

ECE 445 Project Proposal

PARTICULATE MATTER SENSOR NODE

Team 12

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Introduction

Objective

Particulate matter (PM) emissions, particularly particles which are smaller than 2.5 micrometers, have been linked to an array of health complications. The EPA collects data on PM emissions but their data is incomplete and is not enough to conclusively point to PM emission sources. In addition, the current EPA data has blind spots as they don't have a medium to collect data in remote or isolated locations. If the EPA has better data collection, then they can regulate PM emission sources and improve public health.

Solution Overview

Our solution is to create a sensor array that is discrete and durable enough to be deployed near a potential PM emission source for an extended period of time. In addition, our sensor array should be cheap enough that the average high school science class or family could buy an array and use it to conduct a science experiment. Our sensor array will measure PM 2.5/10, wind direction/speed, temperature and humidity. In addition, in order to place our box in a remote location, we will be adding a solar powered battery. Finally, in order to store data we will have a local storage device (SD card) in our box to record all of our data points. Once we have obtained the PM data, it will be uploaded to a web dashboard and viewed in a user-friendly UI. This dashboard will be the central source where users can view our data and download data into a .csv file.

Physical Design

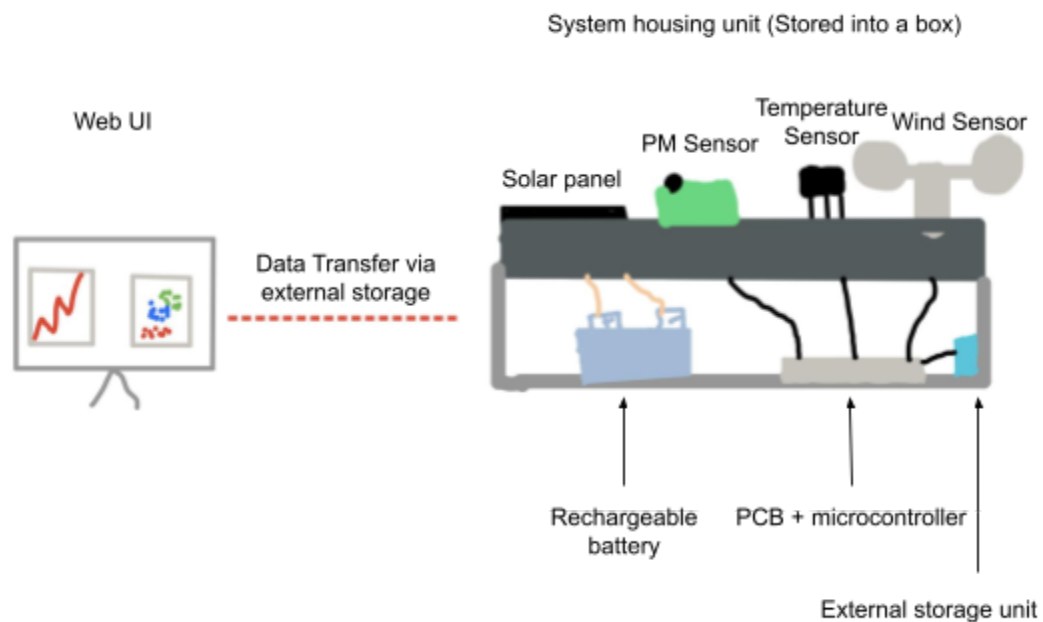


Figure 1. Showcases our system housed inside its' physical housing.

Block Diagram

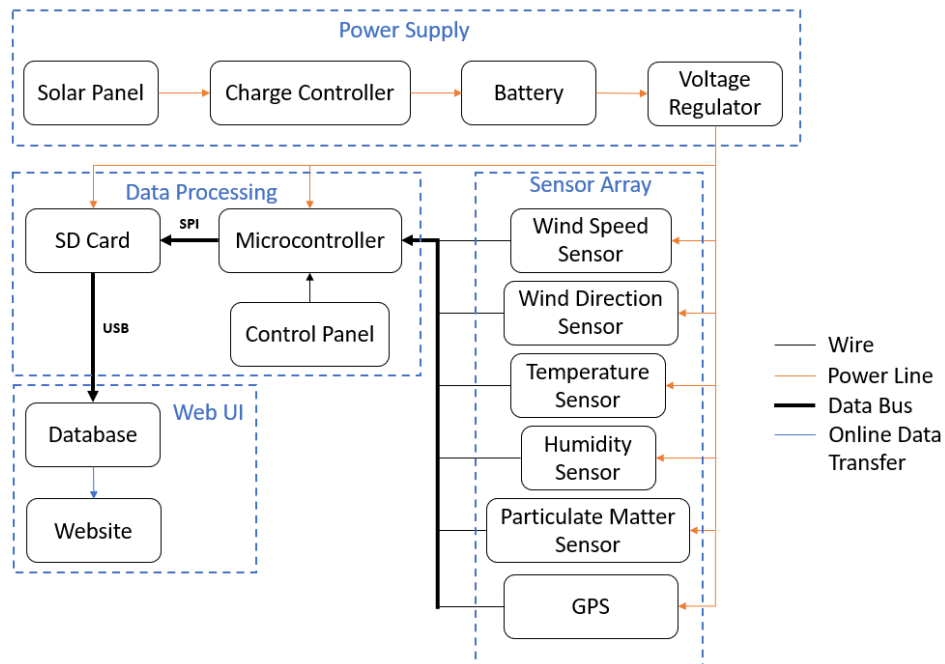


Figure 2. A block diagram of our project including the power, web UI, Sensor, and data processing subsystems

