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Study of Wearable Smart Band for a User Motion Recognition System

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Abstract

Improvements in technology and the advent of smart devices have led to the development of smartphones, tablets, and smart TVs. Further, in recent years, wearable devices have gained considerable research attention. In addition, the increasing interest in the field of healthcare has resulted in an increase in the research and development of wearable healthcare devices. Wearable devices that are incorporated into clothes and accessories allow individuals the free use of their hands. The basic concept of these devices—a device that can be worn instead of being carried—supplements the intellectual capacity of a human; therefore, in this paper, we aim to implement a computing environment to integrate large-scale equipment with these devices. In order to respond to user needs in real time, it is necessary to develop wearable devices that ensure the user's safety. Further, to reduce the discomfort of using multiple devices, wearable devices should be compatible with other devices such that only a single device is necessary. Therefore, in this paper, we combined a smart TV, wearable smart band, and smartphone to enable the user to effectively store physical information; moreover, we developed a system to manage this information.

Keywords: *Wearable, Health-band, Smart TV, Smartphone, Healthcare*

1. Introduction

Wearable technology implies the use of items that are worn by individuals rather than digital accessories that are simply attached to an individual's body. Such technology enables a person to access digital machines located nearby. Presently, wearable technology is receiving significant attention worldwide and is regarded as mobile technology that could replace smartphones in the future. People have become aware of wearable technology; consequently, smart device developers have begun releasing various wearable devices [1].

The applications for wearable devices are currently concentrated in the healthcare field. The benefits of a device on the body that can be freely attached and detached has spurred an interest in human health. The wearable device collects the movement information of the user to provide services. Furthermore, by integrating additional devices (*i.e.*, cell phones, TVs, or tablets) with the smart device, it is possible to expand the range of services [2].

Given this trend, we have developed user motion-aware smart bands that use these recently-developed wearable device technologies. The goal of our proposed device is to recognize human motion with a wearable device similar to a wristwatch; we also propose different applications that can be installed on smart TVs or smartphones so that users can transfer their recorded motion data. We aim to build an effective user-motion recognizing system by integrating different devices with wearable devices. The resulting design and development of these wearable devices and their applications are presented in this paper.

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2. Related Studies

2.1. Wearable Devices

Currently, the global smartphone market is showing a slower rate of growth compared to previous years. Presently, wearable devices are considered the most promising mobile technology to replace smartphones. Wearable devices are digital devices that users can wear. However, such devices comprise not only those devices that can be attached to human bodies, but also those devices that can be installed very close to human bodies. The most noticeable advantage of wearable devices is that they can collect various data regarding the surrounding environment and human body in real time. Wearable devices are expected to become the next significant area of growth in the smart devices market and will benefit from integration with other devices [3-4].

Recently, MIT (Massachusetts Institute of Technology) listed the smart watch as one of the ten breakthrough technologies of 2013 in Technology Review; this demonstrates that wearable technology is receiving much attention worldwide as the most promising post-mobile technology [5]. The growth rate of particular types of wearable devices will vary depending on their market performance. Even if the entire market does not grow significantly in the near future, the healthcare market will be promising until 2016. According to IMS Research, wearable devices are becoming the most essential devices in the healthcare market. Among the many types of devices worn on various parts of the human body, wristbands and glasses are the main types that are being developed; however, several different wearable devices are also being considered [6-7]. Several of the major research institutes show positive responses to the growth of the wearable devices market. IMS Research indicates that wearable device shipments worldwide will be 39–171 million in 2016. Among regional markets, the United States will continue to lead the worldwide wearable device market and Europe is expected to become the second leading market. Japan also shows strength in the infotainment industry, and will soon become a part of the major wearable device market.

