Design and Realization of Intelligent Fish Tank System based on STM32 Microcontroller

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Abstract: With the improvement of people's living standards, people's pursuit of quality of life is also increasing, enthusiast groups are growing, the demand for environmental control of the fish tank is increasingly refined and intelligent, and the ornamental fish industry has come into being. In this paper, we study a system based on STM32 microcontroller for detecting and controlling parameters such as temperature, light, PH, and water depth of the fish tank, and real-time displaying and controlling using the 2.8-inch LCD screen. In addition, the system supports remote control through the cell phone APP, and users can set up timed tasks or perform real-time operations as needed. Eventually, this project has researched and designed a smart fish tank system that can be remotely controlled, integrated with various functions and operated conveniently.

Keywords: Smart Fish Tank; STM32; Detection; LCD Display; Mobile App

1. Introduction

With the booming development of IoT and 5G technologies and the improvement of people's living standards [1], the demand for fish tanks in modern households is no longer limited to simple decorative functions, and there is a growing demand for fish tanks with a high degree of intelligence and a wide range of integrated functions to provide a more comfortable and convenient ornamental fish-rearing experience [2]. Ornamental fish require a strict living environment, including suitable water quality, temperature, and light conditions. It is not easy for people to maintain the aquarium environment in the appropriate conditions for fish for a long period of time, especially when people go out to work or travel, how to ensure the stability of the aquarium environment has become a major challenge [3]. The traditional way of fish tank management often fails to meet these needs, and the emergence of smart fish tanks provides new possibilities for solving this problem [4]. At present, the research of intelligent fish tanks mainly focuses on the combination of sensors and remote control and other directions [5], and the research also has defects in automatic feeding [6], imperfect water quality detection [7], and unintelligent temperature control [8]. This design is based on STM32 as the core, for the detection and control of the temperature, light, and other key information of the fish tank, and at the same time combined with the cell phone APP to realize timed and real-time remote control. It aims to provide a more convenient and comfortable fish farming experience and a feasible fish farming program for fish enthusiasts.

2. Overall System Design

The overall design block diagram of this design system is shown in Figure 1, which mainly consists of four parts: the main control core, sensors, peripherals, and mobile communication. It integrates the detection functions of temperature, light, water depth, and PH value to ensure the stability of the fish tank environment. The main control core intelligently controls peripheral devices such as water circulation, lighting, food feeding, oxygenation, and heating according to the real-time information fed back by the sensors to maintain the optimal environment in the fish tank. In addition, the system is equipped with a touch screen for intuitive display and device control.

3. System Hardware Design

The main control core of this system adopts STMicroelectronics' STM32F407ZGT6 chip, which is based on the high-performance Cortex-M4 core and has the significant advantages of low power consumption and

powerful peripherals. It has 1024K FLASH and 192K SRAM memory capacity, enough to deal with a variety of complex data processing tasks. In terms of hardware resources, it is equipped with 112 GPIOs, 6 serial ports, 2 DACs, 3 ADCs, and 14 timers, which greatly meets the diversified needs of the intelligent control system for fish tanks [9]. In addition, in order to understand the function and definition of each pin more intuitively, this design also provides a detailed introduction to microcontroller pin definition and function as shown in Table 1.

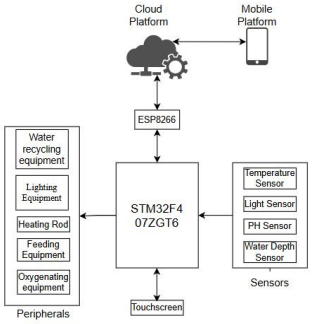


Figure 1. Block Diagram of Overall System Design

Table 1. STM32 Pin Assignment Table

Pinout	Typology	Connected Device	Functionality
PA0	GPIO	Temperature Sensor	Getting Water Temperature
PA1	AD	Light Sensor	Getting Light Intensity
PA6	AD	PH Sensor	Getting the PH value
PA2, PA3	USART	Water Depth Sensor	Getting the depth of the water level
PB5	GPIO	Water Recycling Equipment	Control of pump start/stop
PB6	GPIO	Lighting Equipment	Control of lighting equipment switch
PB7	GPIO	Heating Rod	Control of the water temperature
PB8	GPIO	Feeding Equipment	Control of feeding equipment switch
PB9	GPIO	Oxygenation Equipment	Control of oxygenation equipment switch
PC0-PC7	GPIO	Touchscreen	Data communication with microcontroller
PA9, PA10	USART	ESP8266	Communicate with remote devices

3.1 Sensor Designs

The temperature sensor is an important part of the smart aquarium system, which is responsible for monitoring the water temperature in the aquarium in real-time. This temperature sensor adopts the DS18B20 model, which is notable for its digital output, directly providing easy-to-process temperature data. The DS18B20 is not only easy to connect, but also has waterproof and power-down protection functions, ensuring stable operation in various environments. Its wide measurement range, from -55°C to +125°C, covers the temperature range required by most aquatic organisms, enabling the water temperature in the aquarium to be maintained at a suitable level at all times.

