Classification of Hemiparetic Gait and Normal Gait according to Soleus EMG Signal using Deep Learning Method

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Abstract— **Soleus EMG signals were collected from normal subjects and chronic stroke patients during overground gait. The signals from each gait cycle were converted into continuous Wavelet transform (CWT) images. The training images were used to train 2 types of Convolutional Neural Network (CNN). The trained networks classified the test images into normal gait and hemiparetic gait with over 98% accuracy.**

Clinical Relevance— **This is a preliminary study on a method for the quantitative assessment of neuroplasticity in the gait rehabilitation of post-stroke hemiparetic patients.**

I. Introduction

Gait rehabilitation training in post-stroke hemiparetic patients improves recovery of lower limb motor function by promoting neuroplasticity. There are several quantitative methods to assess recovery of gait function, such as the Functional Ambulation Categories and the Fugl-Meyer Assessment. However, these methods rely on the skill or subjective judgement of the examiner. We would like to find a method that uses EMG signals to accurately assess it. As a preliminary study to find a method, we classified normal gait and hemiparetic gait using soleus EMG signal. There are some studies(1,2) that classify gait disorders using EMG signals. However, they didn't deal directly with hemiparetic gait. EMG patterns during gait cycle in healthy subjects and hemiparetic patients were modelled using 2 types of CNNs. The trained networks classified the test signals into normal gait and hemiparetic gait with over 98% accuracy.

II. Methods

14 healthy volunteers and 13 chronic hemiparetic post-stroke volunteers walked a 5 m long straight line at a self-selected speed. Soleus EMG signals and heel strike signals were measured during gait using Delsys® Trigno™ EMG sensors and Interlink Electronics® FSR-402 force sensing resistor sensors and the walk was repeated several times. To ensure research ethics in human experimentation, the experiment was conducted in accordance with the content approved by the Institutional Review Board of the Korea Institute of Science and Technology (IRB No. 2019-015).

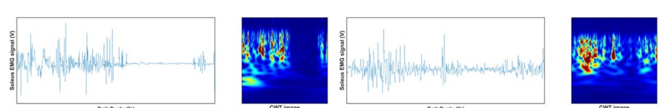
The EMG signal was divided into gait cycles based on the heel strike. The signal for each gait cycle was interpolated to 3,000 points. The CWT of a Morse wavelet was then applied to the interpolated signals. The RGB images of the CWTs were split into 2 datasets. One is a training dataset consisting of about 90% images (normal: 9,730 & hemiparetic: 5,871). The other is a test dataset consisting of about 10% images (1,051 & 637). 2 types of CNN, GoogleNet and SqueezeNet, were trained on the training dataset with a learning rate of 0.0001, a mini-batch size of 128 and an epoch of 20.

III. Results

Table I shows the results obtained by the 2 networks in classifying the test dataset. GoogLeNet's accuracy is 98.8% and SqueezeNet's 99.4%. Fig. 1(a) is an example of normal gait signals and CWT images classified as hemiparetic gait. Fig. 1(b) is an example of hemiparetic signals and images classified as normal gait. In normal gait, the EMG activation level is low in the initial phase of gait cycle (after the heel-strike), high in the middle of gait cycle (before toe-off) and low in the latter half of gait cycle (during swing phase). In Fig. 1(a), the level is high in the initial phase. It does not look like normal gait. Fig. 1(b) looks like normal gait pattern.

TABLE I. Classificattion Results of the Two Networks

Network	**GoogLeNet**		**SqueezeNet**	
Classification	***Normal***	***Hemiparetic***	***Normal***	***Hemiparetic***
Normal gait (1,051)	1,047	4	1,049	2
Hemiparetic gait (637)	16	621	8	629



(a) a healthy subject (b) a hemiparetic patients

Figure 1. Examples of misclassified EMG signals and CWT images

IV. Discussion & Conclusion

More diverse training data is needed to improve accuracy. This approach will be applied to the measured EMG signal when subacute stroke patients improve their lower limb motor function through gait rehabilitation training.

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