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Performance Evaluation of a Metropolitan Air Pollution Sensing System Based on Prototype Design

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Abstract

Air pollution is supposed to be a major provider to early deaths and long-term diseases around the worldwide. Existing systems of metropolitan air pollution observing depends on static sites with low altitude resolution and moreover, lack the means to estimate exposures for individuals. This paper describes the design and evaluation of a low-cost participatory sensing system called Haze Watch that uses a combination of the portable mobile sensor units, smart-phones, cloud computing and mobile apps to measure, model, and personalize air pollution information for the individuals. The ideas are three-fold: 1) The design, prototype and it match the multiple hardware devices and software applications for gathering the air pollution data with high spatial density in real-time 2) The aim to develop web-based tools and the mobile apps for the visualization and estimation of air pollution exposure and 3) conducting field trials to validate our system and establish that it produces much more exact exposure estimates than existing systems.

Keywords: Performance, Metropolitan, and Sensing System.

Introduction

To be healthy, clean air is the basic fundamental requirement for human being. But, according to world health organization (WHO) more than 1.4 billion people are living in a area where the pollution is more than the suggested air quality guideline. The report tells that more than 7 billion people are affected by the pollution. Air pollution can cause cardiac arrest, lungs problem and breathing issues to humans. Observing and managing the air pollution is very important in both much developed countries and under developing countries. Many government organizations look after the air pollution contents and circulate the information regarding air pollution. These organizations have static monitoring devices which will gauge the air pollutant in vast area. But, fixing and controlling these stations are high cost so it limits their numbers. For example, the greater area Sydney has only 15 stations to measure the air pollutant and publish the data. The low altitude uses the mathematical model to calculate the pollutant concentration which can be incorrect.

The current study tells us that the pollutant data gathered from the home or the work, it will totally assume that user is at home or work at all times. But, this value will not be accurate because the user cannot be at home or work at all the time. We all know that as locations change the pollutant concentration will also changes. We develop a participatory sensing system-"Haze Watch" which mainly focuses on crowded place to give the correct location and value of the air pollutant and helps the users in managing the pollution through the personalized tools. The basic contributions are as follows.

(1) The design of a low cost system for users to give the pollution data which is attached with mobile phone application to upload the pollution data and a server to storing the data.

(2) The system will show how the data can be evaluated and consumed by users this also includes a correct models for adding the spatio-temporal data points. Visualization of pollution over a geographical area, and mobile apps that show individual data.

(3) The tests and calculations of a system with a minimum number of users to show that it gives much more accurate values to personal data than

existing systems which is based on collecting the data from static sensors, establishing the possible benefits that larger scale arrangements can bring to our understanding of the relationship between pollution exposure and health.

System Architecture

The system architecture consists of two parts data collection and data consumption .The first part idea is based upon the crowd sourcing i.e. many operators collect and gives the data which is obtained from the sensor parts.

Data collection

1) The sensor part that intellects the air pollution.
2) The application in mobile phone takes the data from the sensor units and it uploads the data to the server.

Data consumption.
3) The data which is uploaded to the server in which the interpolation models to generate saptio-temporal values
4) The polluted data information is seen by the individual user.

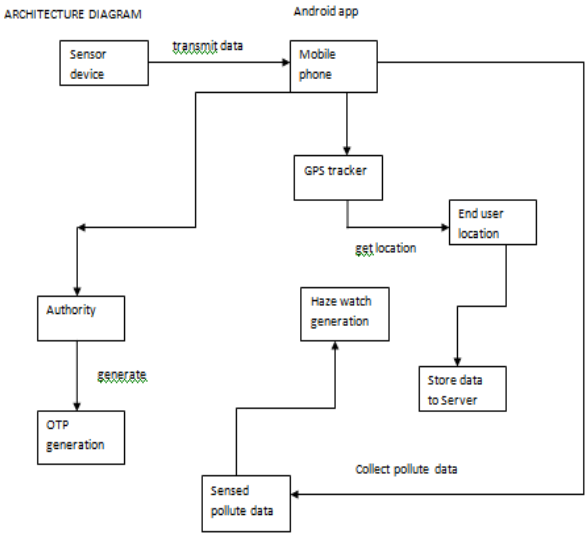
A. Pollution Measurement Node:

The sensor which observes air pollution are created by us (Haze watch) and we compared our senor with many nodes, sensor drones, Haze watch node and many sensors which were arisen in market. The problems faced by us are:

Portability: -One of the main challenges was the device portability, earlier device were fixed and huge and it would not cover the wide range of area.

