AtmoSPHERE

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ABSTRACT
Air quality is an upstream component of human health, which cannot be addressed through primary care health facilities. In this work, we present AtmoSPHERE, a connected, wearable air monitor. Our system is comprised of a wrist-worn sensor suite, a connected smartphone, and a cloud service. The sensor suite measures two major categories of airborne health risks: particulate matter and volatile organics. The phone tags the data with location data and is used to communicate between the sensors and cloud. From the cloud service, we display a dashboard to highlight air quality in travelled areas. To evaluate the system, we collected data from 2 users over the course of a week of normal activity.

ACM Classification Keywords
J.3 Health

Author Keywords
Air quality; Upstream health; Wearable; Connected devices; Distributed sensors.

INTRODUCTION
Approximately half of all known health conditions originate from environmental factors[3]. These factors are generally labelled “upstream” factors due to how they are detached from a person’s immediate symptoms during illness. Upstream factors include variables such as the sanitation of a person’s home, the condition of their workplace, or the local air. The existing health care system is not equipped to handle issues outside the hospital or clinic. However, many upstream factors are simple to identify, straight forward to address. We envision a device that can inform the user and others in the vicinity about one subset of upstream health risks.

In this project, we introduce AtmoSPHERE, a wearable air monitor for both particulate matter and volatile organic compounds (VOC). Particulate matter (PM), is any microscopic matter suspended in the atmosphere. Particulates include dust as well as more dangerous varieties classified by their diameter in microns, known as PM10 and PM2.5. A PM sensor is comprised of an infrared emitting diode and a phototransistor placed diagonally[2]. As particles pass through the path between the two components, deflected light is recorded by the phototransistor. This approach can detect visible dust as well as finer particles, such as PM2.5.

Volatile organic compounds (VOC) are compounds with high vapor pressure at room temperature. VOCs are numerous and varied, and include harmful compounds such as benzene, chlorofluorocarbons, and methylene chloride. A VOC sensor comes in many forms. A semiconductor VOC sensor uses a chemical reaction between the air and a heated substrate, such as Tin Dioxide[1]. As the concentration of VOC in the air increases, the corresponding resistance of the substrate drops by a measurable amount.

AtmoSPHERE is intended to allow distributed sensing of environmental risks. The wearable is linked to a smartphone and through that, our cloud service and data API. By aggregating data from multiple users, we can build substantial maps of local air quality. We expect this device can be used to inform lifestyle changes.

THEORY OF OPERATION
The only physical requirement of the AtmoSPHERE is sufficient air flow through the device. The wearable is designed to be worn on the wrist, where the movement of the arms will agitate air into the sensors. However, the device can be attached to any other location on the body. The wearable also doubles as a stationary air monitor, such as when taken off during charging. While stationary, diffusion is also an acceptable means of passing air over the sensor.

For data collection, the wearable should always be within a short distance of a paired Android phone. The wearable and phone communicate via Bluetooth, so the maximum separation of the two devices should not exceed 10 meters. At the same time, the phone should have location services enabled and at least an intermittent internet connection.

IMPLEMENTATION DETAILS
In this section, we will detail the hardware design, the software features, and the data API. Figure 1 shows the overall system architecture and data flow.

Hardware
The device captures a total of four variables: PM, VOC, temperature, and humidity. The PM sensor is the Sharp GP2Y1010AU0F. The VOC sensor is the AMS AS-MLV-P2. Temperature and humidity are captured together with the Amphenol ChipCap2. We used a TinyDuino Processor Board to collect the sensor values and a TinyShield Bluegiga BLE112 Bluetooth module to communicate with the phone (Figure 2). A RGB LED is used to alert the user in case any sensor values peak.

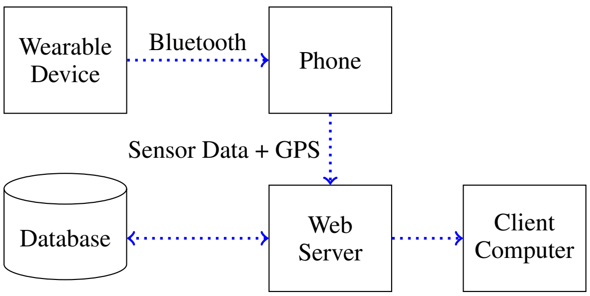

Figure 1. System architecture and data flow.

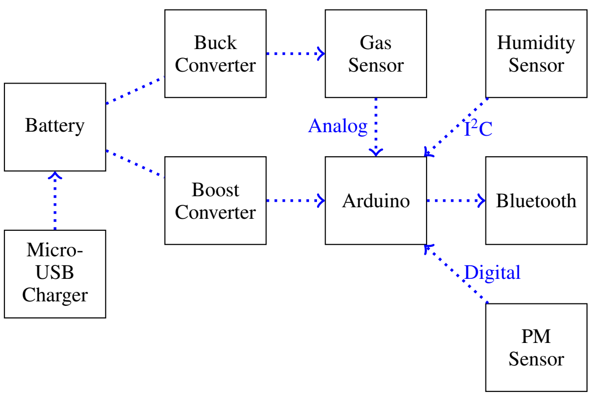

Figure 2. Components of the wearable device.

