Advances in Engineering Research, volume 197
Proceedings of the 2020 9th International Conference on Applied Science, Engineering and Technology (ICASET 2020)

Research and Implementation of Organic Cucumber Intelligent Greenhouse Monitoring System Based on NB-IoT and Raspberry Pi

Yanyan Cao[1*], Ligong Cui[2], Qian Lv[3]

[1]*School of electrical engineering, Binzhou Polytechnic, Binzhou, Shandong, China*
[2]*School of electrical engineering, Binzhou Polytechnic, Binzhou, Shandong, China*
[3]*School of electrical engineering, Binzhou Polytechnic, Binzhou, Shandong, China*
[*]*Corresponding author. Email:: yaya_sd@163.com*

ABSTRACT
With the development and popularization of computer technology, Internet of Things technology and artificial intelligence technology, the application of machine learning, especially deep learning is receiving increasing attention. In deep learning, CNN(Convolutional Neural Network) have demonstrated their advantages in image processing and have been widely used in various artificial intelligence practice projects with outstanding performance. This article mainly combines artificial intelligence technology and IoT technology based on NB-IoT and STM32 embedded systems to complete the intelligent monitoring and detection of the greenhouse environment in which organic cucumbers grow. In this paper, we use deep learning and convolutional neural network to detect and identify the organic cucumber leaf spot, angular leaf spot, anthracnose and bacterial leaf blight, using STM32 embedded system to realize the detection and control of greenhouse atmosphere environment, soil environment, automatic watering and so on. At the same time, the Alibaba Cloud platform is used to remotely monitor and control these. Through the application of all the above technologies, the intelligent growth of organic cucumbers in the greenhouse is achieved, reducing labor and time costs, and improving production efficiency.

Keywords: *NB-IoT, Deep learning, Convolutional Neural Network, Disease identification, STM32.*

1. INTRODUCTION

With the in-depth study of artificial intelligence and deep learning technology, its application in various aspects is becoming more and more extensive. Smart control, IoT technology, deep learning and other technologies are indispensable in application scenarios such as smart industry, smart city, smart transportation, smart agriculture, and smart home. The purpose is to improve productivity, reduce labor costs, and achieve intelligence and automation. This system mainly relies on the organic cucumber greenhouse planting base of Binzhou Zhongyu Food Co., Ltd. We use embedded technology to achieve temperature and humidity detection of cucumber growth and soil temperature and humidity detection in the greenhouse. We use deep learning of Raspberry Pi to achieve disease detection and automatic irrigation. Then use NB-IoT technology to connect the two information to the Alibaba IoT cloud, so as to achieve real-time monitoring, automation and intelligence.

2. SYSTEM STRUCTURE AND HARDWARE COMPOSITION

The main hardware block diagram of the intelligent monitoring system is shown in Figure 1. The embedded system control MCU uses ST's high-performance product model STM32F401RET6, which has the advantages of low power consumption, multiple serial ports, sleep and remote wake-up modes.

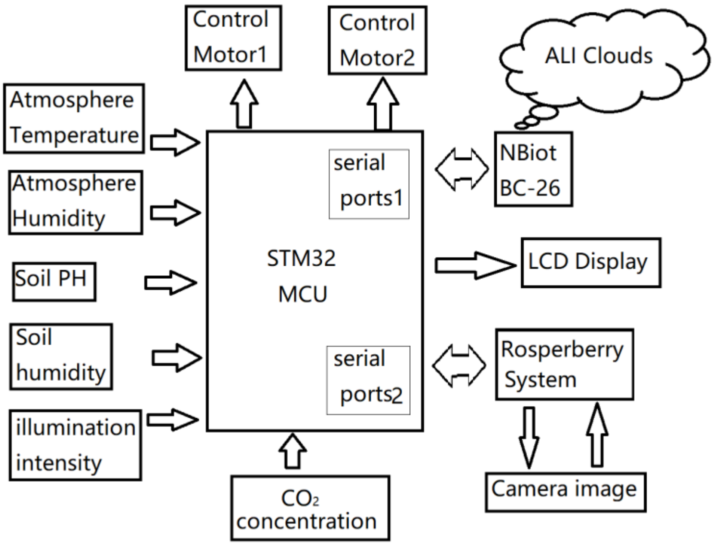


Figure1: The Hardware Structure of The System

In order to save costs and make full use of the functions of the MCU, the real-time clock built in the system is used, and the external clock of the MCU is 32.768KHz crystal, which can meet the system requirements. Under this function, the backup battery is used to maintain the uninterrupted power supply of the embedded chip and ensure the continuous operation of the system clock. The circuit structure is shown in Figure 2.

