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A Review of Research on Intelligent Recognition Algorithms for Meter Representations

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Abstract

Meters can accurately reflect the operation status of substation electrical equipment, Traditional manual inspection due to the heavy workload and low efficiency, easily causes the meter missed and misread, which is not conducive to the production safety of the substation. In order to intelligently identify the number of meters in a substation, this paper summarizes the existing intelligent identification algorithms for meter counts, explores the application of traditional learning algorithms and deep learning algorithms in the intelligent identification of meter counts, and aims to improve the generalizability and robustness of intelligent algorithms.

Keywords

Meter Reading; Deep Learning; Machine Learning.

1. Introduction

Electricity is a clean and renewable energy source, which can meet the needs of daily material production. The substation is an important hub for power transmission and conversion in the power system, to ensure the stable transmission of power, it is necessary to strengthen the condition monitoring of electrical equipment in the substation. Substation equipment is mainly divided into the primary side of the electrical equipment and the secondary side of the electrical equipment, The primary side of the electrical equipment is mainly responsible for power distribution and transmission, and the secondary side of the electrical equipment is mainly responsible for monitoring a variety of primary side of the electrical equipment operating parameters, the measurement of different operating parameters need to be related to the completion of the measuring instrument, so different types of instruments is an important part of the substation.

2. Analysis of the Current Situation of Substation Instrumentation

Transformers, SF6 circuit breakers, voltage transformers, current transformers, and other electrical equipment are common electrical equipment in substations. The transformer is an important part of power transmission, mainly used for conversion between different voltage levels; SF6 circuit breaker the use of SF6 gas as an arc extinguishing medium of a circuit breaker, according to the operational needs of the necessary electrical equipment and lines for input and removal; voltage and current transformers can be electromagnetic induction principle, the voltage level of the primary side of the electrical energy data is converted to the voltage level of the secondary side of the electrical energy data for measurement and protection. The voltage and current transformer can convert the primary side electric energy data of high voltage level to the secondary side electric energy data of low voltage level through the principle of electromagnetic induction, to measure and protect. To ensure the stable operation of the above equipment and to monitor the operating status of different equipment, it is necessary to take readings from the instruments of different equipment to accurately understand the operating status of the equipment. Classified according to different monitoring equipment, the main instruments can be divided into SF6 gas density relay instrument, arrester leakage current monitoring

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instrument, transformer oil temperature meter, etc. The structure of the instrument is shown in Figure 1. Affected by the environmental factors of the substation, the meters in the substation are mostly pointer-type meters. Compared with digital display-type instruments, pointer-type instruments can still ensure the accurate measurement of the value in rain, snow storms, dusty and large temperature differences, and other complex situations.

(a) SF6 gas density relay instrument

(b) Surge arrester leakage current monitoring instrument

Figure 1. Substation Instrumentation

In the substation, the meter can visualize the status of the electrical equipment in the form of numerical value, therefore, the regular inspection of the meter in the substation has become an important link. At present, the domestic substation is still the traditional type, and for the daily maintenance of substation equipment needs to be specialized personnel to carry out regular inspections. The inspection of instrumentation equipment is mainly manual. The traditional safety inspection is mainly through the naked eye observation and camera shooting of the way to observe the instrumentation, the relevant instrumentation data information through the handwritten record of the way to record the collection.The method is shown in Figure 2. Due to the many meters in the substation, using the traditional way of measuring instrumentation inspection, not only the work intensity but also to familiarize professionals with the surface scale distribution of different types of meters in the substation as well as the reading range; traditional inspection work content is more monotonous and repetitive, the task is more boring. At the same time, the substation is mostly established in the wilderness suburbs, in which the instrumentation is mostly installed outdoors, affected by the distance light intensity, and other factors, there will be subjective decision-making in the instrumentation data recording, which can easily lead to the omission of instrumentation data and misinterpretation. With the rapid development of embedded systems, more and more robots are used in the industrial field, to facilitate the daily inspection of substation instrumentation, The electric power field introduced intelligent inspection robots for substation daily inspection, but by the intelligent reading algorithms and hardware conditions, for the distance is far away, and the light is not sufficient instrumentation, there is no way to carry out accurate information recognition.

