RC BOAT POWER AND SIGNAL LEVEL INDICATOR

Project Proposal
ECE 445

Sanchit Anand (sanand8)
Vaibhav Mittal (vmittal6**)**
Sho Harisawa (harisaw2**)**

TA :- Yamuna Phal

1. Objective

RC Toys are a multimillion dollar industry, with buyers from across the planet. One of the main problems faced by enthusiasts is the short battery life of the vehicle. Most batteries last only 10-15 minutes and the battery degrades over time. Another frequent complaint is the low signal range, which often leads to vehicles straying out of range and getting stuck, lost or otherwise damaged. We decided to work specifically on a RC boat because these issues are most prevalent when the toy is in the water as it makes retrieving the toy the hardest as compared to a RC car or a RC bike.

We propose to solve this problem by providing an indication of low levels of signal strength and power, and therefore giving the user a chance to save his boat from harm. We would further propose to implement a tracking mechanism to keep tab on the boat in case it is misplaced (within the range) during operation. The battery level would be detected in hardware (using a simple comparator) and the location would be obtained using a GPS chip the data would then be transmitted via bluetooth to be displayed to the user.

Our device would be located physically on the RC Boat, and would be active during the boat's operation. It would transmit location and battery data to the user's cell phone. An app on the cell phone would have an interface to display signal range, battery level and location. Furthermore, if time permits us to extend our project, we would like to get the boat to steer back to the user in case of low signal or power levels, with the use of magnetometer direction readings and GPS coordinates.

2. Background

Most of us love to play with different types of RC toys, be it a car, boat or even a plane. RC toys are super fun to play with and can fit into anyone's budget. They can cost from anything around $20 - $2000 depending upon the functionality and the complexity. But many users have experienced and complained about major flaws in it's functionality which make them annoying to play with ,

1.) Firstly, The battery life of these toys is around 10-15 minutes after one full charge (which takes 8-10 hours for the first charge and then 4-6 hours for every subsequent charge), which is very insufficient considering how long it takes to charge them in the first place. On top of that one can imagine how annoying it must be to lose a toy or even damage a toy because it ran out of power.

2.) Secondly, for a RC toy costing around $20, the control range is around 115 feet which is not a lot for anyone playing with it and therefore they have to always keep in mind a boundary of sorts and stay inside that or risk losing their toy forever.

Keeping the above two issues in mind and also looking at how big the RC toy industry is throughout the globe, we decided to provide a simple and efficient solution to the problem. We took up the challenge to provide some sort of indication to the user whenever the battery level or the signal level runs below a defined threshold value and time permitting we would like to implement a mechanism to bring the boat back to the user if it strays out of range.

3. Requirements

Our set of requirements are stated as follows:

1. Notify the user when the boat is about go out of the specified range.
2. Our mobile unit should be capable of indicating low battery levels.
3. Our mobile unit should be capable of measuring the approximate location and direction of the vehicle.

