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Design and Development of Smart Water Quality Early Warning System

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Abstract: With the growth of population and the improvement of urbanization level, the water environment problems in our country have become more and more urgent. However, the current monitoring methods of water resources generally have the shortcomings of cumbersome monitoring process, long monitoring time and relatively small monitoring scope, which make the monitoring and management of water resources not timely and cannot better deal with water pollution. We combines IoT technology with electronic measurement technology to develop a water quality monitoring system that can remotely monitor multiple areas. The system is divided into three parts, acquisition equipment, back-end server, and terminal display. The acquisition device uploads the data to the server and stores it in the database. On the terminal, the detection information of the past period of time can be retrieved, and different threshold ranges can be set, so as to achieve the function of timely alarm and facilitate the timely processing of the staff.

1. Introduction

Water pollution monitoring is an important process to evaluate the overall water pollution status by monitoring and analyzing the discharge types of various pollutants, the discharge concentrations and changing trends of various solid pollutants in the water body of the basin. The scope of monitoring objects is very wide, including natural groundwater (groundwater of rivers, lakes, seas and islands) that has not been biologically polluted or that has received biological pollution, and various large-scale industrial land drainage. In recent years, countries around the world have continued to increase investment in scientific research. Use electronic automatic control monitoring technology, chemical analysis processing technology, modern computer digital measurement, control processing technology and other advanced monitoring methods to research and develop online water environment and water quality monitoring. It aims to speed up the establishment of an online water quality monitoring system based on the collection of water quality ecological environment parameters and the analysis of comprehensive measurement indicators.

Since the mid-1980s, several high-parameter river water quality automatic analyzers have appeared successively. They are mainly based on automatic monitoring of water temperature, PH, solvent oxygen demand, chemical oxygen demand, total organic carbon chloride and other water quality measurement index data as the technical basis. The various types of aquatic products independently developed by the Danish Aquatic Products Research Institute and the automatic water quality monitoring technology and equipment of the farm are well-known throughout the world. The industrial fish-farming sewage plant in Germany, which is licensed by Stecomady, adopts the monitoring and management method of the fully enclosed industrial water quality and ecological environment. Using the wireless communication module technology, a wireless detection sensor communication module can be designed and developed, so that the assembly and placement process of the wireless detection sensor equipment can be simplified and the cost can be reduced. The adoption of Internet breeding technology can directly enable breeding managers to realize real-time remote control of the enterprise's breeding and production process. This has an extremely important application significance for enterprises to improve the efficiency of aquaculture production management and reduce production and operation costs.

The system designed and implemented in this paper is based on the various information of water area in multiple places and multiple points. The problems to be solved include: (1) Accuracy of collected data. The signal of the sensor will have greater interference to a certain extent, and at the same time, the signal of the sensor will be fluctuated directly. (2) After the equipment uploads the information of water resources to the server, the stability and efficiency of information transmission, storage and reading. (3) Simultaneous multi-device multi-point acquisition data between the Beidou positioning system is feasible. This system mainly focuses on the detection function. On the premise of the detection parameters, the accuracy of the acquisition and the stability of the system should be considered. At the same time, the fluidity of water should be considered to ensure that the system can detect normally without other influences. The system analyzes the collected data, displays it on the screen of the system, and transmits the data to the collection terminal remotely through the wireless module.

