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Contents

A Study on the evaluation of system performance between Textile capacitive proximity sensor and F-scan

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Abstract

This is a study regarding the development of gait monitoring and measurement system for evaluating of system performance between capacitive textile proximity sensor and F-scan. To evaluate a system performance, we developed an insole type textile capacitive proximity sensor (ITCPS) and application which contains measurement system and monitoring system. To verify system performance between ITCPS and F-scan, Pearson correlation analysis was performed. 4 people participated in our experiments. As a result, correlation coefficient between ICPS and F-scan showed at 0.56, 0.58 (left/right foot). As a result of detecting the step count, the recognition rate was 100% in the remaining segments except for 4.km/h. Based on obtained results of this study, it will be helpful about efficiently development of gait measurement and monitoring system.

Keywords: Conductive textile, Gait, Proximity sensing, Step

1. Introduction

Gait is the most common activity and basic exercise of human in daily life. It also have been researched a long time. Gait includes a many health information such as step, stride, and etc[2]. Based on this, fall, gait balance are being research for an unusual patients such as Parkinson's disease, stroke and hemiplegia patients. Owing to this, many research studies have been conducted using embedding in shoes and insole for gait analysis [1].

Conductive textile has advantage as comfortable, elasticity, and it can be created in various form. As a result, it has been used in research of biomedical engineering for measuring various bio signal[2].

This paper is organizied as follows. Section 2 describes the characteristic of subjects, the textile capacitive proximity sensor, the experiment protocol. Section 3 describes the results of experimental analysis. Section 4 describe summarizes our conclusions and discusses the our future work.

2. Method

2.1 Insole-type capacitive proximity sensor

ITCPS was developed based on theory of capacitive proximity sensing. It designed 270 mm and consists of 10 channel sensors. Each sensors location was shown in **Fig. 1**.

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Fig. 1. The structure of ITCPS
a) each sensors location b) ITCPS structure

2.2 Data measurement and monitoring system

To measure a capacitance, we develoepd a data measurement system as illustrated in **Fig. 2**. **Fig. 2** shows the result of capacitance measurement system. MCU was used STM32 series and MPR121QR2 sensor was used for convert digital signal from analog signal. The data were sampled at 100 Hz. The capacitance monitoring system was developed using C# and it can be saved the 20 channel data.

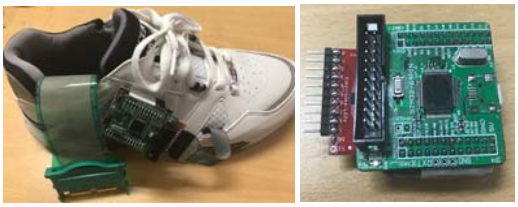

Fig. 2. Capacitance measurement system

2.3 Signal processing

Fast fourier transform (FFT) was performed to check the frequency components constituting the data. As a result, it was confirmed that there is a data frequency component between 0-3 Hz. Based on this, low pass filter which contains 0-3 Hz cut-off frequency, was used. Then, moving average filter which contains 5 point, was used for smoothen data and remove noise.

We developed an local maxima algorithm to detect peaks based on a 0.5 second window frame. Step count was calculated using local maxima algorithm.

2.4 Characteristic of subjects and Experimental protocol

In this study, four healthy people were selected as the subjects. The age distribution was 22-29 with a mean age of 26.

Four experiments were performed per subjects. The data were collected while changing the gait speed on a treadmill. Gait speed is consist of 1.5 km/h, 2.5 km/h, 3.5 km/h, and 4.5 km/h during 3 minutes. Then, Correlation analysis were conducted to verify between ITCPS and F-scan about each gait speed. Pearson correlation coefficient analysis was used for all correlation analysis.

3. Result

3.1 Result of correlation analysis between ITCPS and F-scan

Correlation analysis between ITCPS and F-scan was performed as shown in Table 1-2. Result of correlation analysis about left foot shows that 1.5 km/h is 0.64, 2.5 km/h is 0.6, 3.5 km/h is 0.3, 4.5 km/h is 0.68. In case of right foot, it showed at 0.504,0.619,0.582,0.624. The overall average for the left foot was 0.56 and the right foot was 0.58. The positive correlation between ITCPS and F-scan developed in this study was confirmed.

At the speed of 1.5 km/h, the correlation coefficient of subject 2 was 0.216 and 0.11, and the subjects 4 were 0.018 and 0.162, respectively. The correlation coefficient is low because it is different from the usual gait of each subject.

Table 1. Result of correlation analysis between ITCPS and F-scan (Left Foot)

Subjects	1.5 km/ h	2.5 km/h	3.5 km/h	4.5 km/h
Subject 1	.784	.56	.96	.82
Subject 2	.216	.333	.21	.952
Subject 3	.936	.619	.518	.551
Subject 4	.641	.918	.591	.404
Avg	.64	.6	0.3	.68
Std	.03	.24	0.28	.24

Table 2. Result of correlation analysis between ITCPS and F-scan (Right Foot)

Subjects	1.5 km/ h	2.5 km/h	3.5 km/h	4.5 km/h
Subject 1	.834	.648	.9	.809
Subject 2	.11	.408	.059	.915
Subject 3	.912	.496	.443	.63
Subject 4	.162	.927	.926	.142
Avg	.504	.619	.582	.624
Std	.42	.227	.41	.342

3.2 Result of step count detection according to changes in the speed at treadmill

Step count was calculated for evaluating system performance using local maxima algorithm as shown in Table 12-15. In all other cases except for 4.5 km/h, data between F-scan and ITCPS were found to be 100% identical.

Table . Result of Step count detection (1.5 km/h)

Subjects	ITCPS		F-scan	
	LEFT	RIGHT	LEFT	RIGHT
Subject 1	78	79	78	79
Subject 2	85	85	85	85
Subject 3	79	79	79	79
Subject 4	94	93	94	93

Table 4. Result of Step count detection (2.5 km/h)

Subjects	ITCPS		F-scan	
	LEFT	RIGHT	LEFT	RIGHT
Subject 1	101	100	101	100
Subject 2	111	111	111	111
Subject 3	116	116	116	116
Subject 4	108	109	108	109

Table 5. Result of Step count detection (3.5 km/h)

Subjects	ITCPS		F-scan	
	LEFT	RIGHT	LEFT	RIGHT
Subject 1	125	125	125	125
Subject 2	117	117	117	117
Subject 3	136	136	136	136
Subject 4	125	125	125	125

Table 6. Result of Step count detection (4.5 km/h)

Subjects	ITCPS		F-scan	
	LEFT	RIGHT	LEFT	RIGHT
Subject 1	144	143	143	138
Subject 2	146	146	145	145
Subject 3	151	149	149	149
Subject 4	141	141	140	140

The error rate occurred in the step count of all subjects except the right foot of subject 4. The error rate of the right foot was 0.85% and that of the left foot was 1.22, and the standard deviation was 0.31 and 1.5, respectively.

4. Conclusion and Discussion

In this paper, we developed a user-friendly ITCPS and its measurement/monitoring system. Based on this, we tried to demonstrate superior performance compared to F-scan.

Our proposed sensor and system can reduce user's rejection and can be easily daily gait monitored through application and PC. However, there are limitations such as comparative analysis with the commercial gait analysis system. The number of channels is insufficient, and the pressure distribution can not be measured.

If we can overcome limitations and perform various research, our proposed system will be a more convenient and practical gait analysis/monitoring system.

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