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IT Convergence Self-care Guide Insole

Ki-Bong Kim[1] and Yong-Deok Kim[2*]

[1]Department of Computer Information, Health Institute of Technology, Korea; kbkim@hit.ac.kr
[2]BMSYS Co, Ltd., Korea; bmsys1@naver.com

Abstract

As a keen attention of health care and wellness is paid to a foot, from which health begins, many health care products combined with mobile technology have been introduced to related markets. The present study is aimed to propose an algorithm for sensor signal-based walking information analysis and develop an insole in which a multi-sensor is attached to it and protected a multi-sensor to the insole that is an important part of a shoe. In addition, this study developed an ambulation-based sensor module for self-care guide application by using Micro Electro-Mechanical Systems (MEMS) sensor that can automatically coaches user's convenience and individual activity.

Keywords: Mobile Convergence Insole, Postural Balance, Self-care, Smart Insole, Wearable Multi-sensor

1. Introduction

As consistent and professional health management in the name of 'health care' and 'wellness' became an issue all over the world, health care market has rapidly grown. As part of regulatory reforms, the Korean government selected global health care industry as a new growth engine sector for future creative economy and the needs for wearable health care products in which manufacturing and IT technology are convergenced into one, the related market are being paid more attention[1,4,13]. Domestic mobile wearables market is expected to rise from 1.2 billion USD in 2011 to 23 billion USD KRW, which is equal to continuous growth by 67% on annual average. Besides, fitness monitoring markets such as measuring devices of daily heart rate and calorie consumption are also expected to grow to 400 million USD in 2010 from 120 million USD in 2016, which is equivalent to the growth by 22% on annual average. Particularly, modern people demand more motion in an effort to maintain good health and prevent from illness and, as a result, it turned out that they want to buy wearable terminals. Of them, the measuring devices of calorie consumption and moving distance take 82% of the total purchase intention[1–3].

Although many wearable products that measure and manage motion information have recently been introduced, they are limited to the extent they are used only to monitor motion information such as calorie consumption and walking schedule management like a passometer and the data produced by them are not different by the location they are worn[2,5,11].

The social interest in health care has made atmosphere in which many people want to manage their own motion conditions systematically and scientifically and demanded wearable health care devices or coaching devices that can support their objectives.

According to the survey, the respondents revealed their strong intention to purchase a wearable device as long as it is equipped with such functions as measuring calorie consumption (82%) and moving distance (76.5%) and alarming and automatically collecting motion data (80.5%) in connection with a smartphone. The development of smart devices such as smart phone and wearable computer has become the important base of the growth of wellness market. Especially, the growth of the wearable computer attached to a body and providing bio-data continually is becoming distinctive[5,6,12].

Most of the Korean wearable device market is occupied with the products of global companies. Therefore, the development of a measuring device for postural information can bring in substitution effect with imports. In addition, the increasing use of a smart phone and computer pushes up the number of patients with cervical disk problem so it is very urgent to correct posture. 72.4% of office workers and 27.6% laborers work in unstable posture

*Author for correspondence

and about 30,000 people visit hospitals for treatment of wrong posture every year[2,4].

To correct this impending problem, it is necessary to develop a wearable sensor module connected to mobile, sensor and signal processing technology. Additional, it is also necessary to analyze and design an algorithm that can detects postural balance and motion information. Last, a user convenience-based posture correction guide application is required. In this respect, the present study conducted a study upon the measurement of postural balance and motion information supported by a sensor attached to an insole and realized a product for which IT and insole are convergenced.

2. Related Works

2.1 Insole

Insole is an important structure located at the inner bottom of a shoe and directly contacts with a human sole. It prevents foot fatigue and has a great impact on the wear-ability of shoes and user's activity[10].

As the importance of insole and the necessity of developing it are more recognized along with the improved standards of living and the popularity of sports and leisure, foot health care is considered to be more important. As a result, various functional shoes and insole products have been developed for foot healthcare[8,10,12]. As the standards of living increases and sports and leisure are more enjoyed in Korean society, foot health care is being paid more attention, a technology has developed to collect and measure bio-information on the basis of foot pressure while walking by using a pressure sensor. However, it requires problem solving related to power supply and wireless communication, Furthermore, no IT convergence self-care guide insole technology that is required for the targeted insole has been applied to a domestic market[8,9]. Besides, many countries such as USA, BK, France, Japan and Germany are developing a functional insole that can be applied for multipurpose in various high-tech fields including IT, BT, NT and ergonomics, they pay more attention to shoes themselves than to insole, presenting a variety of shoe items. Many companies like NIKE and Adidas help check the amount of motion, training or cardio motility and provides comparative analysis results to share by using the data on line[10, 17].

