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GOLF SWING ANALYSIS BY AN INERTIA SENSOR AND SELECTING OPTIMUM GOLF CLUB

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The purpose of this research is to build a system to analyse golf swing by using an inertia sensor and select the optimum specifications of a golf club for a golfer. As a result of analysing the relation between golf swing and the specifications of a golf club specializing in the mass characteristic, it became apparent that the specifications connected with the easiness of swing are; the moment of inertia and the length of equivalent simple pendulum of the golf club. The mass property to match each golfer can be specified if 15 parameters are obtained from the inertia sensor attached to the left back of the hand of a right-handed golfer.

KEY WORDS: mass property, gyro sensor, acceleration, Semantic Differential Method

INTRODUCTION: These past several years have seen a remarkable development in sensor technology. Lowe & ÓLaighin（2012）looked at the techniques used in the market including the sensor, and have discussed the possibility of the personal fitness "virtual trainer". Seaman & McPhee (2012) compared the measuring results of positions of the golf club on swing by inertia sensor with the results by motion capture. This study analyzed motion and was not aimed at researching matching sports equipment to uses. In the golf industry, it is popular to provide a custom-made fitting service, which identifies the golf club best suited for each golfer It is common to do a fitting by using a launch monitor so that there is an increased driving distance or an improved directionality to the golf ball. Naruo *et al.* (1997) measured the distortion of the shaft on swing, and have proposed the method of offering the optimal shaft flex. Until now, there have been few studies that show the relationship between the mass properties of the golf club and the results of swing analysis. Moreover, until recently it was standard to use camera equipment or a motion capture system to analyze swing.
In this study golf swing was analyzed using an inertia sensor, which consists of 3-axes gyroscope and 3-axes accelerometers. And the method was built to select the optimum specifications of a golf club for a golfer by using this inertia sensor.

METHOD: The swing was measured by the inertia sensor attached to the back of the left hand of a right-handed golfer. Initially, a sensor was also attached to the waist, but it was found that the feature of the swing could only be caught by measurements from the sensor attached to the back of the hand. Considering the cost and easiness of use, it was decided to use only the sensor on the hand.
The relation between easiness of swing and mass characteristic of a golf club was analysed by using the Semantic Differential Method (SD method).Easiness of swing defined subjective feeling to swing before impact. It was found that the specification connected with easiness of swing are; the moment of inertia and the length of equivalent simple pendulum of the golf club. In this study the mass properties were calculated from parameters measured by the sensor. These parameters indicate the characteristic of the swing of each golfer.
In order to prepare golf clubs with various moments of inertia and length of equivalent simple pendulum, 20g or 40g of lead was attached to a golf club at a position 295 mm or 400mm below the grip. Five kinds of mass property were arranged including a golf club without added mass and a longer golf club. The specifications of the 5 golf clubs are shown in Table.1.

Twenty expert golfers selected their optimal club after having swung the 5 different golf clubs. They answered the questionnaire, as shown in Table.2, and their answers were analysed by the SD method.

As shown in Fig. 1, the time series data was acquired on the swing by the inertia sensor attached to the back of the left hand of a right-handed golfer. The reason why the sensor was attached at this position is that the movement of the left hand is the most important movement for a golf swing and the characteristics of the swing can be extracted if the movement of the left hand is captured. The coordinate system is shown in Fig.2. The inertia sensor was made by Seiko-Epson. The maximum value to measure the accelerometer is ±24G, that of the gyro sensor is ±3000deg/s, and sampling rate is 1000Hz. Measurement data was transmitted to a personal computer by Bluetooth and analysed on that computer. The inertia sensor consists of accelerometers, gyro sensors, MPU, memory, and IC and it weighs only 20g. Therefore it does not influence the swing.

