Smart Golf Ball with an Embedded Microsystem

MCEN 4228: Microsystems Integration

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Abstract—The smart golf ball will be embedded with micro-electronic components that integrates aspects of the game of golf into the palm of one's hand. A smart phone will be able to communicate with the golf ball to tell the player statistics about their game and help them track where their golf ball landed. The smart golf ball would allow for the game of golf to become automated allowing for faster play, reducing number of penalty strokes and helping the golfer improve their game.

1 Project Description

The game of golf, at times, can be one of the most frustrating sports to play, from lost balls, to keeping track of your score and miss calculating distances. By automating the game of golf many of the frustrating aspects of the game can be eliminated. Micro-electronic components embedded in the ball would communicate with a smartphone to tell the user various aspects of their game. Tracking flight, spin and distance of the golf ball could be achieved through microsensors. Microsensors could also be used to calculate the final score for the round. An embedded RF chip would allow for location of where the ball has landed. Finally, all of this data could be stored and sent to a smart devices over bluetooth. All this can inform the user of where their game is striving and what needs more work.

There are a few products today that are able to find golf balls. One product uses a Radar-Golf handheld that receives LCD/pulsed audio strength feedback from the golf ball when the player is with in 100ft of the ball[1]. The ball is enabled with a RFID chip. Another system tracks a golf ball by photo imaging. The imager uses 3.2 megapixels of precision imaging to locate the ball within a range of 35 feet if the ball is 1% visible [2]. However, all of these systems require extra equipment and are limited to just tracking a golf ball.

2 Design Concept

In order for the golf ball to incorporate all of these aspects the golf balls core must be embedded with a variety of components. These components include a sensor module, power supply, bluetooth chip, and RFID chip. To reduce the overall size these devices would need to be 3D packaged together as shown in figure 1.

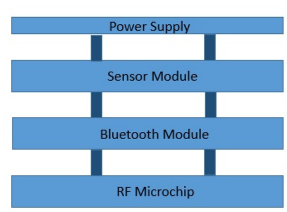

Figure 1: 3D Packaging of microsystem embedded in Smart Golf Ball

The chosen sensor module is the STMicroelectronics INEMO-M1 System-on-Board which can be seen in figure 2.

Figure 2: STMicroelectronics INEMO-M1 System-on-Board

This sensor module has the following key features to insure all functionality of the smart golf ball; 9 axis motion sensing, MEMS sensors include accelerometers, gyroscopes and magnetometer, 6-axis digital encompass, a 3-axis digital gyroscope and an ARM Cortex-M3 32-bit MCU [3]. Figure 3 shows the layout of all of these features. The sensor module makes collecting the data possible.

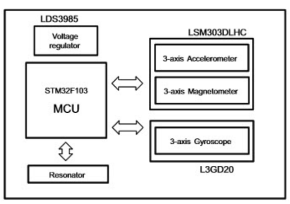

Figure 3: Sensor module layout

This data includes, the number of times the ball has been hit, the spin, speed and trajectory of the ball, and distance traveled. The embedded MCU has built in memory storage to allow for the data collected to be stored before being sent to the user.

A bluetooth component needs to be integrated to allow the data to be sent to the users smart device. TDK global posted a press release in February 2014 announcing the world's smallest Bluetooth Smart module in production. This bluetooth device reduces power consumption to a quarter of classic bluetooth devices, it is much smaller than typical bluetooth devices and it implements easy connectivity [4].

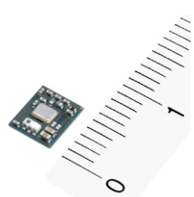

Figure 4: Bluetooth micro module

In order to find the golf ball an RFID chip will be needed as found in other existing products. One's smart device can send out radio frequencies to communicate with the chip allowing for location to be determined. For this device a theft recovery microchip embedded with RFID can be used to satisfy these needs since this device uses radio frequency identification to verify the ownership of stolen items [5] . The theft recovery microchip can be seen in figure 5.

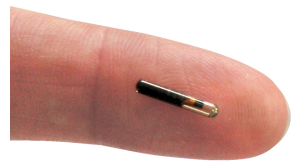

Figure 5: Theft Recovery Microchip

This portion of the design can be established from products today. Radar Golf Inc. has a Ball Positioning System (BPS), which includes a RFID-enabled tracking system that allows golfers to find golf balls within 100 feet [6]. Another company, the Prazza ball finder, shows performance of finding the golf ball with in 110 yards [7]. A representation of these devices can be seen in figure 6.

Figure 6: Prazza Golf Ball Finder Technology

A power supply will also need to be incorporated in the design. First, the device will not require a lot of power because of the minimal size of components used and the small number of components used. Also, the golf ball will be traveling through the air at rapid speeds a significant amount of time during its use, therefore it would be optimal to use a self-powered power supply.

One micro-scale generator uses zinc oxide wires to produce alternating current. Said applications of this product include powering wireless devices in clothing or implanting in ones body to monitor vital signals. Using this device in the smart golf ball would help power the electronic microsystem to help the sensor and bluetooth modules function. The generator shown in figure 7 can produce an oscillating output voltage of up to 45 millivolts [9]. This power is generated by the functionality of zinc oxide under stress. Zinc oxide generates electric potential when put under mechanical stress, in a phenomenon known as the piezoelectric effect [9]. The movement of the golf ball would stretch and release the zinc oxide wires to generate power. The zinc oxide wires can operate self-sufficiently and transfer 7% of mechanical force into electricity [9]. A multiple number of the wires would need to be in the system to sufficiently power the chosen components.