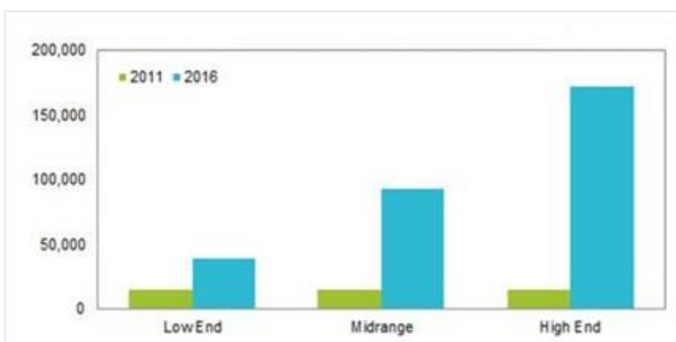

Figure 1. Worldwide Shipment Growth Prospects of Wearable Devices by Scenario

The graph in Figure 1 was recently released by Open Mobile Media and Research in the East Region [8]. According to this graph, wearable devices are poised to become a significant product in 2014. When examining the graph in Figure 2 closely, it is clear that all the items in the graph can be implemented as wearable devices. In fact, healthcare functions, mobile wallets, connected cars, and connected TVs are applications and devices that consumers would like to use at any time and that already work with different smartphones; furthermore, the desire to access such functions more conveniently will make consumers notice wearable devices [9]. In other words, consumers would strongly like these functions to be installed in their devices, and would like devices with such functions to be attached to their bodies so that they can continuously access the devices and functions [10]. With the ability to have continuous access to such functions, consumers will to receive important data filtered by their devices in real time.

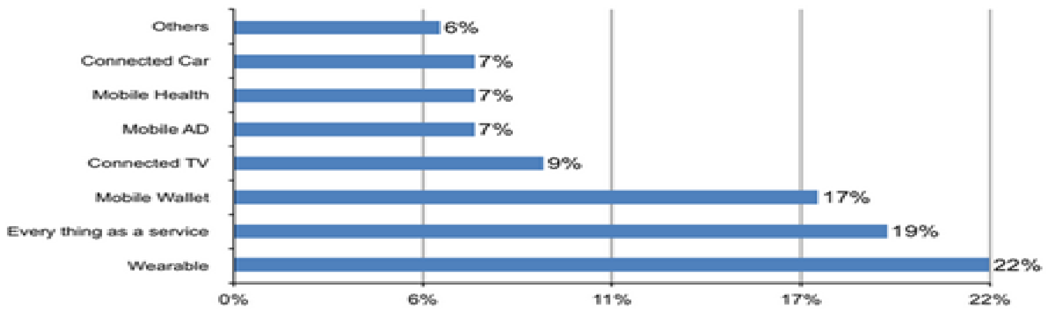

Figure 2. Significant Products in 2014

The reason wearable devices are receiving such significant attention is that wearable devices will be the highest selling devices in the Internet and Technology market after smartphones and tablet PCs. Most research institutes agree that wearable devices will contribute to the next smart device market and fusion activation [11]. In addition, with the advent of 5G and the Internet of Things (IoT), technical concerns faced by wearable devices such as battery life, flexible design, and user interface/user experience design (UI/UX) are rapidly being resolved; moreover, network infrastructure will become more stable in the future.

3. System Development

3.1. Software Model

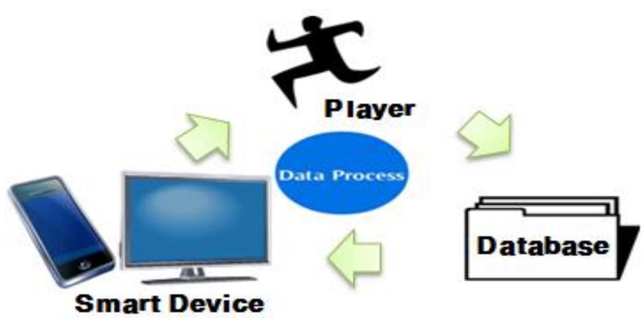

Figure 3. Data Transfer Process

By entering an appropriate exercise goal directly into the wearable device before a practice session, the user can follow the instructions and concentrate on the exercise. It is then possible to connect the user's smartphone to a smart TV, regardless of where the user is exercising, and store the information in a database. In principle, the health band is attached to a body part that depends on the exercise being performed. When the user begins exercise, his/her movement information is transmitted to a smart device such as a smart TV. By analyzing the information transmitted, storing the data, and increasing the exercise count along with the user's motion, the smart TV can display the exercise results in various ways. The data transfer process (shown in Figure 3) is as follows.

