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Distributed subway station safety detection system based on Raspberry Pi

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***Abstract*—To ensure the safety of subway and maintain a good operating environment is the primary task of station operating units. Therefore, the environmental and passenger detection of the key locations in the subway station is necessary, to obtain real-time information such as the air quality status in the station and the density of passenger at the station hall layer and the platform layer. Station operation management department can adjust the station operation and emergency plan in real time according to the various data and information inside the station to improve the security of passengers and property in the station. The traditional detection system performs data processing on the server and has too high requirements for the server. The raspberry Pi as an embedded device have abilities of environment detection, data processing and information transmission on the local area. Multiple Raspberry Pi can be distributed at the key locations in the subway station, sending processed detection data to the server through wireless ways, which can greatly reduce the requirements of the server performance of the station monitoring system. In order to realize air quality detection and passenger detection in station, this paper designs a distributed detection system based on Raspberry Pi 4 platform. Real-time detection and upload of air quality parameters such as temperature, humidity, CO and smoke in station and passenger detection parameters such as passenger number and passenger flow density. The system has the characteristics of low cost, high accuracy and strong real-time.**

Keywords*—Raspberry Pi, environmental detection, passenger detection, distributions

I. INTRODUCTION

In recent years, my country's station transportation has developed rapidly, and station travel has become the first choice for most people. In the subway stations and carriages, there are high closedness, insufficient ventilation, large personnel density, and complicated personnel. Therefore, real-time environmental detection and passenger detection of some key locations in the station are particularly important. At present, there are the following disadvantages of real-time detection methods commonly used in station: 1) Wired transmission method is difficult to change the arrangement according to the changes in environmental conditions, and has certain limitations and blind spots. 2) The data of all sensors and the camera must be sent to the server for data processing. The performance of the server is too high, resulting in a state of "head heavy".

In 2020, the Kai Zhou's research team carried out the design of intelligent ammunition magazine management system based on the Raspberry Pi, which can achieve the collection of environmental information and the monitoring of video images[1]. In 2020, Yi Zhang's research team used environmental pollutant sensors to detect pollutants and made a comparative analysis of development strategies of pollutant sensors[2]. In 2021, Liyao Jiang's research team adopted the STM32F103ZET6 Single chip microcomputer for the design of the subway station environmental detection system. It could use the control screen to display data in real-time and upload it to the cloud server, and then display it in real-time through the cloud server[3]. In 2022, Yonglai Zhang's research team used the vertical acceleration of subway tunnel to detect method of tunnel damage, which can accurately identify the location, type and degree of damage[4-5]. The studies indicate that the station environment is complicated, and STM32F103ZET6 Single chip microcomputer can be displayed on the station environment, but its structure is more complicated and the cost is high. The cost of raspberries is low, and sensors and cameras can be used to collect and process environmental information and image information.

Therefore, a distributed station safety detection system based on Raspberry Pi is proposed to solve the above problems. The system connects the camera and multiple environmental detection sensors to the Raspberry Pi to form a small detection module. Each detection module can be detected in real-time and directly processes the data. The detection results are directly

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uploaded to the server through wireless modules. The station server does not need to perform data processing steps. It can only obtain the processed data information of each module through LAN for analysis, so as to formulate and implement effective operation and scheduling plan according to the changes on site, maintain good station operation environment, and ensure the safety of passengers' life and property.

II. Subway Station Safty Detection System Structure

In the station environment, if the content of CO and smoke exceeds the standard, it will cause people to have symptoms such as shortness of breath, dizziness, headache, and the appropriate temperature and humidity can keep the station environment in a more comfortable environment. Real-time detection of passenger numbers and passenger flow density can better allow the station to play their transportation capabilities, facilitate station operation management department to organize dredging work, and solve the problem of station congestion in a timely manner. Therefore, a detection system using a distributed structure is designed, and the detection data are uploaded to the server for display in real time. The structure is shown in Figure 1. The entire system is divided into three parts: environmental quality detection module, passenger detection module and server terminal display. The environmental quality detection module is composed of a variety of sensors deployed on the Raspberry Pi platform. The sensor module collects data such as temperature, humidity, CO, and smoke in the air according to a fixed period, and calls the communication module to upload the detection data to the server through the LAN for storage and analysis. The passenger detection module collects images by the camera installed on the Raspberry Pi platform, and then uses simplified passenger detection algorithms to process the image. It obtains real-time passenger numbers, passenger flow density and other data, and calls the communication module to upload the detection data to the server through the LAN for storage and analysis. Small detection modules are distributed to the key locations of the station and the carriage, and the wireless connection of Internet of Things can realize flexible arrangement of detection terminal without complex wiring. The station server can obtain data information that each module has processed through the LAN, analyze the information, and formulate effective operation and scheduling plan.