For the power source, we used a Lithium Ion Polymer battery. Due to the different voltage requirements of the sensors and microprocessor, the battery is attached to a boost converter, NCP1402, for most of the components; and a buck converter, ISL85415, for the VOC sensor. For charging the device, we added a Basic Micro-USB LiPo Charger. A switch toggles the connection to the battery, although the device is expected to stay powered continuously. All of the components are placed in a 3D-printed case (see Figure 3).

Phone Application

To connect our device with the cloud services, we require an Android phone of at least version 4.3.1 (Jelly Bean). This version of Android has built-in support for Bluetooth Low Energy, which we is used to communicate between the phone and wearable. The Android application consists of four screens:

- The welcome screen performs some preliminary checks on the services the app requires, such as an internet connection and location services.
- The login screen authenticates the user grants the phone access to our cloud services.
- The Bluetooth screen scans and connects to our device.

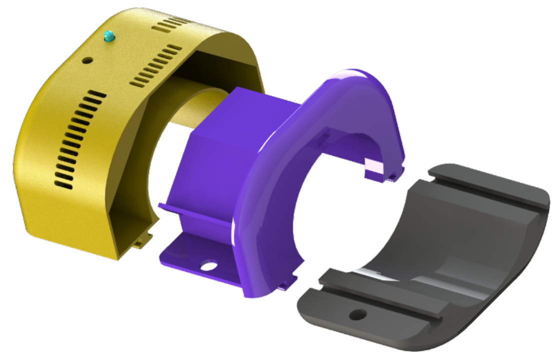

Figure 3. CAD rendering of the housing for AtmoSPHERE.

- The data display screen shows several views of the data from the sensor. The display is fairly simple; more substantial views are available on our associated web site.

The Bluetooth connection is managed with a foreground service. This service reads data from the wearable and pushes the data onto the cloud. When an internet connection is not available, the data is stored locally until an internet connection becomes available.

Web Application

The web interface is built with Django. A simple user registration and login interface exists for differentiating between each user's datapoints. The primary web interface is a dashboard of three data displays: a heat map, timeline, and histogram. Data is shown over the last day or week, or all existing data is shown. Only one attribute collected by the wearable, i.e. PM or VOC, is displayed at once.

Data API

The cloud services follow a REST pattern and are linked to the web interface through a different endpoint.

- `GET /data/` – Returns a list of datapoints gathered by the sensors
- `GET /data/user/` – Returns a list of datapoints gathered by the current user
- `POST /data/` – Adds a single datapoint to the database

The two `GET` endpoints can be further filtered with a query string:

- xmin – Number. Minimum longitude of the data.
- xmax – Number. Maximum longitude of the data.
- ymin – Number. Minimum latitude of the data.
- ymax – Number. Maximum latitude of the data.
- before – Date (Format: YYYY-MM-DD HH:MM:SS). Maximum timestamp of the data.
- after – Date (Same format as above). Minimum timestamp of the data.

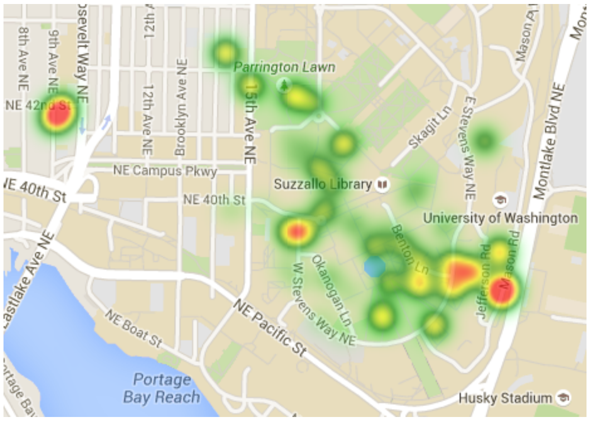

Figure 4. VOC data represented as a heatmap. Red represents high levels, yellow intermediate, green low.

- o – "timestamp". If present, sorts the results in ascending order by time.

RESULTS

We built two prototype devices and gathered data over a week in the vicinity of the University of Washington and Seattle. We expected and observed low levels for PM. We also expected low levels for VOC, however observed values showed high levels of VOC around some roads and within some buildings (see Figure 4).

CHALLENGES

In terms of hardware challenges, minimizing the form factor of the device posed the greatest challenge. The PM sensor in particular requires a set amount of space in order to function properly, due to the optical requirements of the sensor. Smaller versions of PM sensors are physically possible[4], but such sensors are not commercially available as of yet. Instead, we determined that the form factor was less important than a working prototype. As a result, the overall size of the prototype device was increased (see Figure 3).

The VOC sensor exhibited some drift over time. With two devices, we could cross reference the sensor values against each other. PM, temperature, and humidity values all agreed within 2% of one other if the two devices are adjacent. However, the VOC sensor could be significantly divergent.

FUTURE WORK AND DISCUSSION

TODO

CONCLUSION

TODO

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