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A design of intelligent range hood based on Arduino

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Abstract—*This paper designs and implements an intelligent hood control system based on Arduino, which is composed of multiple modules, including gas detection and human body sensing, with a single-chip microcomputer as the core. The system monitors the oil smoke, natural gas concentration, and temperature and humidity changes in the kitchen in real-time using high-precision sensors. The analog signals are digitized by the A/D conversion module and sent to the single-chip microcomputer for processing. The single-chip microcomputer controls the fan speed precisely by pulse width modulation according to the smoke, gas concentration, and temperature data, achieving intelligent adjustment and efficient exhaust. The system has the characteristics of fast response, precise regulation, and energy saving and environmental protection, effectively improving the air quality in the kitchen and user experience.*

I. INTRODUCTION

With the rapid development of technology and a marked improvement in living standards, smart home appliances have been deeply integrated into daily life in modern families, becoming an indispensable part of modern family life. The smart range hood, as a capable assistant in modern family kitchens, is not just a simple tool for exhausting oil smoke, but also a sophisticated device that incorporates various intelligent technologies. It can quickly respond to users' needs and automatically adjust its operating mode, and its level of intelligence directly affects the comfort and health of the family cooking environment [1].

Cooking fumes contain a variety of harmful substances, such as formaldehyde, carbon monoxide, sulfur dioxide, benzopyrene, etc. If people are exposed to them for a long time, they can irritate the mucous membrane of the respiratory tract, induce pharyngitis, tracheitis, etc. respiratory system diseases, and even increase the risk of lung cancer [2]. In addition, cooking fumes will also affect skin health, causing the skin to become dry and rough, accelerating skin aging. There have been relevant studies that confirm that formaldehyde is the most abundant carbonyl compound in the various carbonyl compounds produced in home kitchen cooking, accounting for 12% to 60% of the total, and has the greatest potential lifetime carcinogenic risk to humans. Cooking fume pollution has become a potential threat to the health of restaurant workers and home cooks [3].

Traditional range hoods have certain effect in removing oil smoke, but they also have problems such as low intelligence level, high energy consumption, and loud noise [4]. Traditional range hoods lack intelligent sensing and control functions, and cannot automatically adjust the wind speed and suction according to the concentration of oil smoke. At the same time, their interconnectivity is limited, so users cannot access the operating status and energy consumption of the range hood in real time through smart home systems, nor can they coordinate with other smart household appliances. In addition, traditional range hoods lack personalized setting options, making operation complicated and difficult to control the noise level during operation.

In order to better improve the performance and efficiency of the range hood, scholars at home and abroad have studied the range hood from various angles, including wind speed, air volume, flow field, fume capture efficiency, exhaust efficiency, energy saving and environmental protection, filter material and so on.

Tang-Jen Liu and others proposed a low-cost smart hood system that uses sensitive piezoelectric sensors to sense the level of cooking pollutants, outputting adjustments to the fan speed to improve the fan speed and significantly reduce the noise and power consumption of the hood [5]. G. Ciattaglia and others utilized two different multi-sensor units to monitor temperature, relative humidity, volatile organic compounds, and particulate matter, and could more accurately control the oil smoke collection efficiency of the hood when the level of pollutants generated was detected to be high [6].Guo Zhilin and others studied the exhaust characteristics of hoods based on inherent angle measurement, analyzed the diffusion patterns of particulate matter generated by cooking in different cooking scenarios, considering factors such as the opening and closing of windows, the speed of cooking sources, and the airflow rates of hoods. Based on different airflow organization patterns, they designed auxiliary ventilation systems to improve the exhaust efficiency of the hood [7]. Antonio Valdez Gomez provided a new universal component loudness assessment program that could identify and reduce the noise emitted by kitchen hoods by evaluating the loudness of individual components, thereby improving the hood and reducing the noise generated from its root [8]. The energy efficiency of the blower is evaluated by the FDE (fluid dynamic efficiency) index, which is part of the EEI (energy efficiency index) formula for kitchen hoods. Paolo, Cicconi and others studied the performance of novel virtual blowers by conducting geometric optimization to obtain suitable airflow and FDE values, thereby improving the energy consumption of the hood [9]. Lei Shu and others designed a new hood (NRH) consisting of an efficient particulate air (HEPA) filter circulation component and an exhaust component, in which the airflow rate of the HEPA filter circulation component was 72 l/s for removing particulate matter generated by cooking activities and returning the filtered clean air to the room, and the exhaust component was used to expel particulate matter and other indoor air pollutants to the outdoors, effectively improving the indoor air quality [10].

