

Analysis of Golf Ball Mobility and Balancing based on IoT Sports Environments

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Abstract

Recently, IoT researches using sensor data based on embedded networks in various fields including healthcare and sports have been continuously attempted. This study analyzes golf ball mobility to support IoT application in golf sports field. Generally, since the difference in density occurs due to the condition of the inner material and the abnormal state at the time of the outer skin joining during the manufacturing of the golf ball, the weight of each subset is equal for any two points with the same radius in the sphere cannot be guaranteed. For this reason, the deflected weight of the sphere has the undesirable effect of hitting the ball in a direction in which the weight of the ball is heavy. In this study, it is assumed that there is a unique center of gravity of the ball, and even if the golf ball cannot be manufactured perfectly, it wants to establish the basic principle to accurately recognize or mark the putting line based on the center of gravity. In addition, it is evaluated how the mobility of the golf ball with a deviation from the center of gravity of the golf ball affects the progress path (or movement direction) and the moving distance (or carry distance) after the golfer hits. The basic model of the mobility of the golf ball can help the golfer exercise model and the correlation analysis. The basic model of the mobility of the golf ball can help the golfer exercise model and the correlation analysis.

Keywords: *IoT, Golf ball, Eccentricity, Eccentricity error, Center of gravity, IoT convergence.*

1. INTRODUCTION

There are various kinds of golf balls, which are golf sports equipment, and variously classified according to the purpose of use, color, and brand. The golf ball is composed of a core, a layer, and a cover, and the price of the golf ball increases with each additional layer. In the golf industry, such a layer is commonly called a 'PIECE'. The history of golf balls has evolved with changes in materials, composition and color [1]. Due to the difference in density due to the condition of the inner material in the manufacture of the golf ball and the abnormal condition in the outer shell joining, it cannot ensure that the weight of the two subsets of the same radius for any two points in the sphere are equal. This may be the result of uneven kneading of the endothelium, or uneven chemical bonding at the moment of fusion of the hemispheres. For these reasons, the

deflected weight of the sphere leads to the undesirable consequence of hitting the ball in a heavier direction [2]. Golfers refer to the putting line when putting on a drive shot or green. However, most golf ball manufacturers have drawn the putting line in a fragmentary approach, without considering the golf ball's center of gravity, mobility, and deviation angle. When golfers hit the ball, the ball must be distributed equally to the left and right sides of the ball [3]. If the ball is different from the left and right sides of the ball, the direction of the ball is shifted to the heavy side [2, 4].

In this study, it defines a weight space to track the center of gravity of a spherical ball, and assume that the center of gravity exists inside the ball and that it is unique. Next, assume that all planes including the geometric original point distribute the volume and weight correctly, and assume that the plane containing the origin point and center of gravity bisects the volume and weight of the unstable ball. This study aims at maximizing the straightness and carry distance of golf balls, and conducting straightness (deviation and separation distance) analysis and carry distance analysis [5]. Based on this analysis, the convergence evaluation of the golf ball with mobility is performed to identify the center of gravity line based on the center of gravity of the golf ball.

2. RELATED RESEARCH: GOLF BALL STRUCTURE

After the force of the golf swing in ten thousandths of five seconds, a golf ball of about 4.3cm in diameter and about 46g will fly more than 300 meters with wind resistance. This small ball contains hundreds of scientific technologies, including dimple structures, weights, materials and multi-structures, and is constantly changing and accelerating competition among manufacturers. There are various kinds of golf balls, and they are classified according to the purpose of use, color, and brand. Generally, 'layer' is called 'PIECE' as shown in the following Figure 1.