Complexity: -Next challenge we faced is the device complication and its cost. In the recent approaches the device include sensors, GPS module for location and time and data network with 3g or 4g to update the data in real time. However this approach was complex. Hence we designed a model where the sensor with Bluetooth will transfer data to the application in mobile phone and it is assumed that GPS includes time and location with the pollutant measurements and upload it to the server in real time.

Sensor type: -There are different type of sensor units where our sensor unit includes the 1) gas sensors, (2) microcontroller with built-in ADC to digitize the sensor readings and package them into messages,(3)Bluetooth module to transmit the readings to the user's phone, and(4)battery power supply.



B. Sensor Calibration.

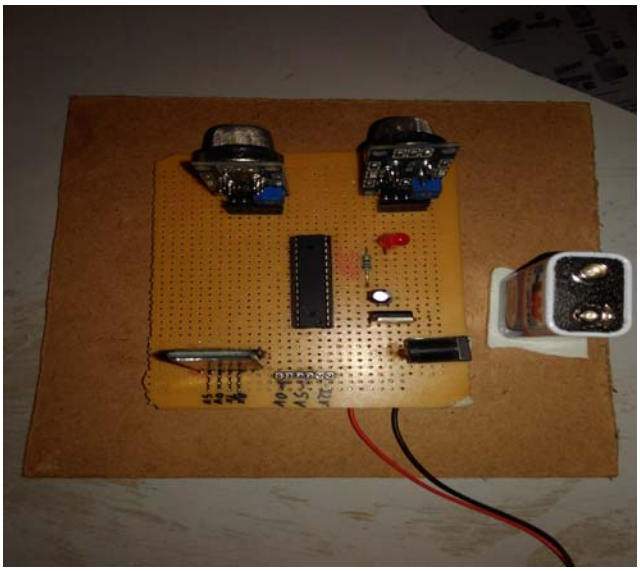
1.Initial calibration method: -After choosing the sensor, we need to calibrate the sensor for accuracy result. In this initial calibration method, we need to calibrate each unit which aims to convert the measurements into pollutant concentration. This method is designed based on the on field calibration approach and one common sensor approach.In this method at every known concentration the units has to be read the output. This was the major problem in this initial calibration method.The following formula to calculate the calibration

Concentration=1/Sensitivity((Vout–Vref/Rgain)– A)

2. Improved calibration method: In initial calibration even though Haze Node sensor was calibrated successfully, but there was an issue or concern about the calibration accuracy. To overcome this problem we designed a improved calibration method The formula to calibrate the sensor

PPM=raw_reading-Base_Line/(0.37736 *(Gain * Ratio))*10^9*rate.

Where baseline represents calibration baseline and rate denotes calibration factor This calculation results indicates that the portable Node Sensor is able to sense the pollutant concentrations in a stable and reasonable accuracy



c) Mounting the sensor device.

The primary is that to mount the sensor on the vehicles where mounting the device was a major challenge. Many sensor such as node sensor and sensor drone sensor can be carried on the top of vehicle, backpack and so on. The sensor is placed in such a way that the wind does not go directly into the vent holes of the sensor which results in large change in air pressure however haze watch does not expose the sensor to sun or rain which leads to better accurate results.

Battery performance is one of the main challenge in sensor where the battery performance is calculated based upon how long the battery will last during continuous operation. It is also important to make sure that the battery is supplying enough voltage to all the parts needed, removing and recharging should also be taken into account. We integrate allow battery indicator into our sensor that will alert the user through a red solid LED when the batteries are low and require recharging.

