Research and Development of Environmental Monitoring Alarm and Automatic Flag Control System for Barracks

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Abstract

This paper proposes a real-time flag alarm system that can monitor air quality and automatically plant colored flags to inform the people in the barracks. This system automatically measures the local PM 2.5 concentrations with PM sensors; and automatically measures the temperature and humidity with temperature and humidity sensors, then converts the measured values into the grades of danger coefficients and the grades of AQI to plant or replace flags by automatic control. The danger coefficient grades are represented by four colored flags, namely, green, blue, yellow, and red; meanwhile, the AQI grades are represented by six colored flags, namely, green, yellow, orange, red, purple, and maroon. Moreover, this system displays all measured data and related information with electronic billboards to provide a reference for people participating in outdoor activities.

Keywords: danger coefficient, air quality index, automatic measurement, real-time control

1. Introduction

The overall air quality is poor, and air pollution is severe in Taiwan, and fine particulate matter (PM 2.5) in the air pollution can cause serious harm to the health of people staying outdoors [1-3]. In addition, the development of industry raises the environmental temperature. As a result, outdoor people often suffer sunstroke and heat exhaustion when exposed to high temperatures. To maintain the health of officers and soldiers engaged in outdoor exercises or activities, the ROC Armed Forces now determine whether it is suitable for the staff to participate in outdoor activities based on the grades of danger coefficients and air quality indexes (AQI) [4].

The meteorological agency (weather center) provides the outdoor temperature and relative humidity measured, and people can use them to calculate the dangerous coefficient. In addition, the environmental protection unit provides the PM 2.5 concentration measured, and people can use it to calculate the AQI. People convert the data obtained through regular (twice-a-day) checks into the grades of danger coefficients and AQI. Then plant two corresponding-colored flags, as shown in Fig. 1. If the grades vary due to changes in the obtained data, People must replace new colored flags.

The use of flags to express the state of air quality originated in the United States. Imperial County, California, began to promote the air quality flag in 2004. It adopted the AQI of the U.S. Environmental Protection Agency (US EPA). It used five different colors, green, yellow, orange, red, and purple, to represent the extent of deterioration of air quality [7]. The US EPA even launched a national school flag program in 2013, using AQI to classify air quality, making corresponding suggestions for

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each color, and promoting the importance of understanding air quality and protecting health through flags [6]. In Taiwan, since 2016, the Ministry of Education has also promoted the air quality flag publicity plan for junior high schools and elementary schools [8]. Every day at 8:00 and 12:30, query the AQI value manually and insert a flag of the corresponding color. Ng et al. [9] conducted a feasibility study on promoting Ireland's second level active school flag (SLASF) program in 2019.

Fig. 1 Flags for AQI and coefficient in ROC Armed Forces barrack

The primary objective of this study is to see if the SLASF certificate is an acceptable program in secondary-level Irish schools. The secondary objectives are to see how feasible it is to operationalize the components needed for testing a year-long intervention [9]. However, there are many problems with the current flag operation methods:

(1) The measured values are average values within wide ranges, but not actual values of officers and soldiers engaged in activities at that given time and place, and there are significant differences between the two groups of values due to environmental conditions and meteorological factors [10-11].

(2) Flag planting after manual conversion and judgment based on the data from the meteorological agency and environmental protection unit costs a lot of labor and may result in mistakes or omissions due to negligence.

(3) Flag alarm alone cannot provide clear alarm information and has poor effects.

(4) Danger coefficients and AQIs are recorded manually once only when flags are planted or replaced (twice a day), and there is a lack of real-time records at all points in time (e.g., every minute), so it cannot provide the information for future tracking, audit or analysis.

This research developed a real-time flag control and alarm system that can monitor danger coefficients and AQI of barracks and automatically plant colored flags to improve the above problems. First, this system automatically measures the local PM 2.5 concentration, temperature, and humidity with a PM sensor, temperature sensor, and humidity sensor to obtain the local real-time monitoring values [12-13]. Next, it converts measured values into the grades of danger coefficients and the grades of AQI, then plants or replaces colored flags by automatic control. Moreover, this system displays measurement information, grades of danger coefficients and AQI, flags, and corresponding alarms with electronic billboards to provide a reference for people participating in outdoor activities. Finally, the system automatically stores information once every minute, including the measured temperature, humidity, and PM values, and the grades and flags of danger coefficients and AQI.

Since current research on environmental monitoring and warnings in schools or barracks focuses on sensors, monitoring characteristics, and impact on health [10-13], more research and system development on air quality flag control methods are needed. Therefore, this paper proposes a system architecture that integrates technologies such as real-time environmental monitoring, automatic flag control, and outdoor billboard display and develops an environmental monitoring and automatic flag alarming system to solve the current problems faced by manual inquiries and flagging in barracks.

2. System Design

This section first describes the grades and alarms of dangerous coefficient and AQI then defines the architecture of the environmental monitoring alarm and automatic flag control system for barracks developed in this study. Finally, the execution process of the automatic flag control system is described, and the interaction of correlative components is stated.

2.1. Grades and alarms of dangerous coefficient and AQI

The outdoor temperature and relative humidity measured by the meteorological agency can be used to calculate the dangerous coefficient, as shown in Table 1 [4]. In this table, four colored flags can express the grades of danger coefficients: green, blue, yellow, and red, representing safe, cautious, alert, and prohibited activity, respectively. Table 1 also shows the activity alarms for each grade of dangerous coefficient.

Table 1 Judgment on grades of danger coefficients and activity alarms

Danger coefficient (dc) = outdoor temperature (°C) + relative humidity × 0.1			
dc scope	Grade	Flag	Activity alarm
$dc < 30$	Safe	Green flag	A1. Normal daily routine.
$30 \leq dc < 35$	Cautious	Blue flag	A2. Normal daily routine, autonomous hydration.
$35 \leq dc < 40$	Alert	Yellow flag	A3. Avoid intense activities and remind hydration.
$dc \geq 40$	Prohibited	Red flag	A4. Avoid outdoor exercises, and hydration is compulsory.

