Proposal: District Shared Parking in Seattle

Team Park N' Go

Rajdeep Singh
Alexander Huttunen
Jisoo Jung
Yaning (Nina) Yang

Project Abstract

The proposed project is to place a single magnetometer (HMC5883L) with a microcontroller (SI4010) at the center bottom of each parking space that is capped and protected with a road reflector. The microcontroller will communicate via a Frequency Shift Keying (FSK) radio signal to a radio in the Raspberry Pi. The benefits to our proposed solution are that it has very low power, low cost and high durability. The Si4010 microcontroller and the magnetometer are inexpensive and Si4010 is "designed for low power battery applications with standby currents of less than 10 nA" (SI4010 spec). This solution provides information about which parking slot is vacant and its performance remains stable across various environments and location. Additionally, due to the low power consumption and high durability of the internal components, the parking sensors should require very infrequent maintenance.

Problems and Goals

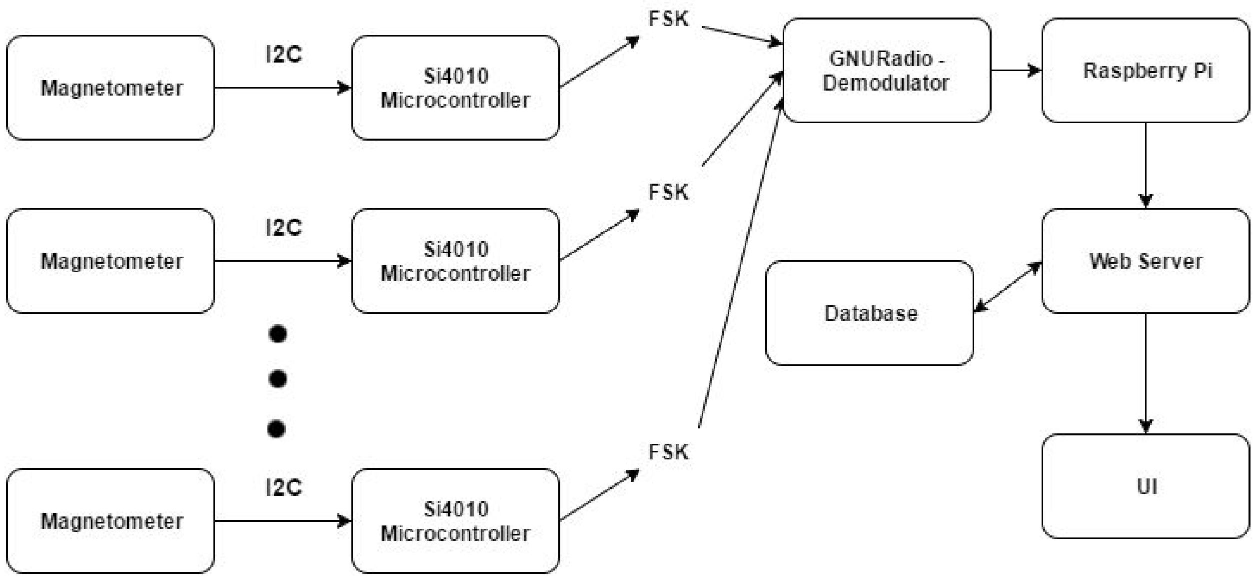
Our goal is single parking spot-scale parking search. With the placement of our sensors at each individual spot we will be able to detect the vacancy of each parking spot. One concern we have is how long the battery will last in each sensor. We plan to power each individual sensor with a battery that has a finite lifetime and will need to be replaced during the life of the product. We hope to have a low enough power consumption so that the battery only has to be replaced on the order of years.

Additionally, we are trying to make the sensor as inexpensive as we can. We hope to achieve this by using chips that are already mass produced for other markets (e.g. magnetometers are used in smartphones) and microcontrollers instead of more powerful systems.

Finally, although our primary focus is to make a sensor that is inexpensive and long lasting, we also hope that it can detect vehicles more accurately than some competing solutions.

Design strategy

Overall system architecture:



1. Each magnetometer is connected to a Si4010 with Frequency Shift Keying (FSK) radio and placed at the center bottom of each parking spot. The sensed data is sent to Si4010 via I2C protocol. The magnetometer will collect data based on the car driving over the sensor. Note that the magnetometer can be placed in front or top of a car since it provides sensor data in all x,y and z-axis.

2. The sensed data from the magnetometer will be evaluated based on the precomputed threshold value and then converted to binary values. If the car is over the magnetometer the return value will be 1 and 0 if a car is not detected.