2.2 Wearables

As wearable devices have recently been launched, the size of the related market grew from 800 million USD in 2012 to 1.5 billion USD in 2014. Particularly, demand is growing, targeting consumer market such as the terminals for healthcare and fitness and multi-functional terminals[2,13,16].

Having grown by 18% to 20% every year, global wellness health care (e-health) market is expected to further grow from 96 billion USD in 2010 to 160 billion USD in 2015. Let's take U.S. market as example. U.S. government itself is supporting smart health care business initiatively initiating and expects it will take up more than 50% of the global smart health care market[1,14,15].

2.3 Ambulation-based Self-care Application

A self-care application for ambulatory information should be developed in consideration of accessibility, information offering, simplicity, visibility and friendliness. It should include UI with motion information based on the data transmitted from a sensor module, ambulatory information, motion information, alarming function of walking and amount of walking and test result. The application also needs such functions by category as personal profile registration, motion target setting, display of actual motion information in time series and pattern, comparison of targeted motion with actual motion, calorie calculation, coaching for period against target and motion strength, personal motion indicators and time series analysis by algorithm, healthcare coaching on the basis of the comparison between personal motion indicators and Korean standard motion index, detection of measuring motion error, multimedia display of user's motion performance rate and level management according to target motion performance[10].

2.4 Ambulatory Information and Estimation of Moving Distance

The proposed application should be able to sense user's daily motion posture and motion information with a multi-axis sensor, distinguish pausing from walking by signal processing, analyze real-time information of posture, incline, walking pattern, walking posture, walking balance to both sides and maintain optimum transmission cycle and protocol Table 1[6–9].

Table 2 shows the measuring results from the estimated step count, stride and moving distance of a user.

Table 1. Results of walking analysis

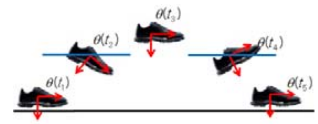
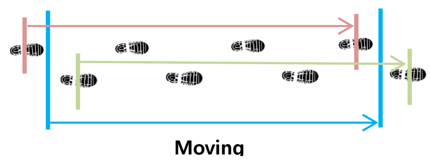
Item	Results	Image
Estimated Algorithm of step count stride	- Tracked information of standard stride, walking habit, walking shape by age, body size and ground condition - The developed module was installed inside the shoes, so that there occurred a change in direction of accelerometer in 3 axes during motion	 $P_x = \int_{t_0}^{T} f_x dt \quad P_Y = \int_{t_0}^{T} f_Y dt \quad P_Z = \int_{t_0}^{T} f_Z dt$
Estimated Algorithm of moving distance	- Calculated moving distance from the estimated step count and stride - Used the average values of right and left foot information	 $\Delta P = \frac{\Delta P_{right} + \Delta P_{left}}{2} = \frac{(stepNum_{right} \times stride_{right}) + (stepNum_{left} \times stride_{left})}{2}$

Table 2. Walking measurement

Indicator	Item	Computational Algorithm
Pattern Analysis	motion day (w), moving distance (d), motion time (t), motion speed (s), motion stride (st), angle of left foot (la), angle of right foot (ra), pressure of left foot (lp), pressure of right foot (rp)	
Mobility (MV) (tachometer-typed)	motion distance, motion time, motion speed	$mv = (d/w + t/w + s/w) \Big/ \sum_{i=1}^{n-1} (d/w + t/w + s/w) * 100$
Balance (BL)	left/right (LR) pressure, maximum pressure minimum pressure, average pressure	$bl = Evg\,(lp)\ vs\ Evg\,(rp)$ $Max\ bl = Max\,(lp)\ vs\ Max\,(rp)$ $Min\ bl = Min\,(lp)\ vs\ Min\,(rp)$
Speed (SP) (tachometer-typed)	maximum speed, minimum speed average speed	$sp = ((s/w) \Big/ (\sum_{i=1}^{n-1} Max(s)/n)) \times 100$ $Max\,Sp = (Max(s) \Big/ \sum_{i=1}^{n-1} Max(s)/n)) \times 100$ $Min\,Sp = (Min(s) \Big/ (\sum_{i=1}^{n-1} Min(s)/n)) \times 100$
Continuity (CO) (tachometer-typed)	motion duration, motion pause time	$Co = t/\ Total\,(t),\ Cv = tv/\ Total\,(t)\ 0 \le Co \le 1,\ 0 \le Cv \le 1$
Activity (AC) (tachometer-typed)	motion distance, motion time motion speed, average pressure	$Ac = (d/w + t/w + s/w + Evg(lp) + Evg(lp)$ $/ \sum_{i=1}^{n-1} (d/w + t/w + s/w + Evg(lp) + Evg(rp)) / n \times 100$
Strength (ST)	motion distance, motion time	$St = (d/t) \Big/ \sum_{i=1}^{n-1} (d/t)/n \times 100$
Calorie Consumption (CA)	motion type, motion time age, sex, motion strength	Standard table of calorie consumption was used to compare age, sex, sport type and motion strength
Motor Health Quotient (HA)	motion day, motion distance motion time, motion speed	By weekly recommended motion indicator standard for Koreans

