STM32-Based Contactless Temperature Measurement and Identification Device

Weiran Xia¹, *, Jiantao Yan² and Yunzhe Li¹

¹School of Information Engineering, Wuhan University of Technology, Wuhan, China
²School of automotive engineering, Wuhan University of Technology, Wuhan, China

*Corresponding author: 282593@whut.edu.cn

Abstract. In recent months, in the epidemic prevention and control in the early stages of the war, the shortage of emergency supplies, supply shortages, global procurement of basic products cannot meet demand and other issues are still fresh in people's minds. At the same time also let a once unknown ordinary product is a great success, which is non-contact infrared thermometer, also commonly known as handheld ear and forehead temperature gun, he plays an irreplaceable important role in the epidemic prevention and control, and if the temperature can be measured at the same time, the use of deep learning to identify and record the identity, then the promotion of the thermometer will be more successful.

Keywords: face recognition, temperature detection, deep learning.

1. Design background
The thermometer designed in this paper uses the STM32F407ZGT6 microcontroller as the control core, and achieves contactless temperature measurement and identity mask recognition for the measured person by using the identity recognition module, mask recognition module, temperature detection module and power supply module. The system uses MLX90614 module and laser distance measurement module to complete the contactless temperature measurement for human body through the algorithm of distance compensation. By using deep learning algorithm, the K210 module is used to deep learn and extract facial features from the member pictures, and finally determine the identity of the subject and carry out epidemic prevention detection. After the final measurement and debugging, this system has achieved the basic requirements of the topic and played part of all functions.

2. System solution

2.1. Solution analysis and comparison

(1) Face recognition program selection
Solution 1: Adopt OPENMV4 camera module for LBP eigenvalue detection to distinguish different face images to identify different people. The LBP eigenvalue recognition algorithm starts from a statistical point of view by recognizing the face feature points in the image and distinguishes different identities according to the matching difference of different feature points. The logic of this scheme is simple and easy to understand, and the program is more convenient to write. The disadvantage is that
the recognition accuracy is poor, it cannot automatically learn and analyze the face module in all aspects, and the error is large.

Solution 2: K210 camera module is used to capture the facial features of people through deep learning algorithm and continuous reinforcement learning, so as to continuously improve the accuracy and finally complete the member recognition. This scheme has higher recognition accuracy and can be continuously improved, and has more room for improvement. However, the running code involves artificial intelligence learning algorithm, which is more complex and costly to understand.

(2) Temperature measurement distance compensation scheme selection

Solution 1: Use MLX90614 with ultrasonic range module for temperature measurement. The ultrasonic range module can calculate the distance by the time difference between transmitting and receiving ultrasonic waves, but the actual measurement found that the ultrasonic module has a large interference in the close distance within 1-10cm, resulting in the general accuracy of range measurement.

Option 2: Use MLX90614 with laser distance measurement module for temperature measurement. The laser module emits a very thin laser beam to the target object, the laser beam reflected from the target is received by the photoelectric element, and the timer determines the time required to calculate the distance from the observer to the target. The accuracy of commonly used modules is generally around 0.1cm. Laser distance measurement module measurement time is shorter and less susceptible to external influences.

Comprehensive consideration, as the topic requires temperature measurement within 1-4cm, the ultrasonic module in the close range of interference, so the use of higher precision program two.

(3) Mask identification scheme selection

Option 1: Using K210 camera module for deep learning algorithm, by giving K210 member masks picture set and continuously identify learning, K210 can better learn to identify various cases of masks with or without the situation and automatically generate a set of recognition algorithm to discriminate masks. The method can make correct judgments for the status of masks in most cases. The disadvantage is that the module needs a large amount of mask image data for a long learning exercise to generate.

Solution 2: Adopt OPENMV4 camera module for color recognition, set a fixed mask color, and detect whether the mask of the relevant color is recognized through color recognition. The process of this scheme is relatively simple, but the uncertainty and universality of mask color leads to mask recognition results are highly prone to errors.

Taking into account, since K210 has higher recognition accuracy and more room for learning progress, it can better meet the requirements of the topic, so Option 1 is adopted.

2.2. Overall system solution design

The system mainly consists of five parts: face recognition module, temperature measurement module, mask recognition module, power supply module, and main control module. The power supply module outputs +5V to supply power to each module, and the main control module can continuously accept data from the temperature measurement module and display it, and can also continuously switch between face recognition mode and mask recognition mode and display the operation results through the keypad.

The architecture block diagram of the system is shown in Figure 1.
3. Theoretical analysis and calculation

3.1. Temperature compensation calculation

Since the MLX90614 alone will show great attenuation with increasing distance, the temperature difference at different distances is measured using the laser distance measurement module $y$ and then use the least squares method to find the temperature difference $\Delta T$ and distance $x$ and the first-order linear regression equation $\Delta T = a \cdot x + b$. The first-order linear regression equation for temperature difference versus distance is then obtained by using least squares to fit the temperature difference function and to revise the original measurement. The equation for the least squares linear regression equation is shown in Equation 1

$$a = \frac{\sum_{i=1}^{n} (x_i - \bar{x})(\Delta T_i - \bar{\Delta T})}{\sum_{i=1}^{n} (x_i - \bar{x})^2}$$

$$b = \bar{\Delta T} - a\bar{x}$$

Observe the experimental measurement data and find that when $2 < x < 300 \text{ cm}$ When the temperature difference curve roughly satisfies the first-order linear regression equation, so the measured values are substituted into the above equation to obtain $a = -0.1, b = 28.5$.

