AHP Algorithm for Indoor Air Pollution Detection and Evaluation System Design

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Abstract: The superiority of buildings, considering their routine in a variety of indoor environmental qualities, is significant to the existing habitants potentials. In order to extract a description of indoor air quality, the concentration of indoor pollutants needs to be obtained and then evaluated. Aiming at the existing indoor air quality monitoring and evaluation system, an AHP algorithm for the design of indoor air pollution detection and evaluation system is proposed, which combines the principles and methods of fuzzy mathematics to evaluate air quality in a confined environment. An experiment was carried out, using the analytic hierarchy process to assign weights. According to the principle of maximum subordination, comprehensive evaluation of air quality in a confined environment was carried out through fuzzy mathematical model. The results from experiments demonstrates the scope of improvement in the design of new buildings and work with prioritization of restricted assets for updating the performance of building. The experimental results show that the humidity value reached 54% RH when the temperature was 25°C, and the humidity value reached 60% RH when the temperature was 19°C. The evaluation results more scientifically reflect the true state of air quality.

Povzetek: Predlagan je sistem za oceno kakovosti zraka v zaprtih prostorih z uporabo AHP algoritma in metode mehke matematike.

1 Introduction

With the improvement of people's living standards, people have paid great attention to environmental pollution [1]. Environmental pollution has also become more important to people. The harm caused by the environmental pollution of the British Industrial Revolution and the environmental pollution problems that the United States once faced have brought heavy lessons for today’s fast-developing science and technology in China. Faced with China's current state of affairs, the development of science and technology is bound to cause damage to the environment. The destruction of outdoor air quality will definitely affect the indoor environment of people's lives. According to a World Bank statistical report, China’s annual economic loss of approximately US $3.2 billion is due to indoor environmental pollution. In addition, according to the investigation of the international testing and environmental agency, at least 30% of the indoor environments of buildings in the world contain harmful substances that endanger human health. The quality of indoor air directly affects people's health and living standards. Indoor environmental pollution has been listed as one of the five environmental factors that are the most harmful to public health [2].

Skyscraper high rises are packed all over China due to congestion. As of late, the load of public and confidential lodging expanded by 782,754 and 1,634,847, separately [3]. Minimal expense public lodging pads have average designs and are typically little, ready to oblige private examples and inclinations. Confidential pads are normally involved by center pay proprietors or occupants. Albeit the living quarters of these pads are bigger, the normal cruciform construction joined with a focal plan lessens the nature of public spaces in those structures [4]. Aside from the level size and design, numerous different factors, for example, the outer climate [5], closeness to foundation and assets and the elements of indoor lodging, for example, family room influence the living space of occupants. The multi-faceted natural execution of the structure, regarding the nature of the indoor environment, perceivability and sound and the nature of the indoor air, additionally affect the strength of inhabitants and their fulfillment with the living space [6].

To work on the presentation of structures in the climate, various deliberate investigation programs have arisen, for example, the Building Research Establishment's Environmental Assessment Method (BREEAM) in the UK and in China, the HK-BEAM Organization has had huge progress in expanding enlistment in its Voluntary China Building Environmental Assessment Program [7]. These cycles frequently incorporate the assessment of the quantity of indoor climate (IEQ); each with a particular credit point for the general outcome. Progressively, the logical order (AHP) process is utilized to handle the speculations, to decide the upsides of the connection between's the tried factors, which are expected to consolidate the joined test results into accumulated places (for example [8, 9]). Concentrates on directed on business structures found that different psychophysical factors impact basic judgment on saw esteem [10]. In private structures, be that as it may, little is had some significant awareness of the occupants' impression of the significance of legitimacy [11]. While property executive organizations might lead a general review of inhabitant's fulfilment with their living space, for example the apparent usefulness of structures under their administration, to recognize regions for improvement, there is an absence of rules on the most proficient method to focus on so more prominent improvement can be accomplished reasonably affordable. The review was expected to close this data hole in the China context. The manuscript is composed as follows: Section 2 is for related work and Section 3 is for research methodology. Section 3 includes research methods followed by results and analysis in Section 4. Last section includes conclusion.

2 Related work

In this section various state-of-the-art work in the field of indoor air pollution detection and evaluation presented.

