DESIGN AND IMPLEMENTATION OF PIG INTELLIGENT CLASSIFICATION MONITORING SYSTEM BASED ON CONVOLUTION NEURAL NETWORK (CNN) /

基于CNN猪只智能分类监控系统的设计与实现

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DOI: https://doi.org/10.35633/inmateh-63-21

Keywords: *Convolution neural network(CNN), Pig classification, Monitoring system, Image recognition*

ABSTRACT
With the development of agricultural information technology, the intelligent monitoring system applied in pigsty can alert people when domestic pigs and wild boars jump into each other's pigsty, and bring convenience to breeding staff. The system uses convolution neural network as the core algorithm to realize the function of real-time monitoring and reminding users. Using Spring MVC framework technology, a pig intelligent classification monitoring system based on C/S architecture is developed. Three layer architecture model of presentation layer, business layer and persistence layer is used. Neural network algorithm is embedded in the image processing module, and Netty framework is used to maintain the connection between each module. Field experiments show that the recognition accuracy of the system can reach 97.08%. This system can be used as a reference for the design of pig intelligent classification monitoring system, and provide a reference for the design of related systems.

摘要
随着农业信息技术的发展，智能化的监控系统应用于猪场中可以对猪场中家养猪和野猪相互蹿窝起到警报作用，为养殖人员带来便利。该系统以卷积神经网络为核心算法，实现了对猪场实时监控并提醒用户的功能。利用Spring MVC框架技术，开发一套基于采用 C/S架构的猪只智能分类监控系统，用展现层、业务层、持久层 3 层架构模型，神经网络算法嵌入于图像处理模块中，采用 Netty 框架去维护各个模块之间的连接。经现场实验表明，系统识别准确率可达97.08%。本系统可以作为猪舍智能分类监控系统设计的参考，为相关系统设计提供参考。

INTRODUCTION

In recent years, with the rapid development of agricultural information technology, people have higher and higher requirements for agricultural technology and equipment. Among them, the breeding industry is developing in the direction of intelligence, and precision management has become more important. It is found that in the process of pig breeding, wild boar and domestic pig often jump to each other’s pigsty, which brings great harm to the growth of pigs. *Weller et al (2019)* put forward that when the pigs are mixed with strange individuals, aggressive behaviour is easy to occur; In order to effectively prevent the occurrence of snatching food and fighting between wild boar and domestic pig, a real-time and accurate monitoring system for pig jumping behaviour is designed, which is of great significance to ensure the healthy growth of pigs and improve the breeding welfare.

Using monitoring system to monitor the behaviour of livestock has become an important auxiliary means of pig breeding. With the progress of technology, the related design innovation is constantly improved, but the ordinary monitoring system can only play the role of real-time monitoring. For example, *Wu et al, (2013),* designed a cattle farm remote monitoring system by using RFID technology and ZigBee technology, the system is simple in layout, low in cost and high in stability, however, the monitor only plays the role of monitoring and does not achieve intelligence. *Zeng et al, (2016),* designed a cowshed environmental parameters monitoring system using ARM technology and WiFi wireless transmission technology, which can accurately monitor the environmental parameters of the cowshed, however, when the temperature in the cowshed is unstable, the system cannot maintain the gas concentration in the cowshed within the appropriate range, and the monitor only plays a monitoring role.

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Zeng et al, (2020), designed a wireless multi-point and multi-source remote monitoring system for pigsty environment by using ZigBee network topology and other technologies.

The system can quickly sense the distribution characteristics of pigsty environment parameters, but the equipment continuous working time of the system needs to be improved, and the monitor is not intelligent. However, this paper designs a pig intelligent classification monitoring system, which can not only play the role of real-time monitoring, but also identify and classify pigs, prevent pig jumping each other's behaviour, and effectively apply to agriculture. The pig intelligent classification monitoring system embedded image recognition algorithm in the image processing module, although there are many technologies applied to the detection and recognition of animal behaviour, they are not applied to the monitoring system.

Yan et al, (2020), used the improved Alexnet model for pig face recognition, which can achieve a high accuracy rate, and the recognition accuracy rate can reach 98.11%, but it has not been applied to the monitoring system, which is lack of practical application.

Zhao et al, (2018), used image processing technology to analyse the leg swing behaviour of dairy cows, and developed a limp detection system based on vision technology, which was also not used in the monitoring system and needs further exploration.

Porto S et al, (2013), used computer vision technology to study the lying behaviour of dairy cows, which showed good robustness and can accurately classify, but at the same time, it lacks the application in the monitoring system, cannot monitor in real time, and does not bring too much convenience for users. This system takes convolution neural network algorithm as the core, which has the advantages of high recognition accuracy and less time-consuming. Compared with *Wang et al, (2020),* who use multi-scale convolution network for pig individual recognition, they can only recognize the pig individual according to the facial features. When the face is completely occluded, they cannot accurately recognize the identity, and the accuracy is not high.

