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Smart structural control and analysis of edge computing power in AI aquaculture

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Abstract

Traditional aquaculture fish ponds are located outside people's living areas. Collecting water environment data and uploading them to the cloud server for processing requires high network resources. Using edge computing power to process local data can solve network resource problems while achieving intelligent coordination between devices. Using the Raspberry *Pi* as an edge computing device in the local space, the system is explained from the three main aspects of the perception layer, the transmission layer and the application layer. The goal of real-time and refined resource management is achieved through intelligent algorithms, so that the data is respectable and credible. Further explore the feasibility of intelligent collaboration in aquaculture. Practice shows that the system runs stably on the physical model and has the characteristics of fast response in perception and control.

Subject Classification: *68 Computer science, 68M18 Wireless sensor networks .*

Keywords: *Edge computing power, Intelligent algorithm, Internet of Things technology, Aquaculture.*

1. Introduction

In recent years, intelligent algorithm is extended to apply various fields [1-95], such as the scale of aquaculture and the increase in species and density of aquaculture have made the safety and quality of aquatic

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products increasingly prominent [1]. In order to solve these problems, Huang Jianqing [1] and others built an aquaculture water quality monitoring system based on wireless sensor networks to realize real-time monitoring of water quality environmental parameters; Zhang Renmi [2] proposed distributed remote integrated monitoring of aquaculture based on Internet of Things technology. The management system collects various sensor parameters and performs computer processing and can make timely decision-making processing when abnormal conditions occur. At present, these systems have two problems: (1) The system only detects the water quality and when there is a problem, it will give an alarm to remind the management personnel without further processing; (2) In the aspect of control, the method of setting thresholds is used to change the environment. It is simply divided into several conditional intervals, which cannot correctly deal with sensor false alarms or caused by sudden changes in local parameters.

Based on this situation, this paper proposes an intelligent aquaculture system based on edge computing wireless sensor network, which can realize real-time monitoring of the water quality of fish ponds and at the same time adaptively adjust the changes produced by the water body, so that the water body environment is relatively normal and stable. The status of the aquatic products provides a guarantee for the growth of the entire life cycle of aquatic products.

2. System scheme design

2.1 *The overall composition of the system*

Based on the needs of the aquaculture environment, the system as a whole consists of 4 layers: the end device layer, the data transmission layer, the edge computing layer and the application layer, as shown in Figure 1.

The sensing parameters of the end equipment in this system include water temperature, PH value, turbidity value and water level; the control part includes air pump control (simulating aerator work), water pump control (simulating pumping and drainage process), feeding control; data transmission. The CC2530 chip used in the layer, integrates the wireless radio frequency module and the microcontroller (MCU) module; because the water oxygen content sensor is expensive; in order to obtain the water oxygen content, according to the water temperature and oxygen content data. The data of the grid network temperature nodes distributed in the pond indirectly reflect the oxygen content of the water body and then determine whether to turn on the air pump. The edge computing layer has

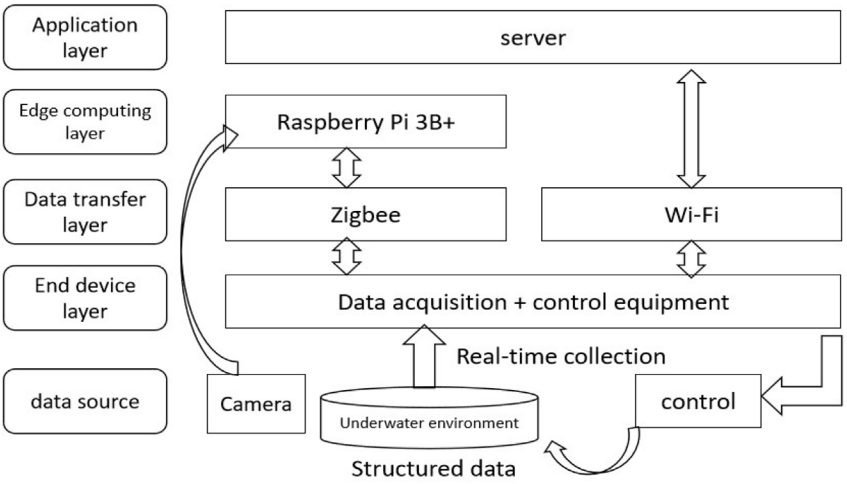


Figure 1

The overall composition of the intelligent aquaculture system

Raspberry *Pi* 3B+ to process the collected data and the application layer performs system viewing and control at the remote end.

