Chapter 12
Livestock and Aquaculture IoT Systems

Pengcheng Nie, Yong He, Fei Liu, Chunxiao Mi, and Chengyong Cai

Abstract Recent years saw the introduction of IoT in livestock farming and aquaculture. Concerning livestock agriculture, real-time information on breeding environment can be acquired through intelligent sensing, quick and safe transmission, and intelligent processing. Furthermore, with the help of computers, real-time monitoring of the breeding environment, fine feeding, monitoring of animal conditions, disease diagnosis and early warning, and breeding management have become available. In terms of aquaculture, water environments can be regulated and maintained in a proper state using IoT. Combined with machine vision technology, information on food intake of aquatic products can be acquired, which can be used as the basis to determine the levels of hunger and to achieve accurate and intelligent feeding. This chapter offers an elucidation on both of the abovementioned breeding, i.e., livestock farming and aquaculture.

Keywords Livestock IoT system · Aquaculture IoT system · Environmental monitoring · Intelligent multifunction

12.1 Introduction

Livestock farming and aquaculture heavily contribute to China's gross domestic product. Against such a backdrop, the application of IoT in these field, increasingly popular these days, could translate into significant improvements in both yield and quality. A demonstration of these benefits will be laid from the following aspects.

China, a global power in agriculture, ranks number one globally with respect to the production volume of livestock farming. As living standards rise, the consumption of livestock and poultry products grew rapidly. The industry of livestock farming, supported by such growth in demand, expanded constantly, attracting a large number of rural surplus labor and improving farmers' income. As a result, livestock

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Y. He et al. (eds.), *Agricultural Internet of Things*, Agriculture Automation and Control, https://doi.org/10.1007/978-3-030-65702-4_12

farming now occupies an increasingly larger proportion of all agricultural revenue. The basic characteristic of modern livestock farming, an intensive industry with large investment, high yield, and remarkable benefits, is that the industry is capital-intensive and labor-intensified, the latter of which is evident when compared with developed countries. At present, as the economy grows further, the labor-intensive agriculture has begun to transition to capital-intensive agriculture. However, both types of intensive productions consume a great deal of labor and resources, and both have a negative impact on the environment to some extent. By adopting IoT, resources can be used rationally, environmental pollution can be relieved, and a high-quality and efficient mode of livestock farming can be established. The following is a summary of the application of the IoT in each link of livestock farming.

Intelligent monitoring of breeding environment. Real-time information of the farm, such as temperature, humidity, light intensity, air pressure, dust density, and concentration of harmful gases, is collected through smart sensors, and the information is then transmitted via either wireless or wired means to a remote server. At last, based on the decisions made by the server-side model, related control equipment are driven to make the appropriate adjustment, thereby achieving the intelligent management of livestock farming environment. Doing so reduces the frequency entering and exiting the workshop, avoids the spread of diseases, improves epidemic prevention, ensures safe production, and maximizes production benefits.

Precision feeding. Studies on livestock nutrition and research on rational feeding hold great significance to the development of livestock farming, resource efficiency, cost reduction, the alleviation of pollution and disease occurrence, and production safety. Precision feeding is achieved by establishing the quantitative relationship model among the growth stage, feeding rate, and feeding amount of different livestock according to the nutritional requirements in each breeding stage and the experience of breeding experts. Moreover, using IoT technology, the environment and group information related to precision feeding can be acquired, and the decision-making system of precision feeding can be built.

Thorough monitoring of livestock reproduction. In livestock farming, by using information technology to improve reproduction efficiency, the number of livestock raised for reproduction can be reduced, thus lessening the production costs and the costs of fodder and forage resources. Therefore, it is essential to provide the most suitable environment for livestock reproduction and to comprehensively manage and monitor livestock reproduction with sensors, RFID, and other sensing technologies to record the estrus of male and female livestock as well as the mating and breeding environment.

Digital management of production. As the industry expands increasingly, recording the day-to-day livestock information using the traditional paper cards can no longer meet the actual needs of production. Relying on IoT technologies, such as the two-dimensional code and radio frequency technology, we can make possible the efficient recording, query, and summary of production information, including growth, reproduction, epidemic prevention, disease, diagnosis, and treatment, based on mobile terminals, providing the critical support for decision-making in high-efficient production.

Aquatic products, a major source of nutrients for humans, contain high-quality protein, low-fat content, rich minerals, and vitamins. More than 15% of the protein intake from animals comes from aquatic products. In 2016, China's consumption of aquatic products reached 69.01 million tons, exceeding pork consumption. It is expected that China's aquatic product consumption will reach 70 million tons by 2023. It can be seen that aquatic products have become an essential part of life. In recent decades, the excessive consumption of marine resources and the destruction of the marine environment have caused severe damages to the marine ecological balance. In response to the problems and challenges, many countries have adopted a series of measures. For instance, China has issued a number of policies and regulations to introduce structural reforms to aquaculture, to rationally plan offshore fishing, and to reduce offshore aquaculture. Since reform and opening up, the Chinese government has pointed out that the development of aquaculture should be focused on cultivation and that vigorous efforts should be made to develop aquaculture so as to reduce the proportion of capturing. Moreover, the government also made clear that innovative approaches for an open marine aquaculture system in the new era should be explored. In 2018, China's total aquaculture production reached 50 million tons, accounting for 78% of all aquatic products sold. Currently, about 45% of the world's aquatic products come from aquaculture. In 2018, the production volume of global aquatic products increased by 2.1%, reaching 178.8 million tons, and though China's aquaculture production accounted for the largest proportion in the world, the country still suffers from many problems in aquaculture. At present, the high production of aquatic products in China is primarily a result of the large-scale consumption of waters and land. This wasteful development model runs counter to green and sustainable development. In addition, the vast majority of farmers still practice the traditional extensive aquaculture model. People involved in aquaculture depend on personal experience to determine the suitability of the farming environment, and their methods tend to be highly subjective, such as observing color and smelling (Guan et al. 2008). Additionally, there are also methods that include laboratory testing, which are time-consuming and labor-intensive. Feeding also relies on experience, a reliance that often results in inaccuracies. Excessive feeding will leave uneaten baits in the water, leading to problems such as water quality degradation, environmental pollution, and aquatic diseases, whereas insufficient feeding will reduce the quality of aquatic products. At the same time, as living standards improve, the demand for high-quality aquatic products has gradually risen, calling us to improve aquaculture technology and achieve efficient aquaculture (Chen 2018).

The *Thirteenth Five-Year Plan for National Aquaculture Development* prioritized innovation and adhered to the innovation-driven strategy. The plan advocated the application of modern technology and equipment and promoted the implementation of smart aquaculture (Huang et al. 2015). The *Thirteenth Five-Year Plan for Information-Based Agriculture* aimed at the integration of information technology and agriculture, including the application of IoT, big data, intelligent equipment, and other technologies to aquaculture (Lee 2000). Therefore, it is of major practical significance to apply IoT, "Internet +," artificial intelligence, and other technologies to modern aquaculture. Information-based and intelligent aquaculture has emerged as an essential way to solve existing problems in aquaculture. Eco-friendly aquaculture is a concept that focuses not only on the economic benefits of the aquaculture but also on the environment. In eco-friendly aquaculture, all aspects of aquaculture and production are strictly controlled, wastes are reused, and a development model of sustainable aquaculture is formed. Adopting modern technologies, such as intelligent equipment, IoT, "Internet +," artificial intelligence technology, and efficient ecological aquaculture, intelligent aquaculture can be achieved, which effectively reduces labor costs and meets the development requirements and trends of modern aquaculture. In this respect, intelligent equipment are applied to high-efficiency eco-friendly aquaculture. Real-time monitoring of water quality is possible with IoT technology, and automatic control is undertaken based on water quality information. Relying on artificial intelligence technology, accurate feeding of bait, and intelligent warning of aquatic diseases are achieved. At last, intelligent, information-based, and eco-friendly aquaculture will come into being.

12.2 Application of Livestock Agriculture IoT System

12.2.1 Architecture of Livestock Agriculture IoT

Similar to the general structure of IoT, the IoT system for livestock farming also consists of three layers: perception layer, network transmission layer, and application layer. Such a structure enables real-time online monitoring and control of the farming environment through the integration of the intelligent sensing technology and equipment for livestock information, wireless transmission technology and equipment, and intelligent processing technology. Refer to Fig. 12.1 for the overall framework of the IoT system for livestock farming.

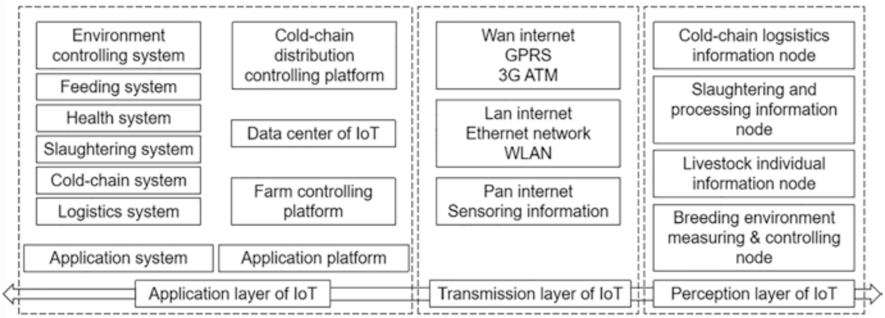


Fig. 12.1 The general framework of IoT system for livestock farming

12.2.1.1 Perception Layer of IoT

The perception layer, the "eyes" of the IoT system for livestock farming, detects, identifies, locates, tracks, and monitors the farming environment primarily using technologies that include sensor technology, radio frequency identification (RFID) technology, two-dimensional code technology, video and image technology, and so on. Sensors are used to collect environmental parameters, such as temperature, humidity, light, carbon dioxide, ammonia, and hydrogen sulfide; RFID and two-dimensional code technology are used to automatically identify individual livestock; and video and image technology is used to capture multiple types of environmental information (Niu et al. 2013).

12.2.1.2 Transmission Layer of IoT

The transmission layer transfers information from the perception layer to the application layer. Its wireless sensor network covers wireless acquisition node, wireless routing node, wireless sink node, and network management system. Wireless RFID is adopted for information collection and transmission in the local area of the site. It is worth mentioning that long-distance data transmission employs GPRS communication technology and 3G communication technology.

12.2.1.3 Application Layer of IoT

The application layer is divided into the public processing platform and the specific application service system. Various kinds of middleware and common core processing technologies are included in the public processing platform, through which in-depth integration of information technology and livestock farming is achieved, and the sharing, interconnection, decision-making, summary, statistics, and so on of the product information are enabled. For instance, the core functions of intelligent livestock farming that involve intelligent control, intelligent decision-making, diagnostic reasoning, early warning, and prediction are made possible with the support of the application layer. The specific application service system, the highest level of IoT-enabled production model, mainly comprises various specific agricultural production process systems, such as livestock farming system, product logistics system, and so on. The specific application of these systems could ensure the correct planning prior to farming, so as to improve the utilization of resources, allow fine management of production, enable efficient circulation after production, and achieve safety traceability. In such a manner, high yield, high quality, high efficiency, eco-friendliness, and safety of the industry could be promoted.