With the continuous development of technologies such as the Internet of Things and artificial intelligence, smart hoods have emerged. They use high-sensitivity oil smoke sensors, temperature sensors, and humidity sensors to monitor real-time parameters such as oil smoke concentration and temperature in the kitchen, and automatically adjust the wind speed and power to achieve precise exhaust [11]. At the same time, smart hoods can also be connected to other smart home devices, and users can control the on/off and wind speed of the hood via a mobile APP [12]. Moreover, they are equipped with intelligent cleaning functions to reduce the user's cleaning burden and extend the product service life [13]. In addition, by using noise-reducing materials and technologies such as micro-perforated panels and sound linings, the noise generated by the hood during operation is effectively reduced [14]. Its intelligent odor-proof design can prevent oil smoke from escaping and keep the kitchen air fresh, providing users with a comfortable and healthy cooking environment.

II. INTELLIGENT RANGE HOOD SYSTEM ARCHITECTURE DESIGN

This paper designs and implements an intelligent environment control system based on embedded, which takes embedded as the core control unit and constructs an integrated and intelligent control architecture. The architecture consists of five core modules: core control module, gas detection module, body sensing module, A/D conversion module and temperature and humidity sensor module. The system is designed to fully monitor and control environmental parameters to ensure indoor air quality and comfort.

Specifically, the gas detection module works together with the temperature and humidity sensor module to capture real-time information on oil smoke concentration, natural gas leaks, and changes in temperature and humidity in the environment. The analog signals output by these sensors are converted into digital signals by a high-precision A/D conversion module, and then transmitted to the microcontroller for in-depth analysis and processing. The embedded system serves as the "brain" of the system, responsible for receiving and decoding these digital signals, accurately calculating the current gas concentration and temperature levels in the environment.

To achieve real-time response and regulation of environmental conditions, the system incorporates a motor drive mechanism. The motor driver works closely with the microcontroller and receives speed instructions from the microcontroller. Pulse width modulation (PWM) technology is used, and the microcontroller generates a PWM square wave signal with a specific period through its built-in timer. The signal directly controls the motor's speed. It is worth noting that in this system, the concentration of smoke, gas, and temperature all have equal priority in regulating the motor's speed. That is, when any of these parameters exceeds the predetermined threshold value, the microcontroller will automatically adjust the duty cycle of the high-level of the PWM waveform to flexibly adjust the fan's rotational speed, in order to achieve the goal of quickly responding to changes in the environment and optimizing the indoor environment.

The intelligent environmental control system designed in this paper realizes accurate monitoring and intelligent regulation of indoor environmental parameters through highly integrated hardware architecture and advanced control strategies, and provides strong support for improving the comfort and safety of living and working environment.

2.1. Core controller

The core control board of the exhaust hood system is developed using the Arduino series development board, which has stronger interactive system design than the 51 single-chip microcomputer. It simplifies the workflow of the single-chip microcomputer and supports multiple expansion modules, such as sensors, LCD screens, and Wi-Fi modules, making it convenient to expand and upgrade projects. In addition, the Arduino UNO R3 has the following advantages. First, the Arduino IDE can run on Windows, Macintosh OSX, and Linux operating systems, while most embedded systems can only run on Windows. Second, Arduino has strong usability, making it applicable to a wider range of scenarios and meeting the needs of different fields, from simple home automation to complex robot control. Third, Arduino can be programmed using the Arduino IDE, which simplifies hardware setup and operation handling through the official IDE, making it easier to write code and maintain it in the long run. For software openness and extensibility, the Arduino programming language can be extended through C++ libraries, and official and community creators have provided rich library files that can be adapted to most sensors and controls. It has a good community environment for learning and expansion. Finally, the Arduino board is based on the ATMEGA8 and ATMEGA168/328 microcontrollers from Atmel, and Arduino is based on the Creative Commons license agreement, which allows users to design their own modules based on their needs. The hardware has high expandability and can add or reduce the functionality of hardware according to the needs of the project design.

