

Intelligent Temperature Control System for Showers Based on Environmental Sensors

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Abstract. Taking a shower is the most relaxing moment of the day for everyone, which relieves fatigue and brings leisure time. However, the sudden fluctuation of water temperature during showering can easily ruin people's mood. Especially in cold weather, unstable water temperature greatly increases the risk of colds among children and the elderly. This design develops an intelligent temperature control system for showers with the adoption of environmental sensors. Meanwhile, the system can monitor ambient humidity and air quality to ensure a comfortable shower environment. On this basis, the project prototype is developed with Arduino and Mind+. After scheme optimization and experimental tests, the system finally meets the design requirements. This project can be applied to every household, possessing promising commercial prospects and strong practical feasibility.

Keywords: Arduino, Environmental Sensor, Intelligent Temperature Control, Shower

1. Introduction

Many people have encountered the annoying problem of fluctuating water flow temperature while taking a shower in daily life. Such abrupt temperature changes not only spoil the pleasant shower experience, but also bring potential health risks. Repeatedly adjusting the unstable water temperature during showering is time-consuming and may lead to illness. People with sensitive physical conditions may even suffer from discomforts such as asthma.

People are extremely sensitive to water temperature and bathroom ambient temperature during showering. Therefore, precise temperature control has always been a key factor measuring the comfort of household bathroom facilities. According to daily surveys, the two most prominent troubles for people in home bathrooms are the perennial cold, damp and stuffy environment that is hard to dry out, and the difficulty in maintaining stable shower water temperature. These two daily problems also reflect the development trend of the bathroom industry in recent years.

With the continuous improvement of household living standards, practical technologies related to bathroom temperature control have also been constantly updated and upgraded. A variety of thoughtful and tech-enabled temperature control designs have emerged one after another, including constant-temperature shower systems, bathroom heaters for dehumidification and heating, and user-friendly intelligent constant-temperature toilets. These humanized designs comprehensively optimize the experience of using bathroom facilities and make daily life at home more comfortable.

In actual shower scenarios, people of different age groups have different perceptions of water temperature. Long-term exposure to excessively hot shower water may cause scalds on the skin, while overly cold water tends to result in colds. For the elderly and children in particular, unstable outlet water temperature will not only undermine the shower experience, but also threaten physical health.

For instance, on October 28, 2019, Liu Jiayi and his father Liu Jiyi signed a pension service contract with a pension center in Luxi County, Pingxiang City. After establishing the admission file, the pension center conducted a physical ability assessment on Liu Jiyi, who was diagnosed with Alzheimer's disease and classified as a severely disabled elderly person. On the morning of December 2, 2019, the staff of the pension center accidentally scalded the elderly man while giving him a bath. The elderly man was hospitalized for 11 days for treatment before being discharged and taken back to the pension center to receive continued care.

These problems can be effectively solved by adopting a digital water heater with temperature control function, which can intelligently regulate outlet water temperature. Based on relevant news reports and background research, this study is proven to have considerable research value and social significance. News about shower scald accidents is frequently reported. After collecting relevant information and investigating existing products on the market, the innovative points of this design are put forward as follows.

1. Safety. Thermostatic shower heads limit the output of overheated water to avoid scalds caused by excessive temperature. High-quality thermostatic shower heads can keep the water temperature fluctuation within 2 degrees Celsius, which greatly improves bathing safety.

2. Comfort. The outlet water temperature of a thermostatic shower head remains stable. Users can set their preferred temperature before bathing without worrying about sudden rises or drops of water temperature during showering.

3. Durability. Thermostatic shower heads adopt an embedded tight joint structure. Without a cold water flow limiting device, they are not affected by water pressure differences. Once the temperature is set, no repeated adjustment is needed, which reduces operational wear and makes the product more durable.

4. Energy saving. Stable water temperature maintained without frequent adjustment effectively avoids water waste, so the product is more water-saving and energy-efficient.

There are many similar products available on the market, which will not be elaborated here. After sorting out a large amount of online data, it is found that existing shower systems are equipped with constant temperature control devices. The innovative points of this paper are summarized as follows:

First, this design targets a wide range of users. For children and the elderly in particular, simple constant temperature cannot meet personalized demands and may even cause safety hazards. Thus, intelligent temperature regulation combined with ambient temperature and humidity monitoring is a more practical design with greater social value.