The substation is a strong electromagnetic field environment, complex electromagnetic signals will cause digital display instrumentation and sensors and other electronic equipment output signal disorder, thus interfering with the stable operation of the equipment. The use of numerical signals back to the instrumentation, you need to consider the stability of the signal, if the use of data lines for the transmission of numerical signals, Although the accuracy of the monitoring signal can be guaranteed, the existing instrumentation in the substation are mostly old-fashioned pointer-type measuring instruments, do not have the signal transmission function, which requires the shutdown of the substation, the existing substation in the traditional pointer-type instrumentation for the dismantling of the replacement, which will result in significant At the same time, if the wireless signal

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is used to transmit the data signal, the signal will be distorted by the interference of the strong electromagnetic environment in the substation, resulting in data loss. In summary, due to the above objective conditions, it is necessary to regularly inspect the instruments in the substation to record the measurement data and ensure the normal operation of the substation.

Figure 2. Traditional manual inspection

3. Domestic and International Research Status and Development Trend

To accurately read the meters in the substation, experts and scholars at home and abroad have carried out in-depth research on the meter information recognition algorithm, in which the overall process of the algorithm is to first identify and locate the meters in the image, and then crop the recognized meter area; detect the scale and pointer for different meters; and finally combine different image processing algorithms to complete the meter reading, the process is shown in Figure 3. Intelligent information recognition algorithms for meters can be divided into two main categories according to the different realization algorithms, one is based on traditional vision processing algorithms, and the other is based on deep learning vision processing algorithms.

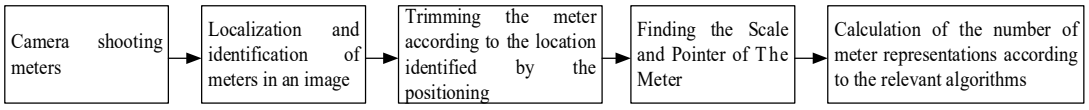

Figure 3. Algorithmic process

3.1 Recognition of Gauge Representations based on Conventional Algorithms

R.Sablatning [1] first used digital image processing techniques for the intelligent identification of the meter's oscilloscope, based on the Hough circle detection algorithm to complete the localization of the meter in the image. Du Jing [2] and others also used the Hough algorithm to localize the meter in the image, and then combined the binarization algorithm with the pointer refinement algorithm to calculate the angle between the zero scale and the pointer, and obtain the meter reading information through the angle transformation formula; Su Lianghe [3] and others improved the Hough algorithm, and proposed the use of homomorphic filtering algorithms to improve the meter localization error due to the uneven illumination; Zeng Lincheng [4] et al. used the mean migration algorithm to first process the image to make the color of the image smoother, then combined with the Hough circle detection algorithm to crop the gauges in the image, and used the adaptive thresholding algorithm to extract the scales and pointers of the gauges. Zhao Lina [5] et al. used a feature matching target detection algorithm based on BRISK ((Binary Robust Invariant Scalable Keypoints, BRISK)) with the K-nearest neighbor algorithm to detect the meter region in the image, and at the same time used the Hough circle detection algorithm to locate the center of the meter's circle, and the traditional scale-invariant feature transformation algorithm (Scale-Invariant Feature Transform, SIFT) and SURF algorithm (Speeded Up Robust Features, SURF) compared to the BRISK algorithm has a high computational speed; Ning Bofeng [6] et al. first used LSD (Line Segment Detector (LSD) algorithm

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to identify the straight line segments in the image within the closed contour region, and then combined with the Hough circle detection algorithm to determine the center of gyration of the pressure gauge for gauge reading; Fang Hua [7] et al. use the SIFT algorithm to match and extract the gauge region in the image, combined with the Fast Hough Transform Detection Algorithm to detect the pointer straight line in the gauge, and then finally use the Angle Transform Algorithm to complete the reading of the pointer gauge. Pointer meter reading; Zhang [8] et al. use the SURF algorithm to extract feature points in the image from the image scale as well as illumination to further determine the location of the meter; Wei Yu [9] et al. use double threshold constraints to improve the Hough transform and improve the algorithm's speed of straight line extraction; He Zhijie [10] et al. use the conditional Hough transform and central projection analysis to achieve the meter Scale fully automatic recognition; Li Zhiwei [11] et al. use the subtraction method to determine the position of the meter in the image, and then combined with the binarization algorithm as well as the Hough transform algorithm to identify the angle of the meter pointer.

