Design of an Unmanned Boat System for Floating Garbage Salvage and Water Quality Monitoring Based on OneNET

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Abstract. In view of the serious floating garbage on water surface and the drawbacks of relevant cleaning equipment, an unmanned boat system for floating garbage salvage and water quality monitoring based on OneNET IOT platform is designed. The design of hardware, software and cloud platform application of the system are introduced in detail. The system is mounted on a small remote-control boat, which monitors water quality data through various sensors and uploads the data to the cloud platform while collecting garbage, and sends warning emails when water quality data exceeds the threshold value. The experimental results show that the system has realized the transmission of monitoring video in real time, remote control of floating garbage salvage, water quality information collection and release, and warning of monitoring data over threshold value. The system has a certain application prospect in water quality monitoring and protection of small-scale water area.

1. Introduction
With the rapid development of economy, the problem of water ecological environment is increasingly prominent. A large number of floating garbage on the water surface not only pollutes the living water source, affects the landscape of the river basin, but also causes serious water quality deterioration. For the small-scale water area, manual salvage boat is still the most commonly used method. But it is inefficient and has a certain degree of danger. The existing unmanned salvage equipment in the market generally has the disadvantages of single function, narrow application range, high labour cost, and it is difficult to be widely used. Furthermore, most of them consume fossil fuel, which will inevitably cause secondary pollution to the environment. In addition, the treatment of water pollution is also faced with the problem of repeated outbreaks. The separation of water quality monitoring and garbage salvage cannot detect pollution in time, leaving hidden danger for pollution outbreaks. In order to solve these problems, a Small-scale remote-control boat system for floating garbage salvage and water quality monitoring is designed, which uses clean energy, needs remote control only, has high salvage efficiency with water quality monitoring function. The measured data can be uploaded to OneNET cloud platform with alarm function when pollution exceeded threshold. It provides a feasible solution to solve the current small-area water floating garbage salvage and water quality monitoring.

2. Functions of the system
The main functions of floating garbage salvage and water quality monitoring system based on OneNET cloud platform are shown as Figure 1:
Figure 1. Functions of the system.

- **Monitoring video transmission function**: collecting monitoring video through the camera module installed in the boat, and then send it back to the mobile terminal through WIFI module in real time.
- **Searching and salvaging garbage function**: searching the floating garbage on the water surface through the monitoring video, using the mobile app to remote control the unmanned boat performing the salvage, and bring the garbage back to the shore for treatment.
- **Water quality monitoring function**: monitoring the turbidity, pH value, temperature and humidity of the water area as the judgment standard of water quality through the sensor carried by the boat.
- **GPS positioning function**: positioning the unmanned boat system through GPS module to obtain its position coordinates.
- **Viewing data function through PC browser**: viewing turbidity, pH, temperature, humidity and GPS positioning data by visiting the PC application website: https://open.iot.10086.cn/iotbox/appsquare/appview?openid=954378f47d5400566c88af67ef298160 in real time.
- **Viewing data function through Mobile APP**: logging in the mobile app to view the same data as PC which is synchronized with the cloud platform in real time.
- **Alarm function of monitoring data over threshold value**: Each water quality parameter of the system has an alarming threshold value. When the monitoring data exceeds the threshold value, the trigger of the system will be triggered, and the system will continuously send alarming email to the user through the cloud platform.

3. Design scheme of the system
The system is composed of hardware, software and cloud platform application:
The hardware part is boat controlled by Arduino UNO R3, which is equipped with motor drive module, garbage salvage module, video acquisition module, GPS module, water quality monitoring module, WIFI module and 2-DOF PTZ to control camera movement. Water quality monitoring module includes temperature, humidity, pH value and turbidity sensors. WIFI module is composed of small router and esp8266 WIFI module.\[1-6]
The software part of the system is designed and implemented by using Arduino IDE to call multiple supporting libraries through C language. WIFI module for video transmission is based on a small router controlled by openwrt system and developed by Linux system. ESP8266WiFi module for information transmission is controlled by AT instruction sent by Arduino board.\textsuperscript{[7-8]} The cloud uses OneNET IOT platform. It uses TCP protocol to connect and upload, and sets trigger alarm system. The mobile phone terminal uses cloud app synchronized with the cloud platform.\textsuperscript{[9-13]}

