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Design and Implementation of Intelligent Image Detection System for Fertilizer Uniformity Based on Internet of Things

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Abstract: In agriculture, it is necessary to put fertilizer, which is conducive to the growth of crops. However, the amount of fertilizer must be strictly controlled, too much and too little will become the obstacles to the growth of crops. With the deepening of agricultural automation, the requirements of fertilizer put are more and more strict, so effective monitoring of the uniformity of fertilizer put is conducive to the good growth of crops. Aiming at the problem of fertilization uniformity detection, this paper designs an intelligent image detection system based on Internet of things technology. According to the actual needs, the system includes three modules: image acquisition, image transmission and image processing. Among them, the image acquisition module uses sensors to collect the land image after fertilization, the image transmission module uses network technology to transmit the collected image to the cloud, and the image processing module uses the good performance of convolution neural network to effectively extract the image characteristics and identify whether the uniformity of image fertilization is reasonable or not after image preprocessing. Through the simulation analysis, it shows that the intelligent image detection system based on the Internet of things can well detect whether the uniformity of fertilization is reasonable, improve the yield of crops, and promote the sustainable development of agricultural health.

1. Introduction

With the rapid development of the country, the development and progress of agriculture is of great significance to the economy and ecology of the whole country [1-2]. A good agricultural scale

can support the food, clothing and economic development of the whole country. As an indispensable and important factor in agriculture, chemical fertilizer can well supplement the fertility of the land and improve the output of crops [1]. But the amount of chemical fertilizer has become a key. Too much or too little is not conducive to the healthy development of agriculture, too much is easy to cause environmental pollution, too little cannot meet the needs of crop growth. In the traditional application of chemical fertilizer, it is not very good to detect the application of chemical fertilizer, and it is not reasonable to analyze whether the uniformity of chemical fertilizer is reasonable, and the unreasonable application of chemical fertilizer results in low utilization rate of chemical fertilizer and serious environmental problems that restrict the development of agriculture. In order to promote the healthy and sustainable development of agriculture, the concept of precision agriculture [4-6] has been put forward. In fact, it is a system that uses the existing information technology to locate, quantify, and time the operation and management of agricultural operations under different spatial variations. However, the research results of precision agriculture technology are mainly focused on nutrient detection, yield and fertilization, and the distribution of soil nutrients. Therefore, in order to realize the informatization and modernization of fertilizer application, it is necessary to effectively test the uniformity of fertilizer application.

The development of the Internet of things [7-9] is based on computers and the Internet. Its purpose is to establish an intelligent network through which information exchange, exchange and processing between things and between people and things can be realized automatically. Through the Internet of things, any object can be connected to the Internet to facilitate information exchange and communication. Firstly, the information of the object should be collected through information sensing equipment, and then the communication should be carried out according to the agreed network protocol. In real life, some chips and software can be embedded into physical entities. These chips and software need to have certain sensing, computing and execution capabilities, and then use the network to transmit, coordinate and process the information of objects, so as to realize the communication between objects and other objects. Internet of things has the characteristics of perception, reliable transmission and intelligent processing. Perception is to collect all kinds of data information of objects by using some sensing devices, such as RFID [10-11], QR code, sensors and so on; Reliable transmission is to send the feature information of the perceived object in time and accurately by combining various telecommunication networks and the Internet; Intelligent processing refers to the process of intelligent management and automatic control of objects by processing and analyzing a large number of data and information in the network. This process needs to be completed by a series of intelligent computing technologies such as cloud computing [12-13], data mining [14-15], middleware, fuzzy recognition, etc. From the definition and function of the Internet of things, the Internet of things technology is very suitable for precision agriculture, and now there are a lot of Internet of things technology applied in agricultural research. The Agricultural Internet of things is another network that is deeply expanded in the field of agriculture through the rapid development of Internet of things technology. With the application and popularization of intelligent agriculture, traditional agriculture is in urgent need of transformation and upgrading [16-17]. More intelligent technology is applied to all aspects of agriculture, precise control of agricultural production is implemented, and the construction of agricultural intelligent technology system is accelerated.