With the development of society, Nag *et al.* found that modern people spend about 80% of their lives indoors, and people's life, work, entertainment and other activities are concentrated indoors [12]. According to survey data, Zacarías *et al.* found that there are 7 million direct or indirect deaths caused by indoor air pollution each year, of which China accounts for one-seventh of the total deaths. Indoor air pollution can be divided into chemical pollution, physical pollution, biological pollution and radioactive pollution. Chemical pollution mainly includes volatile compounds and inorganic gases such as formaldehyde (CH0) [13], carbon monoxide (C0) and carbon dioxide (CO2). Lee *et al.* found that physical pollution mainly includes inhalable particles, dust, etc.; biological pollution is mainly caused by biological fungi, bacteria and other microorganisms; radioactive pollution is mainly radioactive substances remaining in the indoor air [14]. Xie *et al.* found that the four types of pollutants such as oxygen Ra affect human sensory experience and even physical health, and have a great impact on the human respiratory system, endocrine system, and nervous system [15], and even cause disease.

The main feature of indoor pollutants is that they are exposed to a wide range of people, and different people have different sensitivity, age and health factors. In addition, there are many pollutants, such as the daily inhalable particulate matter PM2.5 and PM10, which can directly enter the human lungs and cause extensive lung fibers, leading to pneumoconiosis. CH20 is highly toxic and volatile, which is extremely harmful to the human body. Miao *et al.* found that CO and CO2 are inorganic gaseous pollutants. Normal CO2 concentration has no obvious effect on the human body. However, if the concentration is too high, people will have symptoms such as sleepiness and lack of energy. CO is insufficient carbon. The product formed by combining with oxygen [16] is colorless, odorless, and highly toxic. Deeply poisoned, it will cause irreversible and permanent damage to the brain. Long-term exposure to these pollutants can cause harm to the human body and cause disease. Oyabu *et al.* understand the concentration of various indoor pollutants and judge the pollution level of the indoor environment [17].

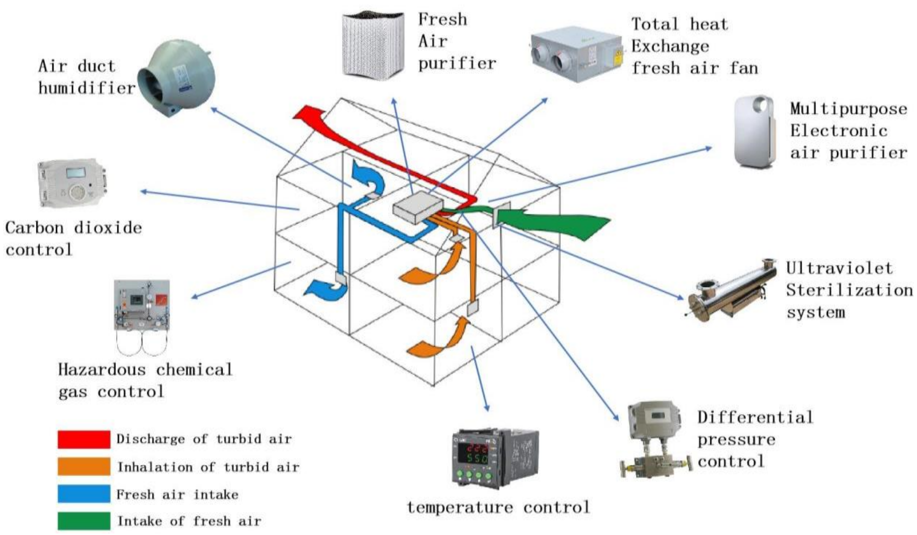

Figure 1: Indoor air quality system solution.

It can keep away from the heavily polluted area in time to avoid harm to the human body. It is very important to monitor these pollutants in real time and evaluate the pollution level. With the rapid development of Internet of Things technology in recent years, China has established a system to monitor outdoor air.

The Environmental Protection Agency will also publish the air environmental quality index and pollution level of each region. Oyabu *et al.* found that it is possible to query the specific concentration values and pollution levels of outdoor air pollutants in real time. At present, most of the indoor air quality monitoring systems are based on wireless sensor networks, such as AHP. WIFI, etc. 18]. Wu *et al.* found that the wireless sensor network itself has its own limitations, requiring the deployment of a wireless office network, which brings a lot of inconvenience. When the monitoring points are many and the distribution range is wide, such as monitoring the air quality status of all residents in a certain community, or even monitoring multiple communities, wireless sensor network deployment is difficult, and there are higher requirements for the deployment network connection points. The traditional sensor network is difficult to implement, and can't even meet the demand [19]. Bluyssen and Cox found that based on this choice, it is also very important to be able to connect a large number of wireless communication technologies with a large coverage area, and a more intelligent and convenient monitoring system is needed to meet the needs of different indoor monitoring scenarios [20].

