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Sewage Monitoring System Based on Artificial Intelligence

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ABSTRACT

In order to avoid the problems of unstable water quality and high treatment cost caused by manual control of operators in wastewater treatment process, it is proposed to design and develop an intelligent wastewater monitoring system. According to the characteristics of numerous sewage treatment devices and unstable control indexes, the soft sensing technology of dissolved oxygen (DO) concentration is combined with computer automatic control technology to design intelligent monitoring scheme of sewage treatment process. The overall structure and function of the system are given, the control software, DO concentration soft measurement module and operation guidance are introduced, which lays a foundation for the concrete implementation of the system. The results show that the intelligent monitoring scheme and the aeration control method based on DO concentration soft measurement are applied to the sewage treatment field, and the hardware integration design and software configuration development are completed. The man-machine interface designed is intuitive and friendly, and the operation is convenient. After field installation and debugging, it is successfully operated in a sewage treatment plant, making the removal rate of effluent impurities reach the expected goal and achieve obvious economic benefits. Therefore, it is of great scientific significance and application value to strengthen the research and application of intelligent control of sewage treatment system in China.

INTRODUCTION

With the rapid development of modern industry and urbanization as well as the continuous increase of population, the water demand is increasing, and the industrial wastewater and domestic wastewater discharged from cities are also increasing accordingly. Sewage discharged directly into the water without treatment will cause serious water pollution, endanger the ecological environment and affect human health. Limited available water resources and pollution of water sources around cities have made water shortage and pollution become one of the most important problems facing all countries. It has become a prominent problem that seriously restricts the sustainable development of economy and urgently needs to be solved.

Artificial intelligence control discipline has been born for many years. With the continuous development of artificial intelligence control, especially its wide application in non-linear and unstable systems, it has attracted the attention of many scientists at home and abroad and become a frontier subject (Ye & Zhou 2015, Shahzad et al. 2017, Leizou & Elijah 2018, Islam 2019). Artificial intelligence control system has strong self-learning, self-adapting and self-organizing ability, and is widely used in large-scale industrial control process, effectively reducing operating costs. For the more complex process control of sewage treatment plant, China mainly stays on the traditional control method. Although intelligent control has become the hot spot and frontier of sewage treatment research and application, the research at home and abroad is still in the initial stage. In the practical application of intelligent control of sewage treatment, most of them are still in the experimental state, which requires more scholars to devote themselves to the research on artificial intelligence control of sewage treatment. Therefore, strengthening the research on intelligent control technology of urban sewage treatment will become the development direction of sewage treatment and environmental protection.

PAST STUDIES

Intelligent control is the advanced stage of the development of automatic control. It is a new subject closely related to artificial intelligence, brain science and intelligence research. In recent years, domestic and foreign scholars and control experts have extensively studied the automatic control method of sewage treatment. A study used fuzzy logic control to study the energy-saving performance of aeration process, developed an aeration control system based on fuzzy logic, and tested the main aeration tank in the pilot-scale BARDENPHO process, which saved 40% energy compared with ordinary

controllers (Truong & Krost 2016). In 2016, studied the dynamic simulation of activated sludge process, improved, predicted and developed a program to improve the accuracy of existing activated sludge process (mechanical model) by neural network (Tao & Xu 2016). Based on a recent research, used on-line integrated control system to control food waste-water with great changes in water quality and quantity (Qian et al. 2015). In 2015, a study established a fuzzy controller by using fuzzy control language, and successfully applied the theory of fuzzy control to the control of steam engine and boiler. Then, many foreign countries successfully applied the method of fuzzy control to industry (Ahonen et al. 2015). Previous research proposed many powerful neuron network models and various effective learning algorithms, which promoted the application of neuron network in many fields including automatic control (Mehrabadi et al. 2015). Based on a study, recent study put forward the expert control system (Peng et al. 2016). All the behaviour of the system can be controlled adaptively. The expert control system is first applied to the distributed process control of oil refining. Since then, more expert control systems have been developed and applied. Recent research successfully realized the control of aeration volume in sewage treatment process by using fuzzy multi-level control, mainly using fuzzy logic control to control the aeration time in the aeration tank, so that oxygen in the air can be fully utilized in the process of biochemical reaction (Ying et al. 2015). A study proposed a hybrid model for anaerobic digestion process based on material balance equation, in which the biological growth rate is expressed through neural network (Han et al. 2017).

