Raspberry Pi based Smart Fire Management System employing Sensor based Automatic Water Sprinkler

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***Abstract* - The smart fire management requires significant surveillance systems to detect and control the fire and fire causing agents automatically. This requirement has been accomplished in this proposed system by employing fire detection system and fire controlling system using Raspberry pi. The fire detection system entails flame detectors along with temperature sensors which reduces the false fire detection rate. The system also notifies the user by emailing the video of fire affected area and gives the updates of room temperature from time to time. A gas leakage sensor has been employed to detect various types of gases like ethane, methane, LPG etc. The proposed fire controlling system performs various functions on detection of fire or gas, which includes switching off the main power supply, switching on the exhaust fan and finally dousing the fire. The water sprinklers have been employed which will be activated on the detection of fire by the employed fire sensors in the system. If temperature rises above the set threshold temperature, then the proposed system will also drop the mail to fire brigade along with the video and notify the user to inform the fire brigade manually. This proposed system can be installed in a hall of maximum area 126ft x 21ft employing one Raspberry pi module.**

Keywords— automatic valve, camera module, exhaust fan, gas leakage detector, IR flame sensor, raspberry pi, temperature sensor, water sprinkler.

I. Introduction

The fire detection systems are considered as one of the most important and vital monitoring systems. Accordingly, the fire detection systems need to have a higher accuracy and smarter ways of fire detection [1]. The fire control facilities such as automatic fire alarm system, fixed fire extinguishing system, smoke control system, emergency lighting and evacuation indication system are widely adopted and play an important role in improving fire prevention and control capabilities [2]. The fire alarm system is a real-time monitoring system that detects the presence of smoke in the air due to fire and captures images via a camera installed inside a room when a fire occurs. The system has the ability to remotely send an alert when a fire is detected. The embedded systems used to develop this fire alarm system are Raspberry Pi and Arduino Uno [3]. Many applications involve detection of flames, fires and explosions that produce emissions ranging from ultraviolet to infrared radiations [4]. The air ventilation system is capable to vacuum oxygen (O_2) and other inflammable gases in room which is the main factor to avoid the fire to widespread [5]. The self-starting of automatic sprinkler system depends on various characteristics of an early fire. It sprays the water effectively to the burning area, thus controlling the fire spreading and extinguishing it. The traditional automatic water sprinklers are glass bulb sprinklers [6]. These sprinklers can be used only once and should be replaced afterwards. Also, they are activated when the flames reach the sprinkler surface installed on the ceiling. This may take a lot of time and may lead to widespread of fire, leading to greater property damage.

The section II of paper describes the design of the proposed fire management system. The section III illustrates the operation and working of the proposed system followed by the implementation and flowchart in section IV. The conclusion of the proposed work has been discussed in section V.

II. Description of Proposed System

The prototype of the proposed fire management system has been shown in Fig. 1 which consists of several modules - Raspberry pi, camera module, power supply (+5V and +12V). The description of the various modules employed in the proposed system has been discussed below in detail.

A. Inverter system

The proposed system fire management system operates on online inverter (online UPS) so that uninterrupted power is readily available to the fire management system all the time for its operation. The proposed fire management system cuts off the power supply to the hall or building by turning off the power supply on the detection of fire.

B. Power supply

In the proposed system, power supply of +5V and +24V has been employed to give the power to sensors and automatic valves, respectively. The +5V supply is required to drive sensors and +24V is required to drive automatic solenoid valve.