Mirmohammadi *et al.* found that currently China has not issued a clear and relevant grade evaluation standard, which has caused different departments to use different evaluation standards, and the evaluation results obtained are also different [21]. According to the information obtained, most of the current indoor air quality evaluation systems mainly focus on single-factor factors, such as the evaluation of indoor inhalable particulate pollution and the evaluation of formaldehyde pollution. Some parts have been comprehensively evaluated, but the pollution factors and the evaluation methods used are not the same. In Figure, it has been dictated that how to choose appropriate pollution influencing factors and evaluation methods to obtain a reasonable evaluation level, and comprehensively and objectively reflect the current monitoring indoor air quality.

3 Research methods

This section describes the adopted methodology for the detection and evaluation of indoor air pollution. The air quality evaluation of a closed environment is to analyze, evaluate and predict the air quality of a certain enclosed area according to certain evaluation standards and evaluation methods [22]. At present, there are many air quality evaluation methods, and the comprehensive pollution index method and expert scoring evaluation method are commonly used. However, in the evaluation process of various situations, due to the many evaluation factors and no clear indicators, the evaluation has a certain tendency and is not objective, and the comprehensive evaluation results have a certain deviation. Especially in the actual confined environment, the impact of human activities and equipment operation on the air quality of the confined environment is more complicated, and the comprehensive effect is difficult to determine. In order to obtain reasonable air environmental quality evaluation results, more and more fuzzy theories have been introduced in recent years to deal with this transitional gradual problem. The theory uses AnaVtic HienarthyProcess AHP to determine the weight of each factor, establishes a fuzzy comprehensive evaluation model, and obtains a more objective evaluation result [23].

It uses the 1~9 ratio scale method suggested by SAATY to construct a pairwise comparison judgment matrix. If there exists $a_{ij} = a_{ik}$ relationship, the matrix is said to have complete consistency. The eigenvector corresponding to its largest eigenvalue can give the relative importance of the index. The order, after orthogonalizing it, is the desired weight vector.

By calculating the maximum eigenvalue λ_{max} consistency index CI and consistency ratio CR, to check whether the consistency of the comparison matrix established above meets the requirements. After determining the fuzzy matrix R and the weight A of each factor, the fuzzy comprehensive evaluation model of the overall environmental quality can be obtained through its compound operation U=A°R. There are many kinds of fuzzy calculation methods, here we use "-" and "+" operators, denoted as M(.,+). In this model, since each factor is normalized, the operation + degenerates into a general real number addition. And this model considers the influence of all factors when determining the degree of membership of the evaluation of each factor to the grade, and the calculation is more refined. Then the elements in U are presented in Equation 1.

$$U_{ij} = \min\left(1, \sum_{1}^{n} a_{ik}. \quad b_{kj} = \min\{1, [a_1 \cdot b_{ij}] + (a_2 \cdot b_2) + \ldots (a_k \cdot b_k)\right) \tag{1}$$

Table 1: Sub-index of mass concentration of sampling items

Sampling point value	**C6H6C6H6**		**HOCO**	**$O\ O_2 O_2 H_3 O_2$**
1#	5.72	33.5	12.6	.11.03.62.13.61
2#	2.51	12.4	0.87	.42.88.86.53.41
3#	1.97	22.4	4.12	.56.96.62.08.61
Average value	3.41	22.86	5.82	.26.63.02.59.3

When evaluating air quality in a closed environment, pollutants with different levels of harm to the human body are selected as the evaluation objects, and the original data of sampling points are selected. After statistical sorting, the relative value is used for fuzzy processing (the ratio of the average value of the measured concentration to the allowable concentration), see Table 1.

With reference to the allowable concentration and emergency allowable concentration of the closed environment, the air quality of the closed environment allows the people working and living within the allowable specified time, and the air quality grade index of the closed environment is defined as: the ratio of each emergency allowable concentration of air quality evaluation parameters in a closed environment to the allowable concentration of the closed environment. The air quality level of the closed environment is divided into 4 levels, which respectively represent the four levels of clean, light pollution, medium pollution and heavy pollution in the air quality status, that is, the evaluation set $V = \{I, II, I, IV\}$. The sub-indices of the air quality classification standards for airtight environments are shown in Table 2.

