A preliminary study on gait recognition between hemiplegic patients and normal people using a textile capacitive pressure sensor

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Abstract. This study was conducted as a preliminary study to evaluate the possibility of gait recognition of hemiplegic patients and normal people. The purpose of this study is to analyze the gait disturbances of hemiplegic patients and normal people through our proposed system. This paper also proposes a 10 multi-channel capacitive pressure sensor and measurement/monitoring system. To obtain a capacitance value, STM32F103 MCU (Micro controller unit) were used and capacitance monitoring system were developed using C# language. To evaluate our approach, 16 people who 8 hemiplegic patients and 8 normal people, participated in our research. Data were collected during walking at 40 meters. SD (standard deviation), CV (coefficient of variance), and time of stride were calculated and selected as a feature. A Random forest, a Decision Tree, a k-NN (k-nearest neighbors) were used to classify these features using the Weka assessment tool. Finally, the gait characteristics of hemiplegic patients and normal persons were compared and analyzed. A 10-fold cross-validation method was carried out to classify gait between hemiplegic patients and normal people. As a result, the overall accuracy of recognition was 65.6% for normal people and 70.4% for hemiplegic patients.

Keywords: Gait, Hemiplegic patient, Capacitive pressure sensor

1 Introduction

Human gait is a very import exercise in daily life. Gait is also the most common exercise during human life. Therefore, various studies related to human walking have been carried out. Especially, many studies related to development of gait measuring device, feature point extraction, and characterization are being conducted [1-2].

Among them, many research are being conducted related to gait of hemiplegic patient. Most hemiplegic patients are suddenly related to the blood vessels of the brain, and the exact cause is not yet clear. Hemiplegic patient mostly was suffered from pain caused by body palsy. In the case of hemiplegic patients, there is a specific gait pattern [3]. Unlike normal people, hemiplegic patients use almost one foot without force on the paralyzed feet.

Conductive textile can be manufactured in various forms, and they are cheap and flexible [4]. Therefore, it is used in wearable device. Many researches have been made on electrodes for measuring biological signals such as EMG (Electromyogram), ECG (Electrocardiogram), etc.

In this study, a conductive textile is developed as a parallel capacitor type pressure sensor, and a device and a monitoring system for measuring capacitance are developed. And, we collected gait data of a total 16 people who are 8 hemiplegic patients and 8 normal people, and calculated a time, a standard deviation and a coefficient of variance of stride using local maxima algorithm. Finally, we used to classify for gait recognition between hemiplegic patients and normal people.

2 METHOD

2.1 Characteristic of the Subjects and experimental protocol

In this study, 8 hemiplegic patients were selected as the experiment subjects, which include 4 males and 4 females. In addition, 8 normal people, including 4 males and 4 females, were selected. For the hemiplegic patients, the age distribution was 54–73 with a mean age of 62.5 years. For the normal people, the age distribution was 27–71 with a mean age of 44.1 years.

Table 1. Characteristic of the Subjects (hemiplegic patient)

	SEX	*Age*	*Height (cm)*	*Weight (kg)*	*Paralyzed side*
1	M	54	174	80	L
2	F	59	167	73	L
3	F	64	159	45	B
4	M	60	178	79	R
5	F	60	150	38	L
6	M	68	168	58	L
7	F	73	145	50	L
8	F	62	150	45	R
Mean		62.5	161.3	58.5	
SD		5.85	12.21	16.69	

Table 2. Characteristic of the Subjects (normal people)

	SEX	*Age*	*Height (cm)*	*Weight (kg)*
1	M	34	174	74
2	F	34	168	54
3	F	31	161	48
4	M	27	178	75

5	M	48	168	63
6	M	44	170	75
7	F	71	158	62
8	F	64	162	72
AVG		44.12	167.37	65.37
STD		16.04	6.78	10.36

The experimental protocol is shown in Fig. 1. The data collected while walking 40 M round trip at a free walking speed.

