EE 491 Senior Design I

Stop Sign Tracking System

Design Document

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Index

I. Introduction

In this project, which is a stop sign tracking system, we need to design an event-trigger tracking system which can send out alerts when the stop sign is tilted or covered by snow. So we need to have sensors and a communication system. In order to connect those two parts together, we also need a good microcontroller. Besides, a power supply is necessary to support all of those three parts. In this project, we have to think about the price of each part because the cost efficiency for stop signs is important. Additionally, we must consider carefully about the operating temperature because the whole system will work outside. The remaining things are the integration of those components and the embedded system.

1. Functional Requirements:

1. Tilt threshold: Once the sign tilt becomes greater than 15 degrees, an alert should be sent out.
2. Send Alerts: Alerts should be event driven and only a message is sent out if an event occurs. Events are something that is being monitored that will render the sign nonfunctional or an incoming request for information. The sensor should specifically figure out what happens to the STOP sign (whether it is covered by snow, or tilted).
3. Wireless Communication: Communication to mobile devices should be wireless to keep cost low.
4. Self-Calibrate: System should calibrate itself to reduce maintenance and installation time.
5. False-Positives: 10% of alerts can be false-positive alerts (alert sent out that sign broke constraints but constraints weren't actually broken).

6. False-Negatives: No false-negatives are allowed (No alert sent out even though constraints were broken).
7. Power Supply: System (the battery) should be supplied 12V. Some of which will be used to directly supply system and the rest to be used to charge a rechargeable source.
8. Tracking: Should be able to locate the sign from the signal.

2. Non-functional Requirements:

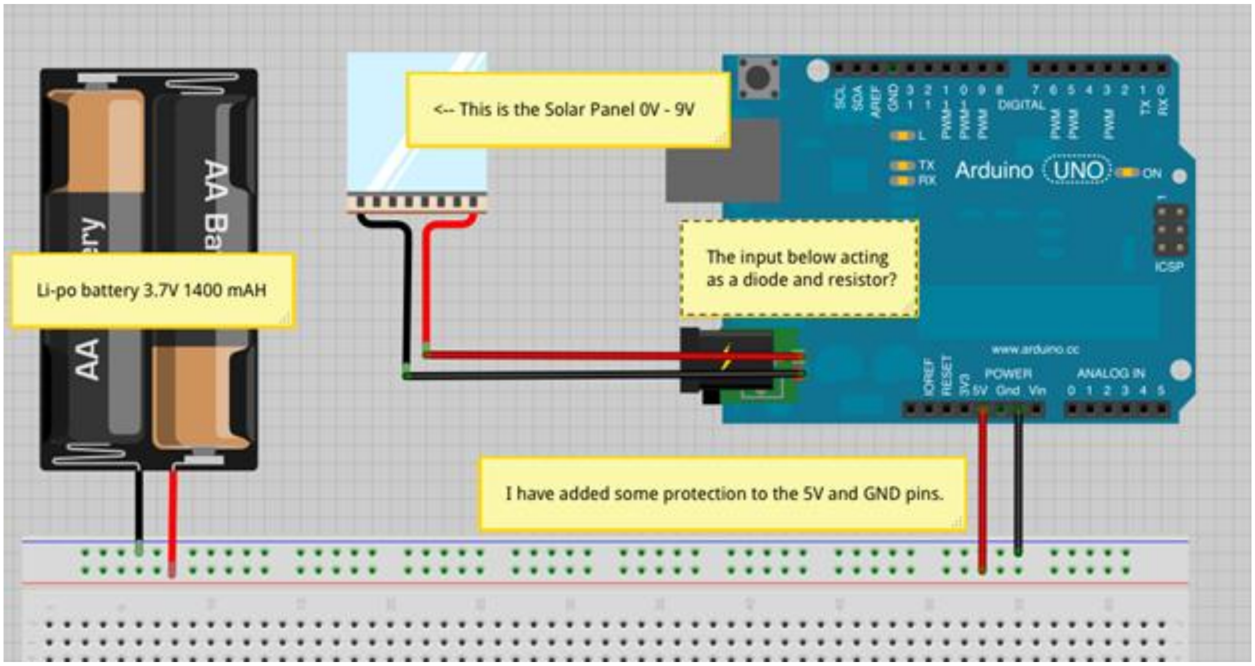
1. Size: The package shouldn't be larger than 20% of the hardware being used.
2. Package: The system should be packaged with ESD materials that are weather resistant.
3. Weather Resistant:
    - -The package should operate in temperatures from -30 F to 120 F.
    - -Water-proof (rain, snow, fog…).
    - -Wind resistant: should stay attached to sign under strong wind (~60MPH).
    - -Easy to Install: Installation onto stop sign should be no more than 10 minutes.
4. Lifetime: System should be able to sustain itself for 10 years.