MATERIALS AND METHODS

For a long time, human beings have been dreaming of creating machines that can imitate human beings in behaviour, thinking and even emotions. To some extent, computer is a tool to enlarge human thinking, and it is the material basis for people to realize this dream. Artificial intelligence focuses on the research on how to make machines have the same thinking ability as human beings. In the field of artificial intelligence, one of the ways for machines to achieve this goal is to make machines imitate human memory and thinking. Expert system is an intelligent program system based on a large amount of knowledge and experience in a specific field. It is an important branch of artificial intelligence to apply artificial intelligence technology to solve various problems by imitating the thinking process of human experts in solving problems. If the expert system is divided into functional modules, it is mainly composed of knowledge base, inference engine and interactive system, which are shown in Fig. 1.

According to the wastewater treatment process, the biochemical treatment system is mainly composed of anoxic tank, aeration tank, and sedimentation tank. The main function of anoxic tank is to remove organic matter, convert macromolecular organic matter into small molecular organic matter, denitrify it, and convert nitrate nitrogen and nitrite nitrogen into nitrogen. Sedimentation tank is used to separate fine granular sludge and remove suspended solids in water. Aeration tank decomposes small molecules of organic matter into CO_2 and H_2 through the biochemical reaction of microorganisms with aerobic bacteria as the subject. Under the action of nitrifying bacteria, ammonia nitrogen is transformed into nitrate nitrogen and nitrite nitrogen. Therefore, DO concentration affects the overall effect of sewage treatment.

In order to build a soft-sensing model of DO concentration, it is necessary to analyse the influence of variables on DO concentration and the coupling degree between variables, and remove the variables with strong correlation and the variables with little effect on DO concentration, that is, feature selection (Alwis et al. 2017). Next, x_1 is used to represent inflow flow, x_2 is COD concentration, x_3 is MLSS concentration, x_4 is NH_3-N concentration, x_5 is aeration volume, and y is DO concentration. The relationship between input and output at the same time is as follows:

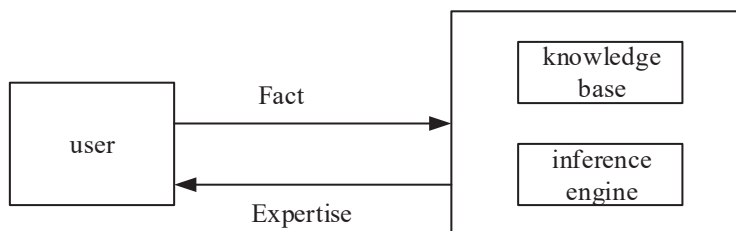$$y(k) = f\left(x_1(k), x_2(k), x_3(k), x_4(k), x_5(k)\right) \qquad \ldots(1)$$

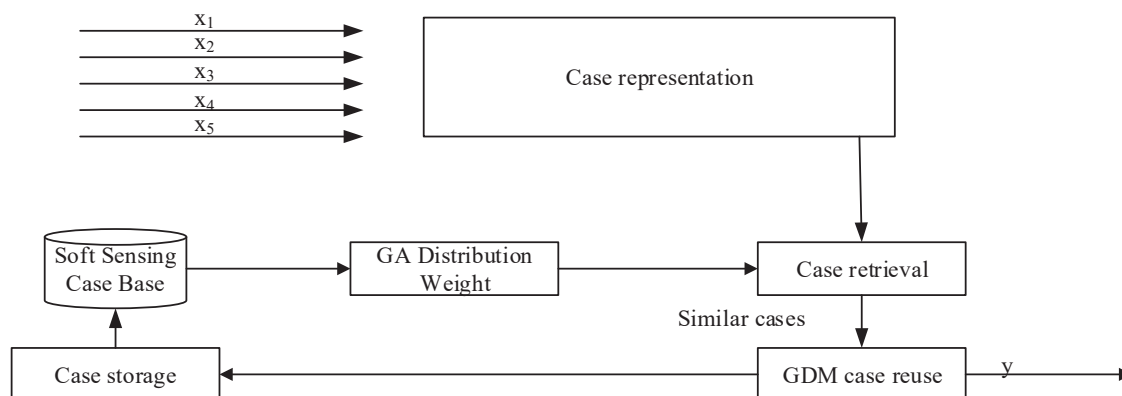Fig. 1: Composition diagram of expert system divided by function.

Fig. 2: Soft sensing structure of DO concentration.

The input-output relationship expressed by Formula (1) has strong nonlinearity, so it is difficult to establish its accurate mechanism model. It is necessary to select appropriate methods for DO concentration analysis and measurement. In summary, in order to achieve DO concentration measurement, it is necessary to solve the following problems: building the structure of the soft sensor model, designing the function of the model, and then giving the algorithm implementation. According to the classical cognitive model, the DO concentration soft sensing model structure shown in Fig. 2 is designed.

