Design of Intelligent Fish Box Based on Machine Vision and Internet of Things Technology

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Abstract

The intelligent fish box based on machine vision and Internet of Things includes many fields such as machine vision, Internet of Things technology, single-chip microcomputer control and so on. It is an intelligent system that receives user instructions or voice control through the Internet to achieve a series of operations. At the same time, there is a temperature sensor in the fish box, which can transmit the temperature to the mobile phone APP in real time, and intelligent control the water temperature in the fish box. In addition, the fish box granaries send information to the user when the fish food is insufficient, and the camera in the fish box can monitor the situation of the fish box in real time, when a fish belly notifies the user to deal with.

Keywords: Raspberry Pi, machine vision, neural network, Internet of things, machine learning

1. Introduction

At the request of China's Ministry of Industry and Information Technology, many places across the country should be based on the positioning of "seeking reform, promoting application and guiding experience", further strengthening application orientation, accelerating the application of new technologies and products such as artificial intelligence, fostering the formation of new economic growth points and exploring more new models, and now the demand for intelligent fish feeding equipment is increasing. The huge demand for intelligent fish boxes in society has also prompted the development and manufacture of intelligent aquarium controllers of various types and applications within manufacturers in different countries around the world. [1] As a result, some controllers with simple circuits, stable operation, and automatic intermittent operation have appeared on the market. However, since different devices operate independently and each has its own environmental parameters, several independent controllers must be installed in the aquarium. This individual control device is relatively expensive, so the research and development of multi-
purpose fish tank controller has been increasingly important to major manufacturers, and a variety of multi-functional controllers have been introduced.[2]

The rest of this paper is organized as follows. The second section carries out the analysis of smart vision fish box functions. The third section carries out the design of the intelligent visual fish box controller. The fourth section carries out the design of the smart vision fish box sensor, including both peripheral sensors and actuators. The fifth part is the software design, which illustrates the control algorithm of each part of the fish box and introduces the neural network vision algorithm to identify the health condition of fish. The sixth part is the system test, which carries out the debugging and preparation of each part. The seventh part summarizes the main contents of this paper.

2. Analysis Of Intelligent Visual Fish Box Functions

2.1. Overall system scheme design

The system is composed of Arduino development board as the main control board, Raspberry Pi as the visual recognition part, plus peripheral circuits. The important components are mechanical structure, Raspberry Pi, camera, main control board, switch, relay, temperature sensor, WIFI module, voice control system, various motors, etc.

The system is controlled by the cell phone side of the APP network to send signals to the microcontroller, or voice control part and the main control board for serial communication. The mechanical part models the automatic

feeding part with the electric control box, and then connects directly with the box.

The system adopts 5V for control electricity, and it can work normally by accessing 220v household socket. The fish box can be automatically connected to the Internet after the power is turned on, and the water pump, oxygen pump, and lights can be switched on and off through the cell phone; and the data collected by the temperature sensor can be transmitted to the cell phone, and the historical water temperature change curve can be viewed at the cell phone. In addition, the voice control part recognizes the sound collected by the radio device and sends the corresponding hexadecimal data to the main control board, which can realize voice control. The fish tank is left with a 4-day fish food bin, so users can open the APP for feeding anywhere; after the fish food bin is empty, the fish tank sends a signal to the user to remind the user to add fish food and reset the food bin to zero position. In addition, the camera can monitor the fish health in real time and send a notification to the user when there is a fish death, so that the user can clean up in time to prevent further pollution of the water body.[2]

2.2. Introduction of external structure

The electric control box body is built with white PVC foam board, which is more sturdy. The circuit wiring is placed inside to ensure the normal function of the system. The design of the electric control box is shown in Fig1.

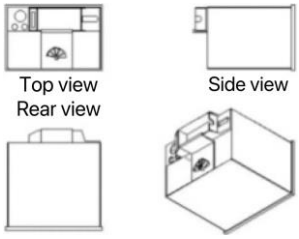

Fig.1 electric control box

The feeding mechanism is obtained by 3D printing instead. The design of the printing feeding mechanism is shown in Fig2.

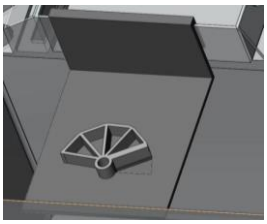

Fig.2 printing feeding mechanism

After each part is prepared, the fish box is built. The design of the smart fish box effect is shown in Fig3.

