Robot Football Indoor Location

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1 Introduction

The Notre Dame Robotic Football Team is an on-campus club involved with building and piloting robots to play a game of seven-on-seven football. The rules are very similar to football, especially with player positions; there are penalties, designed plays to run, field goals and much more. It is currently a small league, consisting of only a few 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.

The major differences between college football and robotic football are two things: seven-on-seven play and completing passes yields bonus points. So in addition to touchdowns and field goals, teams can gain additional points by completing a pass to a wide receiver. So passing is a vital part of any team's offensive game plan.

2 Problem Statement and Proposed Solution

Completing a pass in Robot Football is very difficult, and currently takes a lot of estimation to guess how far the receiver is from the quarterback. Implementing a system that can calculate the distance requires complex coding and technology to calculate the distance between the wide receivers and quarterback. 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.

By using the DecaWave 1000 chip, we will be able to measure the distance between the quarterback, receivers, and beacons on the sideline. Using this information, we aim to triangulate the positions of the receivers relative to the Quarterback more reliably and accurately than the pixicam system. We will implement this using Teensy 3.5 circuit boards which will connect to the DecaWave chip. This will give us an accuracy within 10 centimeters for the vector distance of the receiver to the quarterback. This will allow for nearly precise data which can be used by the RFC to complete passes en route to victory.

3 System Requirements

The system will require some embedded intelligence to function. It must be able to use the position measurements between the DWM1000 anchors and tags to calculate the distance and angle between the quarterback and receivers through the use of beacons on the sideline. The beacons will wirelessly connect to the quarterback and relay the positioning data to it. Further, the system must be capable of switching between which wide receiver is currently being tracked and recorded. Whatever embedded intelligence we have must also be compatible with the quarterback system already in place by the RFC.

However, The Robot Football Club is currently redesigning the “brains” of the quarterback robot, and it will now be using an I2C interface. Therefore, our embedded intelligence will be connected to the quarterback using I2C as well. Rather than try to use an SPI or UART interface that then must be converted, directly coding with I2C allows for a more convenient process.

There will be a total of four-to-five modules created for the robots. One DW1000 chip is placed on the quarterback,and will be connected directly to the main robot control system. The other four (possibly three, depending on budget) modules will be tags that are attached to the wide receiver robots. The tag on the quarterback will not be removable as it must be directly attached to the quarterback processing system. However, the wide receiver modules will be designed to be self-contained so that they can be quickly detached and reattached to different robots without needing to connect to the robot’s internal systems. This is necessary in the scenario where a robot is damaged and must be replaced during the game - if the module is self-sufficient, it can quickly detached and connected to another robot.

There will also be three modules that serve as beacons. These three beacons will require their own DWM1000 anchor chip. Because of Robot Football rule limitations, they may only be stationed on the Notre Dame RFC’s side of the field. Two will be stationed on the corners of their endzone, and one will be placed on the sideline, positioned near the center of the field. Each beacon must receive the positioning data from the wide receiver and quarterbacks, and relay that data to the quarterback in a timely fashion so that it can interpret and utilize the data. The range of all the modules are greater than the size of the football field, so ideally wireless/RF connection will not be an issue.

