UNIVERSITY OF NOTRE DAME
College of Engineering

Robotic Football Positioning System

Eddie Hunckler, Matt King, Stephen McAndrew, and Kate Sanders

Project Description

Our goal was to create a robust, easy to use indoor positioning system for the Notre Dame robotic football team. Starting out, we experimented using several different ranging technologies including ultrasound and Wi-Fi based systems before settling on the DWM1000 RF ranging module. Using this module, we where able to achieve highly accurate distance measurements out to 100ft. A magnetometer was also integrated into our system allowing us to track the board's orientation. The MQTT Wi-Fi protocol was then used to publish our data to a server. Finally, a GUI was created to display the board's position on the field in real time using the ranging data.

Background

Robotic Football at Notre Dame

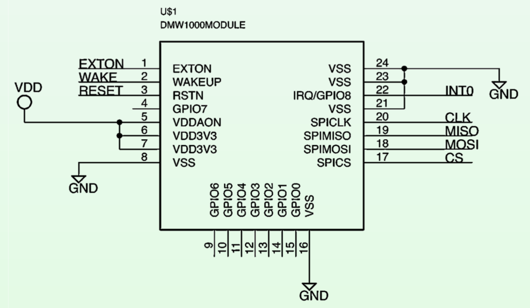
Robotic Football is an intercollegiate engineering and robotics competition modeled after NCAA football.

One of the robots most critical to the success of the team is the quarterback. The quarterback must be able to complete a quick and accurate pass which requires selecting the target, determining the distance to the target, and launching the ball with the proper speed and rotation to hit the target.

Previous iterations of the quarterback have relied on a variety of different sensors to determine the distance from the quarterback to the wide receivers. The most recent update was using a computer vision enabled camera to track the colorful wide receivers. This works well in theory, but in gameplay, the wide receiver robots are often wholly or partially blocked in the field of view of the camera. This gives erroneous data about the relative position of the wide receivers. To solve this, a solution was proposed to track the absolute position of the robots utilizing RF.

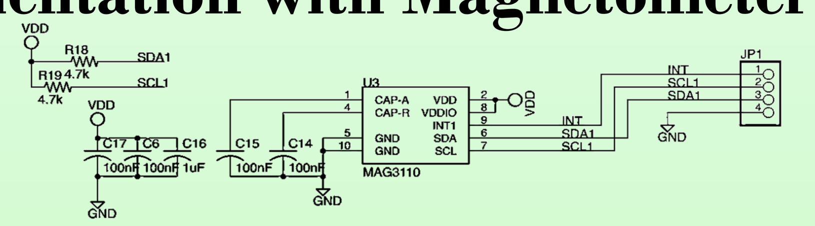
Systems

1. Ranging with DecaWave



The DecaWave DWM1000 uses RF to send correlated messages between an initiator and a responder. The initiator uses the timestamps of transmission and reception embedded in the messages to calculate time of flight and derive the distance to the responder. The DecaWave communicates this data to the PIC32 via SPI.