① The user wears a smart band to the appropriate location depending on the type of exercise.
② Exercise is started.
③ Exercise is finished.
④ User motion information is stored in the server database.
⑤ The user's motion information is output to a smart TV or smartphone.
⑥ The user can view their motion information.

The smartphone application may be configured as shown in Figure 4. When a user executes the application, it is possible to directly select the type and target amount of movement. The user is then ready to exercise by putting on the smart band. The smart band informs the user how much exercise has been completed. When the session is finished, the recorded movement data is saved. The data can be graphed so that the user may easily view their workout history.

Figure 4. Smartphone Application

A smart TV can perform the functions of a smartphone. However, although the smartphone can be used anywhere in conjunction with the smart band, the smart TV is limited to mainly home use. All movements except for running can be used with the smart TV. In order to use the global positioning system (GPS), running movement must be measured by the smartphone, although running data may be uploaded to a smart TV. Figure 5 shows the output screen of the smart TV application.

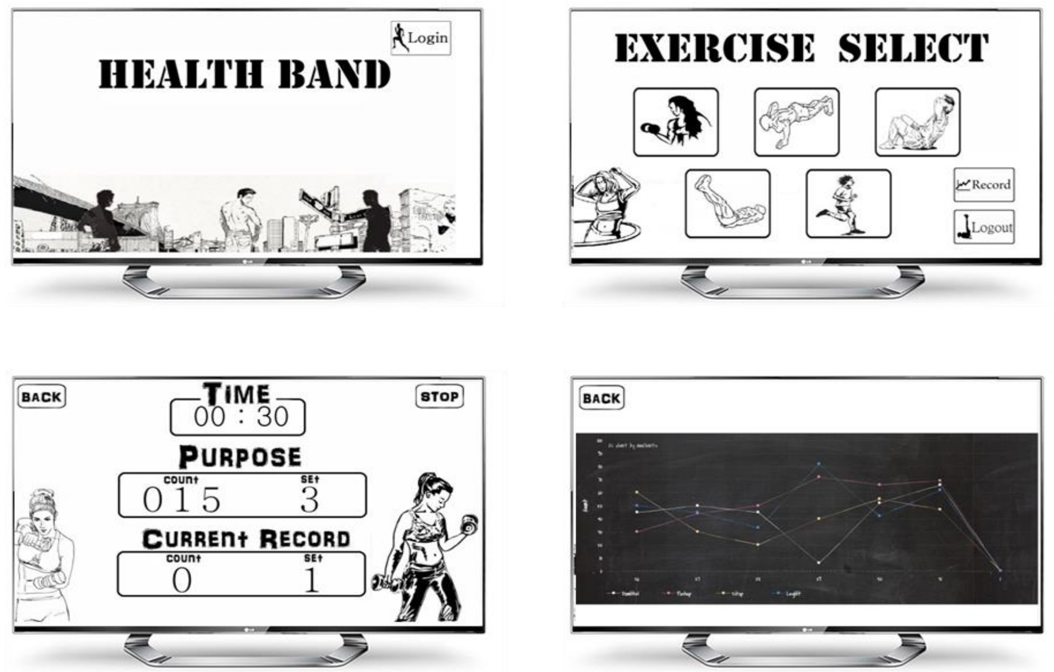

Figure 5. Smart TV Application

The user can select his/her preferred movements. If the user selects a particular mode, the proposed system recommends an exercise routine that is associated with that mode. The application also provides a description of the exercise method, as shown in Figure 4. By providing the right method and dynamic posture required for the exercise, the application helps the user gain the most from their workouts. Moreover, once the exercise is complete, the application can display the exercise duration, number of times a set was repeated, and calories burned. Table 1 is design of the databases.