Table 2: Sub-indexes of air quality classification standards for confined environments

Level	C6H6	Hg	HOCO	CO	SO_2	NO_2	H_3	O_2
Level I	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
Level II	60.2	43.85	13.32	8.6	13.01	6.66	3.56	3.01
Level III	13.20	51.13	26.66	21.73	26.02	20.01	5.11	4.01
Level IV	20.03	142.85	40.01	39.01	40.07	41.30	8.01	4.40

Table 3: Single factor evaluation results

Hierarchical membership	C6H6	Hg	HOCO	CO	SO_2	NO_2	NH_3	CO_2
Level I (clean)	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Level II (light pollution)	60.1	42.85	12.32	8.5	13.05	6.65	3.55	3.02
Level III(medium pollution)	13.1	51.12	26.65	21.72	26.01	20.03	5.16	4.05
Level IV(heavy pollution)	20.02	142.86	41.01	39.01	40.06	41.2	8.02	4.30

Figure 2 presents the computation of important weights data is organized in 4 × 4 comparison matrix. Then in next step the organized data is forwarded to the standard program for the calculation of Eigen values and Eigen vectors. In next step the principal Eigen values are extracted and therefore consistency ratio is computed. In next step the principal Eigen vectors are normalized and then the consistency ratio is evaluated. After the evaluation, normalized Eigen vectors are accepted and the inconsistent dataset is discarded.

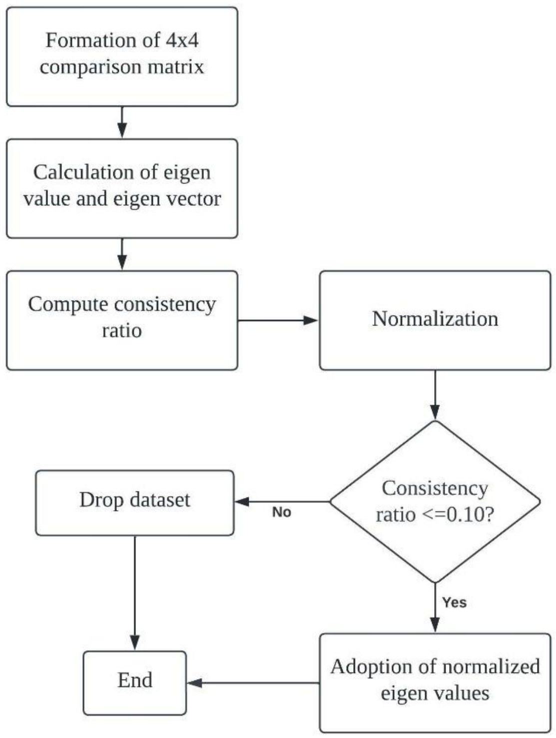

Figure 2: Computation of weight and consistency ratio.

It can be seen that the comprehensive assessment result of the air quality in the enclosed environment is that the membership degree of the air environment quality to the I, II, II, and IV levels is 0.4271.5310.0420, respectively. The single factor evaluation results are presented in Table 3. According to the principle of maximum affiliation, it is comprehensively assessed as a secondary standard (light pollution). The fuzzy mathematics method is used to establish an evaluation model for air quality evaluation in a closed environment, and the weight coefficient is determined by the analytic hierarchy process (AHP), and the comprehensive evaluation result of the air quality in this closed environment is obtained as the level II standard (light pollution). Using fuzzy mathematics to describe the air quality status of a closed environment with a membership function can not only get the air environment quality level, but also reflect the membership status of various pollutants, which improves the scientific nature of the evaluation. However, if the membership function is not established properly, the unreasonable setting of the weight function will also cause inaccurate evaluation results. Therefore, it needs to be further improved in and consistency ratios. Initially, from input each set of practical application to establish a more scientific and reasonable model and evaluation method.

4 Results and analysis

This section illustrates the analysis of results obtained by comparing the seismic forces and finally presents its discussion and summary.

