ROBOT FOOTBALL

High Level Design

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1. Introduction

The desired project goal for the Robotic Football senior design group is to design a robust system to locate and report the position of the quarterback robot and the wide receiver robots. This will allow the quarterback robot to be able to accurately throw the football. We will explore WiFi positioning technology available to complete this task and evaluate it based on building a reliable, robust, and long-lasting system. The goal of this project is to create a robust, easily repairable, and well documented positioning system for robot football that can be easily used for more than one season.

2. Problem Statement and Proposed Solution

Robotic Football is an intercollegiate engineering challenge. It consists of an 8-on-8 game played by robots that are individually controlled by a unique driver. The rules of this competition are written to encourage gameplay to be as similar to what people are used to watching with NCAA football as possible. As with any football competition, one of the most important players is the player in the quarterback position. Robotic football is no exception to this assessment as a reliable, quick, and accurate quarterback is necessary for playing competitively.

The single most difficult problem with the quarterback is completing a quick and accurate pass to one of the wide receivers. There are several elements to completing a pass that need to be addressed in the context of robotic football. The target must be selected, the distance to the target must be determined, and the ball must be launched with the proper speed and rotation to hit the target.

During the past several years, the Notre Dame quarterback has been designed and redesigned mechanically with less design going onto the electrical side of the operation. The primary problem with the most recent setup is that the quarterback cannot quickly and accurately determine the location of the wide receivers. This functionality is necessary for an effective quarterback and essential for a winning team. The current solution relied on a PixyCamera. This is a camera with image processing on board that allows us to track colored objects. This performs ideally within a small distance and in a properly lit room, but in practice, the camera has to deal with non-ideal lighting and longer distances.

The problem is to develop a positioning system for the quarterback and wide receivers that operates independently of the other systems onboard the robots but can interface with them for data transfer purposes. We plan to use wi-fi positioning software to complete this.

Typically wi-fi positioning systems are based on measuring the intensity of a received signal from wi-fi access points with known locations. A number of different wi-fi access points would need to be set up on the edge of the playing field. The robot could then measure the intensity of the signals from each wi-fi access point, and given information about how the signal attenuates with distance, calculate its distance from that point. We also plan to measure the angle of the arriving signal. With this approach, we need specialized directional antennas or antenna array that could measure the angle of an incident signal. With known distances and angles between the wi-fi access points and the robot, trilateration could be used to find the position of the robot. This approach will give us more accurate positioning then the distance gathered from intensity alone.

3. System Requirements

The system requires wi-fi positioning software that interacts between beacons, receivers, and some sort of interface to communicate with the quarterback. It also requires transmitters and receivers for radio frequencies. This means the system has to support four beacons, at least one wide receiver, and a quarterback. These will be positioned throughout the 15.25 by 28.5 meter field of play which is, therefore, the required range.

With the given range and a required time of use, the time of a football game, there arises the issue of powering the devices. Since the receivers and quarterback are already powered with batteries, the same batteries will be used to power the boards on the robots and new batteries will be used to power the boards acting as beacons. The robots' 12 volt batteries will allow the system to run for the duration of a game and longer. We have yet to determine which size batteries will be used to run the beacons so they can operate for the duration of a game.

Given that the batteries will not need to be changed during a game, this system should be independent of user interaction. It should operate automatically while the robots and beacons are turned on. Instead of a user interface, the system uses the SubPos Ranger software and hardware to connect the robots and beacons [1].

Since the system needs to be placed on pre-existing robots we want it to be as small and light as possible so it does not impede their ability to play.

4. System Block Diagram

4.1 Overall System:

There are three main substations: beacons, robots, and a hub. The beacon and robots break down into communication and positioning systems. At the moment we are only dealing with wi-fi positioning, but there exists the possibility of using radio frequencies which has therefore been included in Figure 1 below.