Second, this project adopts Arduino and Mind+ for development, featuring lower development cost and stronger practicality. Experimental tests verify that the device fully meets the design requirements with complete functions.

Third, most current researches focus on intelligent shower heads. There are no cutting-edge research reports on overall intelligent control of shower systems, so this study has prominent innovation.

2. Theoretical research

2.1. Features of SMA (Shape Memory Alloy) thermostatic valve cartridge

Shape memory alloys can respond rapidly to changes in hot water temperature and restore their original shape instantly. When hot water flows into the valve body, the SMA spring will return to its initial state and adjust the water temperature back to the set level [1]. This structure minimizes the abrupt rise of water temperature (temperature overshoot).

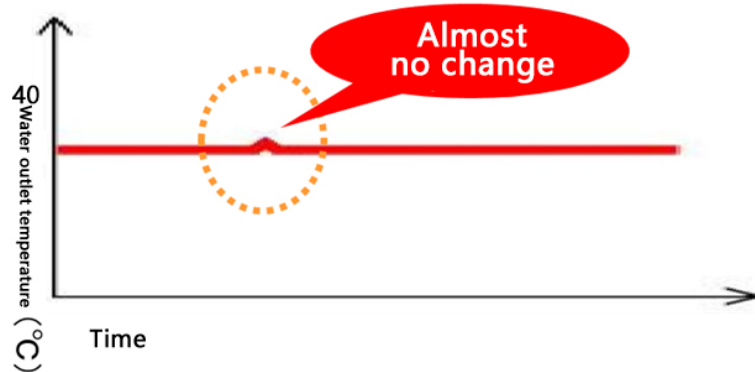


Figure 1. Water temperature change curve of SMA thermostatic valve cartridge (negligible water temperature fluctuation)

In comparison, traditional floating body type valve cartridges will cause obvious temperature overshoot. When hot water enters the valve body and the hot water side of the mixing valve is opened, a surge of hot water will flow out temporarily, leading to a sharp rise in water temperature [see Figure 2 for details].

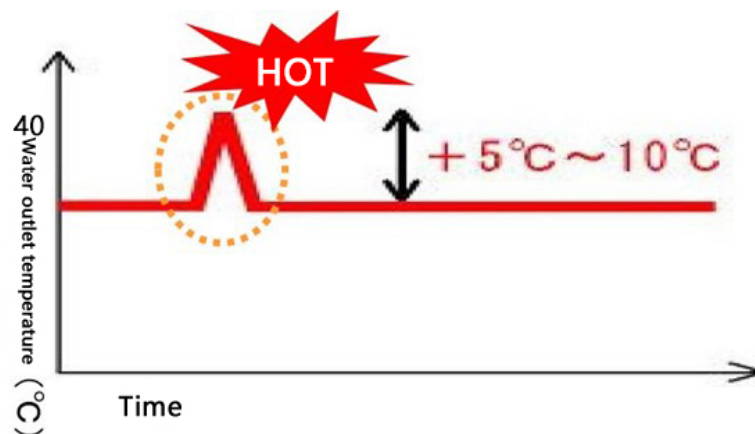


Figure 2. Temperature overshoot curve of traditional floating body type valve cartridge (water temperature rises sharply by 1~5°C to 10°C)

2.2. Structure of thermostatic regulating valve cartridge

Hot and cold water flow into the mixing chamber along the route marked by arrows in the sectional view and then flow out. The temperature sensing part adopts an SMA (Shape Memory Alloy) spring, which can perceive the incoming water temperature instantly. Balancing with the bias spring, the

SMA spring drives the mixing valve to operate and automatically adjust the inflow volume of hot and cold water [see Figure 3].

