Application of BeiDou Navigation Satellite System in Anti-Drowning System

Yong Lei¹, Minghao Chen¹,³, Tianran Sun¹, Wenrui Li², Wensha Gou¹ and Yong Qin³

¹College of Electrical Engineering and Information Technology, Sichuan University
²Wu Yuzhang Honors College of Sichuan University
³chenminghaoscu@163.com

Abstract. Due to the high frequent drowning accident, a new type of drowning-preventing device established on the base of BeiDou Navigation Satellite System, using the compatibility of GPS tech, GSM, GPRS and other Internet of Things technology as well as Vital Signs Detection technology is designed. The situation whether a person is in drowning is judged by the device monitoring the heart rate and oxygen saturation. And the device utilizes Global Positioning System module to find exact location and uses GPRS to send the information of life signal and position. Based on the experiment, this system can decrease the rate of the drowning accident to some extent.

1. Introduction
Recently, drowning accident which causes death to have occurred frequently. By the statistics, seventy two thousand people lose their life annually because of drowning, occupying 7% of all deaths related injury[1]. Given the events of drowning, nowadays only the propaganda is made for preventing drowning in school, government unit and so on in China. And the effect is very limited due to the fact that it does not decrease the rate of drowning accidents effectively.

The core of control is microcontroller STM32 in this device. It also utilizes Beidou system and GPS, GSM communication, GPRS data transformation, humidity sensor and vital signs detection and other relevant technologies. The situation whether the person is near drowning or drowning is estimated by the device automatically. SOS will be sent automatically when it happens. The real-time heart beat rate, oxygen content of blood and positioning information are also contained in the SOS to make sure it could decrease the rate of drowning to the minimum.

2. System scheme design
This system is divided into two portions: satellite positioning communication system and vital signs detection system. When the humidity sensor in the device monitor that the device is below the water surface and the humidity is above a certain value, the BeiDou positioning system will start to locate the device user, process the coordinates of the location and estimate whether the user is in the lake and stream or not. When the user is located in water, the vital signs detection system will start to work and to make real-time monitoring of users’ vital signs and it also sends the first warning to the outside world. The user’s family is able to see the user’s real-time heart rate, blood oxygen content and position through this platform. When the vital signals of the user start to show abnormal fluctuation or have a tendency to go in the wrong way, the second warning will give a warning to the user through a
buzzer, alerting him to get back to the shore immediately. The user’s status will send to their families at once so they could ask for help from the closest fire station and the hospital if necessary. During this process, the vital signs detection system is responsible for the detection of user’s vital signal test and judging if the user is in drowning or not while the satellite positioning communication system is in charge of locating the position of human body and makes sure the message will be conveyed effectively. The combination of these two will help drowning people can be quickly known to the outside world and can be effectively given first aid.

2.1. Satellite positioning communication system

2.1.1. BeiDou satellite positioning technology. Satellite positioning technology of BeiDou is a Chinese independent strategic satellite navigation system which is aiming for the safety of people and the progress of China’s economy. The service, such like positioning, timing and communication all day long and so on, can be provided. The Beidou system can provide multiple fixed frequency navigation signals and use multi-frequency signal combination to improve the service accuracy. Beidou system also has the characteristic of rapid positioning, short message service and precise timing. Position system of Beidou has been developed rapidly in recent years and the positioning accuracy, power loss and other aspects have been improved greatly. The map of Beidou is expected to enter our life in May this year and the unique compatibility of BeiDou system can improve the accuracy of positioning through compatibility with other satellite systems.[2] Emergency message can be sent by the short message service of BeiDou system, when the communication stations where the site is used are no longer available or the location is not covered by a communication base. This means that the system can improve the efficiency of information transmission through two-way satellite signals information transmission. We can predict that the short message service will show excellent performance in remote ponds at rural areas and increase the applicability and dependability of this device.

2.1.2. GSM TECH. Belonging to the second generation cellular mobile communication technology. GSM can run on multiple radio frequencies, which is a cellular network. The advantages of GSM system are the large capacity of the network, strong anti-interference, information sensitivity and high interoperability, etc.[3] But it often suffers from weak signals or even has no signal and therefore the information cannot be transmitted. In this case, GSM and the short message service of BeiDou system should be combined for information transmission.

2.1.3. GPRS TECH. GPRS denotes the generic packet radio service technology. GPRS is able to furnish packet switching. It is achieved packet switching through adding additional hardware entities and modifying the existing base to some extent. The carrier of its data transmission is packet and the cost of using the technology is relatively cheap compared to GSM. The transmission rate of GPRS can reach 56-114Kbps.[4]

2.2. Vital signs detection system

Using the vital signs module to measure the heart rate and the oxygen content is the basic principle of vital signs detection system. The human body suffocates when it is drowning and the lack of oxygen leads to a decrease in blood oxygen content and in the end you will have hypoxemia. Meanwhile, the heart rate increases sharply and the heart appears to have the reflective asystole until heart failure due to asphyxia. Hence, heart rate and blood oxygen content are used as evidences to determine whether the body is drowning.