On the basis of the above framework, the environmental control system of IoT-enabled livestock farming is built and developed, and specific application tests are conducted in the process of livestock farming in accordance with the actual requirement.

12.2.2 Main Management and Applications System for Livestock Agriculture

12.2.2.1 Environment Monitoring System for Livestock and Poultry

To design and develop the environmental control system for livestock farming, the interrelationship among various environmental factors in the system needs to be ascertained: when a given factor changes, the system automatically changes and adjusts the environmental factors to create the fitting environment for growth and reproduction.

In view of the lack of technology and means for effective information monitoring and the insufficiencies in online monitoring and the control of farming environment in China's existing livestock farms, the livestock environment monitoring system has adopted IoT technology to realize real-time online monitoring and control of farming information (Wu 2014).

In the specific process of designing and developing the livestock environment control system, the system is divided into four parts: intelligent sensing subsystem, automatic transmission subsystem, automatic control subsystem, and intelligent monitoring management platform.

Intelligent Sensing Subsystem

Intelligent sensing subsystem, located at the bottom of the IoT system, is mainly applied to perceive the quality of the farming environment. For instance, the subsystem detects the level of ventilation in barns, temperature and humidity, dust concentration, light, carbon dioxide, whether heating or cooling is needed, and whether hydrogen sulfide and ammonia are in the best state. Collecting such information and transforming them into electrical signals through the corresponding and special sensors is the primary way to achieve automatic detection and control, which facilitate the transmission, storage, and processing of information. The schematic diagram of the information collection structure of livestock environment is illustrated in Fig. 12.2.

Automatic Transmission Subsystem

The automatic transmission subsystem uploads the collected information through wired and wireless means, i.e., it transmits the control information above to the receiving device below.

Image information transmission, urgently needed in livestock production, provides technical support for early warning of diseases and insect pests, remote diagnosis, and remote management. To effectively guarantee the quality and performance of the transmission of image, video, and other information, cable network is constructed in livestock farms to support the transmission of video surveillance. The video data are then sent to the monitoring center, allowing remote observation of real-time video inside the farms and enabling image capture and snapshot, triggering alarms, timed video, and so on for the designated area of the farms.

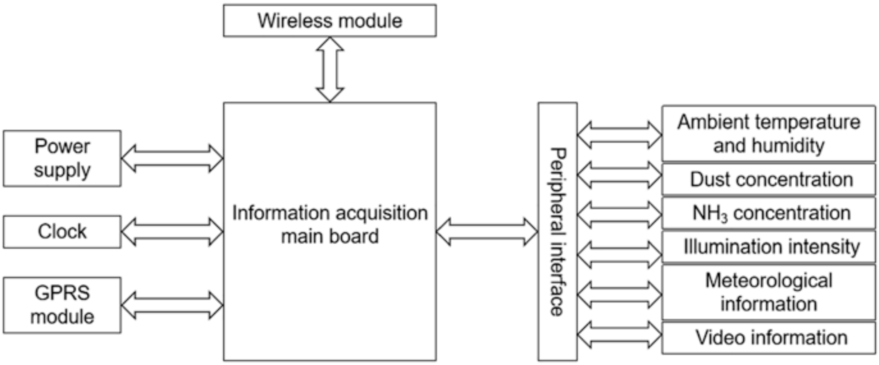


Fig. 12.2 The schematic diagram of the information collection structure for livestock environment

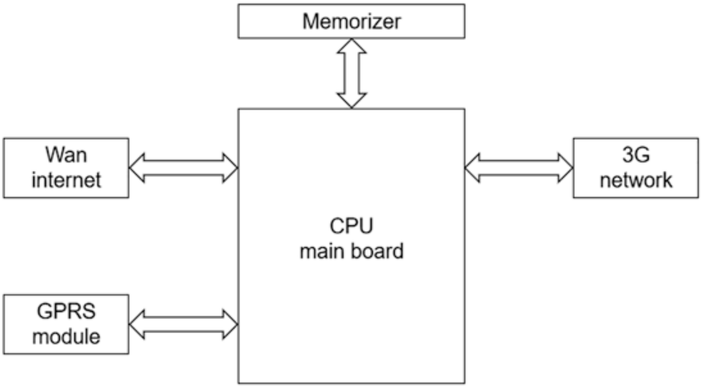


Fig. 12.3 The schematic diagram of transmission node structure

The transmission layer makes it possible to reliably transmit the collected information. In order to enhance the reliability of information transmission, the multi-path information transmission mode is adopted. The chain structure unit of the transmission layer is the transmission node, the basic form of information transmission is the point-to-point transmission, and the multi-hop remote transmission of information is realized via the multi-node configuration platform. The structure of the transmission node is designed according to the basic functions of the transmission node (as shown in Fig. 12.3).

Automatic Control Subsystem

Through intelligent algorithm and expert system, the control layer achieves the intelligent control of livestock environment on the basis of analyzing and collecting information. The control equipment is parallelly connected to the main controller that allows for manual control of the control equipment. According to the

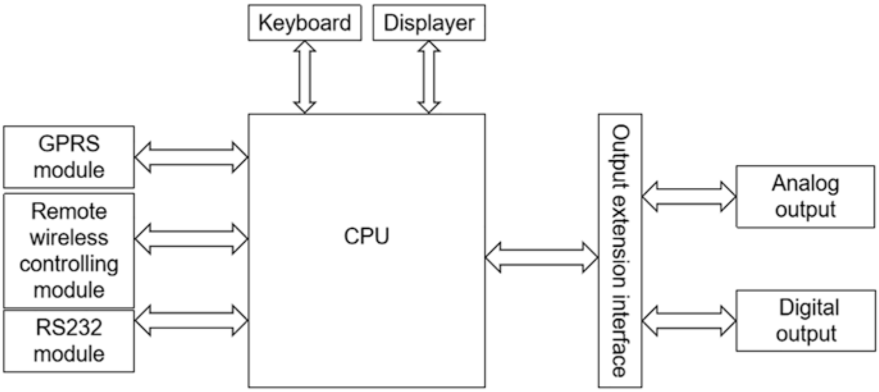


Fig. 12.4 The structure diagram of environment control system for livestock farming

parameters, such as air temperature, humidity, carbon dioxide, hydrogen sulfide, ammonia, and so on, detected by the sensor, the indoor control equipment could be controlled to achieve acquisition of parameters and automatic control. Figure 12.4 is an illustration of the structure diagram of environment control system for livestock farming.

12.2.2.2 Precision Feeding Management System for Livestock Farming

Precision feeding intelligently controls the feeding of fodder in the light of the different nutrient components, contents, and environmental factors required at each growth stage. The functions to be realized by the system are as follows:

Formula of Fodder
The measurement techniques of fodder formula in China's livestock farming, lagging behind those in developed countries, cannot meet the demand of livestock. Tapping into IoT technology and breeding experts' experience, the precision feeding management system established a quantitative model of fodder composition and contents at each stage for different livestock. Additionally, it makes the decisions for precision feeding relying on information on the farming environment and growth state collected by sensors.

Control of Fodder Composition and Content
Based on the establishment of feeding models for different animals, and combined with the actual growth conditions, the intelligent service platform will scientifically calculate the feeding amount and feeding times of the animals in a given day and conduct automatic feeding to avoid human errors.

12.2.2.3 Slaughtering Management System for Livestock Farming

Slaughtering Management

Firstly, the unified and standardized ID code, the crucial link of IoT technology, is utilized to systematically manage the basic information of slaughtering companies, and to supervise the plants' information, hence facilitating centralized management. Secondly, while enclosing the qualified animals for slaughter, the quarantine personnel will inspect the animals entering the waiting pens and record the inspection information, such as inspection date, inspector, cargo owners, quantity, death quantity, existing quantity, urgent killing quantity, and harmless treatment quantity, which will be automatically stored into the system. Thirdly, in the process of slaughtering animals, quarantine personnel could inquire the status of animals waiting for slaughtering through the system, then conduct synchronous quarantine, and supervise the slaughtering companies for quality inspection (refer to Fig. 12.5 for the major features).

Harmless Treatment of Diseased Animal

The harmless treatment of diseased animals covers the basic information of innocuous treatment plants, the mission of centralized plant innocuity, declaration and processing for dead livestock, daily report of innocent treatment, quantity summary of harmless treatment plant, verification for dead livestock and poultry, collection ledger of death of livestock and poultry, disposal transfer receipt for death of livestock, registration of harmless disposal of dead livestock, transport vehicle information of harmless handling, range of vehicle steering, vehicle trajectory monitoring, harmless disposal subsidies, and so on. The system function frame can be found in Fig. 12.6.

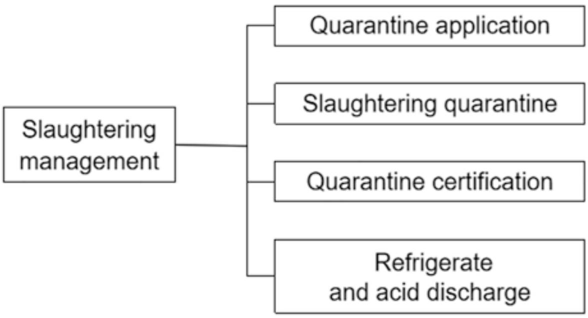


Fig. 12.5 The functional structure diagram of slaughter management module

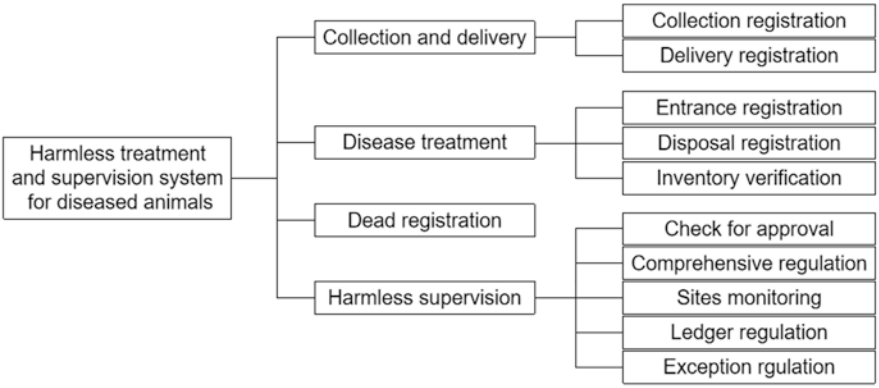


Fig. 12.6 The harmless treatment and supervision of diseased animals

12.2.2.4 Female Reproduction Monitoring System for Livestock Farming

The superiority of the intelligent female reproduction monitoring system lies in improving reproduction efficiency. The reproduction management system mainly includes sensor technology, predictive optimization model technology, and RFID technology. The estrus cycle of female livestock can be scientifically monitored, and precision feeding and digital management can be achieved according to the principle of genetic optimization, thus improving the reproduction efficiency, shortening the reproduction cycle, reducing the number of livestock raised for reproduction, and further lowering down the production costs. The functions of intelligent monitoring of animal breeding mainly include the following aspects.