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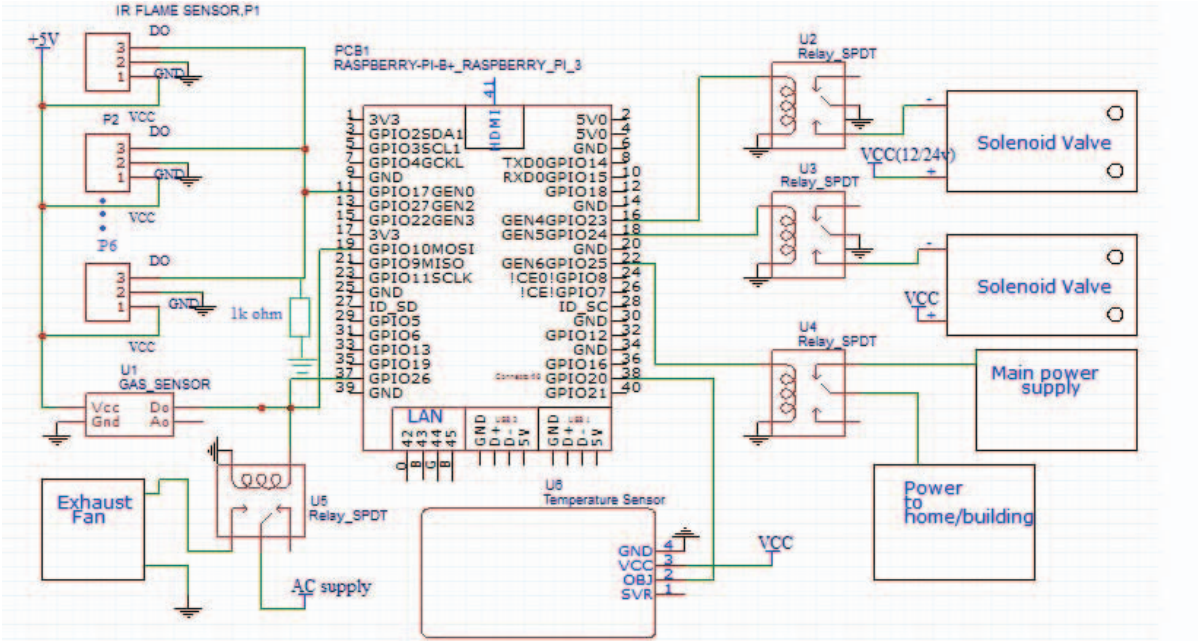

Fig. 1. Circuit diagram of the prototype of the proposed system

C. Raspberry pi

The Raspberry pi 3 is credit card sized single board computer. It has been employed in the proposed system to control the various sensors through GPIO pins. The camera module has also been interfaced with it. The Raspberry pi 3 and the camera module has been shown in Fig. 2(a).

D. IR flamesensor ,Gas leakage detector/Temperature sensor

The IR flame sensors has been employed in the proposed system to detect the infrared rays radiated by the flame. The two temperature sensors DHT11 and one gas leakage detector MQ-5 have been employed to measure the temperature of the room/hall and to detect the gas leakage. The sensors employed in the proposed system are shown in Fig. 2(b).

E. Automatic Solenoid valves and water sprinkler

The automatic solenoid valves have been employed to control the water supply through the water pipes. The water sprinklers have been installed in the proposed system. The solenoid valve opens and closes in order to allow the water flow through each pipe installed in one section. The water sprinklers employed in the proposed system are shown in Fig. 3.

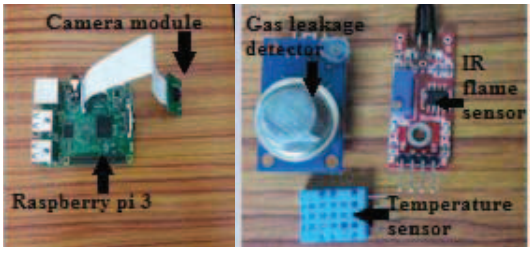

Fig. 2. (a) Raspberry pi with camera module, (b) Gas sensor, Flame sensor, Temperature sensor

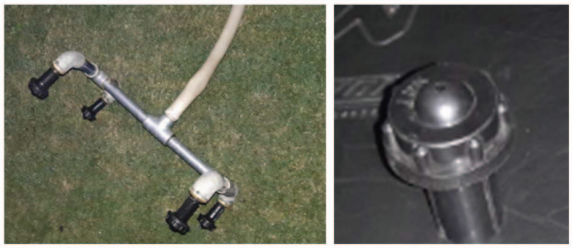

Fig. 3. Water sprinklers employed in the proposed system

F. Automatic gas valve and exhaust fan

The automatic solenoid valves have been connected to Raspberry pi through relay to cut off the supply of gas from source on the detection of gas leakage. The two exhaust fans have been employed to ventilate the hall.

G. Installation of the proposed sensor based water sprinkler

The proposed water sprinkler system entails six IR sensors and two water pipes employing the water sprinklers. These pipes are integrated with automatic solenoid valves which are connected in parallel to one GPIO pin of Raspberry Pi through a relay. The outputs of six sensors are also connected in parallel and the output signal is connected to only one GPIO pin of Raspberry Pi. The current limiting resistors of 1kΩ has been used to limit the current flowing through GPIO pin upon the activation of flame sensors. Hence, the two GPIO pins have been employed for one section. Therefore, by employing 18 GPIO pins of one Raspberry pi, nine such sections can be implemented and installed. The layout of the proposed system water sprinkler system in a hall has been shown in Fig. 4 (Top view) and Fig. 5(Side view).

