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RESEARCH ON VISION SYSTEM OF INTELLIGENT SORTING ROBOT BASED ON DEEP LEARNING

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It is an important step to realize automatic and intelligent production of coal mine to use intelligent sorting robot instead of manual. The vision system, as the "eye" of the intelligent sorting robot, completes the rapid identification, positioning and grouping of the sorting target. Based on YOLOv5, the vision system uses GhostNet to carry out the lightweight design of the model, aiming to ensure the detection accuracy while making the entire model more lightweight, so as to improve the model recognition speed and reduce the operating cost. The model recognition speed of Ghost-YOLOv5 designed and developed is 33FPS, the model size is only 4,2 Mb, and the average detection accuracy is 96,7 %.

Keyword: intelligent sorting robot, lightweight model design, detection model, vision system

INTRODUCTION

The application of deep learning-based target detection algorithm to coal gangue identification combined with intelligent sorting robot is an important step to realize intelligent, automatic and digital coal gangue sorting operation. Industrial sites usually use the characteristics of anti-magnetic, dust-proof, impact resistance, high temperature resistance, corrosion resistance of the industrial computer as the control unit and data processing unit, these characteristics seriously limit the computing power and storage capacity of the computer, so the design of lightweight coal gangue detection model has more practical engineering significance [1].

Based on lightweight convolutional neural network GhostNet, this study designed a lightweight coal gangue detection model, aiming to realize intelligent coal gangue sorting operation while efficiently identifying coal and gangue, combined with intelligent sorting robot.

Introduction of intelligent sorting robot system scheme

According to the demand of coal gangue sorting process, intelligent sorting robot should have the function of identifying and fast sorting coal gangue.The intelligent sorting robot is installed in the coal mine workshop to complete the intelligent and automatic sorting of coal or gangue. The system mainly includes queuing device, vision system, host computer and servo control system and intelligent sorting robot. The intelligent sorting robot system is shown in Figure 1.

After the raw coal passes through the vibration screen, the coal gangue with diameter ranging from 40 mm to 300 mm is sent to the raw coal workshop for coal separation. The queuing device is located at the front end of the intelligent sorting robot system. In order to facilitate the robot to sort coal or gangue out of the conveyor belt, the device can sort the disordered mixture of coal and gangue into left and right queues.

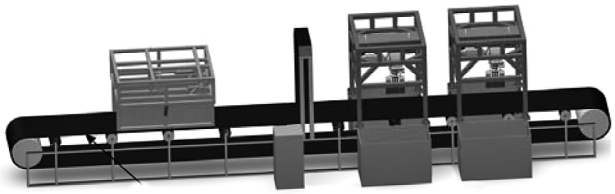

Figure 1 Intelligent sorting robot system

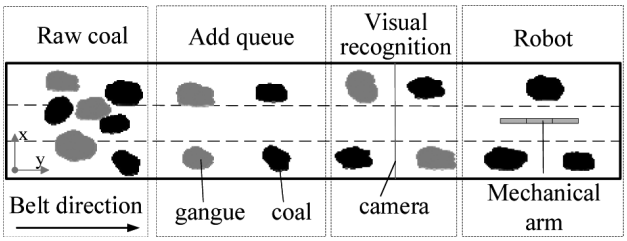

Figure 2 Intelligent sorting robot operation sequence

The vision system is developed based on the lightweight coal gangue detection model, which can accurately identify and quickly locate the coal gangue on the conveyor belt in real time, process the sorting target by combining and grouping, and transmit the processing information to the intelligent sorting robot control system in real time.

The intelligent sorting robot control system establishes communication with the vision system. The control system assigns tasks to the collaborative work of multiple robots according to the received protocol information, and the servo control system issues operation instructions

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such as job track, job speed, and acceleration to the robot to complete the intelligent and automatic coal gangue sorting operation. The operation sequence of the intelligent sorting robot system is shown in Figure 2.

Image preprocessing and coal gangue data set

Coal and gangue have certain similarities in form, texture, gray level and other features, but the coal produced by different coal mines has its uniqueness. Firstly, bilateral filtering algorithm is used to preprocess the coal gangue image[2]. Bilateral filtering is a nonlinear image filtering algorithm, which has a good filtering effect on images. While eliminating noise and smoothing the image, the edge information of the image can be well retained. Let an image, Let an N*N image, the filtered image is f(x,y), the filtered image is g(x,y), the formula for bilateral filtering is as follows:

$$g(x,y)=\frac{\sum_{(i,j)\in\Omega}\omega_s(i,j)\omega_r(i,j)f(x,y)}{\omega_s(i,j)\omega_r(i,j)} \quad (1)$$

$$\omega_s(i,j)=e^{-\left(\frac{(i-x)^2+(j-y)^2}{2\sigma_s^2}\right)} \quad (2)$$

$$\omega_r(i,j)=e^{-\left(\frac{(f(i,j)-f(x,y))^2}{2\sigma_r^2}\right)} \quad (3)$$

In the formula:

$\omega_s(i,j)$ -Spatial domain kernel, representing the Euclidean distance between a point (i, j) and the center point (x,y) in the domain;

$\omega_r(i,j)$ -Value kernel. Represents the absolute value of the difference between the gray value f(x,y) of a point (i,j) in a neighborhood and the center point (x,y).

