A Power Operation Site Safety Assistant System Based on Convolutional Neural Network

Yanjie Zhang\textsuperscript{1}, Hongwei Li\textsuperscript{1}, Yunhou Liu\textsuperscript{1}, Yunfei Wang\textsuperscript{1}, Zhiyuan Pan\textsuperscript{1}, Xin Zheng\textsuperscript{1}, Yawei Jiang\textsuperscript{1}, Jing Liu\textsuperscript{1}, Aijing Li\textsuperscript{1}, Hui Jing\textsuperscript{1}

\textsuperscript{1}Electrical Institute, State Grid Technical College, Jinan, Shandong, 250002, China
\textsuperscript{*}Corresponding author’s e-mail: sduzyj@163.com

Abstract. Field operation safety is the key to the safety production of electric power enterprises. The current safety supervision of on-site work mainly relies on the management regulations. In lack of efficient, reliable and intelligent technical means, the management personnel have to supervise and inspect safety procedure on-site. In order to solve the high cost problem of on-site safety management, an intelligent auxiliary system based on deep learning convolutional neural network is proposed in this paper. The system mainly includes three parts: The portable terminal of operation ticket, AI data recorder and neural network calculation unit. It can realize real-time detection of on-site violations during power grid operation. The deep learning AI method is innovatively introduced into the field of safety supervision of power work site, and it provides a new intelligent way of safety supervision.

1. Introduction
The power grid is a dynamic, complex and changeable system. According to statistics, over 90\% of safety liability accidents are caused by illegal operations, among which, 78\% are caused by habitual violations, and almost all of these accidents occur on-site. Although the electric power enterprise has made strict electric power safety production regulations, it is hard for the management personnel to monitor the rules and regulations execution, due to the lack of technical supervision. In recent years, a series of on-site safety accidents have also fully exposed the weak safety management and control in power operations. The AI technology in power system management has been widely studied in power system. It deals with the power stability analysis, fault diagnosis, smart dispatch, renewable energy or load prediction\cite{1}. Much less study of machine vision for on-site personnel management has been conducted\cite{2}-\cite{5}. In order to improve the safety control of on-site production and solve the problem of power enterprise safety production management, the study of advanced artificial intelligence technology on real-time control and evaluation of power operation on-site work is necessary. In this paper, the Artificial Intelligence technology based on deep learning and convolutional neural network is applied to the on-site supervision of substation operation. The AI management technology realizes real-time monitoring of on-site operation process, capable of correcting illegal operation behaviour, eliminating power grid safety risk and equipment hidden trouble, significantly improves the enterprise’s safety control ability on the production site, and is of great significance to the operation safety and personnel.

AI applications in electric power industry process can be divided into two stages: In the first stage, the expert system and artificial neural network (ANN) is applied in power system in various fields, the researchers made development in academic study, but due to the algorithm obstacle and the limitation of the hardware computing performance, there is not much breakthrough. In recent years, with the
rapid development of the third-generation AI algorithm represented by deep learning and the geometric growth of hardware computing performance, the application of AI technology in the power industry has arrived at the second stage. At present, smart power grid construction is faced with the needs of multi-energy integration, multi-network integration and multi-subject integration. In order to ensure a safer and more efficient operation of the power grid and improve the intelligence and flexibility of the smart power grid, ‘AI plus Power Grid’ has become the inevitable trend of smart grid. In use of AI technology and Internet platform, the AI technology can be integrated into power industry, promoting the safe and efficient operation of the power industry. At present, the application of artificial intelligence in power system mainly includes: Energy prediction, system operation optimization and stability control, fault diagnosis, behaviour analysis of power users, power and comprehensive energy market, network security and protection, power field safety protection, etc. Among them, the application of artificial intelligence in the safety protection of power grid on-site operation is still in the initial stage. The researches mainly focus on power equipment states recognition, personnel identification, safety helmet detection, etc[6]. The identification study on personnel operation behaviour has not yet been reported.

2. Technology Principle
In this paper, artificial intelligence technology based on deep learning convolutional neural network is adopted to make analysis and recognition of real-time images in power operation site. It is capable of identifying violation behaviours in the operation quickly and accurately, raising the alarm. The uniqueness of convolutional neural network lies in that the convolutional layer is connected before the input layer of the network, and the convolutional layer filters the image data to activate certain specific structures, so as to achieve the purpose of image classification and recognition. The basic architecture of the convolutional neural network is shown in Fig. 1.