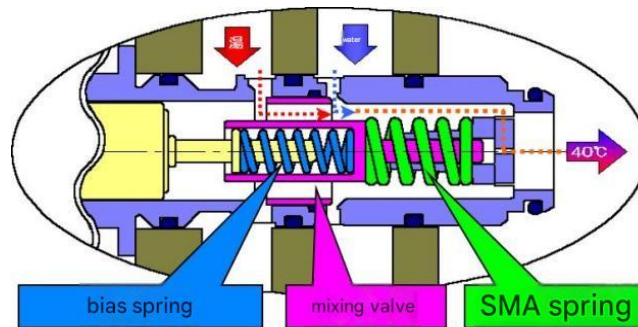


Figure 3. Schematic diagram of structure and water flow direction of thermostatic regulating valve cartridge

(1). Working principle of temperature regulation (when outlet water reaches 40°C)

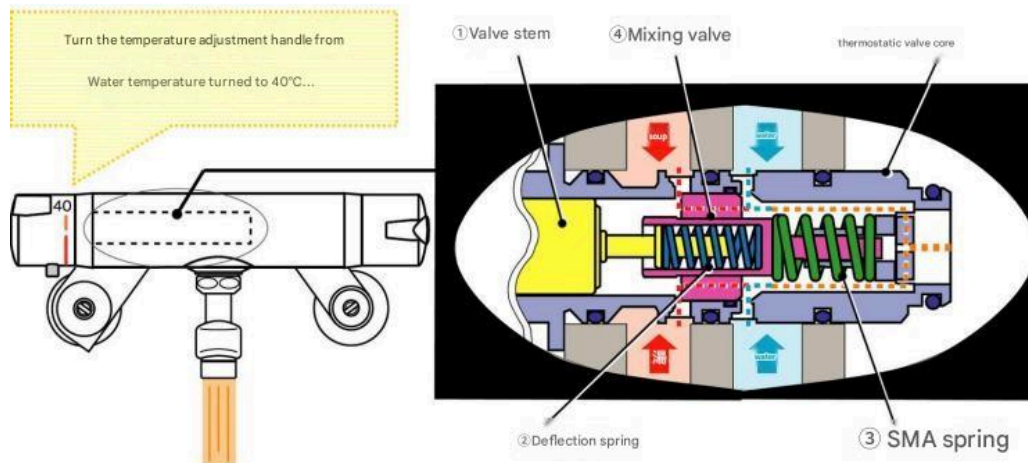


Figure 4. Schematic diagram of the working principle of thermostatic regulating valve cartridge when outlet water reaches 40°C

1. Turn the temperature adjusting handle to move the valve body rightward.
2. The bias spring is compressed.
3. The SMA spring contracts to balance the force of the bias spring, driving the mixing valve to work and allowing hot water to flow in.
4. The SMA spring stretches and contracts with temperature changes to keep the hot water temperature stable.

(2). Working principle of temperature regulation (when outlet water temperature drops)

1. Reduce the inflow of hot water to lower the water pressure and decrease the outlet water temperature.
2. The SMA spring perceives the temperature change.
3. The elastic force of the SMA spring weakens, so its thrust on the mixing valve is reduced.
4. The bias spring pushes the mixing valve rightward to rebalance the force. The inflow of cold water is reduced while the inflow of hot water is increased, so the outlet water temperature returns to the set value.

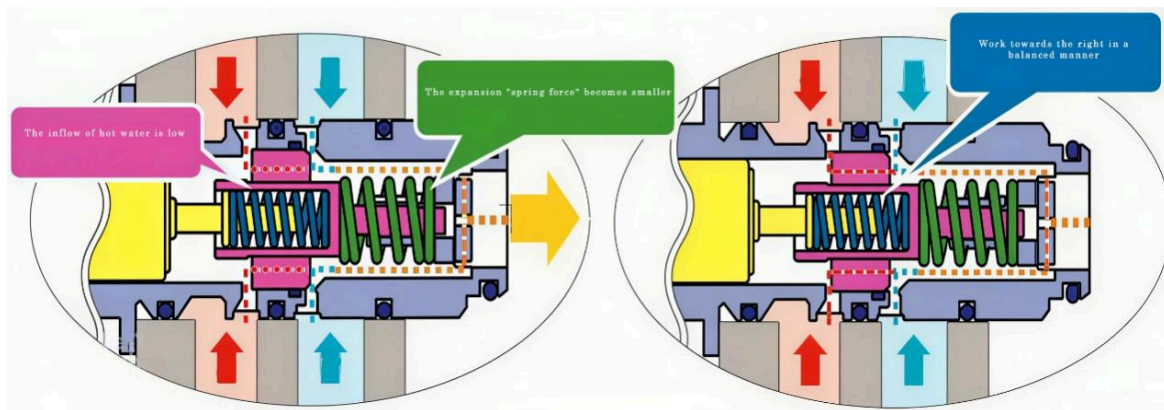


Figure 5. Schematic diagram of the working principle of thermostatic regulating valve cartridge when outlet water temperature decreases