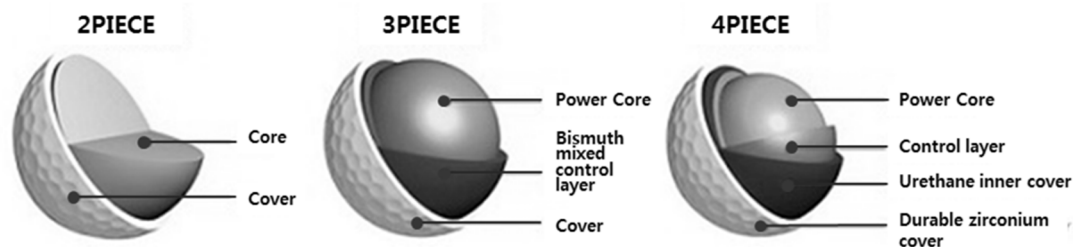


Figure 1. Multiple Layers of a Golf Ball

By the way, the golf ball is made of a multi-layer structure, so if you make multiple layers, there is a slight error in the thickness of each layer. If there is an error, the center of gravity will be on one side and this is called 'eccentricity' which corresponds to the deviation from the center of gravity as shown in the following Figure 2. As golfers routinely focus on swing problems, they don't realize that there is a problem with the golf ball's balance. In fact, according to the test results of 24,192 golf balls using robots, the golf ball manufacturer found that the average deviation was 6.4cm from the edge of the hole cup to the heavy side of the ball when putting 3m [2, 6].

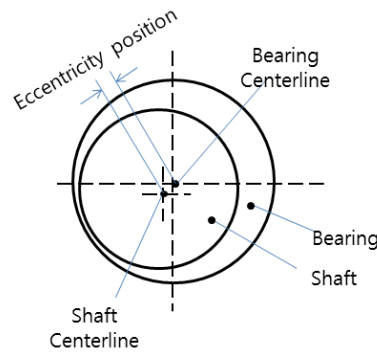


Figure 2. Center of Gravity and Eccentricity of a Golf Ball

Even if a golfer performs a shot or a putt correctly, the golf ball is deviated from the golfer's intention by the eccentricity of the golf ball, and it acts as a factor that indicates the limit and distortion of the player's performance improvement. If the golf ball in progress shows a hook or slice after the golfer hits the golf ball, the cause may be the golfer's striking position, the club's striking point, or the golf ball's eccentricity (deviation from the center of gravity). As a result, the driving direction of the batting is distorted.

As such, golfers are not only swing balanced but also the center of gravity of the golf ball. Therefore, most professional players and golf enthusiasts use the ball centered on the golf ball using brine before the game. Players believe that this principle allows them to control the golf ball in the desired direction [5]. This salt water is manufactured with purified water and specially developed main raw materials that can easily solve the method of catching the golf ball by checking the center of gravity. Even 150ml can be used to accurately center over 300 golf balls, and the period of use is permanent, providing a solution for good scores. In addition, several studies have focused on the analysis of the golf ball's motility based on the team's structure of the ball surface. [7-10].

The center of gravity check method using the brine is recognized as a good way to check the accuracy of the golf ball at rest. However, since the center of gravity of the golf ball in the state of movement by hitting changes dynamically or three-dimensionally, the stationary state of gravity checked in the brine is bound to have errors in the state of movement. Therefore, this study aims to establish the basic research for developing golf ball balancing device by analyzing and evaluating the change of the center of gravity of the motion state as well as the stationary state.

3. EXPERIMENT ENVIRONMENT

3.1 Evaluation Metrics

The purpose of this study is to establish various kinetic analyses according to the deviation angle of golf ball based on the following experimental assumptions. Table 1 below shows the definitions of the evaluation parameters used to analyze golf ball and hitting information in this study.

Table 1. Definition of Evaluation Parameters of Golf Balls

Variables	Metrics	Unit
A_l	loft angle	0~45 degrees
A_a	attack angle	0~45 degrees
A_d	deviation angle	0~45 degrees
V_c	club head speed	mph

V_b	back spin speed	mph
D_t	distance or total distance	m
D_c	carry distance	m
D_r	run (or running) distance	m
D_d	separation distance	m
V_d	drive head speed	mph
V_i	iron head speed	mph

The hit angle is more important than the hit speed. The ball speed mainly affects the carry distance, but the error of the ball angle has a big influence on the fairway settling rate and hole cup success rate. The error rate of the golf ball balance and the center angle of the ball is that when the golf club hits the golf ball, the kinetic energy of the golf club hits the golf ball and the kinetic energy of the golf club batter is converted into the kinetic energy of the golf ball. It affects the rate of energy loss. In other words, the higher the error rate, the lower the energy conversion rate (the inverse relationship). When a golfer hits a golf ball with a putter on green, the kinetic energy of the golf ball affects the distance of movement and the separation distance from the hole cup, depending on the friction coefficient of the grass. In this study, it is assumed that the friction coefficient of turf is constant in order to analyze the kinetic factors according to the variation of the center of gravity deviation of the golf ball.