2 Circuit Design

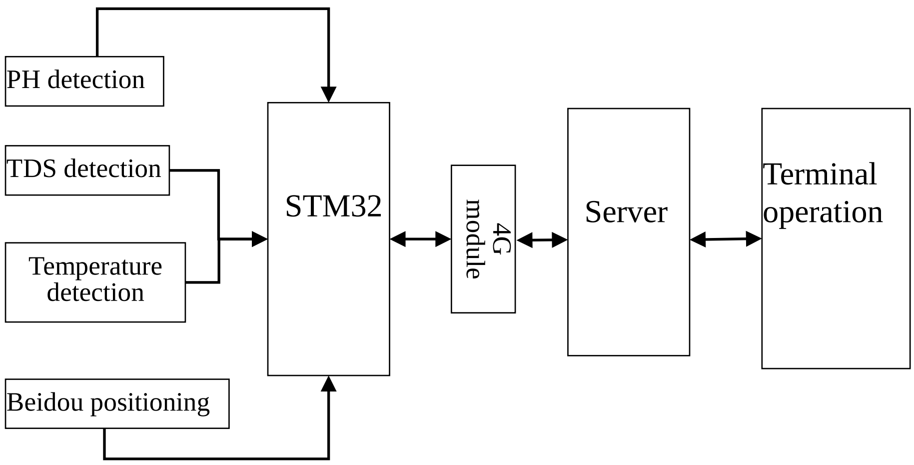

Figure 1: Basic block diagram of the system

The overall functional design block diagram of the system is shown in Figure 1. The main controller of this system uses STM32F103C8T6. The water temperature acquisition module uses the digital temperature sensor DS18B20. The water turbidity sensor TS-300B detects the turbidity information of the water area. Electrode type water pH monitoring sensor monitors the information of pH value in water. Then the collected information is converted into a digital signal through an analog signal. Submit the main control module for data processing and analysis, and display it on the OLED screen. After that, the data is sent to the receiver for remote monitoring and display. The remote display adopts the bluetooth module to send data and receives the data through the serial port receiving software such as mobile phone and computer.

2.1 Design of Main Control Circuit

STM32F103 series microcontrollers integrates functions such as ADC, rich timers and I/O ports. It has the characteristics of low power consumption, stable performance, and reliable. It can realize the multi-function control of the system, and can carry out high-speed data acquisition and processing. This single-chip microcomputer realizes the multi-function control of the system, and can perform high-speed data acquisition and processing. The single-chip microcomputer has multiple I/O pins, which can meet the design requirements of the module, ensure the working hardware conditions of the sensor and the module, and constantly check whether the sensor and the module work normally. If the required information is collected, the program is directly downloaded through the serial port. Its low power consumption and performance can meet the basic design requirements of our products.

2.2 Design of Temperature Acquisition Circuit

DS18B20 is a commonly used digital temperature sensor, its output is digital signal, it has the characteristics of small size, low hardware cost, strong anti-interference ability and high precision. The DS18B20 digital temperature sensor is easy to connect, and can be used in various occasions after being packaged, such as pipeline type, screw type, magnet adsorption type, stainless steel package type, and various models. There's the LTM8877, the LTM8874, and more.

It mainly changes its appearance depending on the application. The packaged DS18B20 can be used for temperature measurement of cable trench, blast furnace water cycle, boiler, machine room, agricultural greenhouse, clean room, ammunition depot and other non-extreme temperature occasions. It is wear-resistant and impact-resistant, small in size, easy to use, and has various packaging forms. It is suitable for digital temperature measurement and control of various small space equipment. Since the system needs to measure the temperature of the liquid, the packaging used is stainless steel packaging.

DS18B20 adopts single bus communication mode, which is transmitted through a data line. The data bus DATA is pulled down by the host (the PA0 pin of the main control module) (the pin is set to a low level) to notify the DS18B20 temperature detection module to send data. When DS18B20 receives the signal of sending data, it will send the data to the host through the high and low level change of the data bus pin. The host judges the level of each bit by judging the high and low level time of the bus pin. Pull the pin high after data transmission is complete. When the host receives a high level for a long time, it judges that the data transmission is completed.

2.3 Design of TS-300B Water Turbidity Acquisition Circuit

The TS-300B sensor can detect the turbidity in the water. The sensing system of the TS-300B water turbidity measuring instrument adopts the bidirectional optical laser beam induction emission control optical path, and has two highly symmetrical different bidirectional photoelectric photon induction emission channels, which produce the same two-way photoelectric induction, the measurement accuracy remains unchanged. Effectively offset the anti-interference effect of various optical splitters and control circuits, so that the entire optical instrument measurement system has long-term high-precision stability and strong anti-interference ability.

The TS-300B water turbidimeter adopts a double beam optical path. It has two highly symmetrical optical and electrical channels, which will produce the same induction, and the measurement difference will remain unchanged. Can be offset in the division circuit, so that the instrument has long-term stability and anti-interference ability; In terms of measurement, try to keep the measurement in dim light. The three pins of the module are the positive power supply, the negative power supply, and the analog data pin. The analog digital pin DATA is connected to the PA2 of the single-chip microcomputer for data transmission. The data acquisition method is used by the A/D conversion module of the main control module, and the A/D acquisition module is used to collect the voltage of the data pin to detect the degree of turbidity.

