Implementation of Fuzzy Logic for Fire Detection Systems in Buildings Based on Internet of Things

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Abstract

Fire disaster is a condition or condition where a building in one place is engulfed in fire. This results in loss of assets/property and loss of life in places such as factories, buildings, markets, housing, gas stations and even forests. The purpose of this study is to manufacture an internet of things based fire detection system using the fuzzy logic method which functions to provide early warning to residents who are outside the home and can monitor if a fire occurs so that it can be dealt with early and minimize losses due to fire. The method used is fuzzy logic with system development using a waterfall, data collection is done by observation techniques and literature study. The results of the research after conducting analysis, design, and testing showed that the automatic fire detection system could detect the surrounding conditions correctly, and also the use of a fuzzy logic system in this system can make the fire detection system more informative by having more fire level indicators namely SAFE, Towards ALERT, ALERT, Towards DANGER, and DANGER. The distance needed by the device to detect fire is about 1 meter.

Keywords: Fire Detection Systems, Fuzzy Logic, Internet of Things, Microcontrollers, Arduino Mega.
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INTRODUCTION

In this country there are many buildings and housing that are located very close to one another. As a result, fires often occur due to electrical short circuits (Adebisi Fatai et al., 2021). This fire disaster is very detrimental to humans, in particular it can cause its own trauma for those who experience it. There are so many causes and impacts of every fire disaster that occurs to cause casualties (Noviana, 2018).

A fire disaster is a condition or condition in which a building is engulfed in flames. This resulted in loss of assets and loss of life in places such as factories, buildings, markets, housing, gas stations and even forests (Isyanto et al., 2020). Based on world data on occupational safety and health accidents, the most serious deaths due to factory fires occur in almost every country in the world with a ranking below natural disasters such as earthquakes or tsunami disasters (ILO, 2018).

There are several factors that cause fires, such as electrical installation short circuits, gas stove explosions, cigarette butts, and others (Addai et al., 2016). In general, a fire is known when the fire has started to grow or the smoke has started to turn black or has been billowing out of the building (Saponara et al., 2021). A security system in buildings (buildings or housing) is needed because the fire hazard does not know the time, so that early prevention can reduce the occurrence of fires, and greater losses (Matrouk, 2022).

We have often heard news about residential fires everywhere and this is not something new for us (Suranto, 2020), but the public seems indifferent and less alert in responding to fire incidents (Amali & Suranto, 2020), especially now that there are so many people working in offices and often leaving houses, but fire hazards can occur in empty houses abandoned by their inhabitants, usually fires that occur in homes are caused by electric currents or gas cylinder explosions, homeowners usually don't know their house has been hit by a fire (Hery et al., 2022). Due to the lack of information about fires because the homeowners were not at home, even though the material losses that occurred as a result of fire incidents were enormous, reaching hundreds of billions, not to mention the loss of life. So we need a system that can provide information about the appearance of early symptoms of a fire, especially now that the development of information technology is very advanced.

The purpose of this research is to create an internet of things based fire detection system using the fuzzy logic method which functions to provide early warning to residents who are outside the home and can monitor if a fire occurs so that it can be dealt with early and minimize losses caused by fire.

LITERATURE REVIEW

Definition of Fire Detection Systems

According to the National Fire Protection Association, fire is an oxidation event where 3 elements meet, namely materials, oxygen and heat which can cause material loss or even human death (NFPA, 2021). Every fire can cause various kinds of losses such as damage to production equipment, production materials, and loss of working time during the production process (Linawati & Purba, 2020).

Detection is a process to examine or examine something using certain methods and techniques (Fauzi, 2019). Detection can be used for various problems, for example in a disease detection system (Berutu, 2020), where the system identifies problems related to disease which are commonly called symptoms (Sinarsari, 2022). The purpose of detection is to solve a problem in various ways depending on the method used to produce a solution (Pambudi, 2020).

Definition of the Internet of Things

According to (Sari et al., 2017) Internet of Thing (IoT) can be defined as the ability of various devices that can be connected to each other and exchange data through the internet network (Sharma et al., 2020). IoT is a technology that allows control, communication, collaboration with various hardware devices, data via the internet network (Gómez et al., 2013). So that it can be said that the Internet of Things (IoT) is when we connect something (things) that are not operated by humans, to the internet (Petrenko et al., 2018). But IoT is not only related to controlling devices remotely, but also how to share data, virtualize all real things in the form of the internet, and so on (Patel et al., 2016). The internet becomes a link between machines automatically. In addition, there is also a user who serves as a regulator and supervisor of the working of the tool directly (Abdul-Qawy et al., 2015). The benefit of using IoT technology is that work done by humans becomes faster, easier and more efficient (Zeinab & Elmustafa, 2017).