The main control of the hood fan is selected as Atmega32u4, which is built using the Arduino UNO R3 board. It uses DIP IC or SMD package with 44 pins including 6 analog pins, 2 VCC pins, 4 GND pins, and 14 digital pins. Of the 14 digital pins, 7 can be used as PWM pins. There is also a MOSI and MISO pin, as well as an HWB pin, which allows users to access the bootloader and can also be used as a regular GPIO pin. There is also a UART port, 4 SPI peripherals, and 1 I2C pin. The ATmega32u4 has 32 KB of programmable flash, 2.5 KB of SRAM, and 1 KB of EEPROM, and can accept any voltage between 2.7 and 5.5 volts, with a operating temperature range of -40°C to 85°C. The ATmega32u4 has a 16MHz crystal oscillator, 20 available IO pins, of which 7 support PWM, 12 analog input IO pins, 32KB of FLASH, 2KB of SRAM, and 1KB of EEPROM. The Arduino board has a built-in serial port, including 5 5V output ports, as shown in Figure 1: Atmega32u4 based on AVR-RISC microcontroller, because AVR uses a Harvard structure, program memory and data memory are separated, can have the same address of the program memory and data memory for independent addressing.

This structure helps Atmega32u4 achieve efficient instruction execution, maximizing performance and parallelism, as shown in Figure 1.

This architecture improves the computing speed by simplifying the structure of the computer, because RISC prioritizes the simple instructions with the highest frequency, and fixes the instruction width, which can reduce the types of instruction formats and addressing methods, thereby shortening the instruction cycle and improving the running speed. AVR-RISC microcontrollers have a high-speed processing capacity of 1MIPS/MHz (million instructions per second/megahertz),

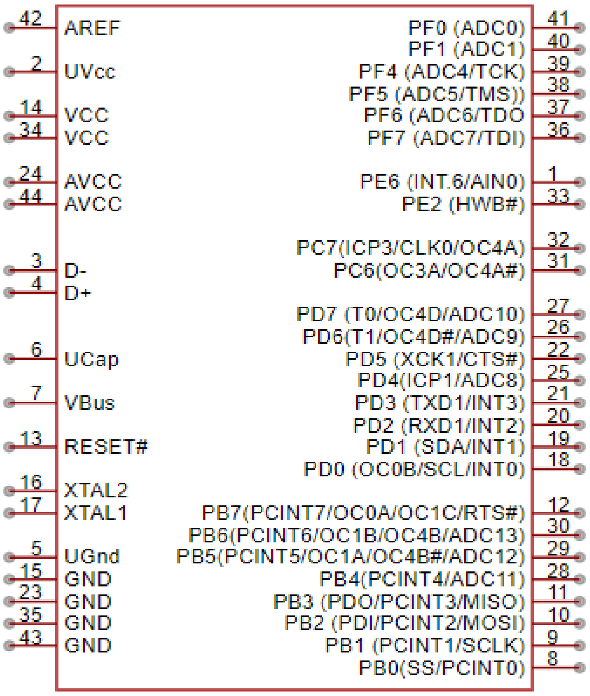


Fig.1 Atmega32u4 structure pin diagram

which means that at the same clock frequency, AVR controller type microcontrollers can handle more instructions. On the other hand, the AVRAVR controller type of microcontroller has a low power consumption characteristic, which makes it perform well in application scenarios that require long running or have strict requirements for power consumption.

2.2. Temperature and humidity sensor module

The design of temperature and humidity sensor used to monitor the temperature and humidity in the oil smoke environment, this design uses DHT11 digital temperature and humidity sensor, which is a temperature and humidity composite sensor containing calibrated digital signal output, it applies a dedicated digital module acquisition technology and temperature and humidity sensor technology, has high reliability and long-term stability, strong anti-interference ability and other advantages.

DHT11 digital temperature and humidity sensor adopts single-wire bidirectional, including a capacitive humidity sensing element and an NTC temperature measuring element, and connected with an 8-bit MCU, DHT11 supply voltage is 3.3~5.5V DC, measuring range is -20~60℃ and 5~95%RH. The sensor has a temperature accuracy of ±2 ° C at 25 ° C and a humidity accuracy of ±5%RH. It is widely used in automatic control, data recorder, humidity regulator and so on.