Estrus Monitoring for Females
Estrus monitoring is an important link in the reproduction process of female livestock. If the right time is missed, reproductive capacity of female animals will go down. To raise the reproduction rate, the number one priority is to monitor the mating period. RFID technology is used to identify individual females, video sensors to monitor their behavior status, and temperature sensors to measure their body temperature. According to the collected data, the system analyzes and determines the estrus information of female livestock.

Female Fodder Management
Pregnant females are identified by electronic tags and are then raised separately in a group environment. Intelligent and automatic feeding (refer to the second section for more details) is conducted according to the precision feeding model and actual conditions of the individual female livestock, so that the growth of female livestock can be effectively controlled.

Database Management of Breeding Livestock

The breeding stock information database ought to be established. The database shall include the individual conditions, reproductive capacity, and immunity status. The database can improve the reproduction capacity of animals and the survival rate of young cubs.

12.2.3 Applications of IoT for Livestock Farming

In the Velos intelligent sow management system, each sow wears an electronic ear tag, which stores all the data concerning their entire life cycle. The amount of feed can be adjusted according to the growth status, activity, breed information, and even seasonal factors. The system recognizes electronic ear tags and controls the automatic feeding mechanism for accurate feeding according to the corresponding feeding curve. This approach avoids fluctuations in sow growth due to inaccurate feeding amounts, feed waste, and stress eating, ensuring that all sows receive the most accurate feed. In addition, the system is equipped with an automatic separator, which separates sick sows, vaccinated sows, estrus sows, and farrowing sows into different areas and marks them in real time. Meanwhile, remote management technology can enable managers in different places to be informed promptly and bring about information-based and modern pig farm management. At present, the Velos intelligent sow management system is widely used, particularly in the Netherlands, a number of European countries, and the United States.

To achieve accurate and intelligent feeding in large-scale farming, it is necessary to be able to identify the individual identity of sows. Velos wears each sow with an electronic ear tag featuring RFID, which is the electronic "identity card" of sows (as shown in Fig. 12.7).

Velos sow feeding station aims at achieving precision feed control of the individual sows. In livestock farming plants, the cost of feed accounts for approximately 35% of the total costs, and the precision feeding of individual sows can help farming plant see their costs reduced. Additionally, physical conditions of sows can be controlled by adjusting the amount of feed. Therefore, automation of feeding delivers tangible benefits to farming plants. Refer to Fig. 12.8 for an illustration of the structure of the feeding station. Adopting advanced sensing technology, image video processing technology, and data processing technology, the Velos estrus monitor enables real-time monitoring of sows and records the identity information of sows that visited boars and the time and duration of visit. Based on the frequency of visits and the time of communication with boars, the employees of the farming plant can render accurate judgment on whether the sow is in estrus and obtain the best breeding time, thereby improving the success rate and reproductive efficiency.

Fig. 12.7 Electronic ear tag

Fig. 12.8 Velos estrus monitor

12.3 Application of Aquatic Agriculture IoT System

12.3.1 The Overall Architecture of the Aquaculture IoT

To bring about information-based and intelligent aquaculture, firstly, various sensors are required for the collection of water quality parameters so as to ensure high water quality for aquatic products. Secondly, the collected information should be transmitted reliably in real time, which demands stable communication conditions. Finally, computer processing system should be used for analysis and decision-making of the transmitted data. In addition, in order to achieve accurate feeding and disease warning, it is necessary to combine IoT technology with image processing methods. This is the case because the precision feeding control and intelligent early warning of disease are enabled by image processing and decision-making. More specifically, images of the remaining bait and the aquatic products are obtained and are then transmitted through communication methods such as Ethernet for processing.

According to the technical support required above, the structure of aquaculture IoT is roughly the same with the average IoT structure, which is divided into three levels: the perception layer, the transmission layer, and the application layer. The structure of the aquaculture IoT system is demonstrated in Fig. 12.9.

12.3.2 Intelligent Water Quality Control System

12.3.2.1 Application Cases of Big Data Cloud Service Platform for Live Pigs During the Entire Industry Chain

Livestock farming, a mega-scale industry, is becoming increasingly important in China's agriculture. In 2013, the total value of livestock farming in China reached 2.8 trillion RMB Yuan, accounting for over 40% of the gross value of agriculture. This makes China the world's largest producer and consumer of livestock farming. For 200 million farmers, tens of billions of animals, and 680,000 veterinarians in China, the amount of data generated is vast and diverse. With the help of deep data mining, the value produced by such data would be immeasurable. Livestock farming is transitioning to data-driven and intelligent production and that the construction of the big data cloud service platform for live pigs during the entire industry chain is essential at this critical stage of the transformation from traditional to modern.

The construction of such a platform was proposed in light of the present situation of information-based development and the project industry development for livestock farming in Zhejiang and Hunan provinces. The data of this project, including the entire business system, underlying data of business platform, industry regulation and service data, and resource data of office business, are encompassed in data

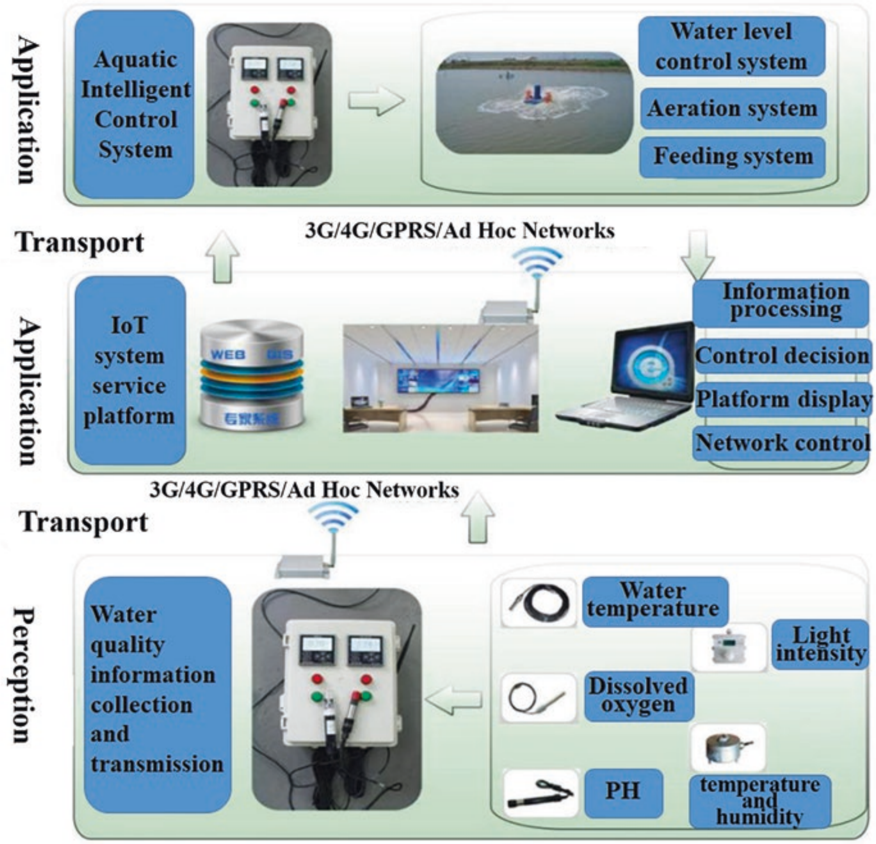


Fig. 12.9 The structure of the aquaculture IoT system

center, which can, at the same time, serve as the basic data platform of the original database and the future business system, covering supervision data, economic data, and business data resources of livestock farming and gradually evolving into a large data center for livestock farming.

Using the safeguard environments for operation, including hardware and software infrastructure, network security, and cloud storage, provided by China Telecom's e-cloud, basic software framework and data standard model are developed and constructed for big data analysis of livestock farming that centers on information collection, data services, and business applications, allowing for the effective integration between supervision administration data and production management data of the whole industry of live pigs and achieving the analysis and application of big data in livestock farming.

Screening is undertaken according to the data dimensions or attributes of multiple categories of the entire live pig industry chain, different performance methods are selected based on business requirements to observe and track the real-time

Fig. 12.10 The schematic diagram of big data display (main interface)

changes of data, and data are thoroughly analyzed to generate searchable and interactive charts that emphasize the presentation of data. Meanwhile, the potential correlation between the data of the entire live pig industry chain is identified to obtain distributed and multidimensional charts. The visualization module can be customized and configured freely (the schematic diagram of which (main interface) is shown in Fig. 12.10). The analysis and supervision system of the entire livestock industry chain covers the supervision of multiple links involving pig breeding, slaughtering, emergency response, and circulation and law enforcement.

Management of Breeding

Management of breeding process covers farm management, data collection management, production process and input management, animal epidemic prevention management, and origin quarantine.

Farm management. Farm management module will be developed and established. Using uniform and standardized ID codes, systematic management will be conducted with respect to such information as enterprise type, enterprise name, production type (breeding type), contact person, contact number, address, legal representative (name, contact number, ID number), industrial and commercial business license, qualification certificate of animal epidemic prevention, harmless treatment facilities, geographical coordinates, farm plans, and so on, so that information-based supervision of farms could be achieved. The geographic locations of the companies involved in livestock farming from all over the world are published on the GIS electronic map. These companies may include large-scale livestock farm households, transport checkpoints, harmless treatment plants of dead diseased animal, fixed points slaughtering companies, fodder production businesses and veterinary drug production and management businesses, and so on (shown in Fig. 12.11).