Li et al, (2019), use computer vision technology to recognize the pig behaviour and individual, and capture the essential features of the pig individual, which is inefficient; Based on the principle of binocular vision, *Li et al, (2018*), designed a pig size detection system. Due to the pigs' active nature, their postures often change, and the measured data have a large error. Based on this, the neural network algorithm has good feasibility.

To sum up, this paper designs a pigs intelligent classification monitoring system with convolution neural network algorithm as the core, install monitors near in the domestic pig and wild boar to each other's channel, whenever the monitor detects that a wild boar is on the way to the nest of domestic pig, our mobile phone will send out a No.1 alarm sound and mark the wild boar. At this time, it will remind the breeders to pay attention to the track of the wild boar and prevent the wild boar from entering the nest of domestic pig. In the same way, when the domestic pig is on the way to the nest of wild boar, our mobile phone will send out No.2 alarm sound and mark the domestic pig, and the breeders will pay attention to the tracks of the pig. The creation of the system to a certain extent played a role in the prevention of domestic pig and wild boar fighting, snatching food and other phenomena, even when the breeders are busy with other things, they can also know the situation of pigs in real time, which not only provides convenience for the breeders, but also ensures the healthy growth of pigs.

MATERIALS AND METHODS

EXPERIMENTAL MATERIALS

The pig intelligent classification monitoring system was tested in January 2021 at Tang County pig farm, Baoding City, Hebei Province, China. The pig farm covers an area of 6000 square meters and is divided into 22 pigsties, including 6 wild boar pigsties and 16 domestic pigsties. The wild boar breed is the second generation boar, hereinafter referred to as boar (as shown in Figure 1).

There are two kinds of domestic pigs, namely Dabai and Beijinghei, hereinafter referred to as domestic pig (as shown in Figure 2).

Wild boar nest is not far from domestic pig nest. After half a month field investigation, it is found that when the breeders do not pay attention, the wild boar will leave their own pigsty to look for food. Because the domestic pig pigsty is not far from the wild boar pigsty, it is possible that the wild boar will enter the domestic pig pigsty. At this time, there will be a fight between the wild boar and the domestic pig. To prevent this phenomenon, we installed a monitor on the channel from pigs to each other's pigsty (as shown in Figure 3).

Fig. 1 - Wild Boar Sample

Fig. 2 - Domestic Pig Samples

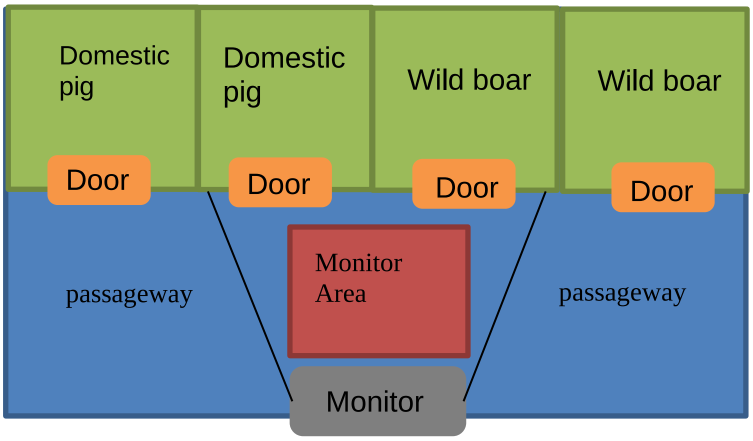

Fig. 3 - Image of Pigsty

SYSTEM DESIGN SCHEME

Overall system architecture

The overall structure of the pig intelligent classification monitoring system is shown in Figure 4. The system consists of three parts: monitoring and detection unit, information transmission system and information processing system. Among them, the monitoring and detection unit are used for image acquisition and image transmission of the channel where pigs lead to each other's pigsty. The data transmission subsystem is used to realize the transmission of network layer signal. The wired long-distance Internet communication is selected. Specifically, the embedded server is used to complete the network transmission of the data from the monitor. The information processing subsystem carries out image recognition and intelligent classification for the received image information, and specifically uses convolution neural network algorithm for pig identification, then the analysis results are transmitted to the client.

