

Air-Sense: indoor environment monitoring evaluation system based on ZigBee network

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Abstract. In the modern life, people spend most of their time indoors. However, indoor environmental quality problems have always been affecting people's social activities. In general, indoor environmental quality is also related to our indoor activities. Since most of the organic irritants and volatile gases are colorless, odorless and too tiny to be seen, because we have been unconsciously overlooked indoor environment quality. Consequently, our body suffer a great health problem. In this work, we propose Air-Sense system which utilizes the platform of ZigBee Network to collect and detect the real-time indoor environment quality. What's more, Air-Sense system can also provide data analysis, and visualizing the results of the indoor environment to the user.

1 Introduction

At present, with the rapid development of Internet of Things (IoT), more and more smart home devices appear in our daily life, and bring numerous convenience to us. There are a lot of applications for indoor environment monitoring ^{[1][2][3][4][5]}. IoT has become increasingly important because of their use to intelligent fields, such as the Smart City, Smart Home, and so on.

Nowadays, IoT is gradually being used in the home for management services ^{[6][7][8]}. For example, electrical devices are controlled through intelligent learning, such as fire alarm and real-time monitoring indoor. However, there are still some challenges in designing IoT service system. Firstly, the sensor nodes work with limited power resource, such as the battery limitation. Secondly, every sensor node can only transmit information for a limited distance and communication bandwidth.

Environment monitoring system serves as a significant application in IoT. A majority of studies focus on environment monitoring. For example, Biyi Fang proposed AirSense is an Intelligent Home-based Sensing System for Indoor Air Quality Analytics through IAQ monitoring and Analytics ^[9]. We spend most of the time indoor every day. According to the World Health Organization (WHO) report, indoor air pollution and high blood pressure, hyperlipidemia and obesity, etc. together act as the top 10 human health threats. According to statistics, half of the world's population suffers from indoor pollution, and indoor pollution has cause 35.7 percent of which respiratory diseases, 22 percent chronic lung disease and 15 percent bronchitis, bronchitis and lung cancer. For example, Siom Lax have research for microbial interaction between humans and the indoor environment ^[10], and Khadija Tijani's paper uses Dynamic Bayesian Network to simulate indoor environment quality ^[11].

In this paper, we design and implement the indoor environment system, which is called Air-Sense system to monitor and predict indoor environmental quality based on ZigBee Network. The system can inform the user of the current indoor environment. When the pollution concentration value

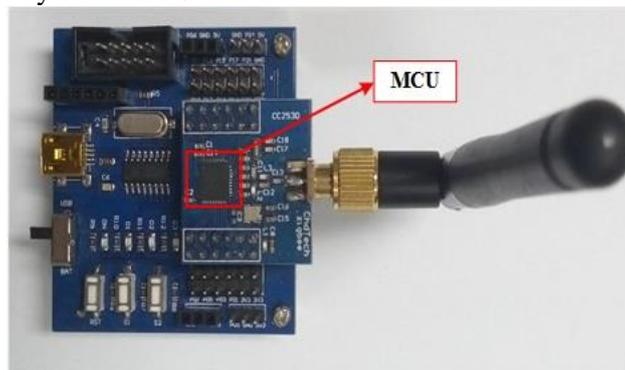


exceeds the national standard value, it will inform the user, and show the type of pollutants to the user. We utilize the ZigBee (IEEE 802.15.4 standard protocol technology) for our network communication, because it has low-power, low-cost and far transmission distance advantages. Our Air-Sense system use four different types of sensors consist of humidity, temperature, PM2.5, and TVOC sensor. Where TVOC includes the general organic gas, such as toluene, formaldehyde, which is seriously harmful to human health. Our Air-Sense system has many distinct characteristics, which can be listed as follows:

