 4.

II. Proposed Method

2.1 *Extraction of finger region*

Many things can become noise when extracting a finger region because the shooting location is the examination room. In this section, we describe the processing method for extracting only the finger region from the captured motion picture.

(i) Setting of Region of Interest (ROI)

In the Finger-Nose-Finger (FNF) test, movement is performed only in a limited area from the patient's nose to the finger of the examiner. Therefore, the region of interest was set. An example of setting the region of interest is shown in Fig.1. The region of interest set by the red frame. Check the movement range of the finger from the moving image and manually set the region of interest.

(ii) Extract noise from background image

In this study, we wrapped a red tape around the patient's fingers and wrapped a green tape around the examiner for testing. Therefore, an object having the same color as the tape is judged as noise. Therefore, the following processing was performed. First, a frame in which the finger of the patient is not taken is taken as the background image. It is shown in Fig. 2. And it is converted from the RGB image to the HSV image. Threshold processing is performed on the H information of the converted HSV image to extract in advance the things that can become noise with the same color as the background finger as shown in Fig. 3. By removing the region of the extracted noise from the region of interest set in (i), preprocessing for extracting fingers correctly was performed.

(iii) Extraction of finger region

The frame of the moving image on which the FNF test is performed and set as the input image. It is shown by Fig.4. And it is converted from the RGB image to the HSV image. Threshold processing of Hue (H) information, Saturation (S) information and Value (V) information of the converted HSV image makes it possible to extract the finger region as shown in Fig. 5. The part surrounded by red circle is finger, and the part surrounded by yellow circle is noise. Each threshold value was manually set because the coloring and lighting conditions differ depending on the condition of image.

(iv) Noise removal

Although extraction of the finger region was performed with (iii), noise remained. Therefore, noise is removed as it is included. Labeling is conducted at the beginning. Labeling is an operation of assigning the same label number to a set of pixels having the same value connected to each other from a binary image. After labeling, the number of pixels for each area is counted, and labels less than a certain number of pixels are regarded as noise and removed them.

(v) Estimation of finger region

Even if noise is removed, not all noise can be removed. When there are a plurality of labels such as Frame t in Fig. 6, the nearest label from the coordinates of the finger detected in the previous Frame t-1 is set as the finger area. Conversely, removing the noise also removes the area of the finger and may result in the label being completely disappeared. In that case, the median of the coordinates is calculated from the preceding and succeeding frames, and the finger region is estimated.

2.2 Feature parameter for disease name diagnosis

In this section, the feature parameter for diagnosing the disease name is examined from the coordinate data of the finger region obtained after the processing in the previous section.

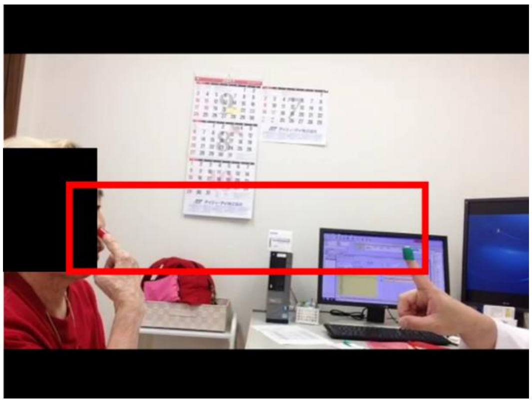

Fig. 1. Setting of Region of Interest (ROI)