Definition of Fuzzy Logic

Fuzzy is linguistically defined as fuzzy or vague which means a value can be true or false simultaneously (Schwartz, 1985). In fuzzy, it is known that the degree of membership has a range of values from 0 (zero) to 1 (one) (Dzitac et al., 2017). Fuzzy logic is a logic that has a value of fuzzyness or ambiguity between right or wrong. In fuzzy logic theory a value can be true or false simultaneously (Ross, 2009). But how much truth and error depends on the weight of membership it has (McNeill & Thro, 2014).

Fuzzy logic has a degree of membership in the range 0 to 1 and fuzzy logic shows how far a value is true and how far a value is wrong (Soleymani et al., 2017). Fuzzy logic is an appropriate way to map an input space into an output space and has a continuous value (Vuorimaa, 1994). Fuzzy expressed in degrees of membership and degrees of truth. Therefore something can be said to be partly right and partly wrong at the same time (Sulaiman et al., 2020).

RESEARCH METHOD

The research method uses the waterfall method with stages, namely identifying problems in the process of collecting materials and data needed, grouping problems, and solving problems (Buede & Miller, 2016). System analysis is the process of analyzing information and problems obtained from the initial stage and also analyzing overall and detailed requirements. System Design, at this stage program design, circuit models, and flowcharts are carried out. In the stage of writing the program code, at this stage, the coding is carried out into a predetermined programming language based on the overall design. The device assembly stage, namely assembling the tools that have been determined based on the design that has been made. In the final stage of system testing, at this stage, the tool will be tested for suitability with what has been designed and carried out tests to detect existing problems and make improvements.

System Analysis

Analysis is a detailed study or research by conducting an experiment which results in conclusions from the decomposition of a complete system into its component parts with the intention of identifying and evaluating all problems that arise, obstacles that occur as well as opportunities and needs so that solutions can be created to overcome problems that arise can build the system to be made.

Factors causing fires include short circuits in electrical installations, exploding gas stoves, and cigarette butts. In general, a fire is detected when the fire has started to grow, the smoke has started to turn black, or has been billowing out of the building. Security systems in buildings are urgently needed because fires come at no time, so early prevention can reduce the occurrence of fires, and cause greater losses.

SYSTEM DESIGN

Design of Fire Detection System

This section contains the general design of automatic fire detectors and the following is a block diagram regarding the hardware for automatic fire detectors that are being designed

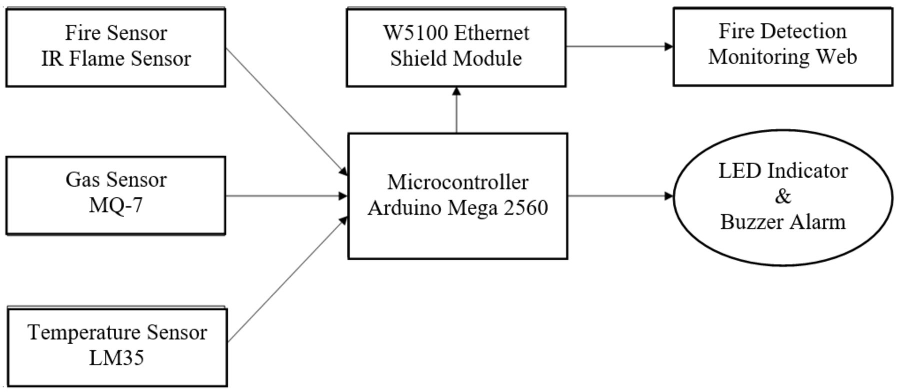


Figure 1. General Fire Detection System Design

Figure 1 shows that this fire detection system uses several components to create a fire detection system in this study and the description of each hardware component is as follows:

1) Fire Sensor

The fire sensor used is a fire sensor that uses infrared to detect a fire. The output from this fire sensor is in the form of an analog value ranging from 0 to 1024 and this analog value will be the input for the fire detection system.