Data acquisition management. The data of sewage discharge from liquid level sensor, pressure sensor, and flow sensor in the live site of production and breeding can be transmitted to the data processing system through wired or wireless network

Fig. 12.11 Farm management (GIS map display)

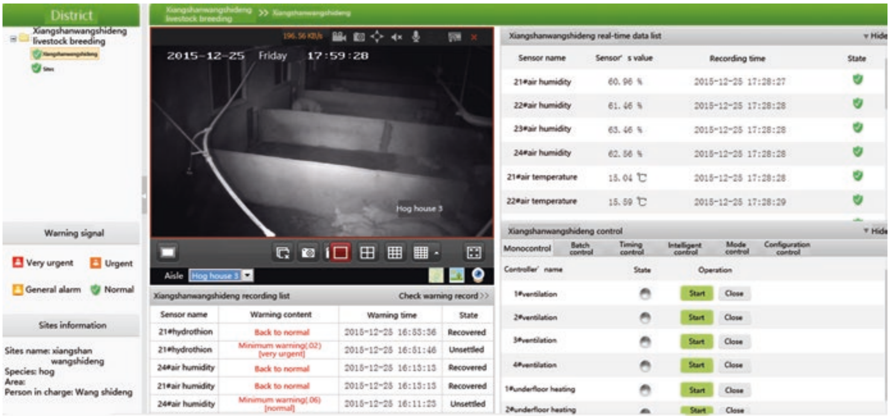


Fig. 12.12 The real-time monitoring of breeding farms

for intelligent analysis and processing. The system can store the past data and build a knowledge base for analysis and processing at any time. When the data related to sewage discharge is abnormal, warning will be given to management staff through short message service, POP window, and music and color warning. Through the platform, the video data of the base can be viewed in real time, and the remote observation of sensor data on the breeding site can be realized by any internet-connected terminal anytime and anywhere. Figure 12.12 is an illustration of the interface.

Production process management is applied to daily production management and statistical analysis of large-scale hog breeding farms. At the same time, it interacts with the higher-level departments for epidemic prevention, quarantine, inspection, etc. Via the process, the necessary production and epidemic prevention data can be uploaded and shared according to the needs of higher-level departments. In addition, the system enables individualized management of the breeding stock. Livestock for sale, associated via ear tags, are managed in batch. The system establishes archives of breeding and epidemic prevention for the particular batch of livestock and gives notice of production, epidemic prevention, and withdrawal period according to the production parameters and immunization programs settings. The system also features operation services such as log-type recording and stage-type economic benefit analysis, owners decision analysis, and application for quarantine, self-checking, and self-verifying for livestock product safety, receiving goods, and interaction with the local regulators. It is noteworthy that the system adopts the B/S mode. While the farm is engaged in production management, the necessary data will be collected and sent to the provincial monitoring data center of livestock farming.

Input management. The safety of fodder and veterinary medicine, the major inputs of livestock farming, is the foundation of the safety of livestock products and the key to ensuring the safety of livestock products from the source. While developing and establishing the input management module, the necessary license information is administered using the uniform and standardized ID code such as the database, geographic coordinates, basic information, and related production and operation license of the production enterprise. The entire-process supervision is achieved, going from company filing, production, sales, and supervision to market supervision and law enforcement, sampling, and release of information releasing.

Animal epidemic prevention management. Epidemic prevention management module is mainly employed by livestock farms, township veterinary stations epidemic personnel, and epidemic prevention supervision departments at all levels. The module is primarily adopted for business management and supervision that covers animal immunization, marking, and so on. The scope of epidemic prevention management module includes pigs, cattle, sheep, chickens, ducks, geese, and rabbits. Breeding stock are quarantined individually, commercial livestock in batch, as are poultry (the batch number determined using ear tags). The batch number of poultry is automatically generated based on the date of birth. The epidemic status of livestock can be registered through app and web terminal, while poultry vaccination status only through the web terminal. Refer to Fig. 12.13 for each module.

Origin quarantine. The livestock will be quarantined at the place of origin when leaving the breeding place, and the process and result of the quarantine at the place of origin will be recorded into the system. Such information will be automatically stored into the system. This process shall be applied to the management of quarantine operations in animal producing areas for the execution of the business processing and supervision of all links of quarantine operations in accordance with ministerial and provincial quarantine regulations. Furthermore, the system achieves a seamless link with the livestock production management system and the designated slaughter quarantine system. It is required that the system shall conform to the management standard of the provincial authority, enable the unified and electronic management of quarantine number, and feature automatic distribution and printing (system functions are as follows in Fig. 12.14).

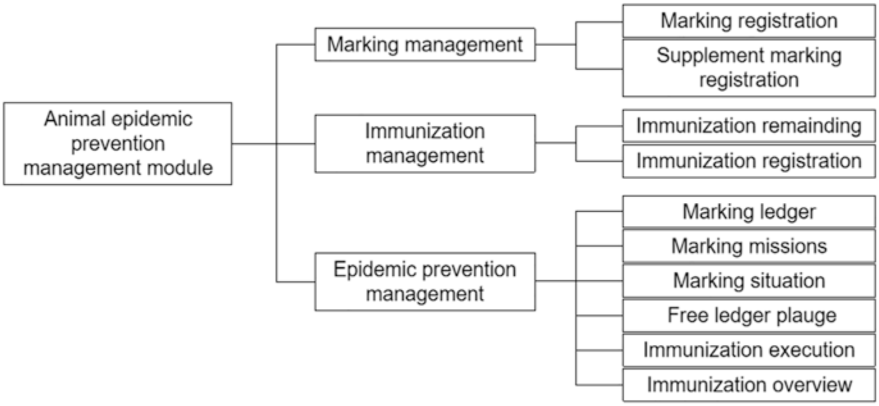


Fig. 12.13 The management module of animal epidemic prevention

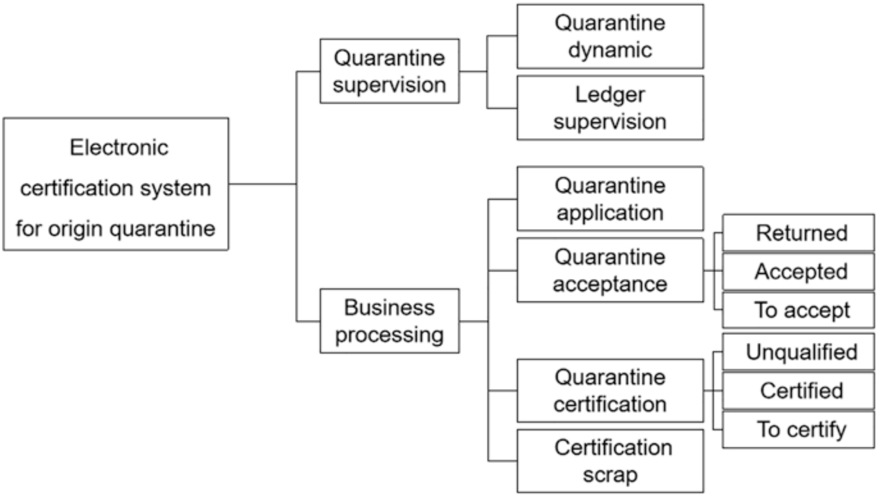


Fig. 12.14 The function diagram of electronic certification system for origin quarantine

Management of Livestock Slaughter

Concerning slaughtering businesses, a series of operations, such as animal admission registration, slaughter declaration, post-mortem inspection, factory registration, retrieving unqualified products, and harmless treatment registration, is enabled with the system. For supervision department, the system allows monthly registration of law enforcement, statistical inquiry of information related to slaughter, and effective linkage with quarantine management (refer to Fig. 12.15 for the interface).

Slaughtering site management. The system allows slaughtering businesses to fill in their basic information and submit it to the relevant authority for review. Moreover, it maintains basic information, supports the upload of business license and other

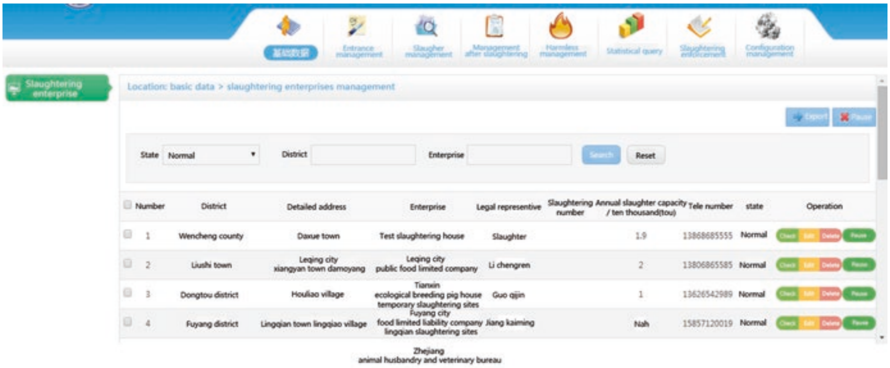


Fig. 12.15 The management interface diagram of slaughtering

credentials, and inquires the progress and details of the application for the record. Besides, the system also ensures that the entity that has been recorded would be able to once again file that record to deal with any change of documents. The records of slaughtering businesses include business numbers generated by system, business name, business type and district (specific to the township and village), detailed address, phone number, corporate information (name, ID number, resume, etc.), contact information of legal person, scale, business license, and self-check laboratory information.

Management of livestock slaughtering. When slaughtering animals, quarantine personnel can inquire the status of animals waiting to be slaughtered through system, then carry out synchronous quarantine on meat productions and sampling inspection of "lean meat essence," and supervise slaughtering businesses in their meat quality check. For products that fail in quarantine and inspection, harmless treatment would be carried out, which could be automatically recorded into the system. For those passing quarantine and inspection, the quick response (QR) code tracing encoding of the products is printed out using the QR code machine with traceability function matched with the system. The QR code encoding information is automatically uploaded to the system data center, through which the QR code tracing code is linked to the quarantine and inspection information of products.

In accordance with the animal slaughter quarantine regulations stipulated by the Ministry of Agriculture, the system enables the information-based management of businesses in terms of entry inspection, quarantine declaration, pre-slaughter inspection, simultaneous quarantine, harmless treatment, and quarantine result treatment. Additionally, it accomplishes the electronic certification of animal products and the networked dynamic supervision of slaughter and quarantine.

Harmless treatment of diseased animals. Seamless connection and automatic digitalization of all links is possible under this system, covering declaration, acceptance, collection, processing, statistics, and subsidies. The whole process is supervised by the system, from declaration of farmers and confirmation of primary supervision veterinarians and insurance survey personnel, to centralized arrangement and collection of harmless plants, and to the presence of harmless plant personnel and confirmation of harmless treatment. The images are shot and are then monitored and kept, while signatures are collected and uploaded by the handheld terminal. The supervision department, processing center, collection system, insurance company, and farm owner can cooperate in processing, thus making it possible to regulate the whole process of harmless treatment of dead animals and making the data traceable.

Emergency Command Management

Through monitoring of key links, transport vehicles monitoring, emergency command and dispatching, the digital traceability of key links for breeding, harmless treatment, transportation and slaughtering, and the emergency command and dispatching for emergencies can be achieved.

