

A Networked Novel Smart Helmet for Human Health Monitoring

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Abstract: This paper designs a networked novel smart helmet for human health monitoring. By integrating a multi-sensor component (heart rate sensor module, body temperature monitoring module, and Beidou dual positioning module, etc.) and combining it with wireless network transmission technology, it has realized the instant feedback and cloud management functions of physiological data and spatial information. This device can not only continuously track the vital signs parameters of the wearer such as heart rate and body temperature but also dynamically capture environmental variables such as movement trajectory and speed, forming a multi-dimensional health assessment network. The promotion and application of this design are expected to significantly optimize the timeliness and data accuracy of individual health monitoring and have positive value in promoting the development of a smart and healthy lifestyle.

Keywords: Smart Helmet; Health Monitoring; Networking; Heart Rate Sensor; Body Temperature Sensor.

1. Introduction

With the development of science and technology and the continuous improvement of people's health awareness, traditional health monitoring methods can no longer meet people's growing health needs. Intelligent and networked health monitoring devices are becoming increasingly popular. Therefore, this paper designs a networked novel smart helmet for human health monitoring, aiming to provide users with more convenient and efficient health monitoring services, that is, users can always understand their own physical condition, detect potential health problems in time, and then take corresponding preventive and treatment measures. Meanwhile, this design can not only be used for daily health monitoring but also for health monitoring during outdoor sports and driving. This not only helps to enhance people's health awareness and health level but also helps to reduce the burden on the medical system, promote the popularization and optimization of health management, and improve the safety of outdoor sports and driving. By integrating a variety of sensor technologies and wireless network technology, the smart helmet can monitor the wearer's physiological indicators and changes in the surrounding environment in real-time, providing strong support for users' health management.

2. Overall programme design

This design is a networked novel smart helmet for human health monitoring based on the combination of STM32 series microcontroller and cloud service platform, integrating various functional modules to provide comprehensive and real-time data support. The system mainly consists of several parts: the core processing unit, sensor module, power management module, communication module, alarm module, and software system. The core processing unit adopts the STM32 microcontroller series, ensuring the system's real-time performance and stability with its high performance and low power consumption. The sensor module includes physiological monitoring sensors, motion state sensors, and environmental perception sensors, which are used to monitor

heart rate, body temperature, speed, posture, and environmental information in real-time, providing detailed physiological indicators and environmental condition data for people. The power management module is responsible for providing a stable power supply for the entire system, ensuring the stable operation of the system during long-term use. The communication module uses wireless communication technology to achieve real-time data transmission between the helmet and the upper computer or other devices, enabling people to view and analyze physiological indicators and environmental condition data at any time. The alarm module alarms through sound or light when it receives abnormal data to ensure people's health and safety. The software system, which combines cloud computing and Internet of Things technology, is responsible for the control and data processing of the entire system, including data acquisition, processing, transmission, and alarm control functions. It ensures the normal operation of the system and the accuracy of the data, and uses artificial intelligence and big data analysis technology to analyze people's various physiological indicators, thereby achieving uninterrupted human health monitoring and achieving the purpose of early diagnosis and follow-up visits. The overall system scheme design is shown in Figure 1.

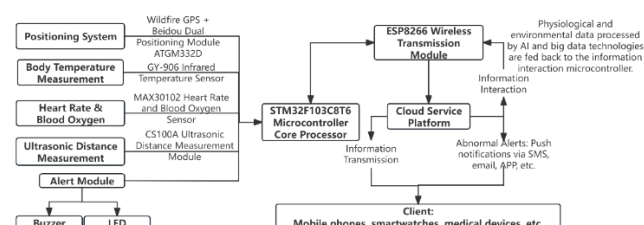


Figure 1. Overall system scheme design

3. System Hardware Design

3.1. Wildfire GPS + Beidou Dual Positioning Module ATGM332D

This module utilizes the 4th-gen low-power AT6558 GNSS SoC (supporting BDS, GPS, SBAS) for position/speed

monitoring. Key specs include 12×16mm size, -148dBm cold-start/-162dBm tracking sensitivity, 2.5m CEP50 positioning accuracy, 32s first fix time, and <25mA operational power. Featuring a serial interface (TX/RX connected to STM32's PA9/PA10 pins), it enables bidirectional data transmission while maintaining high sensitivity, precision, and energy efficiency.

