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Summary of Application Research of Deep Learning in Operational Inspection of Transmission and Distribution Equipment

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Abstract. With the continuous expansion of artificial intelligence in power system, the reliability, security and operation ability of power system have been greatly improved. With the massive collection of data for transmission and transformation operation and maintenance, in-depth learning, as a typical representative of data-driven in the system of artificial intelligence methods, is increasingly appearing in the application scenarios of intelligent state assessment of transmission and transformation equipment. Its excellent robustness can eliminate many kinds of interference in complex environment background, accurately identify and evaluate the target points under test, and greatly reduce the detection of transportation and inspection personnel. The workload of data analysis, processing, evaluation and other links can improve work efficiency and accuracy. This paper attempts to summarize the development process of in-depth learning, relevant landmark achievements and typical applications in the operation and inspection of power transmission and transformation equipment. This paper attempts to summarize the research progress of target recognition, target segmentation, image classification algorithms in depth learning in different spectral cameras of visible light, ultraviolet corona imaging and infrared thermal imaging.

1. Introduction

It is a new challenge to ensure the safe and stable operation of power system facilities, reduce the cost of operation and maintenance, and improve the efficiency and accuracy of operation and inspection. The operation modes of domestic power grid [1] are mainly divided into three types: unattended mode, manned mode and less manned mode. Among them, the manned mode is the traditional substation operation mode, and the unmanned intelligent on-duty operation mode management is a new operation management mode. The traditional maintenance has the following problems [2]. (1) Periodic outage maintenance is required. With the investment of substation and large capacity and ultra-high voltage power equipment, the existing operation and maintenance personnel have been unable to adapt to the needs of the development of the power grid. (2) Planned maintenance of power failure mainly relies on periodic preventive insulation test of equipment, and maintenance of power failure is required, which cannot fully reflect the insulation condition of power system equipment under normal live operation. (3) The workload of planned outage maintenance is large, which affects the power grid and the normal power consumption of users, and it is easy to cause safety accidents. Therefore, the

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transformation of power grid operation and maintenance is urgent. Especially with the help of artificial intelligence power grid [3], how to improve the intelligent operation and maintenance degree of power grid, how to make full use of power grid's human resources, and how to shorten the failure time to make the power grid operate efficiently are very important.

As one of the most valuable directions in the current global technology frontier, the field of artificial intelligence (AI) has been actively taken by the Chinese government and the power industry to study and formulate a series of relevant technology strategies [4], and closely follow the progress of the latest research and development of key technologies such as artificial intelligence. In September 2016, the general office of the national development and reform commission of the People's Republic of China issued relevant policies on requesting organizations to apply for the "Internet +" innovation capacity building program, which mainly provides guidance on relevant industrial policies and research and development directions for enterprises that are pushing artificial intelligence into relevant application fields. In order to accelerate the development and innovation of the emerging artificial intelligence "Internet +" field, and promote the basic research and application of artificial intelligence in the development of the power industry[5], the general office of the state council issued the "development plan for the new generation of artificial intelligence" in the next July. In August of the same year, the state grid corporation of China formally started the formulation and related work of the national development strategy plan of the electric power industry on artificial intelligence, formed the special plan of the state grid corporation of China on artificial intelligence, and discussed the prospect of the application and development of the application of artificial intelligence and other key technologies in China's electric power industry. Looking for the breakthrough points and the advantages of a new generation of artificial intelligence in our country electric power industry, China electric power research institute organized the 208 science and technology conference, and discussed "the artificial intelligence in our country, the main research direction and key technology application in the field of electric power "[6], the conference aims to encourage more personnel engaged in the power industry to explore how to application in power system, key technologies such as artificial intelligence, widely participate in thinking ahead of plan. With the development strategy planning of artificial intelligence and the gradual proposal and deployment of related policies of artificial intelligence, the research and application of artificial intelligence methods have entered a period of rapid development. Artificial intelligence (AI) algorithm system represented by deep learning algorithm has gradually become the mainstream method and new idea of power industry intelligentization.

2. The main methods of deep learning applied in the transportation and inspection of power transmission and transformation equipment

Deep learning roughly includes three basic models [7]: multi-layer perceptron model, deep neural network model and recursive neural network model. Its representatives are DBN(Deep Belief Network), CNN(Convolution Neural Networks), RNN(Recurrent Neural Network).

2.1 DBN deep belief network

In 2006, Geoffrey Hinton proposed the deep belief network (DBN) and its efficient learning algorithm, that is, the method of pre-training and fine-tuning in the later stage of training, which largely avoided the gradient disappearance. This result was published in the journal Science and became one of the main methods of the subsequent deep learning algorithm[7]. DBN method is a generation model of coding machine. As a kind of deep confidence neural network, it can realize unsupervised learning and achieve the effect similar to Autoencoder; and it also can realize the supervision study, which plays the role of the classifier. Whether it is unsupervised learning or supervised learning, its essence is a Feature Learning process, that is, by training the weight between its neurons, the whole neural network can achieve better feature expression according to the maximum probability.