2.2 *System key technology*

2.2.1 Fitting surface equations with least squares method

Because of the entropy increase theorem, the system always tends to become more chaotic [1-12]. The temperature values measured by the sensor nodes are not the same and will change over time. Therefore, the least squares method is used to process the node data, which will be limited [13-32]. The data is fitted by algorithm and the close surface equation is obtained, which reflects the changes in the overall aspect [33-49]. At the same time, it is necessary to use the maximum value of the scene temperature as the input data stream [50-74]. Based on this, the algorithm is used to determine the oxygen content in the water and the growth of fish, the genetic algorithm is used to solve the surface equation and the temperature is used as the fitness to screen individuals. At the same time as the amount of data processing, the maximum value of the multivariate high-order surface equation is solved. According to the data of dissolved oxygen and water temperature, the equation fitted by Matlab is y=0.0039928x2-0.35051x+14.453, The residual norm is 0.40646 and it can

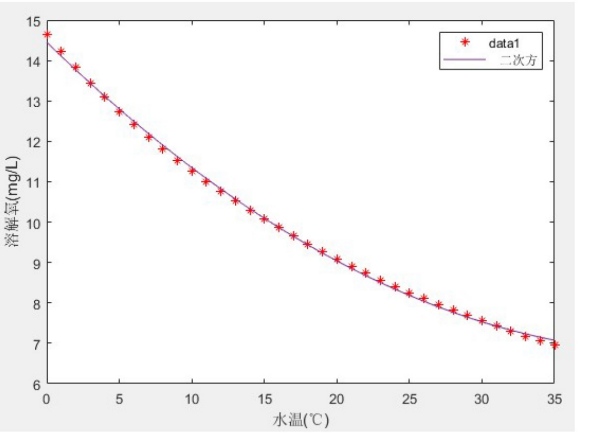


Figure 2

The relationship between water temperature and dissolved oxygen

be determined that this equation meets the experimental requirements. The curve is shown in Figure 2.

2.2.2 Genetic algorithm[8]

Intelligent algorithm is a branch of intelligent technology. As an edge cross-discipline, it perfectly integrates mathematics, biology and many other disciplines, aiming to reduce people's labor and improve efficiency. Here, genetic algorithm is used to solve the maximum value of the fitted temperature surface, instead of mental work.

(1) Encoding

Because the current computer technology generally adopts the binary number system, the binary encoding method not only satisfies the principle of computer processing information, but also facilitates operations such as inheritance, compilation and mutation of chromosomes. A single DNA with a length of 24 is used here.

(2) Decoding

The essence of decoding is to convert the chromosome binary information that is not easy to obtain intuitively into decimal information. The encoding and decoding of genetic algorithms can correspond to the genotype and phenotype of organisms at the macroscopic level and correspond to the two processes of DNA transcription and translation at the microscopic level.

(3) Cross swap

"Cross operation" is an operator that uses a single point or multiple points to cross. First, random numbers are used to generate one or more intersection positions and then two individuals exchange part of the genetic code at the intersection position to form two sub-individuals. That is, an individual is randomly selected as the mother in the population and the cross position is randomly selected and the child obtains the mother's gene at the cross position.

(4) Mutation

In order to avoid premature population convergence in the later stage of the algorithm iteration, for the individual population composed of binary genetic code, the genetic code is reversed with a small probability and for the binary code, 0 becomes 1 and 1 becomes 0. In the algorithm, the mutation position is randomly selected first and then the XOR gate inverts the binary bit.

(5) Judgment of individual fitness

The genetic algorithm determines the chance of each individual in the current population inheriting to the next generation population according to the probability proportional to the fitness of the individual. Individuals with greater individual fitness are more likely to be passed on to the next generation. The problem of finding the maximum value of the objective function can be directly used as a function of the fitness of the individual to be detected. Here the equation of the fitted surface is taken as.