2) MQ-7 Gas Sensor

This MQ-7 sensor is a type of gas sensor that is commonly used in making a system. The MQ-7 gas sensor can measure the concentration of various types of gases in a room, but in this study the MQ-7 gas sensor will focus more on CO gas only. The output from the MQ-7 gas sensor is the gas concentration value in a room and the output value from this sensor will be input to the fire detection system.

3) LM35 Temperature Sensor
This LM35 temperature sensor is one type of room temperature sensor that is commonly used. The output of this LM35 sensor is in the form of a real-time temperature value in a room and the output value of this sensor will be input for the fire detection system.

4) Arduino Mega 2560 microcontroller
Arduino Mega contains all the programs which include the sensor program and the fuzzy logic program itself. The program written into the Arduino Mega microcontroller is useful for making the fire detection system operate as desired.

5) Buzzers
The buzzer in this study is used as an output where the buzzer will make a sound if a fire is detected in the place being observed.

6) LEDs
The LED in this study is used as an output where an LED with a certain color will light up according to the status issued by this fire detection system.

7) Ethernet Shield Module
The Ethernet Shield module is a module used to connect Arduino to the internet using a cable (Wired).

8) Web Monitoring
Data from Arduino will be sent to the web server so that data in the form of temperature, gas and fire values can be monitored anywhere.

Fuzzy Logic Design

The design of the Fuzzy Logic system itself is divided into several stages, including:

1) Create a Fuzzy set
Creating a Fuzzy set is the first step in which at this stage the number of linguistic variables to be used is determined and the distribution of data on each linguistic variable. This fire detection system uses 3 input variables where the input variables are the output values from the fire, temperature, and gas sensors. Each of these input variables also each has 3 linguistic variables. So for the design of the fuzzy system input on this fire detector are as follows:

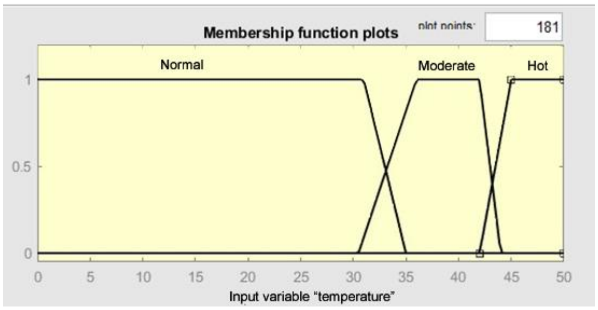


Figure 2. Temperature Input Variable

In Figure 2, 3 linguistic variables are made, which include Normal (0 °C to 35 °C), Moderate (30 °C to 45 °C) and Hot (40 °C onwards). So that in Figure 4.3 if translated it will form the following equation:

$$\text{Normal} = \begin{cases} 1, & x \leq 31 \\ \dfrac{35 - x}{4}, & 31 \leq x \leq 35 \\ 0, & x \geq 35 \end{cases}$$

$$\text{Moderate} = \begin{cases} 1, & 36 \leq x \leq 42 \\ \dfrac{44 - x}{2}, & 31 \leq x \leq 35 \\ \dfrac{x - 30{,}5}{5{,}5}, & 31 \leq x \leq 35 \\ 0, & 30{,}5 \geq x\, dan\, x \leq 44 \end{cases}$$

$$\text{Hot} = \begin{cases} 1, & x \geq 45 \\ \dfrac{x - 42}{3}, & 42 \leq x \leq 45 \\ 0, & x \leq 42 \end{cases}$$

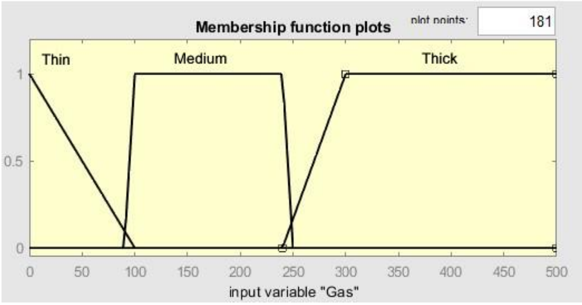


Figure 3. Gas Input Variable

In Figure 3 the gas input variables also have 3 linguistic variables, namely Thin (0 ppm – 100 ppm), Medium (90 ppm – 250ppm) and Thick (240 pmm onwards). So that in Figure 4.4 if translated it will form the following equation:

$$\text{Thin} = \begin{cases} 1, & x \leq 0 \\ \dfrac{100 - x}{100}, & 0 \leq x \leq 100 \\ 0, & x \geq 100 \end{cases}$$

$$\text{Thick} = \begin{cases} 1, & x \geq 300 \\ \dfrac{x - 240}{60}, & 240 \leq x \leq 300 \\ 0, & x \leq 240 \end{cases}$$

$$\text{Medium} = \begin{cases} 1, & 100 \leq x \leq 220 \\ \dfrac{250 - x}{30}, & 220 \leq x \leq 250 \\ \dfrac{x - 90}{10}, & 90 \leq x \leq 100 \\ 0, & x \geq 250 \; dan \; x \leq 90 \end{cases}$$

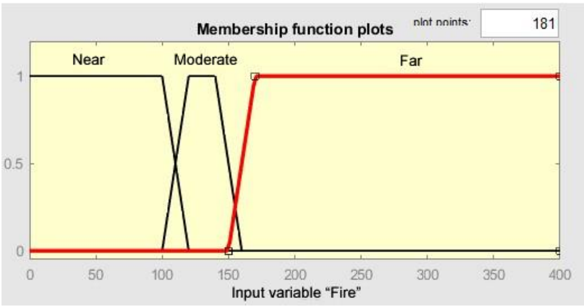


Figure 4. Fire Input Variable

In Figure 4 the fire input variable also has 3 linguistic variables, namely Near (0-120), Moderate (100-160) and Far (150-1023). So that in Figure 4.5 if translated it will form the following equation:

$$\text{Far} = \begin{cases} 1, & x \geq 170 \\ \dfrac{x - 150}{20}, & 150 \leq x \leq 170 \\ 0, & x \leq 150 \end{cases}$$

$$\text{Near} = \begin{cases} 1, & x \leq 100 \\ \dfrac{120 - x}{20}, & 100 \leq x \leq 120 \\ 0, & x \geq 120 \end{cases}$$

$$\text{Moderate} = \begin{cases} 1, & 110 \leq x \leq 140 \\ \dfrac{160 - x}{20}, & 140 \leq x \leq 160 \\ \dfrac{x - 100}{10}, & 100 \leq x \leq 110 \\ 0, & x \geq 160 \; dan \; x \leq 100 \end{cases}$$

In addition to designing fuzzy input variables, at this stage the output variables are also designed and the design of the output variables in this system is as follows:

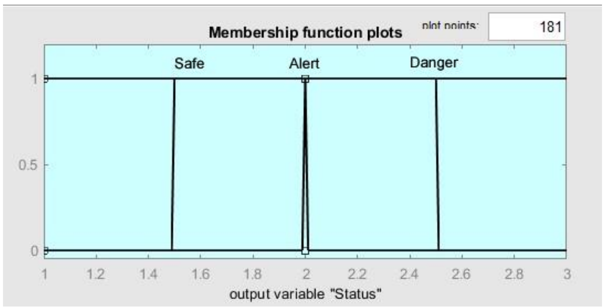


Figure 5. Status Output Variable

Variabel *output* Status

In Figure 5 it can be seen that the output variables of the fuzzy system are designed to have 3 linguistic variables and the three variables are Safe (1 – 2), Alert (1.5 – 2.5) and Danger (2 – 3). It is from this output variable that the level of a fire can be predicted by the fire detection system.

Hardware Design

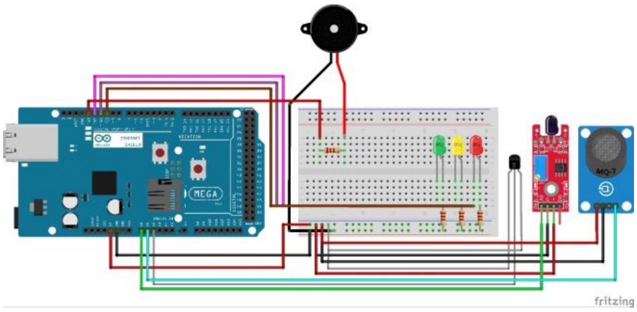
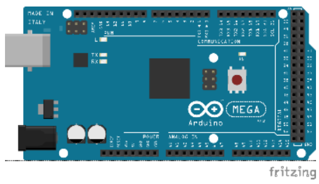
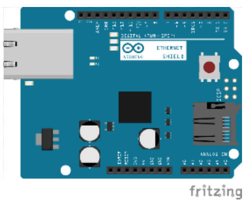
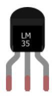
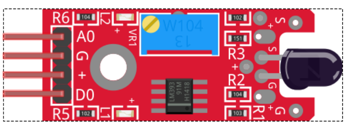
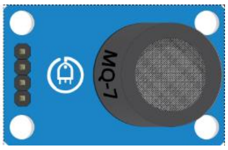
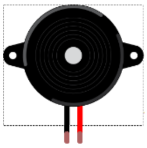
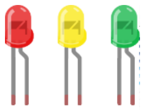