The PM 2.5 concentration measured in the environmental protection unit can be used to calculate the AQI, as shown in Table 2 [5-6]. In this table, six colored flags can express the AQI grades: green, yellow, orange, red, purple, and maroon, representing good, normal, unhealthy for sensitive people, unhealthy for all people, very unhealthy, and harmful to people's health, respectively. Table 2 also shows the health alarms for each grade of AQI.

Table 2 Judgment on AQI grades and health alarms

AQI	0-50	51-100	101-150	151-200	201-300	301-400
PM 2.5 (μg/m^3)	0.0-15.4	15.5-35.4	35.5-54.4	54.5-150.4	150.5-250.4	250.5-350.4
Grade	A. Good	B. Normal	C. Unhealthy for sensitive group	D. Unhealthy for all people	E. Very unhealthy	F. Hazardous
Flag	Green flag	Yellow flag	Orange flag	Red Flag	Purple Flag	Maroon flag
Health alarm	A. Good air quality, low pollution, or no pollution.	B. Normal air quality, with slight effects on a few extremely sensitive people.	C. Air pollutants may affect the health of sensitive people but have insignificant effects on the public.	D. Air pollutants affect all people's health and may significantly affect the health of sensitive people.	E. Health alert: air pollutants may seriously affect the health of all people.	F. Urgent health threat and all people may be affected.

2.2. System architecture

The system architecture of the automatic flag control system is shown in Fig. 2, mainly including a temperature and humidity detection unit, PM detection unit, RS-485 to USB converter, data storage unit, electronic billboard display unit, danger coefficient flag control module, AQI flag control module, signal capture control unit, and a monitoring host machine. All components in this system will be described below:

(1) Temperature and humidity detection unit: detect outdoor temperature and humidity [14] and transmit the detected temperature and humidity signals to the monitoring host machine through the RS-485 interface [15] for calculation.

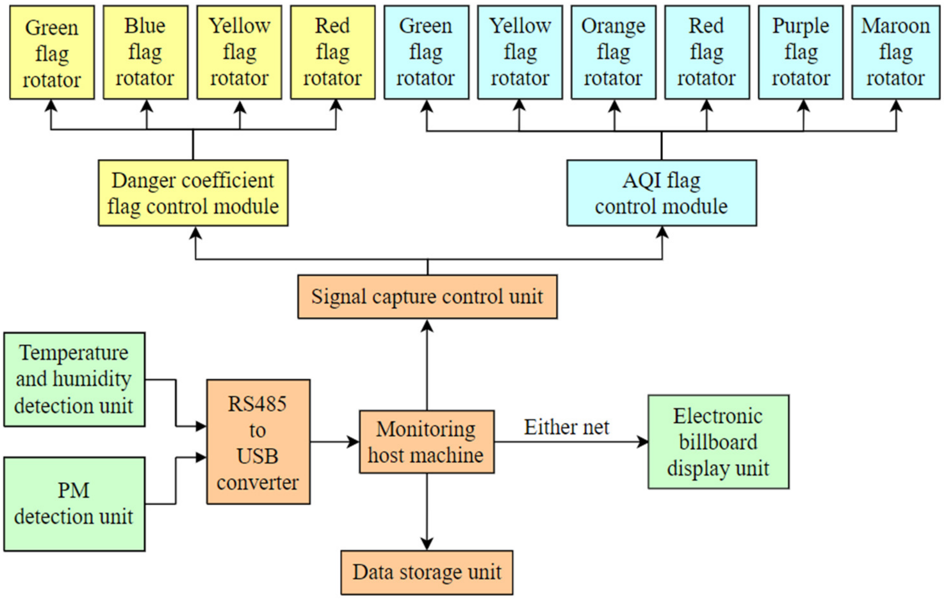


Fig. 2 System architecture

(2) PM detection unit: detect outdoor PM 2.5 and PM 10 [14] and transmit the detected PM signals to the monitoring host machine through the RS-485 interface for calculation.

(3) RS-485 to USB converter: convert signals between RS-485 and USB [16], and establish the interface between detection units (temperature, humidity, and PM) and the monitoring host machine for signal transmission.

(4) Data storage unit: regularly stores the information, such as temperature, humidity, grades of danger coefficients, PM 2.5, PM 10, AQI, and flags, calculated by the monitoring host machine, and provides data for retrieval.

(5) Electronic billboard display unit: display the real-time barrack information at that time and place, such as temperature, humidity, grades of danger coefficients, PM 2.5, and AQI, and show corresponding flags and alarms for people engaged in outdoor activities to view and get real-time information. This display unit is mainly connected to the monitoring host machine by Ethernet cables [17].

(6) Danger coefficient flag control module: this module contains four rotating mechanisms, namely, green, blue, yellow, and red flags. The green flag rotating mechanism is equipped with a green flag, the blue flag rotating mechanism with a blue flag, the yellow flag rotating mechanism with a yellow flag, and the red flag rotating mechanism with a red flag. The danger coefficient flag control module can control four rotating flag mechanisms. It can rotate and raise the correct one-colored flag according to the danger coefficient command transmitted by the monitoring host machine and rotate and lower the other three wrong-colored flags to show the flag corresponding to the correct danger coefficient.

(7) AQI flag control module: this module contains six rotating mechanisms, namely, green, yellow, orange, red, purple, and maroon flags. The green flag rotating mechanism is equipped with a green flag, the yellow flag rotating mechanism with a yellow flag, the orange flag rotating mechanism with an orange flag, the red flag rotating mechanism with a red flag, the purple flag rotating mechanism with a purple flag, and the maroon flag rotating mechanism with a maroon flag. The AQI flag control module can control six rotating flag mechanisms to rotate and raise the correct colored flags and to rotate and lower the other five wrong-colored flags to show the flag corresponding to the right air quality index.

(8) Signal capture control unit: an Advantech USB-4751 adapter card [18] used to transmit control commands of the monitoring host machine to the danger coefficient flag control module and AQI flag control module for flag control.

