

Participatory Sensing for Surya

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November 10, 2007

1 Purpose of Project Surya

Carbon dioxide and elemental carbon in soot, two by-products of fossil fuel combustion, biofuel cooking and biomass burning, have well-documented detrimental effects on human health and the environment at local, regional and global scales [8]. Studies of health impacts estimate that indoor air pollution results in 0.5 [7, 5, 11] to 2.5 million pre-mature deaths each year in India. Environmental studies reveal that carbon dioxide and elemental carbon contribute as much as 70% to global warming as compared to all other green house gases. Unfortunately, reducing emissions of these two particles is difficult because about half of the world's population and 75% of households in India burn biofuels and biomass as a low-cost approach to prepare food and heat homes [10].

In the next two years, Project Surya will replace traditional cooking methods with inexpensive solar and other energy-efficient cookers, and document their role in reducing emissions of carbon dioxide and soot. The project will take place in rural India, across 6,000 homes in 100 villages spanning a 20 km radius.

Surya plans to correlate local environmental data with remote satellite data in order to document the actual reduction in soot emissions resulting from replacement of traditional cooking practices. Precision instruments located in 4 towers installed at the boundaries of the region will document the concentrations of particulates and soot content and solar radiation at the surface. These instruments are sparsely deployed due to cost constraints, but provide high-quality, reliable, and precise quantifications of particle levels. Instruments that pump air through a filter will be placed in all households to collect daily aggregate soot levels. These filters are densely deployed as

they are relatively inexpensive (on the order of a hundred dollars), but do not provide precise or granular readings. Soot levels are approximately quantified using a gray-scale chart that provides a reading from 1 to 10 based on filter color. Epidemiological data will be used to quantify health impacts of the resulting emissions reductions. All data collection will commence six months prior to the deployment of the alternate cookers.

Project Surya was initiated by the two primary investigators (PIs), Professors V. Ramanathan and K. Balakrishnan, and is funded by a combination of industrial, governmental, and international organizations. Villages were selected based on pre-existing relationships with local non-governmental organizations and feasibility of data collection. Final decisions were made by local non-governmental organizations (NGOs) and the PIs after village leaders and other community leaders were approached. Each interested household in the village will obtain a cooker and a cell phone. Cell phones can be used as desired and will have limited voice plans for personal or commercial use as desired.

Our goal is to facilitate the participation of local stakeholders in the data collection and analysis process. We begin with a discussion of the framework we propose to deploy in order to enable high-quality data collection and provide meaningful feedback to users. We conclude with a discussion of questions that arise in designing technologies that enable participation in data gathering campaigns.

2 High-Quality Data Collection Using Cell Phones

We propose to design and deploy a cell-phone based framework to enable robust, scalable data collection from all 6,000 homes. The introduction of cell phones can address several of the challenges that arise in large-scale data collection from low-quality instruments, and provide both interactive feedback to users as well as an interface for users to incorporate their feedback into the data collection and analysis process. In this section we discuss how cell phones will be used to improve data quality from low-quality sensors, and present an architecture to enable systematic and reliable data collection from each household.

Cell phones will be used to improve the quality of data collection in several ways. First, we can use the cell phone imagers to standardize the readings of the filters. Instead of having each user estimate the color of their individual filter, they can take an image of the filter and neighboring color chart with a cell phone. This image can be uploaded to a centralized base station, and analyzed with all other images using standard image analysis techniques to extract soot levels.

Second, cell phones enable reliable, large scale data collection through automated data entry and recording. Analyzing data manually collected daily from 6,000 homes can be time consuming and error prone. In addition to analyzing filter levels, a unique tag included in the image can be used to associate GPS-encoded location tags with the reading.

Third, automated integrity checks can lead to improved data quality. A user can take an image immediately before and after changing the filter. The image taken after the filter is replaced can be used to verify that the filter was changed each day, record the time that the filter was changed so that soot levels can be normalized by exposure times, and to calibrate the initial reading by incorporating the initial color of the filter when calculating final soot levels for the next day. In addition, checks on all images will verify basic characteristics such as light levels and overall image quality. Any failed integrity checks result in a notification to the user.

While we have outlined a preliminary plan based on initial discussions, aspects of this deployment plan can

and will change based on field experience and user input. In addition, preliminary deployment logistics regarding how and when the phones will be charged and maintained, cell tower locations, technical support for the deployment, and enabling personal use of the phones are all subject to change.

2.1 Campaignr: Enabling Systematic Data Collection

In order to support both continued data collection of images from cell phones and also the ability to take surveys from users with feedback and quality checks, we have designed a system consisting of three components: an application that runs on the phone to collect sensor data (Campaignr), a sensor store (SensorBase) to store/aggregate data, and a set of services that interact with the phone and the data-base to enable additional services (Figure 1).



