A Bicycle-borne Sensor for Monitoring Air Pollution near Roadways

Xiaofeng Liu, *Member*, IEEE, Bin Li, Aimin Jiang, *Member*, IEEE, Shixin Qi, and Chaosheng Xiang, Ning Xu

Abstract —*Public bicycle share programs increase population access to bicycles and are becoming more and more popular in Europe and Asia. Because health effect attributed to exposures to near-roadway air pollutants has been concerned in recent years, here we present a bicycle-born data collection device for monitoring air quality near roadways. The system is composed of a low-cost particulate matter sensor, an exhaust gas sensor, a Bluetooth interface, and a GPS receiver that provides both a spatial localization and time to the data collection process. The primary tests indicate this device performs well, and can be integrated into a sensor network for air pollution based a network of shared bicycles*[1].

Index Terms — City air pollution, Environmental monitoring, Low-cost sensor, Public bicycle.

I. Introduction

Nowadays, public bicycle system has become a part of the urban transportation system, which increases the accessibility of public transportation system. It is also known as bicycle sharing systems, or bike share scheme. Public bicycle system is thought to be a way to lessen the use of automobiles for short trips, especially for "last mile", in that it provides free or inexpensive access to bicycle and has integrated with other public transportation systems. As a result, public bicycle system can to some extent alleviate traffic congestion and reduce air pollution.

Public bicycle network almost covers the entire urban area of city where public bicycle system operated. Therefore, it constitutes an ideal infrastructure network for monitoring air quality in the city. In the present, many of the systems used for collecting air quality readings are based on sensor network nodes distributed in specific local regions [1-3]. Many system for monitoring environmental quality use mobile computing devices to collect data with additional sensors and GPS technology [3-5].

A variety of public sensing systems based on Smartphone have been proposed to measure the environmental parameters. There are little projects that utilize public bicycle system to measure air pollutions. In general, public bicycle system is composed of smart bike, smart dock, and terminal touch, which involves wireless GSM/GPRS communication, IC card and/or APP, computer network control and database, RFID, and information management. Smart bike can act as a mobile sensor node with additional sensors that sense the particulate matter and the exhaust gas. Data collection and visualization can be done via the dock station and the terminal touch. Now the existing air quality monitor operated by local Environment Protection Department generally comprises fixed monitoring stations to provide public information on current air quality, and to assess public's exposure to air pollution. The spatial distribution of monitoring network is hard to indicate the air quality of local area.

In this paper, we develop a device measuring both the exhaust gas of motorized vehicles and particulates over roadways. This device can be equipped on the public bicycle as a sensor node. As a result, a mobile sensor network is built up on the public bicycle system to monitor the air quality everywhere in the city. The remainder of the paper is organized as follows. Section Ⅱ introduces the components and functions of the device. The evaluations of device is given in Section Ⅲ. Section Ⅳ concludes our work.

II. Bicycle-born Monitor

The bicycle-born monitor consists of a single-chip processor, a microGPS receiver, a particulate detector, an exhaust gas sensor, a microSD card, and a Bluetooth modulus, as shown in Fig. 1. When the subscribers rent the public bicycle, the monitor starts to collect the air pollution over roadway, and store these data in the SD card. After the subscribers return the bicycle at the dock station, the collected data are uploaded to the data center via the Bluetooth interface.

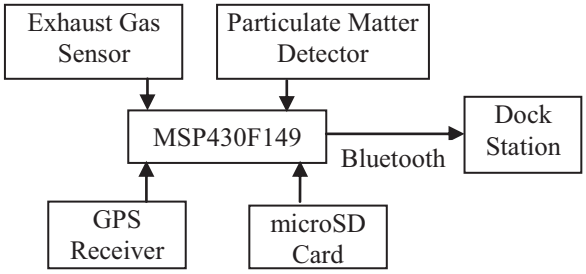

Fig. 1 System Overview

[1] This work was supported in part by the Fundamental Research Funds for the Central Universities of China under grants 2011B11114, 2011B11214, 2012B07314, and the Natural Science Foundation of Jiangsu Province, China under grants BK20141157 and BK20141159.

All authors are with the College of IoT Engineering, Hohai University, Changzhou, 213022, China (e-mail: xfliu@hhu.edu.cn, robby1017591076@163.com, jiangam@hhuc.edu.cn, qsxhhuc@163.com, 361510143@qq.com).

978-1-4799-8745-0/15/$31.00©2015 IEEE

A. Sensors

We concern two classes of pollutants, exhaust gas and particulate matters. An affordable portable optical aerosol sensor, Shinyei PPD42NS, is used to measure particulate matter, which outputs a digital (Lo Pulse) in proportion to PM concentration [6]. TGS 2201 (Figaro Sensor, Japan) is used to measure the exhaust gases because of their broad selectivity to some exhaust gases such as CO_2, N_2, NO_X, CO, and some other gases. A GPS receiver (CM6B, Bonav) is used to obtain the geo-information because it is one of the smallest GPS receiver modules integrated with a finely tuned, high-sensitivity ceramic antenna. We record the timestamped measurement to a microSD card that is connected to the microcontroller with SPI mode. The chip MSP430F149 (Texas Instruments) is used as a low power microprocessor due to mobile sampling on road. The Bluetooth module, FBT06M, is used to upload the collected data to dock station. All components were housed in a 20×10×10 cm polycarbonate case (see Fig. 2), along with a 72h, 2000 mAh lithium-polymer battery.