(9) Monitoring host machine: a personal computer that firstly drives the temperature and humidity detection unit and PM detection unit through the RS-485 interface and receives the data sent back by the temperature and humidity detection unit and a PM detection unit. Secondly, the host machine calculates these data to produce the grades of danger coefficients and

AQI, flags, and alarms. Thirdly, it transmits the measured data and calculated information to the data storage unit for storage and to the electronic billboard display unit for display. Finally, it transmits the control commands to the danger coefficient flag control module and AQI flag control module through the signal capture control unit for automatic flag planting or replacement control.

2.3. System execution process

Fig. 3 shows the system execution process. First, the temperature, humidity, and PM detection units can detect the barrack's temperature, humidity, PM 2.5, and PM 10 in real time (once per second). Then the measured temperature, humidity, and PM 2.5 are transmitted to the monitoring host machine for calculation, to generate danger coefficients and AQI, and to judge their grades, flags, and alarms.

Then, the monitoring host machine can transmit danger coefficient commands, and AQI commands to the danger coefficient flag control module and AQI flag control module in real time, respectively. The danger coefficient flag control module can rotate to raise a colored flag representing a danger coefficient grade (for example, the yellow flag representing “alert”). Likewise, the AQI flag control module can rotate to raise another colored flag representing an AQI grade (for example, the red flag representing “unhealthy for all people”). Therefore, people engaged in outdoor activities can learn the current grades of danger coefficients and AQI according to flags to judge whether outdoor activities are appropriate.

On the other hand, the monitoring host machine transmits danger coefficient information, including measured temperature, humidity, grades of danger coefficients, flags, and alarms, as well as AQI information, including PM, AQI grades, flags, and alarms to the electronic billboard display unit for regular display. It displays danger coefficients and AQI once per minute (30 seconds each) for people engaged in outdoor activities to watch in real-time.

Finally, the monitoring host machine can regularly store the monitored information, such as temperature, humidity, grades of danger coefficients, PM 2.5, PM 10, AQI, and flags, in the data storage unit (such as a data record per minute). That can provide users to retrieve these data at a specific time and place for future tracking, audit, and analysis.

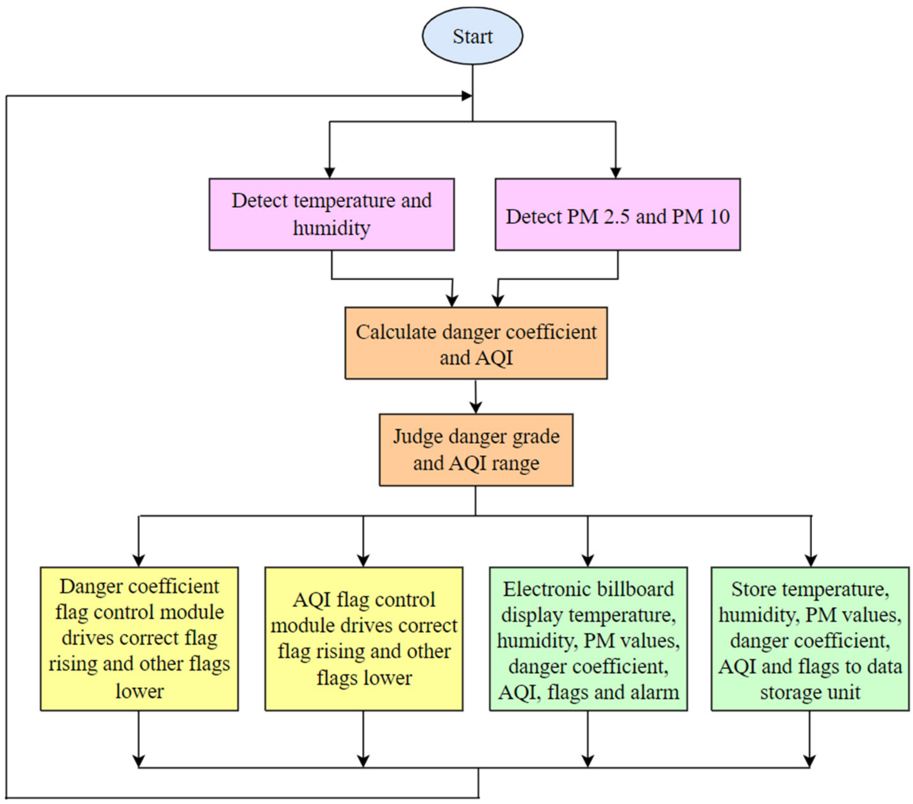


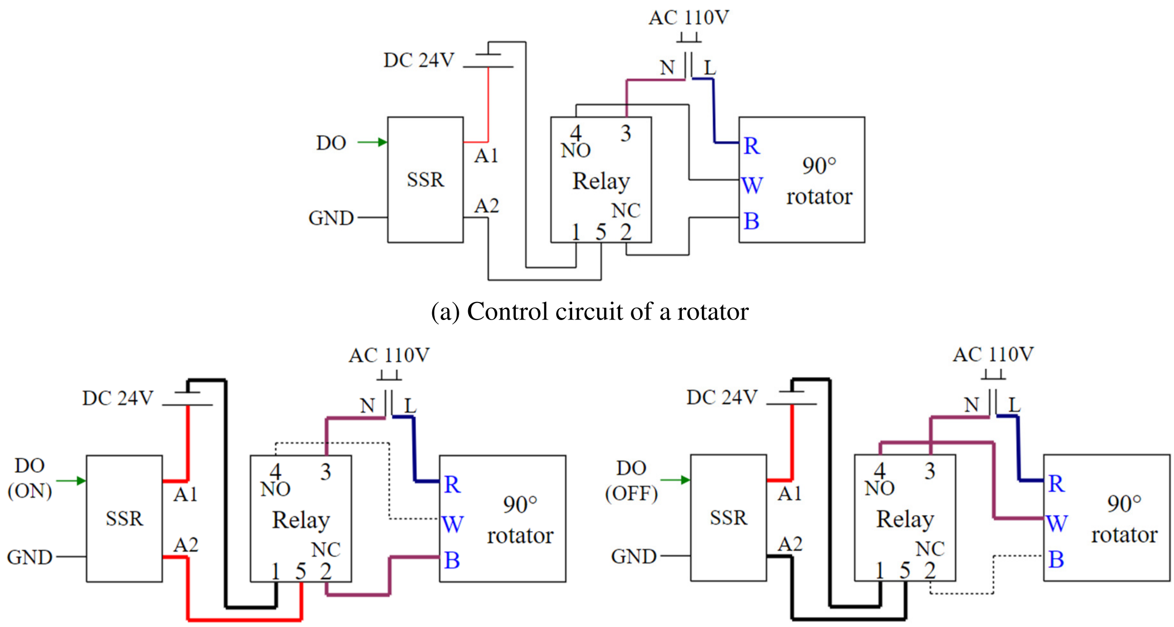
Fig. 3 System execution process

3. Design and Development of the Flag Control System

This section states the design principle of a flag control rotator first, then the complete circuit of the flag control system with four danger coefficient flag rotator*s* and six AQI flag rotator*s*. Finally, the implementation of a physical flag control system mode is described.