4. ECCENTRIC ERROR AND FAIRWAY MOVEMENT CHANGE ANALYSIS

4.1 Analysis of Motion Characteristics of Iron Batter and Fairway

Figure 3 shows the names of the various angles involved (embossed, shot angle, deviation angle, etc.) when the iron club hits the golf ball. Here, the difference in the center of gravity according to the deviation angle of the golf ball gives a change in the embossing, as the deviation of the embossing increases the running distance is further reduced, acting as an additional cause of the decrease in running distance. In Equation (1), the sum of the embossment (A_l) and the deviation angle (A_d) has little effect on the run distance, but the change of the embossment and the deviation angle is inversely proportional to the run distance (D_r) and the separation distance (D_s).

$$(A_l + A_d) \propto \frac{1}{(D_r \pm D_s)} \quad (1)$$

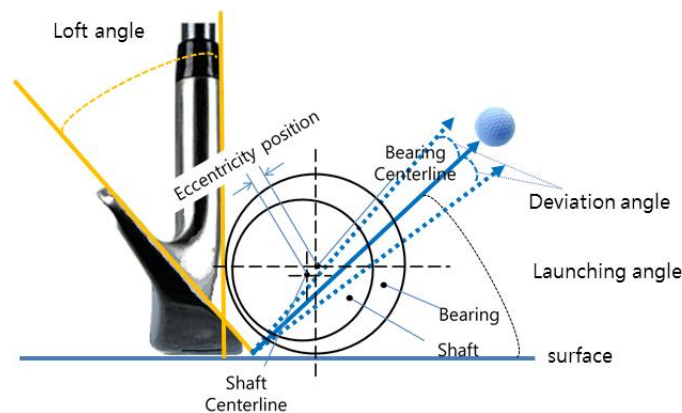


Figure 3. Angular Variation and Angle of Deviation Based on Angle of Deviation

Figure 4 shows the deviation (ε) model representing the separation distance of the landing point of the golf ball from the straight direction of the golf ball's hole cup according to the golf ball's reach distance relative to the deviation angle caused by the striking posture, the golf ball's center of gravity deviation, etc. Figure 4 shows how much distance error (ε) occurs from the direction of the hole-cup when the deviation angle of the golf ball occurs while paying much attention to the aiming.

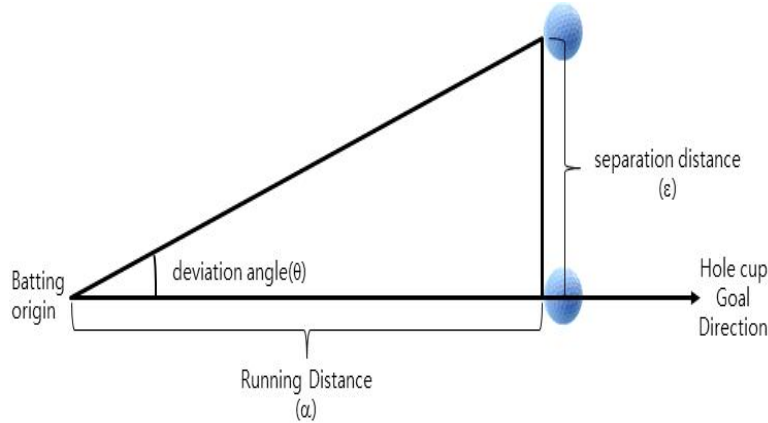


Figure 4. Deviation Angle and Separation Distance

$$\varepsilon = 2 \times \alpha \times \sin \frac{\theta}{2} \quad (2)$$

Although it is impossible to reflect 100% of the actual situation, Equation (2) shows the deviation function that gives an important criterion for establishing the separation distance (ε) for how far the deviation angle of about 1 degree is from the target line of the target hole cup direction.

Figure 5 shows the deviation of the separation distance according to the variation of the deviation angle (1 degree, 5 degree, 10 degree, 15 degree, 20 degree, 25 degree) for each case where the golf ball reaches 0 ~ 200m differently when the golfer hits the eccentric golf ball at the hitting point.