3. The Si4010 will send the data out over FSK at the frequency of around 344 MHz. We will read these frequency by using GNURadio on the Raspberry Pi to receive, demodulate, filter and recover these data as 0's and 1's.

4. The decoded data values will be stored in a database to know the occupancy of the whole parking lot. The data is presented as a Graphical User Interface (GUI) which will be made for the user's convenience. The GUI will be a web application that can be accessed on multiple platforms. Backend works such as receiving data from GNURadio, writing/reading to/from database and providing data to frontend will be handled by a web server.

Strength / Features of our Design

Our proposed system will be cost efficient. The cost is based on each individual parking spots which is estimated to cost less than $10. In addition, our parking sensor is insensitive to environment and locations. This means weather, lighting, indoor/outdoor, street parking, garage etc. will not have an affect on our sensor detecting cars.

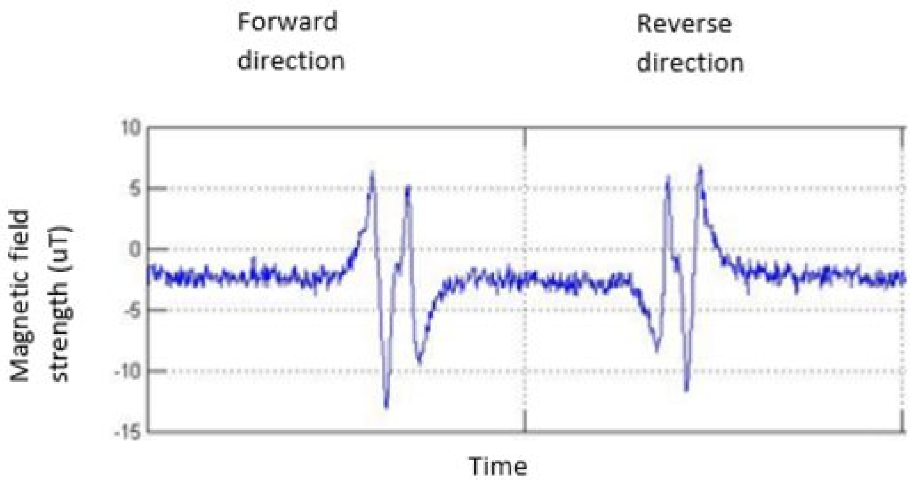
Unknowns/Limitations/Risks

Although we already got a good speed going, our group do not have prior experience implementing many aspects of our project. Some of our group members has been exposed to a lot of the theories but none of us had actually implemented any of it. Such includes manually coding an I^2C driver, receiving and decoding FSK signals into strings and working with magnetometers in general. However, we have made a lot of progress on the I^2C driver and have a plan on how to proceed with decoding the FSK signals. Additionally, we don't have any experience for things such as creating a printed circuit board (PCB) that may be helpful in producing a more polished product.

Preliminary Experiments

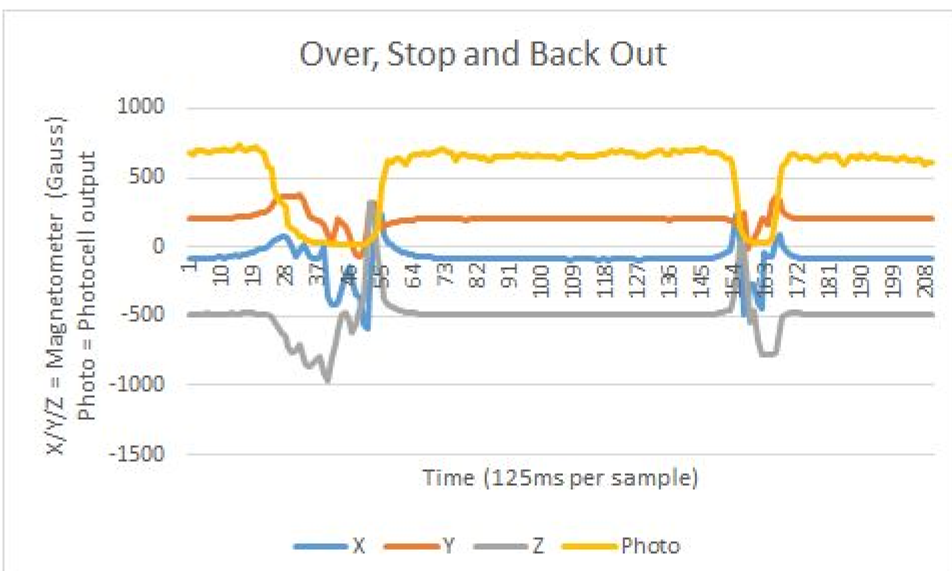
First and foremost we tested the magnetometer sensor with a real car. The sensor is tested on couple different scenarios that could happen in a parking lot: car driving over the sensor, stops and back out, driving over the sensor and through, driving through the parking spot next to the sensor, and driving the car fast next to the sensor. We got promising data with all four different scenarios we thought of at the time.