3.1. Design of flag control circuit

This flag control system can control the synchronous lifting or lower of four colored danger coefficient flags and six colored AQI flags. All colored flags can be raised and lowered by rotators which can rotate forward and backward for 90º. When a rotator rotates forward, the system can raise the colored flag to a vertical position at 90º; when a rotator rotates backward, it can lower the colored flag to a horizontal position at 90º. Fig. 4(a) shows the control circuit of such rotators. The solid-state relay (SSR) is an electronic switch that can be controlled by digital output (DO) signals to determine whether the two output ends; namely, A1 and A2, are turned on. The relay can be driven by DC 24V or 0V and determines that input signals of pin 3 are output through pin 2 or pin 4. The 90º rotator, driven by AC 110V, rotates forward to raise flags or backward to lower flags.



(a) Control circuit of a rotator

(b) Forward circuit of a rotator

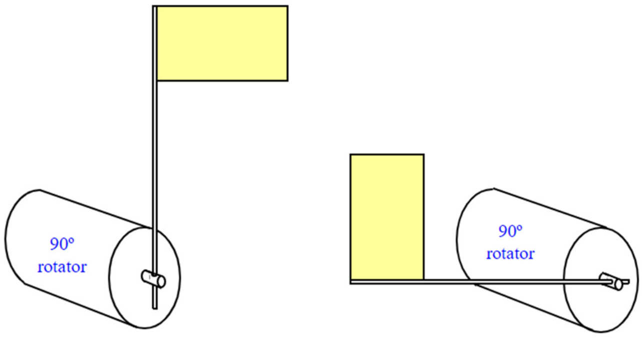
(c) Backward circuit of a rotator

Fig. 4 Forward and backward circuit of a rotator

When DO is under positive voltage (ON), SSR is started, and the voltage of A1 is transferred to A2, so that pin 5 of the relay inputs DC 24V, and AC 110V of pin 3 flows out from pin 2 and into pin B of the 90º rotator, as shown in Fig. 4(b). Hence, N-3-2-B-R-L forms an alternating current circuit so that the 90º rotator rotates forward for 90º, and the flag is rotated forward and raised to a vertical position. When DO is under zero voltage (OFF), SSR is not started, and zero voltage is transferred to A2 so that pin 5 of the relay inputs 0V, and AC 110V of pin 3 flows out from pin 4 and into pin W of the 90º rotator, as shown in Fig. 4(c). Hence, N-3-4-W-R-L forms an alternating current circuit so that the 90º rotator rotates backward for 90º, and the flag is rotated backward and lowered to a horizontal position. Fig. 5(a) shows the state of a colored flag raising and Fig. 5(b) shows the state of a colored flag lowering.

Based on the forward and backward circuits, as shown in Fig. 4, the complete flag control circuit is designed, as shown in Fig. 6. Circuit A on the left shows the control circuits of the danger coefficient flag rotators, which are used to control four 90º rotators (numbers 1 to 4). Circuit B on the right shows the control circuits of the AQI flag rotators, which are used to control six

90º rotators (numbers 5 to 10). 90º rotators 1, 2, 3, and 4 can lift or lower green, blue, yellow, and red danger coefficient flags, respectively, and 90º rotators 5, 6, 7, 8, 9, and 10 can lift or lower green, yellow, orange, red, purple, and maroon AQI flags. 90º rotators 1 to 10 are used with SSRs 1 to 10 and relays 1 to 10, respectively, to form ten 90º rotation mechanisms.



(a) Colored flag raising (b) Colored flag lowering

Fig. 5 Change of colored flag position

On the other hand, DO signals used to drive all SSRs are provided by an Advantech USB-4751 adapter card [18]. Therefore, the monitoring host can transmit the control commands to all SSRs through this adapter card. That is, pins PA00-PA03 of the adapter card provide the needed signals of DO0-DO3 in the control circuits of the rotators for danger coefficient flags, respectively. And PA04-PA07 and pins PB01-PB02 provide the needed signals of DO4-DO9 in the control circuits of the rotators in AQI flags, respectively.