This module calculates user position by analyzing satellite-transmitted pseudorandom codes, comparing timing data to determine satellite distance, and processing ephemeris information to derive WGS-84 coordinates. Collected data is stored internally, transmitted via serial port to the STM32 microcontroller for processing, then displayed locally and relayed to cloud platforms through the ESP8266 module, ultimately delivering navigation services to end-users [1][3]. Figure 2 shows the circuit diagram of the ATGM332D module.

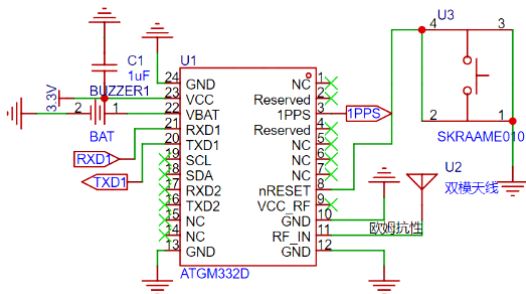


Figure 2. Circuit diagram of the Beidou dual positioning module.

3.2. GY-906 Infrared Thermometer Sensor

The GY-906 infrared sensor (see Figure. 3) [2][3] enables non-contact temperature monitoring (-40°C to 125°C range, ±0.3°C human-body accuracy) in smart helmets via infrared detection. Operating at 3.3V with low power consumption, it transmits real-time data to the STM32 microcontroller via I²C interface. Processed temperature information is relayed through the ESP8266 module to cloud platforms and user clients, offering stable, rapid-response (<1s) health monitoring support.

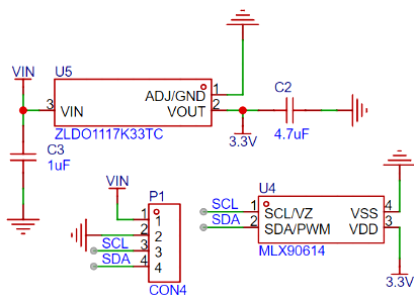


Figure 3. Circuit diagram of the GY-906 infrared thermometer module.

3.3. MAX30102 Heart Rate and Blood Oxygen Sensor

The MAX30102 sensor (see Figure. 4) employs PPG technology with dual LEDs (red/infrared) and a photodetector to monitor heart rate (60-100 BPM range) and blood oxygen saturation (±2% accuracy) in real time. Operating at 1.8~3.3V with low power consumption, it connects via I²C interface (SCL-PB6, SDA-PB5) to the STM32 MCU for data processing. Designed for integration into portable smart helmets, it delivers high-sensitivity physiological metrics to support health monitoring systems [3][7].

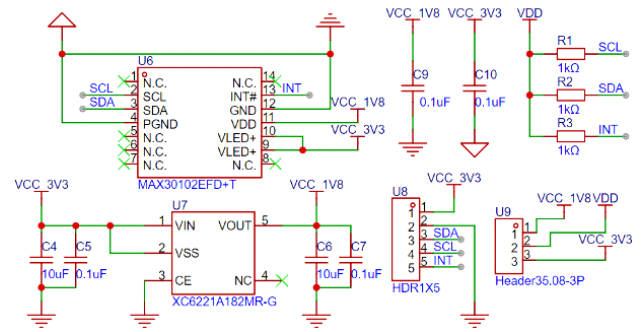


Figure 4. Circuit diagram of the MAX30102 heart rate and blood oxygen sensor.

