MYRON: SMART FOOTBALLS FOR AUTOMATED COACHING

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Our goal is to develop a system that a football player can use to independently assess his performance, without any individual or extra attention from a coach. Based on real-time acceleration data from a smart, instrumented football, the Myron project aims to classify and evaluate various football actions and to discriminate between throwing and other actions (e.g., punt, running). Our smart football is under regulation weight and does not differ significantly from a standard-issue football in terms of its trajectory.

1 Introduction

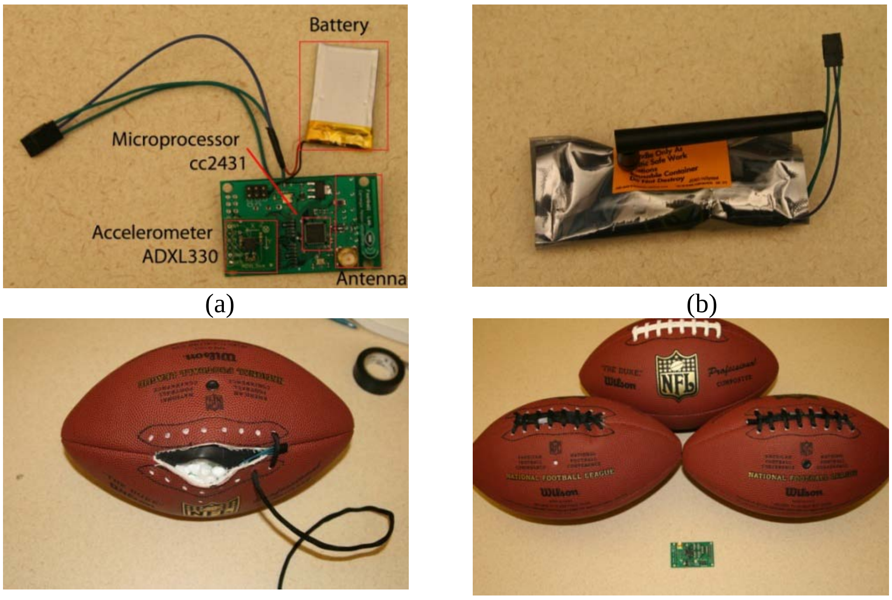
In football, as in many other sports, players cannot typically assess their performance without an observer critiquing their actions in real time or on video. NCAA regulations constrain the number of hours that a college coach can work with a player within a given week. Our goal is to develop a system that a football player can use to independently assess his performance, without any individual or extra attention from a coach. We aim to (i) provide the player with real-time feedback on the accuracy of his actions (e.g., the "goodness" of a 20-yd throw), (ii) prevent players from mislearning actions, and (ii) assist players in training themselves to reproducibly execute specific actions.

A football is subjected to many different movements during a game or practice. We hypothesize that, by analyzing the trends and patterns of the football's acceleration over the span of the movement, it should be possible to classify the type of action (running, throwing, punting, etc.). For instance, running with a football should show large chaotic accelerations because this subjective movement depends largely on the player and his path with the ball. Throwing a football should have a large acceleration parallel to the ball's longer axis, along with a sinusoidal motion along the ball's shorter axis. Kicking should show accelerations along the football's shorter axis, coupled with a sinusoidal motion across a long-short axis pair. The proper selection of acceleration-specific features should support the accurate classification of football actions. Once the action has been classified, additional features can be then examined to determine the repeatability of the action, and to compare it to an ideal instance of the action. This can help a player tremendously in assessing whether he makes a 60-yd throw reproducibly and whether his throw comes close to a "perfect" 60-yd throw. Based on *real-time acceleration data from a smart, instrumented football*, the Myron project aims to classify and evaluate various football throws and to discriminate between throwing and other actions (e.g., punt).

2 Smart Football

To ensure the relevance of our work, we use a standard-issue Wilson NFL football (NFL, 2006), which has the form of a prolate spheroid with size and weight as follows: major axis, 11 to 11.25 inches; long circumference, 28 to 28.5 inches; short circumference, 21 to 21.25 inches; weight, 14 to 15 ounces. We insert our embedded electronics (as described below) into this football.