(6) Copy

The replication operation determines the possibility of inheritance of the next generation according to the fitness of the individual. If the total number of individuals in the population is N; the fitness of individual i is fi, then the probability of individual i being selected

$$Pi = \frac{fi}{\sum_{k=1}^{N} fk}$$

When the probability of individual replication is determined, a uniform random number in the interval [0, 1] is generated to determine which individuals participate in replication. If the individual's fitness is high, the probability of being selected Pi is high and it may be selected multiple times and its genetic genes will spread in the population; if the individual's copy probability is small, it will be gradually eliminated.

3. System hardware design

3.1 *Chip*

In addition to computing power support on the edge side, powerful processing and storage capabilities are also required. Here, the Raspberry *Pi* 3 B+ is selected. The board is equipped with a 1.2GHz 64-bit quad-core Cortex-A53 processor and 1GB RAM for Surface fitting, genetic algorithm and machine vision were performed on the sensor node data to estimate the fish school size; considering the large number of end devices, the cheap MEGA328p was selected as the main control chip of the end device. The parameters are shown in Table 1:

3.2 *System hardware structure*

According to the needs of aquaculture, this system simulates the process of aquaculture. The system consists of sensors, air pumps (simulating aerators), feeding devices and air pumps (simulating water pumping and drainage processes). The hardware structure of the system is shown in Figure 3.

The sensing layer of the end device senses the water parameters of the aquaculture pond and transmits them to the microcontroller for further processing. The ZigBee wireless transceiver is the communication between multiple ponds and the WiFi module is used for data uploading to the cloud to realize the function of remote control; the sensor nodes are mainly Detects the overall situation and then transfer the data to the edge computing power equipment to execute intelligent algorithms and coordinate control devices; web management is an operation interface that is convenient for managers to use. The sensor types here are shown in Table 2.

4. System software design

4.1 *Data processing of grid node water temperature sensor*

Table 1

Related parameters of edge devices and end devices

	Raspberry *Pi* 3B+	**Arduino nano**
chip	BCM2837B0	MEGA328p
RAM	1GB	32KB Flash 2KB SRAM 1KB EPROM
size	85mm*56mm*19.5mm	45*18mm
weight	50g	6g

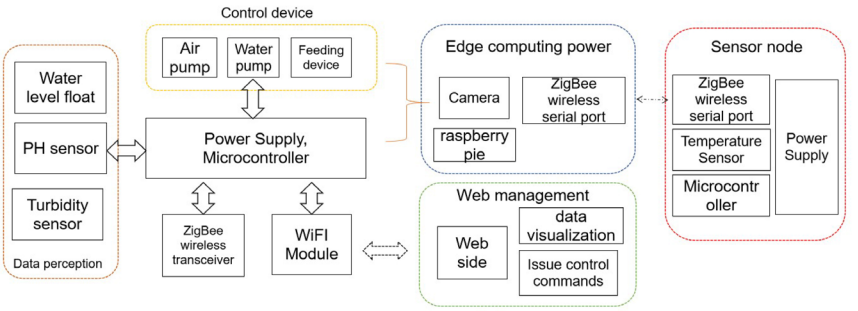


Figure 3

Overall block diagram of system hardware

Table 2

Types and indicators of water environment sensors

Identification parameters	Sensor name or selection	Scope of test
PH value of water body	PH electrode E-201-C	0-14ph
Turbidity value	Turbidity sensor	0-1000±30(NTU)
Water temperature	DS18B20	-55℃~+125℃

This time, 9 grid nodes use the 2.4G zigbee wireless serial port DL-20 module. The Sink node uses point-to-point negotiated communication to transparently transmit the regional data to the edge computing device and the remaining nodes use broadcast communication. As shown in Figure 4.

Here we take temperature as an example [74-95]. The data format is shown in Table 3. The z coordinate is the value of the temperature measured by ds18b20 and the data is plane-fitted using the least square method. The method in Huo Xiaocheng [4] is used, that is, for a given A set of data points (xk, yk, zk, k=1,2,…, N, Find a polynomial of degree m (m=N) $Z=\sum_{j=m}^{0}(\sum_{i=j}^{0}C_{i,j-i}x^{i}y^{j-i})$. Make the total error $Q=\sum_{k=1}^{N}[Z_{k}-\sum_{j=m}^{0}(\sum_{i=j}^{0}C_{i,j-i}x_{k}^{i}y_{k}^{j-i})]^{2}$ is the smallest.