3.4. CS100A Ultrasonic Ranging Module

The CS100A ultrasonic ranging module (see Figure. 5) integrates transmitter, receiver, and digital processing circuits for obstacle detection in smart helmets. Operating at 3~5.5V with 5.5mA current, its compact size (45×20×15mm) enables seamless integration. Triggered by a >10μs TTL pulse on the TRIG pin, it emits eight 40kHz ultrasonic bursts and calculates distance via echo duration using the formula (high-level time × 340m/s)/2. With a 2cm~450cm range, millimeter-level precision, <15° beam angle, and -10°C to +60°C operational range, it provides real-time proximity monitoring to enhance wearer safety [4][8]. Distance data is output as pulse width through the ECHO pin for environmental perception.

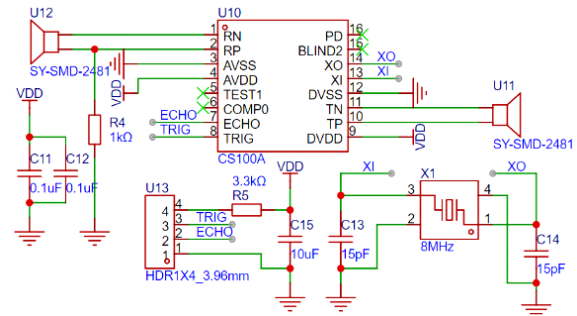


Figure 5. Circuit diagram of the CS100A ultrasonic ranging module.

3.5. Alarm Module

The alarm module (see Figure. 6) combines multi-color LEDs and a buzzer for dual-mode alerts in smart helmets. LEDs signal warnings via color/frequency variations (e.g., rapid red flashes for emergencies, slow yellow for abnormalities), operating at 2-3V/20mA via GPIO. The buzzer generates frequency-specific tones at 3~5V with <50mA current [4]. When health anomalies occur, the STM32 activates synchronized light-sound alerts through GPIO control, ensuring timely user notification for safety-critical responses.

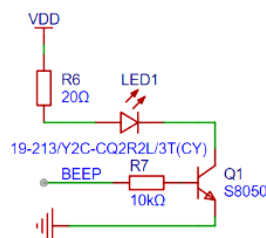


Figure 6. Circuit diagram of the alarm module.

3.6. ESP8266 Wireless Transmission Module

The ESP8266^[10] Wi-Fi module (see Figure. 7) enables wireless data transmission in smart helmets, supporting 802.11b/g/n protocols at 2.4GHz with 150Mbps throughput. This low-power, low-cost IoT module operates in AP/STA modes and utilizes AT commands for configuration. Connected via UART to the STM32 microcontroller, it relays processed health/environmental data to cloud platforms, achieving networked connectivity. Its serial interface ensures seamless integration with sensor data streams for real-time cloud communication.

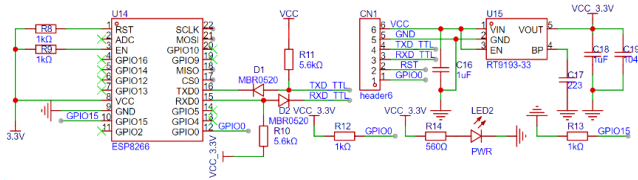


Figure 7. Circuit diagram of the ESP8266 module.

4. System Software Design

The overall system software design revolves around real-time information feedback on the client side, cloud service platform, and helmet edge subsystem, utilizing wireless communication technology to achieve data transmission among them. The client-side APP is built with the Java language, receiving signal status information processed by the cloud service platform and feeding it back to the user; the cloud service platform consists of a cloud computing server^[3] (responsible for real-time data processing, with a high-performance architecture and fault tolerance mechanism), a cloud database (storing physiological and environmental data in a distributed manner to ensure security and integrity), a cloud file repository (storing files using object storage technology to ensure security and privacy), a cloud data abnormality warning module (detecting abnormalities according to preset rules and notifying users), and an MQTT communication server (enabling real-time data transmission and command issuance between the helmet system and the cloud platform); the client, helmet edge end, and cloud service platform transmit data and warning information through the MQTT communication server, forming a closed-loop communication system to provide users with health management and safety assurance services^[5]. The specific process is shown in Figure 8.