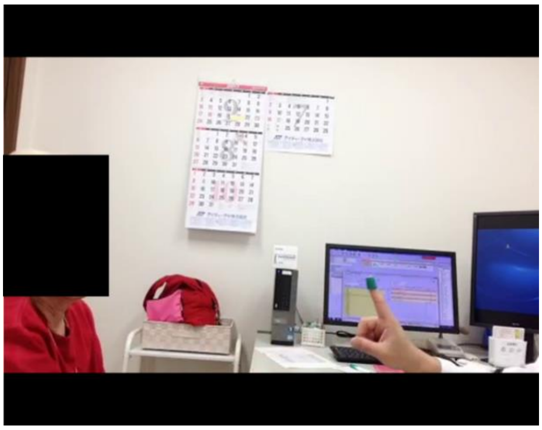

Fig. 2. The background image

Fig. 3. Extracting the noise from background image

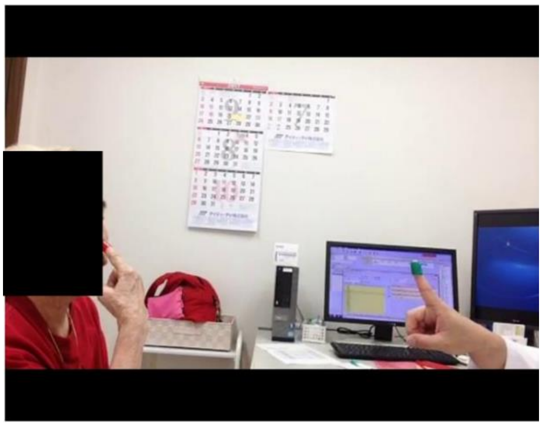

Fig. 4. Input Image

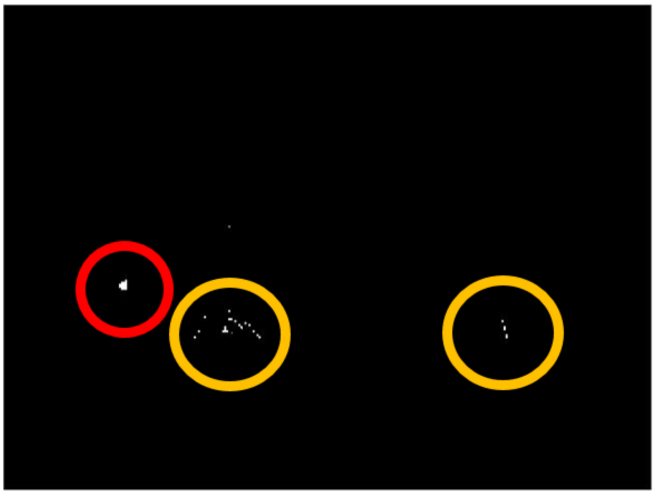

Fig. 5. Extracting the finger region

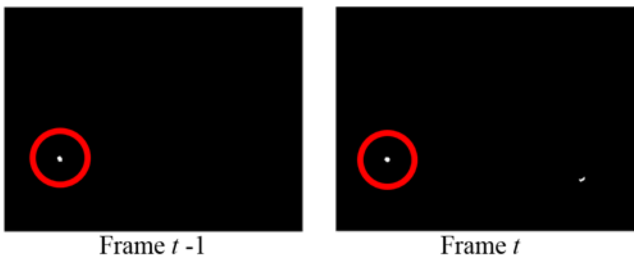

Fig. 6. Estimation of finger region

(i) Root-Mean-Square Deviation (RMSD)

Here we propose a method that uses RMSD to quantify how much the patient's fingers are swaying up and down in the FNF test. First, as shown in Fig. 7, the coordinate data of the finger region obtained in Section 2.1 is plotted on a graph.

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Draw a parabola of a quadratic function approximated by least squares method from the plotted data. Next, it is possible to digitize how much the patient's finger sways up and down by calculating the RMSD for this parabola. The calculation of RMSD is shown in following equation.

$$RMSD = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{n}} \qquad (1)$$

Here, n is the number of data plotted, y_i is the value of the plot, and $\hat{y}_i$ is the value of the approximated quadratic function.

(ii) Calculation variance from acceleration

Finger movements are constant for normal patients. However, patients with symptoms of tremors have variations in velocity. Therefore, the acceleration was calculated for each frame from the coordinate data of the finger region. A graph of acceleration for each frame is shown in Fig.8. Next, the degree of dispersion of the acceleration can be quantified by calculating the variance from the calculated acceleration. The calculation formula of the variance is shown in following equation.

$$s^2 = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2 \qquad (2)$$

Here, n is the number of frames, x_i is the acceleration in each frame, and $\bar{x}$ is the average value of the acceleration.

