1 Introduction

The Notre Dame Robotic Football Team is a club on campus involved in building and piloting robots in a game of seven-on-seven football. The rules and conventions of the sport are remarkably similar to that of actual football - all of the major positions in football, such as quarterback, linemen, and wide receiver, are featured in robotic football. There are penalties, designated plays, field goals, and more. Currently it is a small league, consisting of only a handful of other colleges besides Notre Dame, such as Valparaiso and Purdue. There is a tournament once a year, usually in March, that all the teams participate in and compete against one another.

Scoring works slightly differently in robotic football than in actual football. In addition to touchdowns and field goals, teams can gain additional points by completing a pass to a wide receiver. So, it would appear that passing should be a vital part of any team's offensive gameplan.

2 Problem Description

The problem is that completing a pass is incredibly difficult, as the coding and technology behind gathering the distance between the wide receiver and quarterback is quite complex, making the implementation of such a system is no trifle matter.The robotic football club (RFC) has a system in place for tracking differently-colored receivers using a pixicam mounted onto their quarterback. As the system currently works, the human player controlling the quarterback presses a button on their controller that corresponds to a wide receiver. Then, the pixicam is activated and searches for the correct wide receiver (each receiver has a distinct color, such as green or pink, which allows the pixicam to lock onto it quicker). Once the receiver is found and locked, the pixicam attempts to judge the distance, accelerate the wheels of the throwing mechanism (albeit slowly), and then throw the ball.

While the system is able to accurately measure the lateral (x-axis) displacement between the two robots, it fails to accurately measure the vertical distance (y-axis) between them. Furthermore, the current system runs into interference problems, where the visual of the pixicam is blocked by a defender, which makes tracking a receiver even more difficult. The RFC needs a reliable way to track both the quarterback and the receivers, and a way to translate that tracking data into measurements for the quarterback to successfully complete a pass to the receiver.

3 Proposed Solution

The team intends to use RF flight times from six-to-eight beacons on the sidelines to track receivers on the field by triangulating their positions relative to the quarterback. This will be a much more accurate system than using just a line-of-sight based pixicam to judge distances (as is currently implemented). The pixicam system will not be replaced completely, as it is still an effective system for locking onto a wide receiver. The RF-beacon system will simply enhance the tracking capabilities of the quarterback, and will reliably relay the distance between the quarterback and the chosen wide receiver.

The RF beacons will be continually sending and receiving RF signals that can then be directly sent to quarterback. A module inside the quarterback will then take that data and use it to continuously compute the distance between it and each of the wide receivers. By also tracking which of the distances is a minimum, the rpm of the quarterback's wheels on the throwing mechanism can be continuously adjusted; this will allow for a much quicker time-to-throw-release than what the RFC currently has. When the human controlling the quarterback selects a wide receiver to throw to, two things will happen. First, an override signal will be sent to the quarterback so that the rpm of the throwing mechanism will now be set using only the distance of the selected receiver, instead of the closest receiver. Second, the pixicam system will be used to locate and lock onto the receiver, and if because of interference it is unable, the requisite data can then be obtained through the RF beacon system.

The RFC has asked that two different throwing "modes" be implemented, if possible. The first, currently implemented scenario is that a receiver is selected with a button press, but the ball will not be thrown until the human player decides to pull a trigger on the controller. The second, new option would eliminate the human decision - the player will choose a receiver to throw to and press the corresponding button, but now the ball will be thrown as soon as the pixicam has locked onto the receiver and the most recent data from the RF beacon system is received. In the event that a receiver is wide open, the latter option will theoretically throw the ball faster than the human controller could. But, if the human quarterback wants control of when to throw the ball, the former option would be better.

4 Demonstrated Features

4.1 Location of QB and WRs

Through the use of six RF beacon emitters and receivers, it will be demonstrated that the quarterback and three wide receivers are being tracked in real time.

4.1.1 Distance between QB and WRs

As part of this requirement, it will be shown that the distance between two chosen robots can be measured and displayed in a manner that is usable to the Robotic Football Club.

4.2 Limit the weight of the technology.

The GPS technology cannot exceed the size of the robots and it would be beneficial to not weigh the robots down. We can determine what percentage of the robot weight is being contributed by this technology. The group aims to keep this value around __% due to protection from tackles.

4.3 Build Quality

Both the RF modules on the robot players as well the beacons situated around the field must be able to absorb significant impact from robots within the course of the game. The robots collide into each other at high speeds, often resulting in damage to the robots.