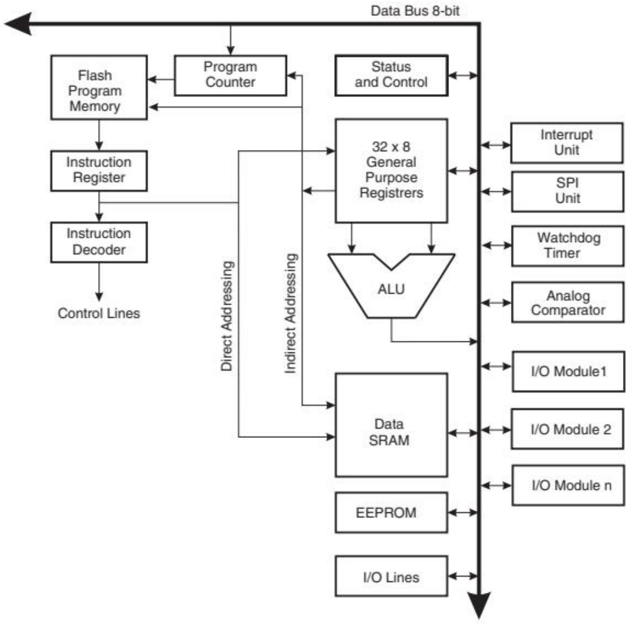


Fig.2 Block Diagram of the AVR Architecture

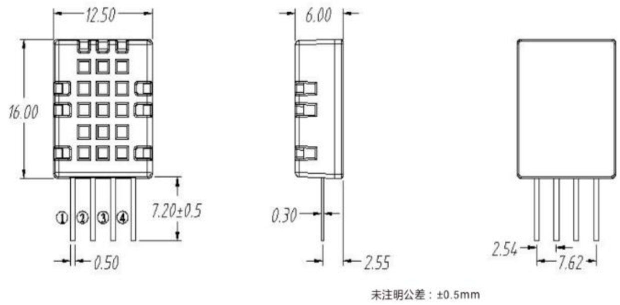


Fig.3 Structure of DH11 (unit: mm)

For data transmission, the DHT11 digital wet temperature sensor uses a single bus data format to complete two-way transmission of input and output for a single data pin port. The data packet is composed of 5Byte (40Bit), the specific data is divided into decimal parts and integer parts, a complete data transmission is 40bit, the high first out. The data format of the DHT11 is 8bit humidity integer data + 8bit humidity decimal data + 8bit temperature integer data + 8bit temperature decimal data + 8bit verification. The timing diagram of the transmitted data is shown in Figure 4.

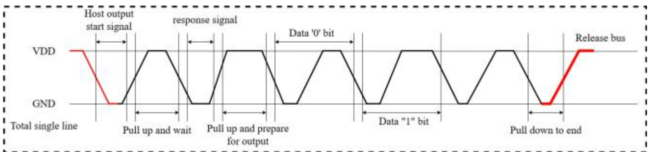


Fig.4 Data timing diagram

2.3. Gas sensor module

The gas sensor in the design is mainly used to monitor the concentration of oil smoke and natural gas in the ambient air in real time, and control the motor speed in real time with the temperature and humidity sensor to control the exhaust air volume. This design uses MQ-2 gas sensor and QS-01 oil fume sensor.

MQ-2 is a semiconductor gas sensor, the gas sensitive material used is the low conductivity of tin dioxide. When there is a combustible gas in the environment of the sensor, the conductivity of the sensor increases with the increase of the combustible gas concentration in the air. The MQ-2 sensor has high sensitivity to propane and smoke, and can also be used to detect combustible gases, which has the advantages of strong durability and low cost. It can detect the concentration of combustible gas between 300 and 10000ppm, its pin connection is shown in Table 1, where VCC: connected to the positive terminal of the power supply, GND: connected to the negative terminal of the power supply, DO: TTL switch signal output, AO: analog signal output：