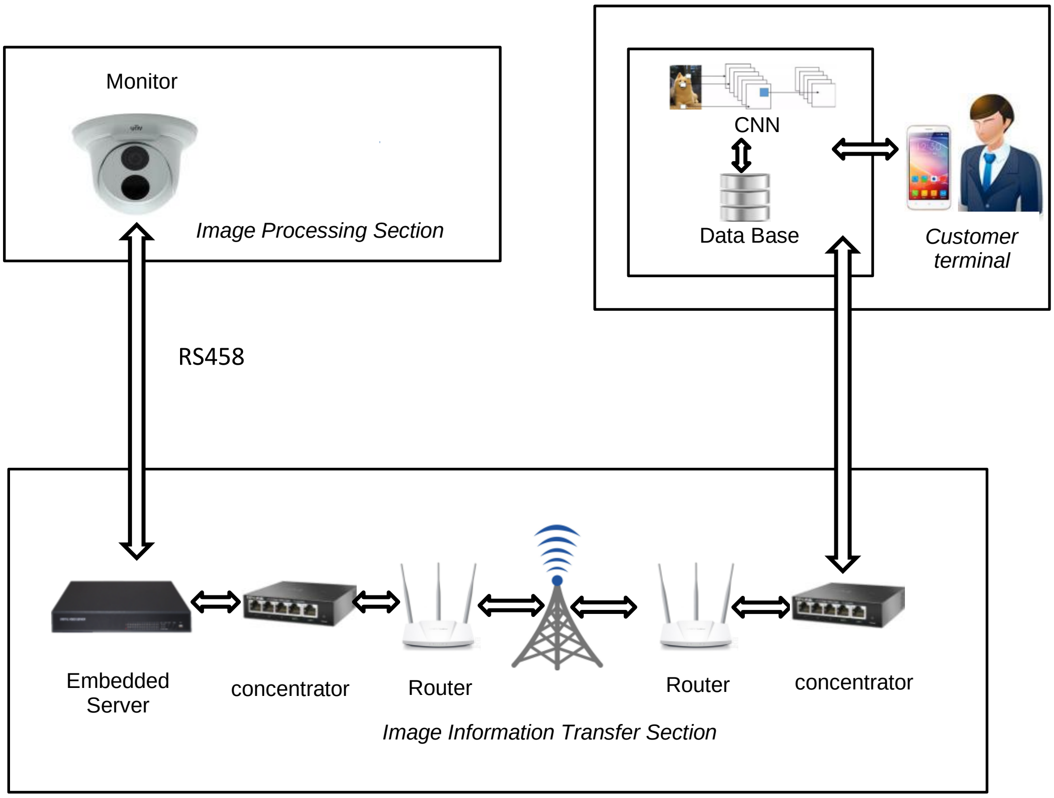

Fig. 4 - Overall Structure of Pig Identification and Classification System

System software architecture

According to the design of the software architecture of the system, the overall architecture is divided into three layers: presentation layer, business layer, data connection layer*(Lv et al, 2020).* As shown in Figure 5. The display layer is composed of front-end, and the user mobile interface is built by H5 technology; the business layer includes image recognition and processing module, alarm module and database module; the data connection layer is responsible for signal connection.