The Internet of things is mainly composed of three parts: perception, transmission and processing of data and information. In other words, the architecture of the Internet of things can be divided into perception layer, network layer and application layer [18]. The main purpose of the perception layer is to perceive all kinds of physical quantities in the real world, and transform the collected data into digital data that can be processed in the virtual world through various technical

means. Therefore, this layer can be regarded as a physical contact layer with perception function, and it is the most basic layer of the Internet of things. Commonly used sensing technologies include wireless sensor network, GPS positioning, RFID technology and image acquisition technology. In the fertilizer uniformity detection, the main application is the image acquisition technology, through the camera to shoot the land image after the fertilizer is put in, using digital technology to process it into digital information for transmission. The network layer of the Internet of things is mainly used to connect each network node in the sensing layer to the network, and realize the network communication function through various network access methods. The network layer is mainly constructed by wired network and wireless network. Wired network refers to the network which uses various network connection media to connect network nodes [19-20]. The main connection media include optical fiber, coaxial cable, twisted pair and various buses. Wireless network mainly includes wireless wide area network which provides wide range connection, wireless metropolitan area network which provides wireless communication in metropolitan area, etc. The network layer is the key to connect the physical entities into the network. In the detection of fertilizer uniformity, the network layer mainly constructs the network structure of camera connection and transmits the data collected by the camera to the cloud for storage. The application layer of the Internet of things combines the technology of the Internet of things with the professional system of the industry to provide users with rich and specific services by using the processed perceptual data. The application layer is mainly used to solve the problems of data information processing and human-computer interface. In the end, the Internet of things needs people to operate and control. In the detection of fertilizer uniformity, the application layer of the Internet of things needs to preprocess the collected images and judge whether the fertilizer uniformity is reasonable. If it is not reasonable, it needs to inform the user in time to deal with it.

To sum up, this paper applies the Internet of things technology to the fertilizer uniformity detection, uses the cameras distributed in different areas to interconnect to form a monitoring network, and transmits the images collected by the cameras to the cloud through the network for storage and processing. In addition, according to the actual needs, the fertilizer uniformity detection system designed in this paper includes three modules: image acquisition, image transmission and image processing. The image processing module is mainly to preprocess the collected image, then extract the features of the image through convolution neural network and judge whether there is unreasonable phenomenon of fertilizer uniformity in the collected image, so as to realize the effective detection of fertilizer uniformity.

2. Introduction to System Related Knowledge

2.1. Internet of Things Architecture and Key Technologies

The Internet of things is a kind of information technology that enables objects to have "wisdom", which enables people to communicate with things, things and things. The main characteristics of the Internet of things focus on three aspects: comprehensive perception, transmission interconnection and intelligent processing. In other words, the structure of the Internet of things system generally includes three modules: the perception layer, the network layer and the intelligent processing layer. There are corresponding key technologies in these three layers to realize the functions of each layer or between layers. The progress of these technologies has also promoted the rapid development of the Internet of things, so that it can be successfully applied in many fields.

1. Key technologies of perception layer

The perception layer is the bottom layer and the most basic layer in the Internet of things system. Its function is to identify things and collect data. In the sensing layer, the most important

technologies include RFID technology, positioning technology, sensing technology and laser technology. These technologies are described in detail below:

RFID (Radio Frequency Identification) is a non-contact automatic identification technology based on electromagnetic theory. It can realize two-way communication through radio frequency without contact, and can automatically identify communication objects. It has strong anti-interference ability, can adapt to a variety of complex environments, and has high identification accuracy and is easy to operate. RFID system includes hardware component and software component. Hardware components include reader and RFID tag, and software components include middleware and application software. In the RFID system, the reader and RFID tag transmit the wireless data through the space set up by their respective antennas, and transmit the RFID tag data to the reader through the coupling of the RF signal. The reader demodulates and decodes the signal, and then sends it to the background controller system for relevant processing.