3. Development of IT-convergence Self-care Guide Insole

By combining existing insole (Insole) with IT technology (sensing and Bluetooth), the present study developed a self-care insole technology that enables users to confirm their walking information on a mobile device in real time.

3.1 Development of Insole for the Attachment of Sensor Module and Protection

It is necessary to establish chemical and physical standards regarding the assembling and adhesion by each part of an insole. It is to form a standard for chemical adhesion of different materials into one during the production of an insole and for prevention of the materials from peeling off from each other. To fuse the insole, therefore, this study used epoxy and polyurethane that do not disturb the measurement of a sensor and Bluetooth and communication; and are not damaged by bending, impact and friction. The strength of fusion was so designed and realized that it can maintain over the reference value of (40N/5Cm) on the basis of measured peeling stress. The insole was also developed to have over PU Gel rebounding property of 90% so that it can protect flat pressure sensor from impact and absorb shock. The finalized Body Mass Index (BMI) has a very low rate of error (2.8%) and the measured data is transmitted to PCB module Figure 1.

The measuring housing for the sensor module attached to the insole was developed to be 16mm (width), 37mm (length) and 1.2mm (thickness). The battery was designed to be 13mm (length), 28mm (width) and 3.8mm (thickness).

Figure 1. Insole inserted with sensor module.

3.2 Development of Ambulatory-based Sensor Module using MEMS (Micro Electro-Mechanical Systems) Sensor

To develop MEMS sensor to attach to the insole, this study performed function design first and then selected parts used for the designed items. Last, it materialized the final insole through artwork and PCB manufacturing work. Figure 2 shows PCB design and manufacturing processes of the product.

3.2.1 Motion Recognition

Motion recognition requires highly efficient hardware that can perform multi-linking functions on the basis of highly performing and distant communication technology (e.g. Bluetooth 4.0) and that adopts Micom consuming low electricity based on MEMS, on-Chip ASIC or RISC. Using Bluetooth 4.0 communication module that run with 2.4Ghz band can minimize the noise with other devices while using 24Bit CRC can maximize durability and transmit more than 100m far. To recognize pausing, triaxial gravity and tilt should be sensed and calculated tilt to provide information of posture estimations, posture holding time and alarming for posture correction. For recognition of walking, walking status should be determined through walking status sensing, 6 axes-based acceleration, gyro-sensor signal processing. In addition, the correlation between convergence information processing of both feet and pre-defined pattern should be calculated for step count, stride, walking pattern and posture.

3.2.2 Communication Protocol

InSole BLE refers to the board that consists of Bluetooth and MEMS sensors installed in Insole and App refers to the application that links to Insole BLE of a smart phone. This study conformed to the communication protocol for Insole_

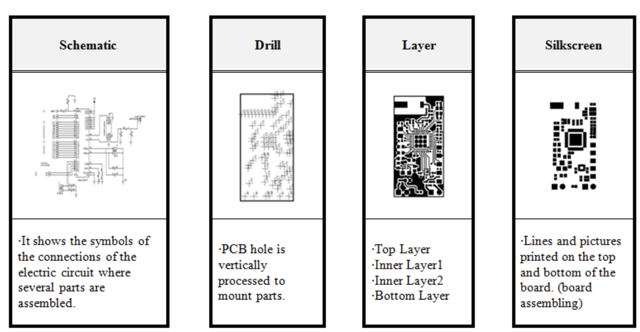


Figure 2. PCB manufacturing process.

