Predicting Asthmatic Events from Environmental Variables

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ABSTRACT
This report documents the results of a proof of concept study on a process for gathering personal air quality data for the purpose of predicting asthmatic events. The system gathers air particulate data through a laser based dust sensor module. This data was then analyzed in order to create a heat map for the areas around my daily route that provide the most risk for asthma related incidents. Existing solutions are either extremely expensive or are too bulky and unwieldy for daily usage. The device concept presented in this report can be dramatically reduced in size with the use of specialized hardware. Rapid prototyping technologies such as Arduino and Grove were used in in the development of this device in order to reduce the time requirements. Future work involes further reducing the device size and integrating with commonplace personal computer devices such as smartphones.

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H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

Author Keywords
asthma; dust sensors; personal informatics; personal data; health tracking;

INTRODUCTION
Asthma can sometimes be a life threatening condition, and yet can still appear seemingly at random. It would be invaluable to be able to see ahead of time what areas I am most prone to asthmatic events and when I am in danger. This could also be easily extended to other individuals with the same condition who could be regularly traveling in the same areas, very likely on a college campus.

Measurement of lung function through spirometry is currently the most accurate method of predicting asthmatic risk. This form of measurment is typically conducted in a clinical setting, not in the daily environment of the patient. In addition this method is invasive and impractical for daily feedback routines.

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As such, I focus on the development of a non-invasive passive system based on environmental factors that can be used to predict asthmatic risk and inflammation. Common environmental factors in asthmatic risk are air pollutants. Two key air pollutants can affect asthma. One is ozone (found in smog). The other is particle pollution (found in haze, smoke, and dust). When ozone and particle pollution are in the air, adults and children with asthma are more likely to have symptoms. [3]

Development of a personal logging device in order to constantly monitor air particulate data and ozone would help to provide a feedback system whereby I am able to visualize what areas in my daily routine place me the most at risk for asthmatic exacerbations.

Beyond respiratory diseases, the continuous monitoring of health and environment through wearable devices has the potential to create a paradigm shift in improving healthcare by empowering patients and doctors to transition from managing illness to managing wellness and outcomes.

PRIOR WORK
Much of the previous work has been based on tracking geolocation data of when a user has to actively use their inhaler such as with the CareTRx "smart inhaler" https://www.caretrx.com/ This solution keeps a record of the all of the user's asthmatic events recordedin a cloud based server system. [1] However, this leaves out the entirety of a lower class of events called asthmatic exacerbations. During these events, a patient suffering from asthma can feel the onset of asthma related symptoms such as tightness of airways and wheezing of the lungs, however they not temporarily disabled as with an asthma attack.

There are many studies showing the correlation between environmental factors and an increase in asthmatic exacerbations. [4, 7] They provide an excellent base for a predictive model of asthmatic occurances.

Finally, there is a wearable device that attempts to accomplish the same goal as this project. The HET system from NC State University uses local temperature and humidity data along with data related to the wheezing of the user's lungs in order to predict when they are in danger of an asthma attack. This system does not keep a record of previous asthmatic events, and in addition it is extremely intrusive and bulky. [2] This project does a very good job at predicting when a patient is at risk for an asthma attack but does not provide any way for them to aggregate and visualize their own personal data.