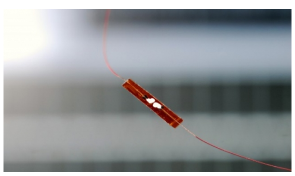

Figure 7: Micro Generator that produces power from movement

3 Key Issues Anticipated

There are many concerns stagnating the implementation of this product. The biggest issue is being able to connect all the components together while saving space. 3D packaging techniques must be implemented, however, this still might not be enough and die-on-die packaging would be most ideal. The smaller the components the better because USGA (united states golf association) has regulations of the weight of golf balls to not weigh more than 1.620 ounces [8]. As well, if a lot of the core of the golf ball is compromised the quality of the golf ball would become very poor and would be unattractive to the user. It is also important to note that for the RFID tracking device the signal sent to the chip would have to be unique enough to not interfere with other golf balls.

The lifetime of the golf ball and components is also a concern. The components would need to be able to withstand the shock and stress from the club head hitting the ball. A reasonable lifetime for a typical golf ball is 3 rounds which yields, for the average golfer, 240 hits. For the smart golf ball to be marketable, at a minimum, it would need to withstand 240 hits. The application of having a golf ball core that can absorb enough shock for the chip to be affected could be key. Hazards on the golf course also deter the lifetime of the golf ball greatly. Being able to integrate tracking in water could be a useful additional feature.

The price of the product is also a major concern. Keeping the price of the golf ball close to the price of top notch golf balls on the market would be key to successful sales. Today Titleists Pro V1 golf ball sells for about $5. An ideal cost for the smart golf ball would be to not exceed $15. A few key marketing issues include golf companies not liking the idea of people losing less balls which could cause their sales to go down. As well, players might not like to spend the extra money on golf balls on top of how expensive golf already is. However, as the advancement in technology continues to grow the price of the electronic components needed will continue to decrease.

Todays smart phones use GPS signals to track distances and directions. With the smart golf ball there would need to be an advancement in the smart phone to send RF signals to the RF chip embedded in the golf ball instead of using GPS.

Overall, the most concerning issue would be to develop a way to compact all of the electronic components in to as small of a volume as physically possible.

4 Analysis

In order to validate the design of the smart golf ball an analysis of the size, power, and protection of components will be implemented.

Beginning with the size being the most constraining factor it is important that the electrical components chosen be the smallest components found on the market. The table below shows the dimensions for each component along with their calculated volumes.

Component	Dimensions (in)	Volume (in^3)
Sensor Module	0.5x0.5x0.08	0.02
Bluetooth Module	0.18x0.22x0.04	0.001584
RFID Chip	0.5x0.09	0.00405
Battery	≈ 0	≈ 0

If all was compressed into a cube form the total volume would be

$$V_{total} = V_{sensor} + V_{bluetooth} + V_{RF}$$
$$V_{total} = 0.42cm^3$$

In addition to reduce the volume even more the packaging of each component could be removed to implement die-on-die packaging. Assuming 20% of each component is for the packaging the the new volume without packaging can be calculated as

$$V_{no-packaging} = 0.8 * V_{total} = 0.336cm^3$$

Considering the size of a golf ball is $V = \frac{4}{3}\pi r^3$, and the typical radius of a golf ball is 0.85in [8], then the total volume of a golf ball is

$$V_{golfball} = \frac{4}{3} * \pi * .85^3 = 2.5cm^3$$

Therefore the volume of the components would take up $\frac{.336}{2.5} \approx 13\%$ of the ball. This shows that it is physically possible to include all the components in a small enough volume to not affect the quality of the golf ball significantly.

It is also significant to note the maximum power the device would consume and if it is possible to support its need. The micro bluetooth module chosen has stated to consume $\frac{1}{4}$ the power that classic bluetooth devices consume. A classic bluetooth device has a max power consumption 2.5 mW [10]. The chosen sensor module has a max power consumption of 1.26W for 300 mA and 4.2 V [3]. The RF component doesnt consume any power because a signal is sent to it from a smart device which supports it with the power it needs. The following table summarizes the power consumption of each component.

Component	Power (Watts)
Sensor Module	1.26
Bluetooth Module	0.000625
RFID Chip	0
Total	1.260625

Given the micro generator can supply 45 mV which is 0.0135 W for 300mA, the following calculation shows the total number of micro generators needed to support the device at maximum power consumption,

$$Total\#ofGenerators = \frac{1.260625}{0.0135} \approx 94$$

The size of each micro generator is 5 microns in diameter and 300 microns in length which yields a total volume for 94 power generators of

$$V_{power-gen} = 94(\pi * 0.00025^2 * 0.03)$$
$$= 5.54\text{x}10^{-5}cm^3$$

This volume is still insignificant to the total volume of the system ($0.336cm^3$). Therefore, the size of the component is not compromised while successfully being able to power the device. As well, since for a majority of the time all components will be in sleep mode (only taking data while ball is in motion and then sending it at the end of each hole) the power generators will be able to recharge and power the components sufficiently.

A golf ball consists of an inner core material (polybutadiene), a boundary layer material (dupont HPF) and a cover material (thermoset urethane).

Figure 8: Inside design of golf ball

The outer casing of golf ball should be sufficient enough to protect the components inside, which would also have a rubber core surrounding them. Testing would need to be done to ensure the lifetime of the components inside to be long enough for the golf ball to have a sufficient amount of use.

5 Conclusion

The smart ball is applicable to all aspects of golf whether it be analyzing your own score, tracking players in a tournament or tracking players for pace of play purposes. It can help with making the game more appealing, as well as improving a players game. The smart golf ball can tell one how many times the ball has been hit and the final score for the played round, where the ball has landed, the distance the ball traveled and the spin and speed of the ball. After a thorough analysis of the design and components the device was found to be physically possible however advancements in technology still need to be made. This advancement includes being able to compact and connect all the components into a cube-like form without wasting any space. This would ensure the golfball to have a good quality while having an embedded microsystem inside its core.

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