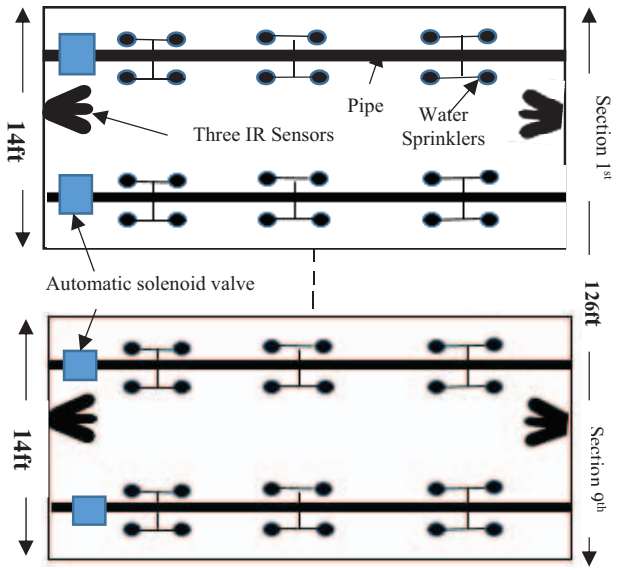

Fig. 4. Top view of the installed sensors based sprinkler system in the hall

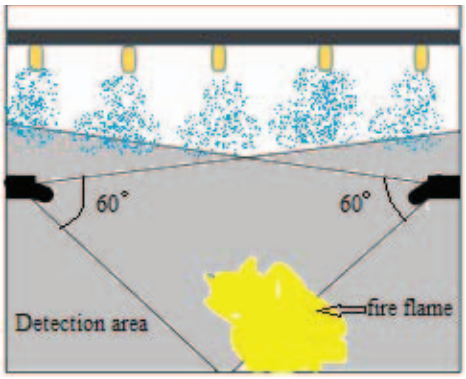

Fig. 5. Side view of the installed sensors based sprinkler system in the hall

III. Block Diagram and Operation of The Proposed System

In the proposed fire management system, the online inverter system has been employed as power supply source. The Raspberry pi is the heart of the proposed system which has been employed to detect the flame and gas leakage using IR flame sensors along with digital temperature sensor DHT11 and the gas leakage detector MQ-5, respectively. The MQ-5 is suitable for detecting of LPG, natural gas, ethane, methane and are less sensitive to alcohol, cooking fumes and cigarette smoke, thus making the system less prone to the false fire alarm detection. The camera module has been interfaced with the Raspberry pi in order to capture the video of fire affected area and email it to the user upon the activation of the flame sensors. The block diagram of the proposed system has been shown in Fig. 6.

The IR sensors, temperature sensors, gas leakage detectors and the relays are controlled by Raspberry pi by means of GPIO pins. The switching position of relays changes according to the response of sensor's output signal which is given to Raspberry. These relays act as switches between +12Vpower supply and valves which cut off the gas supply and water supply from their respective sources. The proposed sensor based water sprinkler

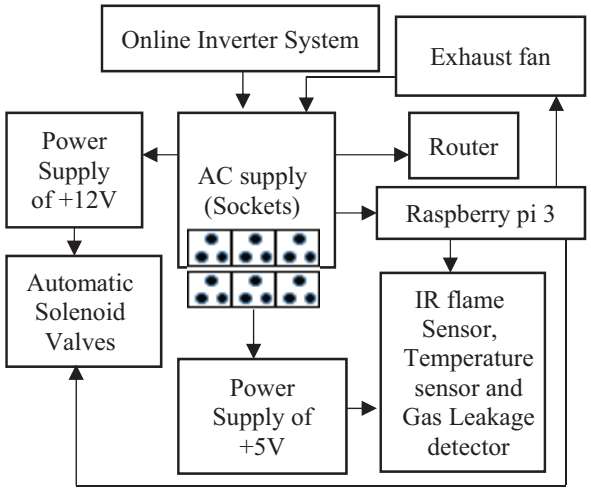

Fig. 6. Block diagram of the proposed fire management system

system entails a valve to control the opening of a pipe which has been installed in every section. This solenoid valve gets activated only when the IR flame sensors detects the flame. When the flame is detected, the IR flame sensors send logic high output signal to controller. The controller compares the temperature value measured by the temperature sensor with the set threshold value. If temperature value rises above the temperature of 303F (30 degree Celsius), the Raspberry pi performs the fire controlling operations which involves the dousing of fire using the water sprinklers. The different operations performed by the proposed fire management system have been discussed below in the Table I.