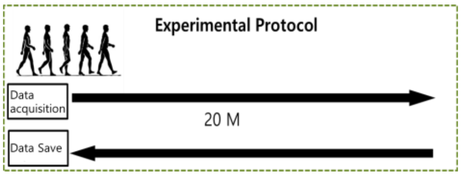
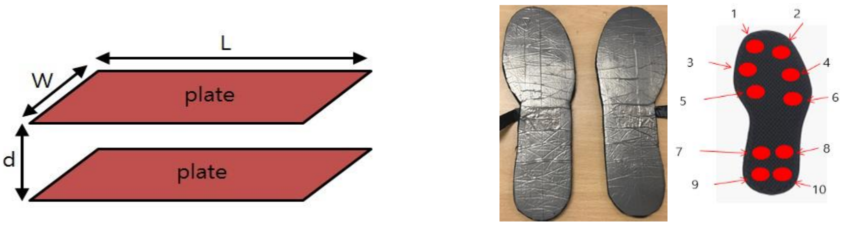


Fig. 1. The structure of parallel capacitor

2.2 Capacitive pressure sensor based on a conductive textile

In this study, capacitive pressure sensor was developed with the structure as shown in Fig. 2(a) using conductive textile as a plate. Equation (1) is a formula for calculating the parallel capacitance value, and C value is derived using the above formula. Based on this, we developed an insole-type capacitive pressure sensor which contains 10 channels as illustrated in Fig. 2(b). Each channel is made up of two plates of conductive textile.

$$C = \frac{\varepsilon_r \times \varepsilon_0 \times A}{d} \quad (1)$$



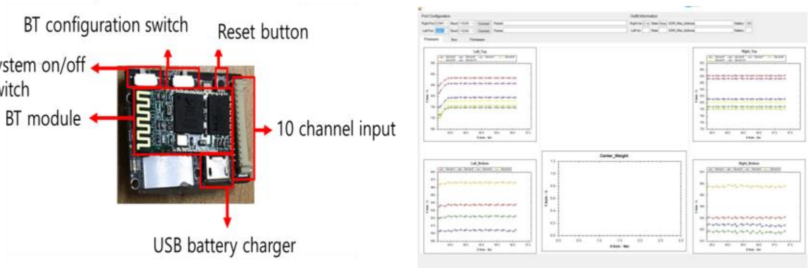
(a) (b)

Fig. 2. The structure of parallel capacitor and capacitive pressure sensor (a) parallel capacitor structure (b) capacitive pressure sensor structure

2.3 Capacitance measurement and monitoring system

Capacitance measurement system was developed using STM32F103 MCU. It contains a Bluetooth module and transmits the capacitance value to the PC as shown in

Fig. 3(a). Data were sampled at 100 Hz. Fig. 3(b) shows the capacitance monitoring system based on C# language. It can be saved data in text file.



(b) (b)

Fig. 3. Capacitance measurement and monitoring system

(a) measurement system (b) monitoring system

2.4 Data analysis, and recognition

First, the data of 10 channels were combined into one data set, and the normalization using the average value was performed. Then, we used the local maxima algorithm to detect the stride and the heel strike and the toe off points of the feet as shown in Fig. 4.

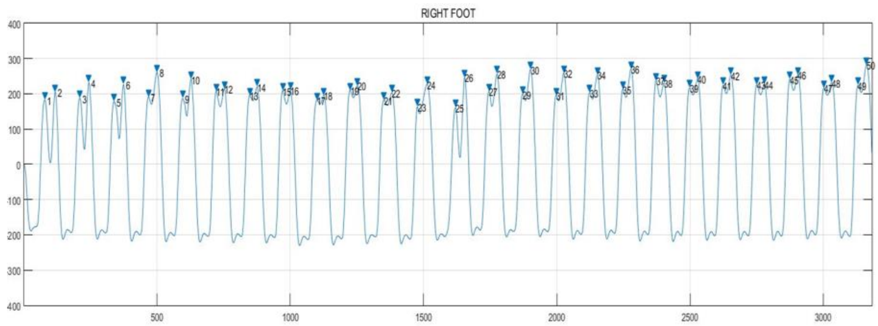


Fig. 4. Heel strike and toe off detection using local maxima algorithm

Then, stride time, CV, SD were calculated and used as a feature for gait classification of hemiplegic patients and normal people. We used a random forest, decision tree, k-NN algorithm to classify the gait data using the Weka assessment tool.