Table 1

Specifications of golf clubs for experiment

Club No	Club length(inch)	weight(g)	Weight location(mm)
1	46.5	0	–
2	45.5	0	–
3	45.5	20	295
4	45.5	20	400
5	45.5	40	400

Table 2

Questionnaire

Favorable	7	6	5	4	3	2	1	Unfavorable
feel light weight	7	6	5	4	3	2	1	feel heavy weight
easy to swing	7	6	5	4	3	2	1	tough to swing
good overall timing	7	6	5	4	3	2	1	bad overall timing
head return to setup position	7	6	5	4	3	2	1	head return not to setup position
comfortable swing	7	6	5	4	3	2	1	uncomfortable swing

Figure 1: Inertia Sensor

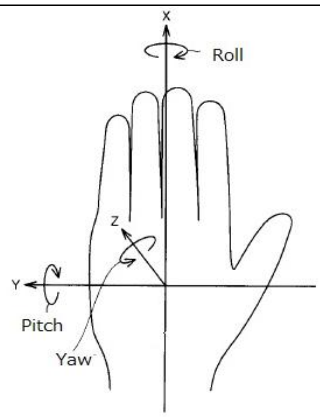

Figure 2:Cordinate system

RESULTS AND DISCUSSION: The questionnaire answers obtained from the 20 expert golfers after swinging the 5 different golf clubs were analysed by using the SD method. The results indicated that the first principle factor was favorability including easiness to swing. The second principle factor was evaluation of weight. Because the second principle factor is independent of the first, the feeling of weight a golf club has, can't be statistical correlated with ease of swing. Easiness of swing is related to the moment of inertia and length of equivalent simple pendulum. There is a value to each person's preference. The difference is derived from the swing. The characteristics of a golf swing can be expressed by data obtained from the sensor. Fig.3 is time-series data obtained from 3-axis accelerometers. Fig.4 is time-series angular velocity data obtained from 3-axis gyro sensors. Fig.5 is time-series angle data that integrated angular velocity. The characteristics of a golf swing can be captured by 15 parameters obtained from these three figures. Moreover, 15 parameters have a correlation with the mass property of a golf club that matches a golfer. If equation (1) and (2) obtained by the multiple linear regression analysis is used, mass property that matches a golfer can be calculated after swinging once. Firstly, a multiple regression equation was obtained from the 20 golfers' data. After that, 120 golfers' data including professional golfers was obtained and the equation was verified. 15 parameters represent feature of a golf swing, e.g. rolling of wrist and strength of uncocking. In conclusion it was possible to determine a 'good' golf club for an individual based on 15 parameters that were output from the inertia sensor. In this research we didn't confirm improvement of the score of a golfer who used the golf club that was selected in the method, we have no doubt that the score will improve.

Table 3
Result of SD method

		factor 1	factor 2
favorability	Variable 1	0.933	0.001
feel weight	Variable 2	0.058	0.973
easiness of swing	Variable 3	0.882	0.219
feel overall timing	Variable 4	0.918	-0.075
head return to setup posi	Variable 5	0.610	-0.236
comfort of swing	Variable 6	0.921	0.085
	contribution ratio	0.619	0.178

factor1 : overall favorability (including easiness of swing)
factor2 : feel weight

Table 4
15 parameters for selecting mass property of golf club

· accelerometer of Y direciton on impact
· angular velocity of roll direction on impact
· angular velocity of pitch direction on impact
· swing time
· downswing time
· maximum of roll angle (absolute value)
· maximum of pitch angle (absolute value)
· maximum of yaw angle (absolute value)
· maximum acceleration of x direction (absolute value)
· maximum acceleration of z direction (absolute value)
· change ratio of acceleration of x direction before impact (jerk)
· change ratio of acceleration of y direction before impact (jerk)
· change ratio of acceleration of z direction before impact (jerk)
· maximum of angular velocity of yaw direciton (absolute value)
· angular acceleration of yaw direction

$$I = X \cdot A_x + C_{xa} \quad (1)$$

where *I* denotes the moment of inertia, *X* denotes matrix of 15 parameters, A_x denotes matrix of regression coefficients, and C_{xa} denotes matrix of constant terms

$$L = X \cdot B_x + C_{xb} \quad (2)$$

where *L* denotes length of equivalent simple pendulum, *X* denotes matrix of 15 parameters, B_x denotes matrix of regression coefficients, and C_{xb} denotes matrix of constant terms

