Mobile Observatory: an Exploratory Study of Mobile Air Quality Monitoring Application

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Abstract
We present *Mobile Observatory*, a mobile air quality monitoring application that provides evaluation of air quality of the city of Zurich, Switzerland. As *Mobile Observatory* utilizes air quality data gathered by sensors mounted on around 10 trams in Zurich, it is able to provide neighborhood-level air quality information within the city. In this paper, we introduce a mobile air quality monitoring application *Mobile Observatory*. Also, we describe a user study with 10 participants and show our preliminary results in hopes of yielding insights toward improving civic and urban engagement on air quality.

Author Keywords
Air quality; mobile applications; sustainability

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
Several HCI and Ubicomp research groups have been involved in projects related to air quality sensing to mitigate air pollution problems, providing platforms for people to monitor air quality. Mobile sensing platform is

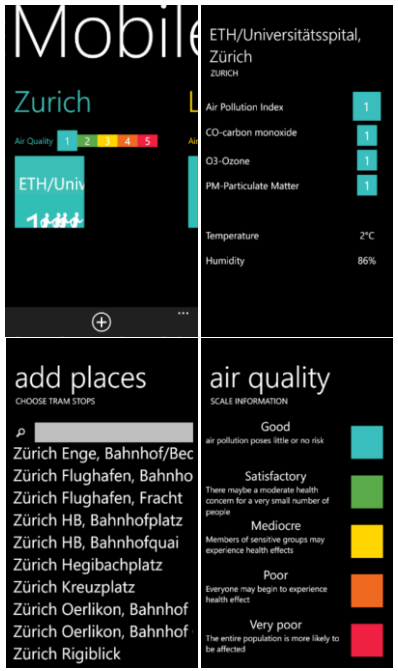

Figure 1. Some screenshots of *Mobile Observatory*. (**top-left**) main screen shows monitoring places, (**top-right)** summary of a monitoring place, (**bottom-left**) adding a monitoring place by choosing a tram stop (can also be done by pinpointing on a map at the time of writing this paper), (**bottom-right**) air quality scale information.

one of the fields that are widely studied nowadays. Mobile sensing allows users to monitor air quality wherever they go with sensors, giving them an advantage over stationary sensors which only measure air quality within their sensing range. Mobile sensors can be attached to the cellular phones, deployed on street sweepers [2] and bicycles [3].

Our work focuses on using existing technology to help people access relevant air quality information, and further understand how a mobile air quality monitoring application is being used. In this paper, we introduce a mobile air quality monitoring application, *Mobile Observatory*, which utilized air quality data from the OpenSense project [1, 7]. The air quality data is gathered by air quality sensors that are mounted on around 10 trams as they pass through Zurich, Switzerland. With this approach, *Mobile Observatory* is able to provide users air quality information of various areas in the city. We present preliminary results of our study, and then conclude with our finding and future works.

Related work

There has been research on measuring and raising awareness of indoor and outdoor air quality [2, 4, 6], but little work has been conducted about providing air quality information on a granular, neighborhood level, and understanding how mobile air quality monitoring applications are being used by citizens. Hooker *et al.* developed an electronic street sign that sent local air quality information to passersby via Bluetooth [4]. *BikeNet*, a mobile multifaceted sensing system in which CO2 sensors are mounted, was also related [3]. Aoki *et al.* tried to sense and improve urban air quality with participation of everyday activities of citizens [2]. *inAir* [6] is a system which measures particulate matter and visualizes indoor air quality on iPod Touch and a webpage. *MAQS*, a personalized mobile sensing system, can monitor indoor air quality with location tracking sensors [5]. In this paper, we present a mobile air quality monitoring application which provides air quality information on a neighborhood level, followed by preliminary results of user study.

Implementation

In existing mobile applications that are released by authorities or city governments, only air quality information of certain areas in which stationary sensors are deployed is provided. Our system *Mobile Observatory* is implemented as a Windows Phone 7 application (Figure 1), where users can monitor air quality of city of Zurich on the go. One of the main features of this application is the capability to monitor air quality of a wide range of neighborhood of the city.

Preliminary results

We conducted a user study in Zurich to evaluate and have a better understanding of how a mobile air quality monitoring application is used in daily life. A total number of 10 people who were living or working in the city of Zurich were recruited. At the end of the study, we interviewed 9 participants (excluded one participant from analysis due to lack of logged data and his unwillingness of having the interview) regarding the use of *Mobile Observatory*, usefulness of provided information, and suggestions about the application.