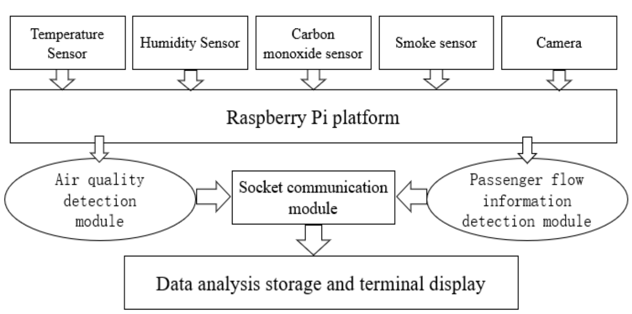

Fig. 1. Distributed subway safety detection system structure based on Raspberry Pi

III. Air Quality Detection Module

A. Sensor Selection

The sensor selection of this system is DTH11 temperature and humidity sensor, MQ-2 smoke sensor, and MQ-7 carbon monoxide sensor[6].

DTH11 temperature and humidity sensor is a temperature and humidity composite sensor that contains calibrated digital signals output, and each DHT11 sensor is calibrated in the extremely accurate temperature and humidity calibration laboratory. The calibration coefficient is stored in the OTP memory in the form of a program. The sensor internal must call these calibration coefficients during the processing of the detection signal. The sensor includes a resistor moisture sensing element and a NTC temperature measuring element, which is connected with a high-performance 8-bit Single chip microcomputer. Single-line serial interfaces make the system integration simple and fast. The super small volume and extremely low power consumption, the signal transmission distance can reach more than 20 meters. The circuit schematic diagram is shown in Figure 2.

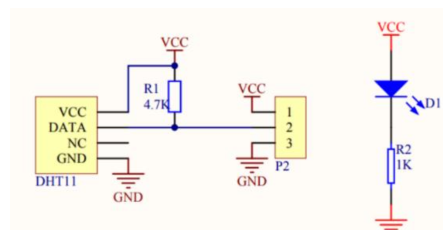

Fig. 2. DTH11 module schematic diagram.

The gas-sensitive material used by the MQ-2 smoke sensor is a tin dioxide (SnO_2) with a lower conductivity in the clean air. When the sensor is in the environment of combustible gas exists, the conductivity of the sensor increases with the increase with concentration of combustible gas in the air. It uses a simple circuit to convert the change of the conductivity to the output signal corresponding to the concentration of the gas. The circuit schematic diagram is shown in Figure 3.

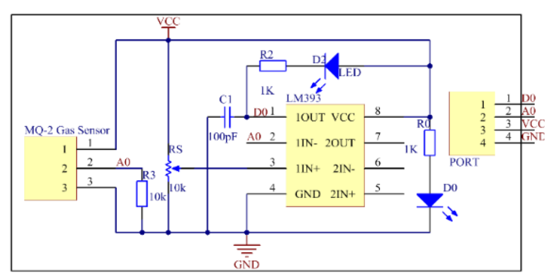

Fig. 3. MQ-2 smoke sensor schematic diagram.

The gas-sensitive material used by the MQ-7 gas sensor is a tin dioxide (SNO_2) with a lower conductivity in the clean air. It uses high and low temperature circulation detection method-low temperature (1.5V heating) to detect carbon monoxide, and high temperature (5.0V heating) to clean the stray gases adsorbed at low temperature. The conductivity of the sensor increases with the increase with concentration of carbon monoxide gas in the air. It uses a simple circuit to convert the change of the conductivity to the output signal corresponding to the concentration of the gas. The circuit schematic diagram is shown in Figure 4.

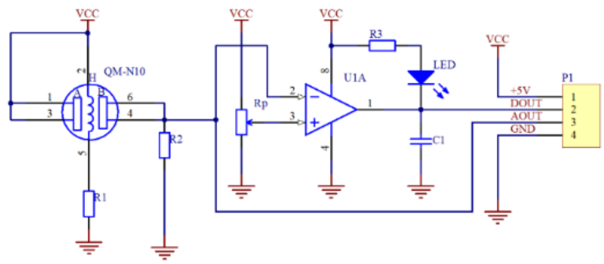

Fig. 4. MQ-7 carbon monoxide sensor schematic diagram.