4.3.1 Quick Access to Modules In-Game

Because of the very physical nature of robotic football, in-game repairs are often needed. In the extreme case where the module is disconnected or damaged, it needs to be built in such a way that it can be quickly accessed by a team of engineers during a game so that they can complete any repairs as quick as possible. Similarly, if the pylons are knocked out of position in the course of the game, they need to be able to be replaced and still be calibrated with the field and the other pylons and robots.

4.4 Adjusting Wheel Speed of QB's "Throwing Motion"

The system must be able to connect directly to the quarterback's mainframe and automatically adjust the rpm of the throwing mechanism. This rpm would be a function of the distance between the QB and its wide receivers, and be able to dynamically and continuously adjust with the difference in distance as the play develops.

5 Available Technologies

5.1 Decawave Chip

There is a DecaWave chip that is made to use radio frequency for indoor location purposes that we will be using in our sideline beacons. The DecaWave chip we will use is the DW1000. The cost for a DW1001 (the newest version) development board is $40, and ordering the part has a 6 week lead time. We will also require at least one Decawave ScenSor UWB Indoor Positioning Wireless Transceiver Module per receiver and beacon, each costing $20 with a 6 week lead time.

5.2 XBee Modules

We will be using the bluetooth technology present in XBee modules to communicate between the controllers and the robots, as that is how the Robotic Football Club currently communicates between the two. We will need to make our own circuit boards for each beacon/robot via using Eagle and Osh Park.

5.3 Power Supply

We will be using our own power supply (Lithium Ion battery). This is to avoid damaging the robots' power supply in case our module malfunctions in any way. That way, if the location system goes down, the robot can still be driven and throw passes manually. Battery life will be significantly longer than the length of a typical game (around 1 hour).

5.4 Arduino

We will be using our location system in conjunction with the pixicam system that the Robotic Football Club is currently using, so we will need a way to communicate with the

Arduino brain of the QB. We only want our location system to be giving data to the QB while on a separate power supply, so we will only hook it up to an open data pin on the microcontroller.

6 Engineering Content

6.1 Beacons

We are going to need to engineer from scratch 4 to 6 beacons that will be durable and useful. Essentially these beacons must be able to use the DecaWave chip to locate all of the wide receivers on the field while being able to endure some brutal collisions from the robots. The beacons can be broken down into 3 areas of engineering work: mechanical, electrical, and software.

6.1.1 Mechanical

All of the electronics of the beacons will need to be contained in a “house” that is able to endure some high-speed collisions from other robots. We will need to find a relatively cheap way to build 4 to 6 very durable structures to house the electronics of the beacons.

6.1.2 Electrical

The electronics of the beacons will need to be able to carry out two major tasks. First, they will need to use the DecaWave chip to locate all of the Wide Receiver robots with accuracy. Second, they will need to be able to transmit position data to the quarterback so that it can determine where to throw the ball once it decides which robot to target. We will likely create the electrical boards in Eagle and send them Osh Park to have them made.

6.1.3 Software

We are going to have to code in the electronics of the beacons in order to get them to do exactly what we want them to do.

6.2 On-board Modules

All three Wide Receivers and the Quarterback will have separate modules that will tell the beacons that they are the robots that need to be tracked. We will build these modules and they will all have their own power source. The engineering tasks of the modules can also be broken down to electrical, mechanical, and software.

6.2.1 Mechanical

Similar to the beacons, these modules will need to have some protecting house that will keep the internal components unharmed while operating at game-speed. We will need to engineer the casing for these modules and have them fit easily inside of the robots.

6.2.2 Electrical

The electrical components inside of these modules will need to be able to tell the beacons that the Wide Receivers and the Quarterback are the robots that need to be tracked (the robots with the modules on them). We may have to design boards in Eagle and ship them to Osh Park to be built.

6.2.3 Software

As with the beacons we will need to do some coding to have the modules do exactly what we want them to do. In regards to software, the Quarterback will need the most attention as it is the “brain” that need to process all of the information in conjunction with the current pixicam system and actually perform the task of throwing the football.

7 Conclusions

There is one pressing concern for the team. The RFC recently informed the team that the beacon system may not be allowed at official tournaments. If this is indeed the case, then a restricted version of the proposed solution above may be implemented, whereby instead of beacons, RF signals will be sent and received by the quarterback robot. While this will hinder the ultimate future goal of creating a true indoor GPS system for robotic football (and other applications, of course), this system would still greatly improve upon the current pixicam system used by the robotic football club.

This project will contain a combination of software and hardware components. More research must be completed prior to beginning construction of the project, as none of the team members have had prior RF experience. However, the senior design team is prepared to handle this project; perhaps more accurately, the team is excited to begin the project in earnest. Even with the accelerated deadline (the project must be completed in time for the RFC to use in March at the tournament), the team is confident that all requirements will be met, and that all the desired features will be successfully implemented in a timely fashion.