Project Name: Future of Football
Team Name: Future of Football

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Preliminary Design Report: Future of Football

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**Project Abstract:**
In the future of football, human error will be virtually eliminated. It is a game of inches and all too frequently these inches are miscalculated, often affecting the outcome of the game. FOF is a total football tracking system. Through ultrasonic communication, the precise position of the football will be constantly recorded with a triangulation algorithm. The location will be displayed in real time via a strip of LED’s running down both sidelines. As the football moves, the adjacent LED will be illuminated. When the ball crosses out of bounds, tracking will cease and the last in-bounds position will be displayed. At the conclusion of the play, a laser line will point to the correct yard line on the field. Time permitting, the path of the ball throughout the play will be recorded and synched with an instant replay system. This allows a referee to replay the video and determine the exact location of the ball for any given frame.

**Introduction:**
Anybody who regularly watches football is familiar with the frequency of bad ball spotting. Attachment to the way things have always been done seems to be the driving force in maintaining the current methods. However, with increased processing power, it is only a matter of time before the game will undergo dramatic technological renovation. To ensure fairness, human error must be eliminated as completely as possible. A football tracking system is inevitable and overdue. The question remains of what is the most efficient method to achieve this goal.

The purpose of FOF is to function as a prototype for future ball tracking systems. The goal is to record the location of the ball at all times with pinpoint accuracy and relay this information to any observers. Feedback is critical if the system is to be used during game play. For this reason, lights along the sidelines seem to be an efficient method for identifying the location of the ball. This is a temporary solution until electroluminescent Astroturf is invented. Sideline lights allow for easy spotting of the ball between plays. The final location of the ball will also be spotted with a laser from above. Current regulations would not permit the laser to be turned on until the conclusion of the play. When inches become important, the instant replay system may be used. This system allows a ref to review the play as is currently done. However, after determining the exact moment when the play ends and then guessing at the ball’s location as is currently done, the video may be frozen and the corresponding lights on the field will display the exact location of the ball at that point in history. This will ensure that every game is decided by the players, and not by the officiating.

**Features:**
FoF is a real time tracking system to serve as a model for implementation in college and professional football. Its features include:

- Minimal hardware inside of the football to operate a transmitter
- Ultrasonic-based triangulation to serve as a model for full-scale RF tracking
- Multiple receiver locations for redundancy and increased accuracy
- Real-time visual feedback for spectators using lasers and LEDs
- High-precision results accurate to within 1” (<1%) to eliminate human error
- Potential for a new paradigm of statistical record keeping and analysis
Technical Objectives:
The main objective of our project is to triangulate the position of a moving football with a high degree of accuracy using a fully scalable method. The secondary objective is to record this trajectory and synchronize this data with a video recording.

- The football should contain as little hardware as possible in order to meet current regulations.
- An ultrasonic transmitter inside the football will ping intermittently to remove the need for an echo-type communication between the field and the ball. This pinging will be accomplished by a 555 timer connected to a Schmitt trigger to send digital pulses. The pulse signal will also need to be amplified to reach the maximum input voltage of 20V for the transmitter. Potential problems here include passing the signal through the material of the football. On a full scale model, RF transmission would be necessary but would require significantly higher clock speeds. In order to replace this with an ultrasonic signal, a hollow ball with a cage structure for its outer shell will be used to minimize wave obstruction. A proposed football circuit is shown in Figure 1.
- Because the football will have internal components, a wireless charging method is desirable.
- The ultrasonic ping will be received by four stations located at three corners of the field. A simple geometrical algorithm will determine the location of the source of the ping in 2 dimensions on the surface of the field. It will also therefore be able to determine when the ball has crossed out of bounds. A proper algorithm would be able to ignore the vertical dimension, giving accurate results no matter how high up the ball is. A proposed field circuit is shown in Figure 2.
- As only 3 receivers are necessary for triangulation, the 4th serves as a means of redundancy. Data points can be generated from any combination of 3 of these stations. This provides assurance of signal receipt even if 1 station does not receive the ping. In the event that all 4 stations receive the signal, the 4 data points can be averaged together to increase the accuracy of the output data.
- The determined location of the ball will be represented as a pseudo-analog signal which will be converted to an 8 bit (or more) digital signal to be output. This output will then be run through a series of decoders in order to illuminate a single LED. CPLD operation is illustrated in Figure 4.
- LED’s will be placed about 1 inch apart. A ball traveling at 6 mph will move 1 inch in approximately 10ms. Therefore an updating time interval of 1ms should be more than sufficient.
- In addition to the LEDs, a motor will be suspended above the field with an attached laser pointing to the field. The motor will be equipped with an encoder for fast response and high resolution. The laser will illuminate at the end of the play and will point to the last position of the ball.
- The field will be a scale model of a full football field. The model should be able to fit on a tabletop. A potential field design is shown in Figure 3.
- The 8 bit position of the ball will be recorded in RAM. Assuming one data point per millisecond and a maximum play duration of 10 seconds, a 10k byte chip would satisfy the minimum requirements.
- A camera module may be set up to record the play. The video would also be recorded and stored frame by frame. Each frame would be linked to the position information mentioned above. When a particular frame is selected, the corresponding positional information will also be selected.
- When a frame is selected, the light corresponding to the position of the ball during that frame will be illuminated.
- High speed cameras would be used for full scale applications. This project will be limited to cameras in the range of 50 frames per second. This means one frame may correspond to as many as 20 positional data points. A running average filter may be used to select a data point.
- Time permitting, the location of first down markers and goal line markers may also be stored. When, during replay, a frame is selected corresponding to a location which achieves a first down or a touchdown, additional displays and lights and bells and whistles could be used to inform the viewers.
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Figure 1: Football circuit