The environment temperature and humidity in the greenhouse is detected by the all-digital temperature and humidity sensor SHT20. This chip can work in a lower temperature environment with good stability. The temperature accuracy can reach 0.5% and the humidity accuracy can reach 3%. 10K pull-up resistor is used in the circuit and the data communication method is I2C. When installing, pay attention to protecting the humidity window of the sensor to prevent dust from entering. It is best to weld at the end of the process to avoid affecting the test value of the humidity sensor. According to the requirements of cucumber growth for the ambient temperature, the temperature during the day is controlled between 20 and 30 degrees, which is not only conducive to the growth of seedlings, but also to rapid growth during the flowering and fruiting period. The ambient temperature at night is controlled to not less than 12 degrees. The specific circuit is shown in Figure 3.

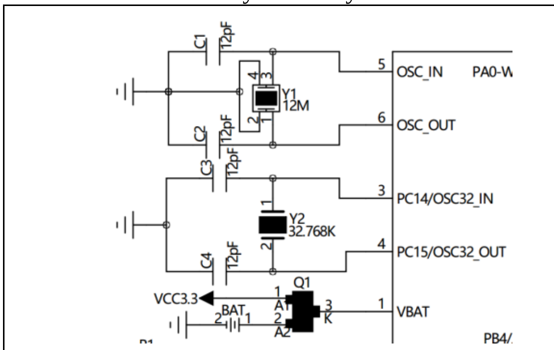


Figure2: The System RTOS Circuit

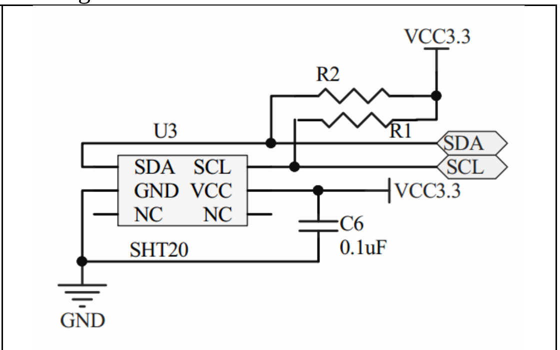


Figure3: Digital T&H Sensor

We used the 5TE soil moisture, temperature and conductivity sensor of Beijing Shiyang Electronic Technology Co. , Ltd. to detect the soil temperature and moisture of cucumber growth, as shown in Fig. 4. The minimum working voltage is 3.6V, which can use the same power supply as the main control board, but the output current must be large enough. In this case, the data collected can directly communicate with the main control chip using a serial port, and the cable length can be customized according to the actual situation. The low temperature requirement of cucumber soil is not lower than 8 degrees Celsius, otherwise measures should be taken to raise the ground temperature.

The BH1750FLV sensor is used to detect the light intensity in the greenhouse. The control center controls the opening and closing of the rolling shutter according to the change of the external light intensity, and determines whether artificial lighting is required. The specific circuit is shown in Figure 5. The communication mode between the BH1750FLV and the MCU is I2C. The control line of the clock line SCL exchanges data with the MCU through the data line SDA.

The man-machine interface is used to display the system time, environment, soil temperature and humidity, light intensity, and motor operation status of various control equipment such as automatic watering, automatic ventilation, and automatic lighting. The 1.3-inch 240 * 240 TFT LCD display of Zhongjingyuan is used. This display uses ST7789VW driver chip. This LCD has two communication modes, parallel port and SPI. We choose to use SPI communication, which is physically connected to the SPI3 port of the main control chip. When there is no key or message transmission, the design will automatically screen for 30 seconds to save power . The control part mainly controls the actions of automatic irrigation motors, automatic lighting motors, and heaters through relays. The MCU controls ULN2003 to drive the relays and the relays control the operation of the motor.

The wireless transmission solution considers the small amount of information transmission. In order to effectively control costs, the narrowband wireless IoT technology NB-IoT is used. The IoT main control chip uses the Quectel BC-26 module of Shanghai Quectel. Figure 4 shows it. This model has a small size, low power consumption, supports the MQTT protocol specification, and can better meet the needs of sending control information and data transmission. Through MQTT micro-message queues, two-way communication between the control end node and Alibaba Cloud is achieved to achieve the purpose of real-time monitoring. Before connecting with the Alibaba Cloud IoT platform, the client needs three steps, including creating a resource micro-message queue MQTT instance, a message storage instance, and a user client ID. The main commands are shown in Table 1 below. For the NB-IoT controller to access the network, it is necessary to set the frequency band, query the IMSI code, activate the network, network registration, configure the IoT platform address and port, and configure message notification.