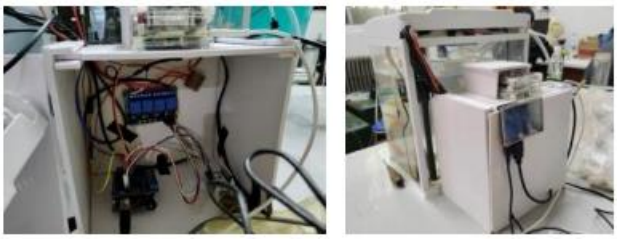

Fig.3 smart fish box effect

3. Design Of Intelligent Visual Fish Box Controller

3.1. Main control board

Arduino UNO uses AtmelAtmega328 chip, which can develop projects easily and quickly. It is an open source controller, which can be programmed, compiled and burned through IDE and USB cable without additional programming tools. The main control board has a total of 0~13 digital inputs/outputs. A total of 0~5 analog inputs/outputs. Internet service provider download is provided. USB power supply is available, as well as external power supply from 5V to 9V. This type of development board can be used as the main control board to realize the control requirements of this smart fish box with good stability and high efficiency, which can reduce the development cost of this system design and improve the efficiency of program development. The PCB design is carried out in the software. The design of the arduino schematic diagram completed using Altium Designer is shown in Fig4.

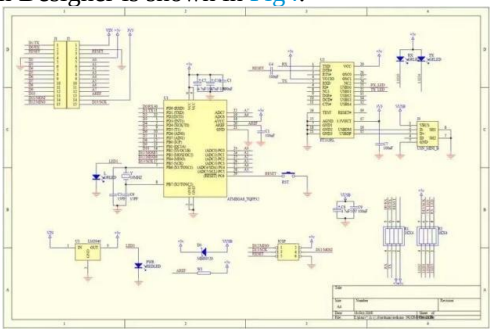

Fig.4 The arduino schematic diagram completed using Altium Designer

3.2. Vision part and camera

(1) Raspberry Pi 4B

This design uses the ARM-based microcomputer motherboard Raspberry Pi 4B to implement the vision part of the smart fish box algorithm, the Raspberry Pi can access devices such as mouse, network cable and keyboard to operate the Raspberry Pi for programming and other work, and can output high-

definition video through the HDMI interface. Its memory hard drive uses a MicroSD/SD card. There is also an Ethernet port on the motherboard, and several hardware ports for USB plugging in.

The Raspberry Pi4B was chosen because of its excellent performance. A 64-bit quad-core processor running at 1.5Ghz ensures that the Raspberry Pi4B has a high processor speed, as well as good memory and an excellent desktop system. The original camera can well meet the requirements of this design for the identification of ornamental fish survival or non-survival.

The design of the Raspberry Pi4B motherboard is shown in Fig5.

Fig.5 Raspberry Pi4B motherboard

(2) Camera

The camera in this design is the original Raspberry Pi camera with five megapixels. The camera in this scheme is connected to the CSI interface in the motherboard to obtain real-time video and detect the survival of fish in the fish box by the neural network run by the Raspberry Pi. The design of the Raspberry Pi supporting camera is shown in Fig6.

Fig.6 Raspberry Pi supporting camera

(3) Networking part

The networking part of this smart fish box is implemented by ESP8266, a low-cost and highly integrated wireless network MCU, which is mainly used for the development of IoT products. This system has stable performance, high integration, a wide range of operating temperature, stable performance during operation, and a built-in 32-bit Tensilica processor, standard digital peripherals, suitable for different working environments.

Hardware, only a small number of peripheral circuits such as interface, RF BLUN, power management module, etc., can reduce the PCB occupation.

With 32-bit Tensilica processor, the power consumption is low. ESP8266 adopts various patented technologies to achieve extremely low power consumption. Its energy-saving approach is suitable for a wide range of low-power applications.

The built-in ultra-low power TensilicaL106 32-bit RISC processor with 160 MHz CPU clock rate and support for Real Time Operating System (RTOS) and Wi-Fi protocol provides 80% of the processing power for program design and development. The design of the ESP8266-12E minimum system is shown in Fig7.