RESULTS AND DISCUSSION

Structure and function of sewage monitoring system: The sewage treatment process is relatively complex, and the corresponding automation technology requirements are as follows: First, the computer monitoring system requires the completion of the start/stop control and operation status detection of the main production equipment. The control can be started/stopped individually or automatically by the computer, requiring the undisturbed switching of different control modes. Second, monitor the values of the main analog parameters and display them to the operator through the computer screen. Third, production process alarm and malfunction handling require the alarm of field equipment to pop up on the computer screen. Fourth, display the trend of various curves on the computer. Fifth, display the report on the computer, and press the report button on the menu to enter the current report, shift report, daily report, monthly report, etc. Sixth, use the global script editor of configuration software to develop advanced control strategy and realize intelligent control algorithm. The overall structure design of the intelligent monitoring system is shown in Fig. 3.

Functional analysis of sewage monitoring system includes, (1) control function: process control; operation control of equipment; and control of key technological parameters; monitoring function: instrument monitoring; and equipment operation monitoring; (2) setting function: the system can set various operating parameters conveniently; alarm function; safety function.

System hardware integration and selection: According to the structure schematic diagram of the intelligent monitoring system and the control requirements of sewage treatment process, the control system is integrated into three layers: the executive layer of electrical equipment, the distributed control layer of programmable logic controller (PLC), and the supervisory management layer of industrial computer. In terms of hardware, the whole control system is mainly composed of industrial computer, PLC control cabinet and power supply cabinet. These core control parts, together with necessary electrical components such as motor, pump, valve, instrument, etc. From the software point of view, it is composed of the user graphical application software on the upper computer and the bottom control program of the PLC. User graphical application software is mainly used to complete human-computer interaction interface, through which users can view system operation information, and participate in system operation control for data management and so on. The bottom control program of PLC is used to complete the real-time control of electrical components and the real-time collection of related data.

After the development of personal computer (PC), for convenience and to reflect the characteristics of programmable controller, programmable controller is named PLC. PLC is an electronic device specially designed for digital operation in industrial environment. A programmable memory is used
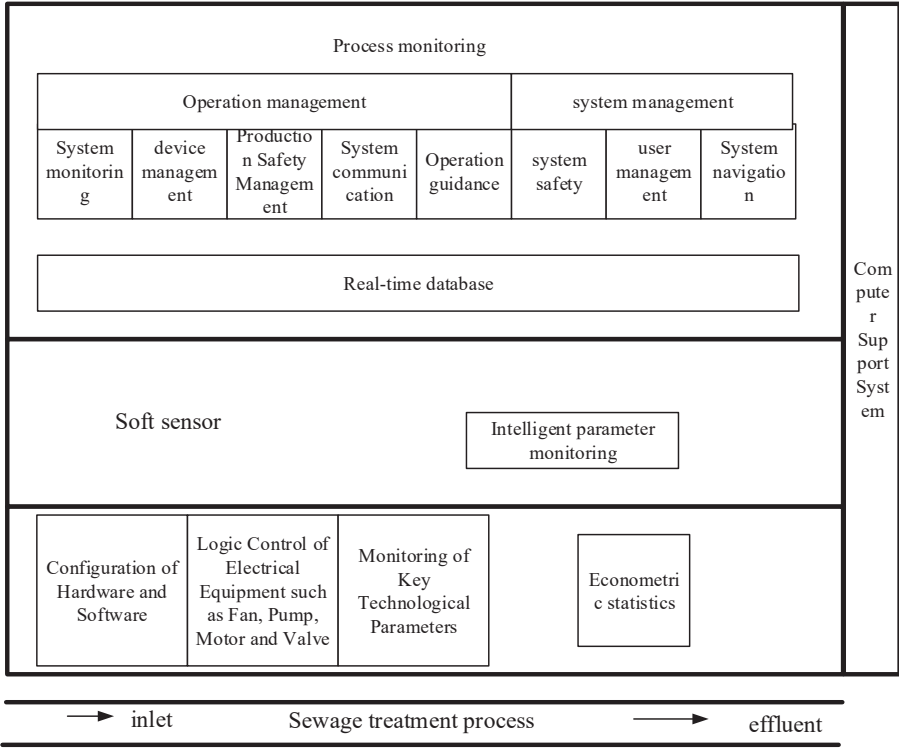
Process monitoring								
Operation management					system management			
System monitoring	device management	Production Safety Management	System communication	Operation guidance	system safety	user management	System navigation	
Real-time database								

Soft sensor

Intelligent parameter monitoring

| Configuration of Hardware and Software | Logic Control of Electrical Equipment such as Fan, Pump, Motor and Valve | Monitoring of Key Technological Parameters | Econometric statistics |

Computer Support System

→ inlet   Sewage treatment process   → effluent

Fig. 3: Monitoring system.