WSN (Wireless Sensor Network) [21-23] is composed of a large number of cheap micro wireless sensor nodes distributed in the monitoring area. These sensors can sense pressure, temperature, humidity and other information, forming a multi hop wireless ad hoc network system, in which they communicate with each other wirelessly and continuously send the information of the target object in the monitoring area to the observer. WSN consists of sensor node, sink node and management node. The monitoring data is transmitted hop by hop along the sensor nodes in the network. In the process of transmission, the monitoring data is gathered in a node (sink node) after multi hop routing, which may be processed by multiple nodes, and finally transmitted to the management node through the Internet or communication network.

GIS (Geographic Information System) [24-26], which is based on computer software and hardware, carries on a series of operations to geographic data, and then provides the management function of geographic data, thus provides a series of map management and decision support functions for users.

GPS (Global Positioning System) is a new positioning method, which combines satellite positioning and navigation technology with modern communication technology. It has the characteristics of all-weather, all-time, uninterrupted real-time high-precision positioning, navigation and timing. Its basic principle is to take the position of a certain moment when the satellite is moving at high speed as the starting data (as known), and calculate the position of the point to be measured by the space distance resection formula.

2. Key technologies of network layer

Network layer, based on the existing mobile communication network, Internet and radio and television network, uses various access devices to connect the information obtained by the perception layer with the transmission equipment, and carries out barrier free, high reliable and high security information transmission. The main technology is 3G (3rd-Generation) technology. Compared with the first generation and the second generation of mobile communication technology, 3G is a kind of cellular mobile communication technology which can transmit voice and data information at the same time and support high-speed data transmission. Its speed is generally over several hundred Kbps.

3. Key technologies of intelligent layer

In the intelligent layer, the perceptual data is processed by cloud computing, data mining, middleware and other technologies to realize the automatic control and intelligence of goods and provide rich services for users. The main technology is cloud computing. Cloud computing is a new application computing method. It shares and connects a large number of computing resources distributed in the network, and provides them to users in the form of resource pool through unified management and intelligent scheduling of software system to realize the on-demand use of

computing resources. It has the characteristics of high scalability, high reliability, high resource utilization and on-demand service. Reducing the burden of user terminals, even as a simple IO device that can make use of the powerful processing power of cloud computing, is the core concept of cloud computing, and its implementation way must be to continuously improve the computing power of "cloud".

2.2. ZigBee Network Topology

Generally, ZigBee network [27-29] can be divided into three types of network structures: star structure, tree structure and mesh structure.

1. There is a coordinator in the star network, which is the core node of the network. It is mainly responsible for the establishment, maintenance and management of the network. It must be full-featured equipment with complete functions. Generally, there are multiple terminal nodes in the network, which can communicate with the coordinator directly and distribute in the whole network. Both thin functional devices and full functional devices can be used as terminal nodes, but they are usually thin functional devices. Because the star network is mostly used in the situation of few nodes, it is very simple to control and synchronize it.

2. The tree network includes a coordinator, which is connected with many star structures at the same time. The leaf node is located at the end of the branch of the tree. It is generally composed of thin functional devices. The device in the network is connected with its own parent node on the top and its own child node on the bottom. The device can communicate with the two nodes point-to-point. Of course, the device can also communicate with other non-parent nodes and non-child nodes, but it is not point-to-point communication, but must be transmitted by path, so as to complete the transmission of data and control information. The coordinator's processing function is stronger than the router's, and the storage space is larger. The obvious advantage of tree network is that its network coverage is very large, but with the increase of the range, the transmission delay of information also increases.