II. Different Systems

Temperature in Iowa: within the range of -20 ℃ to +35 ℃ (this range should be wide enough even if the extreme weather happens).

1. Power Supply

A power supply is needed for the whole system. Our idea is to use a rechargeable battery plus a solar panel. We also need a charging circuit to connect the solar panel with the battery. The power supply looks simple but needs to be considered carefully. Currently, we have a method of how to connect the solar panel and battery to the Arduino Pro using a charging circuit. Based on this, we are looking for a battery and a solar panel which can supply a demanded DC voltage (5V), enough energy (3 days), and have long enough lifetimes (10 years).



2. Tilt Sensor

A tilt sensor is necessary to measure if the stop sign is tilted. In fact, it is an accelerometer. When the stop sign is tilted, the sensor will be able to know how many degrees the sign is tilted by. If the range exceeds ±15 degrees, an alert should be sent out. Typically, a tilt sensor is very cheap compared to other components. It can be just connected to the header of the board of the microcontroller. After comparing with other choices, we decided to use ADXL345 accelerometer.

<u>ADXL345 Accelerometer</u>

http://www.aliexpress.com/item/Free-Shipping-ADXL345-3-Axis-Digital-Acceleration-Of-Gravity-Tilt-Module-For-Arduino/1180370311.html

- Temperature Range: -40 ℃ to +85 ℃
- Price: $4.00
- Supply Voltage: 3 to 5V

3. GSM Module

A GSM module is the communication system that we would like to use. Alerts should be event driven and only a message is sent out if an event occurs. The message should contain the position of the stop sign and also specify if it is tilted by certain degrees. Besides, the communication to mobile devices should be wireless to keep cost low. The GPRS Shield V2.0 can work in the temperature range demanded and has an good interface for the Arduino Pro 328. The price is also acceptable.

GPRS Shield V2.0 (SIM900)

http://www.seeedstudio.com/depot/gprs-shield-v20-p-1379.html?cPath=19_20

- Temperature Range: -30 ℃ to +80 ℃
- Price: $59.90
- Supply Voltage: 3.4 to 4.5V
- Interface: UART

4. Microcontroller

A microcontroller is necessary to process the data from sensors and control the GSM module to send out alerts when events happen. The ATmega328 has an excellent operating temperature range and is able to control the whole system.

Arduino Pro 328 which uses ATmega328 has a very cheap price compared to other boards.

Arduino Pro 328 (ATmega328)

https://www.sparkfun.com/products/10915

- Temperature Range: -40 ℃ to +85 ℃
- Price: $14.95
- Supply Voltage: 3.3V to 12V or 5V to 12V (two models)
- Clock Frequency: 8MHz (3.3V model) or 16MHz (5V model)
- Memory: 32k Bytes of ISP Flash
- Interface: UART
- Size: 53.34×54.08mm (L×W)

III. How the user interacts with the system.

1. Clients

First of all, our clients are people who are working at traffic departments, cities or county offices. One of their responsibilities is to check status of stop sign. If the stop sign falls down or is stolen, the user will be notified via text message.