Key links monitoring. Remote command centers are built into three levels, province level, city level, and county level. The video signal is accessed using network and monitoring equipment from supervision object itself to implement the dynamic video remote monitoring for large-scale breeding farms, slaughterhouses, large wholesale markets, the designated crossings of animals and animal products, dispatching supervision and inspection station for animal epidemic prevention, laboratories of animal husbandry and veterinary, harmless treatment, and other regulatory tasks.

Monitoring of transport vehicles. BeiDou or GPS monitoring shall be conducted on fresh milk transport vehicles and transport vehicles in the harmless chemical processing site to track vehicle movement accurately. Through BeiDou or GPS tracking management system, transport vehicles can be fully tracked in real time, and the monitoring center can stay informed of the location and status of vehicles and goods at any time.

Emergency command and dispatching. On the basis of GIS system (Baidu map), the distribution and control of epidemic and safety incidents can be carried out in an intuitive, convenient, and stereoscopic way. Software that enables geographic positioning is relied on to mark the geographic information of relevant places. In the event of an epidemic or a safety incident, the epidemic spot, the epidemic area, the emergent immunization area, and the area designated for handling the incident can be automatically demarcated, marking the intersections that ought to be blocked. Figure 12.16 offers an illustration of the interface diagram of the GIS system.

Management of Sale Links

Management of sales links mainly includes the management of livestock products (pork), trading sites, and market monitoring management, including the management of livestock products business and marketing sites and the management of market monitoring.

Management of sites designated for the sale of livestock products. The management module of points of sale is developed for the information-based management of the basic information of these points of sale. The information recorded into the module mainly include the address of marketing place, person in charge, contact information, business category, relevant certificates, etc.

Fig. 12.16 The interface diagram of GIS system

Management of market monitoring. Daily automatic collection, statistics, analysis, comparison search of price, and short-term, medium-term, and long-term trend prediction analysis of pork price information in the major agricultural products markets of Zhejiang and Hunan provinces are undertaken to provide macro data for meat (hog categories) trading entities and government departments, hence facilitating relevant decision-making.

Management of Supervision and Law Enforcement

Production and management of fodder and veterinary medicine. The management of the production and operation information on fodder and veterinary drugs primarily incorporates the basic information of feed production businesses, veterinary drug production businesses and veterinary drug management businesses, and the reporting functions of the production capacity and the actual production about main products. The system is also equipped with the functions of retrieval, query statistics, and basic maintenance of the abovementioned information, so as to realize the management of the production and operation of fodder and veterinary drugs, and that of product quality monitoring. The information may be submitted by departments at the municipal and county levels or by the corporate entities themselves. The contents of the information can be updated according to the production regulation of fodder and veterinary drugs.

Supervision and management of animal health. The system is applied to the administrative inspection and business management of animal health in supervision institutes of animal health to achieve administrative inspection and supervision within their jurisdiction. The scope of supervision covers breeding farms, slaughtering and processing sites, animal diagnosis and treatment institutions, harmless treatment sites, isolation sites, etc.

Supervision and law enforcement of animal health. This module is applicable to the supervision, law enforcement, and case management of provincial animal health, mainly covering online case handling, manufacturing, and output printing of all kinds of law enforcement documents and other affairs. The module also features inquiry, statistics, and analysis functions. Entry of information in apps on mobile terminals is possible for on-site law enforcement and case investigation. Additionally, video recording of the law enforcement process is also available. To minimize manual input, multiple types of data can be set as dropdown options for selection, or the basic messages can be displayed automatically. Besides, the standard template of documents in each link of case investigation are also provided.

Electronic certification system of animal quarantine includes the administration of real-name registration for electronic certificate and the supervised management of animal health. The system achieves the all-round management of animal health supervision. This system, applied to the management of quarantine operations in production areas, completes the business processing and supervision of all links of animal quarantine in accordance with the ministerial or provincial quarantine regulations.

Quality and safety monitoring of livestock products. The module is used for the sampling and monitoring service of quality and safety for livestock products. The target users include provincial-, municipal-, and county-level supervision departments. They tap into the module to complete the registration of detection for livestock product quality and safety in production entities, such as breeding farms and slaughtering houses. Meanwhile, it is equipped with the function of query, retrieval, and statistics. The diagram of system interface is shown in Fig. 12.17.

12.3.2.2 Water Quality Monitoring System

In large-scale modern aquaculture, the quality of water is crucial to quality, efficiency, and production of aquatic products (Zhang et al. 2011). Water parameters ought to be promptly adjusted to create an ideal environment for growth.

At present, with respect to the monitoring of water quality, a number of physical and chemical indicators of aquaculture water bodies, such as temperature, salinity, dissolved oxygen content, pH, ammonia nitrogen content, redox potential, nitrite, and nitrate, are automatically monitored and alarmed (O'Flynn et al. 2010). The automatic control of water level, aeration, feeding, and other aquaculture systems and the remote monitoring system for multiple environmental factors of aquaculture have also been initially developed. The intelligent control of temperature, pH, and dissolved oxygen, the most common indicators in aquaculture, is of great significance to aquaculture.

Temperature sensors. Fish, shrimp, and other aquatic products are very sensitive to ambient temperature, and inappropriate water temperatures will affect the normal growth and metabolism of aquatic products. Therefore, water temperatures play an important role in the normal growth of aquatic products. Sensitive to temperature changes, temperature sensors can convert temperature information into electrical signals. These sensors are divided into four main types: thermistors, thermocouples, resistance temperature detectors (RTDs), and IC temperature sensors. Among them, the thermocouple features a simple structure and is widely used, but the device has a low detection accuracy. On the other hand, the thermistor comes with high

Fig. 12.17 The electronic certificate demo diagram

detection accuracy and fast temperature response, yet it may cause self-heating due to excessive current.

pH sensors. pH is significant indicator in aquaculture. At present, electrode potentiometric method is the commonly used pH detection method in aquaculture, while the silver-silver oxide electrode is the most common reference electrode. The basic principle of pH sensors is to convert chemical energy into electrical energy and to determine the pH value based on the voltage. Generally speaking, the method is reliable, yet signal drifts do occur in long-term use. In addition to the method

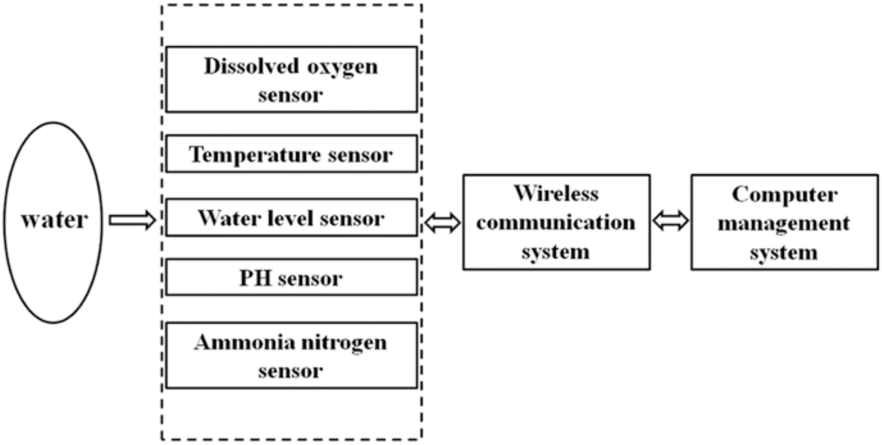


Fig. 12.18 Structure of aquaculture environment monitoring system

listed above, pH values can also be determined via photochemical sensors, pH test paper detection methods, and so on.

Dissolved oxygen sensors. Dissolved oxygen refers to molecular oxygen dissolved in liquid water. For aquatic plants, their survival depends on the amount of dissolved oxygen. At present, the electrochemical sensor is the most common type of dissolved oxygen sensor. The device depends on the detection current to determine the level of oxygen in water. As related technologies mature, optical dissolved oxygen sensors are also gradually applied to the detection of dissolved oxygen. This type of sensors has the advantages of sound stability, high sensitivity, and low drift.

The aquaculture water quality online monitoring system consists of three levels: information acquisition, network transmission, and computer data processing. The overall structure of the system is illustrated in Fig. 12.18. The bottom layer is a data collection node, which adopts a distributed structure. The bottom layer relies on multiple sensors to collect temperature, pH, dissolved oxygen, ammonia nitrogen concentration, and other parameters of the water body and converts the collected data into digital signals. The ZigBee wireless communication module is used to upload the data. The middle layer is the relay node that is responsible for receiving the data uploaded by the data collection node and for uploading the data to the monitoring center through the GPRS wireless communication module. The management personnel monitor the breeding area remotely, thus reducing labor intensity and achieving intelligent and science-based aquaculture.

In order to make the acquisition of information more portable, this design optimizes the water quality acquisition method of the sensing layer. Figure 12.19 is an illustration of the schematic diagram of the pumping structure. The solenoid valve is opened for a period of time and closed afterward. In the water tank, water quality information, such as pH, dissolved oxygen, ammonia nitrogen, and water temperature, is collected by the sensor, the information is then transmitted to the

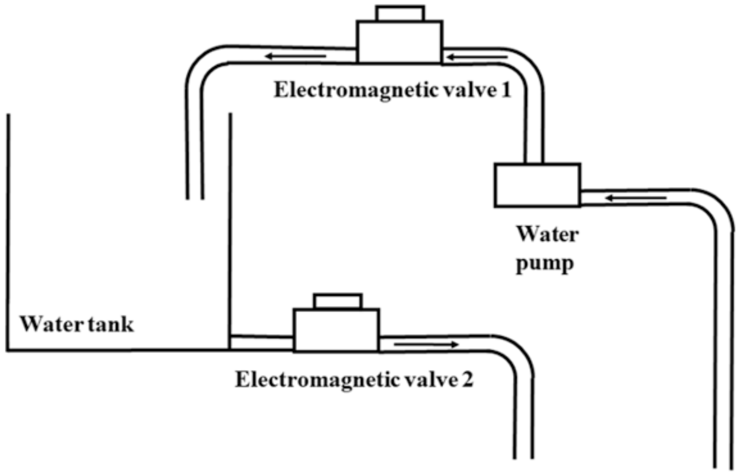


Fig. 12.19 Structure of pumping part

microprocessor, and the acquired data is displayed on the display control screen. Meanwhile, the data is transmitted to the PC in real time through the TCP/IP protocol for remote observation and management. In addition, the collected data will be compared with the predetermined threshold for water quality. If the obtained data exceeds the predetermined range, the system will control external equipment to undertake water quality adjustment. For example, oxygen levels can be increased by opening the waterwheel and the solenoid valve. After information on water quality is collected, the solenoid valve 2 is opened, and after draining for a given period of time, the solenoid valve 2 is again closed.