STOP

Internal processing

communication services

RUN

Self diagnosis
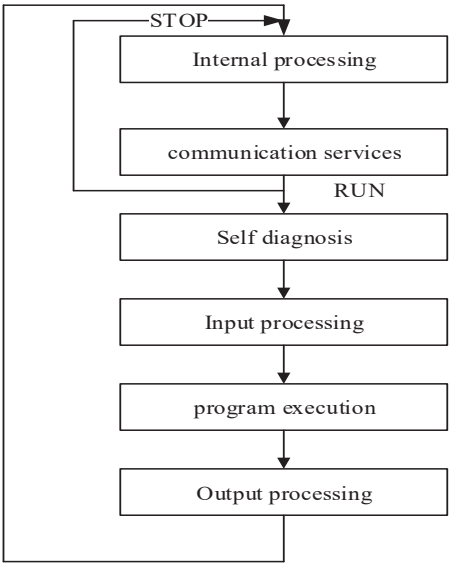
Input processing

program execution

Output processing

Fig. 4: The working process of PLC.

to store instructions for logic operation, sequential operation, timing, counting and arithmetic operation, and to control various types of machinery or production processes through digital or analog input and output. PLC and its related periph-

eral equipment should be designed according to the principle that it is easy to form a whole with industrial control system and expand its functions (Fig. 4).

CONFIGURATION METHOD

Fame View configuration software is based on Windows 2000/2003/XP/Win7/Win8 platform. It runs stably, fast, simple and easy to use, and has powerful functions and good expansibility. It can provide users with economic and perfect automation solutions. It has been successfully applied in metallurgy, chemical industry, electric power, power distribution, environmental protection, building, water treatment and other industries. It has been proved to be suitable for all large and medium-sized automation projects by application. In addition to providing basic functions such as equipment communication, running database, screen, alarm and historical data, it also provides simple and practical database connection, data formula, data service, forwarding service, report forms, dual-computer redundancy, variable groups, global variables, Web publishing and other enhanced functions, which can provide comprehensive support for users and meet users' needs.

The main features of Fame View are the data parallel acquisition and communication of customizable devices; the running database configuration of classified management; the real three-dimensional picture making and picture roaming, and multi-screen dynamic display; the optional configuration of server redundancy; the alarm service of supporting Email and SMS; the database connection function facilitates the correspondence between process variables and database fields, and carries out conditional data storage and reading and writing. Fame View software mainly includes: picture making, communication system, database and report forms, running database, encrypted dog, scripting and so on, as shown in Fig. 5.

Development of sewage monitoring software: From the point of view of design and development, the control system designed can be divided into three parts: The PLC control software, operation guidance screen and development of DO concentration soft-sensing program.