There was a research already done by NXP Semiconductors to observe the magnetometer's behavior when a car passes over it. The generated plot from NXP's experiment was used as a reference.

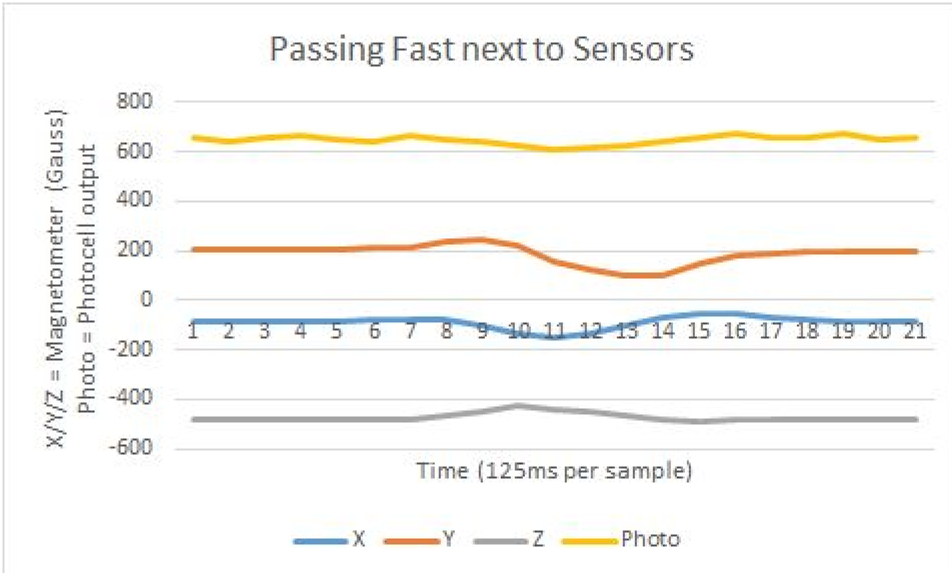


Car Driving Over Magnetometer
Source:
http://blog.nxp.com/connected-car/howto-detect-vehicle-presence-or-movements-with-magnetometers/

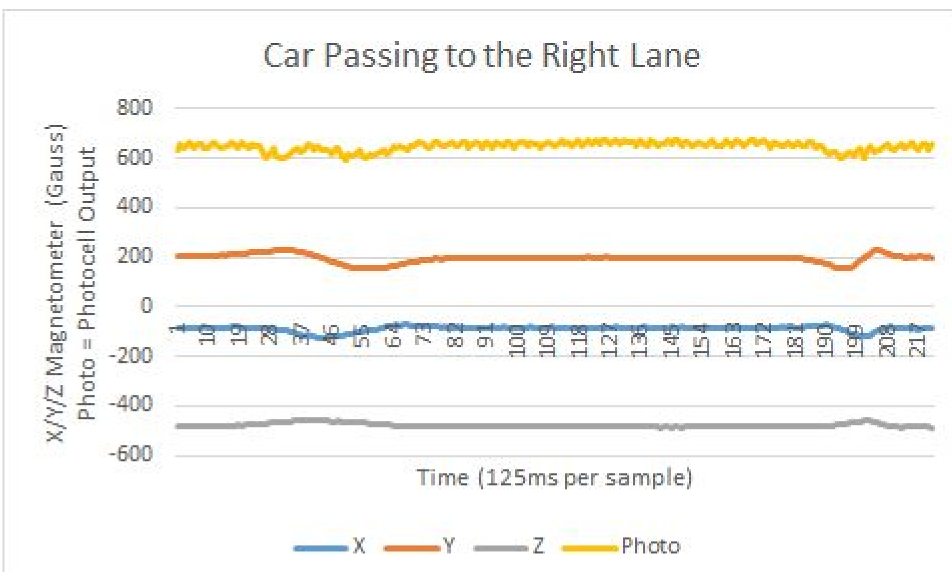
This data is obtained by NXP Semiconductors shows signal changes that are mirrored image of each other. It shows that the sensor works properly and is the behavior we are looking for in our test.



First experiment was held like this: drive a car over the sensors and completely pass them, wait for a while and then drive a car over the sensors again in the reverse direction. There are places where the data is fluctuating. Close look at these two places show that they are mirror image of each other. They are different due to car's speed when it was going over the sensors. The first fluctuation shows that the car went over in slower speed than in the second fluctuation.