General patterns of use

The activity log data was analyzed in terms of (1) where participants used *Mobile Observatory*, (2) usage patterns in the study, particularly, on what day of a

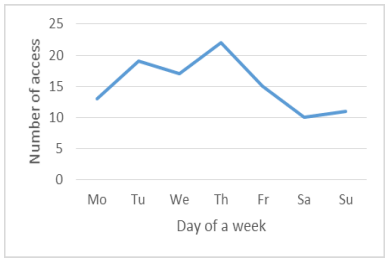

Figure 2. Monitoring pattern in a week.

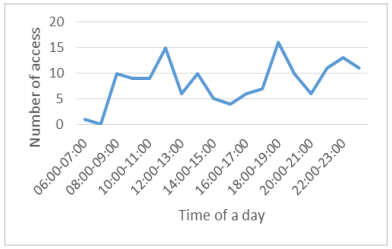

Figure 3. Monitoring pattern in a day.

week and at what time of a day participants monitored it the most. Our data shows that home is the place where participants used the application the most, accounting for 41% of the locations, followed by office with 37%. Around 14% of monitoring events took place while they were on the way. First few days had the highest usage rate but it gradually decreased. As one of the participants said that since there is no abrupt air pollution changes in a city like Zurich, once general air quality pattern is explored it is not necessary to use the application as often as the beginning. P3 said: "I use the application until I understand the air quality patterns, after that I do not have to use it that often." Details of each participant's daily usage and duration of their participation are shown in Table 1. Participants' weekly and daily monitoring pattern are also illustrated in Figure 2 and Figure 3, respectively.

Usefulness of air quality information

A few participants argued that showing air pollutant concentrations was not very informative since it meant nothing to them unless they were environmentalists or health experts. P4 said: "We do not understand what the meanings of those numbers are. They are just numbers for me." Some of the participants claimed that there were no particular needs for them to use mobile air quality monitoring application in a city with constantly clean air. P2 and other participants mentioned that it might be useful in a country with poor air quality. "Whenever I go back to China I could feel air pollution, it will be useful to use it in China'' (P2). P1 also said that it would be more helpful for "factory workers to check their indoor air quality'' than P1 himself. Some participants said that, though, it would be beneficial to make their long term decisions. P9: "…It will be more influential on people's decision if it is worth living in the suburb or want to live next to Bahnhof [train station].'' We found that perceived usefulness of air quality information was closely related to the level of air quality and fluctuations from one level to another.

Besides, air pollution was often compared to weather condition during the interview. Unlike weather changes, the participants would not take any instantaneous action according to air pollution information if there is no hazardous air pollution. P7: "… [Weather condition] does matter for me. [For example] whether or not should I take an umbrella [before leaving]. But for air quality changes…, should I go back home two hours later because my home has bad air quality [at the moment]? Probably not… [if the level on a scale of 1 to 5 changes] from 1 to 5, yes, but not from 1 to 2."

Implications

Some implication areas that emerged from our work and interviews are discussed below. We suggest opportunities for future research in the domain of air quality sensing.

Personalization

Personalization is one of the aspects that our participants deemed crucial in the future system. We found that some participants were willing to know more about air quality information that is provided based on users' context. It was argued that definitive information was not very helpful since it only describes effects of each level of air pollution on health. Also, it does not indicate specifically solutions or tips for the pollution. For instance, taking into account local traffics, environments, and air quality, will help users more clearly understand what causes air pollution in the

	Mean	SD	Days
P1	1.13	1.062	12
P2	1.5	1.366	16
P3	1.75	1.39	16
P4	1.92	1.379	12
P5	0.62	1.044	13
P6	1.38	1.895	13
P7	0.69	1.109	13
P8	0.62	1.044	13
P9	1.38	1.502	13

Table 1. Mean and standard deviation of each participant's daily usage, and duration of their participation.

neighborhood and what they should do with respect to the pollution.

Educational purpose

We believe that harnessing educational aspect is another way of fostering the system if we want to raise awareness and let users be more knowledgeable. Most of our participants were not aware of air pollution, and were not familiar with any knowledge of air quality. We investigated that they rarely navigated to information pages such as, air pollution scale, air pollutants, or index page. It is worth questioning how to allow users gain some knowledge of air pollution as they use the application. Some of the participants suggested that using push notification to give them a piece of "did you know that'' type of information, while others thought that could be too obtrusive to them and they might dismiss the notification without reading it.

Conclusion and Future work

We built a mobile air quality monitoring application for an exploratory user study in Zurich, Switzerland. One of the main features of the application is that it allows users to monitor air quality on a granular, neighborhood level, in Zurich. We then discussed preliminary results and implications of mobile air quality monitoring application which might contribute to further research related to air quality evaluation.

As the next step we are interested in conducting larger scale of user study with a revised application running on various mobile platforms. According to the users' feedback, we are planning to focus on supporting additional features, such as recommendation and educational tips in our system. Moreover, it would be interesting to explore how to incorporate both public human interfaces and mobile applications so as to improve citizen engagements.

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