4. Block Diagram

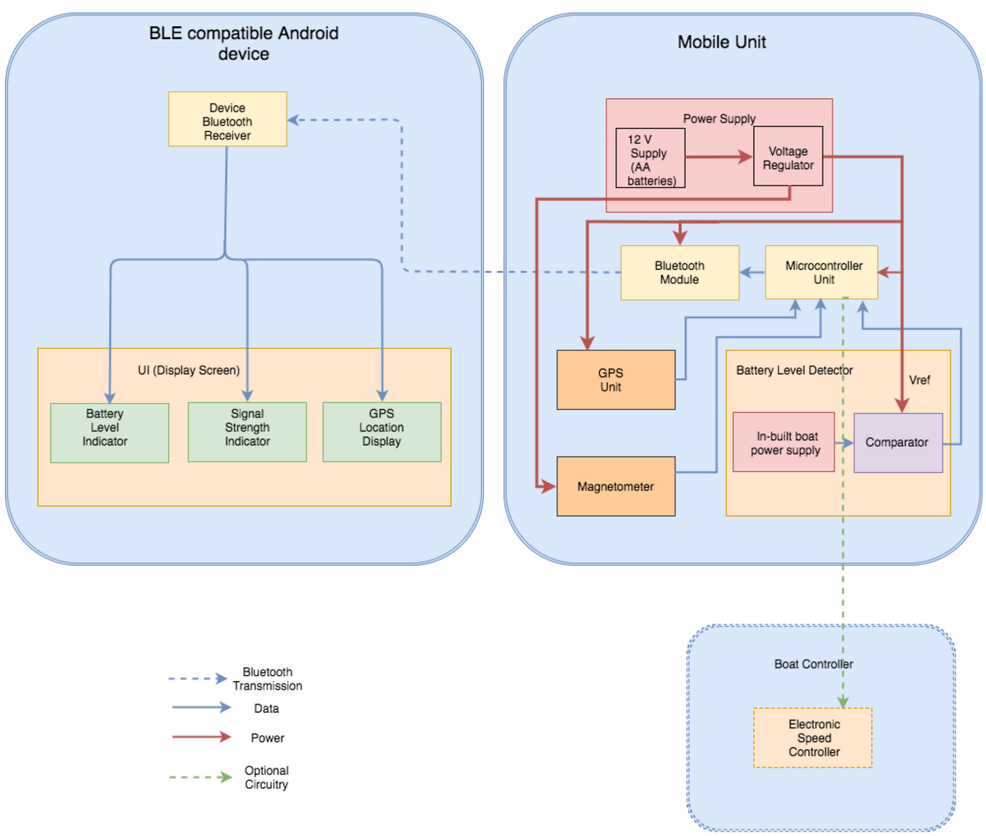

Figure 1. Block Diagram

5. Description

Our project will consist of two main units, namely the mobile unit, and an android application responsible for receiving data from the mobile unit.

The mobile unit consists of a bluetooth module,magnetometer, microcontroller, battery level detector and a GPS unit, and the bluetooth receiver on the android device is used to receive data transmitted by the mobile unit.

The bluetooth module on the boat is responsible for transmitting the following information :-

a. Battery level
b. GPS location

Once this information is received by the android smartphone, it is processed in software and the battery level and the GPS location are indicated as shown in figure 2. To determine the signal strength, we calculate the strength of the received bluetooth signal in dBm in software[9] and use the link budget equation[4] to calculate the distance travelled by the signal from the boat. We then compare the this value with the range of the boat and notify the user if the boat is about to fall out of range.

$$range\ (in\ miles)\ =\ antilog\left(\frac{P_{TX}+G_{TX}-L_M+G_{RX}-P_{RX}-104}{20}\right)$$

where P_{TX} and P_{RX} is the power transmitted by the TX and received at RX (receiver sensitivity) respectively. G_{TX} and G_{RX} is the gain of the transmitter and receiver antenna and L_M is the link margin.

Using this we can easily calculate the distance the signal traveled giving us an estimate for if the boat is in or out of range.

The magnetometer works by measuring the strength of the Earth’s magnetic field in the x,y and z directions. We can do some calculations based on these readings and figure out which direction the boat is facing towards.

The GPS unit will be in constant communication with Geostationary satellites. Each satellite transmits a unique time signal along with orbital information that allows us to decode our latitude and longitude. If we receive signals from 4 or more satellites , we can accurately decipher our location and altitude, which will be transmitted back to the cell phone unit.

Finally, the optional circuitry indicated by the dotted green line is for bringing the boat back into range in case of emergency. This works by measuring the location and direction of the boat, and calculating a new path that would take it back into range of the user. We plan to implement this as an extension the the project, if time permits.