In our implementation of the Myron smart football, we sought to ensure that (1) the player does not feel any altered dynamics when using the smart football, (2) the smart football is within regulation weight, (3) the smart football is capable of the range of motion–throwing, kicking, punting, running–that is required of a football, (4) the battery lifetime of the electronics allows the smart football to communicate its data reliably for the entire duration of an action, and (5) the smart football tracks the real movements of the football reliably, including the actual trajectory/acceleration of the football.



(a) (b) (c) (d)

Figure 1. (a) Myron's electronics, (b) external casing of the electronics, (c) Myron smart football packaging with embedded electronics, (d) real football (white lacing) contrasted with the Myron smart football (black lacing).

Hardware. Myron is built around the Texas Instruments cc2430 line of microprocessors. Each chip combines a cc2420 2.4GHz ZigBee (IEEE 802.15.4) radio with an optimized 8051 microprocessor in one package, allowing for a low-cost, small transmitter within the football. To this base module, we add an Analog Devices ADXL330 triple-axis accelerometer, and a 500mAh lithium polymer battery. In our tests, the battery life of the smart football was over 5.5 hours and our wireless signal range was ~35 yards.

We encase the transmitter module in a Mylar bag for protection, placed it in an evacuated football, and surround it with expanded polystyrene beads. The beads serve to hold the electronics in place, as well as protecting the electronics against hard impact. The accelerometer is aligned so that its X axis is parallel to the football's major axis; the Y and Z axes then lie along the football's minor axis, at 90 degrees relative to each other. This allows us to determine the direction of the football's spin. The smart football weighs 12.5 oz without the original bladder and 16.125 oz with the bladder. Our no-bladder version is actually underweight (compared to the NFL regulation football weight of 14-15 oz.) and is what we use for all of our experiments.

A base station consisting of a receiver module linked to a laptop computer with a serial cable is located on the sidelines, and logs all of the smart football's transmitted data, in real time, to permanent storage on the laptop for analysis.

Software. The transmitter and receiver modules are written in C, compiled with the Small Device C Compiler (SDCC), an open-source ANSI C cross compiler for the 8051 microprocessor. Both the receiver and transmitter modules use interrupt-driven code; a timer interrupt in the transmitter module triggers it to take samples and to transmit, while a radio interrupt on the receiver module triggers it to forward the message to the attached laptop computer that records some portion of the radio message on the sidelines for further analysis. The radio message is sent using the ZigBee collision-avoidance protocol to eliminate interference between multiple transmitter modules in the field.

Operation of the smart football. The transmitter module samples the football's X, Y and Z acceleration every 20ms with the cc2430's 10-bit ADC. These samples are packaged into a radio message, which is transmitted to the receiver module over Zigbee. The receiver module extracts some of the message's information, including the payload (i.e., the sampled accelerometer readings along the X, Y and Z axes) and a termination sequence (to signify the end of the sample). The receiver module removes extraneous information (the packet length, checksum and signal strength) and sends the extracted/relevant information to the attached laptop for logging and subsequent analysis.