12.3.2.3 Water Quality Control System

If the obtained water quality index is beyond the normal range, the system adjusts the water quality by triggering the water quality control device until the water quality information returns to the specified range. The regulating devices are mainly aerators, water change solenoid valves, ozone machines, heating devices, etc. Among them, the dissolved oxygen controller is the key to achieving aeration control. It can drive a variety of aeration devices, such as impeller type, waterwheel type, microporous, and aeration air compressor, to improve water quality and to increase oxygen. The solenoid valve is a key device for adjusting water quality, including the adjustment of pH, ammonia nitrogen, and other indicators. Switching the solenoid valve on and off could control the water in and out of the breeding pond, thus maintaining the water quality index within the normal range. Temperature, another major indicator of normal growth, is primarily adjusted by heating devices.

12.3.3 *Aquatic Disease Warning System*

12.3.3.1 Disease Early Warning System Based on Machine Vision Technology

This system, based on image processing technology and IoT technology, includes perception layer, transmission layer, and application layer. Among them, the perception layer is mainly composed of industrial cameras, stepper motors, and aquatic product observation platforms, as shown in Fig. 12.20. The basic working principle is that the underwater observation platform is lifted by a motor through a rope. After being pulled to a certain height, the camera works to obtain the platform image information directly below it and transmits the image to the application layer through Ethernet. The disease identification model determines the number of aquatic products that are ill or dead and sends a signal to the warning light to urge the breeder to deal with the breeding pond in a timely manner. Figure 12.21 illustrates the working flowchart.

The specific method for implementation of the system is given below. To begin with, the timing of the motor is controlled by the internal clock switch of the main control board (timing can also be achieved through the display control screen). The motor rotates forward at certain intervals and pulls the observation platform from the bottom of the pool at a constant speed. Since most aquatic products, including vannamei and fish, will perish rapidly after leaving the water, the height should not be set too far from the surface of the water. Therefore, the appropriate observation platform height is selected according to the stretching height and motor rotation speed. After reaching a certain position, the motor stops rotating, and the industrial camera obtains the platform image and transmits the collected image information to

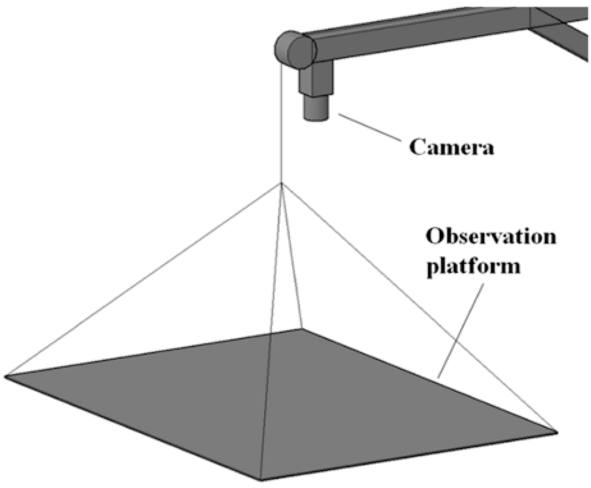


Fig. 12.20 Perceptual structure

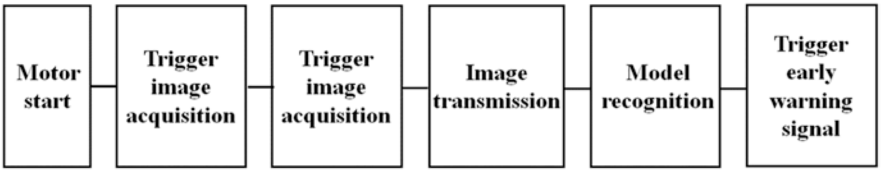


Fig. 12.21 Work flow chart of aquatic disease early warning system

the application end via Ethernet. Based on the established model, whether there is a diseased or dead shrimp can be determined. Such information is used as an early warning signal for breeding, which is available to breeders through PC or mobile terminal.

The functions of the machine vision system mainly include image background segmentation, image feature extraction and optimization, classifier application, data communication between upper computer and lower computer, etc. Primarily, it works through the trigger attribute that comes with the camera. The camera is triggered by combining the switching of the motor on and off with the code in the SDK software development kit. Only one image can be obtained per collection. Through image morphology and classification algorithms, the system achieves shrimp and bait extraction, identification of dead and dead shrimp, and bait recognition. With regard to the application and selection of classification algorithms, the effect of traditional machine learning algorithms and convolutional neural networks (CNN) on the classification of dead vannamei is taken into consideration. Eventually, the identification of dead shrimp and bait identification of vannamei is achieved, and an alarm signal is triggered to remind the staff to intervene and activate the automatic bait feeder.

12.3.3.2 Classification of Sick and Dead Shrimp Based on Image Processing

Based on the color difference between healthy and dead vannamei, and between body and background, healthy vannamei are extracted using the image gray value difference method. Figure 12.22a shows the effective area of the intercept. First, a grayscale histogram of the image is drawn, in which the abscissa represented the gray value and the ordinate represented the number of pixels corresponding to the gray value. The figure reflects the distribution of image gray values in a simple and intuitive manner. Three representative shrimps were selected for analysis, and other samples also demonstrated similar color characteristics. By analyzing the histogram, it was found that when the selected segmentation threshold was 100, the target and the background could be well-segmented. The area where gray value was smaller than 100 was set to 0; otherwise, the gray value was set to 1. Refer to Fig. 12.22b for the ROI image. Then the image was processed by dilation algorithm to eliminate the small and smooth objects. The canny edge detection algorithm was

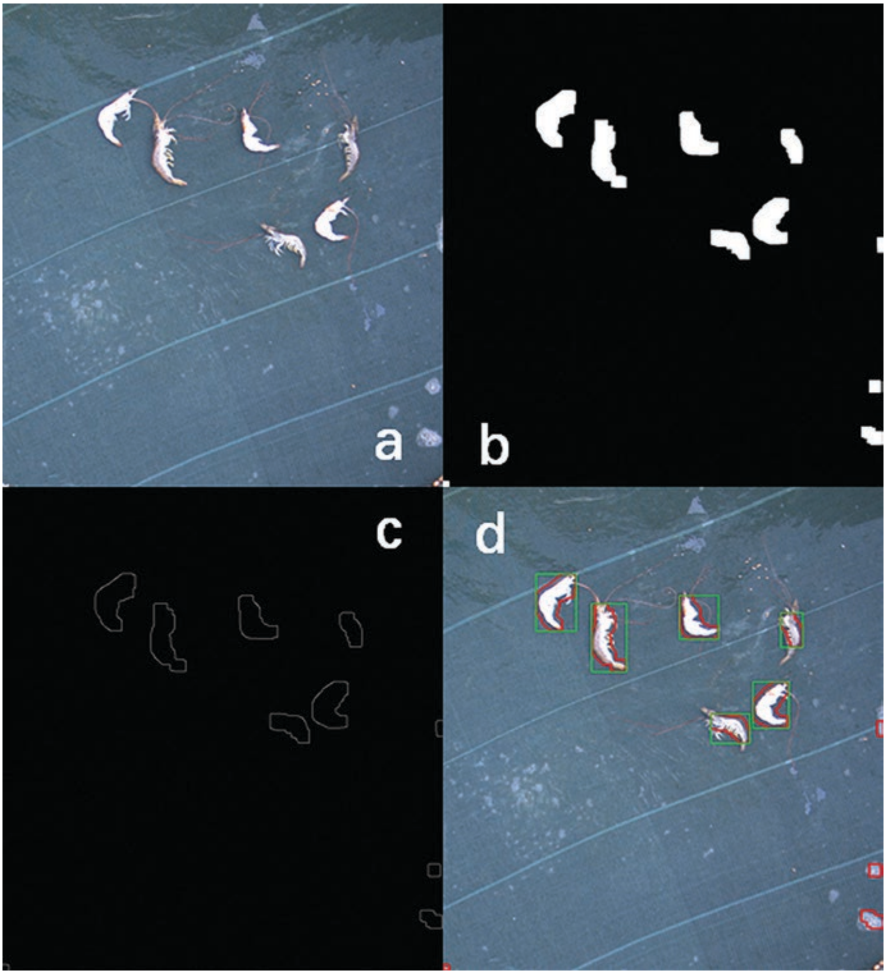


Fig. 12.22 Morphological processing of *P. vannamei*. (**a**) Effective area intercepted, (**b**) binarization, (**c**) target outline, (**d**) original image target selection

relied on to extract the contour of vannamei, as shown in Fig. 12.22c. Processing flow of the algorithm mainly includes the following five steps:

- Smoothing and denoising via a Gaussian filter
- Calculating the gradient intensity and direction of each pixel in the image
- Applying non-maximum suppression to eliminate the spurious response caused by edge detection
- Applying double-threshold detection to determine the real and potential edges
- Completing the edge detection by suppressing isolated weak edges

Finally, the leftmost, rightmost, uppermost, and lowest pixel coordinate positions are obtained according to the extracted edge contours. In order to ensure that the outline of the shrimp could be included in the selected rectangle, the rectangular area was extended by 20 pixels on the left and right and by 50 pixels upward and downward. The finally obtained selected area is illustrated in Fig. 12.22d.

Logistic Regression (LR)
Logic algorithm, simple, efficient, and easy to parallel, has been extensively adopted in many fields. As an online learning algorithm, it can use new data to update various features without the need to re-train past data. By introducing the Sigmoid function in the linear regression model, logistic regression maps continuous output values from the uncertain range into the (0,1) range. This becomes a probabilistic prediction problem. Its objective function is:

$$h_\theta(x) = g\left(\theta^T x\right) \tag{12.1}$$

The definition of the Sigmoid function $g(z)$ is as follows:

$$g(z) = \frac{1}{1+e^{-z}} \tag{12.2}$$

One method commonly used in statistics is maximum likelihood estimation (MLE), which finds a set of parameters so that the likelihood (probability) of data would be greater. There are multiple solutions that could address this optimization problem. Gradient descent, also known as the fastest gradient descent, is an iterative method. The optimal value is approximated by selecting the direction of the parameter that makes the objective function change the fastest at each step.

In this chapter, logistic regression is used to differentiate healthy shrimp from dead shrimp. The sample set of normal shrimp and diseased shrimp were 9352 and 9197, respectively. As a result, the fit score of the classification model (fit score) was 0.92.

Convolutional Neural Network (CNN)
Computing capabilities have grown rapidly in recent years; as a result, convolutional neural network algorithms also matured at a high speed. Featuring unique advantages, the algorithm has been widely used in research on image recognition, target classification, and so on. Common convolutional neural network algorithms mainly involve input layers, convolutional layers, activation functions, pooling layers, and fully connected layers.

The crucial role of the convolution layer is to extract features from the input two-dimensional data. A convolution kernel of a suitable size, also known as the filter or a square matrix of $N \times N$, is set, and its depth is consistent with the data of the input layer. The convolution kernel and the input layer data are continuously dot-multiplied to obtain new data as the next input.