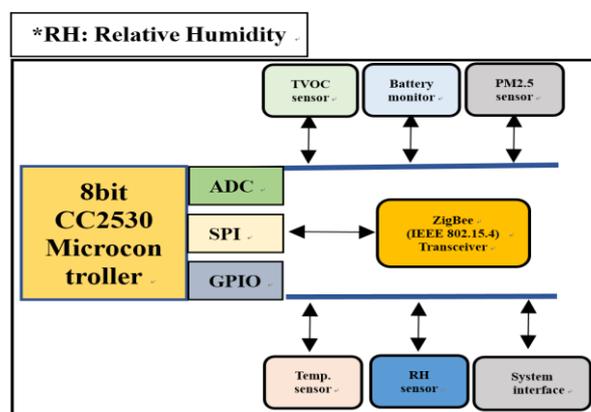
- 1) *Air-Sense System Hardware Platform:* We use the ZigBee technology as communication network, which has several advantages, such as possess low-power, far transmission distance, convenient Ad network model etc. Not only our Air-Sense system is real-time, in which the data collected five times every second, but also possess highly robust, because it has function hardware and software watchdog we designed in the Aire-Sense system.
- 2) *Air-Sense System Algorithms Design:* Based on Bayesian theory, we can predict indoor pollution, which can improve consciousness for immediately addressing indoor environment pollution.
- 3) *Experimental Design:* Our Air-Sense system is distributed in every room of a house for acquiring adequate data information in order to obtain precious experimental results

2 System Design

We implemented the Air-Sense system, which was used to build Smart Home service. Figure 1 (a) and (b) shows hardware design block diagram and the prototype. Because our system is distributed a whole our house, so we should consider it is low-power. What's more, we consider the quality of ZigBee communication why select the SMA antenna.



(a) hardware design block



(b)prototype of hardware

Figure1. Our Air-Sense system implemented hardware diagram: (a) hardware design block and (b) prototype of hardware.

The MCU is based on CC2530 (TI's chip products), which is an 8-bit microcontroller, and we use the type of CC2530F256, which have standard 8051 MCU, as well as the flash memory has 256KB capacity and the RAM has 8KB capacity. Air-Sense is consisting of four different type of sensor, respectively are PM2.5, TVOC, temperature and humidity sensor, and consists of ZigBee transceiver (IEEE 802.15.4 standard protocol), various of environment monitor sensor, and a power of battery controller. We used 256kps and 2.4GHz ZigBee standard protocol for communication with each network nodes, as well as ZigBee is a low-power and lower-cost, so it is widely used for Smart Home and automation control system.

Our Air-Sense system utilized to collect data physical information for real-time analysis pollution status in our house. Furthermore, Air-Sense system can be monitoring pollution status and give to us pollution types. Figure 2 illustrates the test a house experiment, and network nodes are distributed indoor plan module picture. Our experiment test in house where shows network nodes to distributed indoor status and shows the network nodes of work diagram. The house is consisting of three bedrooms, a living room, a balcony, a study room, a bathroom and kitchen to test data collected for completing the experiment. We collect data for a month, while the collection of data analysis to acquiring result. We use Bayesian mathematical statistics theory for prediction indoor environment pollution status, and can be visualized gives the type of pollution and values.

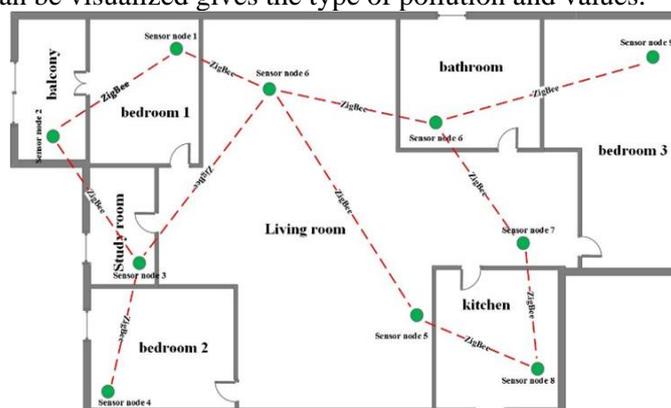


Figure 2. network nodes are distributed indoor plan module picture

3 Data Analysis

In the experiment, we collected physical data to analytic experiment result, and giving us to improving indoor environment to help health for people. Our Air-Sense system collect data for a math for us enough physical information to analysis. it is reported that indoor environment status providing specifies the parameters according to WHO standard. Table 1 shows the parameters of indoor environment status.