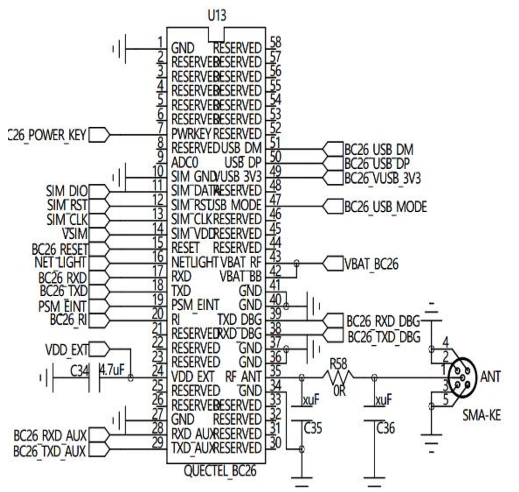


Figure4 : The NBiot MCU BC-26

Test Command	AT+<x>?	This command returns the list of parameters and value ranges set by the corresponding Write Command or internal processes.
Read Command	AT+<x>=?	This command returns the currently set value of the parameter or parameters.
Write Command	AT+<x>=<…>	This command sets the user-definable parameter values.
Execution Command	AT+<x>	This command reads non-variable parameters affected by internal processes in the UE.

Table1: Types of AT Commands and Responses

Cucumber leaves are often affected by diseases during the growing season, which will cause plant death or yield reduction. Therefore, it is necessary to detect and identify in advance and take various measures for effective control. Disease identification and detection need to collect images. The image of leaves is collected using the Raspberry Pi 's official RaspberryPi Camera v2 HD resolution camera with a resolution of 8M pixels. The Raspberry Pi uses the Raspbian system to installs Python software and implements its and Serial communication of Stm32 Main Control Board through the program. The hardware connection is the serial port sending pin HEAD8 of the Raspberry Pi connected to the serial port receiving pin RXD of the main control board, and the serial port receiving pin HEAD10 of the Raspberry Pi connected to the serial port sending pin TXD of the STM32 of the main control board, and then ground them. Only when the terminals are connected to form a common ground can the effective communication of the serial port be guaranteed. Because STM32F401RET6 has multiple serial ports, serial port 3 is selected here to physically connect to the serial port of the Raspberry Pi. Table 2 is an example of a program that implements serial communication between the Raspberry Pi and the MCU in a Python environment. The communication baud rate is set to 115200 BPS.

```
import serial
import time
ser = serial.Serial("/dev/ttyAMA0", 115200)
```

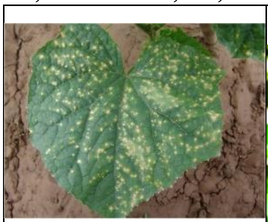
```
def main():
    while True:
        count = ser.inWaiting()
        if count != 0:
            recv = ser.read(count)
            ser.write(recv)
        ser.flushInput()
        time.sleep(0.1)
if __name__ == '__main__':
    try:
        main()
    except KeyboardInterrupt:
        if ser != None:
            ser.close()
```

Table2: The program of serial communication between Raspberry and MCU

3. DETECTION AND IDENTIFICATION OF CUCUMBER DISEASES

3.1 Model training

The system mainly implements the detection and identification of cucumber diseases. There are more than a dozen types of cucumber diseases, such as Corynespora target leaf spot, angular leaf spot, anthracnose, Cucumber anthracnose, Xantpomonas campestris pv. cucubitae, melanosis, etc. We select the four most common ones for monitoring and identification, as shown in Figure 5. According to the preparation stage, we took three months to collect 1,000 pictures of each of the four diseases in the organic cucumber greenhouse of Binzhou Zhongyu Food Co., Ltd., a total of 4,000, and then rotated, zoomed, etc. The operation forms another 4000 sheets, that is, 2,000 images of each type of disease, with a total of 8,000 pictures, and then manually calibrates each picture to form a data set. We randomly selected 1,500 images in each category as the training set, 300 as the verification set, and 200 as the test set, creating a training set of 6,000 images.