In order to verify the accuracy of the formaldehyde detection and the performance of the formaldehyde detection module, the formaldehyde module is connected to the corresponding pins of the main control chip, and the formaldehyde concentration detected by the detection system is displayed and recorded in real time. The working principle of the formaldehyde sensor is a two-electrode electrochemical sensor, which realizes the detection of formaldehyde through the principle of diffusion. Since the sensor used in this detection system is a mature electrochemical sensor developed in China, the Chengsan company has made a specific calibration statement for the corresponding calibration of its formaldehyde concentration before it is put into use. The sensor can be put into use directly. When detecting and calibrating the formaldehyde gas, the formaldehyde gas detected by the sensor is mainly detected from the perspective of the sensitivity, stability, response time, calibration curve, and experimental data of the formaldehyde sensor.

A. Sensitivity

The sensitivity of a formaldehyde sensor refers to the lowest value that a certain sensor can detect the concentration of formaldehyde. The factors that affect the sensitivity are affected by the diffusion rate of formaldehyde gas and electrolyte in the sensor and the chemical characteristics of the internal working electrode [38]. The sensitivity of the ME3-CH2O sensor is defined as: sensitivity=2000nA/cm3.

B. Stability

When measuring the stability of the sensor, two values need to be measured: zero drift and span drift. The following table 4 shows the regulations for the stability of the ME3-CH2O sensor:

Zero drift ≤ 10% FS   Span drift ≤ 10% FS

C. Response time

Response time is a performance indicator that reflects the speed of the sensor. The sensing speed of the electrochemical formaldehyde sensor is determined by the electrolyte resistance between the working electrode and the reference electrode. The sensor used in this system has a well-defined response time in the design, and its stipulation is: response time ≤ 30S.

D. Calibration curve of the senor

The formaldehyde sensor uses the method of permeation tube to define the calibration curve of the sensor. The theoretical basis is that the volatile isolation layer between the water and the top air is constant at a specially designated temperature. The calibration curve is provided for testing in 1.0ppm formaldehyde at 20°C. The following calibration curve of 1.0ppm formaldehyde solution at 20°C is shown in Figure 3.

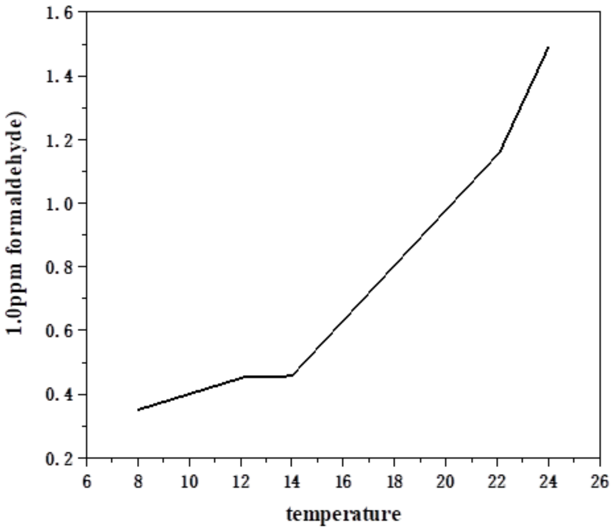

Figure 3: Calibration curve of HOCO.

E. Experimental data

In order to detect whether the measurement of formaldehyde gas is accurate, it was calibrated by comparing it with other formaldehyde gas sensors. The current application WP6900 Agris professional formaldehyde sensor was selected for calibration. According to the relevant information of WP6900, the minimum resolution of the detection device is 0.001mg/cm’. The minimum resolution designed by this detection system is 0.01mg/cm'. Because the resolution of this detection design is lower than that of the WP6900 detection device, it can be calibrated.

Table 4: System test results

Location	**Temperature**	**Humidity**	**HOCO concentration**	**State**
Laboratory	23℃	49%RH	0.03mg/m^3	Normal
Bedroom	25℃	51%RH	0.02mg/m^3	Normal
Canteen	17℃	64%RH	0.03mg/m^3	Normal

A certain concentration of gaseous formaldehyde was obtained by heating the liquid formaldehyde solution for gas detection. The formaldehyde generator can obtain different concentrations of gaseous formaldehyde by heating a certain concentration of liquid formaldehyde and calculating through the formula of the experimental device. The corresponding concentration of gaseous formaldehyde was obtained by heating different concentrations of liquid formaldehyde for measurement. The experiment selected 5 kinds of gaseous formaldehyde with different concentrations, and the calculated concentration of formaldehyde was 0.01mg/cm', 0.015mg/cm3, 0.02mg/cm3, 0.025mg/cm', 0.03mg/cm3. The measured environment was an indoor temperature of 25°C. The HOCO concentration values detected by the two sensors were recorded, as shown in Table 5.