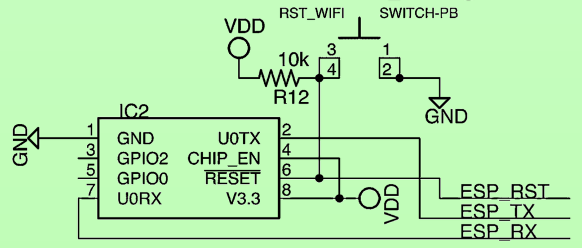
2. Orientation with Magnetometer

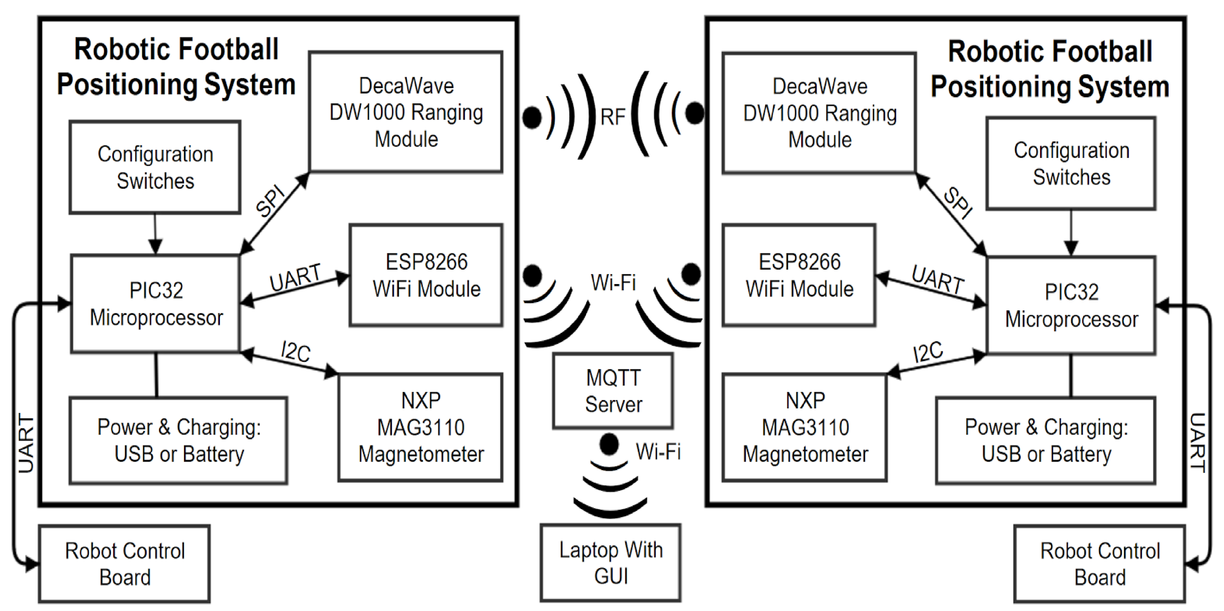


The MAG3110 magnetometer measures magnet field strength in the XYZ axis multiple times a second. This is equivalent to measuring orientation as a vector w.r.t. north. It communicates the measured data to the PIC32 via serial I2C.

3. Wi-Fi with ESP8266-1

ESP8266 is a programmable, low-cost Wi-Fi chip. The ESP8266 was programmed with custom software that enabled the it to act as a UART bridge to a MQTT server.