Here m=9, since $N\geq 1/2(m+1)(m+2)$, m=2.

Suppose the fitted surface equation is

$$Z=C_{20}X_{2}+C_{11}XY+C_{02}y_{2}+C_{10}X+C_{01}y+C_{00}, \quad (1)$$

Total error

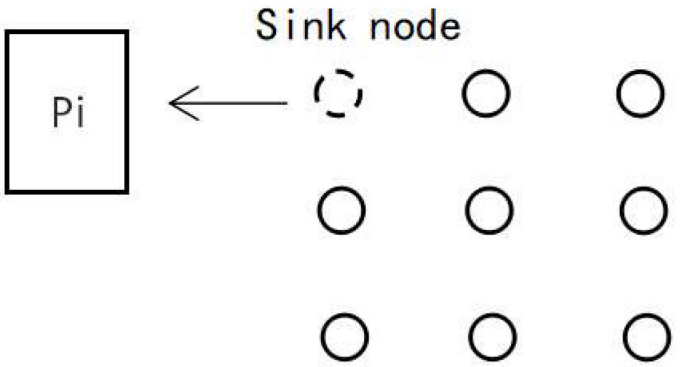


Figure 4
Schematic diagram of grid node distribution

Table 3
Node coordinates and sensor data format

x	*y*	*z*	**Node name**
0	0	26.7	Sink
0	1	26.9	Node1
1	0	26.5	Node2
1	1	26.3	Node3
1	2	26.7	Node4
2	1	26.9	Node5
2	2	27.0	Node6
2	3	26.8	Node7
3	2	26.3	Node8

$$Q = \sum_{K=1}^{9} [Z_k - (C_{20}X_2 + C_{11}XY + C_{02}y_2 + C_{10}X + C_{01}y + C_{00})]^2, \tag{2}$$

Depend on $\frac{\partial Q}{C_{20}} = 0,$

$$2\sum_{K=1}^{9} [Z_k - (C_{20}X_k{}^2 + C_{11}X_kY_k + C_{02}Y_k{}^2 + C_{10}X_k + C_{01}Y_k + C_{00})]X_k{}^2 = 0, \tag{3}$$

$$\sum_{K=1}^{9}[Z_k-(C_{20}X_k{}^4+C_{11}X_k{}^3Y_k+C_{02}X_K{}^2Y_k{}^2+C_{10}X_k{}^3+C_{01}X_K{}^2Y_k+C_{00}X_K{}^2)]^2 = \sum_{K=1}^{9}Z_KX_K{}^2, \tag{4}$$

$$C_{20}\sum_{K=1}^{9}X_k{}^4+C_{11}\sum_{K=1}^{9}X_k{}^3Y_k+C_{02}\sum_{K=1}^{9}X_K{}^2Y_k{}^2+C_{10}\sum_{K=1}^{9}X_k{}^3 +C_{01}\sum_{K=1}^{9}X_K{}^2Y_k+C_{00}\sum_{K=1}^{9}X_K{}^2=\sum_{K=1}^{9}Z_KX_K{}^2, \tag{5}$$

In the same way, the other 5 items contain C_{20}, C_{11}, C_{02}, C_{10}, C_{01}, C_{00} equations.

$$C_{20}\sum_{K=1}^{9}X_k{}^3Y_k+C_{11}\sum_{K=1}^{9}X_k{}^2Y_k{}^2+C_{02}\sum_{K=1}^{9}X_KY_k{}^3+C_{10}\sum_{K=1}^{9}X_k{}^2Y_k +C_{01}\sum_{K=1}^{9}X_KY_k{}^2+C_{00}\sum_{K=1}^{9}X_KY_k=\sum_{K=1}^{9}Z_KX_KY_k, \tag{6}$$

