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IoT Based Sensor-Integrated Swing Analysis System for Effective Golf Practice

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Abstract

Today many convergence services have been proposed in many fields such as technology for measuring the value of a sensor using the Internet of Things, technology for transmitting, technology for servicing an application, and technology for processing data. This study proposes a method to measure and analyze user data by incorporating IoT into golf, one of the popular sports. The current research of golf requires high performance cameras and sensors, and expensive equipment and places because it detects the movement of a golf ball or a golf club. In this paper, we designed a hardware to effectively detect the golf swing motion and embedded it in the golf swing exerciser. As the result, the detection error rate became about 3~4%, enabling golf swing practice at low cost. In addition, the individual data measured during golf practice can be stored in the network, which can be used to provide individual swing correction opportunities or develop into a multiplayer golf game.

Keywords*: Data filtering, Internet-of-things (IoT), golf swing trajectory, golf data analysis, wireless sensor.*

1. INTRODUCTION

IoT is a technology that converges sensing technology that measures values from sensors, networking technology that transmits sensed data, and information processing technology that processes received data [1,2,3]. In addition, various researches are being conducted in the field of sensor networks to utilize sensed data [4,5,6]. Currently, sensor technology is being used in various fields such as sports [7,8,9], and recently methods for measuring results and analyzing user characteristics by integrating IOT sensors with golf have been proposed [10, 11]. These research have limitations of placing a separate camera in a swing space or using a large number of expensive cameras or sensors. In this paper, we designed and implemented a sensor-integrated swing exercise instrument/hardware to efficiently measure/analyze golf swing data by incorporating 6-axis acceleration gyro sensor in the instrument.

2. RELATED RESEARCH

The current research mainly have focused on the method of detecting the movement of the golf club during the swing and the method of detecting the movement of the golf ball after hitting the ball. Most of these studies use sensing and camera technologies to detect and analyze motion. The study of detecting the movement of a golf club using cameras mainly measures the head of a driver moving at high speed in three dimensions [12]. This method requires marking process and has the limitation that the marking must be within the range recognized by the Line-CCD camera. Meanwhile, when using a sensor-based golf swing, a study has found that the golf club

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movement is related to muscle tension. This study draws conclusions by attaching EMG sensors to the human body and comparing them with muscle electromyography using CCD cameras and gyro sensors [13]. This kind of research requires the placement of many expensive sensors and their functions are limited. Some research has also been conducted to correct the golf posture of the beginners by attaching the acceleration sensor directly to the golf club and body [14,15,16]. However, data measured with ordinary acceleration sensors can be error prone, and high performance sensors are difficult to handle and expensive. In addition, sensors attached to the exterior of the club are at risk of being destroyed. A study on the practice apparatus for golf posture correction is also being conducted, but it depends mainly on physical signals, so its measurement is somewhat inaccurate and data analysis is impossible. This study proposes a method to measure swing data efficiently and reliably using 6-axis sensors instead of using multiple high performance cameras and sensors. In order to solve the limitations of the place, we used a practice swing apparatus shorter than the actual club, and the sensor was positioned within the club head for improved accuracy. In addition, we made it possible to utilize the analyzed data using an application.

3. SENSOR-INTEGRATED GOLF SWING PRACTICE ANALYSIS SYSTEM

3.1 Hardware Design

Figure 1 shows the hardware configuration of the proposed system. It is composed of Lithium ion battery to operate the board, LDO to transfer voltage to components on the board when voltage is applied, USB terminal to charge battery, LED to provide information to the user, speaker to output sound, Bluetooth for communication between mobile device and swing practice device, MCU and Mems sensors, I2C interface for communication between MCU and Mems, and GPIO to control of audio and LED.