TABLE I

Various Functions Performed by The Proposed System

Sr. No.	Case	Exhaust fan	Water Sprinkler	Power Supply	Email the message
1	Gas leakage detector activated	ON	OFF	ON	Gas has been detected
		Cut off the gas supply using automatic valve			
2	IR sensors activated	Read the temperature values			
	Temperature Value	x	x	x	x
	25°C-30°C	OFF	OFF	OFF	False detection
	30°C -35°C	OFF	OFF	OFF	
	36°C-40°C	ON	ON	ON	1. Flame has been detected. 2. Send the video of affected area.
	41°C-45°C	ON	ON	ON	
	T>49°C i.e. the system is not able to control the situation	ON	ON	ON	Send the email to fire brigade and inform the user to call the fire brigade
	Note: Temperature values can be selected depending upon the environmental conditions of area.				

IV. Implementation and Flowchart of The Proposed Fire Management System

The flow chart of the proposed fire management system has been shown in Fig. 7. In the proposed fire management system, the controller Raspberry pi 3 continuously monitors the status of IR flame sensor and gas leakage detector. The set of six flame sensors has been installed on the opposite walls of the room in each section to cover the detection angle of 180º, where each sensor covers 60º angle to detect the flame within the combined detecting range of maximum 14 feet as shown in Fig. 4.