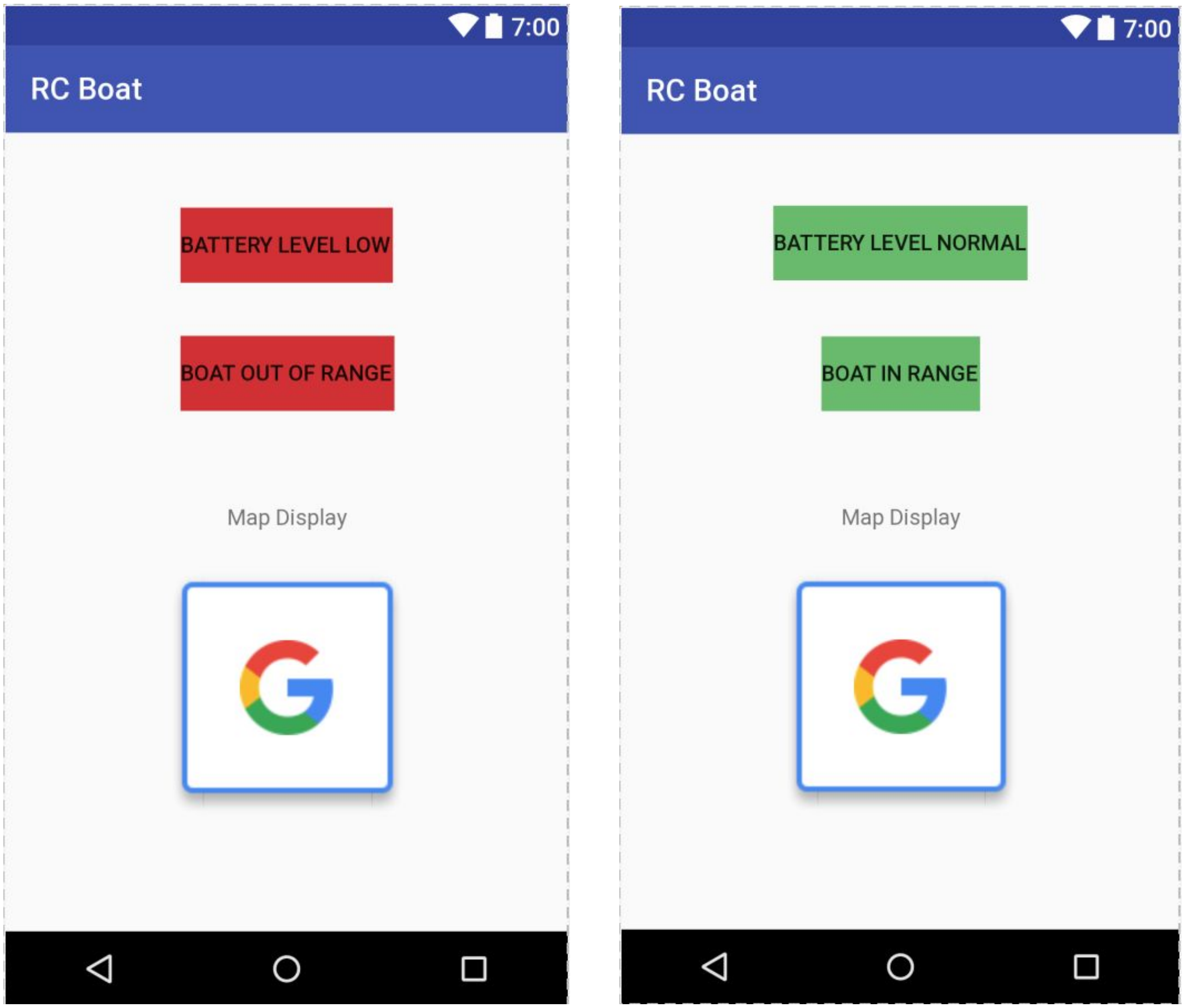

Figure 2. App UI

6. Functional Overview

6.1 BLE compatible Android Device

6.1.1. Bluetooth Module

The bluetooth module receives the signal transmitted by the bluetooth transmitter on the mobile unit. The information is passed on to the android app and the information is displayed (battery level and the GPS location of the boat) for the user.

To determine the signal strength the bluetooth signal power is determined via the android app and the distance of the mobile is computed using the link equation. The user is informed whenever the boat is about to reach its maximum range.

Requirements :

1. *Must be able to communicate with a class 1 radio.*
2. *Must be able to display the information to the user.*

6.2 Mobile Unit (Boat)

6.2.1. Bluetooth Module

The bluetooth module is responsible for communicating with the BLE (Bluetooth Low Energy) [1] compatible android device. The bluetooth module used on the boat is a BLE class 1 radio which enables us to transmit data over long range (almost 100m).

The class 1 bluetooth radio on the boat transmits the battery level and GPS coordinate information to the android device which in turn displays it to the user.[7]

Requirements :

1. *Must be a class 1 radio capable of transmitting over a range of 100 m with a receiver sensitivity of -97dBm with max transmission power of +17dBm.*
2. *Must adhere to BLE protocol [3].*
3. *Low input voltage* $V_{in} = 3.3\ V$ *with* $\pm 5\%$ *tolerance.*

6.2.2. GPS Unit

Uses a GPS chip to monitor the location of the chip and sending it to the transmitter.