Figure 6. Hardware Design

An explanation of the hardware used in the Fire Detection System in figure 6 is in table 1 below.

Table 1. Hardware Description

No.	Hardware	Information
1		Arduino Mega 2560 microcontroller is used as a tool that processes input data which will send data to output devices.
2		This Ethernet Shield module is used to send input data to the existing database on the web server.
3		The LM35 temperature sensor functions as a sensor that detects the temperature in the room.
4		The flame sensor functions as a sensor that detects the presence or absence of fire in the room.

5		The MQ7 gas sensor functions as a sensor that detects gas levels in a room.
6		The buzzer is an output device that receives information from the data sent by the Arduino in the form of sound.
7		The LED light serves as an indicator of whether a fire has occurred or not.

Software Design

Software design is useful as the main controller on Arduino to carry out functions from other devices.

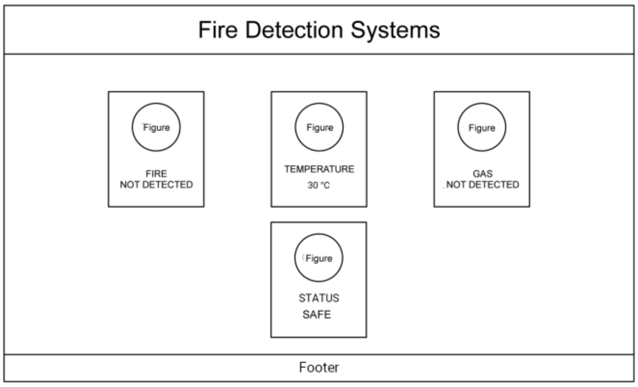


Figure 7. Interface Design Results

Hardware Logic

Table 2. Hardware Logic Information

	Status	Green LED	Yellow LED	Red LED	Buzzer
	DANGER	*Low*	*Low*	*High*	Beep
	ALERT	*Low*	*High*	*Low*	Beeps every 1 second
Condition	SAFE	*High*	*Low*	*Low*	No Beep

Explanation of Fire Detection Systems hardware logic:

1) If the Status (output) is Safe, the green LED is on, the red LED is on, and the yellow LED is off, then the buzzer will not beep.
2) If the Status (output) is Alert, the yellow LED is on, the red LED and the green LED are off, then the buzzer beeps once every 1 second.

3) If the Status (output) is Dangerous, the red LED is on, the yellow LED and the green LED are off, then the buzzer beeps.

IMPLEMENTATION

System implementation is a process of implementing the system that has been designed, where this stage is the stage of putting the system ready for use and also as an effort to realize the system that has been designed.

Table 3. System Implementation Requirements

No.	Hardware Requirements	Software Requirements
1	omputer with specs: Processor : AMD Ryzen 5-3550H 2.1GHz Storage : Harddisk 1 TB + SSD NVMe 256 GB RAM : 8GB DDR4 2400MHz SDRAM	**perating System** indows 11 Home Single 64-bit
2	rduino Mega 2560	**ode Editor** rduino IDE & Visual Studio Code
3	rduino Ethernet Shield Module	**mulator Design** itzing
4	ame Sensor	**agram Design** icrosoft Visio 2016
5	mperature Sensor LM35	**eb Server** pache
6	as Sensor MQ7	**atabase Server** ariaDB
7	D	
8	mper Cable	
9	eadboard	
10	daptor 9 Volt	
11	ccess Point	
13	N	

System Usage Guide

How to Use a Fire Detection System:

1) Give Power to the Arduino by inserting the power cable from Arduino to the mains.
2) After Arduino is connected to electricity, the sensor will automatically turn on and start detection.
3) If the green light is on then it indicates that the status is safe.
4) If the yellow light is on and the buzzer sounds every 1 second then it indicates that the status is alert.
5) If the red light is on and the buzzer sounds then it indicates that the status is dangerous.