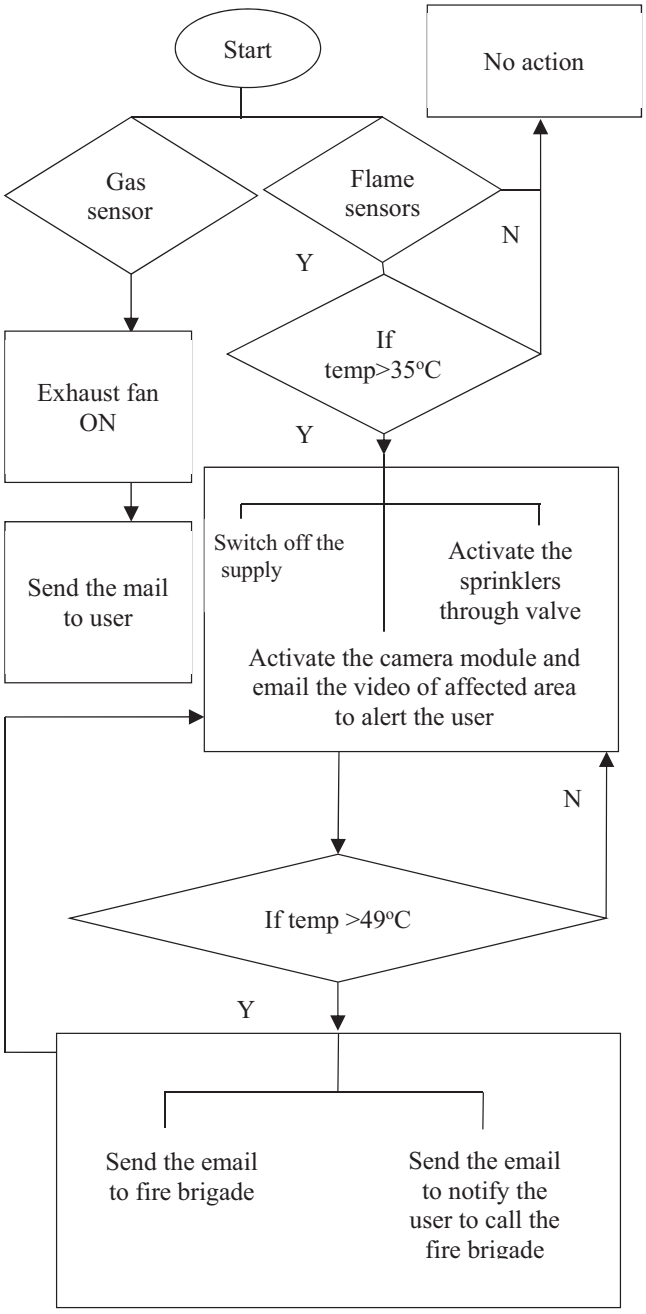

Fig. 7. Flow chart of the proposed fire management system

The detection range of flame sensors depend upon the intensity of flame. When the flame sensors detect the flame, then Raspberry pi measures the temperature value and compares with threshold value. If measured temperature value is less than the 35ºC, then no action will be performed. If temperature is greater than 35ºC, then Raspberry pi switches off the power supply and activates the water sprinklers through automatic solenoid valve. It also activates the camera module system to capture the video and email the video of 10 seconds after every 2 minutes until the fire will be doused and email the video of affected area to alert the user as shown in Fig. 8 and Fig. 9. If the proposed system determines that it is not able to control the fire and temperature value goes on increasing and hit the value above 49º C, then the Raspberry pi sends the address of the fire affected area to the fire brigade through mail and also notify the user to call the fire brigade immediately. The Raspberry pi also monitors the status of gas leakage detector. If the gas leakage detector sends high signal to Raspberry pi 3, then it turn on the exhaust fan and sends the email to user regarding gas leakage. The practical implementation of the prototype of the proposed system has been shown in Fig. 10.