First: Corynespora target leaf spot

Second: angular leaf spot

Third: anthracnose

Fourth: Xantpomonas campestris pv. cucubitae

Figure5：Four Kind of Diseases

Convolutional Neural Network Model

Layer	Type	Maps	Size	Kernel	Stride	Padding	Activation
In	Input	3	240 x 240	—	—	—	—
C1	Convolution	32	240 x 240	5 x 5	1	SAME	ReLU
S2	Max Pooling	32	120 x 120	3 x 3	2	SAME	ReLU
C3	Convolution	64	120 x 120	5 x 5	1	SAME	ReLU
S4	Max Pooling	64	60 x 60	3 x 3	2	SAME	ReLU
C5	Convolution	128	60 x 60	3 x 3	1	SAME	ReLU
S6	Max Pooling	128	30 x 30	2 x 2	2	SAME	ReLU
C7	Convolution	256	30 x 30	3 x 3	1	SAME	ReLU
S8	Max Pooling	256	15 x 15	2 x 2	2	SAME	ReLU
F9	Fully Connected	—	256	—	—	—	ReLU
Out	Fully Connected	—	4	—	—	—	Softmax

Table3: The Convolution Neural Network Model

Image has a color depth of 3 and cannot be grayed out. To some extent, it increases the After the environment is set up, perform model training. The pre-training preparations are to process the collected original images into an image with a size of 240 * 240. Because some diseases need to determine the color of the leaves, the input difficulty of calculation and training time. However, there will be improvements in the accuracy of the model. The specific network training model is shown in Table 3. The structure of the convolutional neural network mainly uses three sets of convolution pooling layers, a fully connected layer, and finally a Softmax classification layer, plus a total of 11 layers of input layers. The input convolutional neural network was used for 30,000 rounds of training, and the highest accuracy rate was 96.75%, as shown in Figure 8. Then use 800 test sets to test, the average test accuracy rate of the four diseases reached 80.5%, as shown in Table 4. This network model and test results prove that it achieves a good recognition effect.

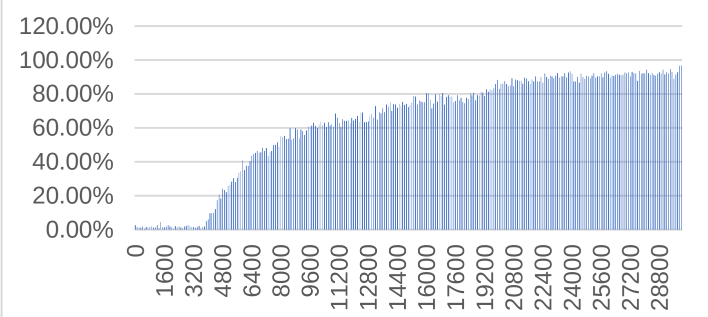


Figure6: The Validation Accuracy of The Model

Diseases Class	Accuracy
First	82. 0%
Second	81. 0%
Third	84. 0%
fourth	75. 0%
Average	80. 5%

Table4: Test Accuracy

3.2 Model migration

Disease detection is achieved by using a convolutional neural network on a raspberry. We use the latest Raspberry4B. The first step is to install the Linux-based Rasbian operating system on the Raspberry Pi. The second step is to install the Tensorflow2.0 version based on Linux on the Raspberry Pi. The command is as follows: pip install tensorflow == 2.0, install the image processing software OpenCV. The third step needs to install the programming environment software Python3.7 and other third-party support libraries such as Numpy.

After the software and hardware environment is set up, use python to program and import the previously trained model into the Raspberry Pi, and start the Raspberry Pi's camera for photo acquisition. The deep learning model was used to identify and detect the disease of the collected cucumber leaves. The recognition result was compared with the features trained from the four disease types, and a percentage was given to return the most likely result. If all the recognition results are less than 25%, it is determined that no valid disease type has been identified.

The Raspberry Pi sends the detection and recognition results to the main control board through the serial port. The main control board displays the man-machine interface and sends it to the Alibaba IoT cloud platform through NB-IoT narrowband communication. The Alibaba Cloud IoT platform provides very easy with access to the API interface, managers can view various information in the greenhouse in a timely manner through the mobile terminal APP or computer client. It can also send commands for disease detection and identification through the client and send them to the cloud. After the main control board receives the commands sent from the cloud, it forwards them to the Raspberry Pi through the serial port. The Raspberry Pi uses the camera to take pictures and then shoot The photos are processed and feature extracted and disease recognition is performed, and the recognition results are returned. The program flow chart of the entire system is shown in Figure 7.