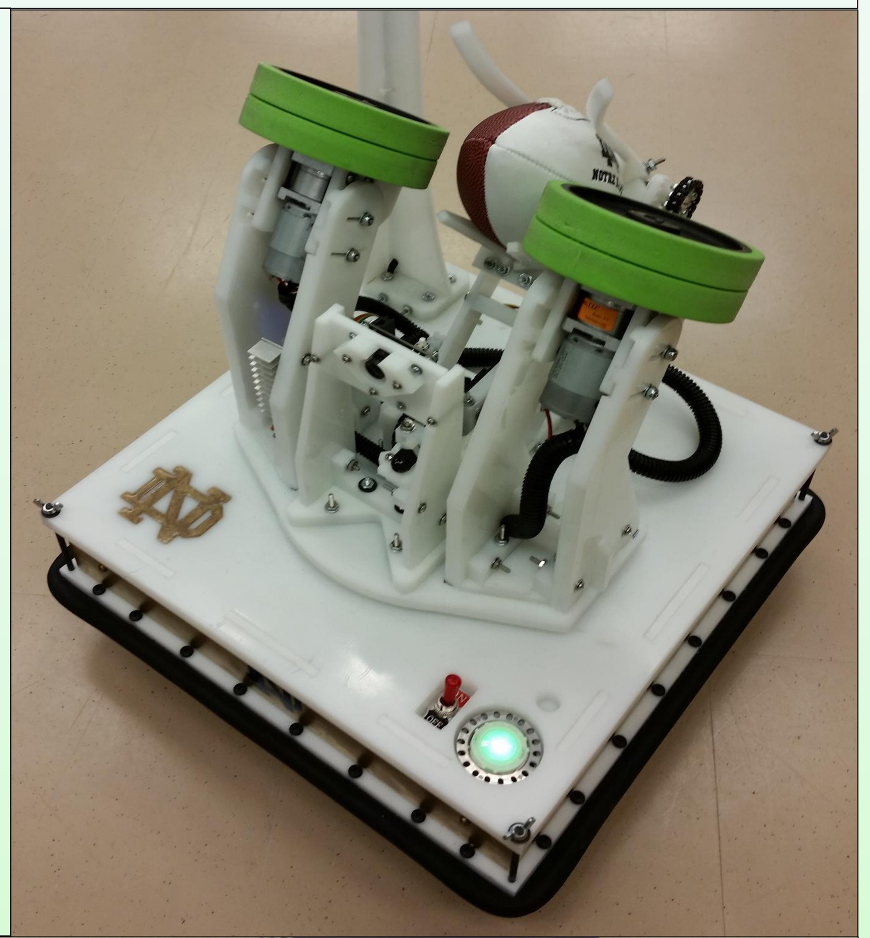




Process

This project started as an idea to create a positioning system that would be implemented by the ND Robotic Football team. We chose the DecaWave to calculate distance due to the speed of the RF transmissions. We used their base code, with extensive alterations, to connect with the PIC. Once working, we were able to transmit the distance between any two boards. Yet for accurate positioning, we still needed orientation. The magnetometer provided the most accurate measurements with the fewest calibrations or calculations. This was implemented into the PIC32 based ranging system. We then implemented the ESP module to transmit the distance and orientation information to a GUI which would continuously calculate the most likely position and orientation.

Like all projects, there were many decisions that took the project in a different direction than originally expected. Our intention for others to continue the process caused us to manage a balance between accuracy and simplicity.

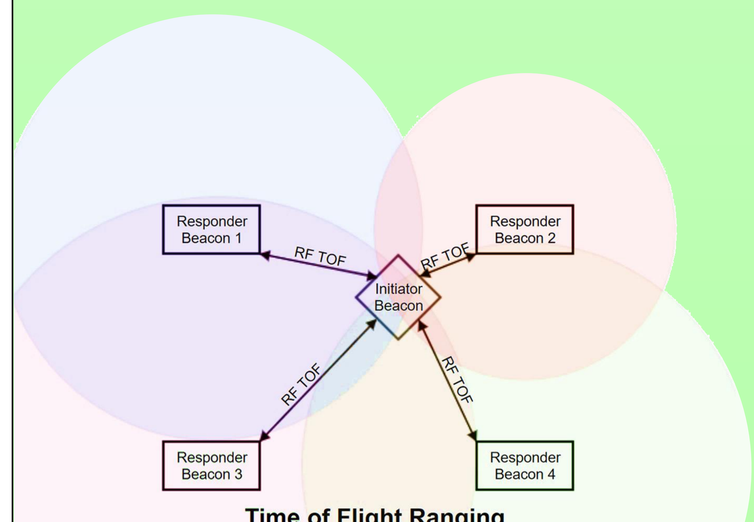


Positioning with a GUI

The GUI continually orients the robot in its current location and direction.

The location is found by storing an array of the robot's distance from a responder and using trilateration based on the average to each. This yields a single point on the field.