2. Product Installation

We are going to use Nema enclosure box type to contain our devices inside. NEMA is rated to protect against designated environmental conditions. A typical NEMA enclosure might be rated to provide protection against environmental hazards such as water, dust, oil or coolant or atmospheres containing corrosive agents such as acetylene or gasoline. We are going to put devices connected in Nema box. There are usually four holes for screws to hold the box with high stability. Then we will use screws to connect Nema box to the pole of the stop sign. The solar cell will be put on the top edge of stop sign for getting enough solar energy. The wire to solar cell will go into Nema box so that it can supply power to each device.

3. Communication between Clients and Products

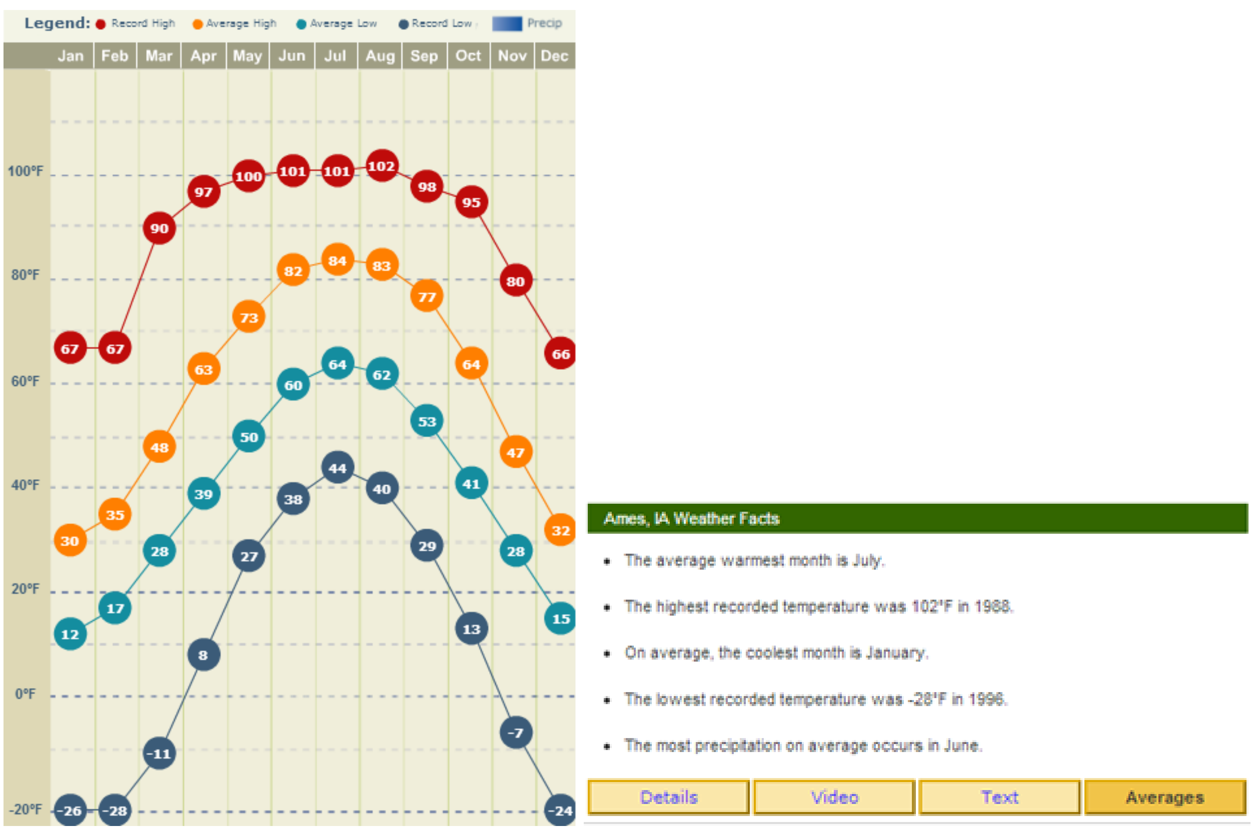
We are going to write the software so that once the modules are installed and powered on for the first time the system should self-calibrate. Once powered on the tilt sensor keeps checking the angle between stop sign and horizontal ground. The sensor will transmit the data to the microcontroller, which determines if the tilt has reached a pre-determined tilt threshold of 15 degrees. Once the data reaches or exceeds this threshold, the microcontroller is going to control GSM module to send a text message to certain clients' cell phones. Before the product is installed, we will program for each GSM module to send a specific information including location of each devices with stop sign. Besides, we can also edit more information like strength of wind, temperature and something else. Then the clients' phones will be notified by a text alarm that contains location of the stop sign. Another way for clients to check the status of stop signs is that they can send a text message to each GSM module. Once the GSM module receives the message, it will transmit the data to microcontroller. After that, the microcontroller will send a signal to tilt sensor for collecting angle or other information. Then, the microcontroller is going to send a signal to GSM module to send the status and information to clients.

