Estimation of Heart Failure by Optical Flow Analysis Using Ultrasound Tomographic Sequences

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***Abstract*—This study uses ultrasound videos and optical flow analysis to estimate heart failure automatically. Feature vectors of left ventricular motion are employed in a Support Vector Machine to classify heart condition based on ejection fraction. The system achieved about 70% accuracy, demonstrating the importance of cardiac motion direction in diagnosis.**

I. Introduction

The detection of heart disease requires specialized testing, which places a burden on patients and physicians.To solve this problem, this study attempts to automatically estimate heart failure by extracting motion vectors from ultrasound videos. This method is expected to improve the accuracy of diagnosis and reduce the burden on medical professionals.

II. Methods

Figure 1 shows an overall diagram of the system. Semantic segmentation in Echonet-Dynamic[1] is used for segmentation of the left ventricle. By applying optical flow analysis using the Gunner Farneback method to consecutive images, motion vectors of the left ventricle are calculated. Angle and magnitude data are extracted from this motion vector. The angle data is divided into 36 equal parts over a range of 0 to 360 degrees, and the number of angles that fall within each part of the range is counted to obtain the feature vector $\boldsymbol{\theta}_\mathbf{i} = [\theta_{i,1}, \theta_{i,2}, \dots, \theta_{i,36}]$. Similarly, for the magnitude data, the range from the minimum to the maximum value is divided into 36 equal parts to obtain the feature vectors $\mathbf{m}_\mathbf{i} = [m_{i,1}, m_{i,2}, \dots, m_{i,36}]$. Where, i is the video index. These are used for estimation by SVM.

$$\text{Minimize: } \frac{1}{2}\sum_{i}^{N}\sum_{j}^{N} \alpha_i \alpha_j y_i y_j \mathrm{K}(\mathbf{X}_i \mathbf{X}_j) - \sum_{i}^{N} \alpha_i \quad (1)$$

where α is the Lagrange multiplier, y is the known the label, $\mathbf{X}$ is the feature vector and $\mathrm{K}(\mathbf{X}_i, \mathbf{X}_\mathrm{j})$ is RBF kernel function. The estimation is based on the classification of heart failure by Ejection Fraction (EF) as defined by the JCS[2]. EF is an indicator of how much blood is pumped from the ventricles to the whole body when the heart contracts and is an important parameter in assessing cardiac function. Estimation was performed for two categories and three categories based on ejection fraction. In addition, the classification performance was compared for three cases: angle only, magnitude only, and a combination of both. We evaluated the estimation results with the average of the three-fold stratified cross-validation. The results are shown in Figure 2 and Table 1.

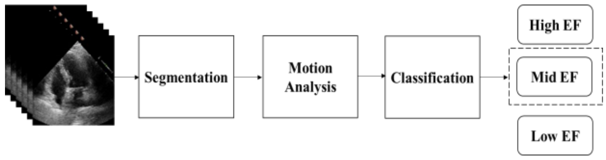

Figure 1. Overall diagram of this study

III. Experiments and Results

This study uses 2700 ultrasound videos contained in the Echonet-Dynamic dataset. There are 700 videos each with EF >50 (High EF), 40≤EF<50 (Mid EF), and EF<40 (Low EF) data, and all videos are unified to 100 frames.

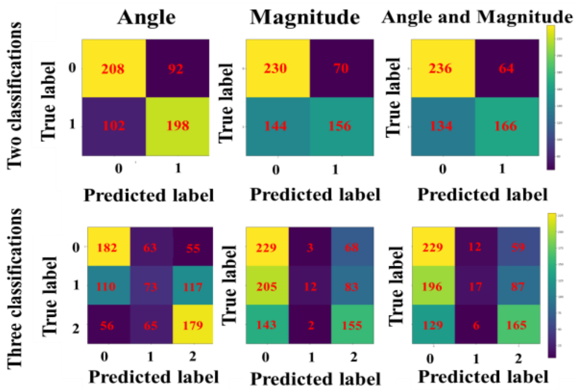

Figure 2. Confusion matrix

TABLE I. CLASSFICATION RESULTS [%]

	Two Class		Three Class	
	Angle	Magnitude	Angle	Magnitude
Accuracy	69.6	65.2	46.8	41.9
Precision	69.6	64.1	45.6	44.5
Recall	69.6	63.2	46.8	41.9
F1 Score	69.7	62.6	45.8	37.1

IV. Discussion & Conclusion

This study classifies heart failure using motion vectors from the left ventricle, achieving 70% accuracy between healthy and reduced ejection fraction hearts. However, classification was challenging for hearts with moderately reduced ejection fraction. The results suggest the direction of cardiac dynamics is crucial for diagnosis, more so than the magnitude of motion vectors.

References

[1] Ouyang, D., He, B., Ghorbani, A. et al. Video-based AI for beat-to-beat assessment of cardiac function. Nature 580, 252–256 (2020).

[2] JCS/JHFS 2021 Guideline Focused Update on Diagnosis and Treatment of Acute and Chronic Heart Failure (2021).

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