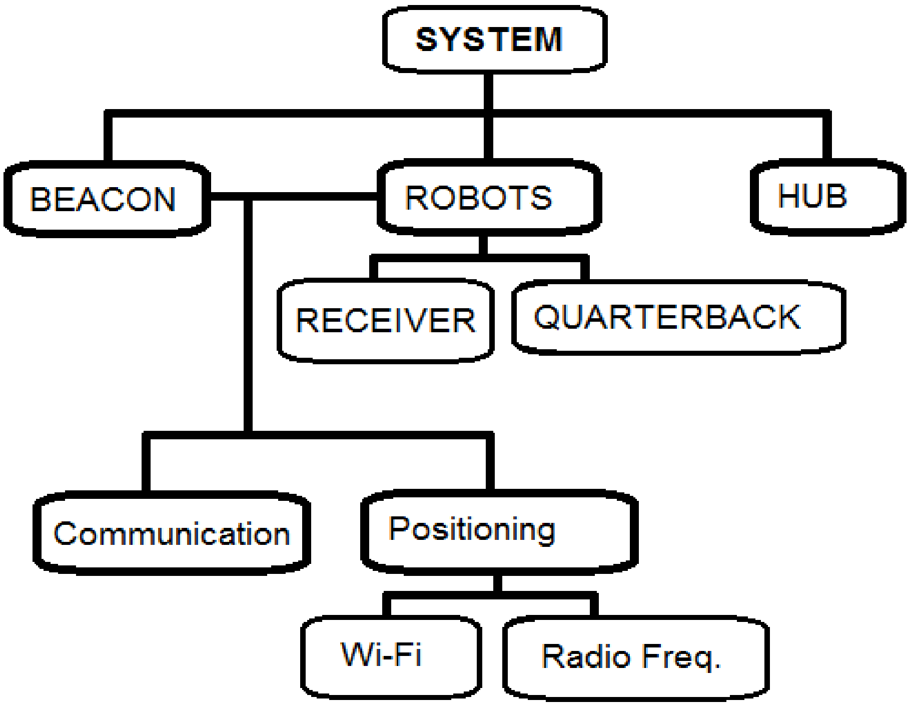

Figure 1. Block Diagram of the Robot Football positioning system

The beacons are the basis for the positioning system as the robots' positions will be determined in relationship to the beacons. They will communicate their position to the robots and the hub.

The robots, either a wide receiver or a quarterback, receive the position of the beacons and communicate their position to the hub. They receive the position of one another from the hub.

Both the beacons and robots will be built on the same basic board, with the software differing between them. The boards for the robots will have functionality to interface with the rest of the robot, and both will have functionality to interface with a laptop for basic serial communication.

The hub is a central database, probably a laptop, and is the interface that connects the beacons and robots and communicates the position of the other devices to each device to cut down on needed connections between the robots and beacons.