The car quickly passed next to sensors in this experiment. Since it's not directly going over the sensors and is going in fast speed the data shows small change in amplitude. This result is useful because we don't want to sense a car when it's not parked. This type of behavior will help reducing false positive detection.



Another experiment was done with the car passing next to the sensors, but with slower speed. It showed similar result as "Passing Fast next to Sensors" experiment. We can observe little fluctuations in the data, but they are much smaller than the ones in "Over, Stop and Back Out" experiment.

In this experiment the car (1) went over the sensors, (2) stopped after completely passing the sensors, (3) went over the sensors again, (4) parked for short time on top of the sensors and then (5) went out back to where it came from. To help interpreting the data here is a list of sample ranges associated with different time interval:

(1) 58 - 153th sample
(2) 153 - 305th sample
(3) 305 - 343th sample
(4) 343 - 381th sample
(5) 381 - 419th sample

Time intervals (3), (4) and (5) show very useful indicator of a parked car. When the car was stationary on top of the sensors X-axis data showed a stable but significant difference between when the car is not over the magnetometer. Y and Z axis did not show much difference in these time intervals, but from observing X-axis data we can actually tell there's a car over the magnetometer.

Implementation plan and milestone schedule

1. Test the magnetometer on Arduino to verify feasibility of using it on this project
2. Setup development environment for Si4010 and run a simple program
3. Setup I2C to communicate the magnetometer with Si4010
4. Send arbitrary signal from Si4010 via FSK and receive from software defined radio
5. GNURadio FSK demodulation to receive correct signal from Si4010
6. Work on filtering data collected from magnetometer to get accurate result
7. Once car detection works and if time permits, continue to building database and web server using Python Flask to provide data to frontend display.

Currently we have completed steps 1 through 4. Each of these steps are depends on the one following. Our goal now is to connect steps 1 through 4 and try to demodulate a known Hex output from the FSK demodulation indicating if the parking spot is occupied or not. Once we have tested these steps we will move forward and filter data and use a real car detection to test our system.

The main focus in this project is to accurately detect the signal, not constructing server, database and UI. So step 7 is planned to be done only if time permits after testing that the car sensing works. Work will be divided roughly like this: two of the members will be working on receiving message via FSK and the other two will be figure out how to sense a car using the processed data we have extracted from preliminary experiment. These tasks can be done in parallel and are planned to be spent roughly about 2 weeks.

Evaluation

We will evaluate our success similar to how we did our preliminary experiment. We will evaluate the accuracy of our sensor the activity of different car movements. For example a car driving over the parking lot and backing out will have the same output as a car driving over and driving through. We will also evaluate the sensor not detecting cars in nearby parking spots or cars passing by.

Related work

http://blog.nxp.com/connected-car/howto-detect-vehicle-presence-or-movements-with-magnetometers/

Our proposed project uses the same magnetometer to detect the presence of a car passing through. The difference is we add additional features to the car detection such as adding Si4010 microcontroller to communicate and sent out data.

Teamwork report

Our team consists of four team members and most of the time we divide work into to two groups with team captain Alex.

Alex- Modified arduino code to allow wireless communication for the magnetometer test. Selected parts that will be used in the design. Setup Raspberry Pi as a C2 interface to upload programs to the Si4010 microcontroller. Worked on getting code compiling for the Si4010. Got most of I^2C working. Installed VNC and created some bash scripts for the Raspberry Pi.

Rajdeep- Currently working on I2C communication protocol. Assisted in code compilation for the Si4010 microcontroller. Connected the magnetometer, photodiode and ultrasonic sensor with arduino yun and performed initial testing along with other team members. Completed the "getting started with Arduino" assignment.

Jisoo- Researched sample code and development environment for using the magnetometer and Si4010 microcontroller. Helped modifying the sample code to send messages from the magnetometer via FSK. Worked with Alex and Raj in debugging I2C to communicate the magnetometer with Si4010.

Nina- helped organize arduino code to initially test the magnetometer and photocell sensor. Helped look for code to setup the wifi on the Si4010 microcontroller. Used GNU radio to receive, demodulate, filter, and recover FSK signals to binary which then can be translated into strings.

We have a really strong team dynamic because each group member has their own specialized area. One team member comes up with design ideas and assist other team members while we puts individual parts into implementation.

Milestones

1. Trying the magnetometer out with an actual vehicle to assess feasibility

2. Achieving I^2C communication between the Si4010 and magnetometer and processing the signal to detect a car

3. Radioing a signal back to the Pi from the Si4010 and processing it on the Pi.