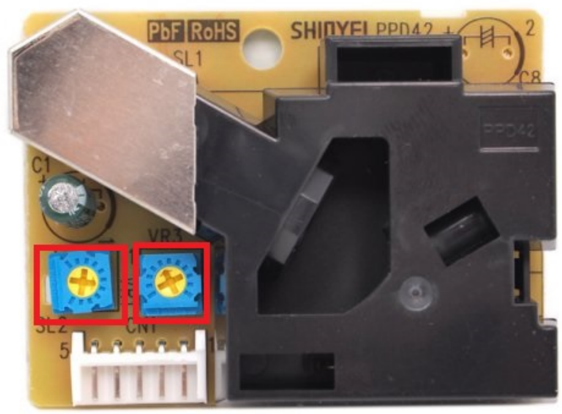

Figure 1. Shinyei PPD42NS dust sensor

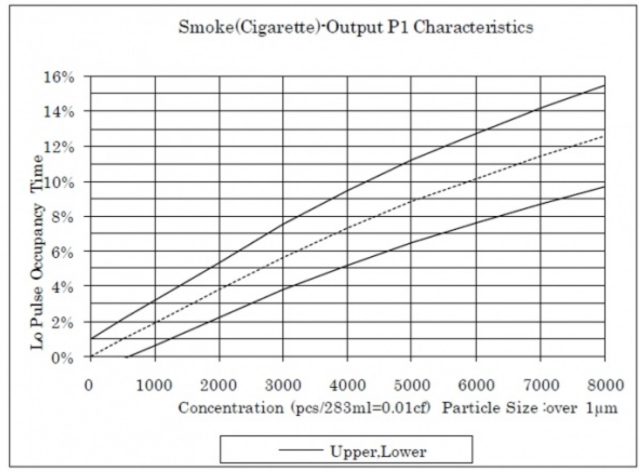

Figure 2. Shinyei PPD42NS dust sensor chacteristic graph

I believe I can design a system that is more natural to use and accomplishes the same results using a mobile application and a "clip on" base station that would attach to a backpack or other personal item. This would accomplish many of the results of previous solutions, while still remaining a passive sensing technology.

IMPLEMENTATION

To serve as a proof of concept and to develop the area of personal logging devices. I have developed a small integrated sensor and controller module that logs dust particulate data around the wearer at all times. There are 2 primary components of the sensor platform.

- A Grove Shinyei PPD42NS dust sensor (Figure 1).
- Arduino Uno Microcontroller.

This sensor module then communicates with a python application running on a personal laptop computer contained within my backpack. The main purpose of the laptop computer is for integrating a geolocation tag with every sensor measurement. Ideally, there would be integration with a smartphone device in order to acquire GPS coordinates, however there were design limitations that will be discussed in a later section.

Dust Sensor

This was an off the shelf Grove compatible component that allowed me the rapidly prototype a module that could reliably measure air particulate data. This Dust Sensor measures the Particulate Matter level in air by counting the Lo Pulse Occupancy time(LPO time) in given time unit. LPO time is in proportion to PM concentration. This sensor can provide pretty reliable data for air purifier system because it's still responsive to particulates whose diameter is 1 μm

It is possible to calculate a concentration of particulate by looking at the characteristic graph of the sensor. (Figure 2) By fitting a cubic polynomial to this charactertic graph, we can calulate the particulate density from the LPO.

When using this in the Arduino sketch we can implement as:

```
ratio = lowpulseoccupancy/(sampletime_ms*10.0);
concentration = 1.1*pow(ratio,3)-3.8*pow(ratio,2)
  +520*ratio+0.62;
```

This possible on the the Arduino because of the high sampling rate of the digital pins on the system. A limitation that I found on the Raspberry Pi system was that the GPIO header was unable to sample at the frequencies used by the LPO output of the sensor module.

Arduino Integration

In integrating the sensor with the Arduino, I was required to use pin D8 on the ATmega328P board architecture. The sampling functionality could only be accomplished by this SMD based analog pin.

The Shinyei PPD42NS dust sensor was wired to the Arduino Uno board as follows:

```
JST Pin 1 => Arduino GND
JST Pin 3 => Arduino 5VDC
JST Pin 4 => Arduino Digital Pin 8
```

The Arduino was powered by a personal laptop computer that was near the device at all times. This was an unfortunate limitation due to power requirements and need to integrate location data with the sensor readings

STUDY AND DISCUSSION

The device was worn by me for a period of about 8 hours during the most active part of my day. I attached the sensor to my shoulder and my laptop and started the python based logging application that I wrote in order to gather the data from the sensor and then append a geolocation tag to each one. The geolocation was acquired through a MacOS based script written by Rob Mathers. [6] The script returned a latitude and longitude based on WPS coordinates optained from the MacOS CoreLocation API. Preliminary testing on this data

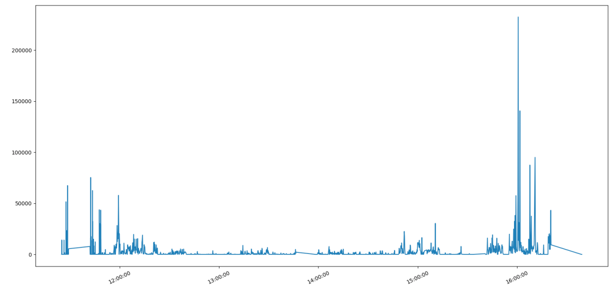

Figure 3. Concentration of particulate matter around me throughout my 8 hour workday.

proved that it was extremely accurate in determining my current location whenever I was connected to WiFi. A location is obtained by measuring the intensity of the received signal from any wireless access points within range of my computer and then comparing these to a public hotspot database that is developed from mobile device GPS location data. [8]

After the 8 hour logging period, a measurment of a time series representation of the particulate concentration in my daily routine was obtained. This can be seen in Figure 3. Looking at this graph, we can see a few period throughout the day where the air quality around me deteriorated dramatically. Those are when I left the indoor office where I do most of my daily work to go eat with friends or walk across campus for a class. There are also a few timeskips. In the first part of the data series, my laptop ran out of battery so there was period of about 15 minutes where I was unable to collect data. In addition, just after 14:00 someone needed to borrow the cable that I was using to monitor serial data from my Arduino in order to print something froma shared printing station. An unfortunate side effect of using shared equipment. The spikes at the beginning and end of the series are when I was walking near construction on Speedway. The dust clouds from the loose earth provided a great opportunity to compare indoor and outdoor air quality during my time wearing the sensor.