4.2 Subsystem and Interface Requirements:

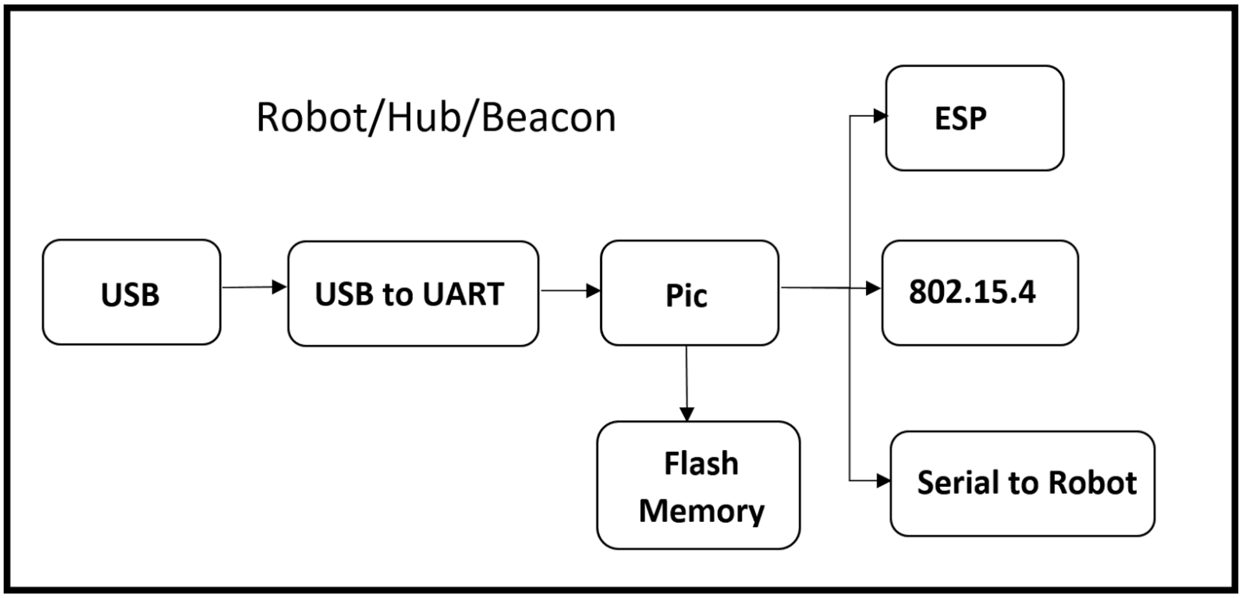

Figure 2. High Level Board Design for the Robot Football positioning system

All subsystems will be run off of the same basic board. The robots and beacons must be able to communicate with each other and the hub, which will be achieved by the ESP chip. The boards for the robots need to communicate with the rest of the robot, while the board for the hub needs to be able to communicate with a laptop. All boards will have a small amount of flash memory that will allow for storing any configuration information and the positions of the robots and beacons. If necessary the system will be expanded with some other RF chip to increase resolution of the positioning system.

4.3 Future Enhancement Requirements

There is the possibility of higher resolution of position and more robots used in the system. Leaving one form of serial communication to the system available will allow to interface with the robot and leaves a possibility of expansion. We also want to include the possibility of expanding to include an inertial measurement unit (IMU) in the decisions about what board we use and how we arrange the final board layout. This system would allow us to use two separate sources of sensor data. If we choose to expand the functionality of this board, we can then simply populate the space allocated for an IMU later and update the program on the main microcontroller.

5. High Level Design Decisions

The beacons are the basis for the positioning system as the robots' positions will be determined in relationship to the beacons. They will communicate their position to the robots and the hub. The robots, either a wide receiver or a quarterback, receive the position of the beacons and communicate their position to the hub. They receive the position of one another from the hub. The hub is a central database, probably a laptop, and is the interface that connects the beacons and robots and communicates the position of the other devices to each device to cut down on needed connections between the robots and beacons. All three of these subsystems will require a board with components as explained below.

Hub/Beacon/Robot Board:

- Use ESP8266 wifi chip for positioning data and basic communication, with the possibility to expand to an additional RF chip to increase resolution of positioning system.
- Some form of flash memory to store position of each robot and beacon and other configuration information.
- Serial communication between each board and a laptop to act as a hub. Will use serial to UART similarly to the method used in class.
- Serial communication between the board and the rest of the robot. Will use serial to serial pins similar to methods used in class.
- Microcontroller for positioning calculation and other functionality. Use PIC32 as used in class assignments.
- Voltage regulator to power board from an external power source.
- USB power source with necessary voltage regulator

6. Open Questions

What is the error of the wi-fi positioning system based on the field dimensions?
What size batteries are required to operate the beacons?
What is the best way to program the ESP8266 and the separately?
What is the best way to realize communication between all the separate boards, and communicate with a laptop?

7. Major Component Costs

Table 1. Board Component Costs

Component	Cost
PIC	Free
ESP8266	$7
Flash Memory	$1
Serial to UART	$2
RF module (optional)	$6
PCB	$30
IMU (optional)	$1
Additional Components	$20

At least 7 boards (beacons, robots, and hub): $67 each = $469

Using PIC, ESP, flash memory, two serial interfaces, wifi, and additional components [2]

Four beacon stands: $10 each = $40

Note: These prices are high estimates. Actual costs will be lower, with additional funding being available after proof-of-concept from the robot football club.

8. Conclusions

We aim to design a robust system to locate and report the position of the quarterback robot and the wide receiver robots in relation to the field so that the quarterback robot will be able to accurately throw the football. We will explore wi-fi technology that is available to complete this task and evaluate it based on building a reliable, robust, and long-lasting system.

9. References

[1] Blecky. "SubPos Ranger." *Hackaday.io*. 2016. https://hackaday.io/project/9242-subpos-ranger.

[2] "Mouser Electronics." *Mouser Electronics, Inc*. 2016. http://www.mouser.com.