2.4 Design of PH Value Acquisition Circuit

Electrode pH sensors can monitor the concentration of hydrogen ions through electrode probes and convert them into electrical signals. Its main working structure principle is used to combine the hydrogen ion active glass thin film electrode with other reference electrodes to form a galvanic cell. The ion glass electrode membrane performs ion exchange with the hydrogen-containing ionic liquid in the specific solution to be detected. During this process, the water and hydrogen ion radiation concentrations in a specific solution current are accurately detected by automatically measuring the ionic potential difference between the two electrodes. Thereby, the ratio of H ions in the liquid in the detected water can be measured. The pH reference sensor probe, commonly known as the new pH reference probe, consists of a new glass reference electrode and a metal reference electrode. The glass hot-dip electrode consists of a new type of glass-plated support rod, glass coating, internal reference ion solution, internal reference ion electrode, electrode cap and electrode wire. Reference electrodes usually have a known and constant two-electrode reference potential and are often used as copper calomel reference electrodes or silver chloride/copper silver chloride reference electrodes. Since the value of piphi is automatically related to the composite temperature, an additional composite temperature compensation electrode is generally added for automatic composite temperature compensation. In this way, the composite temperature electrode of the triode is formed.

Electrode pH sensors are often used to detect hydrogen ions in solutions. The concentration of oxygen and hydrogen ions in the aqueous solution air detected by the pH temperature sensor in the electrode type is easily affected by the change of the external temperature. Therefore, most electrode pH temperature sensors require an automatic temperature compensation control system. Because in the process of using the sensor at this time, each value may have occasional deviation, so in the process of actual use, the value of each sensor must be accurately calibrated to ensure the accuracy. The measurement range of the PH sensor is generally 0~14, and the accuracy can reach 100% ± (the response time is several seconds to tens of seconds, and the sensitivity is 0.1).

The power adapter is used to charge the lithium battery, and the power supply adopts the 7400HA rechargeable lithium battery, which has a relatively small volume, sufficient power, light weight, high power supply efficiency, and the power supply time meets the debugging requirements. At the same time, a solar power panel is used to charge the battery, ensuring that the device can keep working 7×24 hours.

3. System Implementation

3.1 The Way of Data Transmission

According to the surface water environmental testing method, the normal water environmental testing water temperature should not exceed ±1.5℃ every week, and the PH value should be between 6~9. However, there are different standards for detecting different liquid environments, and there are roughly more than 20 kinds. At the same time, it is obvious that it cannot be adjusted in time when the fixed value is written in the equipment, and it is very cumbersome to rewrite the water environment standard with the different test waters. So we recorded all the common standards in life on the front-end software to facilitate the staff to adjust.

There are some places with bad environment in the measured waters, so a long-lasting device is needed. We used a 7400mA battery to meet the battery life of this device. At the same time, a solar panel is added to the device to ensure the battery life of the device. The measured power generation of the solar panel can meet the 24-hour operation of the equipment, and can charge the equipment battery during the day. Use the power in the battery at night to ensure the normal operation of the device.

The system uses the GPRS module to transmit data, as long as the device deployment site can connect to the mobile data network, the data can be transmitted normally. The data transmission method of the device is to send the collected data to the background server when the data is collected. The data is kept in a timely manner. The physical map of the data collection and upload part is shown in Figure 2.