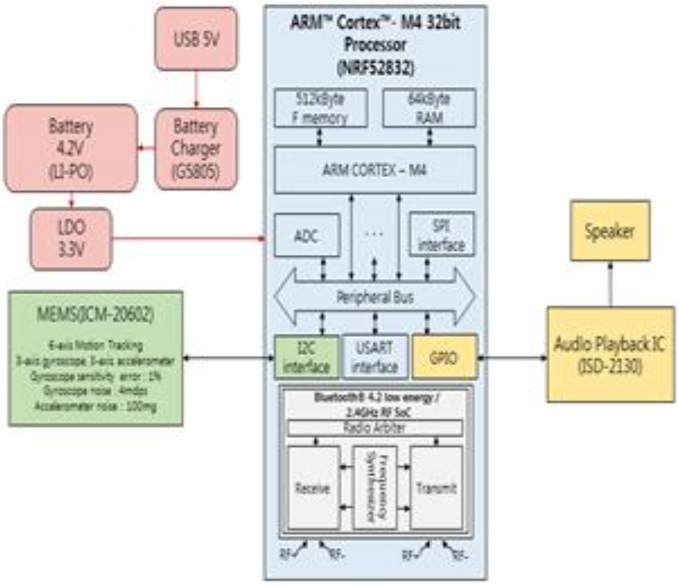

Figure 1: Hardware diagram

3.2 Firmware Design

A. Initialization of Swing Practice Device

When the system of the swing practice device is activated, it is necessary to set up the initial values for the Bluetooth connection, and execution of communication and functions. Acceleration sensor, Bluetooth, and board are initialized.

Table 1 shows three algorithms for initializing the swing exerciser

B. Bluetooth Command Confirmation

After the initialization of the swing practice device, it is ready to connect a mobile device for the Bluetooth communication. After the Bluetooth connection is completed, the Bluetooth command can be transmitted through the mobile device. Bluetooth commands include swing command, battery check command, head speed and golf club set-up command. Table 2 shows the algorithm for checking the Bluetooth command.

C. Swing Command

Swing practice mode starts when the swing command is entered, and then address

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determination process for address positioning, data collection process, data filtering and data transfer process are performed.

D. Battery Command

From the moment the system is first applied, the system continues to be in the On state. Since there is no start and end button, the user should check the battery from time to time and consider the situation.

D. Set-up Command

For the swing practice, the values necessary for the practice should be set. The head speed and the number of golf club the user wants to practice should be set.

Table 1: Three Algorithms for Initializing Swing Exerciser

```
// Algorithm  for Initializing Acceleration Sensor

BSP_Initialize (void) {
Acceleration_Initialize () {
i2c_init (); /* Initialization work for accelerometer and i2c communication */
Sensor_Setup (); /* Check if communication with acceleration sensor works and obtain information */
Sensor_Calibration (); /* save and correct initial data as base data */
}
}

// Algorithm for Initializing Bluetooth
BSP_Initialize (void) {
Bluetooth_Initialize () {/* Initialize Bluetooth Stack and Set Events */
ble_stack_init (); /* Bluetooth connection name setting and gap setting */
service_init (); /* Bluetooth service initialization and configuration (nus – nordic uart service) */
advertising_init (); // Set Bluetooth ad time and speed
conn_params_init (); /*Set parameters such as timeout when connecting to Bluetooth */
}
ble_advertising_start (BLE_ADV_MODE_FAST); /* set up the bluetooth ad and start the ad */
}
```

```
// Algorithm for Initializing Hardware Board
BSP_Initialize (void) {
Board_Initialize () {
BSP_gpio_init (); /* Board GPIO Settings (LED, Battery, External Interrupt, etc.) */
}
}
```

3.3 Software Design

In this section, the data received from the swing practice device are presented via application. After the acceleration and the gyro sensor values are obtained, intervals in the data are detected and expressed as the golf trajectory. The head speed is measured and converted into the flying distance.

Table 2: Algorithm for Checking Bluetooth Commands

```
//Algorithm for Checking Bluetooth Commands

Command_Parsing (uint8_t * data) {/* data: 20byte Bluetooth protocol based command */
switch (data [BT_COM]) {
case SWING:
system_status = status_address;
/* Change system status to address discrimination mode to enter swing mode */
break;
case BATTERY:
system_status = status_battery_check;
// change system status to battery check mode
break;
case SETTING:
system_status = status_head_setting;
// Change system state to head speed setting state
break;
}
}
```

A. Detection of Data Intervals

Intervals in the data, which are received from the swing practice device, are detected. Golf swings include backswing, downswing and follow swing.