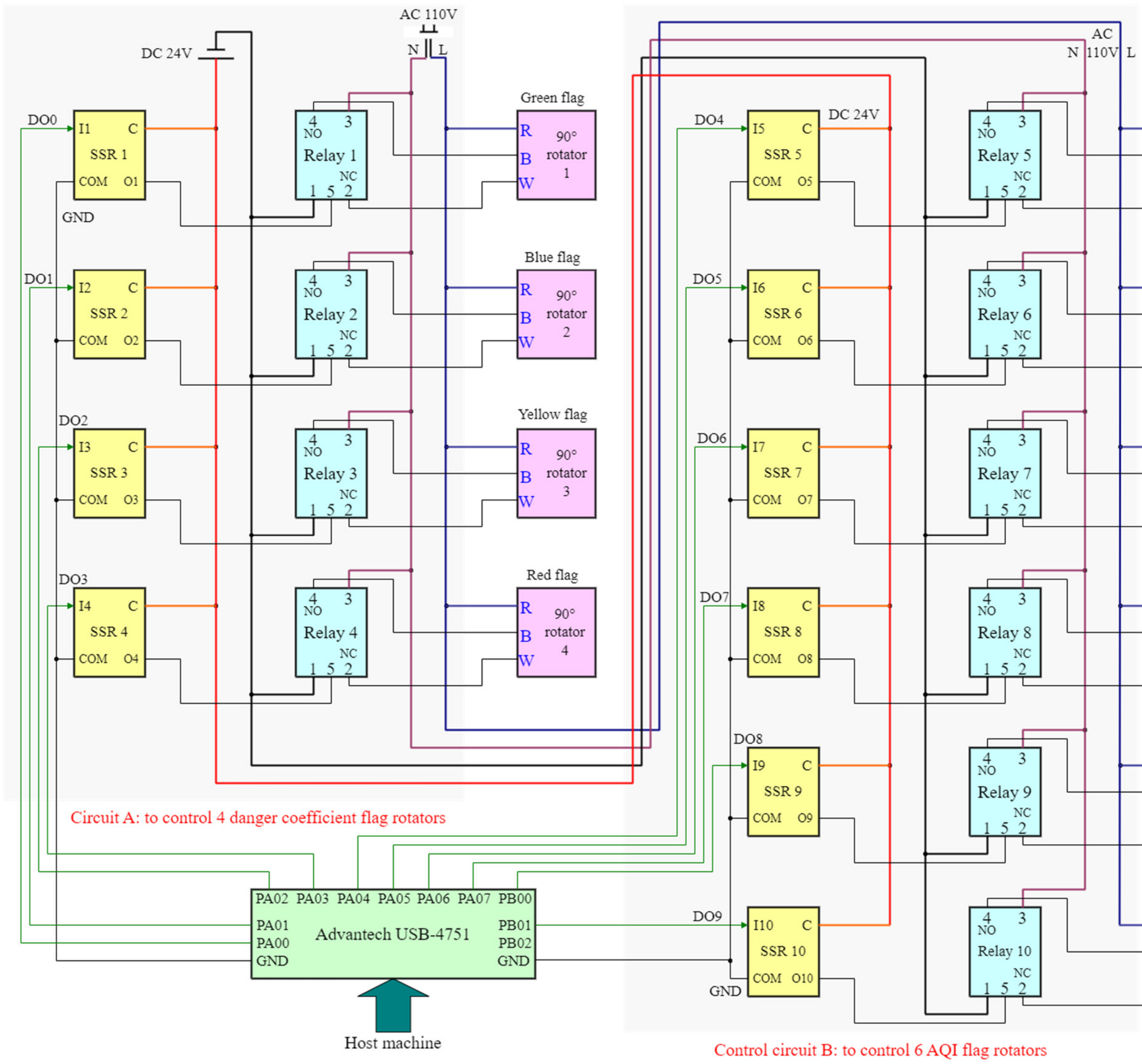


Fig. 6 A complete flag control circuit

3.2. Development of a physical flag control model

Fig. 7 shows the physical flag control model developed in this study. In this physical model, the four 90º rotators at the front can control the green, blue, yellow, and red danger coefficient flags. Only one colored flag is raised vertically at any time and lower the other three horizontally. As shown in Fig. 7, the system raises the red flag now and lowers the other three flags. The six 90º rotators in the back can control the green, yellow, orange, red, purple, and maroon AQI flags. Again, only one colored flag is raised vertically at any time and lower the other five flags horizontally. As shown in Fig. 7, the system raises the yellow flag and lowers the other five flags.

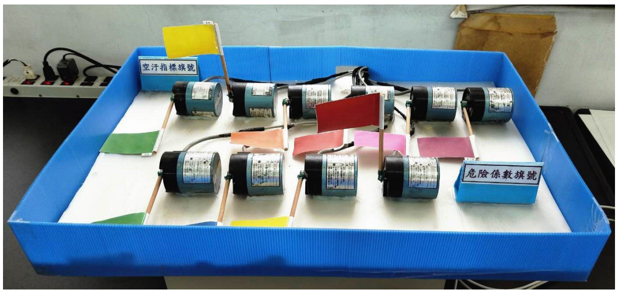


Fig. 7 Physical flag control system model

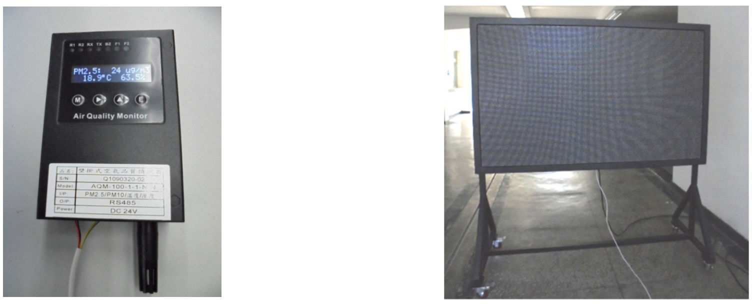
4. Design of the Monitoring Control and Alarm System

This section states the development of an integration detection unit which consists of a temperature sensor, a humidity sensor, and a PM 2.5 sensor first, then the integration of an *electronic billboard display unit*. Finally, the design and development of the monitoring software is described.

4.1. Development of the monitoring and display unit

An integrated detection unit, which can measure temperature, humidity, and PM 2.5 at the same time, as shown in Fig. 8(a) [13], was adopted in this system. In this integrated detection unit, the temperature sensor is a digital sensor with model SHT15 (measuring range: -30-100 ºC), the humidity sensor is also a digital sensor with model SHT15 (measuring range: 0-100 %RH), the PM sensor is a laser particulate matter sensor with model PM3003S (measuring range: 0-1000 *u*g/m^3). The calibration procedure has been performed for each sensor every year. As a result, the temperature sensor was calibrated with an accuracy of ±0.1 ºC, the humidity sensor with an accuracy of ±1 %RH, and the PM 2.5 sensor with an accuracy of ±10 %.

The monitoring host machine can capture measured temperature, humidity, PM 2.5, and PM 10 from sensors through the RS-485 transmission interface for further processing. To meet the outdoor display requirements, the electronic billboard display unit used in this study is a P10 full-color (PH10mm 1R1G1B) high-brightness outdoor display with a resolution of 160 dots × 96 dots and a screen size of 160 cm × 96 cm. This electronic billboard must be supplied with AC 110V power and connected to the monitoring host machine via the Ethernet network. Fig. 8(b) shows the physical entity of the electronic billboard.