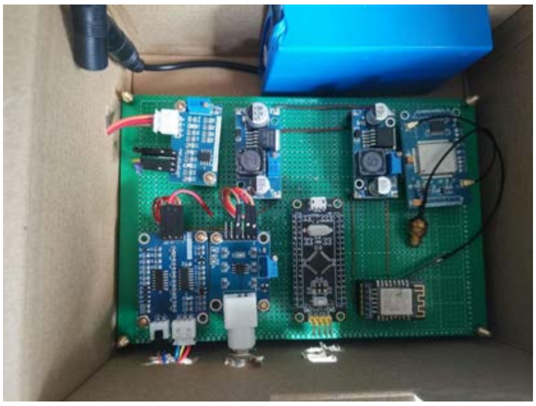

Figure 2: Data collection and uploading part of the physical map

3.2 Server and Database Part

The server part is realized in python language, and uses My SQL database to store data. At the same time, TCP transmission is used to ensure the accuracy of data transmission. The standard judgment information is prepared in the server, and then the data are transmitted to the front-end display. The server-side code is shown in Figure 3.

```
from socketserver import BaseRequestHandler, TCPServer
# from bson.timestamp import Timestamp
from datetime import datetime

import pymongo

conn_str = "mongodb+srv://<username>:<password>@<cluster-address>/test?retryWrites=true&w=majority"
client = pymongo.MongoClient()
try:
    # print(client.server_info())
    # print("Connect success.")
    pass
except Exception:
    print("Unable to connect to the server.")

# dbs_list = client.list_database_names() # 展示数据库名称
# dbs = client.list_databases() # 数据库列表

db_table = client["IOT"]  # 数据库为 test
db_users = db_table["data"]  # 集合为"Users"
```

Figure 3: The server-side code

3.3 Terminal Part

As shown in Figure 4, the terminal interface displays various information returned by the system, including temperature information, PH information, TDS information and turbidity information. At the same time, the corresponding parameter curve graph is generated on the interface to facilitate better analysis by the inspector. There is also an alarm bar for processing abnormal information next to the image, which saves and displays abnormal information more humanely.

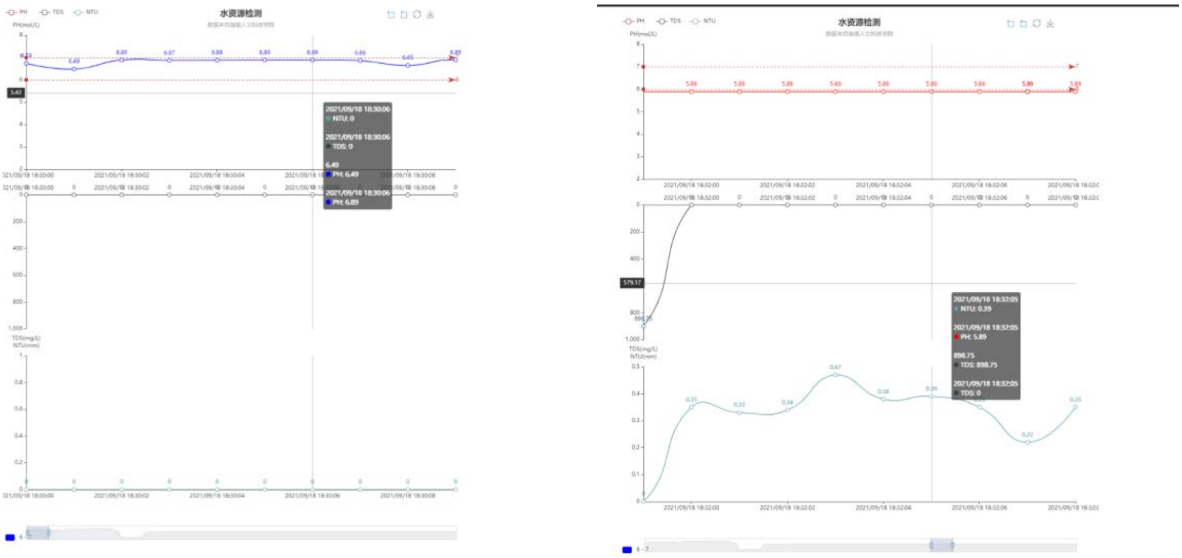

Figure 4: Display rendering of the terminal webpage

4. Program Flow Chart

As shown in Fig. 5, each module on the system is initialized after the system is powered on. After the initialization is completed, the device will collect the moisture composition information of the water under test through the sensor, and then upload it to the server. The server will save the data in the database, and the server will send the processed data to the terminal. Finally, it can be checked and viewed by relevant personnel. The electronic measurement technology and Internet of Things technology used in the system are very mature, and the stability can be guaranteed after testing. The system realizes the collection, uploading, saving and viewing of water resources information as a whole, and realizes a real-time detection system.