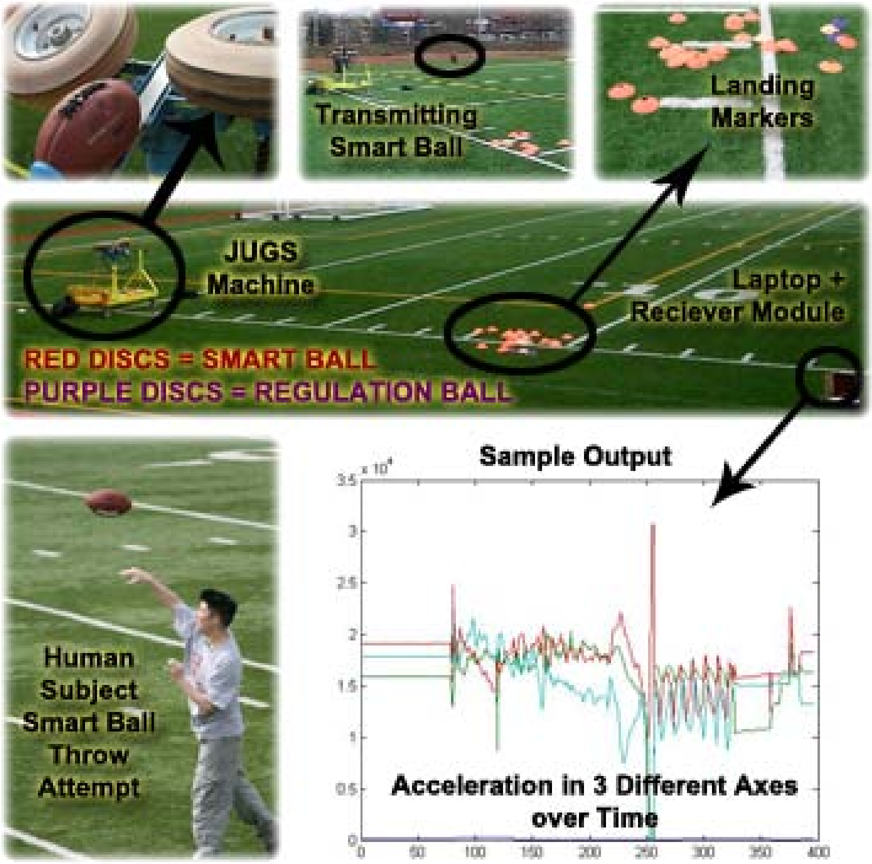
3 Experimental Validation

As with any experimentation, we needed a way to eliminate the subjectivity of different kinds of football actions, particularly with throwing. To this end, we used the JUGS football-throwing machine to create perfect spiraling passes of 10-50 yards. By changing the speed of the JUGS wheels and tilting the JUGS up/down, we controlled the speed and height of a pass. Once calibrated and set, JUGS provided us with a way to consistently launch footballs to a targeted location, enabling reproducible experimentation.

Regulation footballs vs. smart footballs. In this experiment, we calibrated the JUGS machine to execute a 15yd throw. We then launched a regulation NFL football and our smart football at that setting multiple times, resulting in the two balls landing close to one another. We then charted where each ball landed on the ground.

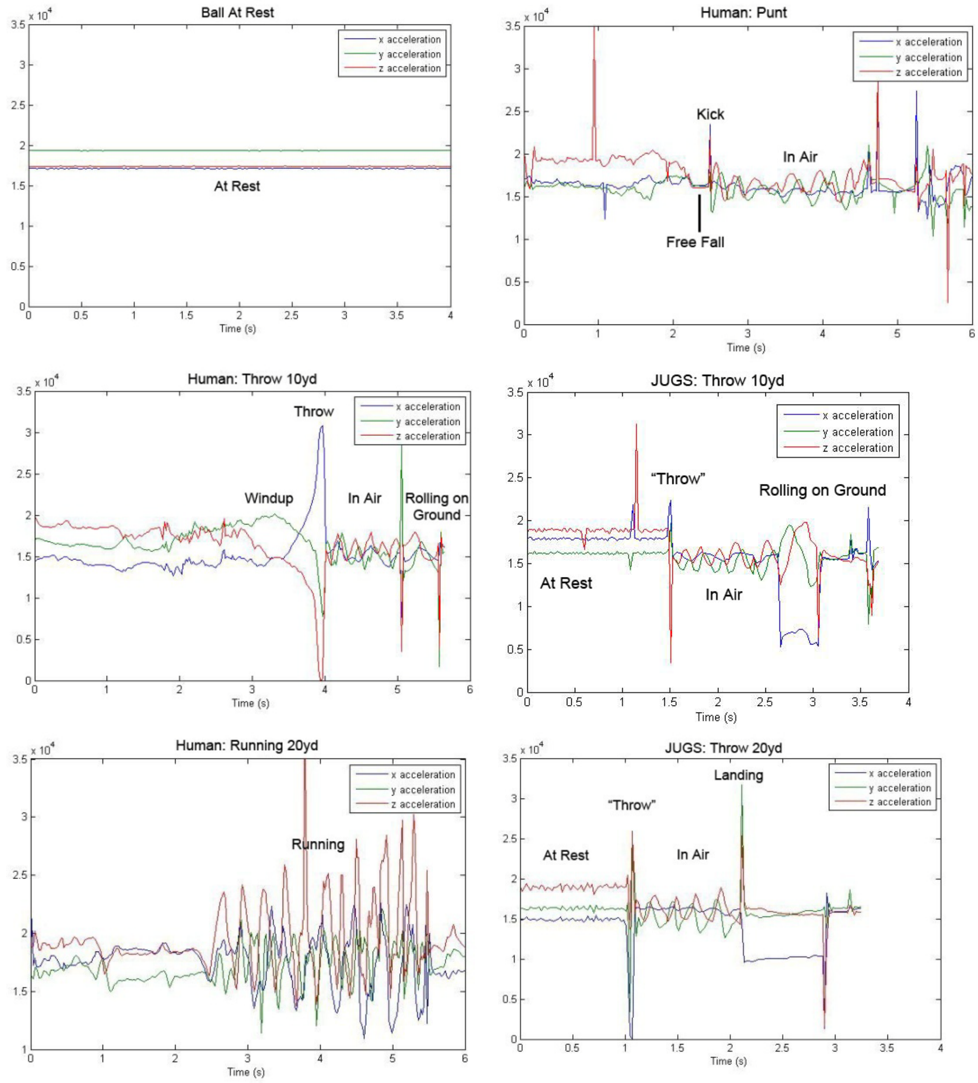
Smart footballs with JUGS machine at various settings. In this experiment, given that we can track the accelerometer readings from our smart football, we planned to launch the smart football five times each from JUGS at different speeds (resulting in various landing distances). After classifying the accelerometer readings, we wanted to see if we could predict the distance of the ball's trajectory from accelerometer reading alone.