Table 1. WHO reports the standard values of the indoor environment

Category name	Units	Standard values
TVOC	mg/m ³	0.60
PM2.5	ug/m ³	10.00
Relative Humidity	RH	40%-70%
Temperature	°C	17-27

The result show that compared to periodic collect data, which can experiment result, situation based data analysis indoor environment a month, and the indoor pollution is approximately at noon and night show the most obvious, and beyond the standard range values. At the same time, we use Bayesian mathematical statistics theory for comparing to practical data, also is accurately predicted indoor environment status.

In this work, we use multi-data fusion technology, which is target discrimination by different type of sensors to collect data. Figure 3. shows Air-Sense system multi-data fusion model, which extract information features to predicted target.

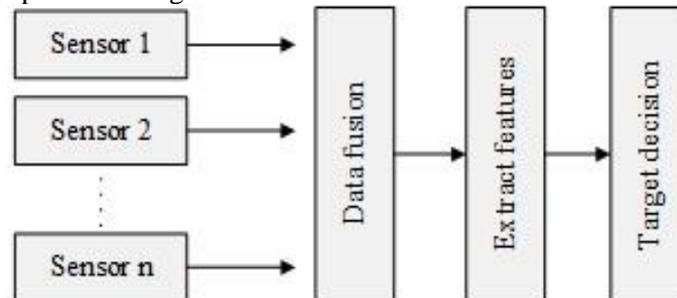
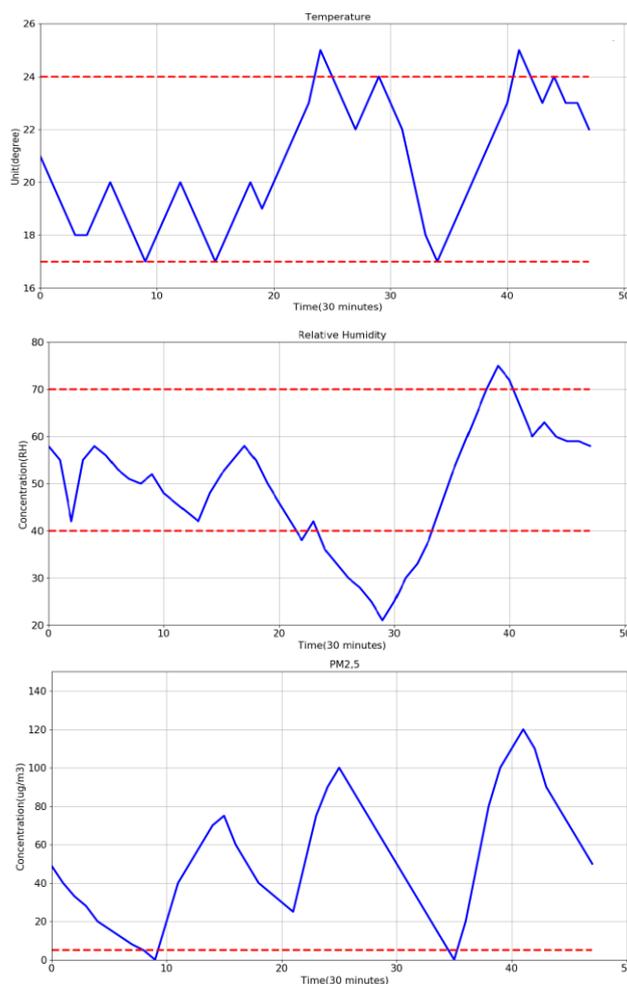