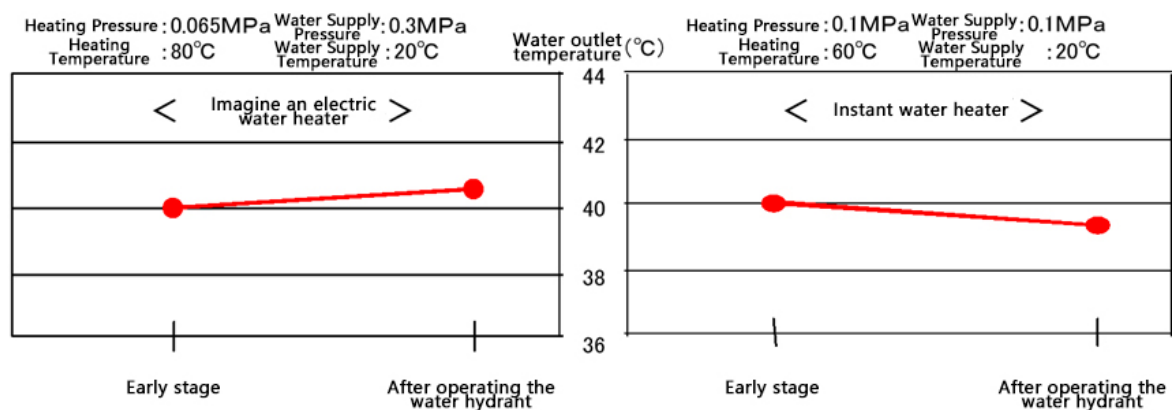


Figure 6. Schematic diagram of valve cartridge movement when shower water temperature recovers to the set value

3. Scheme design

This part presents the overall scheme design of the project. A complete shower system is designed in this study. Environmental sensors are installed on the shower head, with Bluetooth signal transmitters and receivers arranged externally. The collected signals are transmitted to the temperature controller and water heater to adjust the water temperature. The main operation process is as follows: when the environmental sensors detect that the ambient temperature is too high or too low, they send a signal of temperature increase or decrease to the main control board. The signal is then transmitted to the temperature controller via Bluetooth, and the temperature controller further drives the water heater to perform corresponding operations [2].

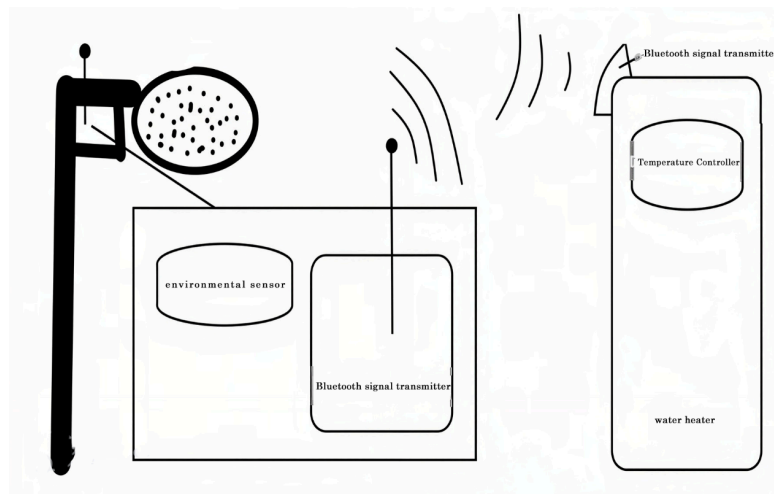


Figure 7. Overall scheme design diagram of the intelligent temperature control system for showers

4. Software and hardware development

To complete the prototype under existing conditions, Arduino UNO is selected as the main control board, Mind+ is adopted as the programming platform, and programs are compiled with LED modules and environmental sensors [3].