B. Connection of Sensor

The DTH11 temperature and humidity sensor uses a Single -line serial interface, which it only needs one DATA output line to communicate with the mainframe. DTH11's DATA cable connects the GPIO4 pin of the Raspberry Pi, about 4ms a communication time. After sending a start signal once, DHT11 is converted from a low power consumption mode to a high-speed mode. After the host start signal ends, DHT11 sends a response signal, sends 40bit of data, and triggers a signal collection. Users can select to read the data, and then switch to the low-speed mode after the data collection. If the DHT11 does not receive the start signal from the host, it does not proactively collect temperature and humidity. 40bit data are: 8bit humidity integer data, 8bit humidity decimal data, 8bit temperature integer data, 8bit temperature decimal data and 8bit check data.

There are two output modes for the MQ-2 smoke sensor: ① Digital output: Set the concentration threshold through the onboard potentiometer. When the concentration of the ambient gas exceeds the threshold, the low level of digital pin DOUT is detected. ② Simulation output: The higher the gas concentration, the higher the voltage output by the AOUT pin and the higher the analog value collected by the ADC. Here we choose a simpler digital pins output, connect the GPIO17 pin of the Raspberry Pi, and set the concentration alarm threshold by the potentiometer [7].

The output method of the MQ-7 carbon monoxide sensor is the same as that of the MQ-2 smoke sensor. Here we also choose the digital pins output and connect the GPIO27 pin of the Raspberry Pi.

The wiring diagram of the three sensors and the Raspberry Pi is shown in Figure 5.

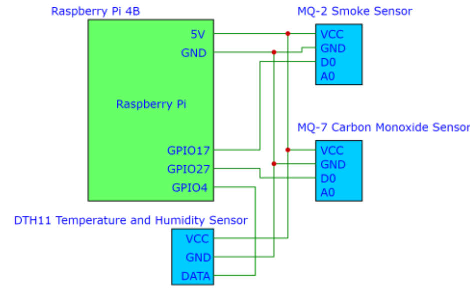

Fig. 5. Raspberry Pi wiring diagram.

C. Software Design

After Raspberry Pi is started, Socket communication is initialized and messages are printed to the console. After the socket connection is okay, the sensor data are collected. The communication between the DTH11 temperature and humidity sensor and the Raspberry Pi uses the monobus method. After the collection is successful, 40 bits of data are sent. 40bit data are: 8bit humidity integer data, 8bit humidity decimal data, 8bit temperature integer data, 8bit temperature decimal data and 8bit check. After receiving the Raspberry Pi successfully, the data splicing can complete a temperature and humidity collection. MQ-2 smoke sensors and MQ-7 carbon monoxide sensors use digital pins to connect the Raspberry Pi. The smoke and carbon monoxide alarm threshold can be adjusted through the onboard potentiometer. When the detection data exceed the preset threshold, a signal is sent to the sensor.

IV. Passenger Flow Information Detection Module

A. Features of YOLOV5

YOLOV5 is a One-Stage algorithm of the network models. In this kind of algorithm, different sizes are used for traversal sampling of images. Then, it uses CNN to extract features and perform direct regression, so that its recognition speed is fast and real-time. And YOLOV5 also has the advantages of easy-to-read code, convenient format conversion and high operation efficiency. In this paper, the characteristics of this detection method are used to improve the efficiency of the statistics of the number of pedestrians in the subway station, and carry out the real-time passenger detection in the station environment.

B. Performance Analysis of Pre-training Models

This article is based on the passenger detection of the Raspberry Pi. Large detection models cannot be used. Therefore, a variety of lightweight Models are used-including YOLOV5s, YOLOV5n, YOLOV5m and YOLOV5s6. Through the comparison of the following three performance indicators, the most suitable pre-training model for this project is selected. Among them, time performance index refers to the detection time of the unprocessed picture through the Raspberry Pi program preprocessing and data enhancement to identification and positioning, and the shorter the time, the faster the detection speed, thus the better the detection performance; Recall performance index refers to the comparison between the detection result and the actual result after the detection model program processing, and the greater the accuracy of the detection results, thus the better the detection performance; Params performance index refers to the total number of parameters that need to be trained in the network detection model. The performance index comparison of specific Model detection data are displayed is shown in table 1[8-10].