The comparison of images before and after bilateral filtering is shown in Figure 3.

In the Figure 3, (a) is the original image, and (b) is the filtered image. After bilateral filtering, the noise of the image is significantly suppressed, and the edge features are more obvious, and the clarity of the image is also significantly improved.

In order to obtain the network model with high recognition rate under various working conditions, it is particularly important to make the data set for model training. In this paper, labelimg is used to create a boundary box for coal or gangue and assign category labels. The label for coal and the label for gangue is stone to complete the production of coal gangue data set.

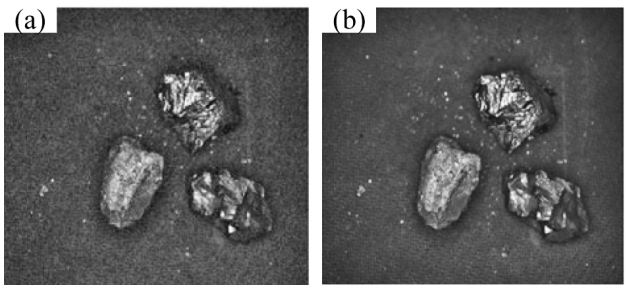

Figure 3 Comparison of images before and after filtering

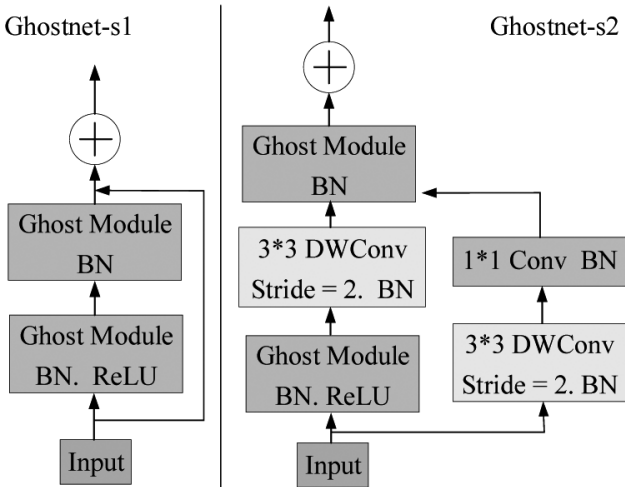

Figure 4 GhostNet network structure

Lightweight coal gangue detection model

GhostNet is a new lightweight convolutional neural network model proposed by Huawei Loya Ark in 2020[3] which uses residual network ResNet to build GhostNet basic residual block Ghost Bottlenecks, as shown in Figure 4: It incorporates multiple convolutional layers and shortcuts to avoid overfitting of the network due to convolutional stacking.

When STRIDE = 1, Ghost Bottlenecks are mainly composed of two stacked Ghost modules, the first Ghost module is mainly used to expand the number of layers of the network and increase the number of channels. The second Ghost module is mainly used to reduce the number of channels, make its output match and add with the residual edge output, and then connect the input and output of the two stacked Ghost modules using a shortcut structure.

When STRIDE = 2, Ghost Bottlenecks compresses the size of the feature graph by adding a deep convolution with step 2 after the first Ghost module to reduce the number of parameters in the network again. At the same time, a depth convolution with step size of 2, convolution kernel of 3*3 and a point convolution with 1*1 are used to compress the input image size, keep the

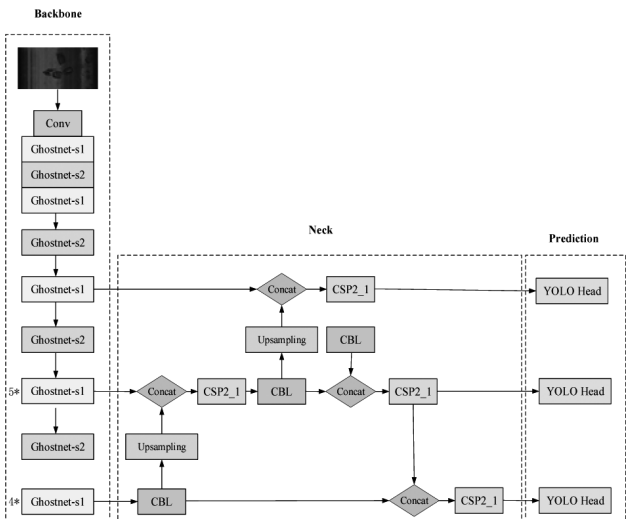

Figure 5 GhostNet-YOLOv5 network structure

main line and residual edge output feature map size consistent, and do addition processing.