(iii) Histogram

Deceleration often occurs near the examiner's fingers when performing the FNF test for patients with tremor. Therefore, it can be converted into a numerical value by calculating the difference between the maximum value and the median value of the histogram as to whether the finger reciprocates with a constant rhythm. First, as shown in Fig. 9, the displacement of the X coordinate of the finger is acquired. Here, the vertical axis is the X coordinate on the image, and the horizontal axis is the frame number. Next a histogram was created by counting the number of X coordinates within the range dividing the maximum value and the minimum value of the X coordinate into five from the displacement of the X coordinate [3]. The histogram is shown in Fig. 10.

III. Experiment

3.1 Experimental environment

To take the video of experimental data, we took the video of FNF test from the lateral direction with a normal video camera at the examination room in faculty of Medicine in our university. The resolution of 480 × 640 pixels and the video with frame rate of 30 fps was used.

Finger region is extracted by the method described in section 2.1 from the video taken by the above method. Further, a feature amount for diagnosing a disease name is obtained by the method described in section 2.2 from the coordinate data of the obtained finger region.

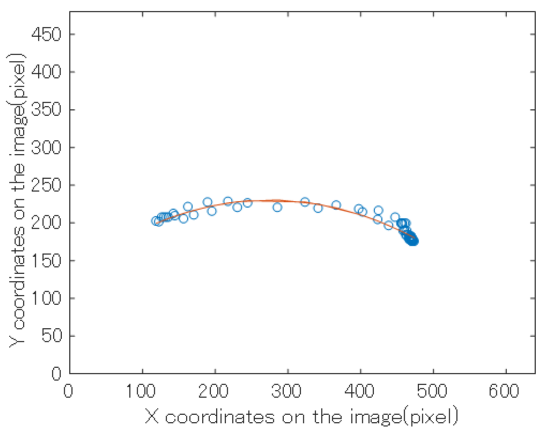

Fig. 7. Plot of finger trajectory and approximate curve

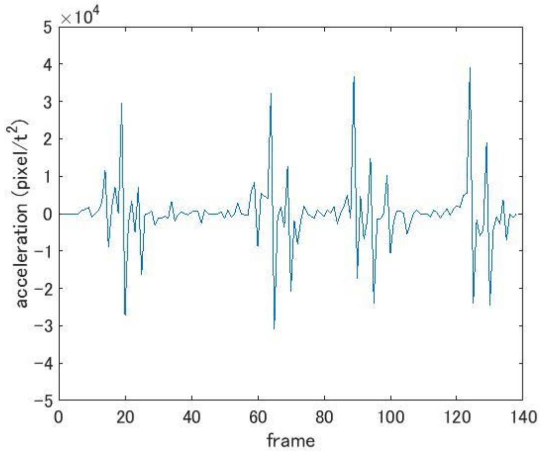

Fig. 8. Graph of acceleration

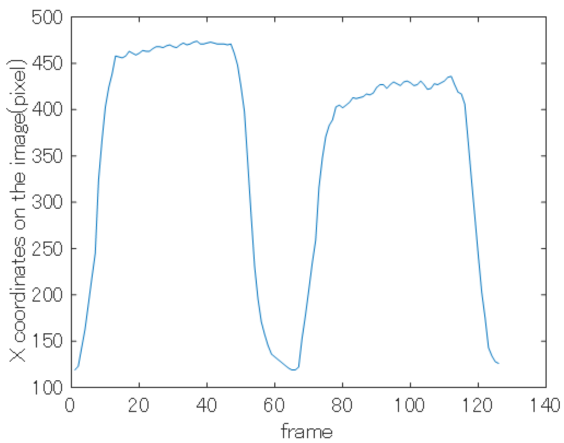

Fig. 9. Displacement of finger X coordinate

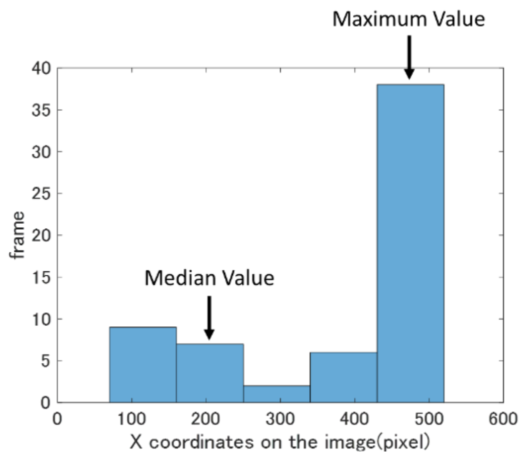

Fig. 10. Histogram of counting the number of X coordinate

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Table. 1. Data of Experiment

	Normal	Essential Tremor	Cerebellar Disorders
Number of video	1	6	5

The experiments were carried out on the video shown in Table 1 above.

3.2 Experimental results

The RMSD calculated from the coordinate data of the finger region is shown in Table 2. We calculate the acceleration for each frame from the coordinate data of the finger region. The results of calculating the variance of the acceleration are shown in Table 3.

Next a histogram is created by counting the number of X coordinates within a range dividing the maximum value and the minimum value of the X coordinate into five equal parts from the displacement of the X coordinate. The result of calculating the difference between the maximum value and the median value of the histogram is shown in Table 4. The difference between the simple maximum value and the median value differs depending on the video.