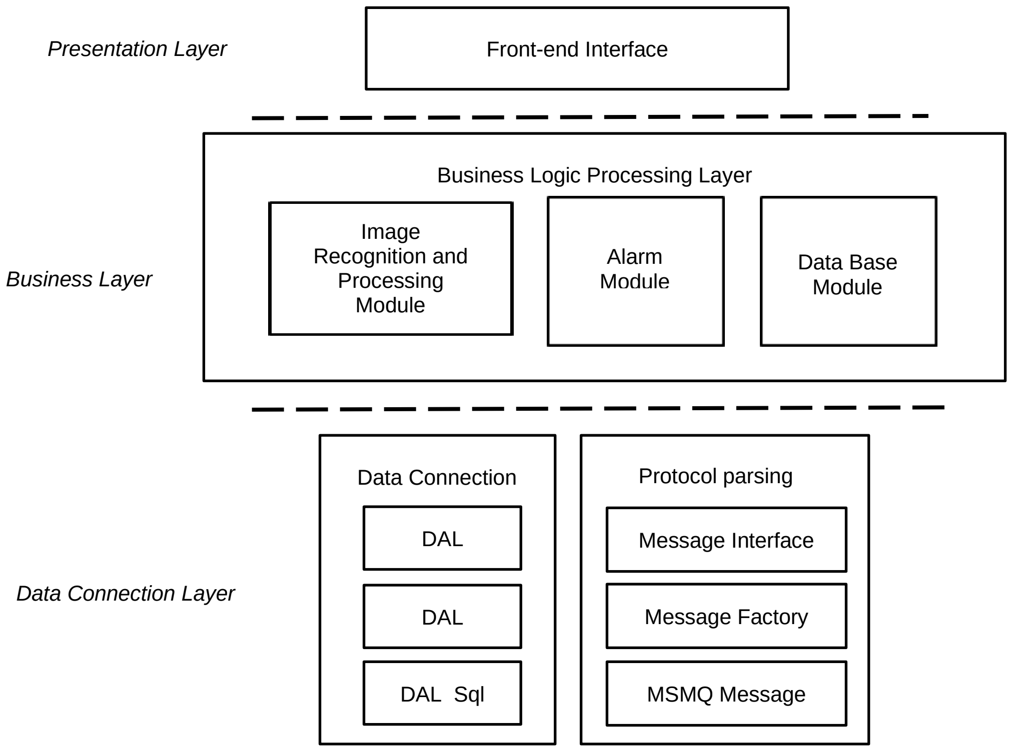

Fig. 5 - Software Overall Architecture Level

Front-end and rear-end design

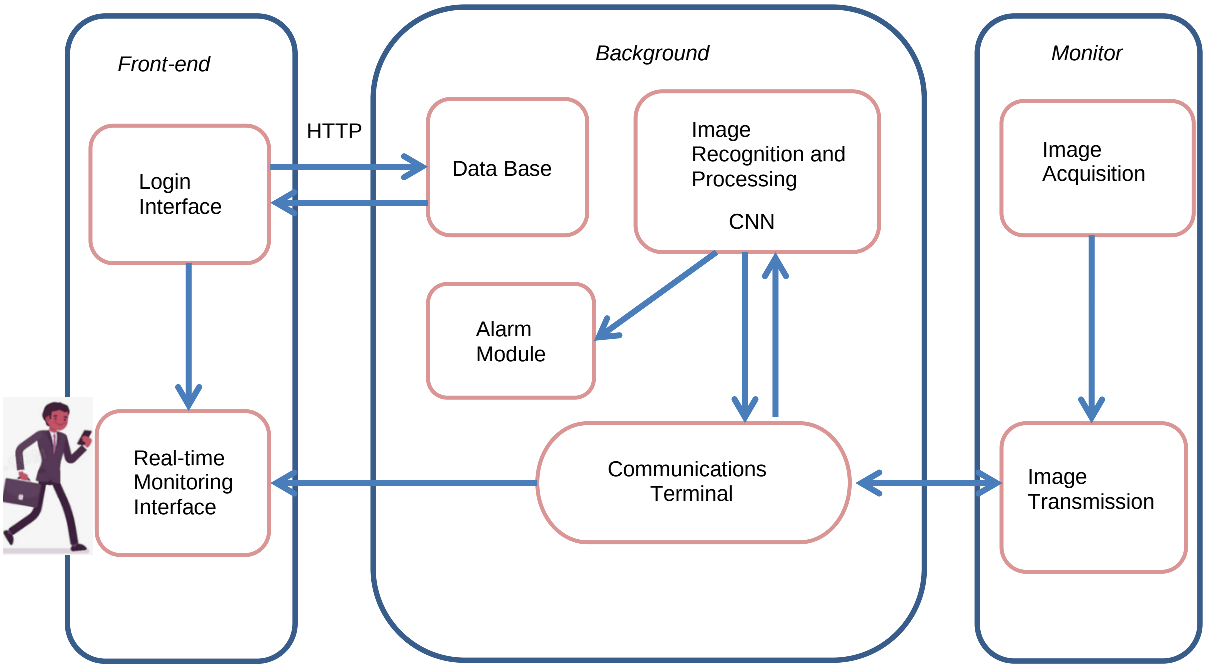

Fig. 6 - System Module Division Diagram

The system adopts C/S architecture, and the embedded server is a web server based on the embedded system, which can be accessed directly through IE browser, with slightly lower hardware requirements *(Zang et al, 2021).*

The front-end is mainly composed of login module and real-time monitoring module. The login module is presented to users in the form of login interface. The login interface is built with H5 technology, and the page layout is carried out. Elements are added to the interface to design a login interface, which includes account, password, password recovery, login and registration buttons. When the registration button is triggered, the registration interface will be presented. New users can register an account for themselves, and then the message will be sent to the database module. The real-time monitoring interface is mainly composed of channel image information from the monitor, opening the camera and closing the camera.

The back end is mainly composed of database module, image processing module and alarm module. The database module detects the data from the login module, and then feeds it back to the login interface. The user's registered account and password are stored in the database. When the user's account cannot be queried in the database, it cannot be logged in. The image processing module is based on convolution neural network algorithm, which can recognize the image information of the real-time monitoring module, and then feed back the recognition results to the alarm module. The alarm module is composed of No.1 alarm sound and No.2 alarm sound. It responds to the results processed by the image processing module and uses two kinds of alarm sound to distinguish two kinds of recognition results.