Table 5: Laboratory testing data of HOCO

Production of experimental device	**The detection system**	**WP6900**
0.01mg/cm^3	0.01mg/cm^3	0.008mg/cm^3
0.014mg/cm^3	0.03mg/cm^3	0.014mg/cm^3
0.03mg/cm^3	0.03mg/cm^3	0.020mg/cm^3
0.024mg/cm^3	0.04mg/cm^3	0.023mg/cm^3
0.02mg/cm^3	0.04mg/cm^3	0.026mg/cm^3

Due to the simple laboratory equipment and the standard gas environment is not easy to reach, formaldehyde gas is dangerous to a certain extent. Therefore, there is a certain error when testing and calibrating in the laboratory. The values measured by the two sensors are compared; the results are shown in Figures 4 and 5.

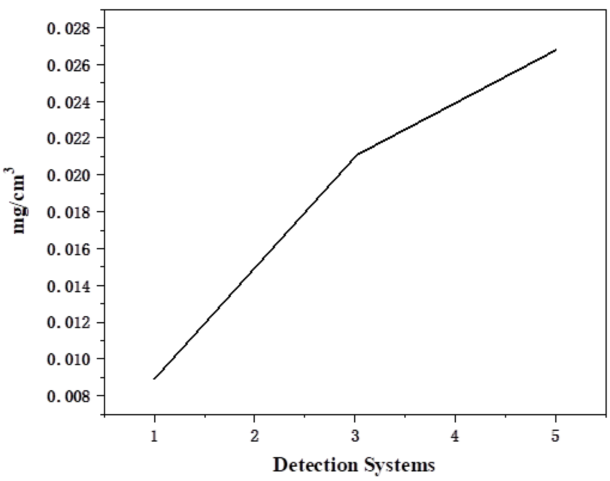

Figure 4: Formaldehyde concentration detected by WP6900.

By comparing the flow chart of the detection results, it can be seen that the designed detection device and the WP6900 have a difference in resolution due to the difference between the two curves, but the detection system can basically meet the measurement of formaldehyde gas concentration.

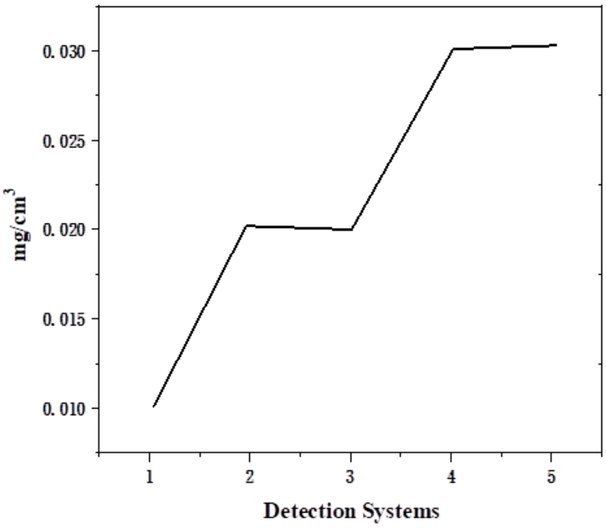

Figure 5: Formaldehyde concentration detected by the detection system.

The performance is measured in terms of indoor environmental quality for living and common area through local residents and visitors. Figure 6 represents the performance measurement of indoor environmental quality rated by residents. Figure 6 represents the performance measurement of indoor environmental quality rated by visitors. The visitors are ranked higher in comparison with the residents for the performance measurement. For example, all the four found the middle value of execution appraisals for the four indoor environmental quality credits given by the guests for the living/visited region in confidential structures surpass 5.1 yet the most noteworthy arrived at the midpoint of rating given by the occupants is lower than 5.0 as presented in Figure 6 and 7. Comparative connection exists for living/visited region in open structures, however not for all indoor environmental quality attributes.