Table. 2. The result of RMSD

Video	RMSD
Normal	2.17
ET 1	5.77
ET 2	6.11
ET 3	4.12
ET 4	3.31
ET 5	6.42
ET 6	7.77
CD 1	14.79
CD 2	4.88
CD 3	4.08
CD 4	7.59
CD 5	6.71

Table. 3. The Variance of acceleration

Video	Variance $\times 10^7$
Normal	1.71
ET 1	5.63
ET 2	7.76
ET 3	4.46
ET 4	6.18
ET 5	1.52
ET 6	3.85
CD 1	6.14
CD 2	8.27
CD 3	7.34
CD 4	1.99
CD 5	3.44

Table. 4. The difference between the maximum and median value of the histogram

Video	Difference between maximum and median value
Normal	26.7
ET 1	55.0
ET 2	29.1
ET 3	21.0
ET 4	41.0
ET 5	37.9
ET 6	42.0
CD 1	28.6
CD 2	17.6
CD 3	37.5
CD 4	25.8
CD 5	32.6

IV. Consideration And Conclusion

There is a symptom that the finger which is a typical characteristic of CD in the FNF test from Table 2 RMSD obtained in this experiment shakes up and down greatly. In that case, it has a high value like CD1. The values of RMSD of other ET and CD are also higher than Normal. It can be seen that the variance of acceleration in Table 3 is higher than Normal in most videos. The difference between the maximum value and the median value of the histogram in Table 4 was a high value in the video decelerating near the examiner's finger in the FNF test.

However, their finger of some patients goes and returns between their nose and the examiner's fingers with a certain rhythm. Therefore, it is considered difficult to judge the disease name with only this feature quantity.

In this paper, by analyzing the FNF test using the image processing technology, we proposed an index to discriminate between ET and CD. Experiments were conducted on three types of moving images: normal, ET, and CD. As a result of calculating the feature quantity from the coordinate data of the obtained finger region, the value of the RMSD becomes high in the case of a CD where typical symptoms are observed. Even in other videos, RMSD was higher than Normal. Acceleration variance was higher for ET and CD than for Normal. The difference between the maximum value and the median value of the histogram was high in the video decelerated near the examiner's finger in the FNF test. It is possible to judge whether it is Normal or not, but there was no big difference between ET and CD in the feature amount proposed this time.

As a future prospect, we will examine feature quantities effective for discriminating between ET and CD. In parallel with that, we will also propose indicators to evaluate and measure severity and treatment effect.

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