3. Mesh network is usually composed of multiple full-featured devices connected to each other to form a backbone network. The communication between these devices is all peer-to-peer, as long as the nodes within the wireless communication range can communicate with each other. In other words, as long as the nodes with routing function can be directly connected with each other in the network, one of them is the coordinator. The mesh network is based on the tree network. The difference is that its data routing is realized through the routing table in the router. This topology network has the advantages of reliability and short delay, but it also needs a lot of storage space.

Through the analysis of several network structures, this paper chooses tree network structure as the internal network construction mode of fertilizer uniformity detection system, so as to build a ZigBee wireless sensor network for the sensing layer of the system, which includes three different network devices, namely coordinator, router and terminal device. In this paper, the tree structure is a combination of the characteristics of the three network structures and the network requirements of the system. Considering the requirements of low power consumption, simple networking, high flexibility, suitable transmission distance and low cost, tree network structure is more suitable. Although the star network is simple in networking, low in power consumption and cost, the coverage of the network is small, which cannot meet the requirements of node dispersion for routing data. However, the mesh network is relatively complex, the highest cost does not meet the requirements of simple networking and low power consumption. In contrast, the tree network is the most able to meet the networking requirements of the system.

3. Study on Intelligent Image Detection of Fertilization Uniformity

In the image detection of fertilization uniformity, this paper uses camera to collect the image of fertilized land in the Internet of things sensing layer, and then uses the network composed of ZigBee tree network structure to transfer the image to the cloud for storage and processing. It is equivalent to building a data transfer station in the cloud. Its function is mainly to store the image to be detected obtained by the image detection system terminal, and to ensure that this information can be taken out anytime and anywhere, so as to facilitate the comparative processing with the image stored in the Internet of things. In the process of image processing, the main research focuses on two aspects: image preprocessing and fertilization uniformity recognition, which are described in detail below.

3.1. Image Preprocessing

1. Grayscale processing

Grayscale processing is an important method to enhance image quality, which belongs to spatial processing. After the gray-scale processing, the dynamic range of the image increases, the contrast of the image is expanded, and the image will be clearer, the features will be more obvious, these changes are conducive to the subsequent image feature extraction and recognition. It is the essence of grayscale processing to modify the gray level of each pixel according to certain rules. After the gray level of the pixel is modified, the dynamic range of the gray level of the image is changed. Gray level transformation can be divided into linear, piecewise linear and nonlinear transformation methods. In practical application, the collected image is usually a color image, and the pixel points of color image are composed of three colors: R (red), G (green) and B (blue), and different colors are composed of different RGB contents. Different from the color image, the gray-scale image only contains the brightness information, not the color information, and its brightness is continuously transformed, that is to say, the gray-scale image is represented by quantifying the brightness value of the image.

The RGB components of pixels in color image are not equal, while the RGB components of gray pixels are equal. That is to say, (0,0,0) is all black, while (255,255,255) is all white, and the middle one is gray. Graying is the process of making color components equal. The corresponding relationship between RGB components of color image and gray image is as follows:

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix}_{gray} = \begin{bmatrix} 0.299 & 0.578 & 0.114 \\ 0.299 & 0.578 & 0.114 \\ 0.299 & 0.578 & 0.114 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}_{color} \quad (1)$$

In other words, according to this formula, we can transform a color image into a gray image.

2. Filtering processing

When the image is generated, transmitted and transformed, the quality of the image will be reduced, the image will be blurred, and the feature will be hidden. The difference between the obtained image and the original image will bring difficulties to feature extraction and recognition. Therefore, it is necessary to reduce or remove the noise in the polluted image, which includes not only the external reasons such as uneven light source or incorrect acquisition method, but also the internal reasons of the system itself. In this paper, the median filter method [30-31] is used to process the image.