BLE board and smart phone App. BLE (Bluetooth 4.0) was used as a means of communication and Insole_BLE was installed in the right and left side, respectively.

3.2.3 Data Format

Figure 3 shoes the format of the data transmitted from Insole BLE.

Step count, vertical angles between steps and directional acceleration were obtained by calculating walking posture every 30 minutes. The collected data was created every 30 minutes and saved in memory device before App was connected. When App was connected, the saved data up to then was sent in data set to App. For example, if App is connected at 13:00 and reconnected at 15:00 when 4 data sets (13:00~13:30, 13:30~14:00, 14:00~14:30 and 14:30~15:000) have been created in Insole BLE, they are transmitted to App at 15:00.

3.3 Development of Self-care Guide Application

Using body pressure information, a smart application was developed to apply UX. Because simple output can't satisfy user's needs and interest, UX was applied to develop necessary UI. An experimental UI applied with UX was derived through theoretical design based on link structure and UX was tested for satisfaction through testing 10 specimens and the satisfaction was divided into 5 levels. For development versions, it supports API8 ~ API16 (Ice-cream, Sandwich)/IOS and Window XP/7/OSX. It uses Eclipse and ADT Bundle as program and C-language as App language to develop Java and AVR. Last, when a smartphone equipped with Bluetooth function requests for transmission, the application responds to it. The transmitted data are received to the application and saved in the database. The self-care guide application includes such personal activity coaching as sensor communication, display of major information, calculation of actual motion information, display of motion amount, motion start/end, history of motion amount, alarming of motion result, motion target setting, personal profile setting and device search and setting.

8 byte	2 byte	2 byte	2 byte
(Start)Time Tag	Step Number	Averaged Vertical Acceleration for stride phase	Averaged Directional Acceleration for stride phase

Figure 3. The format of data transmission.

For synchronization, it is connected to the devices to both sides and inquires data and records inquired data in DataBase. Step count is displayed in sum of 24 data values. Height information, which a user opens in user's profile, is used to get index and calculated by step account*index. Calorie is computed with the interval between the starting time and ending time of data*calorie index by motion. Impulse is computed with impulse received from a device*impulse index. Target performance rate is displayed in image, based on daily 10,000 steps. Selected motion is recognized and its start time is recorded. Progression time is displayed by a stopwatch for motion start. Step count, moving distance and are calculated and displayed during motion. Motion pausing stops the stopwatch and inquires the date created during motion time. The inquired data is stored in DataBase. Posture is expressed in impulse (received from the main screen)*fatigue index. For measuring posture, forward/backward and left and right tilts are displayed in image. Health information displays calorie consumption, moving distance, weight, BMI, step count and target performance rate of the date a user chooses. Motion statistics are displayed on weekly, monthly and yearly base. Personal profile can be registered and modified in setting. Unit setting is for height, weight and distance. Device setting includes searching and connecting to left and right device. Data initialization is to initialize motion information saved in DataBase. Profile setting includes photo, surname, name, sex, height and weight in the personal profile.

4. Conclusion

As such market as health care and wellness has rapidly grown and IT technology ever develops all over the world, the growth of wearables market is being accelerated to maintain postural balance and manage motion information. Furthermore, the government chose global health care market as a new growth engine sector as part of regulatory reforms to realize future creative economy. As a result, wearable health care products in which manufacturing and IT are integrated are more demanded ever and paid more attention. Although many wearable products that measure and manage motion information have recently been introduced, they are limited to the extent they are used only to monitor motion information such as calorie consumption and walking schedule management like a passometer and the data produced by them are not different by the location they are worn.

For the present study, Bluetooth communication and sensing technology-mounted smart insole was developed. In addition, a wearable sensor module combined with mobile and signal processing technology was conceived and embodied. With these, the algorithm for postural balance and motion information was proposed. Finally, an application was completed utilizing all of those. This smart insole synchronized with a mobile device provides basic information analysis necessary for healthcare mobile infrastructure as well as diverse information for smart health care and can be used for the impact analysis of pressure balance on body parts below joints or lower body.

In future, smart insole system is expected to lead to the development of a personalized or illness-customized insole and smart healthcare coaching application for foot. As a result, it will evolve into intelligent smart insole products to preoccupy future health care industry.

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