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Sensing Compensation for an Activity Monitor

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Abstract

One of the most popular types of personal health device is the activity monitor, which is attached to the user's wrist or waist in order to measure physical activity data such as exercise time/duration and calorie consumption. Given that it has an activity sensor and a gyro sensor to measure the speed of a user's movement, an activity monitor can also be used to track the movement of sporting equipment. The accelerator sensor in the activity monitor used for this study can measure up to a certain level. When the activity monitor is attached to a body part or slow-moving sporting equipment, the limit of the certain level is considered to be enough to measure the activity data. However, the peak acceleration of fast-moving sporting equipment may exceed the certain level. In this paper, in order to overcome the limitations of the sensor, the peak acceleration of the fast-moving sporting equipment is estimated using the interpolation method based on the acceleration values of the rest of the movement. Furthermore, it also describes how to calculate a swing surface.

Keywords*: Activity monitor, Moving object, Sensor, Interpolation, Peak acceleration*

1. Introduction

Due to the wide variety of PHDs (Personal Health Devices), the tasks related to PHD management have become more complicated than ever. There are various PHDs being used in the ubiquitous computing environment [1-5]. Some of the typical PHDs include oximeters, blood pressure monitors, blood glucose meters, activity monitors, SpO2 Monitors, and medication dispensers [6-14].

Given that it has an activity sensor and a gyro sensor to measure the speed of a user's movement, an activity monitor can also be used to track the movement of sporting equipment [15-17]. The accelerator sensor in the activity monitor used for this study can measure up to 24G. When the activity monitor is attached to a body part or slow-moving sporting equipment, the limit of 24G is considered to be enough to measure the activity data. However, the peak acceleration of fast-moving sporting equipment may exceed 24G. In this paper, in order to overcome the limitations of the sensor, the peak acceleration of the fast-moving sporting equipment is estimated using the interpolation method based on the acceleration values of the rest of the movement. Also, in order to provide various golf swing information, it is important to obtain the swing surface closest to the real movement path of a swing. Using the swing surface, it can be determined how accurately a swing has been made in this study.

The remainder of this paper is organized as follows. Section 2 discusses the related studies and Section 3 discusses an interpolation scheme to overcome sensor's monitoring limit. Furthermore, it also describes how to calculate a swing surface. Section 4 draws conclusions and discusses some future directions for research.

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2. Related Studies

Studies on tracing systems for moving objects using sensors in a PHD were conducted in [15-17]. Tracing a moving object is the process of recording the movement of objects. In [16], a handy system for tracing moving objects is proposed. The tracing sensors are attached to an object in order to calculate motion data of the object. Then the motion data is sent to a Smartphone or a PC using RF communication. The tracing system proposed in the paper can be used outdoors as well as indoors inexpensively. The movement tracing system proposed in the paper consists of a sensor module, a communication module and a display module. Figure 1 shows the structure of the sensor module of the system.

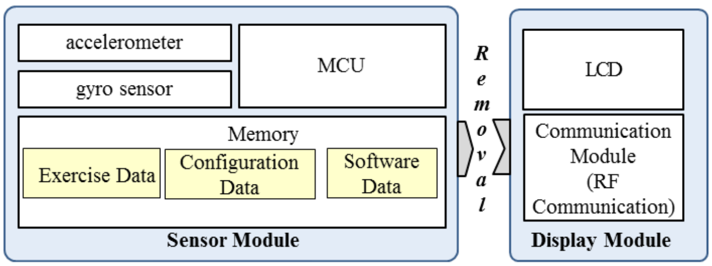

Figure 1. The Structure of the Movement Tracing System

The sensor module measure 300 movement data for 3 seconds. Figure 2 shows an example of the graph of the swing angle and the swing acceleration which can be obtained in the study. Among gyro 3-axises, the y-axis (Acc_y) represents the vertical movement of the object [16].

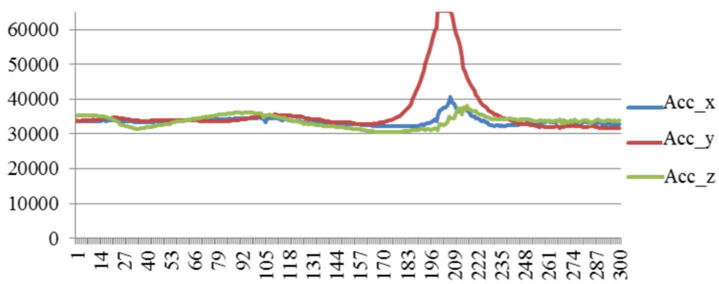

Figure 2. A Graph of the Swing Acceleration

The tracing system in [16] provides the graph of the swing angle and the swing acceleration of the moving objects. The tracing system in [16] provides the graph of the swing angle and the swing acceleration of the moving objects. The accelerator sensor used for this study can measure up to 24G (about 235). When the activity monitor is attached to a body part (*e.g.*, wrist or waist) or slow-moving sporting equipment, the limit of 24G is considered to be enough to measure the activity data. However, the peak acceleration of a golf swing may exceed 24G and the resulting graph may be incomplete.