Figure 3. Air-Sense system multi-data fusion model

We use Air-Sense system collect data indoor environment physical information by temperature, humidity, PM2.5 and VOCs sensors. Figure 4 shows the four different type of sensor collected data in the day. When people at house daily activities, the indoor environmental quality has decreased significantly. For example, we can be acquired the TVOC and PM2.5 of data in the kitchen change obviously, because we cook food to volatile gases and tiny particles, and TVOC and PM2.5 hugely changed indoor environment quality in the living room, because of people smoke seriously affected indoor environment at noon and night.



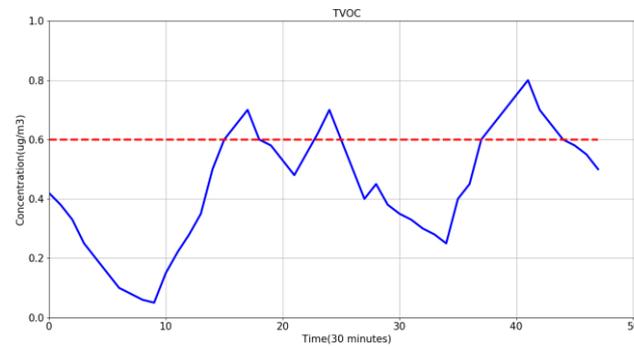


Figure 4. The temperature, relative humidity, PM2.5 and TVOC sensor measurements of indoor environment a day.

4 Implementation and Evaluation

Our Air-Sense system is implemented by processing the data indoor environment to predicted. We use Bayesian mathematical statistics theory for Air-Sense system algorithm, which can accuracy to predicted indoor environment status.

Our Air-Sense system architecture platform based on ZigBee communication technology, which is a robust and efficient way of communicating. What's more, ZigBee technology is a low-power and lower-cost, so we used for Air-Sense system to communication every node of physical information.

Bayesian theory also was widely utilized a lot of applications, such as Artificial Intelligence (AI), machine learning (ML), Big Data and so on. Based on Bayesian Statistical Learning Algorithm, Our Air-Sense system have realized as follows: We define the variable to be predicted as ξ . We assume that the sample point as x_1, x_2, \dots, x_n , as well it is acquire joint probability is written as $P(x_1, x_2, \dots, x_n; \xi)$, and as $P(x_1, x_2, \dots, x_n / \xi)$ or $P(\mathbf{x} | \xi)$, if ξ is known. We use $\pi(\xi)$ to represent the prior distribution of ξ , and often according priori to parameters of ξ to get a priori probability distribution. We utilizes priori probability distribution of $\pi(\xi)$ and conditional distribution probability of $P(x_1, x_2, \dots, x_n / \xi)$, then we can determine joint distribution probability of x_1, x_2, \dots, x_n and ξ , and can get distribution of x_1, x_2, \dots, x_n . Therefore, we can determine the posterior distribution probability of $P(\xi / x_1, x_2, \dots, x_n)$. The posterior distribution probability of $P(\xi / x_1, x_2, \dots, x_n)$ is calculated as:

$$P(\xi | x_1, x_2, \dots, x_n) = \frac{\pi(\xi)P(x_1, x_2, \dots, x_n | \xi)}{P(x_1, x_2, \dots, x_n)} \quad (1)$$

where

$$P(x_1, x_2, \dots, x_n) = \sum_{i=1}^n \pi(\xi)P(x_1, x_2, \dots, x_n | \xi) \quad (2)$$

Our Air-Sense system to achieve the experimental data analysis and processing based on Bayesian network theory, and get the corresponding forecast results. Bayesian theory have utilized in many fields, especially data science application in the fields.