In Figure 4, we can see a map of the area surrounding my daily route with annotated pins marking the particulate measurements that I took throughout the day. This is the most useful graphic for personal reflection that I have generated. On the graph, all points are colorized according to these divisions. [5]

- 0-1000: Green
- 1000-5000: Yellow
- <5000: Red

From this chart, I can glean which areas around campus are the most dangerous for me in terms of the impact that they can have on my asthma.

Unfortunately, the most dangerous areas were those just outside the IEEE student offices which is where I spend most of my free time on campus working on class work. It will be difficult for me to find a way to practically avoid those

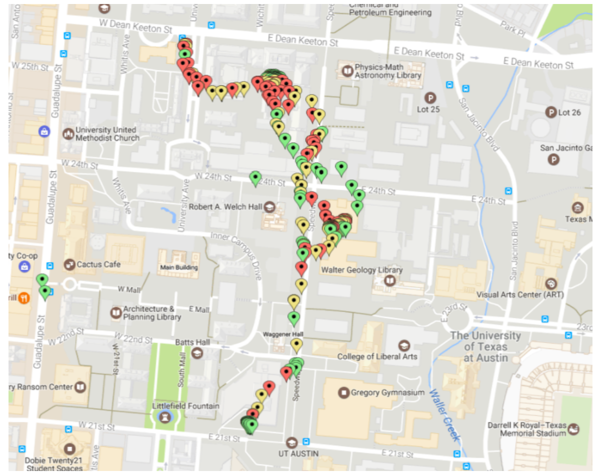

Figure 4. Aggregation of all the geolocation tags with particle concentrations mapped to differnt colors of pins.

areas. But it still provides an interesting proof on concept on analyzing location based heat maps of asthmatic risk.

There are also some inaccuracies in the methods that I used to gather data. When collecting my data I was using the particulate sensor with the main detection area completely open to sunlight. While the sensor is designed to detect the wavelengths of the laser specifically, this may have contaminated a portion of my data. Repetition and additional data collection will be necessary in order to rule that out as a possibility.

CONTRIBUTIONS

All of the data acquired during this study was collected by myself over a single day. The device was built over a period of 2 weeks after having quite a bit of trouble integrating the sensor module into various platforms. Unlike previous efforts to develop an asthma prediction system. This one focuses on using continuous personal data and self reflection in order to develop change in personal habit. This is unique from previous studies in this area, which focus on predictive modeling. [2, 4]

All the code written for this assignment can be found at https://github.com/yursky/asthma-prediction.

FUTURE WORK

This project presents many different areas that I hope I can expand on in the future. One of the greatest hardware limitations that I struggled with throughout this project was serial communications from the Arduino microcontrollers. In my mind, the ideal module structure would be a standalone sensor, Arduino, and battery combination that I could keep connected via Bluetooth to my smartphone. I would then be free to use the GPS capabilities of the mobile device and keep the sensor module very portable. This small change would drastically improve the ease of carrying the sensor around.

In addition, the aggregation of asthmatic events that I encounter through a smart inhaler, similar to many products currently available, would allow me to create a personalized predictive model of what environmental conditions trigger my asthma. This would provide valuable insights to any patient who suffers from asthma. By slightly altering your day to day behavior (e.g taking a different route to class) an individual would be able to lower the risk of a dangerous asthma attack.

Once the sensor is integrated with a smarthphone, a complete suite of monitoring and insight tools can be developed to simplify respiratory disease management. a web based dashboard similar to CareTRx's could be developed that aggregates and visualizes the patient's personalized profile of particulate data. [1] This also provides the opportunity to explore various areas of user design and visualization in the interface developed for the mobile device.

CONCLUSIONS

Low power and low cost portable devices for monitoring air particulates can be developed to aid individuals with managing asthma and other chronic respiratory diseases. These devices can provide extremely valuable insights to users about information related to their personal behaviors and the eventual consequences that they lead to.

This area has a lot of exciting potential for future developments especially in my own designs. I hope to be able to continue working on this in the near future.

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