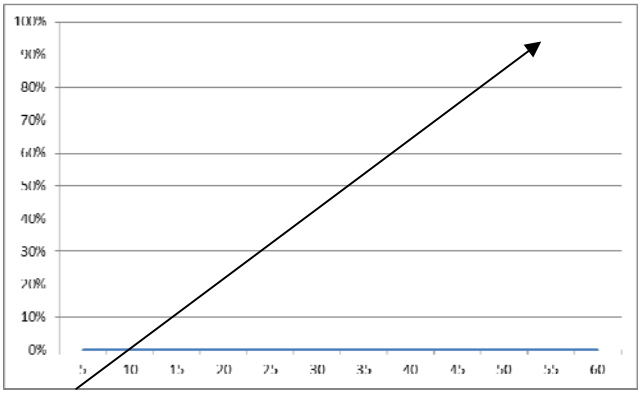
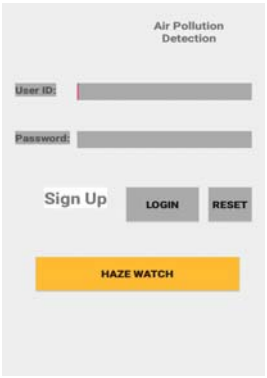


Fig 1 : correlation between CO analyzer and node sensor

D. Mobile App for Data Upload

The sensor device will be connected to the user's mobile phones through Bluetooth. As said before, it depends on GPS and 3G capacity in the phone instead of duplicating the things on the sensor device. As per the survey made on 2011, approximately around 46% of Australians own smart phones and now onwards it is increasing fatly. So we can anticipate that the requirements will not be much difficult to the users. We build up many apps for android related and iOS related phones to communicate with sensor device through Bluetooth. Screenshots of the application interfaces are shown below For example, application that connect mobile phone and Haze Watch node is shown below from which we can observe that ahead begin the apps scans for Bluetooth devices and shows a list of sensor units that are within communication range



After connecting to the suitable unit the application downloads calibration constant for that unit from our sensor. Later on the applications will continuously displays message to the users, such as current location, pollutant type, current pollutant values reported by the unit, current time, up to five samples recorded in the past, etc. here in our design the user need to do only minimal number steps, which is to start up the application and connect to the sensor device at each point of record, latter all the activities are done automatically. Next application which we had developed that will work on node sensor device it will also provide the recording location and route. it also provide us with GPS information and pollutants value along with the recording time. This application will be working out in background and upload the data constantly. Here the air pollution data is collected per every 5 seconds and the it is updated to the server for every 25 seconds. One of the major challenges what we faced was that location stamping of the air pollution data is managed by mobile phones using GPS information, which was lost inside many tunnels. To come out of this problem we developed a interpolation algorithm in the mobile phone app so that the data will be stored

locally while GPS is lost whenever GPS gets re-acquired the stored samples are equally spaced between entry and exit points by a simple interpolation algorithm.

E. Server Database

The last constituent of our data collection structural design is database server. This is the innermost storehouse, hosted in our data centre, to which all our data provider users mechanically upload facts. We also wrote computerized scripts on our server so it provide the data available hourly by the state Department of Environment on pollution levels at their fixed stations in and around city. The structural design of our server software comprises three layers: the web-server layer, the model layer, and the database layer. The *database layer* forms the hub of the system, by acquiring all data and provides a simple interface to take out and filtering readings. We use MYSQL, and it is choose for its effectiveness, dependability, and ease of use when searching and filtering over large sets of data. The *model layer* provides an Abstraction of the data, whereby it can return the air pollution level for any random point in location and time, by employing an fundamental interpolation model over the collected data. This theoretically separates the manufacture of data from its expenditure, allowing an application to be written without constraints on the fundamental data compactness or permanence. Note that all communication with the data occurs via the model, so that a dependable boundary is presented to any application seeking to use the data. The *web server layer* presents the data to the outside world, in the form of web-pages, maps, and applications that access it via an API. A complete explanation of the server design and operation can be found in our report.