3.2. Theoretical justification of identity recognition algorithm

K210 is loaded with face detection model, face five-point key detection model and face 196-dimensional eigenvalue model trained on the voloy3 platform. Face recognition is first performed on the camera captured image to find the location of the face in the image, and then further on the recognized face, the five-point key detection model of the face is used to extract the 5-point coordinate information of the

![System block diagram](image-url)
human standard face and further calculate the 196-dimensional feature value of the positive face image. In the face information entry mode, the calculated feature values are saved. In face recognition mode, the feature value calculated in this recognition is compared with the feature value of the previous matching entry iteratively to find the maximum value of the iteration score, and the identity is considered to be matched if this score is higher than 85.

4. Hardware circuit design

4.1. 1.5V step-down circuit design

Each module of the system requires a DC 5V regulated power supply from the power supply module, so the LM7805 step-down chip is used to design the 5V step-down circuit. After the filtering effect of the battery output DC 12V and the step-down effect of LM7805, the output of the regulated power supply produces a high precision and stable DC output voltage for the whole system, shown in Figure 2.

![Buck circuit schematics](image)

**Figure. 2** Buck circuit schematics

4.2. Laser distance measurement circuit design

The laser range module consists of a voltage regulator and a range measurement circuit, which supplies power to the VL53L0X chip through its own ultra-low dropout voltage regulator chip, making the external power supply selectable from 5V or 3.3V. The VL53L0X chip communicates with the external circuit through the IIC, allowing accurate return of distance parameters. The laser distance measurement circuit schematic is shown in Figure 3.

![Laser distance measurement circuit schematics](image)

**Figure. 3** Laser distance measurement circuit schematics

5. Software programming

The STM32F407, as the master chip of this system, mainly completes the human-computer interaction control and the scheduling and receiving and sending of the three recognition detection modules, while the K210, as the slave, is mainly responsible for the operation of the face recognition module and the data transmission with the STM32F407. The human-computer interaction part is mainly completed by controlling the serial screen and the keypad, and the three recognition detection modules transmit data with the microcontroller through the serial port.

The STM32F407 and K210 software flowchart is shown in Figure 4.
(1) K210 can switch sensitively between recognizing portraits and accepting portraits by pressing a button and continuously cycle through the recognition.

(2) The key control of the main control realizes the selection of three modes of temperature measurement, face recognition, and mask detection.

(3) The serial interface screen can send and receive data through the serial interface to achieve the function of human-computer interaction.

Figure. 4 STM32 and K210 software flow block diagram

6. Test protocol and test results

6.1. System test program
(1) Face recognition test
After recording the facial information of three volunteers, the face recognition results were tested 20 times and the number of correct identifications was recorded, then after temporarily recording the facial information of the fourth new volunteer, the face recognition results were continued to be tested 20 times and the number of correct identifications was recorded. The above link was repeated six times in different test environments, and the test results are shown in Table 1.

| Serial number | 1   | 2   | 3   | 4   | 5   | 6   |
|---------------|-----|-----|-----|-----|-----|-----|
| Number of correct tests in the first group | 18  | 19  | 20  | 19  | 20  | 20  |
| Number of correct temporary entry tests    | 20  | 20  | 20  | 19  | 20  |

As can be seen from the table, the test results were 94% correct.

(2) Temperature test
Starting from 1cm, the temperature sampling was performed every 1cm and the temperature difference with the actual temperature was calculated, after which the test was continued to a long
distance until the distance measured when the temperature difference was greater than ±2℃ was recorded. The test results are shown in Table 2.

| Testing distance (cm) | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 50 |
|----------------------|-----|-----|-----|-----|-----|-----|-----|----|
| Temperature difference (℃) | 0.5 | 0.8 | 0.2 | 0.3 | 0.4 | 1.0 | 1.4 | 2.1 |

As can be seen from the table, the average error of temperature test 1-4cm is 0.914℃, which is less than 2℃ and better than the requirement of the topic. The farthest temperature measurement distance is 50cm, which meets the needs of daily life and work.

(3) Mask identification test

Test site five members wearing or not wearing mask state a total of 20 times, record the number of times to identify the correct, the above test session in different test environment repeated six times, test results are shown in Table 3.

| Identifier number | 1 | 2 | 3 | 4 | 5 |
|-------------------|---|---|---|---|---|
| Number of recognitions | 20 | 20 | 20 | 20 | 20 |
| Number of times correct | 20 | 20 | 20 | 19 | 20 |

As can be seen from the table, the correct recognition rate of the mask is as high as 99%, and it can recognize difficult recognition situations such as wearing non-standard, hand covering the mouth, which meets the daily work requirements.

6.2. Test results and analysis

The system has obtained a reasonable design of contactless thermometer through theoretical calculation, and through actual testing, its face recognition confidence is above 90%, mask recognition confidence is above 90%, and the temperature measurement module accuracy has been within ±2℃ and the farthest measurement distance can reach 50cm. In summary, this system meets the indicators of commonly used thermometers, and can be applied to various living and working scenes, and may be useful in the future the anti-epidemic war may be able to play a role.

References

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