IV. Testing Methods/Verification

For this project to be successful the device needs to function under Iowa weather. The device needs to be able to work during the hottest parts of the summer and the coldest days in the winter. The device needs to work properly through all-weather including snow and rain. To do this we need to perform some durability tests to make sure the device can function properly.

1. Temperature Test

For first Test we need measure is temperature, we will test the device in extreme cold and hot weather. Each part of the device has its own temperature range specified on their data sheets. The accelerometer has a temp range -40 to 85 ℃, the GSM has a range from -30 to 80 ℃ with a max of -40 to 85 ℃, and the Arduino pro (ATmega 328) -40 to 85 ℃. In Coover, there are heating chambers in several of the hardware labs we plan on using the heat stations to test the heat range up to 120 degrees. Research showed that the highest recorded temperature in Iowa was 102 ℉ in 1988. And to test the cold we will use a freezer box up to test temperature at -35 degrees F. The lowest recorded temperature in Iowa was -28 ℉ in 1996.



2. Wind Test, Shock/Vibration Tests (ex. sign falls over is the equipment reusable)

To test the shock/ vibration and wind test we will use the labs in Howe Hall, Howe Hall has labs for mechanical vibrations, acoustics, and stress analysis. The average wind speed in Story county Iowa is 21.21 mph another option is using a vibrating plate to measure the vibrations of the device and to see the after effects. http://www.usa.com/rank/iowa-state--average-wind-speed--county-rank.htm

3. Water Test

To test the enclosure box to see if its water resistance we will use a shower head to simulate rain. To be efficient we will spray water at different angles of the box just like the possibility of rain can do. We can also adjust the shower head's force of water spray on the enclosure to control the pressure of water.

4. Cell Signal Reliability

To test the cell signal reliability we will measure the distance or range the alert can be sent out and received by the end user. We want to found the range of the device.

5. Accuracy of Tilt Sensor and Calibrations.

To accurately test the sensor we will manually perform adjustments to the stop sign tilting to 15 degrees, 30 degrees, 45 degrees, and knocking the sign down. We want to determine the reaction of the sensors and how it will detect changes to the sign.