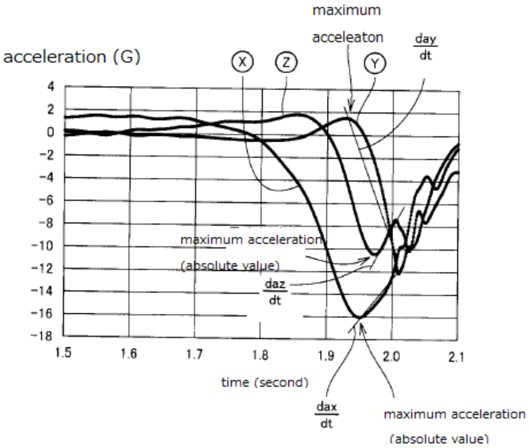

Figure 3: Result of measured acceleration

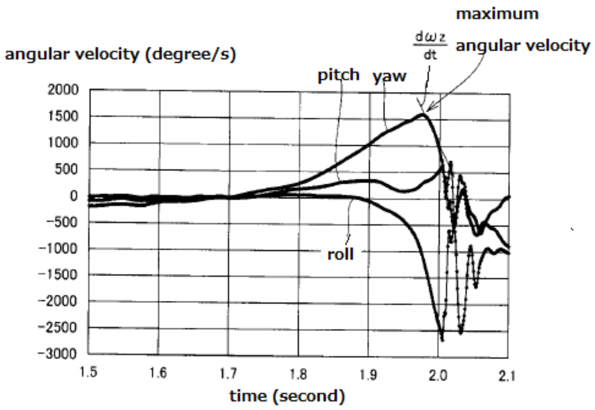

Figure 4: Result of measured angular velocity

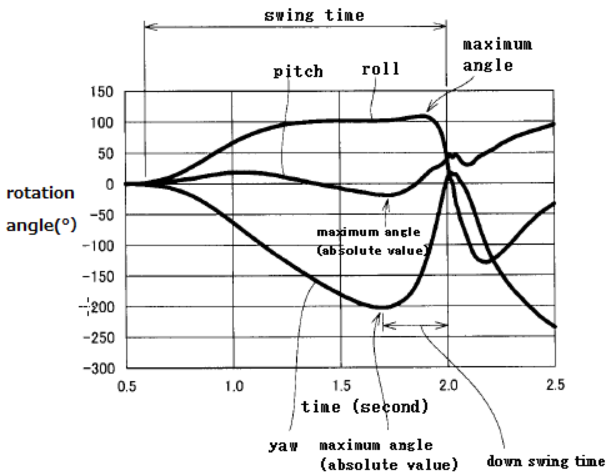

Figure 5: Result of calculated angle

CONCLUSION: The characteristics of a golf swing could be captured by measuring data with an inertia sensor attached to the back of the left hand of a right-handed golfer. A system to calculate the mass property of a golf club that matched a golfer was built. One swing by a golfer with the sensor attached to his hand, supplied sufficient data so that a custom-made fitting could be provided enabling the golfer to have a club that matched his swing perfectly.

REFERENCES:

Lowe, S. & ÓLaighin, G. (2012). The age of the virtual trainer. *Engineering of Sport 9,242*-247

Seaman, A. & McPhee, J. (2012). Comparison of optical and inertial tracking of full golf swings. *Engineering of Sport 9,* 461-466

Naruo, T., Saito, T., & Noguchi, S. (1997). Shaft selection aiding apparatus for selecting optimum shaft for a golfer*. United States Patent* No.6041651.