![Fig. 1 Basic architecture of convolutional neural network](image)

The network structure of convolutional neural network can be divided into four parts, and the functions of each layer are as follows:

(1)Input layer: The input layer is used to receive input data. For images, the input data are two-dimensional pixel values.

(2)Convolution layer: It is also called feature extraction layer. It consists of two parts: the first part is the real convolution layer, which is mainly used for feature extraction of input data. The second part is the lower sampling layer, which reduces the processing amount of data on the basis of retaining the characteristic quantity information, thus speeding up the processing speed.

(3)Full connective layer: Commonly, it is the hidden layer part of the multi-layer perceptron. The back layer network nodes and the front layer network nodes are connected, while the same layer network nodes are not connected.

(4)Output layer: the number of output layer nerve nodes is different according to the needs of specific tasks. When performing a classification task, the output layer of the convolutional neural network is equivalent to a classifier.
Convolution operation includes continuous and discrete convolution operations. The calculation of convolutional neural network belongs to discrete convolution, and its calculation formula is as follows:

\[ y(n) = \sum_{-\infty}^{\infty} x(i)h(n-i) = x(n)*h(n) \]  

(1)

The convolution operation is a linear operation, and the corresponding convolution kernel can also be called a filter. The convolution kernel can determine the size of the operation region involved in the image, as well as the recognition ability of the convolution operation. The specific convolution process is shown in Fig. 2. Where f(x) represents the linearization process, bx represents the activation function.

![Convolution Operation](image)

**Fig. 2 Operation principle of convolution**

In the convolution layer, the input image is convolved with a model-trained convolution kernel f(x), and then a bias term bx is added, which is then input into the activation function of the neuron for processing. Finally, the result of the convolution output layer is Cx.

In the convolution layer, the characteristic parameters of the preorder layer are convolved and used as the input of the activation function to obtain the output graph. Each output graph may contain the convolution of multiple input graphs. In general, we have the formula

\[ x^l_j = f \left( \sum_{i=1}^{M_j} x^l_{i-1} * k^l_{ij} + b^l_j \right) \]  

(2)

Where, x represents the j feature graph in the l layer (convolution layer), and f( ) represents an activation function (the sigmoid function, etc). Mj represents a collection of input graphs.

### 3. System composition

The AI auxiliary system is mainly composed of three portable intelligent auxiliary devices, as described in Fig. 3.

1. Portable intelligent handheld terminal. The smart handheld terminal is used to replace the traditional paper operation ticket. The handheld terminal is a tablet of android system, which is characterized by strong open source and low power consumption. It is connected with the cell wirelessly to obtain real-time data of the cell and send real-time motion signals to the cell through the terminal.

2. Portable AI recorder. The AI recorder is used to obtain video images of field operations in real time. It is a front-end device of the intelligent processing unit and is connected with the processing unit through USB. The AI recorder carries out real-time video acquisition of the field work site and sends it to the processing unit. After the recognition and calculation by the processing unit, it is transmitted to the handheld terminal for man-machine interaction.

3. Portable intelligent processing unit. The intelligent processing unit is used for on-site detection and identification. The processing unit is the core of the system, and the image recognition, processing and calculation are completed by the processing unit. It has 256 GPU core with fast calculation speed, can realize real-time recognition of multiple images and video data, with excellent low power consumption, high deep-learning performance, ultra-small and other characteristics. The processing unit is equipped with a matching extension board, which can realize communication among various devices, real-time identification of violation points in the work scene and give out quick alert.
The three portable devices constitute the basic part of the field operation personal safety intelligent auxiliary system. If the system is applied in the substation environment, it can also be connected to the artificial intelligence inspection robot and fixed video recorder, and realize the safety control of field operation in cooperation with the portable intelligent auxiliary equipment.

![Portable AI recorder](image1)
![Portable intelligent handheld terminal](image2)
![Portable intelligent processing unit](image3)

**Fig. 3 Main components of the system**

### 4. System Function

The intelligent safety auxiliary system can effectively identify habitual violations in power operation site. It provides text prompts and voice warnings for the work stuff on site. Meanwhile, it communicates with the SCADA (Supervisory Control and Data Acquisition) system and PMS (Production Management System) system, acquiring the operation ticket sequence from PMS, real-time data through SCADA. The prompt and alarm messages are wirelessly uploaded to the PMS system. The system can also evaluate the field operations of operators and guardians to provide data support for personnel performance appraisal. The main functions of the system include:

1. **Identification of personnel on site.** In the small scattered work sites, the off duty situation or illegal replacement of work stuff occurs by chance. During the switching operation, The AI identification of the designated personnel on the work ticket through the face recognition or fingerprint identification can eliminate such violation phenomenon. Deep ResNet (deep residual model) and Discrete Adaboost algorithm were combined to develop face identification technology to realize the identification of on-site personnel. Compared with traditional face recognition algorithm, the combined method has fast convergence speed, strong classification ability and lower error rate. When the specified face moves within the range of the station surveillance camera, it automatically samples the moving targets. The tracking face capture technology requires the camera to take clear pictures while the blurry ones are omitted. People move dynamically and the major facial features are captured. The sampled faces are compared with the items in the database and the best matching objects are found. The matching sequence is as follows: If the similarity exceeds the specified threshold, the target recognition result is found. If the threshold is below the threshold, keep rematch for 5 seconds. If 10 consecutive frames of data are correctly matched, the identity of the operator is confirmed and the operation ticket sequence is started. If the operation personnel fail to be identified inside 5 seconds, it will give wireless warnings to the PMS.

2. **Detection of person and equipment.** In use of visual sensors and data processing units on the guardian, the AI system can realize automatic detection and identification of field workers, equipment identification cards, safety tools and switching equipment, etc. For the person detection, the tracking method based on TLD (Tracking-Learning-Detection) can adapt to the situation where the pixel in the corresponding region changes dramatically, it can make the moving target speed fast and have good...
results. However, the algorithm consumes a lot of memory space when tracking objects with slow moving speed, such as substation workers. Since the processing burden is heavy, and the effect is slightly different from the actual position. The KCF (Kernelized Correlation Filters) method is chosen for the track as it has a higher accuracy and smaller tracking difference as long as the work act is simple, which is appropriate for the substation switching operation.

3. Detection of personnel violations. The artificial intelligence system can track and detect the behaviours of the operators in real time. Once it finds the violation behaviours such as not wearing the safety helmet, entering the wrong equipment interval, not wearing the insulating gloves for electricity test, and unlocking the equipment without authorization, it will immediately issue an alarm to prevent the occurrence of safety accidents. The adopted deep convolutional neural network is SSD (Single Shot MultiBox Detector) algorithm. It is a typical regression method, capable of giving the target boundary frame and the corresponding category information. The algorithm integrates all operations into one convolution by using the idea of meshing generation in network. The convolution characteristic graphs of multiple scales are previewed to measure and detect objects of different sizes. To a certain extent, it improves the detection accuracy of small objects. It also adopts the Anchor Boxes idea to sample the candidate areas on the feature map of different scales, thus improves the recall rate. In the training experiment, the image annotation set is 8000. 6000 pictures are cited as training set while the 2000 are test set. The mAP (Mean Average Precision) reaches 77.8% and the MTTD (Mean Time to Detection) is 0.132s. The predicted boxes in substation environment are shown in Fig. 4. The detected “sign” is the bay signboard and the detected “pole” is the electroscope. During the verification act of live part, the portable intelligent processing unit will give an alarm immediately if the insulating gloves can’t be detected.

![Fig. 4 Detection of equipment signboard and violations](image)

4. Process control of on-site switching operation. During the operation, the intelligent handheld terminal replaces the traditional paper operation ticket to realize real-time control of the operation process. Through the artificial intelligence identification technology, personnel’s behaviour is regulated during operation procedure. It can prevent the jump and omission of operation items. At the same time, the intelligent handheld terminal reads the remote control signal, telemetry and remote states of switching equipment from substation monitoring system to shape an interlock logic for locking the occurrence of misoperation.

5. Safety evaluation and training analysis. After the operation, the safety assistant system of artificial intelligence makes safety evaluation to the whole process. The evaluation results and illegal records are transferred to the substation O&M center, human resources and safety management department for analysis. Therefore the work problems existing in the field operation management can be deduced through data analysis, as well as the required training proposals.

5. Conclusion
To sum up, modern artificial intelligence technology provides an effective means for security risk control and evaluation. In this paper, on-site safety intelligent auxiliary system of power grid is developed. Based on advanced technology such as large data, portable artificial intelligence, it can
realize real-time on-site personnel monitoring of work process, timely correct violation behaviour, prevent the personal casualty. At the same time, the safety quality and personnel skills can also be evaluated to provide data support for the on-site safety training, safety management and improvement of the safety control in work scene of power grid. It is of great significance to ensure safety of on-site personnel and safe operation of power grid. Relevant technical achievements have broad market development and application prospects.

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