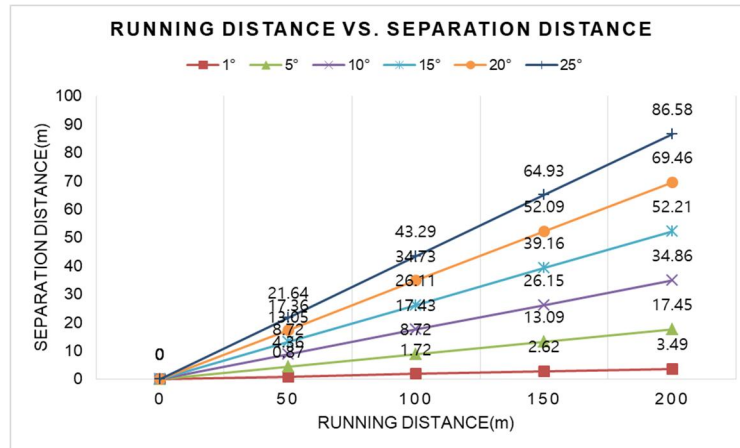


Figure 5. Distance to the Distance from the Variation of the Deviation Angle

4.2 Analysis of Fairway Distance Performance Index According to Attack Angle of Driver and Iron

In Figure 6, the head attack angle of the driver is about +5 degrees, indicating that the driving distance is large when hitting the golf ball. Of course, irons are -5 degrees not optimal, but in general, the larger the iron

number, the smaller the negative attack angle. In other words, the absolute value increases. Here, when the positive deviation angle ($+\theta$) affects the direction in which the attack angle is greater than $+5$ degrees, the carry distance increases and an over-run occurs. On the contrary, when the negative deviation angle ($-\theta$) affects the direction in which the attack angle is smaller than 5 degrees, the carry distance is reduced, resulting in a distance error in which under-run occurs.

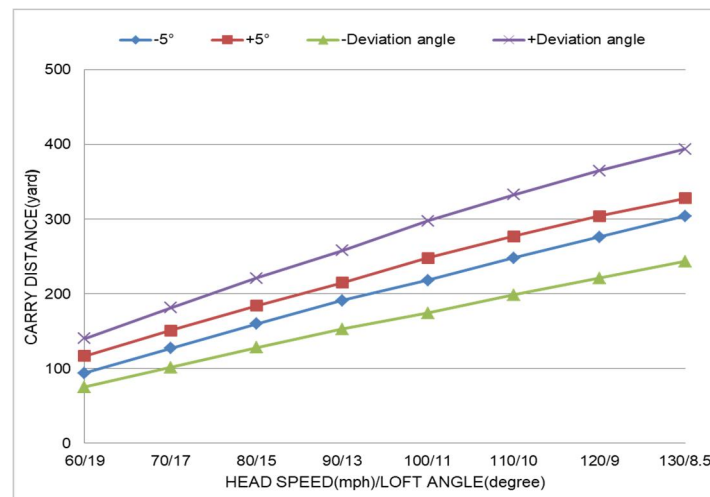


Figure 6. Flight Distance According to Optimum Emboss, Head Attack Angle and Deviation Angle with Driver Head Speed Change

Figure 6 shows that when the attack angle is $+5$ degrees, the carry distance is much larger than when it is -5 degrees. In particular, when the head speed is 100 mph, the carry distance difference according to the attack angle ± 5 degrees is the largest at 30 yards, but the difference according to the ± 5 degrees is generally about 26 yards. Figure 6 shows that, with the same deviation angle, as the head speed of the driver increases, the carry distance and the separation distance increase simultaneously, so that the positive and negative deviation angles have a greater influence.

Therefore, as the carry distance of the golf ball increases, the influence of the deviation angle has a greater influence and the separation distance increases, so that the golfer's golf ball balance needs are more urgent.