In [17], a ubiquitous motion tracking system that tracks sporting equipment using the sensors installed in an activity monitor is proposed and constructed. The activity monitor with the tracking sensors can be attached to places on the body or on sports equipment to calculate the speed and acceleration of these objects. The ubiquitous motion tracking system consists of four modules: A tracking sensor module and communication module in an activity monitor, a communication module in a USB dongle and a motion analyzer module in a laptop PC, as shown in Figure 3. For experiments, an activity monitor with the tracking sensor module and the communication module is attached to a golf club, and a golf swing is taken. The results of the experiments show that the motion data of sporting equipment can be captured and analyzed easily, in both an indoor and an outdoor environment.

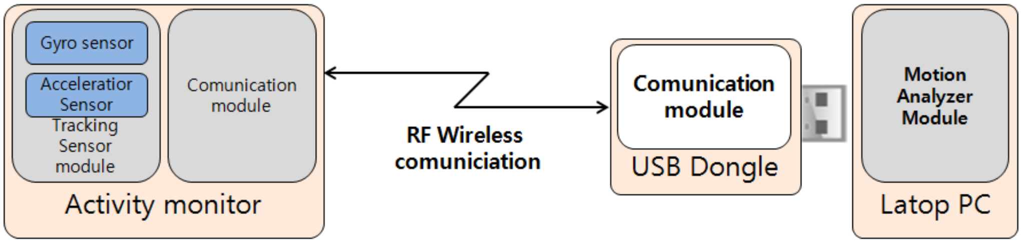

Figure 3. Structure of the Ubiquitous Motion Tracking System

For the experiments in the study, an activity monitor installed with the tracking sensor module and the communication module is attached to a golf club as shown in Figure 4, and a golf swing is taken. The USB RF dongle module is attached to a laptop PC to receive the movement information for the laptop PC, as shown in Figure 5.

Figure 4. Activity Monitor Attached to a Golf Club

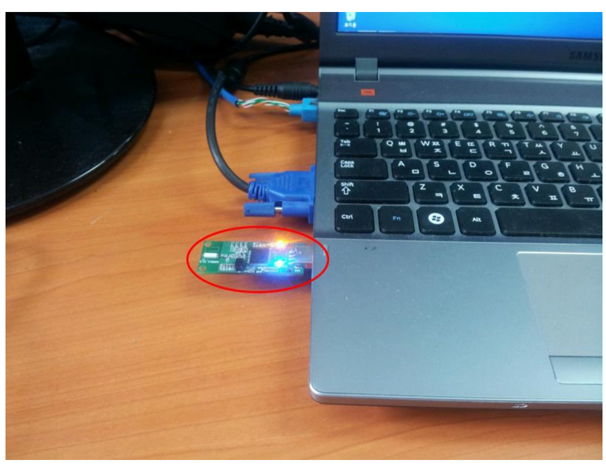

Figure 5. A USB Dongle Attached to a Laptop PC

3. Activity Tracking Analysis of the Activity Monitor

3.1. Swing Path Calculation

Movement data obtained from the acceleration sensor and the gyro sensor are local acceleration $\tilde{a}(t)$ and local 3-axis angle speeds $\omega_x(t)$, $\omega_y(t)$, $\omega_z(t)$ at time t. From these data, we obtain orientation at time t+h as follows:

$$\overline{R(t+h)} = R(t)\begin{pmatrix} 1 & -\omega_z(t) & \omega_y(t) \\ \omega_z(t) & 1 & -\omega_x(t) \\ -\omega_y(t) & \omega_x(t) & 1 \end{pmatrix}$$