3.1. Design and implementation of system hardware

The workflow of the hardware system is roughly as Figure 2:
1) The camera collects video information and transmits the information to the mobile app through the router through WIFI network;
2) The router receives the control signal from the mobile phone, converts to electrical signal and transmits it to the control board;
3) The control board processes the received electrical signals, and controls the video pan tilt, drive motor and salvage device according to the processing results;
4) The sensors on the boat collect environmental information; the main control board controls the ESP8266WiFi module to send the information in a fixed format after processing.

Figure 2. Schematic diagram of system hardware.

- **Motor drive module**: The motor drive module is composed of two 9V high-speed DC motors with an effective voltage of 7-9v. The speed and steering of the boat are adjusted by the analog PWM wave output from Arduino board to control the motion of the boat.
- **Garbage salvage module**: Garbage salvage module is the part of the system to realize the function of salvaging floating garbage, which is driven by a steering gear of MG996360. The slope of the lower half of the mechanical arm is small, so that the lower half of the mechanical arm can be close to the horizontal state as much as possible when it is put into the water. The salvage net uses a large hole plastic net. The action of the module is remote controlled by the mobile app.
- **Video acquisition module**: The video acquisition module is a small camera with OV7752COMS sensor, with resolution of 640 * 480 and output rate of 30 frames. It is installed on the platform to collect the video picture of the boat when it is sailing. The video return to the remote-control interface of the mobile phone for display.
- **GPS module**: It is composed of a ceramic antenna and a set of signal amplification circuit. The module is the neo-6m version with charging electronics. It can short-term memory the satellite search data, mainly used to locate the boat's position by 24 GPS satellites.
DHT11 sensor module: DHT11 temperature and humidity sensor is a temperature and humidity composite sensor with calibrated digital signal output, including a resistance type humidity sensor and an NTC temperature sensor. So, the measured temperature and humidity data can be calculated by reading the voltage change of the output port.

Turbidity sensor module: Turbidity sensor is a sensor to measure the turbidity degree of water body. The inner part of the sensor is an infrared tube. The conversion current can be obtained through infrared transmittance, and then the current signal can be converted into voltage signal to calculate the turbidity data.

pH value sensor module: The pH sensor is used to determine the pH value of water. The composite electrode of this module is put into the solution. It uses the solution loaded by itself to react with the external solution, and outputs the voltage signal. After the amplification and analysis of the module, the approximate pH value of the measured solution can be calculated according to the formula.

WIFI module: It consists of a small router and an ESP8266WiFi module. The small router uses the AR9331 chip pre-set by OpenWrt for video return and the remote control of the mobile app to the boat. The ESP8266WiFi module is an ultra-low power consumption UART WIFI transparent transmission module, which has five states and three operation modes, namely, idle state, receive state, transmit state, sleep state and command state, station mode, AP mode and station + AP mode.

3.2. Design and implementation of system software
The software execution flow of the whole system is shown as Figure 3. The system software design includes monitoring unit design and control unit design, both of which are designed with Arduino IDE.

Main program of detection system: The main program of the detection system is to configure the main control board, set the appropriate baud rate for each sensor, then complete the initialization of each sensor, write the AT instruction to the ESP8266WIFI module through the Serial function, set it to the pass through mode, complete the connection with the external network and the OneNET server, and call the sensor subprograms to read the data in the main loop.

Main program of control system: The main program of the control system is used to control the movement of the boat, the rotation of the PTZ and the movement of the salvage device. First, the initialization and self-test of the system are completed after completing the module configuration, and then the signal receiving function is used to refresh the received signal continuously, then the instructions received are analyzed and the operation function corresponding to the instructions is invoked to control the operation of the unmanned boat.