Table 1 Pin diagram of the MQ-2 sensor

Pin	GPIO
VCC	3.3V/5V
GND	GND
DO	NC
AD	PA1

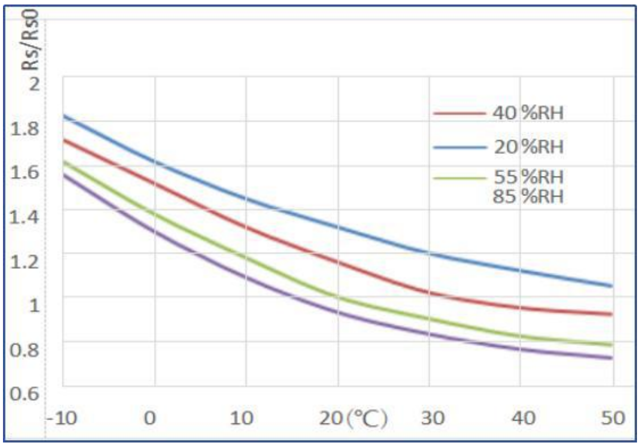


Fig. 5 Typical temperature and humidity curves of the sensor

The smoke detector MQ-2 exhibits different resistance values for different concentrations and types of gases, so it is necessary to adjust the sensitivity of the mechanical components when using this component. The variable resistor RP2 in Figure 3 is used to adjust the sensitivity. The coal gas smoke detection principle diagram is shown in Figure 3, and it is connected to the smoke detector with an AND gate and used with INT0 for interrupt. When the coal gas content in the kitchen is below the set value or does not contain coal gas, the resistance value of MQ2 becomes very large, and the voltage at pin 2 of the comparator is higher than that at pin 3, emitting a high voltage, and INT0 inputs a high level, not triggering the interrupt. When the coal gas content in the air increases, the resistance of MQ-2 decreases, and when the voltage at pin 2 of the comparator receives a voltage lower than that at pin 3, which usually means that the detected coal gas concentration has exceeded the predetermined safety threshold. In this case, the comparator will immediately output a low-level signal, which is used as a trigger signal to initiate an interrupt process. Once the interrupt is triggered, the system will jump to the corresponding interrupt service routine (ISR) to be executed. Inside the interrupt service routine, a series of operations will be performed, including starting the hood to eliminate dangerous gases and triggering the alarm mechanism to warn users of the current potential danger. Such a design is intended to quickly respond to situations where coal gas concentration exceeds the standard, ensuring environmental safety.

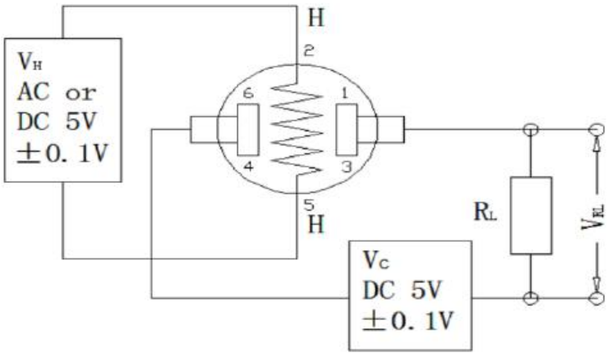


Fig.6 MQ-2 test circuit

The above figure shows the basic test circuit for the MQ-2 sensor. This sensor requires two voltages: the heater voltage VH and the test voltage VC. Of these, VH is used to provide the sensor with a specific working temperature, which can be supplied by a DC power source or an AC power source. VRL is the voltage across the load resistor RL in series with the sensor. Meanwhile, VC is the voltage used to test the load resistor RL.

The QS-01 sensor is also a tin dioxide semiconductor gas sensor with high sensitivity to VOCs and other pollutants in the air, and a fast response time. The QS-01 has three pins and can provide excellent sensing characteristics at very low power consumption. This module is well suited for use in air quality control systems, exhaust fans, and air purifiers. Its circuit diagram is shown below.

Figure 7 shows the sensitivity characteristic curve detected by the QS-01 sensor, which is reflected by the relationship between the sensor resistance and the gas concentration. There is a logarithmic relationship between the decrease of sensor resistance and the increase of gas concentration