(a) Integrated temperature, humidity, and PM sensor

(b) Physical P10 full-color high-brightness electronic billboard

Fig. 8 The monitoring and display unit

4.2. Monitoring software design

In this study, the Visual Basic language [19] was used as the tool to develop the system monitoring software. Fig. 9 shows the structure of the developed monitoring software. As shown in Fig. 9, there are three main function modules: system parameter setting, connecting acquisition test, and automatic monitoring control. The system parameter setting module allows users to set system parameters. The connecting acquisition test module calls the sensing value capture module to test the RS-485 connection and sensor capture.

Finally, users can perform the automatic monitoring control module when the connecting acquisition test is valid. This module will first call the sensing value capture module to capture the measured temperature, humidity, and PM 2.5 concentration. After processing, it will produce the grades of danger coefficients and AQI, flags, and alarms. Then, it calls the flag control module for automatic control of danger coefficient flags and AQI flags and calls the billboard display module to display measurements and information. Finally, it calls the data storage module to store measurements and information.

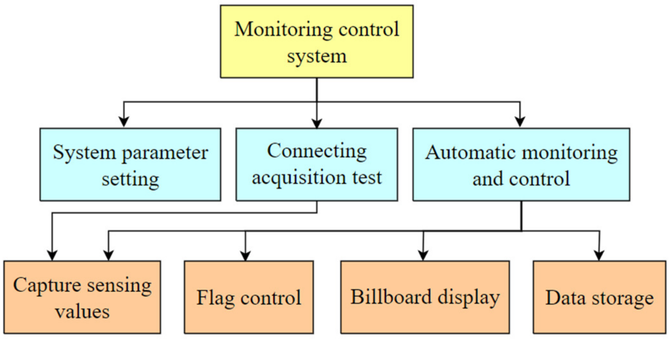
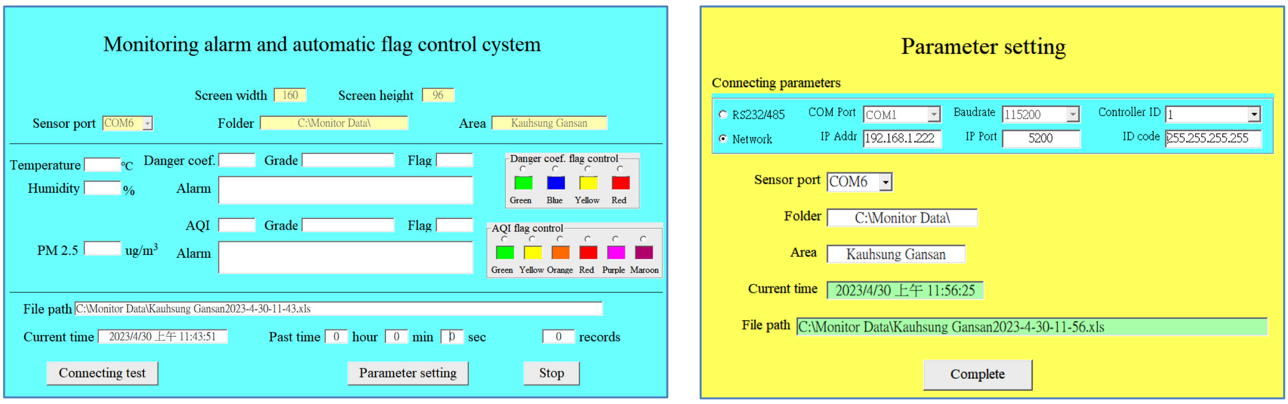


Fig. 9 Monitoring software structure

After starting the system monitoring software developed through Visual Basic, Fig. 10(a) shows the startup screen. The top of the screen displays the monitoring parameters, such as the display size of an electronic billboard, sensor port, and archive information of the monitoring area. In the middle of the screen, the monitoring alarm and automatic flag control system displays the measured temperature, humidity, and PM 2.5, and the calculated information based on the measured data, such as the grades of danger coefficients and AQI, flags, and alarm, is displayed in the middle. The parameter setting displays the control of danger coefficient flags and AQI flags. The bottom of the screen displays the filing path, the current date and time, the duration, and the number of stored data. The bottom row provides command buttons for administrators and users.



(a)Startup screen after starting the monitoring software (b) Screen of system parameter setting

Fig. 10 Screen design of monitoring software

The system administrator may set the system parameters at the beginning. The administrator can click the "Parameter setting" button at the bottom of the startup screen in Fig. 10(a), and the system will enter the "Parameter setting" screen (as shown in Fig. 10(b)). Next, the administrator can set the parameters of the electronic billboard connection, sensor port, archive folder, and monitoring area on this screen. The system can automatically generate the filing path for output data according to the archive folder, monitoring area, and the date and time separately added. Finally, the administrator shall click the "Complete" button to finish the parameter setting and return to the startup screen shown in Fig. 10(a).

5. Automatic Monitoring Control

Users can first click the "Connecting test" button at the bottom of the startup screen when using the system. Next, the system will carry out a sensor acquisition test. The sensors of this system adopt RS-485 transmission interfaces. In such transmission interfaces, the monitoring host machine first issues a read command to sensors and then reads sensor data to acquire measured data. After the valid connecting acquisition test, users can click the "Start monitoring" button to start the real-time monitoring control and alarm process. Fig. 11 shows the execution screen.