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Figure 1. DBN Network Structure Diagram

As shown in figure 1, DBN's network structure diagram is made up of several layers of restricted boltzmann machines (RBM) stacked, in which the hidden layer of RBM in the upper layer becomes the display layer of RBM in the next layer, that is, the output data input of RBM in the upper layer is transmitted to RBM in the next layer. In the process of DBN network's training display, it is necessary to train the RBM of the upper layer sufficiently to train the RBM of the current layer and the RBM of the next layer.

DBN is suitable for pattern recognition scenarios with high dimensional characteristic quantities in the operation and inspection of power transmission and transformation equipment. It can have more variations according to different specific application scenarios, and its component "part" RBM is improved, including convolution DBN(CDBN) and other algorithms combined with application [7]. In literature [8], after the transformer characteristic gas confidence sample set was established, the depth confidence network (DBN) method in the depth neural network was adopted to construct the diagnosis model of the classification depth confidence network, and the fault diagnosis of the transformer was finally achieved online. In literature [9], a circuit breaker fault diagnosis method combined with DBN and Softmax classifier was adopted to extract high-level feature information by using deep confidence network to reduce the data dimension. Finally, the fault classification was classified and evaluated by Softmax. The literature [10] proposes a method for transformer partial discharge pattern recognition based on DBN, and uses the adaptive learning rate to control its ability to search the global optimal solution in the process of model training, achieving higher recognition accuracy and faster algorithm running speed.

2.2 CNN convolutional neural network

Convolutional neural network is one of the most commonly used artificial neural networks to process two-dimensional image information. Its weight sharing network structure is similar to that of human brain optic neural network, which reduces the complexity of two-dimensional input parameters, reduces the number of weights, and improves the training and operation efficiency of the algorithm model. This advantage is most obvious when the input of network is multi-dimensional image, so that the image can be directly used as the input of the network model, avoiding the complex process of feature extraction and data reconstruction that requires subjective manual setting in the traditional recognition algorithm [7].

The remarkable achievements in the field of machine vision make the convolutional neural network the most widely researched and applied deep neural network. In recent years, the relatively famous convolutional neural network models mainly include Lenet network in 1986, Alexnet network in 2012, GoogleNet network in 2014, VGG network in 2014, and Deep Residual Learning network in 2015. The convolutional neural network model technology improved versions, depth of the model, model of organization and the network structure and so on all have certain difference, but the basic computing unit of these models are the same, as shown in figure 2 are basically includes the convolution operation unit layer, pooling computing unit layer, all connected computing unit, etc. [24].

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Figure 2. CNN Network Structure Diagram

CNN is suitable for the application of two-dimensional input parameters such as image and video input in the operation and inspection of power transmission and transformation equipment. As for the CNN algorithm itself, it was originally applied to the classification and prediction of images or video frames. In recent years, researchers have carried out a variety of variations and optimizations on CNN, so that it can be applied to a broader range of power machine vision scenarios such as target recognition and target segmentation. In literature [11], the author adopted the target identification branch of CNN: Faster R-CNN model to identify and detect various fault phenomena of insulators on transmission lines. In literature [12], the author determined and classified the position points of abnormal state of cable equipment by inputting pictures of abnormal cable equipment into the improved YOLO model of CNN.

2.3 RNN recursive neural network

DNN and CNN neural network cannot classify and predict the time series, but the time series is inseparable from the voice and video information closely related to the time axis, and the input timeline and the input information have a complex correlation. In order to meet this demand, RNN cyclic neural network was born. As shown in figure 3, the characteristics of RNN cyclic neural network are closely related to time series. The input layer comes from the hidden layer of the upper element in the sequence, and the signals from the hidden layer interact with the current hidden layer, and then pass to the last layer in turn to classify the time series data and make prediction.





In the operation and inspection of power transmission and transformation equipment in power system, there are a large number of online and offline detection data, including linear data of one dimension and video data of two dimensions. When linear data of one dimension is combined with time series, a corresponding detection curve is formed; when image data of two dimensions are combined with time series, video data is formed. At this time, RNN recursive neural network becomes one of the best choices for processing curves and videos.

In recent years, researchers have also carried out related researches and applications of RNN in the field of power transportation. In literature [13], a picture recognition model is proposed to diagnose the faults of various power transformers. Bat algorithm and cyclic neural network are combined, and the parameters of cyclic neural network are improved by bat algorithm to realize the diagnosis and evaluation of transformer faults. The literature [14] adopted the cyclic neural network prediction model based on the backward propagation algorithm based on the transformer timing sequence signal decomposition, combined with the characteristic parameters of a variety of external factors, to achieve the prediction of electric load. The relevant results show that the prediction addition has a certain degree of improvement compared with the traditional method.

3. Conclusion

The development goal of power system is to build a smart grid. Many aspects of smart operation and inspection in the grid rely on deep learning, and the improvement of reliability, safety and operation capability of power equipment cannot be achieved without the research and reference of intelligent diagnosis algorithm based on deep learning [15-20]. With a large collection of power transmission and transformation operations maintenance data, as a method of artificial intelligence in the system with a typical representative of the data driven, deep learning widely appears in the application of intelligent power transmission and transformation equipment condition assessment scenarios. By independent end-to-end extraction of target features, it can effectively eliminate the background noise to accurately identify and detect the target, greatly reduce the work of delivery inspection personnel in the process of test data analysis, processing and evaluation, and improve work efficiency and accuracy.

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