X--Ray Digital Image Advanced Processing and Buffer Layer Defect Intelligent Identification of Power Cable

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Abstract. With the rapid modernization of the city, power cable has been widely used in the process of urban construction. In the course of cable operation, cable faults become more and more frequent, which has a great impact on national economy and people's life. The method of digital X-ray imaging can realize the nondestructive testing of power cable body and obtain clear and intuitive X-ray digital image. But it lacks the advanced processing and defect recognition method of X-ray digital image, and can not directly detect and identify the cable body and defect from the original digital image. Therefore, this paper studies the power cable X-ray digital image advanced processing and buffer layer defect intelligent identification technology. By using gray scale processing technology, the original image gray scale range is compressed to the human eye identifiable range, and then the defect identification is carried out. Then the traditional convolution neural network CNN and the full convolution neural network FCN are used to train the image data to realize the intelligent recognition of the power cable buffer layer defect. The research shows that compared with the traditional convolution neural network CNN, the full convolution neural network FCN proposed in this paper has more clear and intuitive recognition effect.

1. Introduction

Power cable is an important basic power supply equipment for urban development. The running data of the State Grid Corporation of China and the China Southern Power Grid show that in recent years, there have been many cable failures caused by the defects of the water-resistant buffer layer of the cable[1-2].

X--ray digital imaging technology as an effective nondestructive testing method has been widely used in various industries[3-5]. At present, it has been gradually applied to the field of defect detection of power grid equipment[6-7]. Its detection object is generally equipment metal parts. Quality detection of tension-resistant wire clamp pressing of transmission line is a typical application scenarios [8-9] and internal structure detection in GIS substation[10-11]. The tension-resistant wire clamp in "three-span" section of all transmission lines in basic construction stages is sampled according to 10% ratio. The tension-resistant wire clamps in "three-span" section of transmission lines in operation are all general inspected combined with power outages. It plays an important role in the safe operation and maintenance of transmission lines. The enterprise standard of Q/GDW 11793-2017 Technical guideline for radiographic inspection for hydraulic crimping quality fittings in overhead transmission line has been promulgated.
X-ray digital imaging technology is still a new technology in the field of cable defect detection. There is still a lack of research on advanced processing of cable X-ray digital image and intelligent identification of buffer layer defect. Therefore, this paper studies the X-ray digital image advanced processing technology and buffer layer defect intelligent identification technology of power cable, and realizes the X-ray digital image advanced processing and buffer layer defect intelligent identification of power cable.

2. X-ray digital imaging technology

2.1. Basic principles of X-ray digital imaging
X-rays of different energies also have different ability to penetrate the detected material. Both theoretical and experimental studies show that when a narrow beam or a single energy X-ray passes through a uniform layer of matter, the intensity of ray attenuates exponentially, and the incident intensity attenuates with the increase of the thickness of the penetrating object, that is:

\[ I = I_0 e^{-\mu \rho x} \]  

(1)

\( I_0 \) is the intensity of the incident ray beam. \( I \) is the intensity of the post-ray beam of the transmission material. \( x \) is the thickness of the material. \( \mu \) is the line attenuation coefficient (cm\(^{-1}\)) is the unit). \( u \) represents the attenuation index of the X-ray passing through the unit length material in unit time.

![Figure 1. Basic schematic diagram of X-ray digital imaging.](image)

2.2. Application Principle of Cable Detection
X-ray digital imaging technology is based on the different transmission penetration ability of different density materials. Because X-rays vary with the thickness and density of the internal components of the object passed through, the radiation dose after attenuation changes, and the black-and-white contrast on the imaging plate varies, which can distinguish substances of different densities.

Density of each layer and the defect density of the buffer layer of high voltage cable are shown in table 1. The density of the buffer layer defect is quite different from that of the insulation layer and aluminum sheath near the buffer layer. In theory, the density deviation over 1.5% can be distinguished by DR detection technology. Hence, it is feasible to use DR system to detect the buffer layer defects of high voltage cable.

| Each layer structure                          | Density (g/cm\(^3\)) |
|----------------------------------------------|----------------------|
| Copper conductor                             | 8.5-8.9              |
| Conductor shielding layer                    | 1.14                 |
| X-LPE insulation                             | 0.93                 |
| Insulation shielding                         | 1.17                 |
| Semi-conductive buffer water resistance layer| 1.00-1.38            |
| Buffer layer defects                         | 3.50-3.90            |
3. Advanced processing of power cable X-ray digital image

For the image grayscale display system represented by 0~255, the correct recognition rate of human eyes when the grayscale series is 8,16 and 32 is about 93.16%, 68.75% and 45.31%, respectively. Since the gray level series of the DR device reaches 16 bit = 65536 gray scale, and the difference between the defect and the surrounding image is small, the human eye in the original image can not clearly distinguish the defect, as shown in figure 14(a). After image advanced processing, the difference between the defect and the surrounding image is increased by gray scale, which can be clearly identified, as shown in figure 14(b).

4. Intelligent identification of cable buffer layer defects

4.1. Intelligent identification technology

As the number of cable images is increasing, artificial recognition will inevitably consume a lot of energy. In order to deal with the automatic recognition of large-scale images, this paper uses the algorithm model based on deep neural network to identify the X-ray images of cable buffer layer defect. The recognition models are mainly traditional convolution neural network CNN and full convolution neural network FCN. The traditional convolution neural network is used for classification recognition, and the full convolution neural network is used for pixel-level recognition, as shown in figure 3 and figure 4:

The implementation steps are as follows:

Step 1: Mark the original image defects.

Step 2: Because the proportion of defects relative to the resolution of the whole image is very small, the sliding window is used to divide the original image and its labeled image into local images with a resolution of 448*448 at the same time. If the local image includes the labeled elements, the local image is considered as a defective image, marked as a positive example, and conversely, as a counterexample.

Step 3: The deep convolution neural network is used to train the image data.

Step 4: Using F1 score (Coordinated value of recall and precision) and mIoU (Intersection-to-parallel ratio) to evaluate the training effect of the CNN and FCN model, respectively. The training process and results of convolution neural network and full convolution neural network are as follows:

| Wrinkle aluminium sheath | 2.86 |
|--------------------------|------|
| Black flame retardant (PE) | 1.35-1.45 |
4.2. Intelligent identification results
CNN image recognition is carried out in the form of a boX-, in which P represents the probability of identifying defects, the recognition effect is shown in figure 6. FCN image recognition is carried out by piX-el-level red, and the recognition effect is shown in figure 7.

From figure 6 and figure 7, we can see that from the recognition effect, compared with the traditional convolution neural network CNN, it has a more clear and intuitive recognition effect using the full convolution neural network proposed FCN in this paper.
5. Conclusion
X-ray nondestructive testing technology has been widely used in many industries and has a good practical basis. Aiming at the lack of research on X-ray digital image advanced processing and buffer layer defect intelligent identification technology for power cable, this paper uses gray scale processing technology to compress the original image gray scale range to the human eye identifiable range, and then carries on the defect identification. The whole convolution neural network FCN proposed in this paper trains the image data to realize the intelligent recognition of the power cable buffer layer defect.

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