Device Installation

Device installation is the process of assembling and installing all the hardware components.

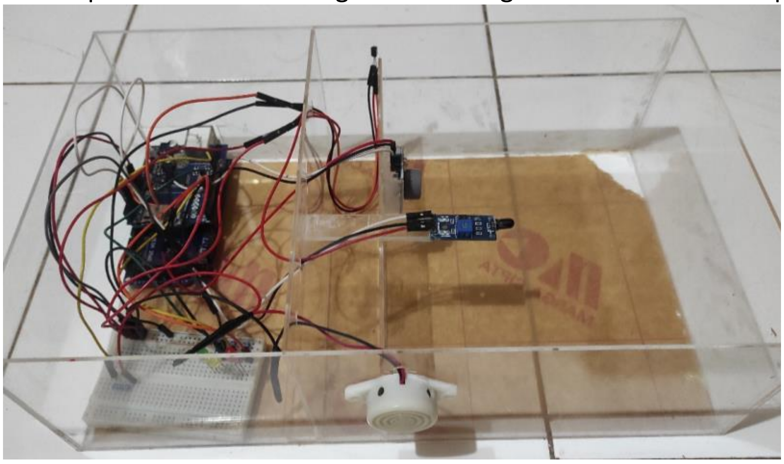


Figure 8. Results of Fire Detection Systems Hardware Implementation

Results of Software Implementation

Guide to Using Fire Detection Systems

1) Give Power to the Arduino microcontroller by inserting the power cable from Arduino into the mains.
2) After the Arduino microcontroller is connected to electricity, the sensor will automatically turn on and start the detection.
3) If the green light is on then it indicates that the status is safe.
4) If the yellow light is on and the buzzer sounds once every 1 second then it indicates that the status is alert.
5) If the red light is on and the buzzer sounds then it indicates that the status is dangerous.

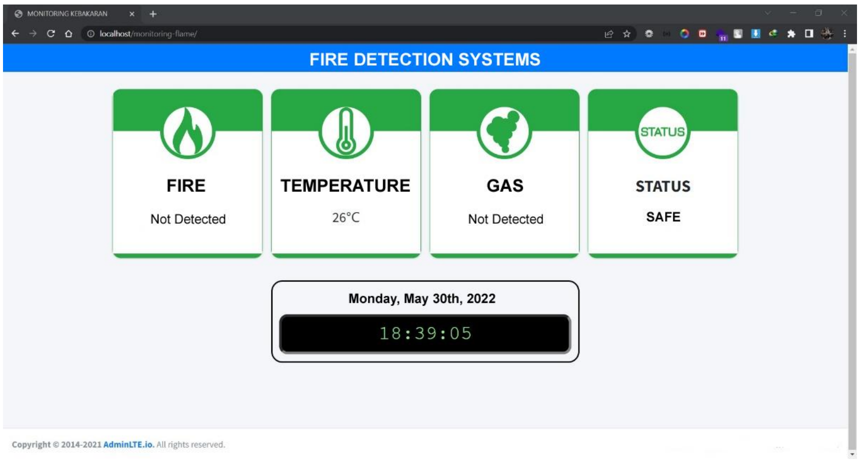


Figure 9. Results of Implementation of Fire Detection System Software

CONCLUSION AND RECOMMENDATIONS

Conclusion

After conducting system analysis, design, and testing, it can be concluded that an automatic fire detection system can detect the surrounding conditions correctly and also the use of a fuzzy system in this system can make the fire detection system more informative by having more fire level indicators, namely SAFE, Towards ALERT, ALERT, Towards DANGER, and DANGER. The distance required by the system to detect a fire is relatively close, which is around less than 1 meter.

Recommendations

The following are suggestions that the compiler can use for the development stage of this system, including:

1) This system cannot be connected directly to the fire department so that fires can be handled quickly.
2) This system has not yet reached the stage where it can be implemented in daily

activities because the sensors used are still limited to prototypes.
3) The first prevention feature can be added, such as pouring water so that the fire does not spread.

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