Arduino UNO Main Control Board:

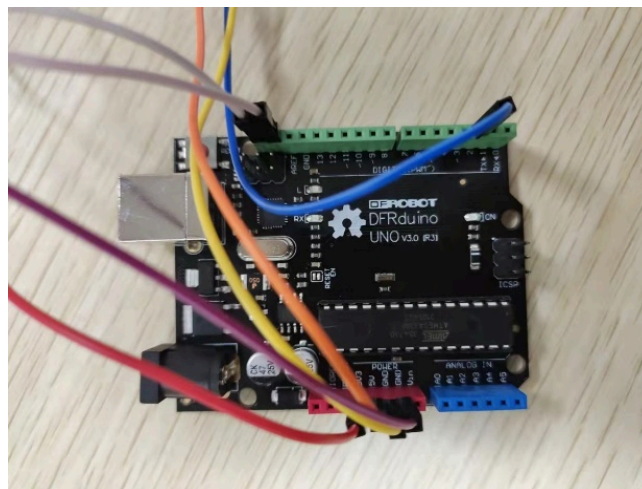


Figure 8. Physical picture of Arduino UNO main control board

DFRduino UNO R3 is an open-source simple I/O platform. It supports a development environment similar to Java and C languages, enabling users to quickly create interactive works with Arduino language and software such as Flash and Processing. In this project, it serves as the main control board to process data collected by functional components.

LED Module:

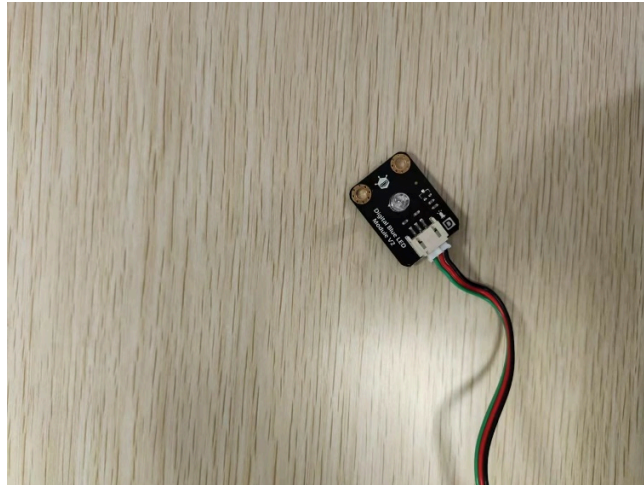


Figure 9. Physical picture of LED module

LED (Light Emitting Diode) is a type of semiconductor diode made of compounds containing gallium (Ga), arsenic (As), phosphorus (P), nitrogen (N) and other elements, which can convert electric energy into light energy. When electrons combine with holes inside the diode, visible light is emitted. LEDs are widely used as indicator lights or for character and digital display in circuits and instruments. In this design, LEDs replace buzzers to send reminders and warnings when the water temperature rises.

Environmental Sensor:

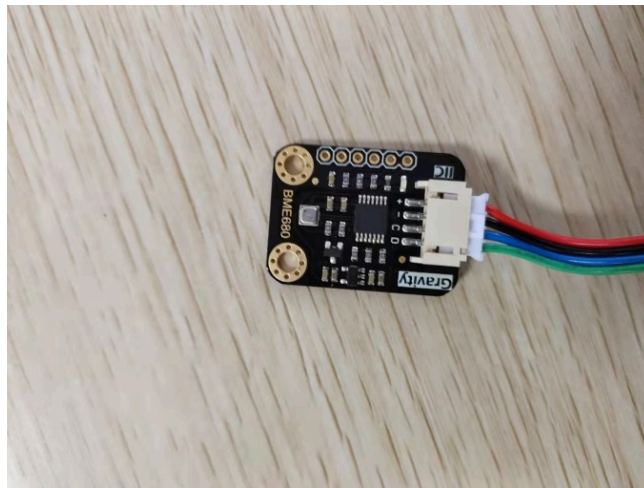


Figure 10. Physical picture of environmental sensor

The adopted environmental sensor is a four-in-one MEMS environmental sensor (BME680), which can measure four parameters including VOC (Volatile Organic Compounds), temperature, humidity and air pressure. It is highly suitable for temperature monitoring. Adopting MEMS technology, the sensor features small size and low power consumption, so it can be applied to low-power scenarios such as wearable devices. It is an ideal choice for weather stations, smart home systems, the Internet of Things and wearable devices. Its compact size makes it the preferred temperature detection component for this intelligent shower system.