$\overline{R(t+h)}$ may have incorrect orientation since the right-hand matrix becomes $1+\omega_x^2(t)+\omega_y^2(t)+\omega_z^2(t)$, which is always greater than 1. Therefore, polar decomposition [18] is performed on $\overline{R(t+h)}$ to get the correct orientation, as follows:

$$\overline{R(t+h)} = R(t+h)S(t+h)$$
$$R(t+h) = \overline{R(t+h)}S^{-1}(t+h)$$

For given local acceleration data, global axis acceleration can be obtained as follows:

$$a(t) = R(t)\cdot\tilde{a}(t) - g$$

Then, by using the Euler method (Wikipedia), the speed and position of the moving object can be obtained as follows:

$$v(t+h) = v(t) + h\cdot a(t+h)$$
$$x(t+h) = x(t) + h\cdot v(t+h)$$

We will assume that the initial speed and the initial orientation are as follows:

$$v(0) = 0$$
$$R(0)\cdot\tilde{a}(0) = g$$

3.2. Interpolation to Overcome Sensor's Limit

The accelerator sensor used for this study can measure up to 24G (about 235). When the activity monitor is attached to a body part (*e.g.*, wrist or waist) or slow-moving sporting equipment, the limit of 24G is considered to be enough to measure the activity data. However, the peak acceleration of a golf swing may exceed 24G. In order to overcome the limitations of the sensor, the peak acceleration of the golf swing is estimated using the interpolation method based on the acceleration values of the rest of the swing. For the interpolation, the Bézier curve [19] is used to obtain a smooth curve. As shown in Figure 6, the maximum acceleration value the sensor used in this study is 65520. Let t be the time frame when the acceleration value of the swing exceeds the measurement limit of the sensor (*i.e.*, when the interpolation begins) and t+k be the time frame in which the acceleration value of the swing comes down under the measurement limit of the sensor (*i.e.*, when the interpolation ends). Then, the acceleration values we have to calculate are $a(t+1), a(t+2), \ldots, a(t+k-1)$. The cubic Bézier control point can be obtained as follows:

$$P_0 = a(t)$$
$$P_1 = a(t) + \left(a(t) - a(t-1)\right) * \frac{k}{3}$$
$$P_2 = a(t+k-1) + \left(a(t+k-1) - a(t+k)\right) * \frac{k}{3}$$
$$P_3 = a(t+k-1)$$

Finally, the interpolated acceleration value at time t can be obtained as follows:

$$a(t') = P_0(1-\tilde{t})^3 + P_1(1-\tilde{t})^2\tilde{t}^1 + P_2(1-\tilde{t})^1\tilde{t}^2 + P_3\tilde{t}^3$$
$$\tilde{t} = (t'-t)/k$$

The final acceleration graph after the interpolation work is shown in Figure 7.