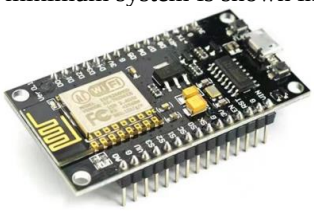

Fig.7 ESP8266-12E minimum system

4. Design of smart vision fish box sensor

4.1. Voice module

SU-03T is a speech recognition chip with small size, low power consumption and low cost, which can be easily applied to all kinds of smart products that need voice control, such as various smart homes. The design of the SU-03T application circuit schematic is shown in Fig8.

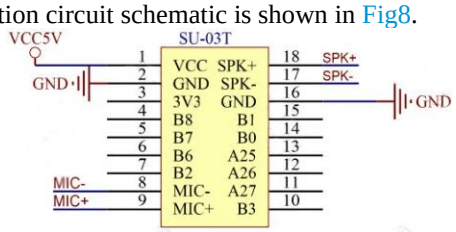

Fig.8 SU-03T application circuit schematic

The on-board microphone is used as the radio device of the voice module. It adopts electret capacitor φ with the size of 4.0*1.2mm. The working voltage is 1.1V-10V and the sensitivity is 42dB. The design of the on-board microphone is shown in Fig.9. The design of the system function block diagram is shown in Fig.10.

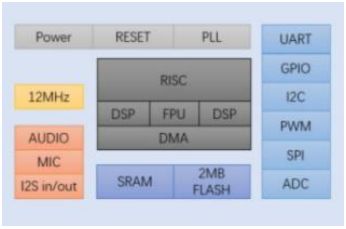

Fig.9 on-board microphone

Fig.10 system function block diagram

The module collects voice information through the microphone, analyzes the spectrum, extracts features, and compares them with the pre-
set command library, and finally sends the recognition results to the on-
board processor for the next step, such as serial transmission, etc. The SU-
03T module can also be developed using an online platform to improve the accuracy and speed of voice recognition. Its low power consumption and high development efficiency can meet the needs of the voice control part of this design.

4.2. Temperature sensor

The design uses DS18B20 type digital temperature sensitive element as the temperature sensor, and the water temperature detection line of the probe is sealed with stainless steel and other waterproof measures.
DS18B20 is a new type of thermal digital sensing element, which ensures sensitivity to temperature, data transmission through a one-
wire bus transmission method, and has a very low delay. [3] DS18B20 type digital thermometer are a unique number, and according to the number to identify the corresponding sensor. The length of the sensor wires can be increased or decreased as required by the user. In this design, water temperature detection in the fish tank is carried out using a waterproof treated DS18B20 probe. The design of the DS18B20 temperature sensor circuit schematic is shown in Fig.11.

Fig.11 DS18B20 temperature sensor circuit schematic

4.3. Servo

The 180° digital servo servo DS3235 is used for the servo. The servo control panel within the digital servo used in the design of this paper is controlled by MCU, which provides one PWM pulse width and can lock the directional angle. It has high control accuracy, good linearity, and close integration with the control protocol to achieve a minimum control angle of 0.9° or less. The built-
in digital circuit board, metal material gears, CNC aluminum mid-
case, double ball bearings, fast heat dissipation, and higher durability.
In the application of this design, the servo is directly connected to the feeding mechanism, and the servo turns through 36° for every feeding command received by the main control board. With a 7.4V power supply, this servo can reach a torque of 35 kg*cm and takes only 0.11 seconds to turn through 60° [8]. It allows precise control of the angle, fast heat dissipation and long life, which is good for the automatic feeding function of the fish box. The design of the Servo Interface is shown in Fig.12.

Fig.12 Servo Interface

4.4. Motor relay

This design uses JQC-3FF-S-
Z relay. The common terminal and normally open contact are connected to the fire wire at one end and the appliance at the other end, and the zero wire is directly connected to the appliance. The control end is connected to 5V control power, GND and microcontroller IO. When the command is received, when the corresponding pin becomes low voltage, the normally open contact of the relay will be closed, thus turning the appliance on. The design of the JQC-3FF-S-Z relay is shown in Fig.13.

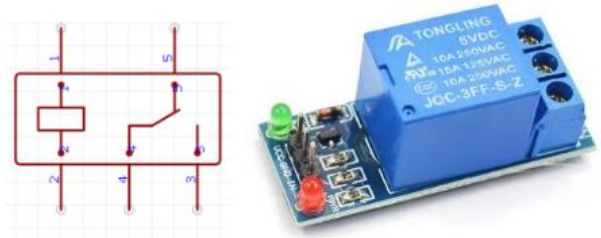

Fig.13 JQC-3FF-S-Z relay

4.5. Buzzer

This design uses a 5V buzzer 12065. the negative terminal of the buzzer shares ground with the microcontroller, and the positive terminal is connected to the IO of the main control board. when the fish food bin is empty the microcontroller will set the pin to high level, thus triggering the buzzer to remind the user of the purpose. The design of the Buzzer is shown in Fig.14.