Humans throw, run, and kick smart football. In this experiment, for the same setting as JUGS, we had some of the authors throw, run with the ball and punt that many yards. We captured the landing spots and attempt to classify the actions.



4 Results

As seen from the graphs shown, there are distinct "signatures" for each of the actions analyzed using the smart ball data. The JUGS system's throw is markedly different from that of a human. The JUGS machine induces a sudden high acceleration, while a human throw shows more gradual changes in acceleration, as well as a distinct reversal in acceleration as the human thrower winds up to release the ball forward. Similarly, the signature of a punt shows a period of freefall followed by high acceleration, unlike any other observed action. The signature of running with the ball shows an unexpectedly high periodic acceleration (rather than the chaotic acceleration that we expected), but its high intensity and frequency seem to be different from those of the ball's ballistic motions. Furthermore, the periodic motion of the ball in flight is fairly distinct; because the ball is in ballistic flight, the only visible acceleration is that due to the spiral. We expect these unique signatures of different football actions, visually discernible by accelerometer data alone, to lend themselves to automated classification.



5 Related Work

Many approaches have been developed for localization and data collection through smart/instrumented sports equipment. Accurate Technologies, Inc. has embedded, among other sensors and detectors, radio-frequency communication into golf balls. In John and Foltz (2004), a phase-difference algorithm was used to determine a football's location and to characterize its motion. Adidas, in cooperation with Cairos Technologies, implemented a smart soccer-ball design that used magnetic-field detection to notify an official, via radio communication to his/her watch, when a goal was scored, as described in Ling, D. et al (2006). In Cavallaro, R. (1997), using an IR sensor embedded in a hockey puck, SportVision highlighted the puck's path on TV broadcasts to improve the audience's ability to follow the course of a hockey game. In Nowak (2003), an embedded data-recorder system captured accelerometer data along three axes to measure spin and wobbles along a football's trajectory. While other work has also attempted to instrument footballs, Myron differs in its attempts to classify accelerometer data into specific football actions such as throw, punt, kick, etc.

6 Conclusion

The Myron project has developed a smart football that is able to provide classification of football actions through real-time accelerometer data alone. Our experiments show that our current instrumented ball does differ from a standard football in trajectory. Our future research directions for Myron include (i) using passive RFID tags within the football, (ii) improving the packaging solutions, (iii) improving location tracking of the football, (iv) extending battery-life for every charge, and (v) distinguishing more football actions through accelerometer data, emphasizing a more detailed kicking/punting classification.

Acknowledgments

We acknowledge the support of the Carnegie Mellon Tartans' Coach Richard Lackner, and appreciate the insights provided by the Tartans coaches that motivated this work.

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