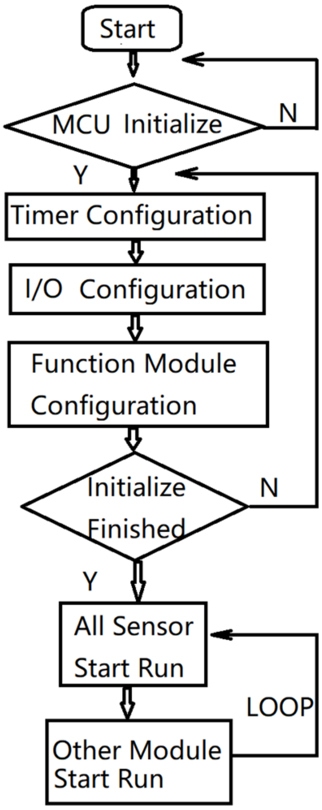


Figure7: MCU Work Flow Chart

4. CONCLUSION

Through the establishment of this system, the intelligent detection and control of the organic cucumber greenhouse is realized, and the information of the atmospheric environment and soil is reported in real time. The system automatically controls the corresponding equipment based on the detected information, and trains the identification of the four diseases. The model is implanted in the Raspberry Pi, and the corresponding disease recognition is performed through the Raspberry Pi. The recognition accuracy rate is more than 80%, and the recognition and detection results are uploaded to the Alibaba Cloud network through the IoT chip and NB-IoT communication, in order to manage The judge's judgment gives valuable information.

REFERENCES

[1] Wen Zhichao. Research on Classification and Recognition of Pests and Diseases Based on Evolutionary Algorithm and Improved Bag-of-Words Model [D]. Guangzhou: South China Agricultural University, 2016.

[2] Ji Xiaoli. Detection of powdery mildew of cucumber leaves based on support vector machine ［D］. Shenyang: Northeastern University, 2014.

[3] DONG P X, WANG X D. Recognition of greenhouse cucumber disease based on image processing technology [J]. Open Journal of Applied Sciences, 2013, 3: 27-31.

[4]F. He, X. Gao, M. Wang, B-Y. Wang, L. Zhang, Learning weighted assumptions for compositional verification of markov decision processes, ACM Trans. Softw. Eng. Meth. 25(3) (2016) 21.

[5] H. Debbi, A. Debbi, M. Bourahla, Debugging of probabilistic systems using structural equation modelling, Int. J. Critic. Comput. Based Syst. 6(4) (2017) 250–274.

[6]Wang Gaoli. Design of Intelligent Ventilation and Irrigation System in Greenhouse Based on AT89S51 Microcontroller [J]. Modern Manufacturing Technology and Equipment, 2019 (2): 103-105.

[7]R. Bouchekir, M.C. Boukala, Learning-based symbolic assume-guarantee reasoning for Markov decision process by using interval Markov process, Innov. Syst. Softw. Eng. 14(3) (2018) 229–244.

[8] Du Ruijuan, Minawar Wumaier, Huo Dayong. Intelligent automatic watering system based on AT89S51 single-chip microcomputer [J]. Research of Agricultural Mechanization, 2018, 40 (7): 206-210.

[9] Jing Pengbin. Design of campus intelligent watering system based on AT89S52 [J]. Electronic Test, 2019 (8): 15-17. [8] Liu Tianyu, Xu Xiaohui, Song Tao, etc. Android-based Intelligent Greenhouse Control And realization [J]. Water-saving irrigation, 2018, 273 (5): 96-98 + 102.

[10] P. Xu, Research and application of near-infrared spectroscopy in rapid detection of water pollution, Desalination and Water Treatment, 122(2018)1-4.

[11] Zeng Lingpei. Design of intelligent agricultural greenhouse control system based on PLC [J]. South Agricultural Machinery, 2017, 48 (19): 38-39.

[12] Hu Min, Chen Hongbo, Xu Liangfeng, et al. Cucumber disease recognition algorithm based on color and texture features [J]. Journal of Electronic Measurement and Instrument, 2015, 29 (7): 970-977

[13] P. Xu, N. Na, A. M. Mohamad, Investigation the application of pristine graphdiyne (GDY) and boron-doped graphdiyne (BGDY) as an electronic sensor for detection of anticancer drug, Computational and Theoretical Chemistry,1190(2020):112996.