Table 1. Design of the Databases

Table	Record	Collation	Comment
Dumbbell	11	Utf-general-ci	Information recorded on the dumbbell
Leglift	11	Utf-general-ci	Information recorded on the leglift
Member	6	Utf-general-ci	Information recorded on the users
Pushup	11	Utf-general-ci	Information recorded on the pushup
Run	11	Utf-general-ci	Information recorded on the run
Score	6	Utf-general-ci	Information recorded on the score
situp	11	Utf-general-ci	Information recorded on the situp

3.2. Hardware Model

A variety of wearable devices such as smart glasses or wristbands have been developed and either been released or are currently scheduled for product release. Products have been developed for clothing, sports, health, education, and games in a variety of sectors. Launched smart watch products have so far had weak sales. Hard, rectangular smart watches are in fact not selling more than expected. However, the Nike Fuel Band, by incorporating health functions, has had sales volumes better than we anticipated. Because health-related products sell well, there is much interest in them. This product is also more comfortable to wear than other smart watches.

In this paper, we propose a system developed for a smart band that works in conjunction with smartphones and smart TVs to record and manage user movement information. The proposed smart band uses a built-in gyro sensor to recognize and measure a user's motion (shown in Figure 6). Gyro sensors incorporate a gravity sensor. Existing sensors can detect horizontal and vertical movements; they can also detect acceleration by sensing gravity. Gyro sensors recognize movement of the device, such as horizontal (left and right) and vertical (up and down) movements. In other words, one gyro sensor can recognize height, rotation, tilt, and acceleration. It is possible to determine inclination and position after filtering out noise from the sensor acceleration values.

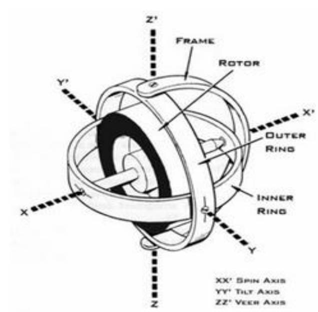

Figure 6. System Gyroscope

The gyro sensor is built into the smart band so that when the user is exercising, the sensor can record values that determine the user's motion. The user begins exercising after attaching the smart band to his/her wrist. While exercising, the gyro sensor measures various values so that the system can analyze the user’s data at a later time, make improvements to the training routine, and show the user how to improve. While the user is actively exercising, it is possible for the gyro sensor to determine the user’s momentum, whether the user can achieve the target value, and whether the user’s exercise posture is correct. Depending on the type of movement, the user can set a range of values for the gyro sensor that can be compared to the values the gyro sensor records when the user is moving; subsequently, this comparison can be used to determine the user’s posture. Hence, the user can request to be shown the best position for completing the exercise.

Figure 7 shows the Wi-Fi module and smart band. The user may wear the band in various locations according to the mode of motion and movement. The gyro sensor is built into the smart band, and it is possible to calculate the number of user movements. The Wi-Fi module of the smart band is also built-in so that the user can communicate with the server Wi-Fi. Data can then be transferred to the server via the Wi-Fi module of the smart band and the movement information of a user can be analyzed.