Fig.14 Buzzer

5. Software Design

5.1. Control algorithm of each part of the fish box

(1) General part

The main control board code development environment is arduino IDE, which is convenient and fast to develop and burn, and reduces the development difficulty. The overall idea of the code is that the arduino serial port receives the signals sent by the voice module and ESP8266, and judges the functions to be realized according to the signal type.

The first initialization: configure the pins and serial port baud rate, set some variables to be used later, and make each structure in the initial state.

The second step is the main loop, read the serial data, enter the condition judgment nesting, when the serial port has no data, the system standby; when the serial port receives data, enter the next level for condition judgment, when the condition is met, the corresponding operation will be executed. The design of the Control flow diagram of main control board is shown in Fig.15.

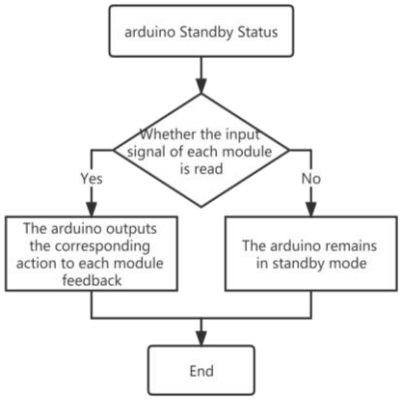

Fig.15 Control flow diagram of main control board

In the design, the lighting, oxygen pump, pumping pump and heating rod are all controlled by relays, which only need to output the corresponding pins to low level when the corresponding command is received or the corresponding conditions are met. The idea of the automatic feeding mechanism is slightly different. The feeding mechanism is controlled by the servo, and each time it receives a command, the servo will turn through 36°, i.e., one-tenth of the circumference. When the bin reaches the last frame, i.e. there is no fish food left, the bin is reset to the initial position, the attitude variable is set back to the initial value, and the buzzer pin is output high to prompt the user.

(2) ESP8266 networking part

1. Temperature sensor data processing

According to the analysis of the principle of DS18B20 implementation, the temperature sensor stores a temperature complement value and inverts its low 8 bits (LS Byte) and then performs +1 operation to restore to the original code. The Hex code data of the temperature value acquired by the temperature sensor is stored in RAM, and then the Hex code is converted to BCD code and stored in RAM. Write sensors.requestTemperatures() to send the command to get the temperature, sensors.getTempCByIndex(0) to return the water temperature measured by the sensor. esp 8266 through WIFI and through the Temp component to display in the cell phone APP. The design of the Mobile phone APP in the numerical components and historical temperature effect is shown in Fig.16.

Fig.16 Mobile phone APP in the numerical components and historical temperature effect

2.Mobile APP interface

With the help of blinker platform secondary development cell phone APP operation interface, connected to the third party server to achieve network control. Users can switch on/off the device, send the set temperature to the fish tank, watch the real-time situation and historical temperature curve of the fish tank, check the water temperature and the remaining days of fish food through this interface. The design of the Mobile phone APP interface is shown in Fig.17.

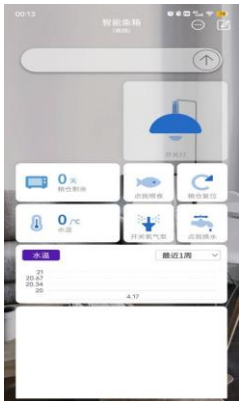

Fig.17 Mobile phone APP interface

When the button of the interface is pressed, ESP8266 sends the corresponding control command to arduino according to the switch status, and the function written corresponds to the components of the cell phone interface one by one, and the corresponding code is executed when the corresponding component is pressed. The numerical component is used to display the numerical value, which is the usage of Temp in the previous section.[4]

(3) Voice control part

The voice control part is written in C. The keywords are set during development, and the voice chip extracts the features from the voice and compares them with the keywords. The code is written and the serial port sends the corresponding data to the main control board when the corresponding command is recognized, thus realizing voice control. the SU-03T module can also be intelligently learned by other platforms to improve the recognition accuracy.