The Hough circle detection algorithm can complete the localization of the instrument in the image, but the implementation of the algorithm needs to be pre-set to achieve the appropriate parameters, while the algorithm's spatial and temporal complexity is high, in the positioning of the instrument in the image is susceptible to the influence of the image of other geometric features of the circle. The SIFT algorithm and SURF algorithm are based on the detection and matching of the feature points of the algorithm, the algorithm is susceptible to the influence of the environment, the light intensity the image resolution, and other factors. The algorithms are susceptible to environmental factors and are affected by factors such as light intensity and image resolution, which can produce interference information due to too many feature points, which in turn leads to matching failure. In summary, the use of traditional algorithms for the intelligent recognition of meter representations has poor generalization and robustness.

3.2 Deep Learning Algorithm based Recognition of Instrument Representations

With the significant development of AI technology, artificial intelligence has gradually achieved a wide range of applications in various industrial fields; with the gradual improvement of the performance of graphics cards and other hardware devices, deep learning algorithms have also been further promoted, and more and more target recognition algorithms based on deep learning have been applied in production practice, such as the use of Faster R-CNN [12], RetinaNet [13], FCOS [14], and YOLO v5 [15], etc. At the same time, to more accurately recognize the targets in the image at the pixel level, researchers and scholars have designed deep learning-based semantic segmentation algorithms, among which the classical semantic segmentation algorithms are FCN [16], PSP-Net [17], DeepLab V3 [18], and U-Net [19] neural networks. To improve the accuracy of instrumentation information recognition in substations, more and more researchers and scholars use deep learning algorithms to improve the instrumentation information recognition algorithms.

To accurately locate the meter in the image, Lu Yahan [20] used Faster R-CNN neural network to identify the target of the meter in the image, which greatly improves the problem of the meter localization error brought by the Hough circle detection algorithm as well as the feature point matching algorithm, and then combines the subtraction method with the Hough transform, to identify the pointer based on the color difference, and to obtain the measurement of the meter through the angle transformation algorithm. readings; Kunfu Peng [21] optimized the Faster R-CNN network by adjusting the weight parameters so that the network can locate the gauges in the image more accurately, and based on the Mask R-CNN [22] semantic segmentation network for the localization of dashboard pointers; Zhiqiang Sun [23] designed the dial segmentation link on the basis of the Mask R-CNN in order to filter the interference of the external environment, and at the same time improving the anchor frame ratio of the network model, so that the network can more accurately recognize the location of the meter in the image; Liu Kwai [24] combined traditional algorithms and deep learning algorithms, first used Faster R-CNN neural network to localize the dashboard, and then combined the traditional algorithms of least squares fitting straight line algorithms as well as the angle

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transformation algorithms, to unfold the rounded surface of the meter as a rectangle, and through the calculation of the pointer and scale distance proportional relationship to obtain the final meter reading information; Zengguang Zhang [25] used Faster R-CNN network for meter target identification, then combined with the Hough transform as well as the region growing segmentation algorithm to complete the pointer-type meter reading; Chen Huang [26] improved the backbone feature extraction network of Mask R-CNN neural network through the Resnext-50 [27] network to improve the meter target detection accuracy under the guarantee of the meter target detection accuracy, reduce the computational parameters of the Mask R-CNN network, while using the Hough circle detection algorithm with the improved Canny edge detection algorithm to obtain the center of the meter's circle, and finally use the angle transformation algorithm to obtain the meter readings; Jiang Lifeng [28] improved the algorithm by replacing the residual structure in the original network with the Res2Net [29] structure using the SPP (Spatial Pyramid Pooling, SPP) to solve the problem of fixed size of CNN input image size, which enhances the instrumentation target recognition capability of YOLO v3 [30] network; Tao Jin [31] et al. increased the robustness of the network model by adding residual module to the backbone feature network of YOLO v4-tiny [32] to enhance the network's meter recognition ability, and at the same time, combined with the Hourglass network [33] to extract the scale and pointer keypoints on the surface of the instrument panel, to complete the localization of the pointer of the measuring instrument; Aiping Jin [34] et al. combined the YOLO v5 algorithm with the U-Net algorithm, to complete the localization of the meter as well as the extraction of the pointer contour, respectively; Lei Geng [35] et al. combined a self-encoder with the cavity convolution to construct a cavity fusion module and improve the U-Net neural network, so that the network can accurately segment the dense scale and pointer of the meter; Liqun Hou [36] et al. used the YOLO X [37] neural network to identify and localize the meter panel, then constructed the U-Net neural network based on the ECA attention mechanism [38] to extract the feature points of the meter panel scale and pointer, and finally combined the angular transformation algorithm to accurately recognize the surface indications of the dashboard.