The basic idea of value filtering is to sort the gray values of all pixels in a window centered on a certain point (x, y) from large to small. If there are odd pixels, the middle value is taken as the gray

value of the point (x, y). If there are even pixels, the average value of the two middle values is taken as the gray value of the point. Suppose that the sequence of pixels in the window is $f_1, f_2, \mathrm{L}, f_n$ in turn, and the window with the template length of m is used to filter the sequence of pixels. The gray values of n points are arranged from small to large, and the pixels in the center are selected as the filter output. The filtering steps are as follows:

(1) Place the template in the image so that the center of the template coincides with a pixel point in the image;

(2) The gray value of the pixels in the template is obtained;

(3) Arrange the gray values of the obtained pixels from small to large;

(4) The gray values of the central pixels of the sequence are obtained;

(5) Use this gray value to replace other gray values.

3.2. Image Detection of Fertilization Uniformity

After preprocessing the collected image, it is necessary to extract the features of the image and identify whether the uniformity of fertilizer is reasonable. Based on the properties of convolution neural network [32-34], this paper uses convolution neural network to extract the features, and finally connects Softmax [35-36] classifier to classify the image. Convolution neural network is a special structure of deep feedforward neural network, which consists of three parts: convolution layer, pooling layer and activation function.

1. Convolution layer

Convolution is the most important linear operation in convolution neural network. Convolution is the most common operation for digital image. The specific expression is as follows:

$$y = f\left(\sum_{j=0}^{J-1}\sum_{i=0}^{I-1} x_{m+i,n+j} w_{ij} + b\right), (0 \le m \le M, 0 \le n \le N) \tag{2}$$

Where x is a two-dimensional input vector of size (M, N), w is the convolution kernel of size $J \times I$, b is offset, y is the output characteristic diagram, the size is $M \times N$, f is the activation function.

When the parameters of convolution kernel in convolution layer are fixed, the features extracted by convolution layer are also single. The advantage of convolution neural network is that its convolution layer can contain each convolution kernel. As long as the parameters of convolution kernel are set differently, then convolution layer can extract different features, that is, each convolution kernel in convolution layer can output a different feature map. If there are n convolution kernels, then after convolution operation, the convolution layer can output n corresponding characteristic graphs, and then input the n characteristic graphs to the pooling layer. The core of the convolution operation is to replace the full connection of the previous neural network by weight sharing and local connection. Reliance on the amount of axial data to avoid local optimal solutions or overfitting in convolutional neural network training. Because convolution operation is trained by the way of weight sharing and local connection, which makes it invariant to displacement, scale and deformation, the characteristics obtained by convolution operation training have topological correspondence, robustness and other characteristics.

2. Pooling layer

Pool operation can reduce the space dimension by aggregating the space or feature types. Its main purpose is to reduce the calculation complexity and enhance the translation without deformation. Pool operation can effectively reduce the parameters of the next layer, so it can effectively avoid the over fitting of the network. There are many types of pooling operations, such

as maximum pooling layer, average pooling layer, norm pooling and log probability pooling. There is also a kind of pooling method called spatial pyramid, which can obtain the scale information of convoluted feature map, so it is also called multi-scale pooling method. The spatial pyramid's pooling method transforms the convolution feature of any scale image into the same dimension. By transforming the image of different sizes into the same dimension, the convolution neural network can process the image of any size without image cutting and compression, so as to improve the performance of the network.

3. Activation function

The core of activation function is to introduce the non-linear mapping between layers, which can improve the ability of describing the complex non-linearity of the whole network. How many layers of the network, if only a simple linear combination, cannot express the complex semantic features without nonlinear mapping through activation function. So, activation function is very important to the mapping ability of network.

The commonly used activation functions are: ReLU, Sigmoid function, Tanh function. Among them, tanh function and sigmoid function are the same because their gradients will disappear when they tend to 0 or 1. The difference is that the output of tanh function is 0-centered, so tanh is more popular than sigmoid, but it still has the problem of gradient saturation, which restricts its application. ReLU outputs a part of neurons to 0, which makes the network sparse, so that the problem of gradient saturation of sigmoid and tanh functions does not occur, which effectively avoids the problem of network over fitting. At present, the network basically uses ReLU as the activation function.