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Figure 2 shows the change in acceleration vector. In this figure, the section ① is where the acceleration increases and decreases. This interval marks the backswing in which the device starts moving backwards in address mode. The down swing is defined as the interval where the device starts moving downwards to hit the ball in the top position after the backswing. It is the interval where the acceleration value increases until the maximum value as in the section ②. After that, ③ is the follow swing interval. It does not recognize and remove the data from the section where the data values change after the follow swing.

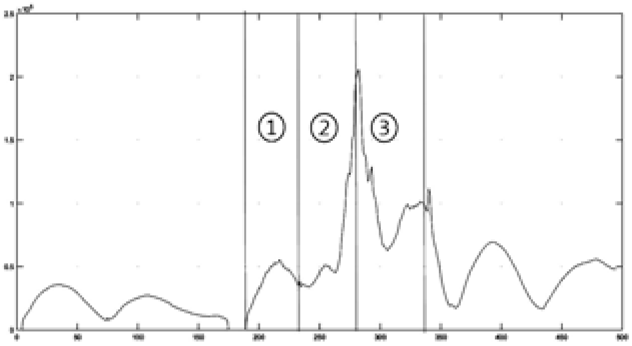

Figure 2: Changes in Acceleration Vector

B. Detection of Data Intervals

To detect the trajectory of data, we need to know the instantaneous velocity and position. The instantaneous velocity is the value of the vector as shown in equation (1), where the value of the vector is calculated by adding the value of the previous acceleration and the value of the previous vector, and then adding half of the value of the current acceleration minus the value of the previous acceleration.

$$Velocity(x)_n = Acc(x)_{n-1} + Vel(x)_{n-1} + \frac{Acc(x)_n - Acc(x)_{n-1}}{2}$$

$$Velocity(y)_n = Acc(y)_{n-1} + Vel(y)_{n-1} + \frac{Acc(y)_n - Acc(y)_{n-1}}{2}$$

$$Velocity(z)_n = Acc(z)_{n-1} + Vel(z)_{n-1} + \frac{Acc(z)_n - Acc(z)_{n-1}}{2} \quad (1)$$

After instantaneous velocity is calculated, the position is calculated by adding the previous position to the value of the previous vector, and then adding half of the value of the current vector minus the value of the previous vector as shown in equation (2).

$$Position(x)_n = Vel(x)_{n-1} + Pos(x)_{n-1} + \frac{Vel(x)_n - Vel(x)_{n-1}}{2}$$

$$Position(y)_n = Vel(y)_{n-1} + Pos(y)_{n-1} + \frac{Vel(y)_n - Vel(y)_{n-1}}{2}$$

$$Position(z)_n = Vel(z)_{n-1} + Pos(z)_{n-1} + \frac{Vel(z)_n - Vel(z)_{n-1}}{2}$$

(2)

$$Ellipse\_Modeling = A \times x^2 + B \times x \times y + C \times y^2 + D \times x + E \times y + F = 0$$

(3)

4. EXPERIMENT AND ANALYSIS

This section describes the analysis after comparison with the results of the experiment. For the measurement and comparison of the sensors, we measured a circle with a self test, Sensors were attached to the screen golf club, and the head speed and the flying distance were measured and compared.

4.1 Swing Sensor Accuracy Analysis

In order to test the sensor reliability of the prototype swing device, we compared the data of an actual circle with the measured data from the sensor. The swing device was mounted on the golf club tester, and a 360-degree circle was drawn to measure and compare sensor data.

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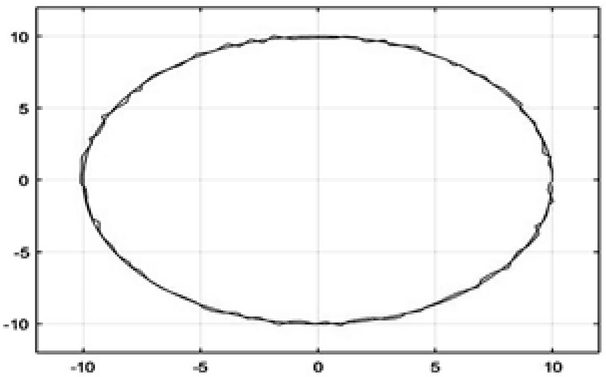

Figure 3: Circle Data Comparison

Figure 3 shows two circles close to each other. First, the uneven lined circle is the measured data, and the straight lined circle is the actual circle data. Instance values of the two data are shown in Table 3 below. The calculation of the error is shown in equation (4) and the error rate in (5).