Programming:

The program is compiled on the Mind+ programming platform. Launched in 2013, Mind+ is one of the earliest graphical programming tools in China and has gained wide recognition across the industry after continuous optimization. It supports mainstream open-source hardware platforms including Arduino, micro:bit and ESP32, as well as a large number of extended electronic modules. It covers science and innovation education fields such as artificial intelligence and the Internet of Things, making it an ideal platform for program development. The program starts with the initialization of the BME680 sensor. The second program segment sets a judgment condition: when the value detected by the BME680 sensor is higher than 20, the main control board will turn on the LED connected to Pin 2 for one second and then turn it off for another second. The third segment realizes serial port string output to read the temperature data collected by the BME680 sensor. The whole program is thus completed.

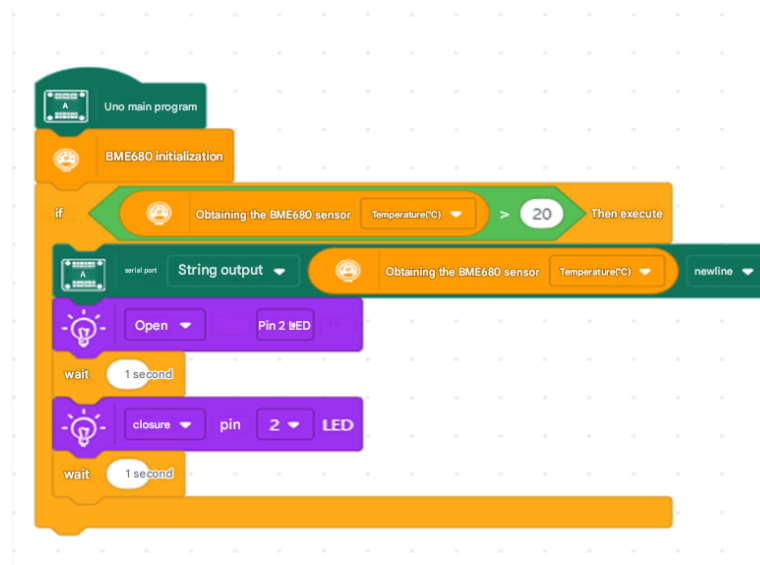


Figure 11. Flow chart of main control program for UNO based on Mind+

After completing hardware assembly and program compilation, the physical model was manufactured and software tests were carried out. The whole process is recorded as follows.

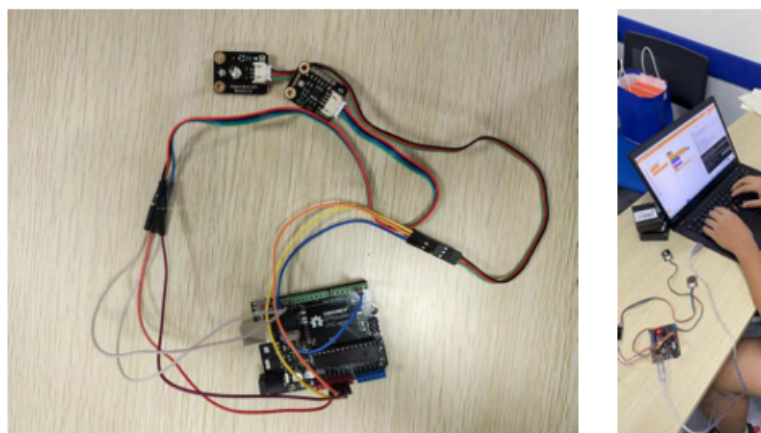


Figure 12. Photos of hardware assembly and model manufacturing of the intelligent temperature control system

Test results show that the device can accurately measure ambient temperature, humidity, air quality and other indicators, and the collected data fully meet the requirements of temperature control. In the simulation test, radio frequency communication is used to transmit temperature signals to realize remote temperature regulation, achieving the expected test effect. Therefore, the proposed design conforms to the design specifications and satisfies all functional requirements [4, 5].

5. Conclusion and prospect

This design develops an intelligent temperature control system for showers based on environmental sensors. The system can also monitor ambient humidity and air quality to create a comfortable shower environment. The project prototype is developed with Arduino and Mind+. Through scheme optimization and experimental verification, the system finally reaches the preset design standards. This product can be popularized in every household, with promising commercial prospects and strong implementability [6]. Nevertheless, this research still has some limitations, and instantaneous real-time temperature control has not been fully realized. In the future, it is expected that such high-tech products can enter ordinary families, bring convenience to people's daily life and deliver more benefits to the society.

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