The water depth sensor, on the other hand, is a device used to monitor the water level in the fish tank. It utilizes a resonant depth sensor commonly found in washing machines, which is inexpensive but offers excellent performance. It is suitable for a wide range of liquids and is unaffected by fluctuations in the surface liquid, accurately reflecting the actual water level in the fish tank. Its measurement range is between 0 and 2 meters, which is sufficient for most home fish tanks.

Light sensors play a key role in fish tanks by monitoring the light intensity inside the tank. This light sensor adopts the BH1750 model, which is characterized by high accuracy, low power consumption, and wide dynamic range. In high-precision measurement mode, its measurement range is up to 0 to 65535 lux, which can accurately reflect the light condition in the fish tank. By monitoring and adjusting the light intensity in real-time, it can provide a suitable light environment for aquatic organisms in the fish tank.

The PH sensor is then used to monitor the pH of the water in the fish tank. This in-line PH sensor is characterized by high accuracy, ease of use, and fast response. It can reflect real-time changes in the pH value of the water in the fish tank, helping users adjust the water quality in time to ensure the healthy growth of aquatic organisms. Its measurement range is between 0 and 14, covering the common PH value range.

3.2 Peripheral Designs

Water circulation equipment mainly includes

pumps, this design uses peristaltic pumps as the core of the water circulation equipment, the choice of peristaltic pumps because it is not only low noise, but will not disturb the tranquility of the fish tank and the fish tank next to the fish tank, and more importantly, it can be adapted to different water qualities, to avoid contamination of the water quality and the pumps caused by direct contact.

Oxygenation equipment utilizes a membrane pump, a dry-running vacuum pump that is compact, yet powerful, low noise, and lightweight to provide a steady and continuous supply of oxygen to the tank.

The lighting fixtures are 12V strips, which are inexpensive and provide continuous lighting needs.

The heater bar uses a 24V 100W oil sump electric heater bar, which will provide 25W of power at 12V, which is able to meet the needs of the use, as well as meet the needs of higher use.

The feeding equipment consists of a motor and a screw, the motor adopts small noise by waterproof treatment N20 motor, through the motor drive screw for feeding. Ensure the food can be put into the fish tank evenly and in the right amount.

The touch screen adopts a 2.8-inch LCD screen, through which users can intuitively understand the data of the fish tank and control the lighting equipment, feeding equipment, and oxygenation equipment through touch to realize intelligent management.

3.3 Wireless Communication Design

This system adopts the ESP8266 chip to realize wireless communication, which not only integrates WiFi function but also consumes very low power and has powerful processing capability at the same time. In this system, we choose the MQTT protocol as the communication bridge between the cell phone and the device, and the MQTT protocol ensures the stability and real-time performance of the data transmission process with its lightweight, efficient, and reliable characteristics.

The main steps to establish communication first involve connecting the ESP8266 chip to the WiFi network, followed by configuring the MQTT client and connecting to the MQTT proxy server. Once the connection is successful, the system is able to publish and subscribe to messages, realizing bi-directional transmission of data. This communication method not only improves the flexibility and scalability of the system but also provides users with a more convenient operating experience [10].

3.4 Fish Tank Structure Design

In the field of fish tank design, common types of structures include bottom filter fish tanks, back filter fish tanks, and side filter fish tanks. Bottom filter and back filter tanks are usually used in medium to large-sized aquarium designs due to their strong filtration ability and large capacity. However, considering that this system is designed for small to medium-sized fish tanks, we chose the Side Filter Fish Tank as its construction type.

The design of this side filter aquarium carefully considers the living needs of the fish and is divided into four main areas: the fish living area, the device placement area, the water filtration area, and the heater oxygenation area. The fish living area is where the fish swim, the device placement area is used to install all necessary aquarium equipment, the water filtration area ensures clear water quality, and the oxygenation area is responsible for maintaining a constant water temperature and providing sufficient oxygen to the water. The structural design is shown in Figure 2 and Figure 3.