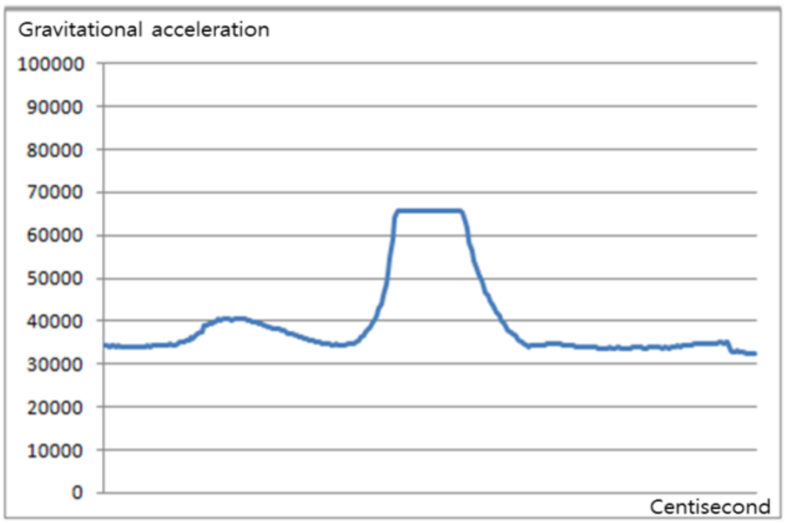

Figure 6. Acceleration Graph Before Interpolation

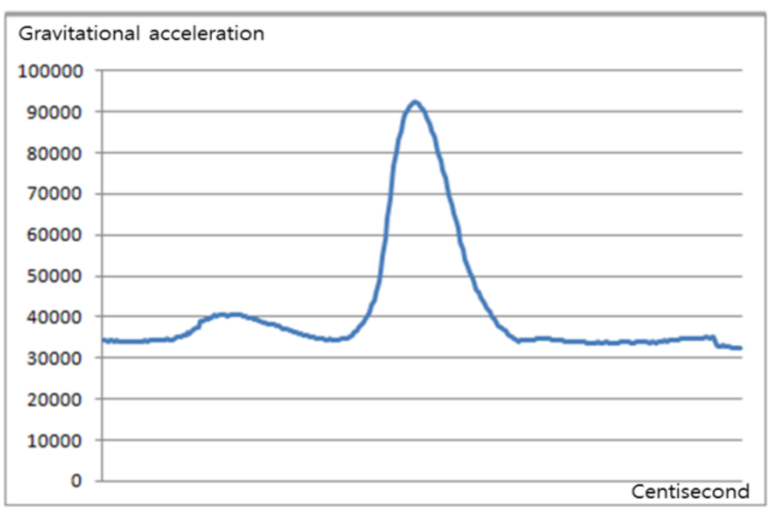

Figure 7. Acceleration Graph After Interpolation

3.3. Calculation of a Swing Surface

In order to provide various golf swing information, it is important to obtain the swing surface closest to the real movement path of a swing. Using the swing surface, it can be determined how accurately a swing has been made. To do this, the moving path is analyzed using the principal component analysis method [20] in order to obtain the basis vector as follows:

$$\mu + c_0(t)y_0 + c_1(t)y_1, \text{ where } c_0(t), c_1(t) \text{ are constants.}$$

Then a surface consisting of the starting point μ and the basis y_0, y_1 can be obtained as follows:

$$\mu + c_0(t)y_0 + c_1(t)y_1$$

Since the swing surface we have to find consists of points which are closest to the points on the swing path, it remains for us to find the starting point and the basis that satisfy the following equation:

$$\min_{\mu, y_0, y_1} \sum_t \|(\mu + c_0(t)y_0 + c_1(t)y_1) - x(t)\|^2$$

4. Experiment

The objects for which motion can be tracked include human body parts or sporting equipment. For this experiment, the activity monitor is attached to a golf club to track the movement of the golf swing, as done in [17]. The motion tracking display can be done by the swing analyzer of the monitoring server. As shown in Figure 8, the display shows a view of a golf swing. The swing lines are colored to show how fast the golf swing is at that time. The faster the swing, the redder the segment of the line. The brightest red represents the fastest swing.

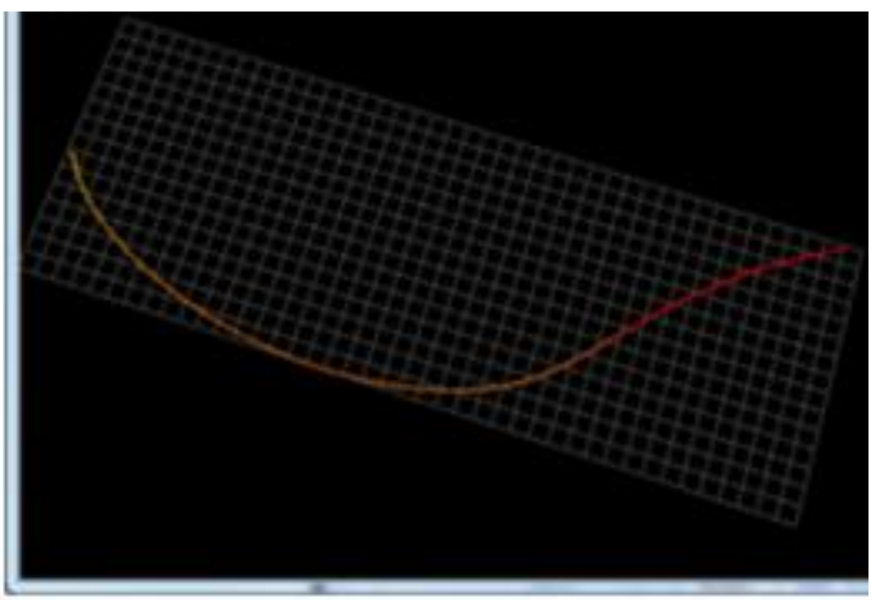

Figure 8. Motion Tracking Display of a Golf Swing

5. Conclusion

Given that it has an activity sensor and a gyro sensor to measure the speed of a user's movement, an activity monitor can also be used to track the movement of sporting equipment. The accelerator sensor in the activity monitor used for this study can measure up to 24G. When the activity monitor is attached to a body part or slow-moving sporting equipment, the limit of 24G is considered to be enough to measure the activity data. However, the peak acceleration of fast-moving sporting equipment may exceed 24G. In this paper, in order to overcome the limitations of the sensor, the peak acceleration of the fast-moving sporting equipment is estimated using the interpolation method based on the acceleration values of the rest of the movement.

In order to provide various golf swing information, it is important to obtain the swing surface closest to the real movement path of a swing. Using the swing surface, it can be determined how accurately a swing has been made in this study.

Acknowledgements

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