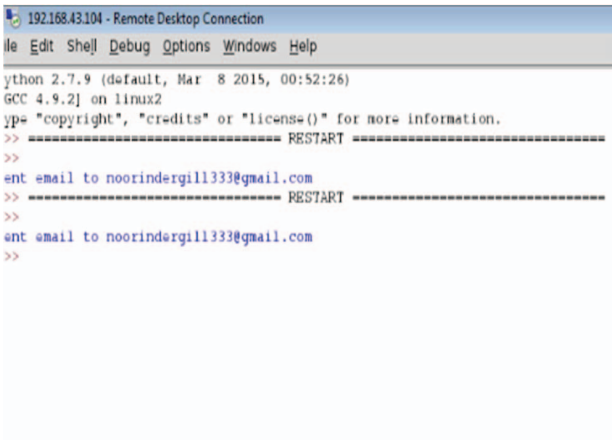

Fig. 8. Screen shot of the email sent to user by Raspberry pi

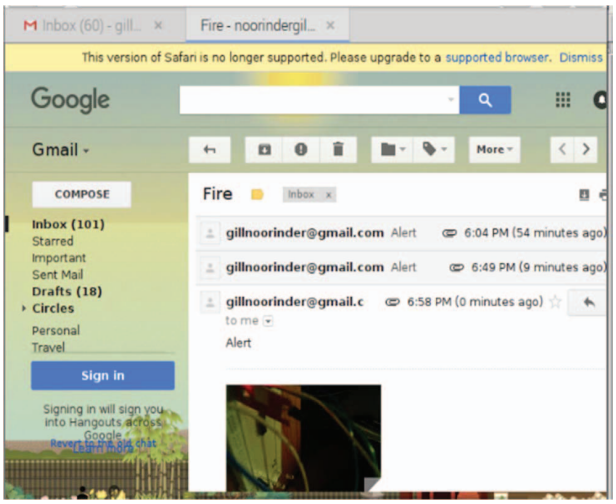

Fig. 9. Screen shot of received email by user regarding fire alert

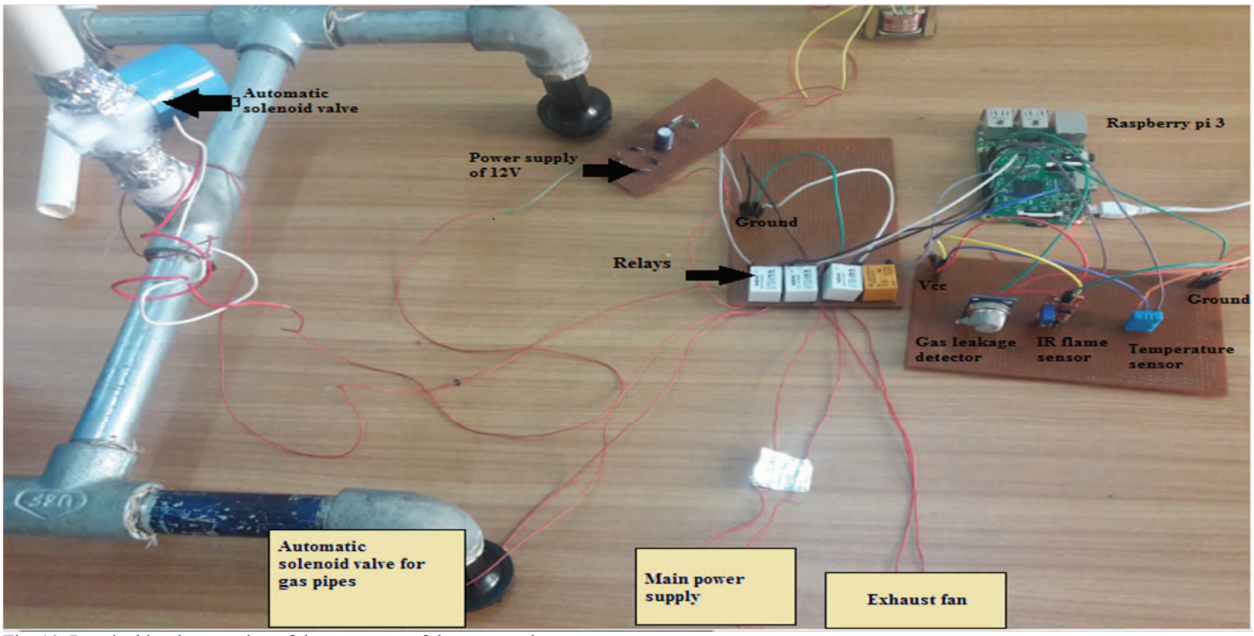

Fig. 10. Practical implementation of the prototype of the proposed system


Fig. 11. Working of water sprinkler

V. Conclusion

In this paper, a Raspberry Pi based smart fire management system has been proposed for the fire detection and control. The proposed fire management system has the advantage of early detection of fire as well as fire causing agents with a low rate of false fire detection due to employed IR flame sensor and the temperature sensor. The sensor based water sprinklers employed in the proposed system are more efficient as compared to the traditional fire sprinklers. The traditional fire sprinklers entail glass bulb that blow up when they come in contact with the flames and hence they can be used once and needs to be replaced every time. Secondly, the response time of the traditional water sprinklers was more as compared to the employed sensor based sprinklers in the proposed system. The various techniques have been used to notify the user and the fire brigade about the fire affected area.

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References

[1] S. Bayoumi, E. AlSobky, M. Almohsin, M. Altwaim, M. Alkaldi and M. Alkahtani, "*A Real-Time Fire Detection and Notification System Based on Computer Vision*," 2013 International Conference on IT Convergence and Security (ICITCS), Macao, pp. 1-4, 2013.
doi: 10.1109/ICITCS.2013.6717783

[2] X. Fang, Z. Di and W. Jun, "*Fire Safety Management Information System Design for Key Social Organizations*," 2014 Fifth International Conference on Intelligent Systems Design and Engineering Applications, Hunan, pp. 493-496, 2014.
doi: 10.1109/ISDEA.2014.118

[3] M. S. Bin Bahrudin, R. A. Kassim and N. Buniyamin, "*Development of Fire alarm system using Raspberry Pi and Arduino Uno*," 2013 International Conference on Electrical, Electronics and System Engineering (ICEESE), Kuala Lumpur, pp. 43-48, 2013.
doi: 10.1109/ICEESE.2013.6895040

[4] D.Starikov, C. Boney, R. Pillai and A. Bensaoula, "*Dual-band UV/IR optical sensors for fire and flame detection and target recognition*," IEEE Sensors for Industry Conference, 2004. Proceedings, pp. 36-40, 2014.
doi: 10.1109/SFICON.2004.1287124

[5] M. F. M. Fuzi, M. N. F. Jamaluddin and M. S. N. Abdulah, "Air ventilation system for server room security using Arduino," 2014 IEEE 5th Control and System Graduate Research Colloquium, Shah Alam, pp. 65-66, 2014.
doi: 10.1109/ICSGRC.2014.6908697

[6] F. Wu, Y. Cui, F. Qu and L. Mai, "Experimental Study on Fire Extinguishing Characteristics of Automatic Sprinkler System," *2015 Sixth International Conference on Intelligent Systems Design and Engineering Applications (ISDEA)*, Guiyang, pp. 389-392, 2015.