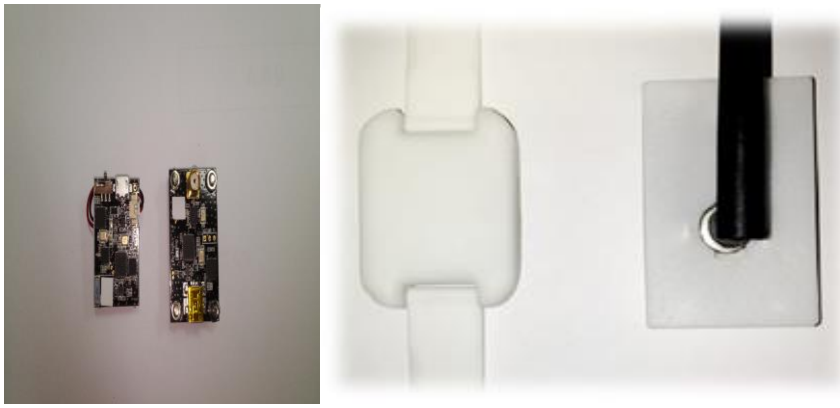

Figure 7. Smart Band and Wi-Fi Module

For example, for a biceps curl, the user attaches the smart band to the wrist. The band then moves up and down with the arm, calculates the number of movements, and records the elevation using the gyro sensor. In the case of push-ups, the smart band is attached to the arm and calculates the tilt of the gyro sensor when the upper body is moved up and down. Along with the smart TV and Wi-Fi module, a smartphone can provide information to the user. Smart TV, smart bands, and smartphones communicate via Wi-Fi to transmit and receive data. Data collected by the smart bands are stored in a database to analyze and manage the movement information of the user over the long term.

4. Performance Evaluation

4.1. Experiment

In the system proposed in this paper, it is necessary to accurately measure the number of user movements using the built-in smart band gyro sensor. The position at which the smart band should be worn is different for each motion mode. The range of the gyro sensor must be set at each location. With the range set, it is necessary to measure the number of user movements. In order to set a range associated with an exercise, the smart band was tested by wearing it and directly measuring the value of the gyro sensor at the start and end points of each movement. Table 2 lists the numerical values determined for each exercise.

Table 2. Ranges for Each Application

	Numerical ranges for each application		
	Roll	Pitch	Yaw
biceps curl	-82.70 ~ -78.74	-23.29 ~ -12.25	-164.73 ~ 117.33
pushup	-50.07 ~ 33.39	21.09 ~ 45.87	-110.82 ~ -90.26
sit-up	8.76 ~ 104.32	-18.45 ~ 57.98	152.49 ~ -55.93
leg raise	19.25 ~ 96.18	13.77 ~ -16.49	86.17 ~ 75.60

When a user wears a smart band for exercise, the number of movements within the range value of the sensor is observed. By monitoring the position for each exercise the smart band can correct the position of the user and improve their exercise. Figures 8–11 show screenshots of the measurement program used for this test. The left images show the sensor values at the start positions, and the right images show the sensor values at the end positions.