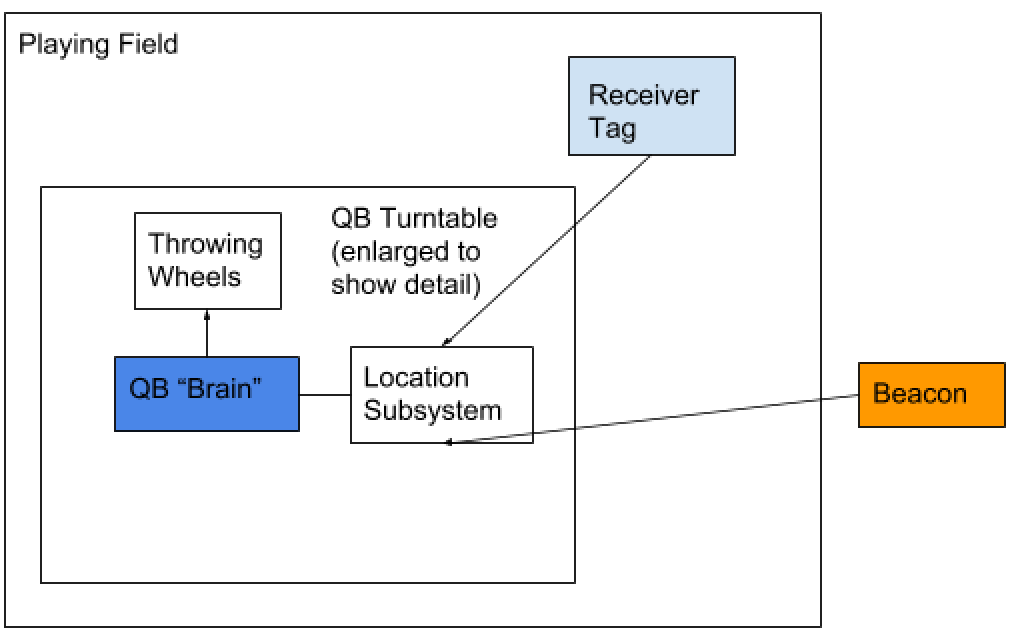
In order to be active for the duration of a robot football game (roughly one hour), these modules need to be powered for at least that amount of time, preferably longer to account for exceptions. To that end, the plan is to use a 9V battery to supply the power. The Robot Football club has said that the modules can be directly powered by their robots if desired. However, because the plan is to make the modules self-sufficient and able to be easily removed, the Senior Design team has opted instead to use battery power.

The RFC team has given no specific requirements regarding the weight of our modules, but the current plan is to make them quite light so as not to affect the performance. The beacon modules, however, will be housed in a sturdy frame that can withstand being hit by robots during gameplay. The size of our modules will be important; this is especially true for the quarterback, as it has limited room on its top. This is an important reason why the Teensy board will be used - it is compact enough to fit in the allotted space on the robot, yet has enough pins to be the center of our modules.

Because the robots in robot football move quite fast, when the robots collide, there is a high chance of damage. Our modules must be able to withstand the damage of a hard hit by an opposing team's robot. Therefore, all the DWM1000s will be housed within a compact box that can wither the rough contact. In addition, the mechanism to remove and connect these to various robots cannot be too simple, or else the modules will fly mid-play.

4 System Block Diagram

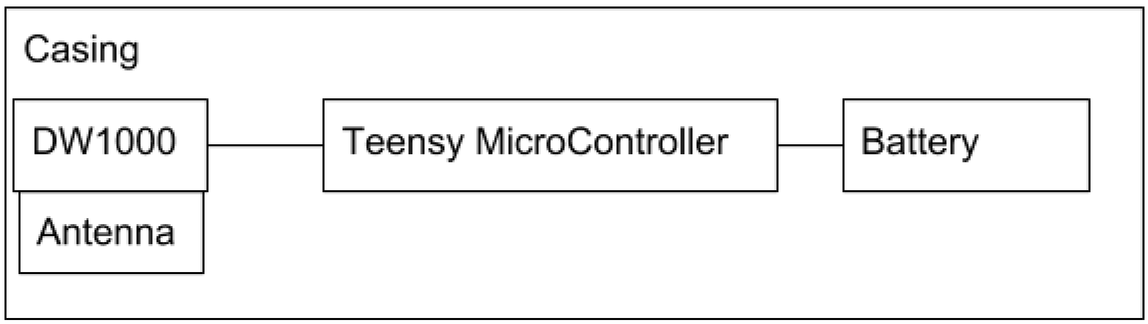
4.1 Overall System:



Most of the overall system hardware has already been built by the robot football team. Our location subsystem will be mounted on the QB bot, and the receiver tags and beacons will be built by us. The location subsystem will send a signal to each receiver tag and beacon, and measure the distance between the QB and each of these points. It will then calculate the location of each receiver relative to the QB using the Beacons on the sideline as a reference point. This data will be given to the QB brain using I2C communication protocol, and the QB will adjust the power of its throwing wheels accordingly.