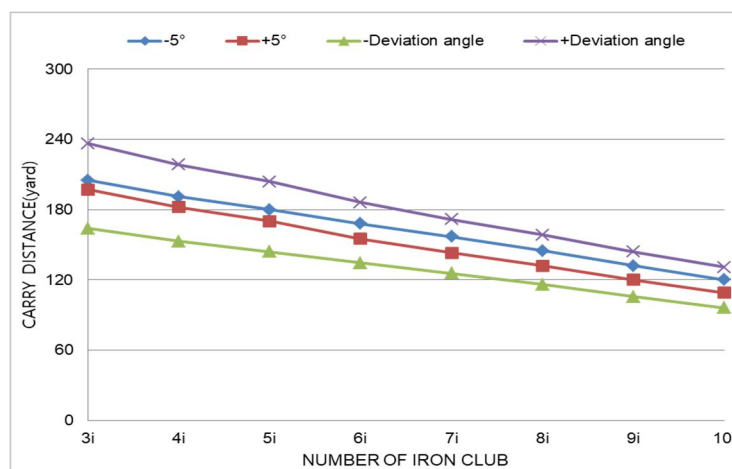


Figure 7. Flight Distance Change according to the Attack Angle and Deviation Angle of 3 to 10 Irons

Figure 7 assumes that the same deviation angle, the smaller the number of iron clubs, the greater the carry distance and the separation distance at the same time, which is shown to be more affected by the positive and negative deviation angles. Therefore, when the golfer hits with the 3rd iron rather than the 10th iron, the separation distance is increased by being more affected by the size of the deviation angle. So you can see that golf ball balancing is more necessary. According to the change of iron speed and attack angle, the driving distance of the 8th iron with ± 5 degree attack angle and deviation angle ($\pm\theta$) is represented graphically as shown in Figure 7. The iron will increase the carry distance by hitting the golf ball with a 5 degree increase in attack and deflection angles.

What is an attack angle? The attack angle is the vertical angle between the club face and the ground at the moment the club head approaches to hit the golf ball, the positive attack angle is to raise the golf ball while the negative attack angle is to lower it.

In particular, raising or lowering the golf ball hardly changes the spin value of the golf ball.

4.3 Analysis of Balancing Process and the Center of Gravity Convergence

The golf ball balancing device an automated device that searches for the center of gravity of the golf ball moving at a constant speed, displays the center of gravity converged, and optimizes the direction and range that the golfer to hit the center of gravity (the position where the deflection angle is minimized) of the golf ball.

This section defines a balancing model to minimize the influence of the deviation angle of the golf ball and describes the center of gravity convergence solution of the moving golf ball.

Figure 8 shows a model of the center of gravity convergence process according to the time course of the golf ball's rotational speed. Here, as the rotational speed of the golf ball increases, the time required to converge to the center of gravity of the golf ball decreases. In addition, when the golf ball rotation speed is constant, the larger the angle of deviation with the center of gravity shows that the more time it takes to converge.

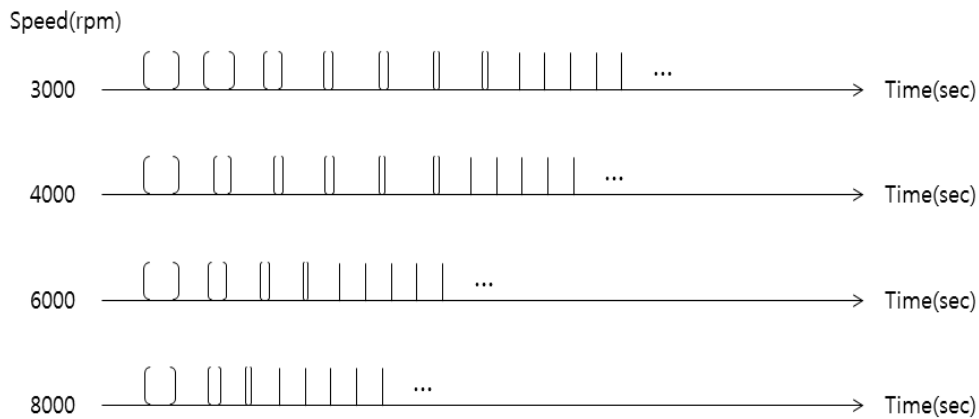


Figure 8. Correlation between Balancing Speed and Convergence Time

Figure 9 shows the rate of change of convergence time required to converge in the direction of the center of gravity according to the change in the center of gravity deviation of the golf ball when the rotational speed of the golf ball rotating in the balancing device changes from 3,000 rpm to 8,000 rpm.