The pooling layer changes the size of the image, a form of down-sampling. Convolutional networks are equipped with multiple forms of nonlinear pooling functions: average pooling, maximum pooling, etc. The max pooling is applied in this chapter. The size of the pooling is 2 × 2. The maximum pooling is essentially a process of filtering features. At the same time, the pooling layer will continue to reduce the size of data. Therefore, the number of parameters and calculation will also go down, avoiding overfitting to a certain degree.

Currently, the popular activation functions include sigmoid, tanh, relu, leaky, etc. Relu is used as the activation function here (Nair and Hinton 2010). Relu has its own advantages. First, it is free from vanishing gradients. Second, it increases network sparsity. Third, the computational complexity is small. Relu is expressed as:

$$f\left(x\right)=\max\left(0,x\right) \tag{12.3}$$

Figure 12.23 is an illustration of the function image.

The dropout layer plays a significant role in deep networks. As the number of network layers increases, the number of parameters increases rapidly, leading to overfitting. What is meant is that the network cannot generalize new data well and the difficulty of network training will significantly ramp up. The holding probability is between 0 and 1, usually between 0.2 and 0.5, and the probability p was set to 0.25 in this article.

When the above steps are executed, the convolution-activation-pooling-dropout loop process is completed. What this means is that all the features are connected through the fully connected layer, and the output value is finally sent to the classifier.

In this chapter, Conv (3 × 3 × 16) was used, which was a convolution layer. The 16-channel filter size was 3 × 3. Stride (1,1) was selected, which represented that the step size of the convolution process was 1. Maxpooling (2 × 2) was selected, which meant that it was a maxpooling layer with 2 × 2 filters.

In this sample set, the normal shrimp body and the diseased shrimp body were the same as above, 9352 and 9197, respectively. Each training reads 32 pieces, all of which were repeated 30 times. It was found that when cycling times was eight, the classification accuracy reached 92.03%, and the loss value was 0.2316.

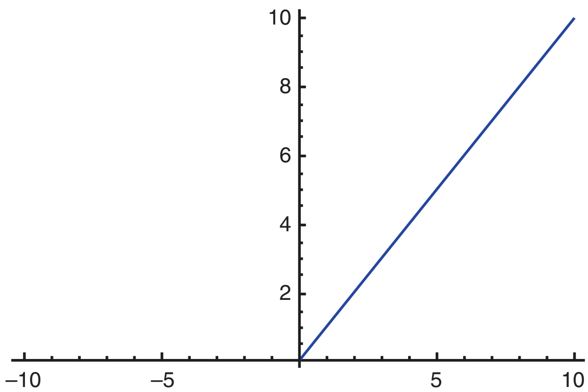


Fig. 12.23 Relu function

12.3.4 Precision Feeding System

12.3.4.1 Introduction of Precision Feeding System

Feeding methods is critical to aquaculture – improper feeding methods can result in wasted resources, and excessive feed may contribute to eutrophication, which causes pollution to aquaculture waters and brings unnecessary economic losses.

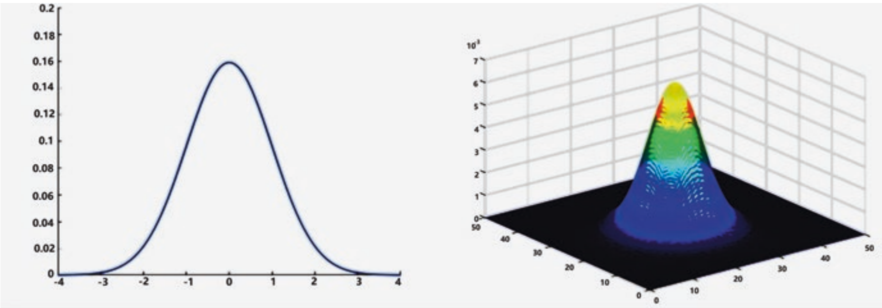
To achieve precision feeding, the model of the quantitative relationship among the growth stage, the feeding rate, and feeding amount should be established based on relationship between length and weight of aquatic products. Moreover, the relationship between the length and weight of each breed needs to be analyzed. Likewise, the relationship among external factors, such as light intensity, water temperature, dissolved oxygen content, turbidity, ammonia nitrogen and breeding density, and the absorption capacity and nutritional intake of fish bait, should be analyzed. By doing so, demand-specific feeding is achieved, and the loss of bait and costs are reduced.

In this chapter, a precision feeding system based on image processing technology is applied. The image acquisition method, the same as the aquatic disease early-warning system, is achieved by starting the motor to pull up the observation platform and triggering the camera to work. The acquired image is transmitted to the application through Ethernet. The remaining bait is discriminated and counted by the established model, which is used as the basis for determining the hunger levels of aquatic products (*P. vannamei*, fish, and so on). According to the remaining amount, the amount of bait is adjusted to achieve precision feeding.

12.3.4.2 Method for Identifying and Counting Bait Based on Image Processing

There are two types of targets in the image: bait and shrimp. In order to distinguish the two targets and identify the bait, this article completed the segmentation of bait targets based on the HSV color space of the image. In particular, H values represent hue, S values represent saturation, and V values represent brightness. Unlike the RGB color space, the HSV color space features an inverted cone model. The angle represents hue, the saturation represents the distance from the point to the central axis, and the brightness represents the position on the central axis. The ranges of the three components in OpenCV are H: 0 ~ 180, S: 0 ~ 255, and V: 0 ~ 255. Compared with the RGB color space, the HSV color space can reflect the hue, brightness, and vividness of image colors in a more intuitive manner.

Gaussian filtering, used in this chapter, is a common linear filtering smoothing algorithm. The goal of its adoption is to filter out Gaussian noise, which is a kind of noise with a probability distribution showing a Gaussian distribution. Gaussian filtering determines the parameter weights according to the shape of the Gaussian function to achieve smooth filtering. Figure 12.24 shows one-dimensional and



$$F(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \qquad F(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$

Fig. 12.24 1D and 2D Gaussian distribution functions

two-dimensional Gaussian distribution function graphs. The bait target could then be acquired according to the HSV threshold segmentation method. The image was binarized and then processed by the dilate algorithm. Target edge was processed by Canny algorithm. The processing results are shown in the Fig. 12.25. The remaining amount of bait was determined by calculating the number of targets.

This system is mainly designed for the breeding of pearl gentian grouper (hybrid of tiger grouper and gentian grouper). This intelligent management and control system are primarily involved with the water quality control of aquaculture ponds and ultraviolet sterilization ponds. In particular, one of the aquaculture ponds is selected as a demonstration pond. Major indicators of the system include pH, dissolved oxygen, and ammonia nitrogen. Data on water quality is obtained in real time to determine the "health status" of water quality. When the pH value is not within the normal range, the switches of the water inlet and outlet solenoid valve will be triggered to speed up the water change. When the dissolved oxygen value is not within the normal range, the aerators will be activated. When the ammonia nitrogen value of the tail water is not within the normal range after treatment, it will be indicated that the treatment effect of the purification cycle system failed to reach the requirements and the breeding personnel are prompted to cope with the situation in time.

12.3.4.3 Land-Based Multi-Niche Circular Aquaculture System

Based on the theory of niche complementarity, the land-based multi-niche circular aquaculture system forms an ecological circular aquaculture mode through species of different nutritional grade and achieves the goals of high efficiency, safety, energy efficiency, and emission reduction by optimizing the systematic aquaculture capacity and via control measures.

The system locates on the coast of the East China Sea in Longwan District, Wenzhou City, Zhejiang Province, China. The aquaculture base where the system is

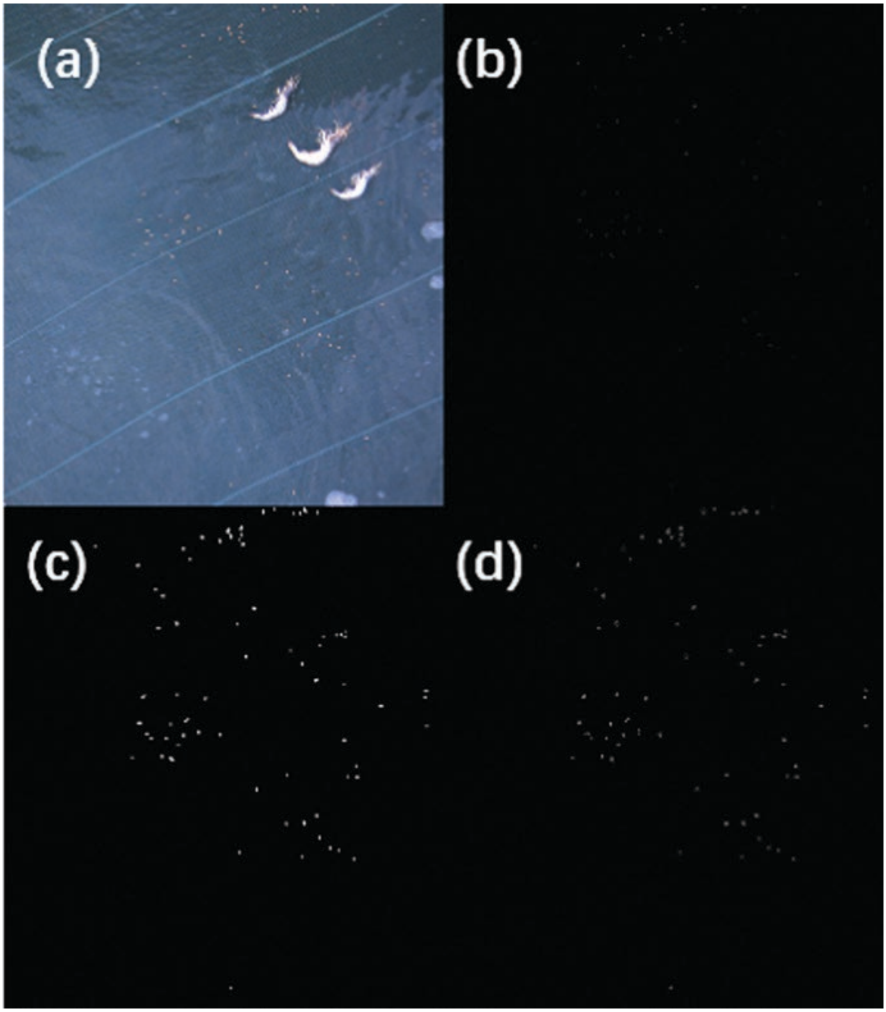


Fig. 12.25 Target processing results. (**a**) The original image, (**b**) binarization, (**c**) dilate process, (**d**) edge extraction

at covers a total area of 276 acres and is composed of five functional areas and two supporting systems. The five functional areas are high-level intensive cultivation area, seed breeding area, shellfish breeding area, plant cultivation area, and ecological purification area. The two supporting systems are circulating water channels and online water quality monitoring systems.