F. Data Modeling, Visualization, and Personalization

1) *Interpolation Models:* By means of accumulation produced mobile units, we anticipate to compute air pollution at much better-quality spatial granularity than existing from the government's permanent monitoring stations today. However, since no organization can measure pollution over all points in space and time, we need to employ models that can approximate concentrations casing the full metropolitan space under concern. The accessible mechanical approaches to approximation the spatial portion of air pollution range from simple experimental techniques such as interpolation to a variety of numerical degeneration methods or data driven models such as land use degeneration and neural networks to more complex models including atmospheric chemistry and scattering.

2) Web Based Visualization: The web application contains of a client-side component and a server-side component, divided by a network. As described previous, the server stores the geo-referenced data in the MySQL database, runs the interpolation models, generates a outline map for particular datasets, and exhibits uncertainty handing out APIs to outer surface applications. The client side runs a web-based form input that allows users to enter location, moment, and other parameters, and pass those to the server. The pollution outline map generated is overlaid on Google maps, selected for its ease-of-use, recognition, and well predictable API. Our client performance uses benchmark web technologies of HTML, CSS and JavaScript, and also Leverages the power of AJAX with PHP server-side scripting to deliver the utmost data modelling and apparition capacity.

3) Mobile App for Health Impact: We consider that even if a quite minute of users in a region may carry our sensor device and donate pollution data, everybody must gain from the data, and be empowered with individual tools to approximation and handle their pollution exposure. To this end we developed an iPhone application that tracks the user, and computes their exposure *a posteriori* based on their location trace. Our app allows the user to start and stop tracking their route, which get recorded as a trip. The user can see a list of their trips, and for each trip, compute the standard exposure to each pollution. The trip Can also be seen overlaid on a map, and the pollution exposure can be seen as a graph.

Validation and Field Trials

Validation and field trials are used to explain the validation of sensor platforms and field trials which will fetch better air pollution information for individuals.

A) Validation of sensor platforms

Validation of sensor platforms are done to check the validation of the various sensor devices, and that includes haze watch node, node sensor and sensor Drone sensor. We have conducted many trails for this, in the initial trail we make use of profitable observations and haze watch sensor and we kept on the car. The carbon monoxide contents were recorded and the contents are displayed. The pollution content in the metropolitan cities are shown through the graph and later on we assume that the measurements are correct with respect to

construction, calibration, software and recorded information from government organizations are collected and compared with our proposed system.

B) Trails with exposure estimation

Once we get the correct and exact information from the sensor devices we perform many experiments to find out how our proposed system deals with the estimation of air pollution exposure. Our mission is to estimate how correctly we can find the air pollution exposure with respect to individual person in the software of the user's phone. If our estimation is correct then it will show that exposure for large populations. The graph which is shown below represents the multiple data contributors. For this trails we make use of tunnels and roads. The altitude variations are shown the graphs.

c) Impact of mobility on personal dosage

We come across with several limitations in our proposed system that is, it has low-density in position. In future, we believe that the results obtained are improved significantly with positioning density. The discussion with the government departments are going on to obtain, positioning and integration of our proposed system. Another limitation is that it does not sense periodic pollution events. in spite of this limitations we believe that our proposed system gives the much more better exposure than current government existing systems.

In this case below figure represents individual exposure for 24 hours period with respect to morning and evening travelling to/from work by car. Another figure represents time spent and carbon monoxide dosage in different location in a day.

Inhaled_dose=respiratory_minute_volume* CO_concentraton*time*conversion_factor.

Where, RMV (respiratory minute volume) tells volume of air taken by a person per minute. It is known from the statistics that an individual spends less than 10% of his time on road; nearly 30% of the daily pollution dosage comes from his travelling.

D) Deployment challenges

Since we have built and trailed the system from past few months, we have learnt that inter corrective nature of the project makes it full of challenges on many fronts.

Conclusion

In this project we defined the planning, trial product and estimated the low-cost air pollution detecting system. The proposed system compared with many convenient pollution detecting components. The proposed system contains mobile phone apps and haze-based service to determine the pollution contents in the urban areas in real time. The individuals can view the pollution contains in the environment by making use of mobile apps and by making use of this information the people can understand how much they are obstructed by the air pollution. The proposed system provides exact results for the individual user.

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