We compare the results of the predicted reslut with the actual values, as shown in Figure 5, (a) and (b) we can see that the accuracy of our Air-Sense system algorithm is approximately more than 96%. We have implemented Air-Sense system though robust hardware platform and effective algorithm for predicting and collecting indoor environment status help to our health in daily life.

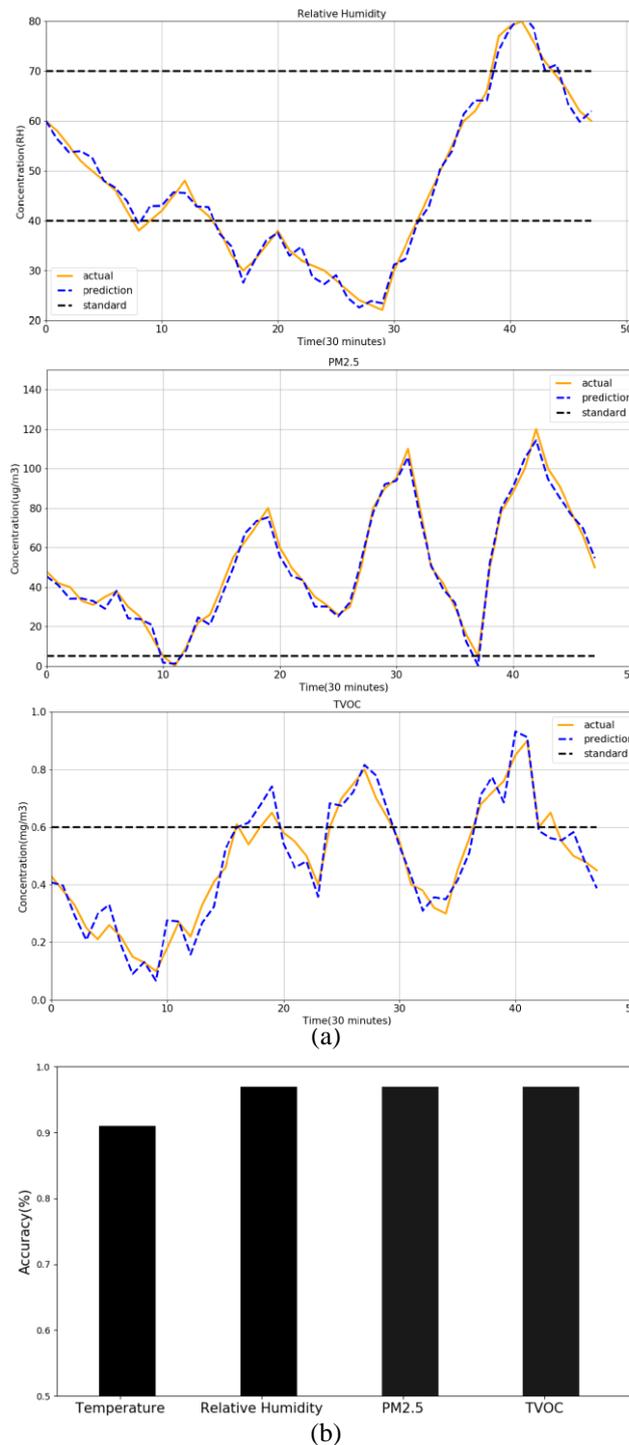


Figure 5. Experimental result: (a)the actual value of each type of sensor is compared with the predicted value of Air-Sense system; (b) Air-Sense system accuracy of the prediction, the accuracy of each sensor parameter type is approximately more than 96 percent.

5 Conclusion

We implemented the real-time monitoring indoor environment system, which is based on the analysis of Bayesian statistical theory on the platform of ZigBee Air-Sense system. In this paper, we are to achieve our Air-Sense system functions by Bayesian statistical theory algorithms. Through a lot of

data collection and analysis, our Air-Sense system shows its performance well where the accuracy reaches up to 96%. In the future, we want to optimize our Air-sense system so that it can bring greater value to our daily lives, and improving our health.

Acknowledgement

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