$$C_{20}\sum_{K=1}^{9}X_k{}^2Y_k{}^2+C_{11}\sum_{K=1}^{9}X_kY_k{}^3+C_{02}\sum_{K=1}^{9}Y_k{}^4+C_{10}\sum_{K=1}^{9}X_kY_k{}^2+C_{01}\sum_{K=1}^{9}Y_k{}^3 +C_{00}\sum_{K=1}^{9}Y_k{}^2=\sum_{K=1}^{9}Z_KY_k{}^2, \tag{7}$$

$$C_{20}\sum_{K=1}^{9}X_k{}^3+C_{11}\sum_{K=1}^{9}X_k{}^2Y_k+C_{02}\sum_{K=1}^{9}X_KY_k{}^2+C_{10}\sum_{K=1}^{9}X_k{}^2+C_{01}\sum_{K=1}^{9}X_KY_k +C_{00}\sum_{K=1}^{9}X_K=\sum_{K=1}^{9}Z_KX_K, \tag{8}$$

$$C_{20}\sum_{K=1}^{9}X_k{}^2Y_k+C_{11}\sum_{K=1}^{9}X_kY_k{}^2+C_{02}\sum_{K=1}^{9}Y_k{}^3+C_{10}\sum_{K=1}^{9}X_kY_k+C_{01}\sum_{K=1}^{9}Y_k{}^2 +C_{00}\sum_{K=1}^{9}Y_k=\sum_{K=1}^{9}Z_KY_k, \tag{9}$$

$$C_{20}\sum_{K=1}^{9}X_k{}^2+C_{11}\sum_{K=1}^{9}X_kY_k+C_{02}\sum_{K=1}^{9}Y_k{}^2+C_{10}\sum_{K=1}^{9}X_k+C_{01}\sum_{K=1}^{9}Y_k +9C_{00}\sum_{K=1}^{9}Z_K. \tag{10}$$

Calculate x, x_2, x_3, x_4, y, y_2, y_3, y_4, z and the permutations and combinations between them and bring them into the corresponding equations and get 6 equations in a 6-element linear equation system.

The simultaneous equations use Gaussian elimination method to find the coefficients of the surface equations. After obtaining the equation form (1), the genetic algorithm is used to go through the steps of encoding

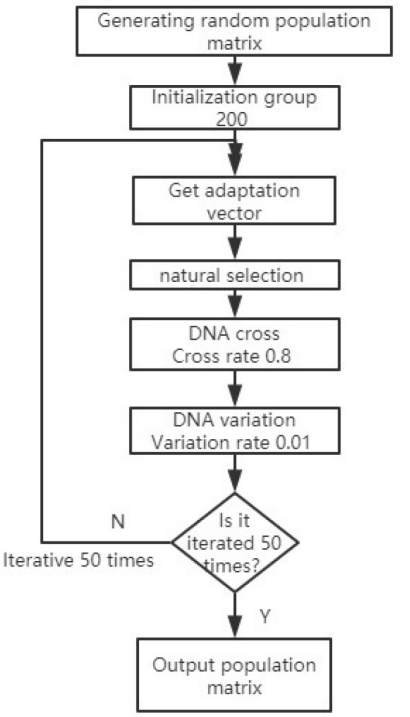


Figure 5

The process of obtaining surface equations by genetic algorithm

and decoding, crossover and mutation and natural selection to obtain the maximum temperature coordinate, as shown in Figure 5. Find the air pump adjacent to it through the coordinates and then let the air pump work according to the threshold. Filter before the numerical input of the sensor, delete the larger deviation in a set of data, to prevent the pollution of dirty data.

4.2 *Average quality algorithm of fish school*

The system needs to estimate the average size of the fish school and it is best to conduct surveying and mapping without fishing. Therefore, image recognition technology is the main technical means. For this reason, a physical index of tilapia needs to be found as a direct measurement value and then based on Relations get the desired value. When studying the relationship between the measurable traits of fish, such as the body length-weight relationship, age-weight relationship, age-body length relationship, etc., statistical methods are usually used and the correlation coefficient

is important. In fact, even if there are two unrelated physical quantities, statistical methods can be used to find the "correlation" between the two. However, the establishment of a truly universally meaningful functional relationship must consider the biological significance and dimensional harmony of each statistical trait [4]. On this basis, the research object is tilapia, which does not require a very precise mass size. For this reason, we adopted the relationship between body length and weight based on statistical probability:

$$W = 1.3168 \times 10^{-2} Ls2998; \text{[5]} \tag{11}$$

W is the body weight of the fish and Ls is the body length of the fish. After obtaining the relationship between body length and weight, use the open cv-python open source tool to perform grayscale operations, filtering operations, binarization threshold segmentation, Canny edge detection, morphological operations, etc. on the acquired images [6]. The specific operation process is shown in Figure 6:

The corrected image uses a bar-shaped object with a known physical real length placed on the left frame of the image and the bar-shaped object is parallel to the left frame and slightly smaller than the left frame. Scale = the number of pixels occupied by the object image / the actual size of

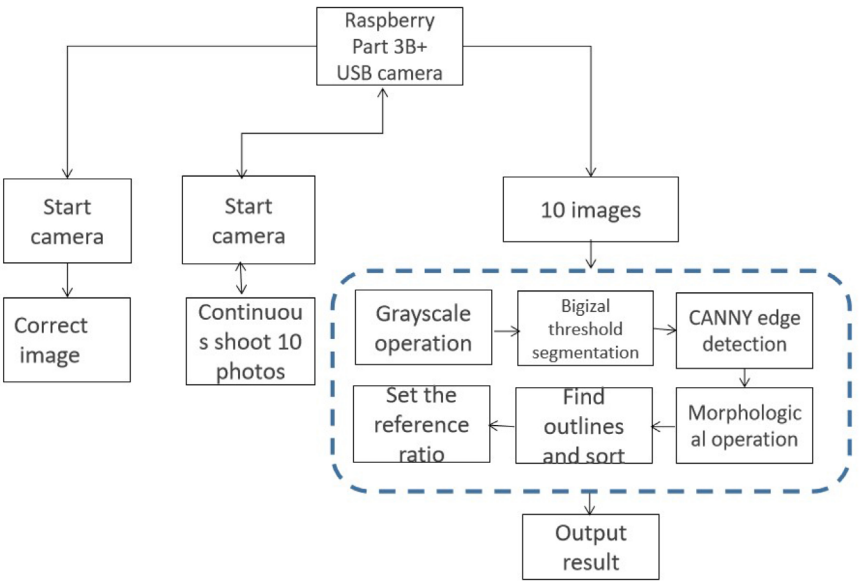


Figure 6

Work flow chart of edge computing power

the object. Using this proportional relationship, the body length of other tilapias on the image can be obtained and then the predicted weight value can be obtained by formula (2).

4.3 *WEB end design*

In order to achieve cross-platform control of the system, the Vue framework and Baidu's open source data visualization tool ECharts are used to facilitate the operation and viewing of data by management personnel. Vue is a progressive framework for building user interfaces. It adopts a bottom-up incremental development design method. It is a more flexible and open solution with a simpler architecture. It is suitable for developers to quickly grasp all its features and put them into use. It is also convenient Integrate with third-party libraries or existing projects [7]. In this system, in addition to requiring the stability of the host computer, real-time response to data is also an indispensable aspect. Using ECharts to speed up development efficiency, the visualization of sensor data gives people an intuitive feeling.

5. System test

5.1 *Web management end test*

First, perform real-time visualization of some of the acquired data and pour clean water into the fish pond model to simulate the data. After a period of time, the effect is shown in Figure 7. The water pump, air pump and feeding device are tested, the system is working normally and the instructions are issued by the server to the main control module of the fish pond.

5.2 *Thermal map simulation of pond water temperature*

The effective communication distance of the wireless serial port DL-20 module is 250 meters. After the data is collected, it is transmitted to the Raspberry *Pi* through the serial port for calculation and the coordinates of the maximum value are obtained. The effect of running on the PC here is shown in Figure 8.