Temperature and humidity measurement subprogram: The temperature and humidity sensor used in the system is DHT11 sensor module. The subprogram introduces DHT. h library and calls the library function DHT.temperature and DHT.humidity to read the temperature and humidity data directly, and then call the data upload function to upload the data to the OneNET cloud platform. Because the temperature and humidity data correspond to two data streams in the cloud, it is necessary to write the temperature and humidity data into two HTTP packets. So, it is need to call the two upload function to complete the upload of the temperature and humidity data.

pH value measurement subprogram: The pH electrode uses the potential difference between the liquid inside and outside the probe to judge the pH value of the liquid, so the data to be processed in the code is the collected voltage data. First, the noise data is eliminated through the circular collection judgment, the processed voltage data is converted into the pH value by the given formula, and the upload function is called to upload the data.

Turbidity measurement subprogram: The measuring principle of turbidity sensor is to detect the light transmittance of water solution through a photoelectric sensor, judge the turbidity of water solution according to the light transmittance. When input ports collect voltage signal, the illegal data is removed firstly, then the data and formula provided in the manual are used to calculate the turbidity of water quality, and the upload function is called to upload the data.
• **GPS module subprogram:** Because the GPS module needs to communicate with the main control board through serial port, but the WIFI module has occupied the TX and RX ports of the main control board, so it is necessary to introduce the software serial.h library to set pins 13 and 12 as the soft serial port, directly read the original GPS data received by the soft serial port, then extract the longitude and latitude of WGS-84 format from the original data according to the package header in the analysis function, and then convert it to BD-09 format, so as to be adaptable to Baidu map API, and finally upload function is called to upload data.

![Diagram of system software execution process](image)

**Figure 3.** System software execution process.

• **Design of the mobile App:** This app is connected with the terminal WIFI module to receive the video returned by the video acquisition module, and at the same time, it can send instructions to remote control the unmanned boat. So, this app is designed in two parts: one is used for receiving and displaying the returned video, receiving the encoded information of the returned video from WIFI module, decoding and displaying it on the mobile phone, and the other is used for inputting and encoding the remote-control instructions.

3.3. **Design of cloud platform application**

OneNET cloud platform is China Mobile's IOT platform, which is positioned as PAAS service. The platform provides three communication modes, Ethernet, GPRS and WIFI. The system uses the ESP8266WiFi module to build WIFI communication, and the data interaction between the cloud and the terminal is mediated by the router connected to the external network to establish a TCP connection to transmit HTTP request message. The design process is shown as Figure 4:
OneNET cloud platform provides a convenient way for users to build applications. The resource management mode of the cloud platform is: user-project-device-data flow-data point. When registering a project, the system will assign an APIKey, which has the maximum access rights to the project. Only after verification can the equipment and data flow under the project be operated. After the project and equipment are created, a data flow receiving data point needs to be set for each sensor, a trigger needs to be configured for each data flow, and a threshold value needs to be set to realize the data out of range alarm function; in order to improve the image and convenience of data viewing, an application needs to be created to view data. The application building process is shown as Figure 5:

Projects and devices on the cloud platform exist in virtual form, which is equivalent to OneNET automatically allocating private cloud space for connected terminal devices. The storage mode of data points in the cloud is key value. Key includes device ID, data flow ID, time and etc. Value is data, and Key-Value storage mode can make data points correspond to the correct data flow.