TABLE I. MODEL PERFORMANCE INDEX COMPARISON

Model	Model Performance Index Comparison		
	Time	***Recall***	***Params***
YOLOV5n	1.12	61.1%	1.9
YOLOV5S	1.87	77.8%	7.2
YOLOV5m	3.66	72.2%	21.2

It was found by comparing the Time, Recall and Params data of several Model models. The detection time of the YOLV5n pre-training model is the shortest, the detection accuracy is the lowest, and the total number of training parameters needs to be the least; YOLOV5m pre-training model requires the most total training parameters and has the longest detection time. YOLOV5n pre-training model detection time is only 0.75s less than the YOLOV5s model, but its accuracy is reduced by 16.7% compared to the YOLOV5s model, and the total number of training parameters decreased by 5.3. YOLOV5m pre-training model not only the detection time was 1.79s longer than that of YOLOV5s model, but also its accuracy is reduced by 5.6%, but the total number of training parameters increased by 14 more than YOLOV5s models. Therefore, the comprehensive consideration of the station detection environment has selected YOLOV5s pre-training model that is most suitable for the number of subway stations.

C. Parameter Adjustment of the Pre-training Model

From many pre-training models, the YOLOV5s model is most suitable for this project. In the YOLOV5s algorithm, conf-thres is a confident threshold (detection accuracy), and iou-thres is the IOU threshold of NMS. After comparison of different parameters, the most accuracy and the most consistent conf-thres and iou-thres are selected.

Conf-thres: It is the confidence threshold (detection accuracy). When the threshold is greater than this threshold, the passenger can be detected. Conversely, it cannot be recognized.

Iou-thres: It is the ratio threshold of intersection and union-(the prediction box ∩ the real box size) / (prediction box size ∪ real box size) (the value of the intersection and union of the prediction box and the real box). If iou-thres is larger, it is easy to regard different prediction results for the same item as multiple prediction results for multiple items, resulting in multiple prediction results for one item. On the contrary, if iou-Thres is smaller, it is easy to regard different prediction results for multiple items as different prediction results for the same item, resulting in only one prediction result for multiple items.

Table 2 shows the adjustment results of conf-thres and iou-thres parameters. By comparing the adjustment results of conf-thres and iou-thres parameters (the result is the number of detection):

When conf-thres is 0.20 and iou-thres is 0.35, the detection accuracy of platform is the highest and the number of people detected is 15, which is the most consistent with the fact. When conf-thres is 0.30 and iou-thres is 0.35, the detection accuracy of security checkpoint is the highest and the number of people detected is 8, which is the most consistent with the fact. When conf-thres is 0.25 and iou-thres is 0.35, the detection accuracy of outbound gate machine is the highest and the number of people detected is 13, which is the most consistent with the fact. When conf-thres is 0.35 and iou-thres is 0.35, the detection accuracy of entrance and exit of station is the highest and the number of people detected is 9, which is the most consistent with the fact.

TABLE II. CONF-THRES AND IOU-THRES PARAMETERS ADJUSTMENT RESULTS

IOU. / **Conf.**	Conf-thres And Iou-thres Parameters Adjustment Results						
	0.15	0.25	0.35	0.45	0.55	0.65	0.75
0.20	11	13	15	17	17	20	28
0.25	11	12	14	14	16	18	23
0.30	10	11	12	12	12	13	16
0.35	10	11	12	12	12	12	12
0.40	10	11	12	12	12	12	12
0.45	9	10	11	11	11	11	11
0.50	6	6	6	6	6	6	6
0.55	6	6	6	6	6	6	6

In the best parameters, the detection results with the highest accuracy of different environments are shown in Figure 6.

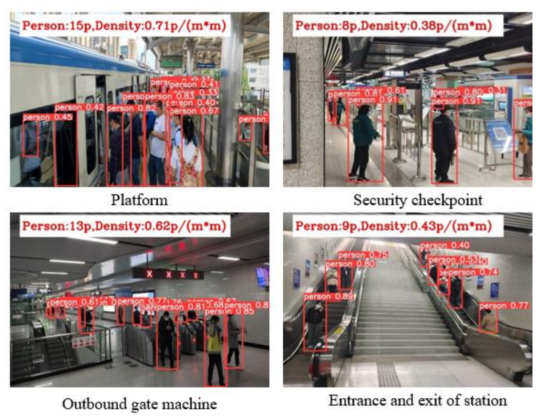

Fig. 6. Detection results diagram.

V. COMMUNICATION MODULE

Through the LAN, the system uses python's own socket module to transfer the detected data images to the PC server. Here, the air quality detection module is used as an example to explain the software work process of the detection system. First, query the IP address of the PC terminal, set the IP address of the PC side to the input port, and open the PC terminal MySQL database to connect it with the database and turn on the database. After the Raspberry Pi is started, the sensor and socket are initialized, and the output channel is connected to the PC. At the same time, the PC create the receive channel and connect through the same IP address. If the sensor data are not successfully read, it is re-collected; if it is successful, Raspberry Pi sends the data to the PC server, and the next data read is delayed for 10 seconds after the data are sent. Finally, the data sent by the Raspberry Pi uses the MySQL inserting statement “insert into” into the database, and then completes the communication of the data[11].