Vital signs module is a noninvasive test method using Photo PlethysmaGraphy by calculating the residual light intensity after a certain intensity of light absorption through living tissue, determining the blood physiological information. The volume of blood in the skin is periodic pulsating with the systolic and diastolic cycles of the heart. This variation will tell us cardiac function, blood flow and
other physiological information that can be used for the measurement of heart rate and oxygen blood content.[5]

3. System hardware design

3.1. Hardware design of Satellite Positioning and Communication system

The hardware design of the satellite positioning communication system is based on the MC20 chip, STM32 single-chip microcomputer as the core of the BDS+GPS dual-mode antenna positioning and communication system.

MC20 module is a multi-functional wireless module which integrates high performance GNSS engine and four-band GSM/GPRS engine. You can choose the All-in-one scheme or the Stand-alone scheme.

This design mainly adopts the Stand-alone scheme, as shown in Figure 1, which can achieve information transmission of GSM and GPRS, etc. The Stand-alone scheme is that GSM part communicates with MCU via main serial port, such as sending AT command and transmitting GSM data. The GNSS part communicates with MCU through GNSS serial port, such as sending PMTK command and output of NMEA statement[6].

MC20 integrates location, GSM, GPRS and other modules, which greatly miniatures the device and leaves the device more portable.

![Figure 1. Stand-alone scheme function block diagram.](image)

3.2. Hardware design of Vital Signs Measurement system

In the hardware design of the vital sign measurement system, the core of the detection is Max30102 blood oxygen detection sensor and STM32 single-chip microcomputer. These two important hardwares and the small display screen and the power module constitute the whole detection system.

Max30102 is an integrated sensor for detecting heart rate and blood oxygen content. It can give out and receive red or infrared light. Their peak LED wavelengths are 660nm and 880nm respectively. After the Max30102 receives the light intensity signal, the signal is amplified and digitally filtered, then the output is stored in the internal first-in-first-out(FIFO) memory to complete the acquisition of the original pulse wave[7]. Finally, the Arduino processor can read the data through the standard IIC compatible communication interface on the module and calculate both heart rate and oxygen saturation.

4. Design of system software

4.1. Design of satellite positioning communication system

What the main principle of operation of the positioning system is that it powers up the GNSS (Global Navigation Satellite System) in the MC20 and is controlled by different microcontrollers pin on different circuit boards, and then acquires all the data through the command. Finally, the system stores
information about latitude and longitude after positioning. The system is verified by software such as u-Center or GNSS Viewer, whether the positioning software's data is accurate.

The system mainly uses TCP transparent mode to transmit data on GNSS. When the system starts sending messages by the MC20, the module's transparent mode needs to be started up first. When the system exits the transparent mode, it needs to be set for a certain time delay.

The system can configure the module to transmit after launching the projection. Initially, we should close the TCP connection and scene recognition. Then we need to use module of IP SYTATUS to determine if the module is initializing. Finally, we can allocate QIMODE=1.

We can set the data, measured by the vital signs measurement system and positioned by positioning system, to wait for transmission, after starting the data transmission function of GPRS.

4.2. Design of Vital Signs Measurement System

4.2.1. Software Design of Heart Rate Measurement. When the system measures the heart rate, the heart rate value is obtained from the PPG signal using the time domain method. Firstly we use the Max30102’s FIFO memory to get the intensity signal of infrared light. Then we calculate the average value of the light intensity and use it as the DC signal for the entire sampled waveform. We eliminated the DC signal of the intensity signal of infrared light at sampling points, making them become AC signals that can pass through zero point. We average the AC signal from every four adjacent sampling points. Then we add all the averages and take the average again to get the threshold of AC signal at the minimum peak. The threshold is used as a demarcation point and then we take the AC signals that are greater than or equal to the threshold. We sort the AC signal at each sampling point from the largest to the smallest. We discard the AC signals of some sampling points according to the adjacent range of these sampling points, so that the influence of sharp clutter around the peaks in the same cycle will be reduced. Finally, we arrange the sampling points of the AC signals that are used as peaks based on the time of acquisition, in order to calculate the average of the time between adjacent peaks, which are used as the cycle for each beat of the heartbeat. We obtain the heart rate according to the calculation formula of heart rate[8]. The program flow is shown in Figure 2.