Communication between modules

This pig intelligent classification monitoring system establishes socket connection between background modules, and the background adopts Netty framework to maintain this connection *(Lv et al, 2020).* Netty is a NIO based client-side and server-side programming framework. At the same time, Netty is a high-performance event driven, asynchronous non-blocking IO (NIO) Java open source framework, which is provided by JBoss for establishing TCP and other underlying connections. Based on Netty, high-performance HTTP server can be established to rapidly develop high-performance, high reliability network server and client programs. It supports fast development, maintainable, high performance, protocol oriented server and client, avoids using the underlying API directly, and reduces the complexity of network programming *(Huang et al, 2021).* When a connection interruption is detected, the background can automatically initiate a reconnection to ensure the continuity of the connection *(Wei et al, 2020).*

SYSTEM WORKFLOW

System process overview

The pig intelligent classification monitoring system is different from the ordinary monitoring system. The system is based on CNN algorithm, so that the monitoring system can not only monitor in real time, but also remind users, which brings great convenience to users. When the monitor senses the light source, it firstly converts the light into electric charge, and then converts it into digital signal through the analog-to-digital converter chip. After compression, the digital signal is stored in the internal memory of the monitor, and then the image information can be transmitted to the embedded server through the serial port according to a certain data frame format. Finally, the embedded server is used to complete the transmission of the monitor. After the image data is transferred to the background, the background calls the image processing module to identify the image data, and returns the processed data to the front end for display *(Guo et al, 2020)*. The working process of the whole system is shown in Figure 7.

The working process of the system is as follows: firstly, the monitor collects the image of the pig's access to the other pigsty; secondly, the server pre-processes the collected image and randomly selects samples to form a random sample to ensure the credibility of the experiment *(Zhang et al, 2021)*. Thirdly, the server transfers the processed samples into the convolution neural network model for calculation and analysis to obtain the classification of the samples. Finally, when the classification is wild boar, the background is pushed to the front interface, which marks the wild boar on the channel leading to the pigsty and sends out No.1 alarm sound; When it is calculated and classified as a domestic pig, the background is pushed to the front interface, which marks the domestic pig on the channel leading to the pigsty and sends out No.2 alarm sound.

