Establishment of Boiler Deep Learning Image Recognition Model

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1. Background

The boilers of large coal-fired power plants shoulder the important task of supplying steam to turbines for power generation. If the boiler tube leaks, the unit must be shut down for maintenance, which will at least cause negative impacts such as loss of power generation and increased system cost for adopting more expensive alternative power sources. According to a survey, 80% of power plants' forced outage events are related to boiler tube damage, of which water wall tube failures cause 40%. Inspection personnel often need to set up scaffolding or ride in a hanging cage to conduct inspections at high places on water wall pipes, which is costly, time-consuming, labor-intensive, and susceptible to industrial safety risks. Since unmanned aerial vehicles (UAV) can provide a wide range of real-time image capture, and artificial intelligence (AI) image recognition technology can quickly and accurately identify faults, this study combines the two to detect boiler tube faults at Linkou Power Plant

YOLOv3 boiler tube object detection model

The boiler tube object detection model developed in this study is YOLOv3 [1-3], which is composed of the backbone network DarkNet-53 and post-processing modules, as shown in Figure 1. The backbone network DarkNet-53 contains 23 residual blocks, which are responsible for extracting useful features of input images. The post-processing modules, including a series of convolution operations, upsampling, and concatenation, detect objects at three different scales. This study picked up drone videos through the Pengo HDMI to USB-C 4K image extractor from 2022/3 to 2023/4 and collected a total of 750 frames of images of the water wall pipes of Linkou Power Plant. Of these, 240 frames of defect images are used as input data for the YOLOv3 boiler tube object detection model. In order to prevent overfitting due to insufficient data during network training, this study used data augmentation techniques to rotate and flip the original defect images by 30°, 120°, 180°, 210°, and 270° to obtain augmented 2,880 frames of images. 90% of which were used for model training and the remaining 10% for validation.

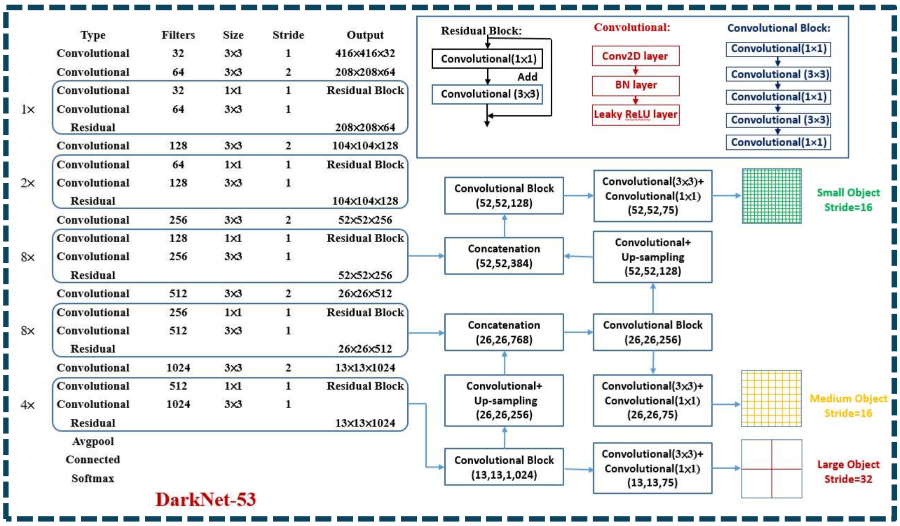
2. Results

The performance index in this model, mAP and object detection speed, are 0.4064 and 29 fps, respectively. Figure 2 shows the comparison between the ground truth bounding box and the predicted bounding box. It can be seen that the predicted boxes can mostly precisely match the ground truth ones. As far as detection is concerned, providing information about boiler tube defects is enough to allow on-site personnel to quickly find out the boiler tube damage, locate leaks, and minimize the adverse effects and losses of boiler tube failures. The results of this study are as follows:

(1) The study found that broken sites and other defects are easier to identify. At the same time, circumferential cracks and axial cracks are less identifiable because they are easily confused with the environmental background.

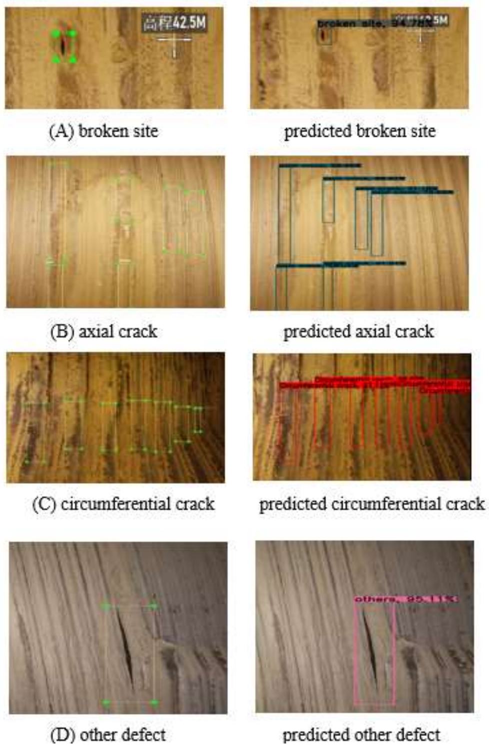
(2) The frame rate in this study is close to 29 fps, which makes the video images very smooth and facilitates real-time object detection.

(3) Establishing a real-time object detection technique can offer on-site personnel information on the boiler tube damage and location of leakage and minimize the negative effects and losses.



Source: Compiled by this study

Figure 1 YOLOv3 boiler tube object detection model architecture



Source: This study

Figure 2 Comparison between ground truth box and predicted box

3. References

[1] Joseph Redmon, Santosh Divvala, Ross Girshick, Ali Farhadi, "You Only Look Once: Unified, Real-Time Object Detection," Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR), pp.779-788, 2016.

[2] Joseph Redmon, Ali Farhadi, "YOLO9000: Better, Faster, Stronger,"*Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, pp.7263-7271, 2017.

[3] Joseph Redmon, Ali Farhadi, "YOLOv3: An Incremental Improvement," *arXiv:1804.02767*,Vo1., 2018.