4. Conclusion

Comprehensive research scholars at home and abroad on the existing substation meters indicate the number of intelligent recognition algorithms, although the intelligent algorithms based on deep learning can improve the recognition of the instrumentation target gender universality and robustness. But by the influence of complex environmental factors, there will be interference to the intelligent reading of the instrument number, there is a distance too far and leading to the instrument fuzzy problem, which will not be conducive to the normal recognition of the scale and pointer; at the same time, the intensity of the light will also be on the intelligent reading of the instrument number of interference, because of the low intensity of light caused by the scale and the pointer can not be recognized normally. There are many types of meters in the substation, and it is necessary to optimize the existing algorithms to complete the intelligent reading of different types of meters.

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References

[1] Sablatnig R, Hansen C. Machine vision for automatic calibration of analog display instruments[C]// Machine Vision Applications in Industrial Inspection III. SPIE, 1995, 2423: 356-366.

[2] DU Jing, WEI Honglei, FAN Shuangjiao et al. Automatic Recognition Algorithm of Pointer Pressure Gauge Based on HOUGH Transform[J]. Machine Tool & Hydraulics,2020,48(11):70-75.(In Chinese).

ISSN: 2414-1895 DOI: 10.6919/ICJE.202310_9(10).0018

[3] SU Lianghe, YE Kaiming, TANG Jincheng et al. Research on Identification Techology of Circuit Breaker Pressure Gage Based on Image Processing[J]. Electric Switchgear,2017,55(06):31-33+38.(In Chinese).

[4] Zeng Lingcheng, Li Xinhai, Lin Yuede et al. Research on Reading Recognition Technology of SF6 Short Pointer Meter[J]. Electric Switchgear,2021,59(06):30-34.(In Chinese).

[5] Lina Zhao, Lijuan Zhao, Zida Ning et al. A positioning recognition method for SF6 pressure pointer meter[J/OL]. Electrical Measurement & Instrumentation:1-11[2023-08-30].(In Chinese).

[6] NING Bo-Feng, DONG Zhao-Jie. Study on intelligent reading method of substation SF6 barometer based on image recognition[J]. Automation & Instrumentation,2020(06):48-51+56.(In Chinese).

[7] FANG Hua,MING Zhiqiang,ZHOU Yunfeng et al. Meter Recognition Algorithm for Equipment Inspection Robot[J]. Automation & Instrumentation,2013,28(05):10-14.(In Chinese).

[8] Zhang H, Bai J, Li Z, et al. Scale invariant SURF detector and automatic clustering segmentation for infrared small targets detection[J]. Infrared physics & technology, 2017, 83: 7-16.

[9] WEI Yu, YANG Yaoquan. Automatic detection equipment for index-instrument[J]. Electrical Measurement & Instrumentation,2004(10):30-32+62.(In Chinese).

[10] HE Zhijie, ZHANG Bin, JIN Lianwen. Highly accurate automatic dial recognition[J]. Computer Aided Engineering,2006(03):9-12+18.(In Chinese).

[11] LI Zhiwei,GUO Ge. Study on a new recognition method of pointer meters[J]. Microcomputer Information, 2007(31):113-114+126.(In Chinese).

[12] Ren S, He K, Girshick R, et al. Faster r-cnn: Towards real-time object detection with region proposal networks[J]. Advances in neural information processing systems, 2015, 28.

[13] Lin T Y, Goyal P, Girshick R, et al. Focal loss for dense object detection[C]//Proceedings of the IEEE international conference on computer vision. 2017: 2980-2988.

[14] Tian Z, Shen C, Chen H, et al. Fcos: Fully convolutional one-stage object detection[C]//Proceedings of the IEEE/CVF international conference on computer vision. 2019: 9627-9636.

[15] Zhu X, Lyu S, Wang X, et al. TPH-YOLOv5: Improved YOLOv5 based on transformer prediction head for object detection on drone-captured scenarios[C]//Proceedings of the IEEE/CVF international conference on computer vision. 2021: 2778-2788.

[16] Long J, Shelhamer E, Darrell T. Fully convolutional networks for semantic segmentation[C]//Proceedings of the IEEE conference on computer vision and pattern recognition. 2015: 3431-3440.

[17] Zhao H, Shi J, Qi X, et al. Pyramid scene parsing network[C]//Proceedings of the IEEE conference on computer vision and pattern recognition. 2017: 2881-2890.