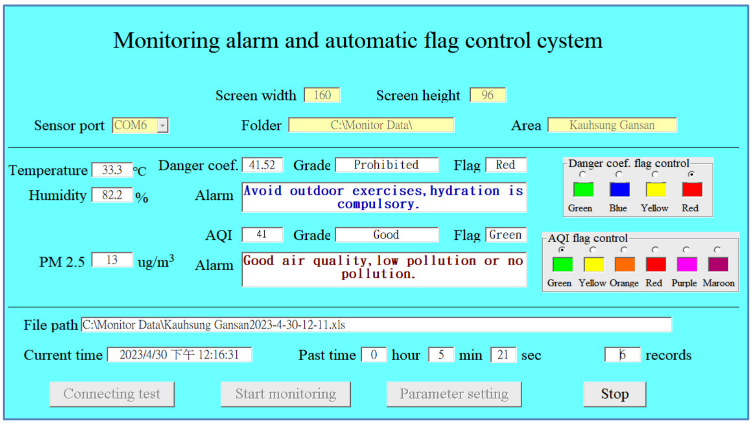


Fig. 11 Execution screen of starting of the monitoring control and alarm

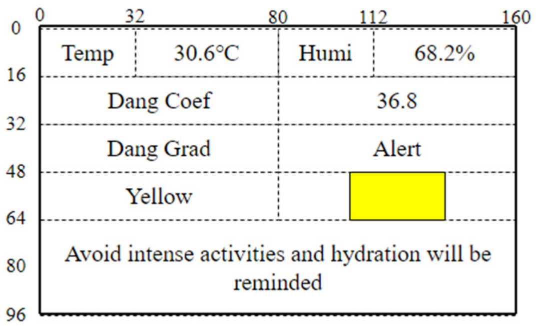
The system starts to capture temperature, humidity, and PM 2.5 once a second. Due to the processing of temperature and humidity, the system can generate the parameters such as danger coefficient (dc), grade (g_{dc}), flag (f_{dc}), and alarm ($alarm_{dc}$) automatically. Likewise, due to the processing of PM 2.5, the parameters such as AQI (aqi), grade (g_{aqi}), flag (f_{aqi}), and alarm ($alarm_{aqi}$) are generated automatically. Table 3 expresses the methods to calculate all parameters.

Table 3 Parameters calculating algorithm

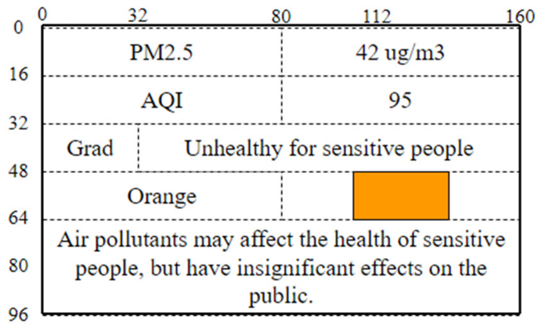
$dc = d_{temp} + d_{\mathrm{humi}} \times 0.1$	else if $15.5 \le pm25 < 35.5$ then
if $dc < 30$ then	$aqi = 51 + [(pm25 - 15.5) / 20] \times 50$
g_{dc} = safe	g_{aqi}= $\mathrm{grade_B}$
f_{dc} = Green	f_{aqi} = Yellow
$alarm_{dc}$ = $\mathrm{statement_{A1}}$	$alarm_{aqi}$ = $\mathrm{statement_B}$
else if $30 \le dc < 35$ then	else if $35.5 \le pm25 < 54.5$ then
g_{dc} = cautious	$aqi = 101 + [(pm25 - 35.5) / 19] \times 50$
f_{dc} = Blue	g_{aqi}= $\mathrm{grade_C}$
$alarm_{dc}$ = $\mathrm{statement_{A2}}$	f_{aqi} = Orange
else if $35 \le dc < 40$ then	$alarm_{aqi}$ = $\mathrm{statement_C}$
g_{dc} = alert	else if $54.5 \le pm25 < 150.5$ then
f_{dc} = Yellow	$aqi = 151 + [(pm25 - 54.5) / 96] \times 50$
$alarm_{dc}$ = $\mathrm{statement_{A3}}$	g_{aqi}= $\mathrm{grade_D}$
else if $dc \ge 40$ then	f_{aqi} = Red
g_{dc} = prohibited	$alarm_{aqi}$ = $\mathrm{statement_D}$
f_{dc} = Red	else if $150.5 \le pm25 < 250.5$ then
$alarm_{dc}$ = $\mathrm{statement_{A4}}$	$aqi = 201 + [(pm25 - 150.5) / 100] \times 100$
end	g_{aqi}= $\mathrm{grade_E}$
if $pm25 < 15.5$ then	f_{aqi} = Purple
$aqi = [(pm25 - 0) / 15.5] \times 50$	$alarm_{aqi}$ = $\mathrm{statement_E}$
g_{aqi}= $\mathrm{grade_A}$	else if $pm25 \ge 250.5$ then
f_{aqi} = Green	$aqi = 301 + [(pm25 - 250.5) / 100] \times 100$
$alarm_{aqi}$ = $\mathrm{statement_A}$	g_{aqi}= $\mathrm{grade_F}$
	f_{aqi} = Maroon
	$alarm_{aqi}$ = $\mathrm{statement_F}$
	end

The system will display all captured and generated information on the screen in real-time and automatically control the danger coefficient flags and AQI flags. For example, as shown in the middle of Fig. 11, the measured temperature is 33.3 ℃, and the humidity is 82.2%. As the calculated danger coefficient is 41.52 and classifies the corresponding grade as "prohibited," the corresponding flag color is red with the warning "*Avoid outdoor exercises under the sun. Hydration is compulsory*." Moreover, now, the measured PM 2.5 is 13 ug/m3. The calculated AQI is 41, classified as "good" and represented by a green flag. It generates the alarm of "*Good air quality, low pollution, or no pollution*." As shown in Fig. 11, the flag control area on the right side in the middle of the screen shows that the danger coefficient flag is now red (only the red flag is marked ʘ). The AQI flag is green (only the green flag is marked ʘ).

