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## ABSTRACT

The Common Sense project is developing mobile environmental sensing platforms to support grassroots community action. To this end, we are building a family of hardware and software components that can be used in a range of applications, as well as developing new communication paradigms that enable communities of non-experts to gather and produce information that is “credible enough” for experts and policy-makers. The demonstration showcases one such platform, currently deployed on street-sweeping vehicles in a major U.S. city.

## Keywords

Air quality sensing, environmental science, environmental justice, mobile participatory sensing, street sweepers.

## INTRODUCTION

Mobile participatory sensing [1] uses consumer electronics (such as mobile internet devices and mobile phones) to capture, process, and disseminate sensor data, complementing alternative architectures (such as wireless sensor networks) by “filling in the gaps” where people go but sensor infrastructure has not yet been installed. While some types of sensors are already commonly present in consumer devices (e.g., geolocation, motion, sound, etc.), other kinds of compact, low-power sensors (e.g., air quality) are not yet commonly included but offer the ability to collect additional data of individual and social interest.

To make environmental sensing useful for practical action, one must do more than just “collect” and “present” data. Environmental activists have continuous requirements to produce information artifacts that are “credible enough” to engage with bureaucracy; appealing enough to be useful in community mobilization; and personally relevant enough to maintain interest and motivation [2]. We therefore seek to enable community members to engage in collaborative “citizen science” [5] or “street science” [2] that will be useful in interactions with government agencies and non-government organizations (NGOs). In doing so, we posit that one can go beyond the groundbreaking and inspirational work of electronic artists in using environmental sensor data for awareness-raising and social provocation, exemplified by work such as that of Jeremijenko (<http://www.nyu.edu/projects/xdesign/feralrobots/>) and da Costa (<http://www.pigeonblog.mapyourcity.net/>).

To this end, the Common Sense project is developing both:

- Hardware/software sensing platforms that allow individuals to collect environmental information. These consist of commodity mobile devices that communicate with custom data acquisition boards containing environmental air quality sensors.
- Mobile and Internet-based software applications that allow people to analyze, share, and discuss environmental information in order to influence environmental regulations and policies.

## A FAMILY OF RESEARCH PROTOTYPE PLATFORMS

If the kind of sensing-based applications we envision prove out, we would expect the required sensors to be integrated directly into mobile devices. For prototyping, however, we are developing a set of board designs and embedded software and we plan to release these components to the research community as they stabilize. All board designs are based on the popular TI MSP430 microcontroller, and flexibility across consumer devices is maximized by making Bluetooth available as a short-range interconnection option. Boards can be selectively populated with carbon monoxide (CO), nitrogen oxide (NO<sub>x</sub>), and ozone (O<sub>3</sub>) gas sensors as well as temperature, relative humidity, and motion (3D accelerometer) sensors. Location data is provided by GPS on the associated mobile phone. We are currently using single-board designs for human-carried devices, as well as split-board designs for vehicular use. The split-board designs isolate most of the electronics from exposure to the environment (Figure 1).

## GOIN’ MOBILE: THE STREET SWEEPER DEPLOYMENT

We believe it is critical to develop not only technology components, but experience in working with all parts of the environmental policy “eco-system” – local and regional governments, public health NGOs, atmospheric scientists, activists, concerned citizens, and so on. Our initial trial is therefore one we expect to involve all relevant parties.

In this trial, we are collaborating with the City of San



Figure 1. Split- and single-board sensor board designs.



**Figure 2. Variants of the sensing platform, enclosure-mounted on city street sweeping vehicles.**

Francisco to put our air quality sensing systems on the municipal fleet of street sweepers. Street sweepers are vehicles that use mechanisms such as water sprays, brooms, and collection bins to clean debris from city streets (Figure 2). Our devices collect street-by-street air quality readings as the vehicles do their work, and the street sweepers have the key property that instrumenting a few vehicles provides both extensive and systematic coverage of the city.

The street sweepers also offer us the opportunity to test and refine our system in a very challenging real-world environment. For example, there is the question of whether the emissions from the street sweeper affect the readings. We attach the enclosure to the front or top of the trucks to reduce that effect and we are planning studies to compare readings from our devices with readings taken a few meters away from the street sweepers in order to better calibrate our data and assess potential effects of emissions. Similarly, the street sweepers present challenges for enclosure design. The enclosure must ensure appropriate airflow to the sensors while simultaneously protecting the electronics against water, dirt, and physical hazards such as low-hanging tree branches. To address these issues, we have developed a robust enclosure split into two compartments. The first compartment contains the gas sensor board, a fan, air flow vents with baffles to minimize water intake, and drains for condensation. The second compartment is sealed and contains the main board and a

mobile phone (Figure 2).

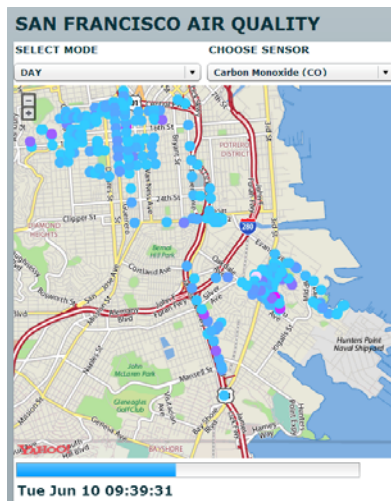
We have deployed our air quality sensing system on several street sweepers and are currently collecting CO, NO<sub>x</sub>, O<sub>3</sub>, temperature and humidity data. These sensor readings plus GPS data are sent to a database server via GSM text messages. In the near future we expect to launch a public website which will provide live and historical data from this deployment. Web-based visualization tools have been developed to show this data (see, e.g., Figure 3) but the website will also provide online community features to support discussion of interesting phenomena (c.f. [3]) and strategies for practical action. With concrete data artifacts in hand, we will then work iteratively with a range of community groups (already engaged through prior design fieldwork) to develop additional applications.

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**Figure 3. A sample visualization tool (detail).**