High Level Requirements

1. Our system is able to collect PM data once per hour for at least 1 month at a given location.
2. Our system is able to easily store in an external storage device and output the PM data to web UI.
3. Our solution's total cost of construction should be around \$300, making it accessible and scalable.

Subsystem Requirements

Data Processing Unit

- The Data Processing Unit manages the storage of all sensor data. A microcontroller controls an SD card and communicates to sensors via GPIOs. It also contains a small user interface with an LED, a button, and a 3 position slide switch.

Microcontroller

- The ATmega328P microcontroller handles data storage and communication with sensors. It reads and writes to the SD card cache through SPI (Serial Peripheral Interface). It reads from the sensors via the microcontroller's GPIOs.

- *Requirement 1: The microcontroller must be able to communicate over the SPI at speeds greater than 4.5Mbps (each).*
- *Requirement 2: Must sink or source 10mA +/- 5% on each of GPIOs at 5V +/- 5%.*
- *Requirement 3: The microcontroller will stop taking readings from the sensors if the battery's voltage falls below 2.5V*

SD Card

- A 32GB microSD card will be used to store air data. It connects to the microcontroller via SPI.
- *Requirement 1: The SD card must be able to hold a month's worth of sensor data collected at one hour intervals.*
- *Requirement 2: The SD card must be able to store data whether the device is powered on or off.*

Button 1 (Control Panel)

- An on/off button will be used to turn the box on and off. It will connect to the microcontroller.
- *Requirement 1: The on/off button must be able to turn the box on and off.*

Status LED (Control Panel)

- An RGB LED will be used to display the status of the box. An RGB light will be used in order to map different colors to different device statuses (working, sensor error, SD card error, successful GPS location update, etc). The LED will be connected to the microcontroller.
- *Requirement 1: The LED must be able to display 6 or more distinct colors to the user.*
- *Requirement 2: The LED must be able to respond within a second of any device errors.*

3 Position Slide Switch (Control Panel)

- A slide switch to select between five minute, one hour, and three hour data collection frequencies.
- *Requirement 1: The LED must be able to display 6 or more distinct colors to the user.*

Sensor Array

- The Sensor Array consists of 5 sensors: a wind speed sensor, a wind direction sensor, a temperature/humidity sensor, a particulate matter sensor, and a GPS module. Each sensor will communicate with the microcontroller via GPIOs. The sensors will be powered by the voltage regulator.

Wind Speed

- The Adafruit Anemometer Wind Speed Sensor is capable of measuring wind speeds between 0 m/s and 32.4 m/s at .1 m/s resolution. The sensor provides analog outputs between 0.4 and 2.0 volts. The microcontroller will record the analogue voltages and convert them to wind speed values.
- *Requirement 1: The wind speed sensor must be able to collect data for a month on end without a significant (greater than 10%) loss in accuracy.*

Wind Direction

- The RK110-02 is an analogue wind direction sensor, capable of making measurements between 0 - 360 degrees with a 3 degree tolerance. It requires a 5, 12, or 24 volt input. It has a 0 - 5 volt analogue output and a 4 - 20 mA analogue output to choose from. The microcontroller will record the analogue values and convert them to wind direction values.
- *Requirement 1: The wind direction sensor must be able to collect data for a month on end without a significant (greater than 10%) loss in accuracy or need for recalibration.*
- *Requirement 2: Calibration should take less than 10 minutes.*

Temperature and Humidity Sensor

- The DHT22 Sensor is capable of detecting air temperature and humidity. The sensor can track humidity from 0 to 100% with 2-5% accuracy and temperature from -40°C to 100°C with $\pm 0.5^\circ\text{C}$ accuracy. The sensor outputs a digital signal to the microcontroller.
- *Requirement 1: The temperature and humidity sensor must be able to collect data for a month on end without a significant (greater than 10%) loss in accuracy.*

Particulate Matter Sensor

- The Adafruit PM2.5 Air Quality Sensor is capable of detecting a range of particulate matter in the air. It can sense PM of size 0.3 μm , 0.5 μm , 1.0 μm , 2.5 μm , 5.0 μm and 10 μm , as well as PM1.0, PM2.5 and PM10.0. It will communicate to the microcontroller via UART.
- *Requirement 1: The PM sensor must be able to collect data for a month on end without a significant (greater than 10%) loss in accuracy.*