Figure 1: Diagram of Campaignr framework.

Campaignr is a program that runs on the phone that can be configured to collect various types of input from the user and also capture sensor modalities. In our specific case, we will configure Campaignr to upload images taken by users of color charts, and in some instances use it to collect additional information from the user by enabling surveys. The information collected from Campaignr will be geo-tagged with the GPS coordinates of the readings and then sent wirelessly to SensorBase. SensorBase is a data archive service that enables users to publish, share, and manage sensor data. Finally, services will be built on the backend to interpret the data that is provided and provide appropriate feedback to the user. For example, there will be a service that is used for data integrity checks on

the filter images that are provided and send SMS messages to the phones through Campaignr if adjustments are needed.

Although most components of the system are currently functional, we believe that there will be additional changes needed once it is installed in a deployment setting. The user interface component will be especially critical and will be adjusted based on field tests.

3 Participation

Project Surya specifies four modes of community participation: 1) Involving village members in all stages of the implementation, avoiding top-down approaches with the help of local NGOs; 2) Providing information as it is collected to the community in order to inform people of the health impacts of indoor air pollution; 3) Empowering the community by providing resources and access to local NGOs to act based upon the collected information; and 4) Training youth of all ages in the community to collect scientifically useful data through collaboration with local colleges and schools. To begin this process, the primary investigators are developing relationships with large governmental bodies, local NGOs, and community leaders in each region.

In order to understand how the cell phones can facilitate aspects of participation outlined above, we decided to consider the following design ideals for the process. Below we have listed a collection of questions that we are considering as we are further designing the system as whole. We base our questions on a current literature search.

System Design First, we consider the importance of incorporating local context and expertise into system and data collection design by engaging user participation in the design process. Israel et. al emphasize the need for understanding how data collection and system design leverage/recognize community structure, strengths, and resources [6]. Corburn et. al build on this idea, suggesting that such local community knowledge “practical, collective and strongly rooted in particular place” affect data collection strategy and make for better system design [3]. We hope to engage in a participatory design process in order to incorporate knowledge about cooking habits, com-

munity structure, and mobile phone use into system design.

Israel et. al question the role of participation beyond the system design process, and ask how local knowledge should influence the initial research questions, or pose new questions [6, 1]. Byrne et. al ask how communities can play a role in “identifying and prioritising research questions, assisting in the design of the research, playing an active role in identifying the best sources of information, acting as a sounding board...and finally, in reaching conclusions?” [1].

Feedback Second, we consider how the system should be designed in order to provide appropriate feedback to participants, and not just involve them as data collectors [6, 12]. Findings and knowledge disseminated to all partners can be used to increase capacity [6], inform people of health issues [12], or educate participants on other “risks”, or personal implications of involvement in the study [4, 2].

Providing such feedback could impact the design of software infrastructure on phones, the specifics of the phone and display design, and tools provided for analysis and visualization of the data. Rambaldi et. al highlight the need for visualization tools that are more specifically adapted than “generic” or traditional GIS. They suggest that a more “Critical GIS” that takes into account context of data collection, local knowledge and alternative visualizations [9].

Case-making Third, we consider how the system should be designed in order to support a community in self-mobilizing [1], formulating and implementing a campaign, or effecting change [6, 12]. Israel et. al suggests an ecological approach to data collection that enables action to be taken across all factor areas [6]. We also consider what will occur after the study is completed: What will happen with the results? Can people keep the stoves and cell phones? Should the communities be involved in the publication and lobbying process [6].

Ideally, the system will be flexible enough to support campaigns initiated by participants separate from the predetermined data collection goal [4, 2]. One example might be if participants wanted to monitor polluters in other areas, or obtain data on their neighbors and sur-

rounding communities. In the Photovoice project, instead of receiving a pre-determined data collection goal, participants were simply given cameras and asked to document anything that was important to them [12].

Privacy We are planning to take several steps to preserve privacy of participants. Users will manually trigger image capture only when desired. The campaign framework will enable participants to review images before releasing them for general view.

4 Conclusion

Project Surya will lay the foundation for reducing soot emissions across the planet. Clearly, reduction of soot emissions will have a major positive impact at the local level (reducing fatalities in villages and cities); at the regional level (avoiding potential negative impacts on monsoon and glaciers that feed rivers like Ganges and Brahmaputra); and at the global level (reduction of global warming).

Our contribution to Project Surya is a work in progress and an investigation into participatory design process. Although an initial system is designed, we plan to continue development, using the questions posed in this paper, to design a participatory sensing system.

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