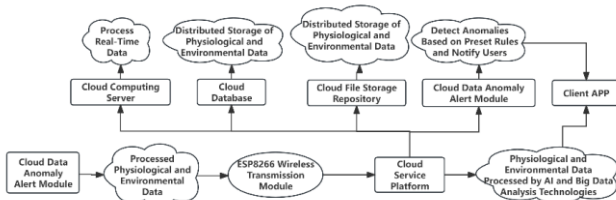


Figure 8. System software design flowchart.

4.1. Client Layer (Mobile End)

The client layer, namely the mobile end, is an Android client APP based on Java, adopting an object-oriented design pattern. It is equipped with core functions such as real-time reception and visualization of physiological indicators processed by the cloud (e.g., body temperature, blood oxygen) and environmental data (e.g., speed, position), pushing warning information (via SMS or APP notifications), and

implementing user interaction interface and configuration management.

4.2. Cloud Service Layer (Platform End)

The software design of the cloud service layer (platform end) ^[6] is composed of several subsystems. The cloud computing server, employing load balancing and fault tolerance mechanisms, is responsible for real-time data processing, analysis, and forwarding, ensuring stability under high concurrency. The distributed cloud database, utilizing MySQL/NoSQL technology and data backup and recovery functions, stores structured data such as physiological indicators and environmental parameters. The object storage repository, leveraging object storage (e.g., AWS S3) and data encryption technology, manages unstructured data like videos and images. The abnormality warning module, through threshold detection and rule engines, monitors data abnormalities in real-time and triggers multi-channel alarms, supporting custom rules. The MQTT communication server, based on the MQTT protocol and Topic subscription and publishing mechanism, acts as a data transfer hub connecting the client and edge ends.

4.3. Edge End Layer (Hardware End)

The software design of the edge end layer (hardware end) centers on the STM32F103C8T6 microcontroller and ESP8266 wireless transmission module as hardware cores. It is capable of sensor data acquisition (for physiological and environmental signals) and preprocessing, can encapsulate and parse MQTT messages, achieve bidirectional communication with the cloud, and control the local alarm module based on received cloud warning instructions.

4.4. Edge End Layer (Hardware End)

The software design of the communication mechanism [9] covers the data transmission process and key technical characteristics. The data transmission process is divided into the uplink (see Figure 9), where data travels from the sensor through the STM32, ESP8266 module, MQTT server, cloud computing server, and finally reaches the database or repository; and the downlink (see Figure 10), where warning information is sent from the warning module, through the MQTT server and STM32, to trigger the local alarm module or push notifications to the APP. Key technical characteristics include: leveraging the lightweight nature of the MQTT protocol and its QoS tiered support to ensure real-time performance and achieve low-latency communication; ensuring reliability through cloud load balancing and edge end reconnection mechanisms to maintain stable communication; and safeguarding security through transport layer encryption (TLS), storage data encryption (AES), and access control.

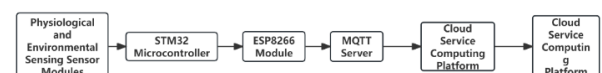


Figure 9. Data transmission uplink diagram.

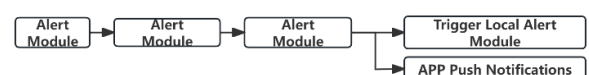


Figure 10. Data transmission downlink diagram.

5. Testing and Validation

5.1. Positioning System

The positioning accuracy and cold start time of the ATGM332D module were verified. In an open area, the smart helmet and a high-precision GPS receiver were used simultaneously to record longitude and latitude data, and the positioning error and first positioning time were statistically analyzed. The results showed that the positioning error was within 2.5 meters (CEP50), and the average cold start time was 32 seconds, consistent with the module's nominal values. The data results are shown in Figure 11.