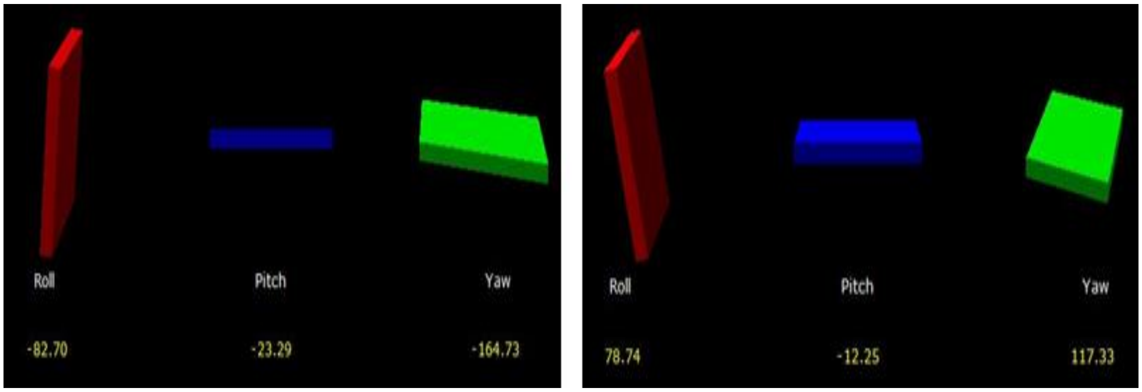

Figure 8. Biceps Curl Position Range

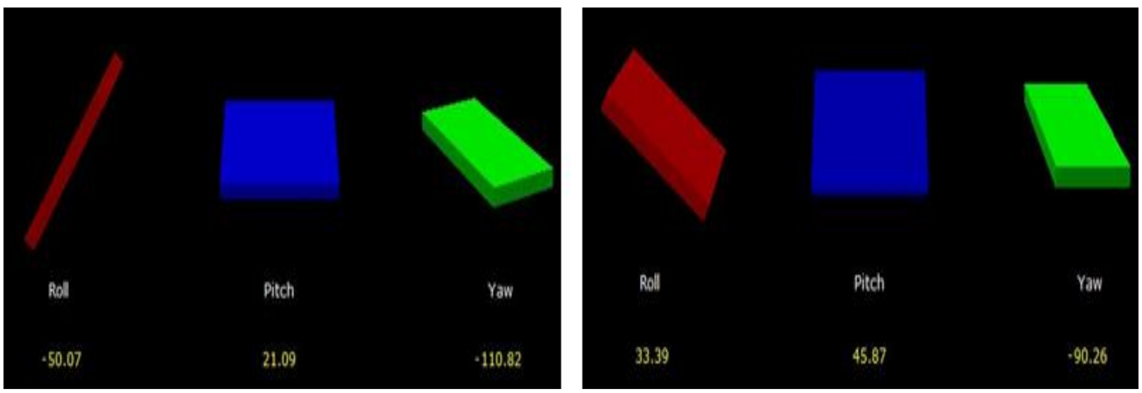

Figure 9. Pushup Position Range

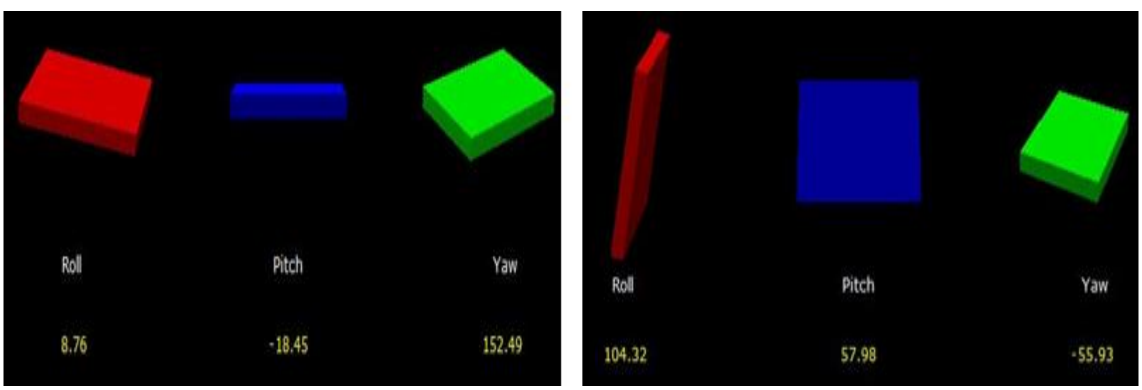

Figure 10. Sit-up Position Range

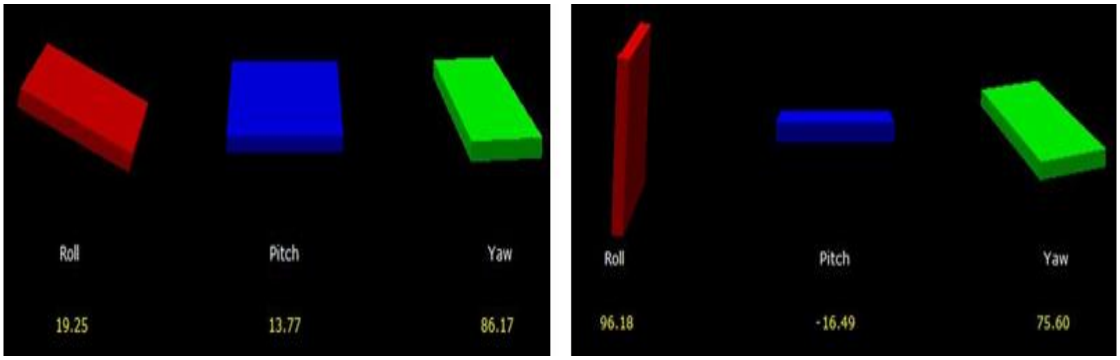

Figure 11. Leg Raise Position Range

4.2. Evaluation

To verify the accuracy of the measurement for each movement range, the number of movements measured by the smart band was compared with the actual number of movements. Over five days, test participants carried out five daily sets of 10 repetitions for each exercise. Table 3 compares the number of movements measured by the smart band with the actual number of movements.

Table 3. Comparison of Actual Movements Versus Movements Identified by Smart Bands

	Actual movements	Smart band measured	Error rate
biceps	1,750	1,726	1.42%
pushup	1,750	1,711	2.22%
sit-up	1,750	1,739	0.62%
leg raise	1,750	1,709	2.34%

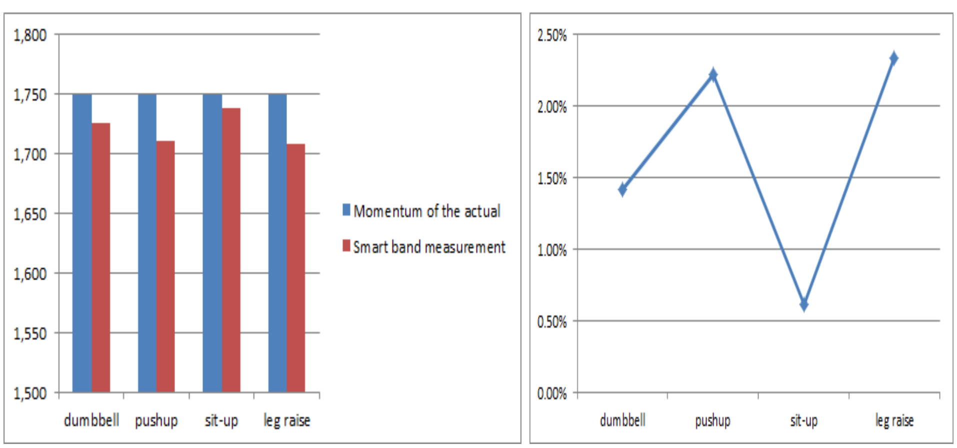

Figure 12. Number of Recorded Exercises and Error Rates

The results show that the number of motions may be measured using a smart band. An error rate of about 1–2% occurred for each exercise. The error rate can be caused by incorrect movements by the user as well as data transfer errors. The data transfer problems are a subject for continued research. When the movement count is not incremented, if it can be determined that something went wrong with the exercise, the user can be instructed to perform the motion again. Thus, it is possible to modify incorrect exercise habits of the user and assist him/her to exercise more effectively.

5. Conclusions

In this paper, we described the development of an application that integrates smart TVs and smartphones with wearable devices. In addition, the paper proposed the implementation of a gyro sensor to be used in wearable devices in order to recognize user motion. The user can then save their motion information using a smart TV or smartphone for further analysis. Five movements could be measured, depending on user selection. The gyro-sensor built into the smart band calculated the repetitions of an exercise. Results of the experiment show that there was a small error rate, but the recorded movements of the user were broadly correct. Research to reduce the error rate must be carried out. The smart band is equipped with a built-in Wi-Fi module such that data communication is possible and the exercise history of the user may be stored for further analysis. The user is able to wear the smart band and practice in any location as well as see a record of the movement on a smart TV or smartphone.

Wearable devices are the next generation technology that could replace smartphones and peripheral devices, and a diversity of applications that can utilize such devices has been studied. In the future, research must be conducted not only on motion recognition, but also on the use of wearable devices in the IoT environment. In addition, the best UXs and UIs for this application should be investigated.

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