The voice recognition chip is connected to MCU and transmits the data using JSON format. After receiving this data, the serial port analyzes it to get the recognition code corresponding to the current command and executes the corresponding operation accordingly.

5.2. Neural network vision algorithm for identifying the health status of fish

(1) Data collection and processing

Firstly, a crawler is used to crawl images of goldfish from the web when they are healthy and when they are dead. When crawling with the crawler, we found that a large part of the collected data set was inaccurate (e.g., the background was too complicated), so we first reduced the number of data sets and selected some of them that were relatively pure and met the requirements of this design as data . The design of the Data set part of the data is shown in Fig.18. The design of the 3D diagram of data features is shown in Fig.19.

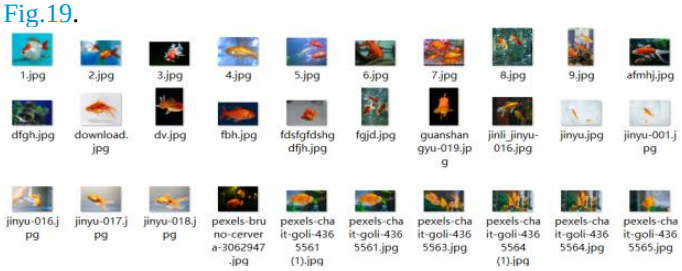

Fig.18 Data set part of the data

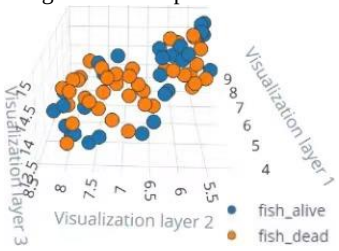

Fig.19 3D diagram of data features

The images were set in RGB form, and a normalization operation was performed on the images to convert each pixel channel of the image to a floating point value between 0 and 1. Before training all the images are resized t

o 320*320px using the shortest axis fit method. after finis hing the data processing work, the dataset is split into test set and training set in a certain ratio (two to eight) and la beled with the correct label for each object in the image, a nd finally the features are extracted. Most of the survivin g data features are located in the upper right of the coordi nate space, while most of the features of the dead data are concentrated in the lower right.

(2) Object detection model based on MobileNetV2
In order to achieve a good detection of fish survival in thi s design, this paper uses the MobileNetV2-
based object detection model. The object detection algorit hm is run on the Raspberry Pi to acquire images and outp ut information about the class and number of objects in th e images and their locations.

The effort to build a working computer vision model from scratch is significant, as a wide variety of input data is required to make the model generalize well, which ma kes the training time of the model long, which can take se veral days. To make this process more tolerable and faste r, the fishbox is designed to use migration learning. In tur n, well-
trained models can be piggybacked and only the upper la yers of the neural network need to be retrained, resulting i n more reliable models that are trained in a very short per iod of time and use smaller data sets.

This design uses the MobileNetV2 SSD FPN-Lite pre-
trained model that has been trained on the COCO 2017 da taset with images scaled to 320x320px. in MobileNetV2 SSD FPN-
Lite, we have a basic network (MobileNetV2), a detectio n network (single detector or SSD) and a feature extractor (FPN-Lite).
The base network MobileNet, such as VGG-
Net, LeNet, AlexNet and all other networks, are based on neural networks. The base networks provide advanced fu nctionality for classification or detection. If fully connect ed layers and softmax layers are used at the end of these n etworks, a classification network is obtained.[5]
Also, it is possible to remove the fully connected layers a nd softmax layers and replace them with detection networ ks such as SSD, Faster R-
CNN, etc. , to perform object detection. The design of the Schematic of classification network is shown in Fig.20.

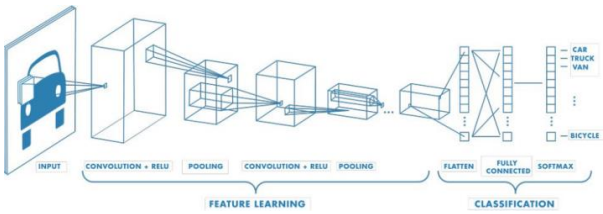

Fig.20 Schematic of classification network

The most common detection networks are SSD (Sin gle Shot Detection) and RPN (Region Proposal Network). When using SSD, we only need to take one shot to detect multiple objects in an image. On the other hand, Region Proposal Network (RPN) based methods, such as the R-CNN series, require two shots, one for generating region proposals and one for detecting objects for each proposal. As a result, SSDs are much faster compared to RPN-based methods, but usually swap accuracy with real-time processing speed. They also tend to have problems i n detecting objects that are too close or too small. Feature pyramids are a challenging approach in targets of differe nt sizes, especially on smaller targets.