The GPS module is responsible for updating the position of the boat periodically on android device. The GPS module is a small antenna that transmits data with the satellite above the sky. The module must have a low-power profile and should function when there is at least clear path between the module and the sky.[8]

Requirements :

1. *Must be capable of transmitting over a clear sky above sea level with receiver sensitivity of -162 dBm.*
2. *Must be able to update the position with 5Hz minimum*
3. *Low input voltage* $V_{in} = 4V$ *with* $\pm 5\%$ *tolerance.*

6.2.3. Battery Life Detector

Measures the battery level of the onboard power supply. To implement this, we will use a simple comparator to compare a reference voltage with the voltage level of the boat inbuilt battery. We are planning to use LM393 dual comparator to accomplish this as it is readily available in the senior design lab.

Requirements :

1. *Must be able to determine the voltage level of the battery accurately when it goes below 5V.*
2. *Must provide a high signal when the voltage level falls below the reference voltage (5V) and a low signal when the voltage is above the reference voltage.*

6.2.4 Power Supply

We use a 12V AA battery to provide power to the onboard hardware. The power from the AA batteries is then fed into a voltage regulator which gives us regulated DC 5V for the microcontroller. We are planning to use LM7805 voltage regulator which provides regulated 5V output from an unregulated 12 V input.

Requirements :

1. *Must provide a stable reference voltage to the comparator* $V_{ref} = 5V/\pm 5\%$.
2. *Must provide regulated voltage to the bluetooth module* $V_{DD} = 3.3\ V/\pm 5\%$ *and the GPS unit.*

6.2.5 Magnetometer

We will use a magnetometer onboard the device to track the direction that the boat is facing.The direction will be initially calibrated towards the user [6].

Requirements :

1. *Voltage requirements between 3.3V - 5V DC.*
2. *Sensitivity of around* $\pm 0.1\ \mu T$.
3. *Capable of transmission at data rates 60 Hz and greater.*

7. Risk Analysis

The limiting factor for data transmission over bluetooth is the limited capability of the class 2 radio on the android device. The max receiver sensitivity of a class 2 radio is around -86 dBm and its max transmission power is around +3 dBm. Whereas for a class 1 radio the receiver sensitivity is -97dBm with max transmission power of +17dBm . Therefore by using a class 1 radio with a class 2 radio we can expand the range of the data transmission of the class 2 radio on the handheld device as the class 1 module on the boat has a better sensitivity which means that it can detect smaller signals transmitted over a long range. But if our theoretical calculations fail, then our system could be critically affected and would be rendered useless.

Motion and water also present a risk for this project. Our bluetooth module needs to be waterproof as water on/in the boat would be a certainty and therefore we need to take care that the bluetooth module and all other peripherals don't get wet .

Power would be another issue. Our implementation would be useless if It cannot function for longer periods of time without charging the regular RC boat.

Finally, we must be able to decipher the relative location of the boat from the data given by GPS unit and magnetometer, and provide a path for the boat in case of low power or weak signal levels. If we are inaccurate in our estimate, the boat could possibly get lost.

8. Ethics & Safety

One of main concerns during the project, according to IEEE Code of Ethics [2], is "to accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment". First, special precautions must be taken for the mobile unit. In case water enters the sealed container, it should not be unsafe for handling, or provide any risk of electrocution.

Another concern is “to maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitation” [2]. Our potential risk lies in our handling of power supply. We must monitor the power supply, and ensure that the voltage and current are within reasonable limits to avoid any meltdown or explosions.

During the development procedure, technical issues may occur, and need the TA to help us out. We want to make sure that we “seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others”[2], and give proper credit to any help that is offered not only from TAs, professors but also others.

Finally, all team members should “assist colleagues and co-workers in their professional development and to support them in following this code of ethics” [2]. We will make sure that we respect each other, offer and accept criticism within our team, and support each other when in need.

9. References

[1]- https://en.wikipedia.org/wiki/Bluetooth_Low_Energy
[2] - http://www.ieee.org/about/corporate/governance/p7-8.html
[3] - https://electronics.stackexchange.com/questions/144799/bluetooth-range-and-power
[4] - https://www.allaboutcircuits.com/technical-articles/wireless-range/
[5] - https://www.quora.com/What-Bluetooth-low-energy-BLE-devices-are-on-the-market-today
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[9] - https://stackoverflow.com/questions/15312858/get-bluetooth-signal-strength