A LabView-based Smart Aquaculture system

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Abstract. To facilitate aquaculture farmers’ management of fish ponds and realize automatic detection and real-time response of water quality, we developed a LabVIEW-based smart aquaculture system. This system uses applications developed on the LabVIEW platform as the control centre, and uses the NI USB-6001 data collection card to collect parameters like dissolved oxygen, pH scale, water level from sensors, and displays and releases warnings on the monitoring warning interface. When the parameters of dissolved oxygen (DO), pH scale and water temperature fall below the standard values, the system will automatically start the oxygen generator, the pump and the heater to realize automatic control.

1. Introduction
The water quality has direct impact on the growth and culturing efficiency of fish. Conventional aquaculture methods collect water quality parameters by the rule of thumb or through instruments, which are not accurate, require heavy workload, high labour costs, and have poor real-time performance [1]. It is necessary to develop a system that can automatically detect the aquaculture environment, monitor the water quality around the clock, realize real-time data transmission and give timely warning and conduct control of water quality problems [2].

2. System design
The LabVIEW-based smart aquaculture system is developed by graphic programming software LabView, the structure of which is shown in Figure 1. The sensors collect water quality parameters and send the data to the simulation input terminal of the NI USB-6001 data card to perform A/D conversion, and then for further processing on LabVIEW. According to the water quality, the manual or automatic control signals are sent to the NI USB-6001 digital output terminal, and the transistor control circuit is used to control the oxygen generator, the pump and the heater.

The functions available in the system include the following:
(1) Data conversion and storage: The system can convert the signals from sensors to water quality parameters.
(2) Monitoring warning: The system can monitor water quality parameters including the DO, pH scale, water temperature, conductivity, ORP, water level. The users can set the threshold values of different water quality parameters; and when the actual values exceed the thresholds, the system will release warnings.
(3) Equipment control: when the DO falls below the lower threshold, the oxygen generator will be automatically started to adjust the value to a proper level; when the water level falls below the lower threshold, the pump will be automatically started to inject water to the pond; when the water
temperature falls below the lower threshold, the heater will be automatically started to heat up the water. The users can also manually control the oxygen generator, the pump and the heater.

Figure 1. System Structure

3. Hardware design

3.1. Selection of sensors

The parameter DO (dissolved oxygen) refers to the amount of oxygen dissolved in water and is a major reference to determine the purification abilities of the water body [3]. The DO sensor used in this study is JF-DO-485, which consists of two metal electrodes connected to electrolytes and a selective thin film. The thin film can only be penetrated by oxygen and other gases, but cannot be penetrated by water and other dissolved substances in water. The oxygen that passes the thin film will be reduced on the electrode and produce weak diffusion current; and in a certain temperature, the current and the DO is positively correlated. The available output modes include the 485 mode, 4-20mA or 0-5V; and this system uses 0-5V output (three-wire mode); the measuring range is 0-20 mg/L, which is a linear correspondence; the accuracy is 0.1mg/L and the working voltage is DC5V/DC12V.

The pH value of the water will influence the growth of fish and content of nutrients in water. The JF-PH-485 sensor is used as the pH sensor, which consists of a glass electrode, a reference electrode and a temperature electrode. The output voltage of the sensors is 0-5 V, the measuring range is 0-14, and the accuracy is 0.01; the working voltage is DC5V/DC12V.

To provide a suitable environment for the fish, it is necessary to control the temperature of water in the pond. The WZ/P platinum temperature sensor is used in this study for water temperature detection, and he output is 4~20mA. The Pt100 platinum resistance probe is used in this sensor, which has good linearity.

Conductivity refers to a solution’s capacity to conduct electricity, which reflects the content of electrolytes and indirectly indicates the salt content in water. The JF-COND-485 sensor is used as the conductivity sensor. The output mode is 0-5V, the measuring range is 0~80 s/cm, the accuracy is 2% FS and the working voltage is DC5V/DC12V.

The oxidation-reduction potential (ORP) indicates the redox state and is an important indicator to assess the water quality of the aquaculture environment. The JF-ORP-485 sensor that integrates the transducer and electrode functions is used as the ORP sensor. Its output mode is 0-5V, its measuring range is -1900~+1900 mV, the accuracy is 0.1 mV, and the working voltage is DC5V/DC12V.

Proper water level control is necessary for aquaculture environment management, especially in high-temperature or low-temperature environments. The piezoresistive level sensor SSL1002 is used in this study as the water-level sensor, which is based on the positive correlation between the detected static pressure and the height of the detected solution. The output mode is 0-5V, the measuring range is 0-5 m, and the working voltage is DC 7-36 V.
3.2. NI USB-6001
The USB-6001 data collector manufactured by National Instruments in the U.S. is used as the I/O conversion instrument. NI USB 6001 is powered by USB, and can be used as 8 single-end analogue input (AI) channels or be configured as 4 differential channels. The device also contains 2 analogue output (AO) channels, 13 digital input/output (DIO) channels and one 32-digit calculator. It has 16-bit resolution and a sampling rate of 20 kS/s [4]. When the DAQ device, such as the NI USB-6001 device, is used for program development, the NI-DAQ assistant provided by the NI Company to set the voltage and current measuring channel to realize seamless connection between the LabVIEW and the hardware product USB-6001.

4. Software design
The smart aquaculture system consists of software modules including the data conversion and storage module, the monitoring and warning module and the device control module.

4.1. Data conversion and storage
The sensors in this system use 0-5V or 4-20 mA standard signals. The USB-6001 sensors deliver the signals to the LabVIEW software, and uses the NI-DAQ assistant to create the voltage or current measuring channels to obtain the voltage and current signals. The signals are then converted to water quality parameters and stored to the Access database for future inquiries by users.

4.2. Monitoring warning

Figure 2 shows the monitoring and warning interface. This system will automatically display water quality parameters like DO, pH, water temperature, conductivity, ORP and the water level. The users can set the upper and lower thresholds of these parameters, and the system will display the reference thresholds of these parameters for users. When the actual value exceeds the thresholds, the warning light turns on to realize automatic warning. The pH monitoring module is shown in Figure 3. The modules for other five parameters follow the same design principles.
4.3. Device control

Figure 4 shows the device control interface. The users can start the oxygen generator, the pump or the heater manually, and set the automatic value for DO, water level and temperature. Figure 5 shows the module of the oxygen generator. When the oxygen generator is turned on manually, or the DO is below the pre-set value, or the DO is below the lower threshold, the oxygen generator control signal will be ON. This signal will be sent to the DAQ assistant, and the corresponding digital input terminal of the USB-6001 device will output high level, control the transistor to pull in, and the oxygen generator will be started to add oxygen to the pond. The design principles for the pump and the heater control modules are the same.
5. Conclusions
To solve the problems of traditional aquaculture systems like high labour cost and poor real-time performance, the NI USB-6001 device is used to automatically collect water quality parameters like DO, pH value and water temperature. The LabVIEW platform is used to display these parameters, release warning, and realize automation or manual control. In this way, an automatic, integrated and scientific smart aquaculture management system is established.

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