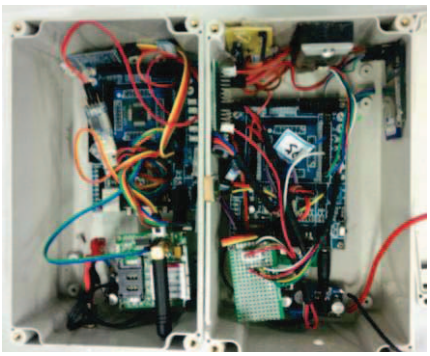

Fig. 2. Physical view of bicycle-born monitor

III. Evaluation of Device

We carried out two tests of the device in two different environmental conditions. First, we sampled the air quality in indoor environment and that near the exhaust pipe of a car idling. Signals outputted from the PPD42NS sensor are a series of pulses of 0-5V amplitude and of approximately 10-100 ms duration related to particulates matters. Results were shown in Fig. 3. It was clear that the concentration of particulate matters was much higher at the exhaust pipe than that at indoor environment (see light blue line in Fig. 3).

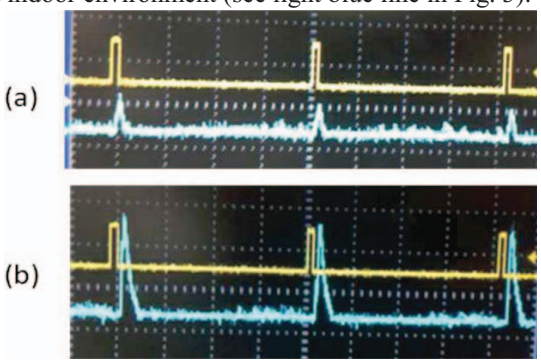

Fig. 3. Detection of particulate matter using the PPD42NS sensor inside the building (a) and near the exhaust pipe (b). Yellow line denotes the time clock, and light blue line denotes the outputs of sensor (Units: Voltage).

We further validated our monitor in mobile setting. The monitor was mounted on the bicycle to sample the air pollution over roadway in the center of Changzhou city. The data was visualized via the Baidu' heat map, as shown in Fig. 4. The concentration of particulate matters over roadways with heavy traffic flow was much higher than that over roadways with less traffic flow.

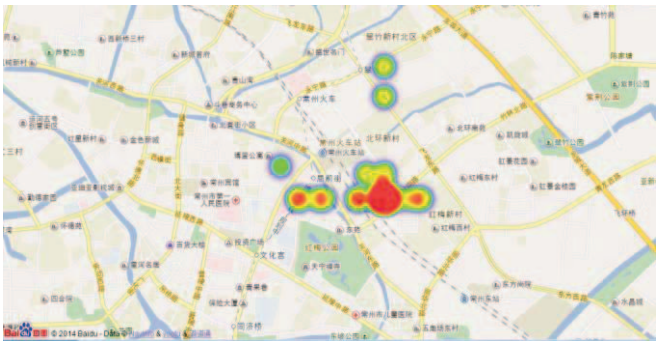

Fig. 4. Air quality (particulate matter) at the center of Changzhou city. Red: High concentration; Green: Low concentration.

IV. Conclusion

Public bicycle system has been viewed as an innovative way for inner-city transportation and meanwhile it has constituted a novel infrastructure of sensing network. The paper introduces an innovative way for monitoring air quality of city based on the public bicycle network system. We focus on the design and development of bicycle-born monitor integrated with a particulate matter sensor, an exhaust gas sensor, and a midcrop. The demonstrations of monitor in two environmental situations indicate that it is an effective means for people to sense air pollution.

References

[1] J. Beutel, O. Kasten, F. Mattern, K. Römer, F. Siegemund, and L. Thiele, "Prototyping wireless sensor network applications with Btnodes," *In Wireless Sensor Networks,* Springer Berlin Heidelberg, 2004, ch.22, pp. 323-338.

[2] R. M. Kling, "Intel mote: an enhanced sensor network node," *in Int'l Workshop on Advanced Sensors, Structural Health Monitoring, and Smart Structures*, Keio University, Japan, 2003, pp. 12-17.

[3] E. M. Tapia, S. S. Intille, L. Lopez and K. Larson, "The design of a portable kit of wireless sensors for naturalistic data collection," *In Pervasive Computing,* Springer Berlin Heidelberg, 2006, ch.8, pp. 117-134.

[4] E. R. Vivoni and C. Richard, "Real-time streaming of environmental field data," *Computers & Geosciences, vol.* 29, no. 4, pp. 457-468, Mar, 2003.

[5] E. Kanjo, S. Benford, M. Paxton, A. Chamberlain, D. S. Fraser, D. Woodgate, and A. Woolard, "MobGeoSen: facilitating personal geosensor data collection and visualization using mobile phones," *Personal and Ubiquitous Computing,* vol. 12, no. 8, pp. 599-607, 2008.

[6] M. Penza, D. Suriano, M.G. Villani, L. Spinelle, M. Gerboles, "Towards air quality indices in smart cities by calibrated low-cost sensors applied to networks," *in IEEE SENSORS 2014*, Valencia, 2014, pp. 2012-2017.