The main purpose of this paper is to determine whether the uniformity of fertilizer is reasonable, that is to say, to classify the collected images reasonably. Therefore, at the end of convolution neural network, Softmax classifier is connected to classify the images.

4. Results Analysis

Based on the Internet of things technology, this paper studies the problem of fertilizer uniformity image detection. In view of the actual demand, this paper studies the system from three modules: image acquisition, image transmission and image processing. Image acquisition is mainly to build a sensor network to collect images through cameras, while image transmission is to use network technology to realize the communication of each node, and to transmit the collected images to the cloud for storage and processing. Image processing is the focus of this paper. Through image preprocessing, the quality of image is enhanced, and the feature extraction and classification of subsequent image are guaranteed.

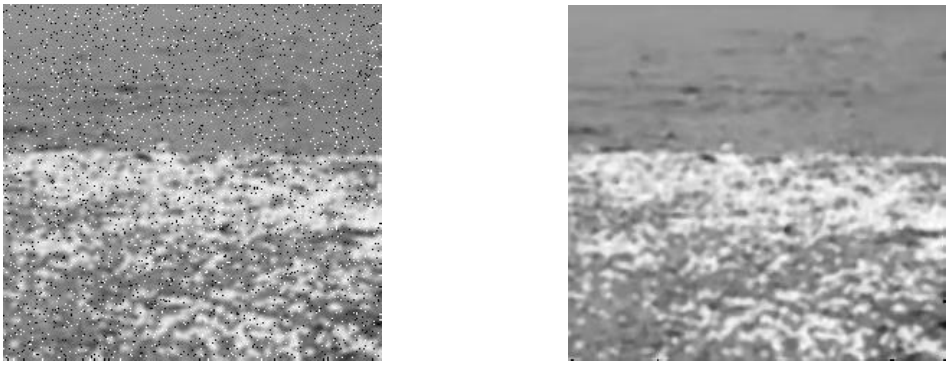
In image preprocessing, this paper processes the image through grayscale processing and filtering processing. Fig.1 shows the result of image graying, in which Fig.1 (a) is the original image and Fig.1 (b) is the grayscale image. It can be seen from Fig.1 that after the image is grayed, the dimension of color image is reduced to grayscale image, and the dimension of image is reduced from three-dimensional to two-dimensional. The image data is reduced, which is conducive to the subsequent feature extraction of the image, but the basic contour and information of the image are preserved.

In image preprocessing, filtering is an inevitable step, because the image is easy to produce noise in the process of acquisition and transmission, and the existence of noise will lead to the degradation of image quality. As shown in Fig.2 (a), after the salt and pepper noise is contained, the image is blurred, which will bring interference to the subsequent image feature extraction and is not conducive to the subsequent image processing. Therefore, image filtering is required in image

preprocessing. Fig.2 (b) is the denoised image after filtering. Comparing the two images, it can be seen that after filtering, the quality of the image is improved, and the image recovery is clear, which is conducive to the subsequent image feature extraction.

(a) Original image (b) Grayscale image

Figure 1. Image grayscale processing



(a) Noisy image (b) Denoising image

Figure 2. Image filtering

After image preprocessing, the convolution neural network is used to extract the features of the image, and at the end of the network, the Softmax classifier is used to classify the fertilizer uniformity image reasonably. In order to illustrate the classification performance of convolution neural network, this paper compares it with traditional classification methods based on SVM, neural network, BP neural network, etc., and obtains the classification accuracy of each method as shown in Table 1, and draws the comparison figure as shown in Fig.3.