The development of monitoring software for intelligent control system of sewage treatment process includes operation guidance screen, control software and model software. The structure of the whole monitoring software is shown in Fig. 6. The control network and equipment network are configured by the application software Fame View. In the process of configuration, communication nodes can be set to facilitate the allocation of network resources and so on. After configuring the device communication data table in Fame View, PLC, monitor and model machine can communicate through the configurable ethernet, exchange data and information with each other, and realize data sharing and information exchange between monitor and model machine in OPC mode.
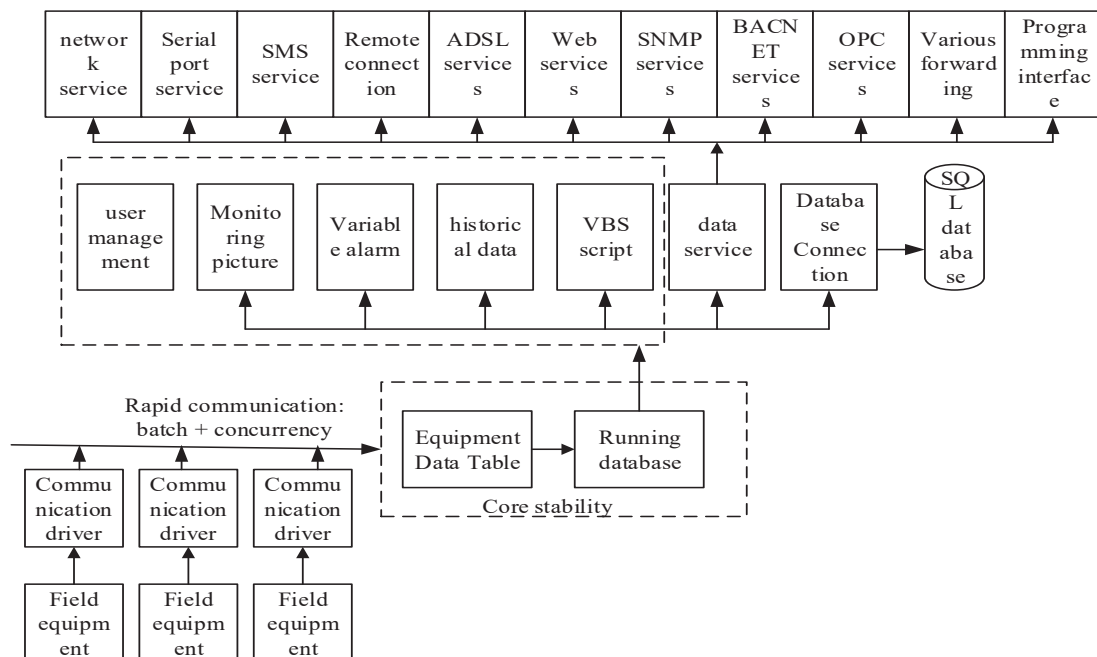
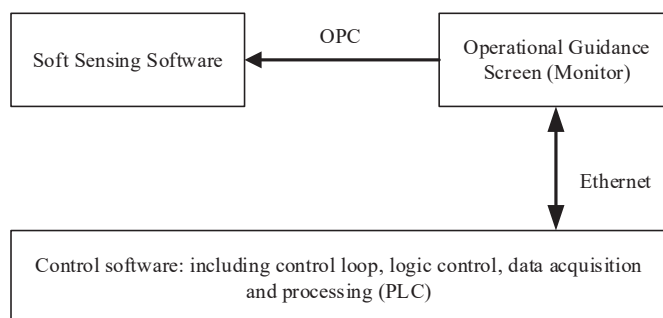Fig. 5: Time and temperature at maximum pore pressure in 10 mm depth.

Fig. 6: Structural diagram of monitoring software.

Development of control software: Connecting with the actual production, the production situation is changeable, and the control software needs to adapt to the requirements of field operation. Therefore, the overall flow chart of the control software is determined. The development of the control software of each control station is based on Step7V5.5 software. There are many control processes, so ladder diagram and function block are used in programming. Fame View is a powerful control system monitoring software, which can compile monitoring program and friendly operation interface according to user's requirements. The VB software based on Fame View can compile complex calculation and processing programs. The development of DO concentration soft measurement is based on VB software and implemented in the model machine. The operation guidance and monitoring screen designed and developed by this system has two main functions: One is to monitor the status of the equipment, including the operation, stop, failure, and parameter display, and the other is to control the status of the equipment, including the start and stop of the equipment, parameter setting and so on. Through the operation of the above operation interfaces, the changing trend of temperature, pressure, flow rate, pH value, and DO concentration can be monitored, and the fault alarm can be displayed, so that operators can guide and control the operation on site at any time.

CONCLUSION

The sewage treatment intelligent control system has been studied in depth. From the choice of control network to the establishment of diagnosis and decision-making and monitoring system, faster and more economical solutions have been put forward. The whole research involves biochemistry, physics, automatic control, machinery, electronic technology, computer technology, communication, network, instrumentation, water treatment and safety engineering and many other disciplines, which is a comprehensive research field. The sewage treatment control system designed has the following characteristics: Completing the design of electrical control part based on PLC technology, realizing the design of hardware configuration and software of PLC system according to the control requirements of sewage treatment process, and completing the development of monitoring software based on configuration technology. The domestic Fame View software is used to develop the sewage treatment monitoring software, which has the functions of alarm inquiry, report inquiry and printing, real-time curve inquiry and user management. It provides a completely open and friendly man-machine interface for customers, realizes the remote monitoring of field equipment, and meets the control requirements of the system.

Through the comprehensive study of the sewage treatment control system, the selection of practical equipment, the establishment of the best system scheme and the determination of appropriate parameters can effectively guarantee the quality of oily sewage treatment, improve the work efficiency, reduce the labour intensity of employees, and avoid the waste of energy, thus making the whole sewage treatment process more economical. At the end of the project, reviewing the implementation of the whole system, it is found that the system function can be further enhanced and expanded, and the automation level can be improved in many aspects.

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