Healthcare Shoe System for Gait Monitoring and Foot Odor Detections

Treenet Thepudom[1], Thara Seesaard[2], Wathang Donkrajang[2] and Teerakiat Kerdcharoen[1,3,*]
[1]Department of Physics, Faculty of Science, Mahidol University, Bangkok 10400, Thailand
[2]Materials Science and Engineering Programme and Center of Intelligent Materials and Systems (CIMS), Faculty of Science, Mahidol University, Bangkok 10400, Thailand
[3]NANOTEC Center of Excellence at Mahidol University, National Nanotechnology Center, Thailand
[*]Corresponding author: teerakiat@yahoo.com

***Abstract*—Recently, we are living in an era filled with unprecedentedly growing senior population. Nowadays, smart technologies for healthcare have been increasingly interested by general consumers due to their numerous advantages such as affordability, user-friendliness, point-of-care usability and social-ability. In this paper, we have developed a smart shoe system with ability to observe human gait patterns and foot odor. The motion pattern and foot odor measurement systems were installed inside the shoes using force sensitive resistors (FRSs), bending sensors and chemical gas sensors. Thereby the FRSs and bending-sensor were installed beneath the foot while chemical gas sensor array was installed inside the tongue of the shoes. In addition, zigbee technology was used as data communication between all sensors with a receiver USB-connected to a computer. This system was developed to be consumer-friendly having a compact size and using low-cost technologies. It was demonstrated that this wearable device could classify different types of human gait patterns and foot odors during the duration of wearing time.**

Keywords—data shoe; wearable electronics; zigbee; gait pattern; food odor

I. INTRODUCTION

Nowadays, healthcare technologies have played a prominent role, especially in advanced countries, due to rapidly increasing number of elderly population. Hence the growth of aging societies necessitates the development of healthcare devices to better support elder living conditions. One of the most familiar health issues of the elderly is walking problem which consists of gait abnormalities up to falling. Such problems lead to various severity such as breaking bone, paralysis and even death. In recent years, many researchers have concerned about this issue and tried to develop a smart device to alleviate such problems. Thus, smart shoe is a technology that can monitor gait behavior and provide early warning before a dangerous situation will happen. Gait is a pattern of movement that can characterize human behavior and could provide the health conditions of elderly. Therefore, tracking of gait provides several benefits such as early detection of abnormal walking that can prevent or diagnose future diseases, i.e., falling, deteriorated bone and Parkinson's symptom [1].

In fact, several techniques are available to observe gait behavior such as optical and force scanning systems. However, these methods have several disadvantages such as being expensive, requiring a trained technician to operate and low comfort. In the last century, Morley et al. [2] developed and insole-based system to monitor the conditions inside the shoe. Subsequently, other researchers have gradually invested in the development of various medical shoes. In our case, we sought to develop a smart shoe system which can not only observe gait patterns, but also measure foot odor of the wearer. Foot malodor is a common issue caused by the accumulation of sweat [3]. This problem can damage the personality and social acceptability of the owner. Such issue has been realized in this work as to increase the functionality of the shoe. Therefore, our healthcare shoe can measure the gait behavior and foot odor at the same time as presented in Fig. 1. The shoes can be used to discriminate between normal/abnormal walking and diagnose foot odor problem. We hope that this work will provide more choices in healthcare technology to the consumer healthcare market, especially for the elderly users.

II. MATERIALS AND METHODS

A. Data-Shoe Configurations

The concept of this device is based on low-cost technology for the benefit of consumers. To observe the gait behaviors, low-cost FSRs and bend sensor are located inside the shoe, specifically embedded within the insole of the shoe. From Fig. 2, the sensor installations are divided into 3 main positions, namely the ball, lateral and heel positions (position no. 1-6), while the bend sensor is located on the middle of the insole (position no. 7). In addition, a gas sensor array consisting of 8 different sensor elements is located on the tongue of the shoes. Each chemical gas sensor was fabricated by screen-printing different types of polymer-carbon nanotube composites onto

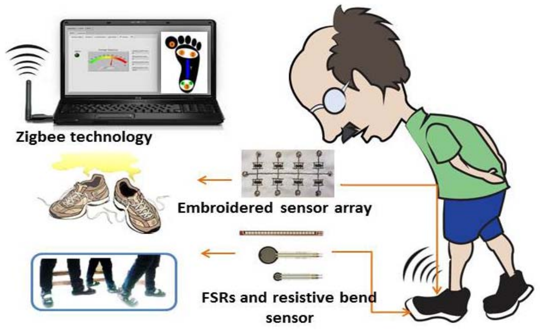

Fig. 1. Schematic diagram of healthcare shoe monitoring system

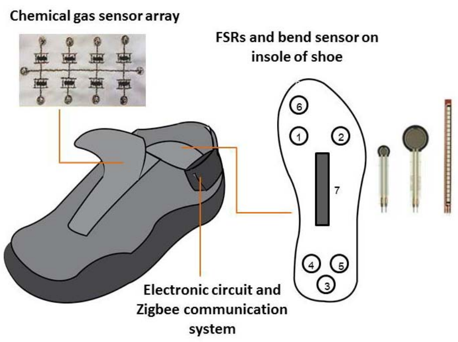

Fig. 2. Various sensors installed inside the healthcare shoe.

the fabric electrodes formerly embroidered on the surface of a cloth. Such design allows all sensor surfaces to be flat, easily installed and conveniently maintained (the shoes can be washed by removing the electronic components).