5.3 *Average fish quality test*

The set-up camera is located directly above the feeding port. The usb camera is used to sample the video stream of tilapia activities. In order to achieve the effect of this identification more accurately, the video taken this time is set to take a picture every 1 second and save it in a folder, a total of 10 pictures. In order to correct the photo in the correct position, we use a

-	鱼塘1				鱼塘2			
时间	温度	浑浊度	PH	水位	温度	浑浊度	PH	水位
1534774530.685261	24.43	693	6.69	正常	24.87	847.4200000000001	6.57	正常
1534774531.1112235	24.43	693	6.69	正常	24.87	847.4200000000001	6.57	正常
1534774532.8239868	24.43	693	6.69	正常	24.87	862.68	6.58	正常
1534774532.9768345	24.43	693	6.69	正常	24.87	862.68	6.58	正常
1534774535.105395	24.43	724.36	6.69	正常	24.87	862.68	6.58	正常
1534774535.4633262	24.43	724.36	6.69	正常	24.87	862.68	6.58	正常
1534774537.4743376	24.43	724.36	6.69	正常	24.87	832.3000000000001	6.59	正常
1534774537.694835	24.43	724.36	6.69	正常	24.87	832.3000000000001	6.59	正常
1534774539.3935122	24.43	693	6.68	正常	24.87	832.3000000000001	6.59	正常

Figure 7

Screenshot of part of the management interface

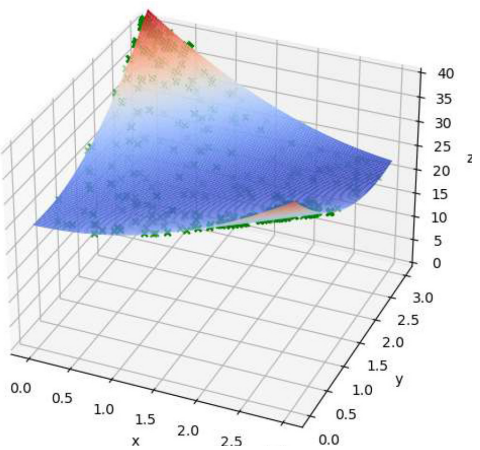


Figure 8

Raster node temperature fitting surface

certain long colored marking line as a reference line. The camera position is verified one by one on the photos captured by the video stream and the effect is shown in Figure 9.

The adjusted result uses the marker on the left as the reference point and the size of the reference point is a known quantity and the average size of the fish school in the area is estimated based on this. Here we select a picture and infer the weight of the goldfish based on the image to be 0.64kg and then traverse the size of other fish schools in the viewing angle to finally get the average quality of the entire area of the breeding area and determine whether it meets the fishing conditions, as shown in Figure 10. Show.



Figure 9

Video stream capture screenshot

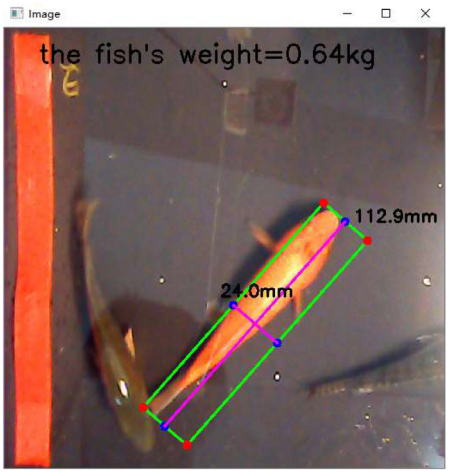


Figure 10

A picture for the quality of fish

6. Experimental results and analysis

Practice has shown that in water quality monitoring and control management, the delay is mainly due to the delay of network transmission, which can collect data in real time and control the work of the drainage, air pump and feeder of the control system; in solving the equation to fit the curved surface and the genetic algorithm, computing power is required. support. The average quality of the fish school can meet the expectations of the experiment under the condition of little environmental interference. In practical applications, the water surface environment is more complicated and the interference generated is large. It is necessary to improve the algorithm before it can be promoted and used. In practical applications, sonar equipment can be used to capture and describe the size of the fish school and the water layer where the fish school is located more accurately.

7. Conclusion

In order to get closer to the real environment of aquaculture, it is necessary to extract the characteristics of the main factors of the production

environment. Considering that the Internet of Things generates a large amount of data uploaded to the cloud for analysis, waste of network bandwidth, high latency and many other drawbacks, the introduction of edge computing can solve the problem. This article is based on an attempt to realize intelligent aquaculture under edge computing. After a period of operation, the control device and sensing device are operating normally and the high temperature point can be found by fitting the surface of the water body temperature, indicating the feasibility of using edge computing power to intelligent aquaculture sex.

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