This method, Feature Pyramid Network (FPN), uses the concept of feature pyramid design, which can improv e the recognition accuracy and processing speed.

6. System operation test

6.1. The commissioning and preparation of each part

Feeding mechanism adjustment, use the cell phone APP for feeding mechanism debugging, after debugging, the initial angle of the servo is set to 42 °, feeding mecha nism and chassis hole position with a better.

After adjusting the feeding mechanism, the cell phon e APP was used to control the fish box to complete all kin ds of actions. After testing, the pumping, oxygen pump, a utomatic feeding, lighting and other functions can operate normally. The difference between the processed data of t he temperature sensor part and the actual water temperatu re is very small, and the heating equipment turns on norm ally when the water temperature is lower than the user's s et temperature to realize the automatic control of water te mperature.

Voice part: hardware construction is completed, start the program writing and burning. sU-
03T module program burning needs to be completed with the help of burning tool UniOneUpdateTool. Burning fir mware needs to be burned first, and then power supply to the module, sometimes it is necessary to carry out multipl e power supply and power failure to ensure the burning of the firmware. The design of the Firmware burn-in is shown in Fig.21.

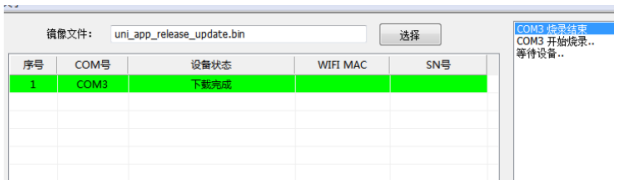

Fig.21 Firmware burn-in

The number of training rounds is gradually increase d from 20 to 50, so the number of rounds is set to 50 to en sure the training efficiency.

6.2. Run and derive results

After the control code is written, the smart fish box i s woken up by the "Little Fish" command, and the fish bo x will complete the corresponding action when the comm and "lighting" is said to the fish box; the fish box can be p ut back into the standby state by using the end command, and it needs to be woken up again to realize the command The end command can put the fish tank back into standb y state, and it needs to wake up again to realize the comm and. For the vision part, after the parameters are set, the tr aining of the model begins. The design of the Confusion matrix is shown in Fig.22.

	BACKGROUND	FISH_ALIVE	FISH_DEAD
BACKGROUND	99.5%	0.2%	0.4%
FISH_ALIVE	16.7%	83.3%	0%
FISH_DEAD	12.5%	0%	87.5%
F1 SCORE	1.00	0.83	0.64

Fig.22 Confusion matrix

Run the vision part of the algorithm, deploy the model to identify the survival status of fish to Raspberry Pi4, run t he command at the command line to automatically compi le the model with full hardware acceleration, download th e model to Raspberry Pi, and then start detection. The obj ect coordinates and labels are output when the object is d etected, and both dead and healthy fish are correctly label ed in the interface. [6] The design of the Code running interface is shown in Fig.23. The design of the Target detection effect is shown in Fig.24.

Fig.23 Code running interface

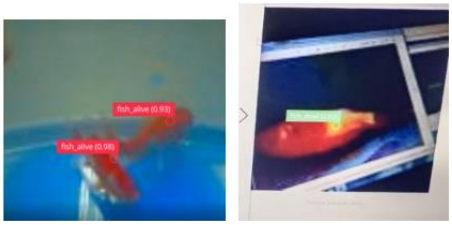

Fig.24 Target detection effect

7. Conclusion

Nowadays, smart home and Internet of Things techn ology is developing rapidly, and the design of smart fish box in this paper is following the trend of technology dev elopment, and various kinds of knowledge such as microc ontroller, machine vision, artificial intelligence and voice control are cooperated with each other to form a complete system, and it is believed that various kinds of smart fish boxes will be more widely used in the automated fish rea ring in the future. This design combines the knowledge of several disciplines to improve the human-computer interaction experience, and it is believed that th ere will be more and more demand for this type of produc t in the market.

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