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Design of Wind Turbine Blade Icing Detection System based on Deep Learning

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Abstract

As the goal of carbon neutrality is proposed, new energy power generation represented by wind power is ushering in rapid growth. China's wind power is mainly distributed in the Three North regions, which have long winters. In cold weather conditions, wind turbine blades may freeze, which not only affects the efficiency of wind power generation, but may also cause shutdowns in severe cases and induce safety accidents. Traditional deicing methods are mostly manual deicing, which not only cannot achieve real-time monitoring, but also requires shutdown during deicing, which reduces the time and efficiency of wind turbine power generation. Based on this background, this project has designed an automatic deicing and defrosting system for wind turbine blades based on image recognition and solar energy utilization, aiming to realize real-time monitoring of blade icing status and fully intelligent zone deicing.

Keywords

Wind Power; Automatic Deicing and Defrosting; Solar Energy.

1. Introduction

Wind is a renewable, non-polluting and huge reserves of energy. Since 2012, China's developed wind energy has been the world's first for many years[1]. As people's requirements for the ecological environment and energy demand continue to increase, all countries are stepping up the development and utilization of wind energy. The use of wind energy is to convert the kinetic energy of the wind into mechanical energy and then into other forms of energy. The kinetic energy of the wind is converted into mechanical energy through the wind turbine, and then the generator is driven to generate electricity, which is converted into electrical energy. However, the surface integrity of the wind turbine blade has a great impact on the efficiency of wind energy utilization[2]. The icing generated on the wind turbine in the cold season will greatly reduce the aerodynamic characteristics of the wind turbine blade, thereby leading to a reduction in the output power of the wind turbine. In addition, the imbalance of the wind turbine blades due to the formation of ice will increase the load on the main components of the wind turbine, thereby reducing the service life of the wind turbine; at the same time, the load generated by the icing will also increase the stress of the tower and cause structural damage[3].

Deicing of wind turbine blades becomes the key. At present, the deicing of wind turbines is mainly divided into active deicing and passive deicing[4]. Traditional deicing methods are mostly manual deicing, which is inefficient and cannot be deiced in real time. In addition, wind turbines need to be shut down during deicing, which reduces power generation time. How to perform real-time deicing, minimize downtime and increase power generation time is the key to the icing problem of wind

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turbines. Based on this background, this paper designs an automatic deicing and defrosting system for wind turbine blades based on image recognition and solar energy utilization.

2. Wind Turbine Physical Platform Construction

First, the model of the large-scale power generation wind turbine was reduced and modeled, and the three-dimensional modeling diagram as shown in the figure was obtained. The model contains a solar panel module, which is used for the auxiliary power supply of the wind turbine; a controller module, which is used to receive the results of image recognition; a camera module, which is used to capture the ice coating on the blade surface; and it also contains three blades. We built the physical object based on the 3D modeling. The wind turbine model made of lightweight materials has the advantages of light weight and strong stability. It can work normally in a wide temperature range of -40°C to 80°C, and the body will not be deformed. The double-bearing fan rotor can keep the wind turbine stable during operation and avoid jitter. The material of the blade is high-strength resin, and the material of the generator casing is die-cast aluminum. The pole height of the wind turbine model is 1.2 meters, and the blade radius is 0.6 meters.

Fig. 1 Wind turbine 3D model and physical construction

In order to achieve regional monitoring and control, we divide the blade surface into seven regions. Experience has shown that icing at the tip of the blade is often not obvious, and near the hub, icing begins to become serious. Accordingly, there are relatively fewer heating fins laid at the tip of the blade. The blade partition is shown in Fig. 2.