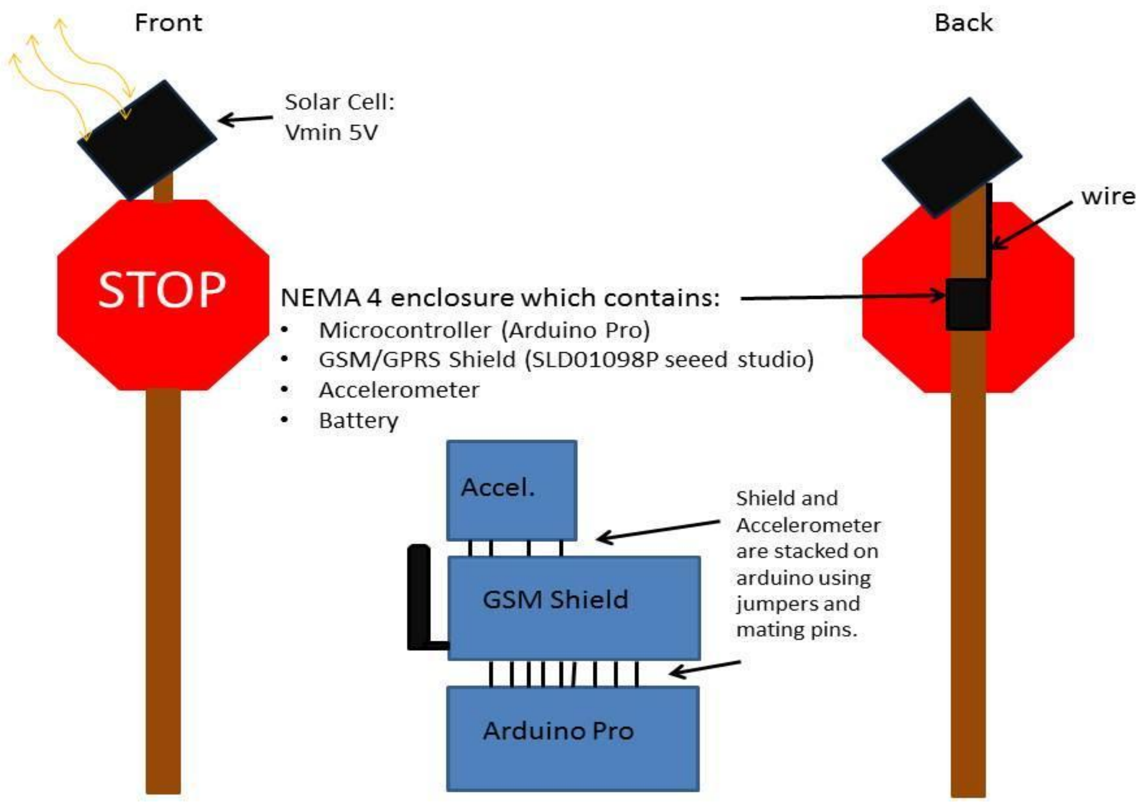
6. Longevity of Power System

To test the longevity of the power system we will run the GSM and Arduino to max output to see how they function. The power supply can be tested to by using fluorescent light instead of sunlight to determine the max engergy that is absorb. We can leave the device on to determine how much time it needs before the battery dies.

V. Schematics/Models

Found below is sketch of how we envision this project attaching to the sign as well as interfacing with each other. In addition to the sketch some pseudo-code and logic flow has been provided based on our current knowledge of the hardware being used and our functional goals for this project. For each function where the GSM/GPRS module would be used, the AT command to accomplish the desired task has been provided.

1. Schematic Drawing



2. Pseudo Code

Import files:

Header files that enable serial.

Header files possibly required for accelerometer or GSM module.

Other files written separately for organizational purposes.

Initialize serial (set baud rate), gsm/gprs:

```
void setup()
{
mySerial.begin(119200);
Serial.begin(119200);
delay(500);
}
```

Recipients of alerts:

Dictionary filled with cell phone numbers or email addresses that the alert should be sent too.

This will be used later when sending notifications. A while loop will cycle through the dictionary and send the alert to each contact.

Assign variables for location:

ID = EastWestStreetName-NorthSouthStreetName

Function send text method:

```
mySerial.print("AT+CMGF = 1 \r"); //text mode
delay(100);
mySerial.println("AT + CMGS = \" + country code+1+area code+phone number\""); //send SMS message
```

```
mySerial.println("message goes here");
delay(100);
mySerial.println((char)26); //ASCII code of ctrl+z is 26
delay(100);
myserial.println();
```

Low Power Sleep Mode:

Wake up every x amount of minutes to check tilt.