Table 1: Instance Data of Circle Comparison

No	Experi_ment X	Experi_ment Y	Circle X	Circle Y	Error Rate
1	9.71338	2.377026	9.845932	2.436073	14.5%
2	8.472551	5.611862	8.389345	5.354784	9.3%
3	3.623578	9.320391	3.642726	9.24762	7.5%
4	2.092387	9.778646	2.012969	9.770431	7.9%
5	8.253356	5.646425	8.226017	5.62648	3.3%
6	5.651128	7.280455	5.210741	7.277464	3.7%

C is the actual circle coordinates and P is the measured circle coordinates. The average error rate was initially about 8%, but by repeating the test and revising values, it was confirmed that the error rate converged to about 3~4%.

$$Error_n = \sqrt{(C(x)_n - P(x)_n)^2 + (C(y)_n - P(y)_n)^2} \quad (4)$$

$$Error_{Percent} = \frac{\sum_1^n Error_n}{n} \times 100 \quad (5)$$

4.2 Head Speed and Flying Distance Derivation

The highest head speed value should be detected from the data received from the swing practice device. The acceleration vector is detected using equation (6). At first, the vector value of the detected acceleration is stored as the value of the head speed. Then every calculation, the head speed is detected by comparing the previous head speed with the current head speed and storing the higher head speed.

$$Vector_{accel} = \sqrt{a_x{}^2 \times a_y{}^2 \times a_z{}^2} \quad (6)$$

When head speed detection is completed, it is convert to flying distance by club. Table 4 shows the average flying distance for each club by head speed. Value of variables was calculated from the relationship between the head speed and the flying distance.

Table 4: Average Flying Distance per Club by Head Speed

Head Speed	70 (mi/h)	80 (mi/h)	90 (mi/h)	100 (mi/h)	110 (mi/h)
Driver	165.506 m	188.366 m	212.140 m	235.915 m	259.689 m
Iron # 6	104.241 m	119.786 m	134.416 m	149.047 m	164.592 m
Iron # 7	98.755 m	112.471 m	126.187 m	140.817 m	154.533 m

Iron # 8	91.44 m	104.246 m	117.957 m	130.759 m	143.560 m
Pitching Wedges	77.724 m	88.696 m	99.669 m	110.642 m	122.529 m

In general, systems using vision sensors must hit an actual ball. It can play golf game by additionally showing swing image, head speed, flying distance, ball speed, ball spin, etc. Increasing the number of vision sensors allows for more accuracy, while the cost is enormously high but there is still a gap with real golf [17-19]. However, the golf practice device with 6-axis sensor does not hit the real ball, so there is no restriction on the place. It can be used anywhere and guarantees convenience. It also provides a practice environment by providing the swing trajectory and head speed of the golf club, and flying distance of the golf ball. Difference from the actual golf can be large because it does not hit the ball, but the basic practice for the swing is enough, and there is an advantage that the golf game can be easily played without any environmental constraints.

5. CONCLUSION

In this paper, we proposed an IoT based golf swing practice analysis system. The research on golf swing data processing proposed so far has introduced the method of using high performance cameras, the method of attaching sensors to the human body, and the method of simply attaching sensors to the golf club. However, these methods have disadvantages in that it is limited in place, expensive, and inaccurate. In this paper, we designed and implemented a hardware of the golf swing practice device to improve accuracy of golf practice equipment and solve the limitation of expensive equipment and location. Through the golf swing practice device, it is possible to measure the trajectory of golf club, the speed of the club head, and the flying distance of golf ball without any place restrictions. In addition, it is possible to practice more accurately than the mechanical golf practice device, which is a swing exercise device. It is also at low cost since it is implemented using only 6-axis acceleration, gyro sensor modules. Moreover, because, using the IoT technology, golf swing practice device and mobile devices can transmit and receive data to and from other mobile devices or servers through Bluetooth communication, users can check and utilize the information of various and accurate golf swings suitable for him..

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