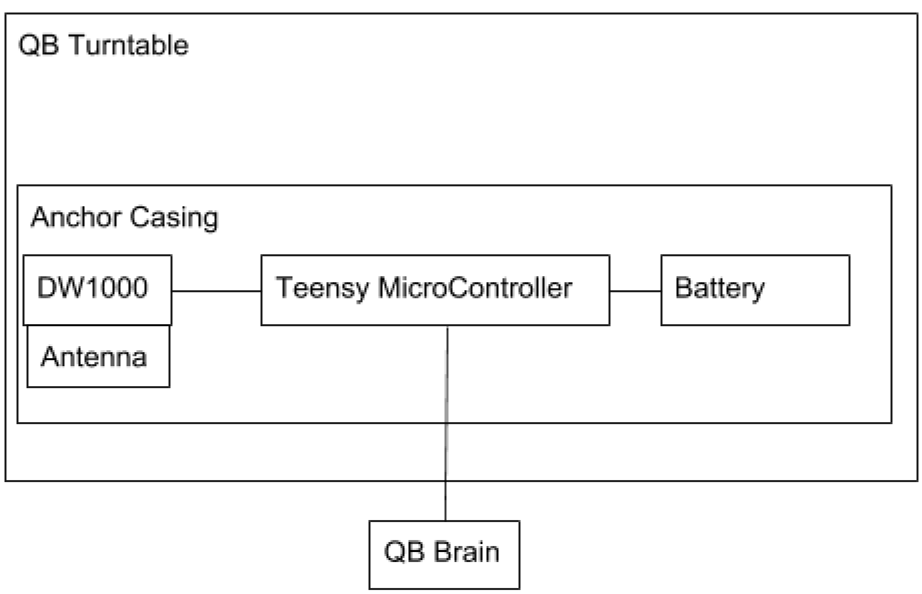
4.2 Subsystem and Interface Requirements:

4.2.1 Receiver Tag



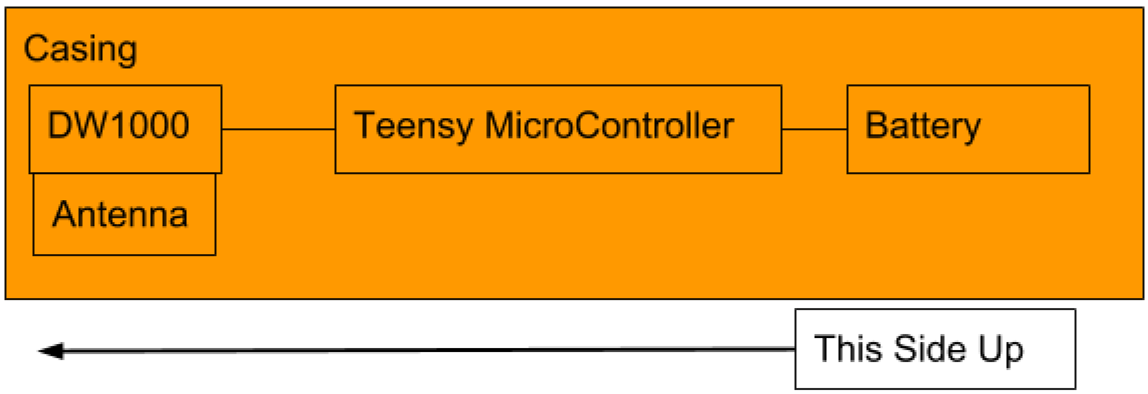
Each receiver tag will consist of a DW1000 chip configured in tag mode connected to a Teensy microcontroller. This subsystem will have its own dedicated power source, and will be placed inside a plastic casing to protect against hits. They will then be mounted in the basket of the receiver. Each of these tags will have a unique ID associated with them, so the QB can tell each receiver apart. Each tag will be mounted in the basket of their respective receivers.

4.2.2 Location Subsystem



This subsystem will consist of a DW1000 chip configured in anchor mode connected to a Teensy microcontroller. This subsystem will also have a dedicated power source, and protective casing. This subsystem will also be connected to the brain of the QB using I2C communication. It will measure the distances between the QB and the receivers, and the QB and the sideline beacons. This will allow us to have a reference distance to triangulate with without using sideline beacons. We would prefer to do all triangulation calculation on our Teensy microcontroller, but if the robot football team wants us to use the QB brain, we will use that controller instead. This subsystem will be mounted on the turntable of the QB, outside of the robot's casing. If it were mounted inside, the thick protective casing would prevent radio signals from getting through, rendering our system useless.