The connection between the terminal and the cloud is completed through the ESP8266WiFi module. It is known that the module has five operation states and three operation modes. Because the system needs to carry out multi-point transmission of multiple sensor data, the module selects the station transmission mode, and then configures the information of the router of the module to connect with the external network, The data interaction between OneNET platform and external connection is
conducted through TCP protocol, so the module needs to establish TCP connection and configure server address to complete the connection between terminal and cloud. The above steps are all configured by the main control board through the serial function to write the AT instruction to the module. The AT instructions and their definitions required for the connection process are shown as Table 1:

| Instructions          | Meaning                              |
|-----------------------|--------------------------------------|
| AT                    | enter AT instructions                |
| AT+CWMODE=<mode>      | <mode> is the operation mode of the module |
| AT+RST                | reset                                |
| AT+CWJAP=<ssid>,<pwd> | ssid: WIFI name, pwd: WIFI password  |
| AT+CIFSR              | Query module IP port                |
| AT+CIPSTART="TCP", "183.230.40.33",80 | establish TCP connection, 183.230.40.33 is server address, 80 is port |
| AT+CIPSTATUS          | get TCP connection status            |
| AT+CIPMUX=<mode>      | start multiple connections           |

After the connection between the terminal and the cloud is established, the connection program will not be executed, so as to avoid the occupation of network resources by frequent connection and improve the efficiency of data upload. In response to the possible connection interruption, the system made an emergency record. When the connection is interrupted accidentally, the terminal immediately will stop data upload and tries to reconnect. After the reconnect fails 10 times, the system will carry out a buzzer alarm to remind and check the fault.

The RESTAPI communication mode adopted by OneNET cloud platform is based on HTTP protocol and JSON data format. The client can use the RESTAPI to operate the resources provided by cloud platform, and the ESP8266WiFi module packages data to the cloud through HTTP request message.

The main methods and functions of HTTP request message to operate resource are shown as Table 2:

| HTTP method | description |
|-------------|-------------|
| GET         | view resource information                   |
| POST        | new resources                                  |
| PUT         | update resource                                |
| DELETE      | delete resource                                |

The HTTP datagram consists of the request line, the request header and the request body. The request line indicates the HTTP method used by the datagram. The request header indicates the target of the datagram. Because the data point is stored in the form of key value, the request header information is the key part of the data point as the upload address of the data point. In addition, it also includes the project API key to ensure that the message has the right to operate the device data flow.

In the system, the cloud mainly accepts data, so the HTTP post method is mainly used. Table 3 shows the post method and examples:

| Message field   | Sending control Instructions |
|-----------------|------------------------------|
| HTTP method     | POST                         |
| URL             | http://www.heclouds.com/cmds |
| HTTP headers    | API-Key:aaaa-bbbb-cccc       |
| URL parameters  | device id:==// receiving data device ID |
| HTTP content    | JSON format or binary data   |
Cloud applications include PC applications and mobile applications. PC applications can directly log in to the website to view. Mobile applications need to download the device cloud app and search application WaterQuality which is matched with OneNET cloud platform. Both PC and mobile application interfaces can be designed in the cloud, simplifying the design process.

- **Interface design of PC application**: After the cloud platform is created and applied, different controls can be selected according to the characteristics of different data flows to realize different monitoring methods, including text, curve chart, column chart, instrument panel, map, picture, switch and etc. The application of unmanned boat system is mainly used for the display of environmental historical data and real-time data, and also to show the law of data change. So, curve chart, instrument panel are chosen with the corresponding map control and GPS. After the interface design is completed, it can be published. When passing the audit, users can log in to the website to realize convenient data monitoring.

- **Interface design of mobile application**: OneNET cloud platform provides a device cloud app that synchronizes with PC terminal. Its application interface can be designed directly on the PC side. The cloud platform synchronizes directly to the mobile phone side. When viewing data on the mobile phone side, users only need to download the device cloud app, search the application WaterQuality to view the data, and the application also has the function of commenting and praising, so as to get users’ feedback.

4. Conclusion
Based on OneNET IOT platform, the unmanned boat system for floating garbage salvage and water quality monitoring mainly involves three aspects: software, hardware and cloud platform application design. The significance of the design is to integrate the garbage cleaning and water quality monitoring, to realize the unmanned operation, to reduce the risk of garbage cleaning, to improve the cleaning efficiency, and timely to feedback water quality information to avoid the outbreak of pollution. It has certain application value and market prospect for environmental monitoring and protection of small-scale water area.

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