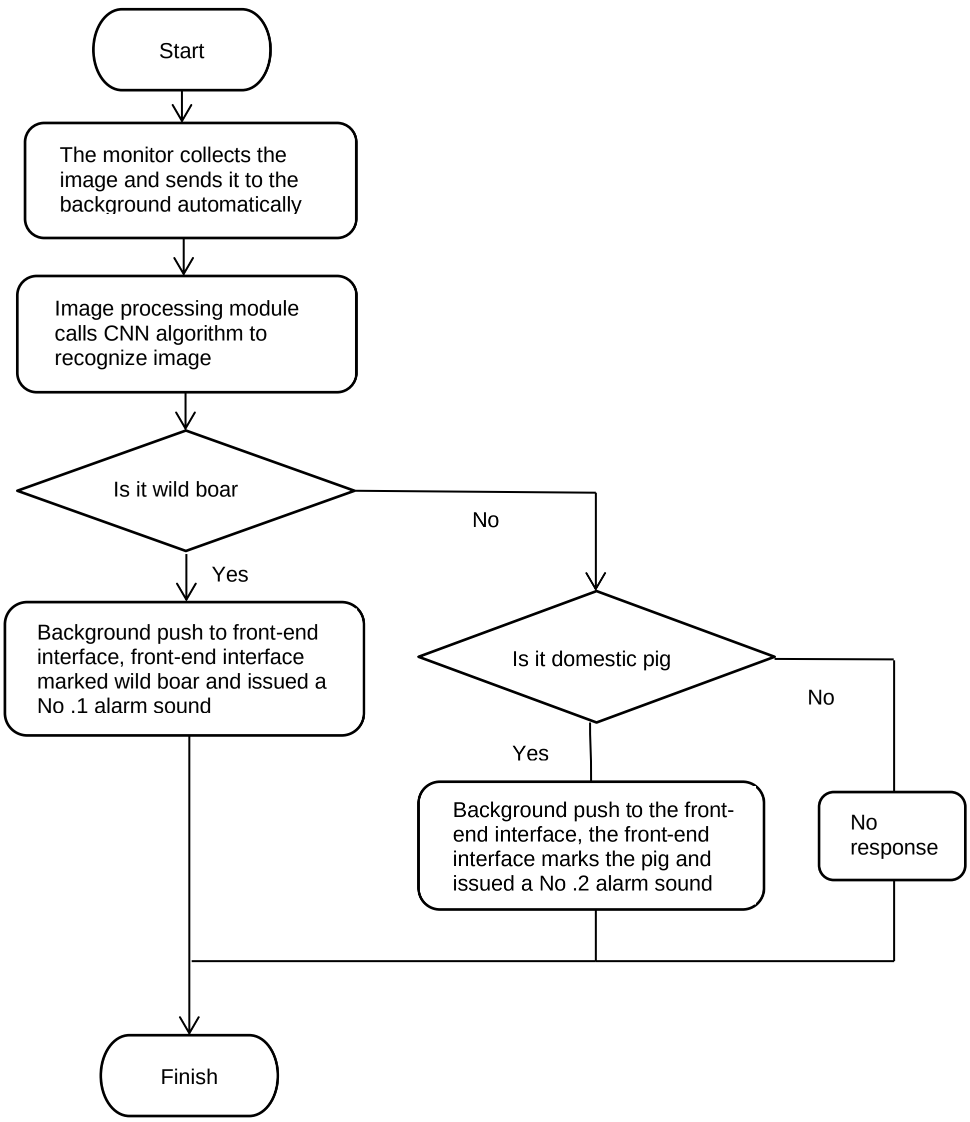

Fig. 7 - System Workflow

Core algorithm principle

In this experiment, convolution neural network algorithm is used to identify and classify wild boar and domestic pig, as shown in Figure 8. The model includes two layers of convolution layer, two layers of pooling layer, two layers of full connection layer, one layer of dropout layer and one layer of softmax layer.

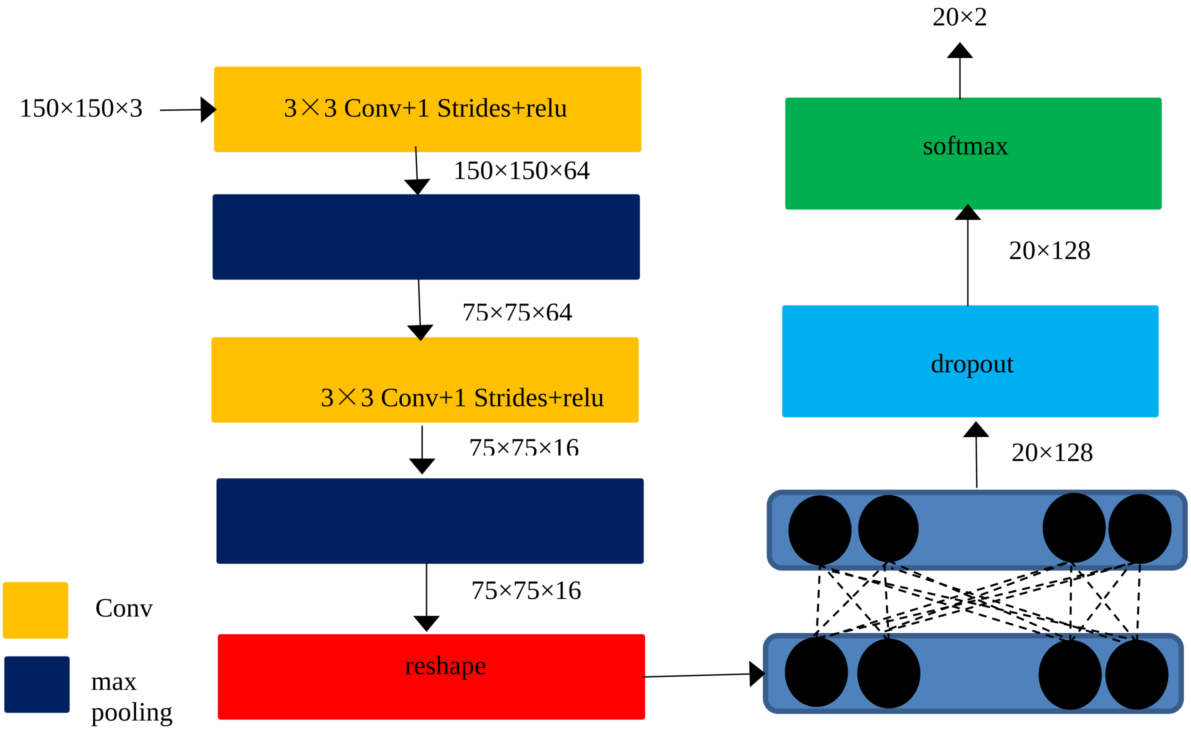

Fig. 8 - Algorithm model diagram

Convolution layer is the core of convolution neural network algorithm. In convolution layer, the preprocessed image can be extracted by the corresponding operation between filter and preprocessed image. In this model, 64 filters with 3×3 channels are set in the first layer of convolution layer, strides is 1, padding is "same", and 16 filters with 3×3 channels are set in the second layer of convolution layer, strides is 1, padding is "same".