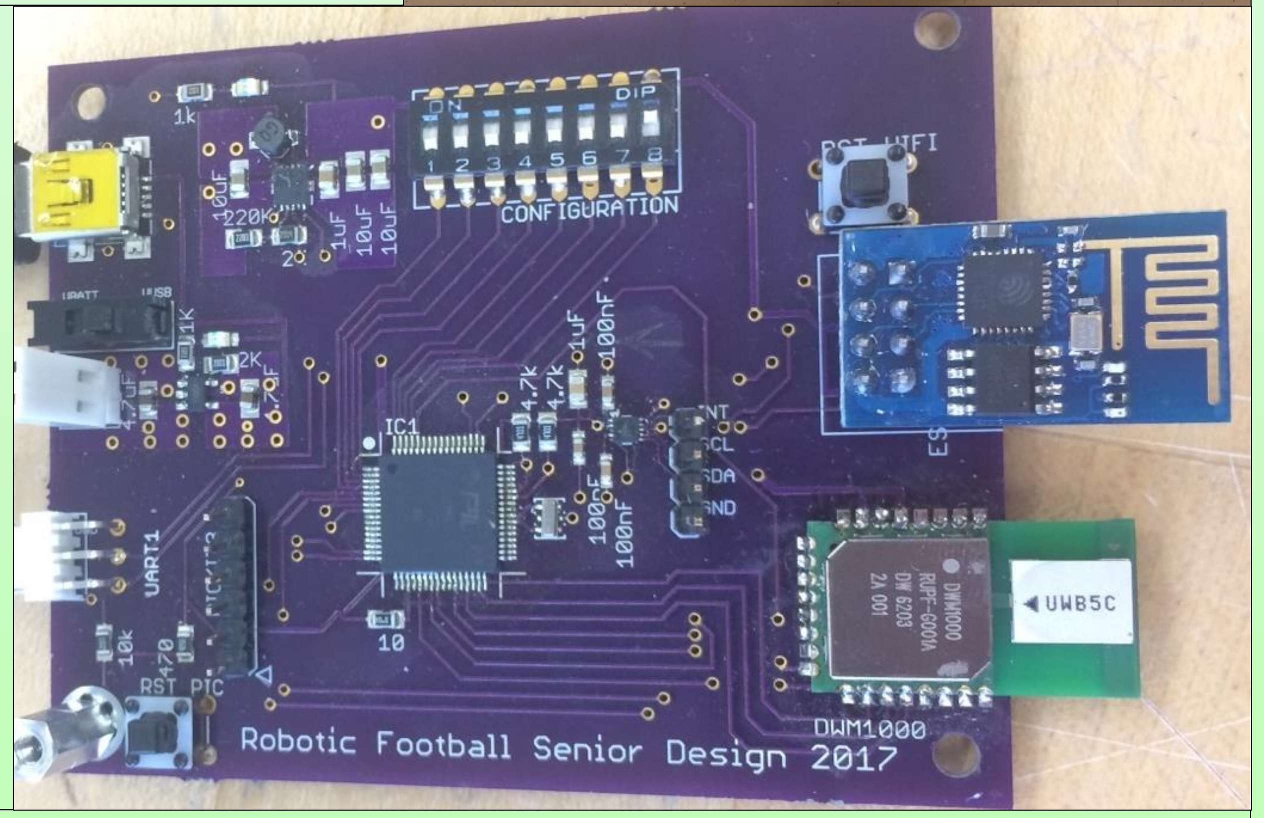
The direction is found by using the magnetometer measurements to compute the vector direction w.r.t. north. The pre-measured angle between north and the y-axis of the field is added to give the direction on the field.



Time of Flight Ranging

Results

- **Long Rang & High Accuracy:** measures distance out to 100ft with an accuracy of ±3 inches
- **Low Cost:** only $45 per board
- **Low Power:** able to run on Li-Ion batter power for +1hr
- **Highspeed:** 10 ranges a second for maximum accuracy
- **Quick Setup:** easy to configure with on board switches
- **Simple Data Acquisition:** position data sent via Wi-Fi to MQTT server
- **Easy to use GUI:** allows user to track position in real time



Future Developments

1. **Full Integration:** Fully integrate the Ranging System into the quarterback and wide receiver robots for Robotic Football. This can then be the primary method for determining distances between the quarterback and wide receiver robots because it reduces the possibility of interference inherent in previous camera based tracking systems.
2. **Increased Functionality:** Expand this positioning system to track more than one robot at a time. This will enable more autonomous features in the robotic football competitions.
3. **Easy Implementation:** Develop the GUI to be compatible with multiple OS perhaps utilizing a web-based interface. Also, expand the Wi-Fi functionality to operate with existing Wi-Fi networks in any location.
4. **Robustness:** Increase the RF reliability by antenna selection and placement suitable to avoid interference of other robots in the area.