GPS

- The NEO-6M GPS Module is capable of tracking location with 2.5m horizontal position accuracy. The sensor uses serial communication to transmit data in the NMEA language, the standard language used by GPS manufacturers.
- *Requirement 1: The GPS module must be able to identify and communicate to the microcontroller the location of the box while the device is powering on.*
- *Requirement 2: The GPS module must be turned off after the power on process in order to mitigate battery drainage.*

- The Web UI will be a simple webpage that enables the user to visualize and interact with the data they've collected. Users will remove the SD card from the box and plug it into their computer in order to extract the data. They can then upload the file to our webpage. The webpage will store the data in a simple MySQL database.

Website

- The website will be a simple page written in React and PHP. The data from the device will be uploaded to the user's computer via USB. From there, the user will be able to drag and drop the file into the website. Once the data is uploaded to the website, it'll display a dashboard of data in the form of graphs and maps. The website is responsible for parsing the data in the file.
- *Requirement 1: The website must have a graph or map for all data types collected (location, speed, direction, temperature, humidity, and PM).*
- *Requirement 2: The website must be able to parse and display the data within 5 seconds of the file being uploaded.*

Database

- MySQL will be used for the database. It'll be used by the website to fetch data for the dashboard.
- *Requirement 1: The database must have tables for all data types collected (location, speed, direction, temperature, humidity, and PM).*

Power Supply

- The power supply unit produces, stores, and distributes electricity at the correct voltages. A solar panel generates electricity which is routed through a charge controller to safely charge a lithium ion battery. A voltage regulator will step the battery voltage down to 3.3V and 5V for the sensor array and data processing unit.

Solar Panel

- A 1 Watt solar panel will supply electricity to the lithium ion battery to boost the sensor node's deployment time in the field.
- *Requirement 1: The solar panel must be able to supply 1 Watt +/- %10 at MPPT*
- *Requirement 2: The solar panel must supply at least 4.4V +/- 10% at MPPT*

Charge Controller

- The charge controller will read the battery's charge and supply electricity from the solar panel if the battery is not full. The charge controller will also ensure that the battery is not overcharged by the solar panel.
- *Requirement 1: The charge controller will not charge the battery past 4.2V to ensure the battery does not fail.*
- *Requirement 2: The charge controller must supply 4.2V +/- 10% during charging*

Lithium Ion Battery

- Two of Tiny Circuits' ASR00050 rechargeable lithium ion batteries will be connected in series to provide power to our sensor node. The total output voltage will be 7.4 volts to satisfy the maximum voltage requirement. In addition, there will be a total of 2.5 Ah of capacity.
- *Requirement 1: The battery must be able to supply power to the sensor node for a month when the node is making measurements at one hour intervals.*
- *Requirement 2: The battery should be able to be safely recharged.*
- *Requirement 3: The battery must supply 7.4V +/- %10*

Voltage Regulator

- Two LM2596 DC-DC voltage regulators will step the battery voltage (7.4) down to 3.3V and 5V to provide power to the sensor array and data processing system.
- *Requirement 1: The voltage regulators must be able to supply at least 50 mA to ensure that all components can function properly.*
- *Requirement 2: Must be able to output 3.3V +/- 10%*
- *Requirement 3: Must be able to output 5V +/- 10%*

Tolerance Analysis

In terms of risk, our data processing module poses the biggest challenge from an operational and design point of view. The functionality of the data processing module is integral to the success of our system, since this module is in charge of converting all of the sensor's analog signal to a digital signal. Furthermore, each sensor will have its own sensor protocol that will need to be used by the microcontroller. For example, the wind speed sensor outputs a voltage of 0.4-2.0 V, and the temperature and humidity sensor will output a digital signal to our microcontroller. We will need to account for this varying protocol during the signal processing. In addition, our data processing module writes the digital sensor data to our internal memory. Without this module, we would not be able to process the data that our system is intended to retrieve. We need to make sure that the data processing module can convert analog signals to digital, and perform R/W operations for a lengthy period of time without failure.

Ethics and Safety

Our project is meant to be fully unsupervised when our system is collecting data at a given location. We have identified 2 ethical and safety issues that could occur from our system.

First, one ethical concern is that our system could be placed in private property without prior approval. This would be in breach of IEEE Code of Ethics #9 [1] which states “to avoid injuring others property”. To counter this, we will provide labeling on the box, as well as documentation which states where a user can/can't place their box.

Second, a safety concern we have is that our rechargeable battery could potentially overheat and pose a fire risk. This is a particular concern since our box is meant to be placed in a remote location, and could pose a wildfire risk. In accordance with IEEE Code of Ethics #3[1], “to avoid real or perceived

conflicts of interest whenever possible”. We will design our box such that it provides isolation of our battery and voltage regulators to limit overheating.

Citation

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