In the two-layer convolution layer of the model, strides is set to 1 and padding is set to same. According to the parameters, the calculation formula for the size of the output image feature graph is as follows:

$$Sizeoutput = \left\lceil \frac{Sizeinput}{strides} \right\rceil \tag{1}$$

$Sizeinput$ represents the size of the input image of the convolution layer, $strides$ represents the step size, $Sizeoutput$ represents the size of the output image feature map after the convolution layer.

In the pooling layer, the max pooling method is used to extract more important features than objects. In this model, a 3×3 pooling window is selected for the first pooling layer, and the strides is 2; a 3×3 pooling window is selected for the second pooling layer, and the strides is 1.

The full connection layer is set with weight parameters, the feature can be further extracted by weight parameter. In order to ensure the nonlinearity of the model, the data is ReLU operated after each calculation to ensure that each parameter can be changed when training the model, which feature will not be biased, and the gradient will not disappear. In the full connection layer, the number of neurons will affect the quality of the trained model. Too many neurons will cause over fitting, and too few neurons will cause under fitting. In this model, 128 neurons are selected in the two full connection layers, at this time, the best model can be obtained.

The weight parameters are set in the full connection layer to further extract features. The calculation formula is as follows:

$$A = W \times X + b \tag{2}$$

A is the size of the feature map after the output of the full connection layer, W is the weight parameter, and X is the size of the feature map when the input of the full connection layer, b is the offset term.

The softmax layer sets the parameter 128×2 (in this model, the wild boar and domestic pig are identified and classified, so the category is divided into two categories). The score of each category is obtained by calculating the input data.

Algorithm workflow

The process of recognition and classification model of wild boar and domestic pig based on convolution neural network is as follows:

Set BATCH_SIZE is 20 in the model, and each time 20 images with size of 150×150 and channel of 3 are input into the convolution neural network model. In the first layer of convolution layer, the corresponding operation is performed with 64 filters with size of 3×3 and channel of 3, and the strings is set to 1. For the sake of fairness, the model can extract the features of each part of the image, using the filling model, setting padding to "same", which can make the size of the output image consistent with the size of the input image. The output data can be operated by ReLU (linear rectification function), which can ensure the nonlinearity of the model, reduce the interdependence between parameters and prevent over fitting. After the first layer of convolution, the size of the feature map is 150×150, and the channel is 64. At this time, the output image feature map is too large. In order to reduce the amount of parameters, we need to go through the pooling layer, compress the size of the feature map, and select more important features. Through the first pooling layer, the sliding window is 3×3, and the strides is 2. Through this layer, the output feature map size is 75×75, and the channel is 64. After entering the second layer of convolution layer, 16 filters with 3×3 channels and 64 channels are set up to carry out corresponding operation, and then the output data is operated by ReLU (linear rectification function). The size of the output feature map is 75×75 and the channel is 16. For the same reason, it also needs to pass through the pooling layer. In the second pooling layer, the sliding window is 3×3, and the strides is 1. In the same way as the first pooling layer, the more important features of the image are selected. Through this layer, the output feature map size is 75×75, and the channel is 16. In the full connection layer, 90000×128 weight parameters and 128 offset terms are set. At this time, the size of the output feature map is 75×75×16, and each feature map needs to be stretched into a size of 1×90000 by reshape operation. Since 20 images are input each time, the size of all feature maps is 20×90000. After the first layer of full connection layer, the size of feature map is 20×128. In order to ensure the nonlinearity of the model, after each full connection operation, it is necessary to carry out the ReLU (linear rectification function) operation. Then, a full connection operation is performed, 128×128 weight parameters and 128 offset terms are set, and the size of the output feature map is 20×128. A dropout operation of the output feature map is needed to prevent overfitting of the model, which can make the trained model have strong generalization ability. Finally, the score of each category is obtained through softmax layer.

After judging the category of pigs, the algorithm can frame the pigs in the image and locate the pigs. When it is detected that the pig is a wild boar, it will send out No.1 alarm sound, and the boar will be circled with a red box; When it is detected that the pig is a domestic pig, it will send out No.2 alarm sound, and the black domestic pig will be circled with a yellow box, and the white domestic pig will be circled with a green box. In the training model, each training can calculate the loss value of the training, optimize the loss value, make the loss value as small as possible. In this model, through the experiment, it is found that when the learning rate is set to 0.0001, after multiple training, we can get a high accuracy model.

RESULTS

Implementation of core algorithm

Figure 9 shows the change of the loss value in the process of training the model. With the increase of the number of iterations, the loss value generally changes in the direction of decreasing. By analysing the data, when the number of iterations is 641, the loss value is only 0.02, and then with the increase of the number of iterations, the loss value will not fluctuate too much.

Figure 10 shows the change of the accuracy in the process of training model. With the increase of the number of iterations, the accuracy generally changes in the direction of increase. When the number of iterations is 221, the accuracy reaches the highest. When the number of iterations increases by 511, the accuracy rate remains at 100%.