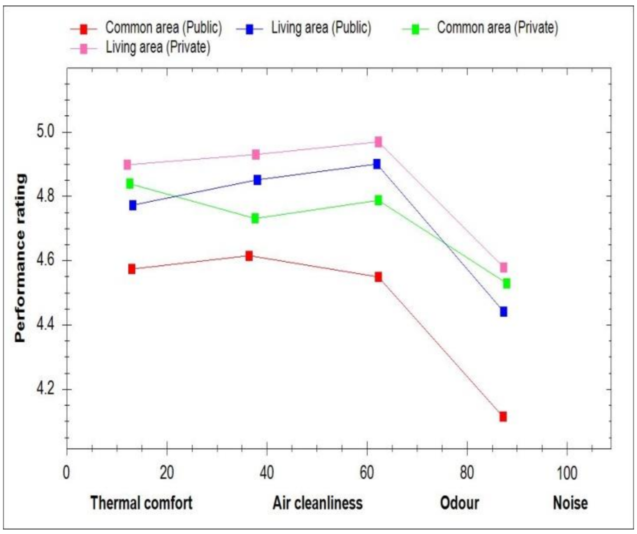

Figure 6: Performance measurement of indoor environmental quality rated by residents.

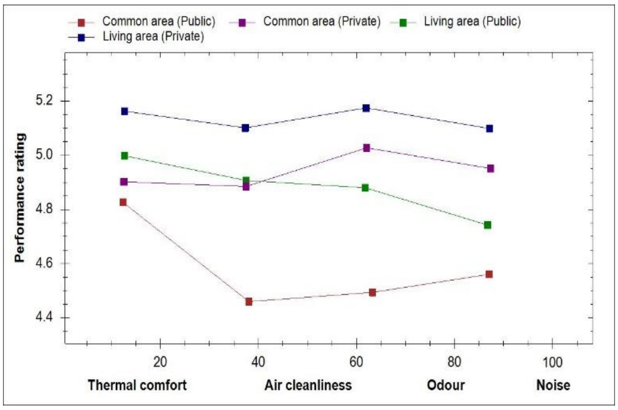

Figure 7: Performance measurement of indoor environmental quality rated by visitors.

The temperature sensor DS18B20 and HS1101 humidity detection module to the processor was connected through the corresponding interface. The detected data is processed and sent, and printed and displayed on the LCD screen and serial port, so that the temperature and humidity of the greenhouse can be measured. The main control chip can complete the measurement and display of temperature and humidity by using the microcontroller to code the temperature detection and humidity detection modules. The detected humidity value was displayed on the LCD screen or printed to the serial port. The purpose was to allow us to see the detected temperature and humidity value more intuitively. The indoor greenhouse temperature values detected by the detection module are shown in Table 6.

Table 6: Formaldehyde concentration detected by the detection system

Temperature value	**Humidity value**
25℃	50％RH
23℃	49％RH
17℃	64％RH
19℃	60％RH

In the software programming of temperature and humidity detection, accurate and stable temperature and humidity values are obtained, and finally output is displayed in order to provide convenient applications for people.

5 Conclusions

A low-power, portable indoor air quality detection system based on AHP algorithm IS designed. In the process of designing and completing the whole detection system, the research status of indoor air quality detection system was analyzed in detail, and the overall structure of the system was designed. According to the hardware platform built by the detection system, the detection system software scheme is designed to make the hardware part of the detection system complete the system requirements. The humidity value reaches 54%RH at 25℃, and the humidity value reaches 60%RH at 19℃. e the results of the designed detection system is tested and analyzed. It is mainly for testing the detection module, the communication test between the system detection device and the intelligent terminal upper computer, the overall function of the system, and the analysis of the test results. Although the designed indoor air quality detection system can achieve its basic detection functions, the system still has shortcomings and improvements. Due to time and condition constraints, this design still needs further improvement. Since the designed indoor air detection system is still in the laboratory stage, the mutual application of the functional modules used by the detection system will increase the cost and power consumption of the detection system. The purpose of reducing system power consumption and cost can be achieved by designing a reasonable application circuit and reducing the size of the board. The performance analysis in the normal region that the clients perceived was for the most part lower than the corresponding in the living/visited region, among which the worst thing is noticed as noise. The performance examination, in light of the general reaction of the clients, has shown the way that the gaps between them can be distinguished. This is the sort of data that helps managers for improving the utilization of the frequently compelled assets to manage structures. Besides, it can illuminate the regions for development in existing structures and the vital adjustments for building plan in future.

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