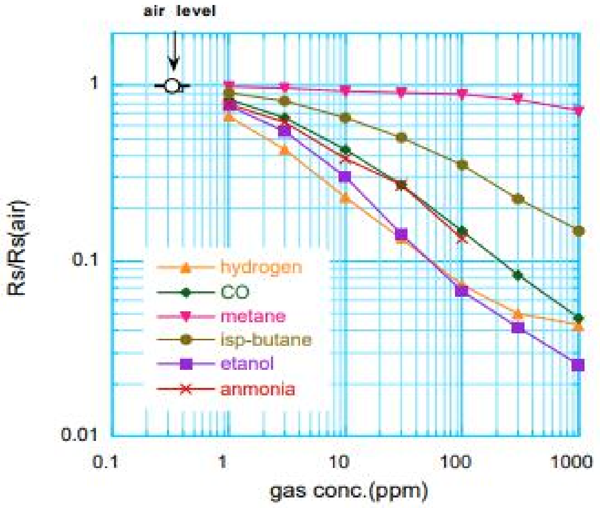


Fig.7 Sensor sensitivity characteristics

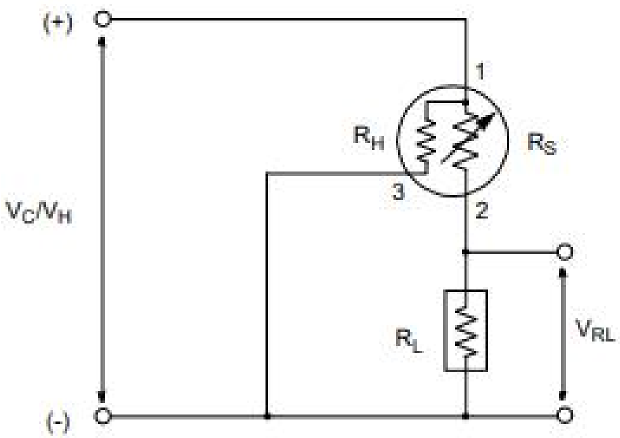


Fig.8 Standard circuit of QS-01 sensor

2.4. Body sensing module

The human body sensor module is mainly used to detect whether there is human activity in front of the range hood, and can control the switch of the range hood. The design adopts HC-SR501 human body sensor module, which is an automatic control module based on infrared technology and adopts LHI778 probe design, and has the advantages of high sensitivity, strong reliability and ultra-low voltage operation. It can work at the temperature of -50~+70℃, and the induction Angle is <100 degrees' cone Angle.

HC-SR501 is an intelligent human body sensing module that has a high degree of automated sensing capability. When a human enters its predetermined sensing range, the module will immediately output a high-level signal as a response to the detection, and when the human leaves the sensing area, the module will automatically enter a delay state and output a low-level signal, achieving an automated "exit detection". The module is designed flexibly with multiple trigger modes, and users can easily switch its trigger mode by simply adjusting the jumpers on the solder pads. In the non-repeatable trigger mode, the module will output a high-level signal once it detects a human and wait for a predetermined delay time, regardless of whether the human continues to be within the sensing range during the delay time. After the delay time is over, the output will automatically return to the low-level state. This mode is suitable for applications that require a single response. The second trigger mode is the repeatable trigger mode, unlike the non-repeatable trigger mode, in this mode, as long as the human remains within the sensing range and does not exceed the total delay time, the module's output will continuously remain at the high-level state. Only when the human completely leaves the sensing range does the delay start counting, and the low-level output is output after the delay time is over. This mode is particularly suitable for situations where continuous monitoring of human activity is required.

It is worth noting that the HC-SR501 module undergoes an initialization phase upon power-up, which lasts approximately one minute to complete self-testing and preparation. Subsequently, it transitions into a standby state, poised to promptly respond to changes in the sensing area. This meticulous design ensures optimal operational readiness of the modules prior to deployment.

Combined with the above functions and circuit design, the programming flow chart is compiled, as shown in Figure 10, and compiled in C language.

In manual mode, users can adjust the output power of the hood through the human-machine interface.