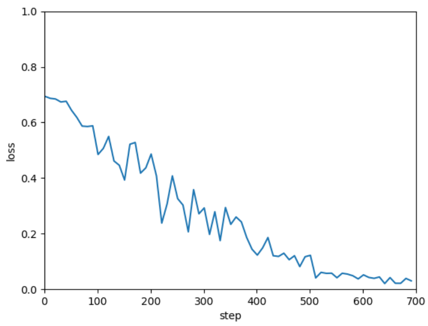

Fig. 9 - Loss-step Graph

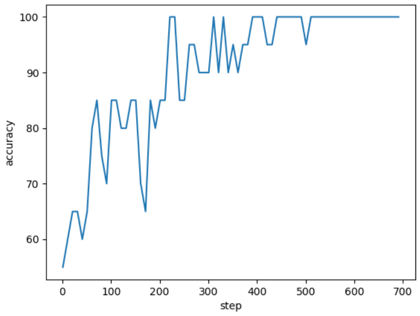

Fig. 10 - Accuracy-step Graph

Table 1

Pig identification results of test samples

Pig category	Number of test sets piece	Correctly identify quantity piece	Accuracy %
Wild boar	120	117	97.50
Domestic pig	120	116	96.67

A number of 240 randomly selected test sets (120 domestic pig test sets and 120 wild boar test sets) were input into the pig recognition and classification network. The trained pig recognition and classification network is used to detect the accuracy of the test set, and the results show that the accuracy of the network reaches 97.08%. The data show that the network has a good effect on pig recognition and classification under different light intensity.

User interface display

This pigsty intelligent classification monitoring system has good practicability, the monitor is installed near the channel that the domestic pig and the wild boar often lead to each other's pigsty, so the area irradiated by the monitor plays an important role in judging whether the wild boar and the domestic pig are likely to jump into each other's pigsty. When the breeder is indoors, he can open the mobile phone to watch whether there are pigs walking in the channel at any time.

When a black domestic pig leaves its own pigsty and goes to the direction of the wild boar house, the black domestic pig will inevitably pass through the area illuminated by the monitor. At this time, the mobile phone will send out No.2 alarm sound to remind the breeder to pay attention to the tracks of the domestic pig. At this time, the breeders can open their mobile phone and see the black domestic pig walking in the shooting channel of the monitor through their mobile phone, as shown in Figure 11, the black domestic pig is marked by a yellow box. At this time, the breeder needs to be alert to the black domestic pig, and prevents the black domestic pig from going to the wild boar’s pigsty. Similarly, when a white domestic pig leaves its own pigsty and goes to the direction of the wild boar pigsty, it will send out No.1 alarm sound, as shown in Figure 12. The breeder can see the white domestic pig marked by a green box through the mobile phone.

When a wild boar leaves its own pigsty and goes to the direction of the domestic pig pigsty, as long as it passes through the area illuminated by the monitor, the mobile phone will give out No.1 alarm, and the interface shown in Figure 13 will appear on the mobile phone. The wild boar is marked with a red box. At this time, the breeders should be more vigilant, the wild boar is more ferocious and faster, so the breeders should pay more attention to it. Before the wild boar had the tendency to go to the pigsty at home, breeders arrived at the scene in advance to prevent the occurrence of pig fighting.

Fig. 11 - Black Domestic Pig

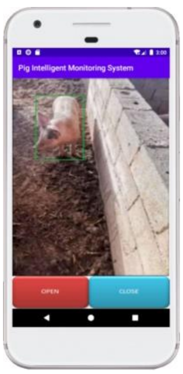

Fig. 12 - White Domestic Pig

Fig. 13 - Wild Boar

CONCLUSIONS

Aiming at the problem that the behaviour of pigs in pigsty will affect the growth of pigs, this paper studies a system based on convolution neural network algorithm to identify and detect the behaviour of pigs. The convolution neural network algorithm and the monitoring system cooperate for target recognition and detection, which can achieve the demand of accurate recognition and classification. The convolution neural network algorithm is integrated into the image processing module of the client, which can monitor the behaviour of pigs in real time and give an alarm. In addition, the system also expands other functions of the client to meet the needs of the market. Compared with the traditional method of distinguishing domestic pig and wild boar by naked eye, this method has faster detection speed, higher accuracy and greatly saves human resources. Experiments show that the accuracy can reach 97.08%. The system is of great significance to the research of real-time detection of pigs.

ACKNOWLEDGEMENT

This paper is supported by the research project of Shanxi Province excellent doctor work Award Fund (Research on model detection technology of Agricultural Internet of things, No: SXYBKY201721).

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