[18] Chen L C, Papandreou G, Schroff F, et al. Rethinking atrous convolution for semantic image segmentation[J]. arXiv preprint arXiv:1706.05587, 2017.

[19] Ronneberger O, Fischer P, Brox T. U-net: Convolutional networks for biomedical image segmentation [C]//Medical Image Computing and Computer-Assisted Intervention–MICCAI 2015: 18th International Conference, Munich, Germany, October 5-9, 2015, Proceedings, Part III 18. Springer International Publishing, 2015: 234-241.

[20] Lu Ya Han. Research on substation power meter detection and reading recognition algorithm [D]. Nanjing University of Science &Technology, 2019.(In Chinese).

[21] Kunfu Peng. Research on Pointer Meter ReadingRecognition Method based on Deep Learning[D]. University of Science and Technology of China, 2020.(In Chinese).

[22] He K, Gkioxari G, Dollár P, et al. Mask r-cnn[C]//Proceedings of the IEEE international conference on computer vision. 2017: 2961-2969.

[23] Sun Zhiqiang. Research and realization of automatic identification of pointer meter reading based on machine vision[D]. Qufu Normal University, 2021.(In Chinese).

[24] Liu Kwai. Recognition of the Analog Display Instrument Based on Deep Learning[D]. Huazhong University of Science and Technology, 2017.(In Chinese).

[25] Zengguang Zhang. Research on the Method of Pointer InstrumentReading Recognition Based on Deep Learning[D]. Harbin Engineering University, 2020.(In Chinese).

[26] Huang Chen. Research on Information RecognitionMethod of Substation Instrumentation based on Machine Vision[D]. Changchun University of Technology, 2022.(In Chinese).

ISSN: 2414-1895 DOI: 10.6919/ICJE.202310_9(10).0018

[27] Xie S, Girshick R, Dollár P, et al. Aggregated residual transformations for deep neural networks[C]// Proceedings of the IEEE conference on computer vision and pattern recognition. 2017: 1492-1500.

[28] Jiang Lifeng. Research on Automatic ReadingTechnology of Substation PointerInstrument Data Based on Deep Learning[D]. Tianjin University of Technology, 2022.(In Chinese).

[29] Gao S H, Cheng M M, Zhao K, et al. Res2net: A new multi-scale backbone architecture[J]. IEEE transactions on pattern analysis and machine intelligence, 2019, 43(2): 652-662.

[30] Redmon J, Farhadi A. Yolov3: An incremental improvement[J]. arXiv preprint arXiv:1804.02767, 2018.

[31] TAO Jin,LIN Wenwei,ZENG Liang et al. Pointer meter reading recognition based on YOLOv4-tiny and Hourglass[J]. Journal of Electronic Measurement and Instrumentation,2023,37(05):1-10.(In Chinese).

[32] Bochkovskiy A, Wang C Y, Liao H Y M. Yolov4: Optimal speed and accuracy of object detection[J]. arXiv preprint arXiv:2004.10934, 2020.

[33] Newell A, Yang K, Deng J. Stacked hourglass networks for human pose estimation[C]//Computer Vision–ECCV 2016: 14th European Conference, Amsterdam, The Netherlands, October 11-14, 2016, Proceedings, Part VIII 14. Springer International Publishing, 2016: 483-499.

[34] JIN Aiping,YUAN Liang,ZHOU Deqin et al. ldentification Method for Reading of Pointer Instruments Based on YOLOv5 and U-net[J]. Instrument Technique and Sensor,2022(11):29-33.(In Chinese).

[35] Geng Lei, Shi Ruizi, Liu Yanbei et al. Instrument image segmentation method based on UNet with multi-scale receptive field[J]. Computer Engineering and Design,2022,43(03):771-777.(In Chinese).

[36] Hou L, Wang S, Sun X, et al. A pointer meter reading recognition method based on YOLOX and semantic segmentation technology[J]. Measurement, 2023, 218: 113241.

[37] Ge Z, Liu S, Wang F, et al. Yolox: Exceeding yolo series in 2021[J]. arXiv preprint arXiv:2107.08430, 2021.

[38] Wang Q, Wu B, Zhu P, et al. ECA-Net: Efficient channel attention for deep convolutional neural networks[C]//Proceedings of the IEEE/CVF conference on computer vision and pattern recognition. 2020: 11534-11542.