B. Data Communication System

To facilitate the user, wireless sensor network based on Zigbee technology was used in this work. Among various wireless technologies, Zigbee provides several advantages over other techniques due to cheap cost, low weight, long battery life and flexibility to many applications. It can send/receive signals at the range of 10- 300 meters, so that user can easily apply in their home area. The Zigbee circuits are located inside a small pocket outside the shoe.

III. Result and Discussion

In a previous work, we have classified gait patterns between normal and abnormal walking styles, namely normal walking, tip-toe walking and dragging right [4]. Moreover, we have separately tested the ability of the chemical gas sensors to measure foot odor during wearing. Both experiments have yielded satisfactory results with positive prospects for real-world applications. In the present works, we have developed novel smart shoes which combine these two techniques within the same shoe in order to measure gait patterns and foot odor at the same time. Fig. 3 shows the signals from FSR and bend sensors as obtained from distinct gait behaviors. The output signals show significant data of each sensors group (sensor no.1-7) during wearing. To simplify this, the principal component analysis (PCA) was introduced to classify all datasets and provide comprehensible visualization as shown in Fig. 4, where PCA clearly illustrates the clustering of 3 different gait patterns and foot odor during the passage of time. It was found that 3 types of gait patterns are clearly distinguished, whereas the foot odor data show an obvious progressive direction of foot malodor after wearing for 3, 5 and 8 hours, respectively.

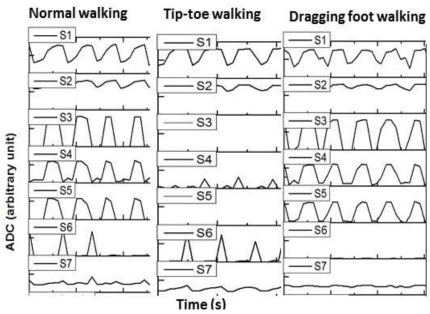

Fig. 3. Typical signals obtained from FSRs (no. S1-S6) and bend sensor (no. S7).

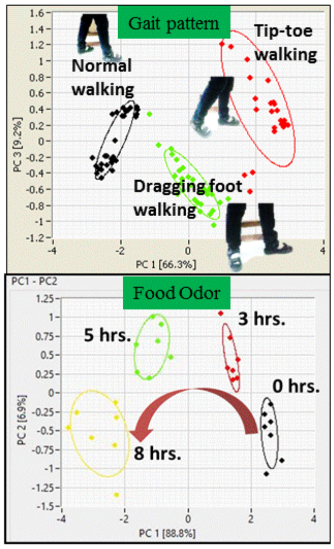

Fig. 4. PCA scores plot in two dimensions for the analysis of 3 different gaits and foot odor during the passage of time.

IV. Conclusions

A healthcare shoe was developed to add more choice into the healthcare consumer market. It consists of force sensitive resistors, resistive bend sensor and chemical gas sensor array integrated under Zigbee wireless communication technology. The results reveal the potential of the shoe as a healthcare device that can discriminate different types of gait patterns and foot odor during wearing. This wearable technology is affordable by general users to access advanced capability such as detection of abnormal walking that can prevent or diagnose future diseases, i.e., falling, deteriorated bone and Parkinson's symptom.

Acknowlegement

This project was supported by Mahidol University and National Nanotechnology Center (NANOTEC grant no. P-12-01157).

Refference

[1] T. Yoshida, F. Mizuno, T. Hayasaka, K. Tsubota, Y. Imai, T. Ishikawa and T. Yamaguchi, "Development of a wearable surveillance system using gait analysis," Telemedicine and e-health, vol. 13, no. 6, 2007.

[2] R. E. Morley, E. J. Richter, W. Klaesner, K. S. Maluf and M. J. Mueller, "In-shoe multisensory data acquisition system," IEEE transsaction on biomedical engineering, Vol. 48, pp. 815-820, 2008.

[3] C. Wongchoosuk, M. Lutz and T. Kerdcharoen, "Detection and classification of human body odor using an electronic nose," Sensors, Vol. 9, pp. 7234-7249.

[4] W. Donkrajang, N. Watthnawisuth, J. P. Mensing and T. Kerdcharoen, "Development of a wireless electronic shoe for walking abnormalities detection," IEEE biomedical engineering international conference (BMEiCON-2012), pp. 1-5, 2012.