Wake up if text message received.

Text message controlled sleep cycle.

Force on for a certain period if sign is at high risk for falling over (during windstorm).

Tutorial on how to sleep:

http://playground.arduino.cc/Learning/arduinoSleepCode

Tilt Interrupt:

If tilt > 15 degrees: call function send SMS message ("HELP I'VE FALLEN AND I CAN'T GET UP. I am at this location" + ID).

Useful AT Commands:

AT+CMGR --> Read SMS Message

AT+CMGW --> Write SMS Message to Memory

AT+CMSS --> Send SMS Message from Storage

AT+CSAS --> Save SMS Settings //if we change settings it would be important to save them

AT Command Manual:

http://garden.seeedstudio.com/images/a/a8/SIM900_AT_Command_Manual_V1.03.pdf

3. Part List (Current Estimated Total: $101.15 + Variable Text Cost)

1) Solar panel (5V).

2) Lithium ion battery rechargeable.

3) GPRS Shield V2.0 (SIM900) - GSM - $59.90
http://www.epictinker.com/GPRS-Shield-V2-0-p/sld01098p.htm

4) ADXL345 Accelerometer - $4.00
http://www.aliexpress.com/item/Free-Shipping-ADXL345-3-Axis-Digital-Acceleration-Of-Gravity-Tilt-Module-For-Arduino/1180370311.html

5) Arduino Pro 328 (ATmega328) - $14.95
https://www.sparkfun.com/products/10915

6) Sim card and Plan $10 at $.20 per text using a pre-paid AT&T plan - $3.80
http://www.amazon.com/gp/product/B000YHCEQM/ref=olp_product_details?ie=UTF8&me=&seller=

7) Nema enclosure box type - $18.50
http://www.automationdirect.com/adc/Shopping/Catalog/Enclosures/Metal/NEMA_3R/Screw_Cover_Wall_Mount/RSC040404

NEMA Type	Definition
1	General-purpose. Protects against dust, light, and indirect splashing but is not dust-tight; primarily prevents contact with live parts; used

	indoors and under normal atmospheric conditions.
2	Drip-tight. Similar to Type 1 but with addition of drip shields; used where condensation may be severe (as in cooling and laundry rooms).
3, 3S, 3X	Weather-resistant. Protects against weather hazards such as rain and sleet; used outdoors on ship docks, in construction work, and in tunnels and subways. 3X includes corrosions.
3R	Intended for outdoor use. Provides a degree of protection against falling rain and ice formation. Meets rod entry, rain, external icing, and rust-resistance design tests.
4 and 4X	Watertight (weatherproof). Must exclude at least 65 GPM of water from 1-in. nozzle delivered from a distance not less than 10 ft for 5 min. Used outdoors on ship docks, in dairies, and in breweries. The 4X model has corrosion resistance.
5	Dust-tight. Provided with gaskets or equivalent to exclude dust; used in steel mills and cement plants.
6 and 6P	Submersible. Design depends on specified conditions of pressure and time; submersible in water or oil; used in quarries, mines, and manholes.

7	Hazardous. For indoor use in Class I, Groups A, B, C, and D environments as defined in the NEC.
8	Hazardous. For indoor and outdoor use in locations classified as Class I, Groups A, B, C, and D as defined in the NEC.
9	Hazardous. For indoor and outdoor use in locations classified as Class II, Groups E, F, or G as defined in the NEC.
10	MSHA. Meets the requirements of the Mine Safety and Health Administration, 30 CFR Part 18 (1978).
11	General-purpose. Protects against the corrosive effects of liquids and gases. Meets drip and corrosion-resistance tests.
12 and 12K	General-purpose. Intended for indoor use, provides some protection against dust, falling dirt, and dripping noncorrosive liquids. Meets drip, dust, and rust resistance tests.
13	General-purpose. Primarily used to provide protection against dust, spraying of water and noncorrosive coolants. Meets oil exclusion and rust resistance design tests.