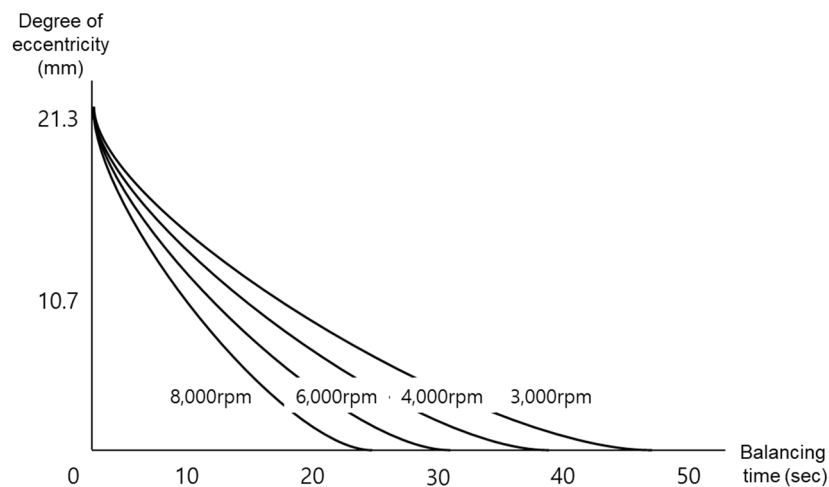


Figure 9. Correlation between Golf Ball Rotation Speed and Balancing Convergence Time

In Figure 10, the x-axis shows the balancing time it takes for the center of gravity to converge, and the y-axis shows the center of gravity deviation, which represents the deviation distance (degree of eccentricity) from the center of gravity of the golf ball. This graph shows that the greater the center of gravity deviation, the longer the balancing time that converges to the center of gravity. When the center of gravity deviation is 20mm, the center of gravity convergence time takes about 45 seconds, and in the case of 10mm, the center of gravity balancing time takes about 25 seconds. This graph represents the convergence radius (weight-center deviation magnitude) R , that is, the series of convergences at the center-of-center deviation x .

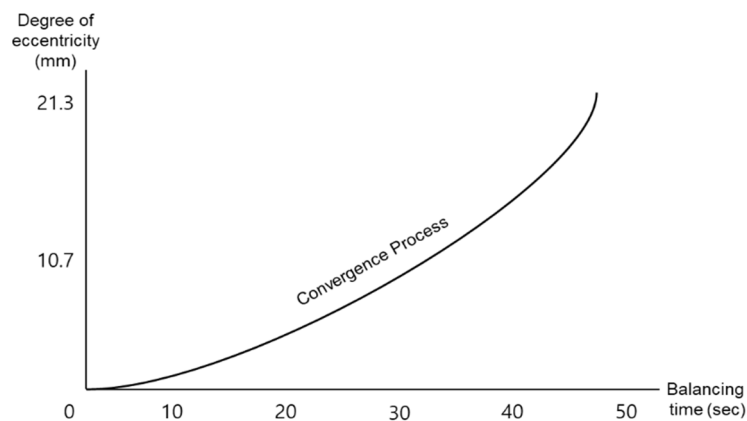


Figure 10. Convergence Process of Golf Ball Balancing and Center of Gravity

This convergence function can be expressed as a power series such as the following Equation (3). If the convergence radius R is given as a positive number or ∞ , the power series can be understood as a function defined above the convergence interval. This function becomes a polynomial function. So the function has properties polynomial.

$$f(x) = \sum a_n x^n = a_0 + a_1 x^1 + a_2 x^2 + \cdots a_n x^n + \cdots \quad (3)$$

5. CONCLUSION

This study analyzed and analyzed the deviation angle, flying distance, and separation distance when hitting the golf ball with the golf clubs. Assuming that the golf balls reach the same reach distance, the larger the deviation angle of the golf ball, the larger the separation distance with respect to the straight line in the direction of the hole cup. Golf balls having the same deviation angle have a longer error distance in proportion to the separation distance as the reach distance increases.

In conclusion, long distance professional players with longer reach and range are more affected by the golf ball's balancing index (or degree of golf ball's deviation angle). So pay attention to the golf ball balancing index.

In the future, it will develop a model to improve the mobility by analyzing the correlation with the golfer based on the mobility model of the golf ball.

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