Figure 2: Field Circuit
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Figure 3: Field Design

Figure 4: Flow Charts
Components:
Ultrasonic transducers – ProWave: Bistatic open-type 400ST/R120

Two parameters were of top concern when selecting the ultrasonic components. Those were effective range and beam angle. The field is intended to be approximately 4 feet wide and 9 feet long, corresponding to the dimensions of a regulation size NFL field. This gives a maximum diagonal distance of approximately 10 feet. Since sensors accurate at 10 feet are usually not accurate under half a foot, we have elected to move the sensors 6-12 inches away from the field. This gives a necessary effective distance of 0.5 to 10.5 feet. Although Prowave does not publish the effective distance in their datasheet, we obtained assurance from the manufacturer that the sensors would meet our needs. The placement of the sensors at the corners of a rectangle means that for maximum efficiency they need to receive signals from at least a 90 degree span. Figure 5 shows that the beam angle of this product satisfies this requirement.

DC motor – 19:1 Metal Gearmotor 37Dx52L mm with 64 CPR Encoder

Using a laser to project on a field of 10 feet with 1 inch accuracy requires high precision in motor position. For this reason, rather than a servo motor, we selected a dc motor with a feedback encoder. A servo motor takes a PWM signal of 50 Hz, corresponding to a 20 ms period which is too slow for our purposes. The DC motor pictured in figure 6 has a gear down ratio of 19 to 1 with a 64 count encoder. This yields a motor capable of 500 rpm’s with over 1200 counts per revolution. This is an accuracy of almost 1/4 degree. The encoder feedback is in the form of a PWM signal shown above. A simple count of the pulses will show how far the motor has turned.

Laser - Laser Straight Projective Leveler with Water Leveler
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We are using a laser to mark a yard line on the field. For this reason the point lasers are undesirable. The laser level provides a laser line up to 20 feet in length which is more than sufficient. This component will be able to project a laser that will span the width of the field.

Processing – Altera EPM7064SLC44-10 CPLD

Our original intent was to use a low power MSP430 in the football and a high speed MSP in the field circuit to handle the interrupts and a CPLD to perform all the decoding. A 555 timer circuit has replaced the need for a controller in the football. It appears as though we may be able to use the CPLD to receive the data from the ultrasound receiver directly, eliminating the need for the other controller. The Altera CPLD is already available. If it does not meet our needs we may continue shopping. The breakout board used for the Altera in EEL3701 is shown in figure 8.

LEDs – Bright Green T1 (3mm) Right Angle LEDs

A 10 foot field with 2% accuracy requires approximately 60 LEDs. For this reason we have chosen to use 64 LEDs connected to (4) 4 to 16 decoders. If we find our accuracy in processing is better than this 2% resolution, we may add more LEDs. A large package of the LEDs shown in figure 9 was available for a great price so we will try to work with those.

IC’s –

Circuit requirements for this project include a 555 timer capable of greater than 1kHz frequencies, a Schmitt trigger to digitize the signal and eliminate rise time data anomalies, a voltage regulator to convert our 12 volt batteries to the 20 volt max handled by the transducers, an amplifier to increase the 5 volt digital signal to 20 volts, and 4 decoders to use an 8 bit position signal to light up one of 64 leds.
The football circuit requires a high voltage at a low weight. The 12 volt alkaline batteries shown in figure 11 are an inch long and weigh less than an ounce. For this reason they were chosen. The field can use a 5 volt dc power supply from a wall source.

**Cost Objectives:**
Sensors were purchased from Newark.com for $87. A camera, if used, is already available but retails for $50. CPLDs are already on hand but are relatively cheap otherwise. All other chips were ordered from Jameco for less than $20. A large quantity of LEDs was obtained from Goldmine Electronics for $20. The Laser is approximately $20. The current motor choice costs $40 but also requires a $25 motor driver. Field and ball materials should total less than $40. Total project cost is estimated at $300.

**Separation of Work:**
All work so far has been split evenly. All foreseeable work will continue to be split evenly as much as possible. Kevin has expressed an interest in the software aspects of this project and Erik will then take the bulk of the hardware configuration, including calibrating the sensors and wiring the field.

**Gantt Chart:**
Below is the preliminary estimate if how time will be managed over the course of the semester.
References:
Carnegie Mellon Football Engineering Research Group

http://www.footballtracking.org/

Materials and Resources:
Critical needs include a low power processor, and extremely lightweight batteries, RF, and sonar equipment to be placed inside the football. The field processor should also have large pinout capabilities for LED array.