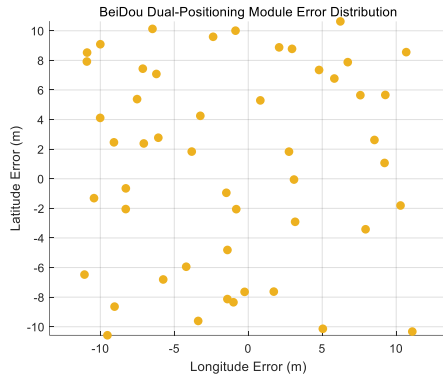


Figure 11. Positioning system function test diagram.

5.2. Body Temperature Sensor Test

The accuracy and stability of the GY-906 infrared thermometer module were verified. Under room temperature conditions, a high-precision infrared thermometer gun and the helmet sensor were used simultaneously to measure the forehead temperature of the same subject, with 50 sets of data recorded. As shown in Figure 12, the measurement error range was $\pm 0.2^{\circ}\text{C}$, with a standard deviation of 0.08°C , indicating that the sensor has high stability.

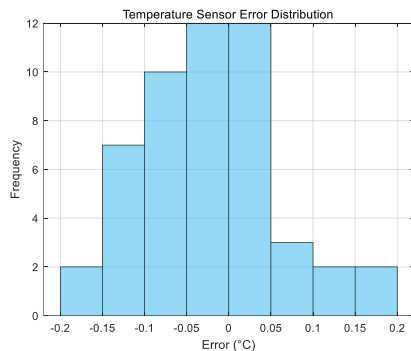


Figure 12. Body temperature sensor function test diagram.

5.3. Body Temperature Sensor Test

The measurement accuracy and real-time performance of the MAX30102 heart rate sensor were verified. The smart helmet was worn by 10 subjects, while a medical-grade heart rate monitor (ECG heart rate monitoring watch) was used simultaneously to record data. The test results shown in Figure 13 indicate that the maximum error between the heart rate measured by the smart helmet and that measured by the medical-grade device was $\pm 2\text{BPM}$, with an average error of $\pm 0.8\text{BPM}$, meeting the requirements for daily health monitoring.

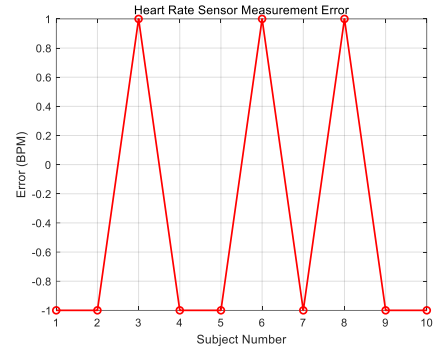


Figure 13. Heart rate sensor function test diagram.

5.4. Data Transmission Real-time Test

The wireless transmission delay of the ESP8266 module was verified. The helmet continuously sent 100 sets of data to the cloud, and the end-to-end transmission time was recorded and analyzed. As shown in Figure 14, the average transmission delay was 120ms, with a packet loss rate of less than 0.5%, meeting the real-time requirements.

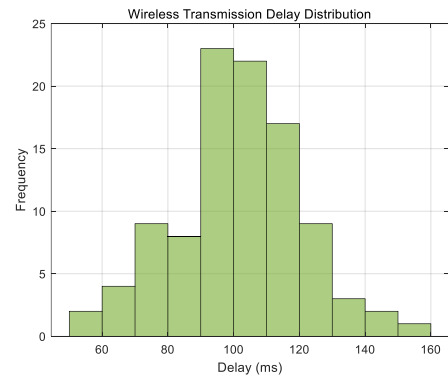


Figure 14. Data transmission real-time test diagram.