VI. Data Analysis Storage and Terminal Display Module

The detection system collects data and obtains pictures by the Raspberry Pi, and then uploads the data detected by the sensor and the passenger captured by the camera to the server by LAN. First use the PyCharm to create a Django project, set the setting.py file to connect it with the MySQL database, and then use the model module to create a database table. Second, create an app, add an app routing to the main route, put the web page in the Templates file, and add web route and view route to the APP route. Finally, add a view function, obtain data and pictures in the database, and add timing program to the web program, so that the project program automatically at a certain interval to obtain database data and upload to the Web interface for display.

The station detection data are uploaded to the server by the LAN and real-time display. The server display interface is shown in Figure 7. This interface is mainly divided into two parts, one is the display of temperature, humidity, CO concentration, smoke concentration, number of pedestrians and pedestrian density measurement data and detection pictures on the platform floor. The other part is the display of temperature, humidity, CO concentration, smoke concentration, number of pedestrians and pedestrian density measurement data and detection pictures on the entrance and exit.

Fig. 7. Display interface.

VII. Conclusion

In order to solve the problem of real-time environmental detection and passenger detection at some key positions in subway operation, the distributed station safety detection system designed here has realized the multi-directional dynamic data collection of air quality and pedestrians in the station environment based on the raspberry Pi platform by using multi-sensors and cameras, and completed the real-time uploading and storage of data and displayed on the Web interface. In the process of actual operation, the data detected can be clearly and accurately displayed. The device is compact and easy to install, and adopts wireless data transmission mode to transmit data to the server by LAN, which is very suitable for the application in the station environment. The detection data obtained have good integrity, real-time, and accuracy, and has good practical value in maintaining the safety of the station.

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References

[1] K.Zhou and Y.H.Yuan, “A Smart Ammunition Library Management System Based on Raspberry Pie,” Procedia Computer Science, vol.166, pp. 165-169, March 2020.

[2] Y.Zhang, Y.Zhu, Z.T.Zeng, G.M.Zeng, R.Xiao, Y.R.Wang, Y.Hu, L.Tang and C.L. Feng, “Sensors for the environmental pollutant detection: Are we already there?” Coordination Chemistry Reviews, vol.431, March 2021.

[3] L.Y.Jiang, Y.Cui and Y.Y. Zhang, “Design of Metro Station Environment Monitoring System Based on STM32F103ZET6 Single Chip Microcomputer,” Electronic Test, vol.9, pp.33-34, 2021.

[4] Y.L.Zhang, X.Y.Xie, H.Q.Li, B.Zhou, Q.Wang and I. Shahrour, “Subway tunnel damage detection based on in-service train dynamic response, variational mode decomposition, convolutional neural networks and long short-term memory,” Automation in Construction, vol.139, July 2022.

[5] Z.H.Zhang, K.Ji and J.W.Dang,”Research on an image-based crack detection method for subway tunnels based on feature analysis,” Journal of Electronic Imaging, vol.30, September 2021.

[6] S.Divyashikha, S.Suraj and S.Vaibhav, ” ABE based raspberry pi secure health sensor (SHS),” Lecture Notes in Electrical Engineering, vol 397, pp. 599-610, 2017.

[7] S.Chaturvedi, P.Khanna and A.Ojha,” A survey on vision-based outdoor smoke detection techniques for environmental safety,” ISPRS Journal of Photogrammetry and Remote Sensing, vol.185, pp. 158-187, March 2022.

[8] I.Gupta, V.Patil,C.Kadam and S.Dumbre, “Face detection and recognition using Raspberry Pi,” in 2016 IEEE International WIE Conference on Electrical and Computer Engineering (WIECON-ECE), 2016.

[9] D.Priyanka, K.Dharani, C.Anirudh, K.Akshay, M.P.Sunil and S.A. Hariprasad,” Traffic light and sign detection for autonomous land vehicle using Raspberry Pi,” in 2017 International Conference on Inventive Computing and Informatics (ICICI), 2017.

[10] X.Li, J.Y. He and Y.H.Yuan,” A way of analyse of behavior monitoring for the elderly based on Raspberry PI,” in 2021 2nd International Conference on E-Commerce and Internet Technology (ECIT), 2021.

[11] J.K.Chaithanya, M.Alisha, S.M.Sagar and K. Raghuram, “Development of Real-Time Violence Detection with Raspberry Pi,” Lecture Notes in Electrical Engineering, vol.844, pp. 59-73, 2021.