4.2.3 Beacons

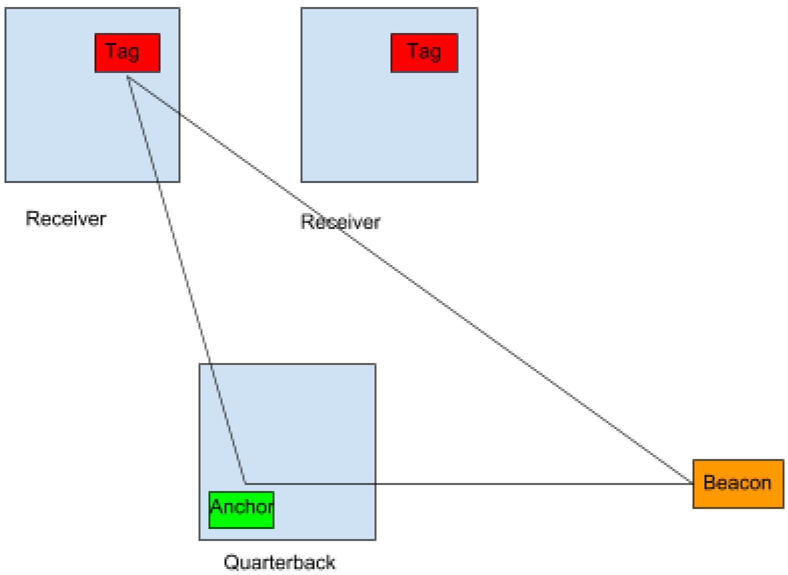


The Beacons are essentially stationary Receiver Tags. The Beacons are made up of a DW1000 chip in Tag mode, a Teensy MicroController, and a battery for power. They will be mounted inside an orange case to mimic the look of endzone pylons in football. Their role is to serve as a reference point for triangulation of the receivers' changing positions. The range on the DW1000 is much longer than the length of the field, with data being read close to 60m. Due to their long range, we should only need beacons on the sideline that belongs to our team.

4.3 Future Enhancement Requirements

The longer battery life we can give our modules, the more convenient our system will be for the robot football team. As of now, we are deciding to use a 9V battery, but as building and testing gets underway next semester, it is likely we will redesign the subsystem we use to power all of the Tags, Beacons, and Location Subsystem.

5 High Level Design Decisions



We have been going back and forth these past few weeks on whether or not to use beacons in our overall positioning system. Our biggest concern was if it would be against the rules to place them on the sidelines of the field during a robot football game, or if the rules would be changed against us shortly after placing beacons around the field. After meeting with Prof. Schafer, we ultimately decided to move forward with using beacons. Placing beacons just on our side of the field should be well within the rules of the game. This system will work better than the backup plan, which was to mount a beacon on the QB itself. Having sideline beacons will give us much better results for triangulation, and will be much more useful to the robot football team.

6 Open Questions

How will the Receiver Tags and Location Subsystem be mounted securely enough not to fall off after a big hit, but still allow the team to replace and interchange them on the fly?

What size battery will we use to power our system?

Should we design a new board to make our design as compact as possible?

7 Major Component Costs

Component	# In Stock	# Needed	Price Per	Price Total
DW1000 Chip	4	4	$50	$200
Teensy Board [3.5]	1	7	$25	$175
DW1000 PCB	2	2	$40	$80
9V Lithium-Ion Battery	0	8	$10	$80
Wires & Connectors	N/A	N/A	N/A	N/A
Outer Shell Material	N/A	N/A	N/A	N/A
Velcro Strips	N/A	N/A	N/A	N/A

Our major components will be the DW1000 Chips, DW1000 Printed Circuit Boards, a 9V Lithium-ion battery, and a few Teensy Boards. We will also need wires and connectors, some kind of outer shelling to protect the internal components, and possibly velcro strips to secure the internal components. The price of smaller items is much less significant relative to the expensive components and we will try to use resources and materials available to us through the Robotic Football Club. Our estimated price total for the major components is about $535.

If needed, we could cut back on the number of receivers that we “tag” to save money. Once we show the Robotic Football Club the capabilities of our system, they may want to pay for the rest of the receivers to become “tags”. If we were to tag two less receivers (and only tag two receivers instead of four) our total cost would be cut down to $365.

8 Conclusions

The team will create a robust system to determine the distance between QB and receiver, and use that information to tell the QB how much force to use to throw the ball the proper distance. As of now, we are ready to begin modifying our base code that tells the distance between two modules in meters and outputs this value to the serial monitor in Arduino. The team needs to conduct more research on I2C communication, the protocol that the robot football team specified they want us to use to link our Location System to their QB.