5.5. Alarm Module Effectiveness Test

The timeliness and accuracy of alarm triggering for abnormal data were verified. Three scenarios were simulated: abnormal heart rate ($>150\text{BPM}$), abnormal body temperature ($>38.5^{\circ}\text{C}$), and obstacle proximity ($<1\text{ meter}$), each tested 50 times. The alarm triggering time and false alarm rate were recorded. The results showed that the average alarm response time was 1.2 seconds, with a false alarm rate of less than 2% (see Figure 15). The LED and buzzer worked together, with a user perception rate of 100%.

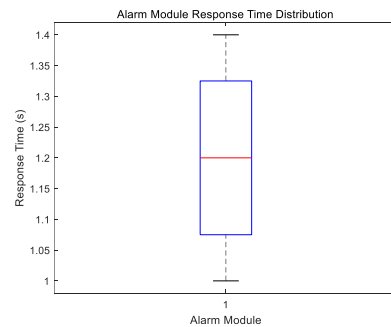


Figure 15. Alarm module effectiveness test diagram.

5.6. Ultrasonic Ranging Module Test

To verify the accuracy and stability of the CS100A ultrasonic ranging module, the following experiment was designed: in an indoor environment without strong noise

interference on a flat surface, a fixed obstacle (a flat wooden board) was set up. A laser rangefinder (with an accuracy of $\pm 1\text{mm}$) was used to calibrate the actual distance (50cm, 100cm, 150cm, 200cm), and each distance was measured 10 times. The measurement values of the ultrasonic module were recorded, and the error (measured value - actual value) was calculated to evaluate the error distribution and standard deviation of the module at different distances. The test results showed that the average error increased slightly with distance (see Figure 16), with an error of $\pm 0.5\text{cm}$ at 50cm and $\pm 1.2\text{cm}$ at 200cm. The standard deviation was less than 0.3cm for all distances, indicating good measurement repeatability. Linearity analysis showed a correlation coefficient of 0.999 between the measured values and actual values (see Figure 17), indicating high linearity of the module output.

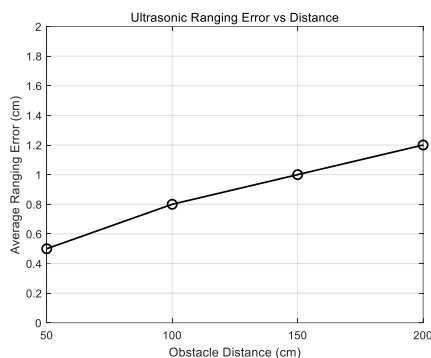


Figure 16. Ultrasonic ranging error variation with distance.

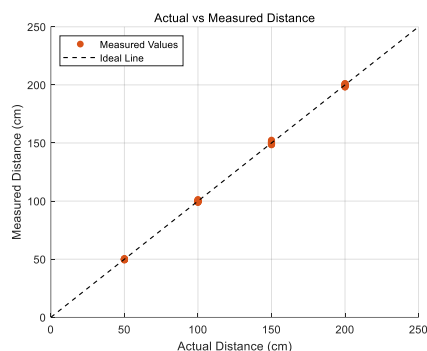


Figure 17. Comparison between ultrasonic ranging ideal value and measured value.

6. Conclusion

This paper designs a networked novel smart helmet for human health monitoring based on the combination of STM32 series microcontroller and cloud service platform. It integrates core processing, sensor, communication, alarm, and software system modules to collect and comprehensively monitor, analyze, and process human physiological indicators such as position, body temperature, and blood oxygen, as well as environmental data. The edge subsystem realizes local data processing, storage, and warning, the communication interface module ensures reliable communication, the local file storage module realizes data backup and query, artificial intelligence and big data analysis technology provide personalized suggestions, the data abnormality warning module ensures safety, the cloud service platform realizes cloud storage, processing, and analysis, and the client-side

APP facilitates users to view data and receive warning information. In terms of technological innovation and advantages, it has achieved technological integration and innovation by combining edge computing with cloud computing, improving the system's processing capabilities and scalability. It has also improved the warning mechanism by establishing a multi-level data abnormality warning system to handle abnormal data in a timely manner and ensure health and safety.

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