3 Results

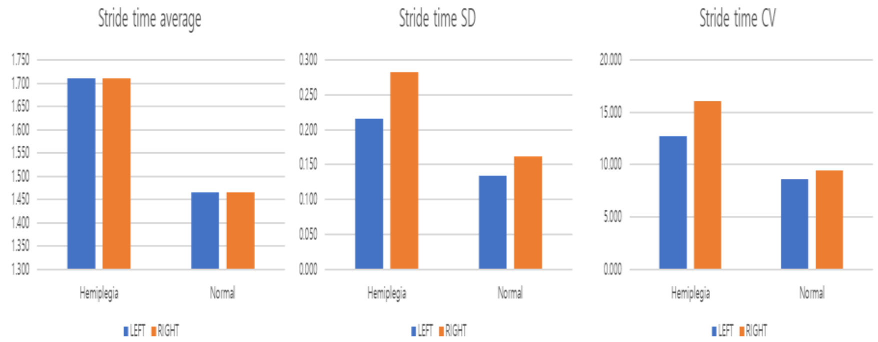


Fig. 5. The results of stride time, standard deviation, coefficient of variance

Fig. 5 shows the mean stride time, CV, SD of all subjects (hemiplegic patients and normal). The stride time of patients with hemiplegia was 0.245 seconds longer than that of normal people, respectively. In case of hemiplegic patients, SD were 0.08 and 0.11 second larger than normal people in left and right foot, respectively, and CV values were also 4.14 and 6.57 larger, respectively. Patients with hemiplegia showed that walking was not constant because one side of the body was paralyzed compared to normal people.

Tables 3 and 4 summarize the accuracy for each classifier for between hemiplegic patients and normal people using a 10-fold cross validation method. For the accuracy of each classifier hemiplegic patients, random forest was 60%, decision tree was 71.4%, k-NN was 80%. The average accuracy about all the classification algorithms was 70.46%. The precision of the k-NN algorithm was higher than the other algorithms.

In case of normal people, the accuracy of each classifier showed at 66.7%, 66.7%, 63.6%. The average accuracy about all the classifier algorithms was 65.6%. The average recognition rate of all classifiers of hemiplegic patients was 4.4% higher than that of normal people.

Table 3. Detailed accuracy for each classifier for hemiplegic patients

Classifier	TP rate	FP rate	Precision	Recall	F-measure
Random Forest	0.750	0.500	0.600	0.750	0.667
Decision Tree	0.625	0.250	0.714	0.625	0.667
k-NN	0.500	0.125	0.800	0.500	0.615

Table 4. Detailed accuracy for each classifier for normal people

Classifier	TP rate	FP rate	Precision	Recall	F-measure
Random Forest	0.500	0.250	0.667	0.500	0.571
Decision Tree	0.750	0.375	0.667	0.750	0.706
k-NN	0.875	0.500	0.636	0.875	0.737

4 Conclusion and Discussion

This study was carried out as a preliminary study to evaluate the possibility of gait recognition between hemiplegic patients and normal people. In order to gait recognize, we developed a 10-channel capacitive pressure sensor of insole-type using a conductive textile and its measurement/monitoring system. Then, we calculated a feature such as stride time, CV, SD.

A total 16 people, who are 8 hemiplegic patients and 8 normal people, participated in our experiments. Also, we used to classifier which is random forest, decision tree, k-NN algorithm for gait recognition. As a result, we obtained accuracy that random forest was 60%, decision tree was 71.4%, k-NN was 80% for hemiplegic patients and 66.7%, 66.7%, 63.6% for normal people.

Our research has a many limitation. At first, the number of feature was insufficient, and we didn't consider the height, weight, etc. of each subject. The number of subjects also is not sufficient. In the future, if we overcome these limitations, we think that we can classify more accurate and various gait patterns between hemiplegic patients and normal people. Through obtained of this research, we think it can be helpful about gait recognition between hemiplegic patients and normal people.

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