![Figure 2. Flowchart for measuring heart rate.](image)

![Figure 3. Flowchart for measuring blood oxygen content.](image)
4.2.2. Software Design of Measuring Blood Oxygen Content. Our formula measuring blood oxygen content is $S = A_1 \cdot R^2 + B_1 \cdot R + C_1$. The values of $A_1, B_1, and C_1$ were determined experimentally. There are currently four ways to get the calibration curve: 1. Experimental data is obtained directly from the human body and used to draw calibration curves. 2. We acquire data from a simulated circulation system with a simulated tissue model in the laboratory. 3. Get data from animal experiments. 4. Pulseoximeter emulator[9]. We chose the empirical value from the official in the experiment. $A_1 = -45.060, B_1 = 30.354, C_1 = 94.845$ and $R = \frac{\lambda_1 - \lambda_2}{\lambda_2 - \lambda_1}$. $\lambda_1$ signifies red light and $\lambda_2$ signifies infrared light. We can calculate the value of $R$ through the AC signal and DC signal of the intensity signal of red light and infrared light.

To determine the alternating amount, we employ the peak method. That is, we select the peaks and valleys of each periodic waveform in the 100 data after sampling for 4s. To get the volume of alternating current, they are subtracted from each other. We calculate the average of the highest and lowest values for all cycles, which is used as the alternating amount of the entire waveform. We use the average of the highest value of the entire waveform to subtract the volume of AC, to get the volume of DC. We can calculate the value of R according to the formula, and then calculate the content of hemorrhagic oxygen[9]. The program flow is shown in Figure 3.

5. Experimental result

5.1. The measuring result of BeiDou module

To use the BeiDou module to locate experimental location and corresponding latitude and longitude information was obtained. Through the MC20 module, we could know the BeiDou positioning data, GPS positioning data and joint positioning final data respectively. Because the static PPP positioning accuracy and convergence of dual mode positioning were better than the single mode position[10], this experiment employed the information of the former. Figure 4 reveals the measured latitude and longitude information.

When the longitude and latitude information was automatically imported into the upper computer, the corresponding location could be automatically located. The result was shown in Figure 5.

It could be seen from the figure above that the measured latitude and longitude information was correct and it could effectively track users' position. It was credible.

Figure 4. Latitude and longitude information map of BeiDou test.
5.2. The experimental results of basic vital signs measurement

By using the Max30102 sensor, we test heart rate and blood oxygen levels of testers. The heart rate was measured by Max30102 and the Mi Band respectively, for the same part of the wrist, and each time the measurement results were obtained by taking the average value for a certain period of time. The blood oxygen content was measured by Max30102 and YK-83C finger sandwich oximeter. In order to compare the difference between wrist and finger blood oxygen content, we decided to test oxygen content of blood at the wrist and fingers through Max30102. Meanwhile, it was also measured by finger clip oximeter and the measurement results were obtained by taking the average value for a certain period of time. The results were shown in table 1 and table 2.

Table 1. Comparison of heart rate test

|       | 1st test | 2nd test | 3rd test | 4th test | 5th test | 6th test | 7th test | 8th test |
|-------|----------|----------|----------|----------|----------|----------|----------|----------|
| Mi Band (bpm) | 76       | 79       | 77       | 79       | 83       | 84       | 82       | 87       |
| Max30102 (bpm) | 76       | 80       | 77       | 80       | 87       | 84       | 83       | 86       |
| Relative error | 0%       | 1.26%    | 0%       | 1.26%    | 4.81%    | 0%       | 1.22%    | 1.15%    |
Table 2. Comparison of blood oxygen content

|                        | 1st test | 2nd test | 3rd test | 4th test | 5th test | 6th test |
|------------------------|----------|----------|----------|----------|----------|----------|
| The blood oxygen content measured by the clip-type oximeter (YK-83C) | 98%      | 98%      | 97%      | 96%      | 98%      | 95%      |
| The blood oxygen content measured at the wrist (Max30102)          | 100%     | 100%     | 97%      | 99%      | 100%     | 96%      |
| The blood oxygen content measured at the fingertips (Max30102)      | 99%      | 99%      | 98%      | 97%      | 100%     | 95%      |

5.3. Experimental results of information communication

Whether the specific drowning signal detection device of a single chip computer could effectively transmit information, the experimental results were shown in figure 6.

![Communication display information](image)

From the above figure we could know that the information sent included the user's location information (the latitude and longitude information) and the wearer's vital signs. Hence, you only need to automatically import the latitude and longitude information into location program in practice, which will transform these into map position. So the user's actual location information can be triumphantly displayed.

6. Conclusions

In this article, a device built on the BeiDou Navigation Satellite System is designed. The device effectively combines information such as humidity, geographic position, heart rate and blood oxygen content, and sets multiple warnings to enhance the reliability of the device. And contrasted with the traditional anti-drowning methods, this device has features of convenience, accuracy, real-time and so on, which makes the risk probability of drowning accidents reduce effectively.

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