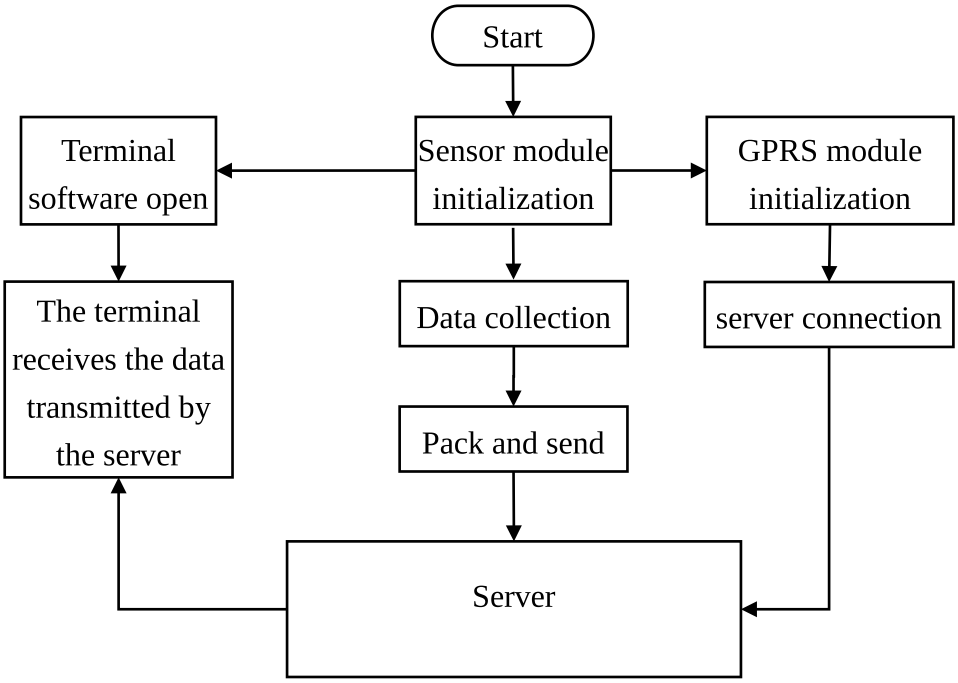

Figure 5: System program flow chart

5. Data Testing and Analysis

Table 1: System test result table

Test items	Standard pH	PH detector	Test PH	Standard TDS (PPM)	TDS test pen detection	Test TDS (PPM)	Standard Turbidity (NTU)	Water quality detector turbidity detection turbidity (NTU)	Measure turbidity (NTU)	Digital thermometer (°C)	temperature (°C)
Pure water	6~7	6.89	6.75	0~9	3.32	3.44	⩽1	0.41	0.34	27.6	27.6
Tap water	6.5~8.5	7.21	7.19	⩽ 1000	196.56	198.26	⩽1	0.89	0.87	27.8	27.9
Sediment water	none	7.41	7.36	none	195.37	196.34	none	471.89	468.34	27.9	27.8
Coca Cola	2.5~4.2	2.89	3.13	none	563.23	569.23	none	978.23	986.23	27.8	27.8
Milk	none	5.81	5.76	none	894.28	898.75	none	765.56	789.34	27.9	27.8

After completing the production and debugging of the software and hardware systems, and confirming that the detection end and the display end can be used and transmitted normally, we test the data of five different liquids respectively. After reading out the values of various sensors and calculating, the data map of various values of water resources detection is restored. In the case of confirming that the various signals are not distorted, compare and record the obtained data with the data tested by the existing water quality testing equipment on the market. The test results are shown in Table 1.

Before the test results in the above table were obtained, we carried out many measurements. The above table is only a small part of our extensive tests, which basically meet our ideal goals. It can realize remote detection of various numerical changes of water resources. Both pH sensors and TDS sensors can accurately detect changes in water resources and send them to the display. This makes it convenient and accurate to detect water resources remotely.

6. Conclusion

In order to solve the problem that the pollution of water resources cannot be solved in time, we designed and implemented a smart water quality early warning system based on electronic measurement. The test results show that the platform runs smoothly, has good human-computer interaction, and is easy to install and deploy. It realizes remote real-time monitoring of water environment information and facilitates better management of water resources information. The next step is to add more detection parameters and further expand the processing capacity in software to improve stability.

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