Table 1. Performance of several image classification methods in fertilization uniformity image

Method	Accuracy(%)
Classification based on SVM	77.2
Classification based on neural networks	81.5
Classification based on BP neural network	84.3
Method of this article	90.2

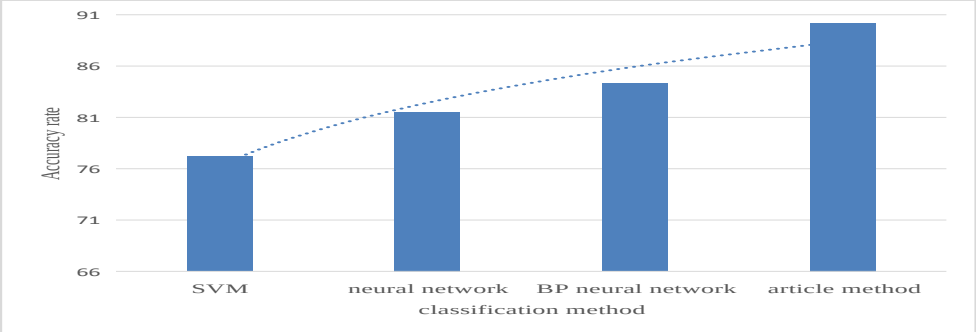


Figure 3. Performance comparison chart of several image classification methods

Combined with Table1 and Fig.3, it can be seen that the performance differences of several methods in fertilizer uniformity image classification are relatively large, among which the worst SVM based classification method has an accuracy rate of only 77.2%; the second is classification method based on neural network, with an accuracy rate of 81.5%; and the second is classification method based on BP neural network, with an accuracy rate of 84.3%. In this paper, convolution neural network is used to extract image features and use Softmax classifier for classification. The performance of this method is better than the other three classification methods, and the accuracy is 90.2%.

In addition, after the function is realized, a stable system is needed to ensure that the system can work for a long time. Therefore, it is necessary to test the system stability designed in this paper, and get the system stability curve as shown in Fig. 4. It can be seen from Fig. 4 that the system in this paper has good stability and can meet the requirements of good and stable operation of the system.

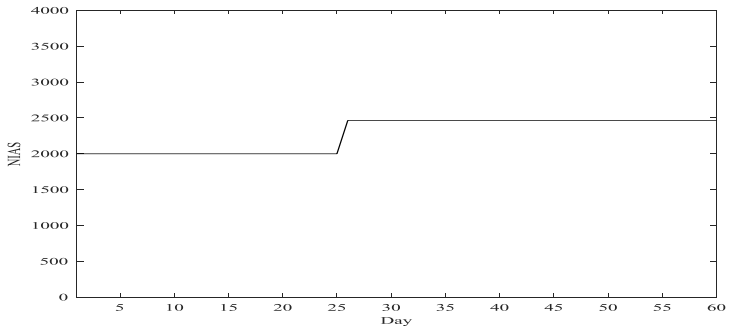


Figure 4. System stability curve

5. Conclusion

With the proposal of precision agriculture, more and more modern scientific and technological means are applied in the field of agriculture, which also brings good application results. But at present, there is no targeted research results on the problem of fertilization uniformity detection. In order to better promote the healthy and sustainable development of agriculture, based on the Internet of things technology, this paper studies the problem of fertilization uniformity detection, and proposes an intelligent image detection system of fertilization uniformity based on the Internet of things. According to the actual needs, the system designed in this paper is expanded from three modules: image acquisition, image transmission and image processing. The image is collected by the image acquisition module, and then transmitted to the cloud by the image transmission module

for storage and processing. The image processing module is mainly to preprocess the image, then use convolution neural network to extract the image features, and at the end of the network, connect the Softmax classifier to classify the fertilizer uniformity rationality. Through the simulation analysis, after image preprocessing, it can effectively improve the quality of the image, avoid the interference of noise in the acquisition and transmission, which is conducive to the subsequent feature extraction and classification of the image. In addition, the stability of the system is tested, which shows that the system designed in this paper can meet the requirements of the stable operation of the actual system. In conclusion, the intelligent image detection system based on the Internet of things designed in this paper can detect whether the fertilization uniformity is reasonable, and promote the healthy and sustainable development of agriculture.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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