In this study, based on YOLOv5 network [4], The Ghost-YOLOv5 target detection model is designed based on GhostNet lightweight convolutional neural network. GhostNet is used as the Backbone part of the network to extract coal gangue features. A total of 5 downsampling operations are carried out. As a result, the prediction of the candidate frame position of the neural network is not accurate. To solve this problem, the feature structure is also enhanced by combining feature pyramid network FPN and path aggregation network RPN on the Neck part of the network, and the feature maps after stage3, stage4 and stage5 are respectively taken for feature fusion. The structure diagram of the designed lightweight target detection model is shown in Figure 5.

EXPERIMENT AND RESULT ANALYSIS

Based on the above design results, the lightweight neural network Ghost-YOLOv5 is trained with coal gangue data set, and the hyperparameters of model training are set as shown in Table 1:

After training 100 epochs, the training results are shown in Figure 6:

As can be seen from the figure above, the Loss curve of the Loss function decreases rapidly after the training of Ghost-YOLOv5 to the third epoch, and with the increase of training times, the loss curve decreases steadily and finally converges well.

YOLOv5s and Ghost-YOLOv5 were selected to conduct comparative experiments in terms of model size, recognition effect and recognition speed, respectively, to analyze and evaluate the performance of the trained lightweight network model. The average AP value of each model, Map@0,5, recognition speed FPS and model size are shown in Table 2:

As can be seen from the above table, the average detection accuracy of the original YOLOv5 is 96,7 %, but the recognition speed of the model is only 17 FPS, and the weight of the model reaches 14,3 Mb. The network model is large and the recognition speed is low. The improved Ghost-YOLOV5 uses a lightweight neural network Ghost, with an average detection accuracy of 92,3 %, but it performs well in terms of recognition speed and model size, with an FPS of 33, an average recognition speed of 30 ms per image, and a model weight of only 4,2 Mb.

Table 1 **Experimental environment**

parameter	value
Epochs	100
batch-size	64
img-size	640*640
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Table 2 **Experimental results**

Model	mAP@0,5 %			FPS	Size (Mb)
	Stone	Coal	All		
YOLOv5s	98,2	97,6	97,9	17	14,3
Ghost-YOLOv5	97,1	96,3	96,7	33	4,2

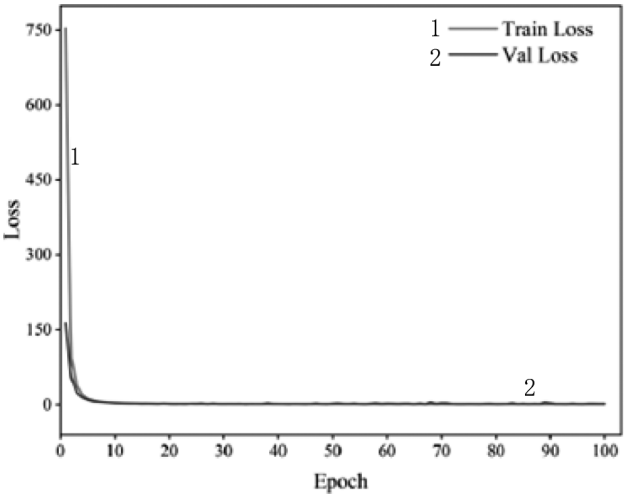

Figure 6 Loss curve of the model

CONCLUSION

Vision system, as the "eye" of intelligent sorting robot, is an important part of realizing automatic and intelligent coal separation. Although the object detection model based on deep learning can achieve high detection accuracy, in practical application, due to convolutional stacking, the model has a large number of weight parameters, which requires high calculation and storage of hardware equipment. In this paper, the lightweight coal gangue detection model Ghost-YOLOv5 is designed based on lightweight convolutional neural network. The average recognition accuracy is 96,7 %, FPS is 33, and model size is only 4,2 Mb. The recognition accuracy is high, and the recognition speed block is more suitable for practical engineering applications.

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Note: The responsible translator for English language is J. B. WANG - North China University of Science and Technology