The tail water from the breeding area and high-level intensive culture area collects most of the bait and feces through the tail water treatment system, and the rest flows into the various shellfish breeding ponds through the circulation channel. First, the microalgae and organic debris in the water are removed by the shellfish filter-feeding function in the shellfish culture area. It then flows through the circulation channel into the planting area. Thirdly, through further biological, physical, and chemical purification, it flows into ecological purification ponds. After a period of time, water enters the underflow wetlands. Then, after the zooplankton and algae are settled in the water, it is pumped into the sand filter. Finally, it flows back into the greenhouse and high-level intensive culture areas.

By tapping into the multi-nutritional coupling effects of fish, shrimp, shellfish, algae, and salt-tolerant plants, the system maximizes the use of materials and energy in the system and delivers economic benefits. In addition, because the aquaculture water is recycled in the system, there is no need to inject water from external sources, hence reducing the dependence on the external environment and the ecological impact caused by sewage.

The risk of vannamei farming is relatively high, primarily because of the lack of precise monitoring and intelligent control equipment, particularly in high-density farming environments. Dissolved oxygen is the key to the survival of shrimp, as hypoxia can easily cause suffocation, while oxygen enrichment easily increases the risk of waterborne bacteria and infections. Therefore, the system developed an online water quality monitoring system and automatic control equipment to achieve online monitoring and control of water quality in the culture pond. The designed control scheme is illustrated in Figs. 12.26 and 12.27. The control instructions of the monitoring center are mainly based on the real-time information received from the fishing pond IoT and are sent to the controller through communication. The controller executes the operations of automatic oxygen increase, automatic drainage, and water supply according to the control commands. The principle is shown in Fig. 12.28. In addition, when combined with machine vision technology, it achieves identification and early warning of sick and dead shrimp and accurate feeding of bait.

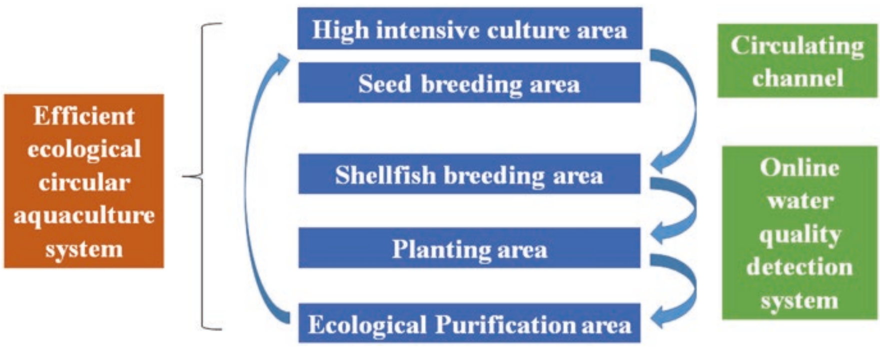


Fig. 12.26 Land-based multi-niche cycle breeding system

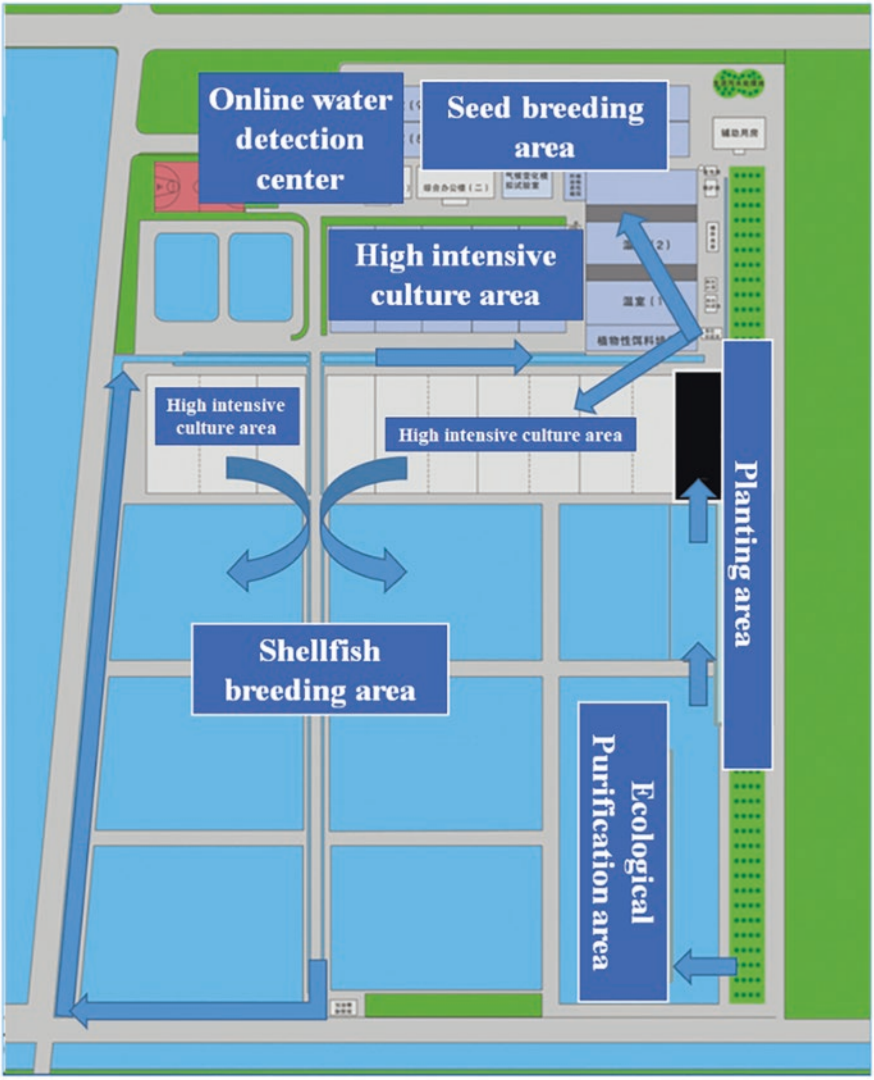


Fig. 12.27 Land-based multi-niche cycle aquaculture system

12.3.5 *Circulating Aquaculture System*

The industrial aquaculture system with recycling water, available at Dongtou Base, Zhejiang Aquaculture Research Institute, China, is mainly composed of aquaculture ponds, curved screens, pumps, sedimentation tanks, biological purification tanks, protein separation tanks, UV sterilization tanks and aeration tanks, etc. Figure 12.29 offers an illustration of the system.

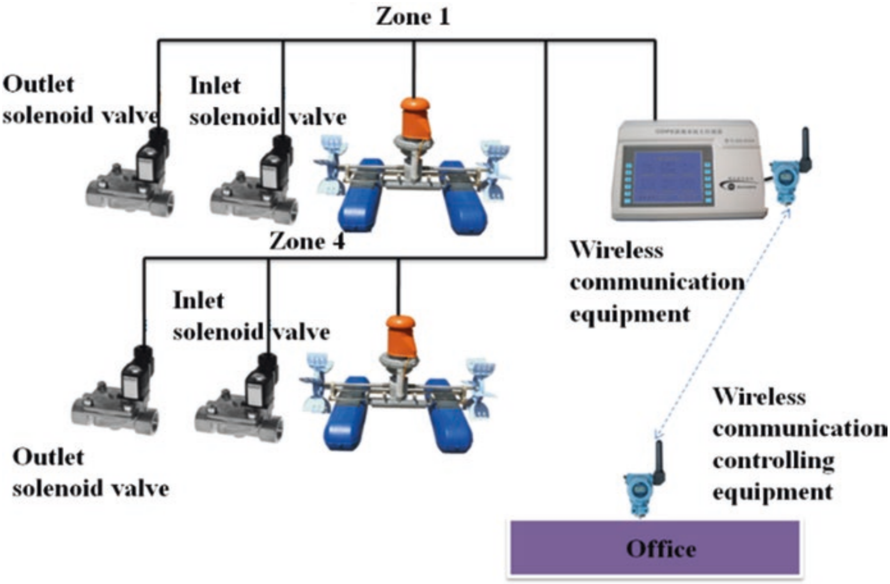


Fig. 12.28 Automatic aeration and water exchange of IoT

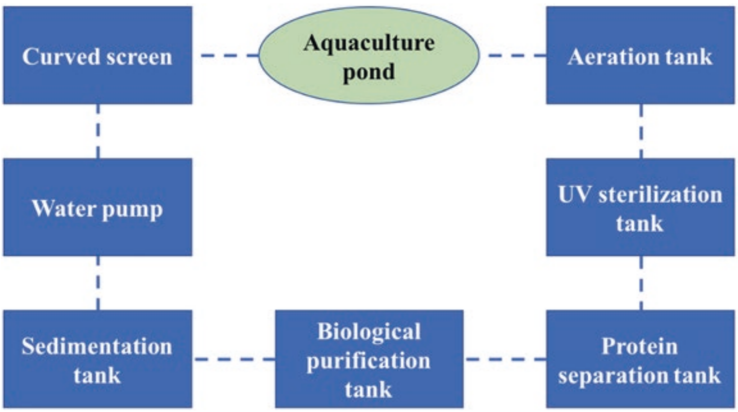


Fig. 12.29 Circulating water industrialized aquaculture system

12.4 Summary

Livestock farming and aquaculture are the major components of modern agriculture. Modern livestock farming and aquaculture is no longer limited to the modernization of the breeding process. It has evolved into the modernization of infrastructure, the modernization of management, the modernization of living and consumption, the modernization of resources and environment, and the modernization of science and technology. All these require the support of modern science and technology, especially that of modern information technology.

As a highly integrated information technology with comprehensive application, IoT has become one of the commanding heights of a new round of economic and technological development. The development of IoT technology has provided opportunities for the information-based growth of modern livestock farming and aquaculture, while aquaculture provides an application platform for the development of IoT technology.

Using sensor technology, wireless sensor network technology, automatic control technology, machine vision, radio frequency identification, and other modern information technologies, the livestock farming IoT system monitors the environmental parameters of livestock in real time. Additionally, the system rationally controls the environment of livestock farming according to the growth needs of livestock. The system allows automatic monitoring of livestock environment, fine feeding, breeding, slaughter management, and digital sales management.

Aquaculture IoT systems play a major role in aquaculture. It has transformed the traditional approach of heavy consumption of resources and extensive management in aquaculture, made possible the monitoring of the water quality and environment, and addressed the problems of the water quality deterioration caused by improper feeding and excessive drug use. Aquaculture IoT systems improve the quality of aquatic products and reduce the incidence of aquatic diseases. Relying on such systems, issues relating to aquatic product quality and aquatic environment pollution can be addressed, hence improving people's livelihood.

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