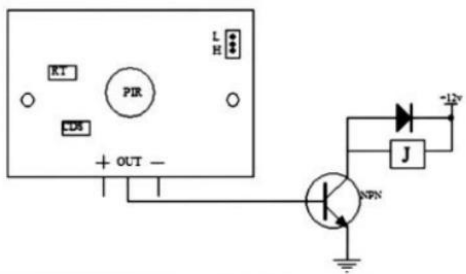


Fig.9 External usage of the sensor

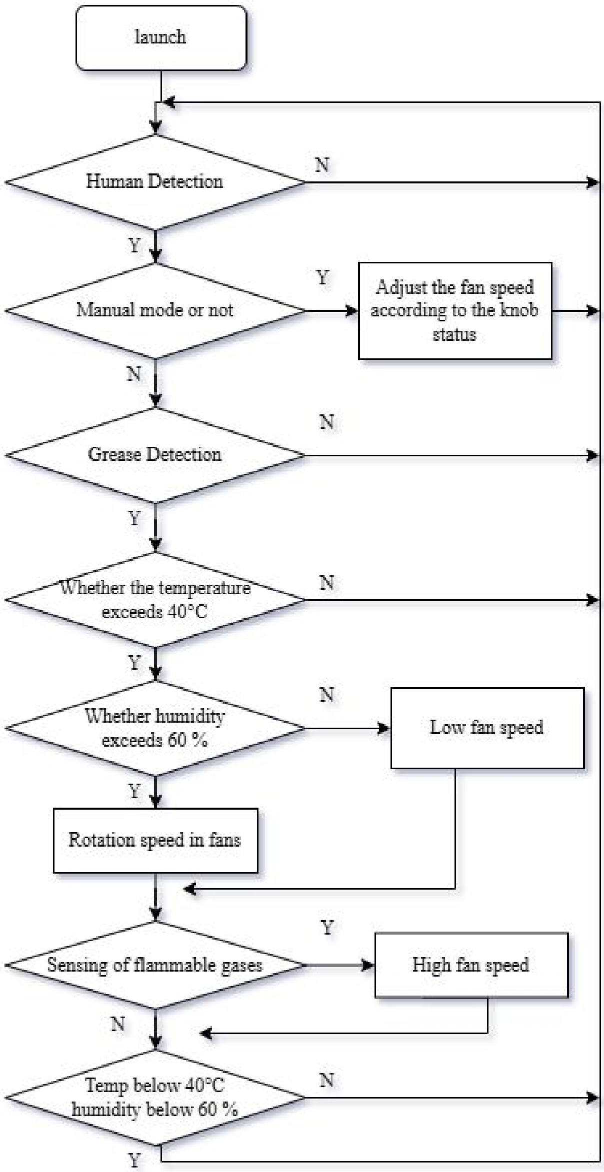
III. SYSTEM SOFTWARE DEVELOPMENT

In automatic mode, if the HC-SR501 human body sensing module detects activity in the kitchen, the potentiometer controlling the motor speed is dragged to adjust the speed of the fan, which will be kept within the three pre-set speeds of high, medium, and low, depending on the changes in environmental parameters. During this process, the DHT11 digital temperature and humidity sensor plays a crucial role by continuously monitoring the temperature and humidity in the kitchen.

If the temperature exceeds 40°C and the relative humidity is below 60%, it indicates that the air in the kitchen is relatively dry, so the system will set the fan speed to low. On the other hand, if the temperature remains above 40°C but the relative humidity rises above 60%, it means that moist and hot air may affect comfort and air quality, so the system will automatically increase the fan speed to the medium level. The MQ-2 gas sensor and the dedicated oil smoke sensor are responsible for monitoring the concentration of combustible gases and oil smoke in the kitchen.

Once these sensors detect any abnormal conditions, such as a gas leak or excessive oil smoke concentration, the system will immediately respond by increasing the fan speed to the highest level to ensure the quick exhaustion of harmful gases and oil smoke to protect the safety of people inside the environment. Additionally, the system has intelligent energy-saving features.

Whether in automatic or manual mode, when no exhausting is needed, the hood can automatically shut off the motor to avoid unnecessary energy waste. This feature helps save energy and prolong the service life of the equipment. When the hood is in standby mode, the main control unit will continue to power all the sensors to ensure that they can continuously monitor the kitchen environment, so that potential safety hazards, such as oil smoke accumulation or gas leakage, can be detected in non-working hours to guarantee the overall safety of the environment.



IV. CONCLUSION

This paper designs an intelligent exhaust hood controlled by Arduino system, which can achieve unmanned operation through a sensor system consisting of QS-01 sensors, human body sensors, and MQ-2 sensors, to improve the best use experience of exhaust hoods. In automatic mode, the exhaust hood can adjust the fan speed according to the data feedback from various sensors to adapt to the size of oil smoke, combustible gases, and humidity and temperature, to a certain extent, realizing the intelligent control of exhaust hoods.

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