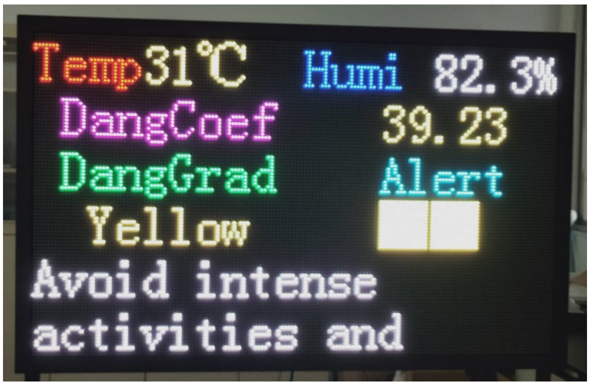
On the other hand, the system displays the monitored results in sequence on the P10 electronic billboard in a circular manner once a minute. The system monitoring software mainly transmits monitored and alarmed contents to the P10 electronic billboard through the C-Power 5200 API communication interface [17, 20] for display. Fig. 12(a) shows the design of the danger coefficient display page for the P10 electronic billboard, and Fig. 12(b) shows the design of the AQI display page. As shown in Fig. 12(c), the P10 electronic billboard displays danger coefficient information and AQI information circularly once a minute (now shows the page of danger coefficients).



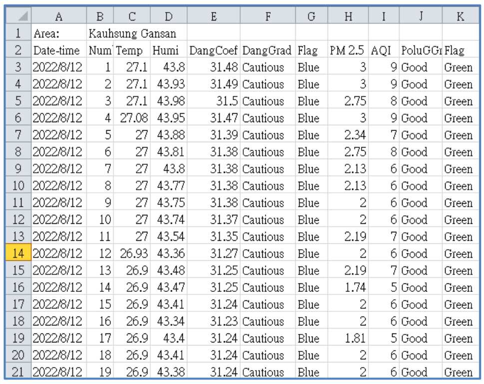
(a) Design of danger coefficient information display page



(b) Design of AQI information display page



(c) P10 electronic billboard



	A	B	C	D	E	F	G	H	I	J	K
1	Area:	Kauhsung Gansan									
2	Date-time	Num	Temp	Humi	DangCoef	DangGrad	Flag	PM 2.5	AQI	PoluGGr	Flag
3	2022/8/12	1	27.1	43.8	31.48	Cautious	Blue	3	9	Good	Green
4	2022/8/12	2	27.1	43.93	31.49	Cautious	Blue	3	9	Good	Green
5	2022/8/12	3	27.1	43.98	31.5	Cautious	Blue	2.75	8	Good	Green
6	2022/8/12	4	27.08	43.95	31.47	Cautious	Blue	3	9	Good	Green
7	2022/8/12	5	27	43.88	31.39	Cautious	Blue	2.34	7	Good	Green
8	2022/8/12	6	27	43.81	31.38	Cautious	Blue	2.75	8	Good	Green
9	2022/8/12	7	27	43.8	31.38	Cautious	Blue	2.13	6	Good	Green
10	2022/8/12	8	27	43.77	31.38	Cautious	Blue	2.13	6	Good	Green
11	2022/8/12	9	27	43.75	31.38	Cautious	Blue	2	6	Good	Green
12	2022/8/12	10	27	43.74	31.37	Cautious	Blue	2	6	Good	Green
13	2022/8/12	11	27	43.54	31.35	Cautious	Blue	2.19	7	Good	Green
14	2022/8/12	12	26.93	43.36	31.27	Cautious	Blue	2	6	Good	Green
15	2022/8/12	13	26.9	43.48	31.25	Cautious	Blue	2.19	7	Good	Green
16	2022/8/12	14	26.9	43.47	31.25	Cautious	Blue	1.74	5	Good	Green
17	2022/8/12	15	26.9	43.41	31.24	Cautious	Blue	2	6	Good	Green
18	2022/8/12	16	26.9	43.34	31.23	Cautious	Blue	2	6	Good	Green
19	2022/8/12	17	26.9	43.4	31.24	Cautious	Blue	1.81	5	Good	Green
20	2022/8/12	18	26.9	43.41	31.24	Cautious	Blue	2	6	Good	Green
21	2022/8/12	19	26.9	43.38	31.24	Cautious	Blue	2	6	Good	Green

(d) Output files stored in the format of EXCEL

Fig. 12 Electronic billboard design and data records stored

After users enable the automatic monitoring, the system will automatically constitute "filing paths" with "archive folders," "monitoring areas," and "current time." As filing paths for real-time information monitoring and processing, the system stores a record every minute. The contents stored are the average values of 60 data captured per minute and the processing results.

$$avg_{temp} = \frac{\sum_{i=1}^{n} d_{tempi}}{n} \tag{1}$$

$$avg_{humi} = \frac{\sum_{i=1}^{n} d_{humi}}{n} \tag{2}$$

$$avg_{pm25} = \frac{\sum_{i=1}^{n} d_{pm25i}}{n} \quad (3)$$

$$avg_{pm10} = \frac{\sum_{i=1}^{n} d_{pm10i}}{n} \quad (4)$$

$$dc = avg_{temp} + avg_{humi} \times 0.1 \quad (5)$$

Eq. (1) to Eq. (3) express the calculation of average values of temperature, humidity, PM 2.5, and PM10, where $n = 60$, Eq. (4) expresses the calculation of danger coefficient *dc* and the *dc* is put into Table 3 to calculate the new danger coefficient g_{dc}, flag f_{dc}, and alarm $alarm_{dc}$. The parameter avg_{pm25} calculated by Eq. (3) is used to replace the parameter *pm25* in Table 3 to generate new parameters AQI grade g_{aqi}, flag f_{aqi}, and alarm $alarm_{aqi}$. In addition, this system automatically sets the files in EXCEL format, so the EXCEL software can open and process various data. Fig. 12(d) shows the contents and formats of archives stored in this system.

6. Conclusions

This paper has developed a flag control and alarm system to monitor danger coefficients and AQI for barracks in real time and automatically plant or replace flags. Firstly, the system can automatically measure PM 2.5 concentrations with PM sensors and measure the temperature and humidity with temperature and humidity sensors to obtain the local real-time monitoring values. Secondly, this system automatically converts measured values into danger coefficients and AQI grades to plant or replace flags by automatic control. Thirdly, this system displays measurement information, grades of danger coefficients and AQI, flags, and the corresponding alarms with electronic billboards to provide a reference for people participating in outdoor activities. Finally, the system automatically stores information once a minute, such as the measured values of temperature, humidity, and PM, and the grades and flags of danger coefficients and AQI, to provide a reference for future tracking, audit, or analysis.

Conflicts of Interest

The authors declare no conflict of interest.

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