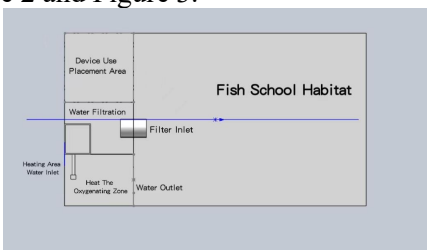


Figure 2. Top View of the Fish Tank Structure

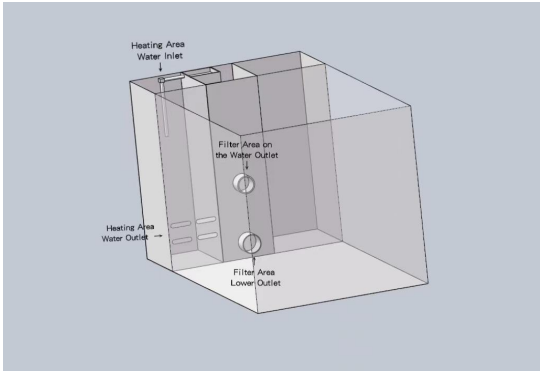


Figure 3. Side View of the Fish Tank Structure

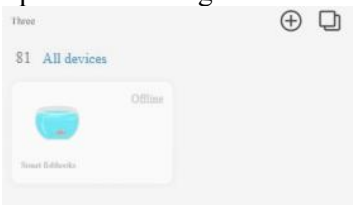
4. System Software Design

In developing this intelligent fish tank system, this system adopts Keil 5 as the software development platform and uses C language for programming. When the system starts, the execution starts from the main function, which is responsible for the initialization, data detection, and peripheral control of the whole system. The main function first performs the necessary device initialization to ensure that all hardware modules are in the correct working state. Then, the main function will loop continuously to perform real-time data detection and control the peripherals according to the detection results. The control parameters of these peripherals can be set through the touch screen or mobile terminal, and the user can flexibly adjust them according to the actual needs. At the same time, the system will display the real-time data through the touch screen or mobile terminal, so that users can always understand the status of the fish tank.

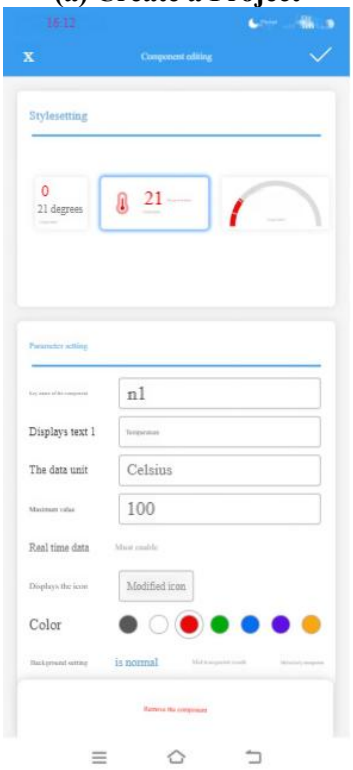
The sub-functions mainly include the following three: the first sub-function is responsible for handling the collaboration between the temperature sensor, the heating rod, the PH value sensor, the water depth sensor, and the water circulation equipment. When the detected temperature, PH value, or water depth is lower than the set value, the system will automatically turn on the corresponding peripheral devices to make adjustments; when the detected value returns to the normal range, the peripheral devices will be turned off. The second subfunction focuses on the linear control between the light sensor and the lighting device. By linearly mapping the light value to the voltage value of the lighting device, the system is able to ensure that the light in the fish tank is maintained in a relatively constant environment, providing a comfortable living environment for the fish. The third subfunction controls the operation of the oxygenation and feeding devices through timers. When the set time is reached, the system will automatically turn on the corresponding equipment; after the equipment has been running for a period of time, it will be automatically turned off again to ensure that the supply of oxygen and food in the fish tank is within the appropriate range.

5. Mobile Design

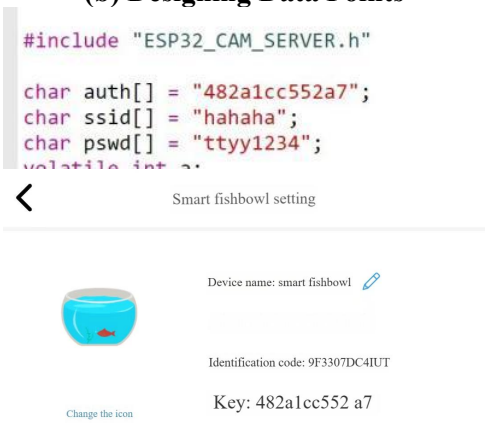
The mobile design is generated through Point Light Technology. The method of generating an APP by Point Light Technology is simple and very developer-friendly and does not need to be operated like Android APP development. Its design process is as Figure 4:



(a) Create a Project



(b) Designing Data Points



(c) Configuring the Network

Figure 4. Steps to Generate APP for Lighting Technology

The final generated APP interface is shown in Figure 5.

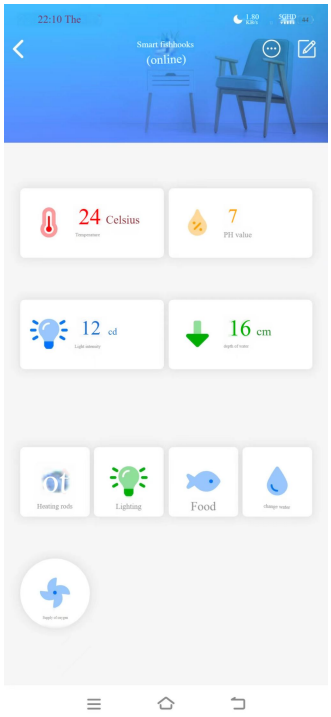


Figure 5. APP Interface

6. Concluding Remark

Based on STM32F407ZGT6, this system successfully realizes the all-around management of the smart fish tank, including the functions of accurate temperature detection, intelligent timing oxygenation and convenient remote control. Users can easily manage the fish tank environment through simple operation, which provides more choices and convenience for fish-keeping enthusiasts. However, the degree of intelligence of this system is still to be improved and will be optimized and improved in subsequent research.

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