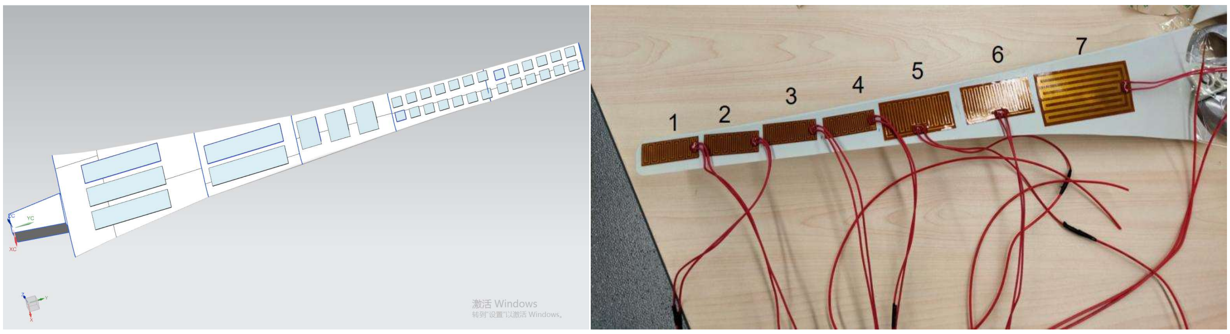

Fig. 2 Partition modeling and physical layout of blades

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3. Image Recognition Platform Construction and Testing

3.1 Traditional Image Recognition

The accuracy and efficiency of deicing depends on the accuracy and accuracy of image recognition. This section first uses the traditional Canny algorithm to try. Canny has a good recognition effect in object edge detection and other aspects, so it is widely used in traditional image recognition. Fig. 3 shows that the Canny algorithm has a good edge detection effect on black objects and can accurately determine the location of foreign objects, but it has a poor recognition effect on transparent acrylic panels, and it can hardly capture the outline of transparent acrylic panels.

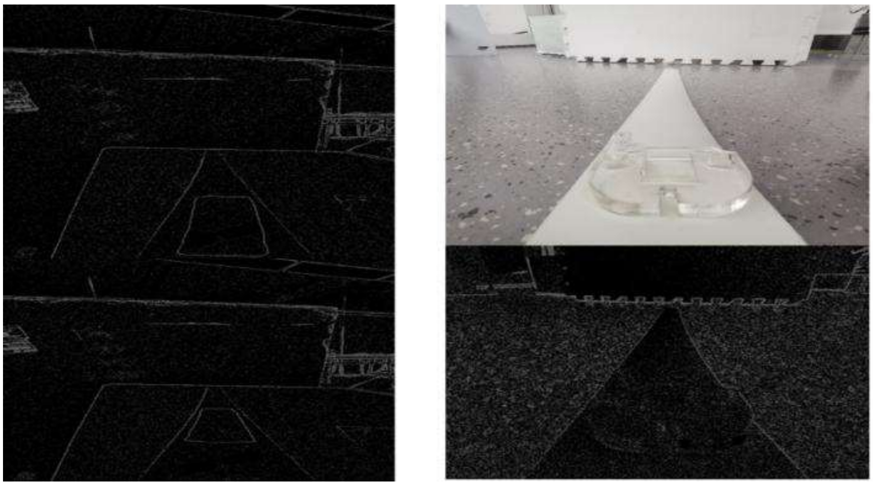

Fig. 3 Traditional Canny algorithm recognition effect

By improving the Canny algorithm and comparing different traditional algorithms, the results shown in the table are obtained. In the table, A represents the total number of pixels detected by the algorithm, B represents the 4-connected number detected by the algorithm, and C represents the 8-connected number detected by the algorithm. The smaller the C/A, the better the continuity of the image edge, the smaller the C/B, the better the single-edge response. The results show that the improved algorithm is better than the traditional Canny algorithm and other algorithms in extracting edge connectivity and single-edge response, but there are still problems in the accuracy of identifying transparent or translucent objects such as ice, especially the thickness.

Table 1. Statistical results of edge detection of different algorithms

Algorithm	**edge detection C/A**	**edge detection C/B**
Canny	0.2153	0.4834
Sobel	0.1847	0.3608
Roberts	0.2894	0.5266
Modified Canny	0.1143	0.2367

3.2 Deep Learning Image Recognition

Convolutional neural networks have incomparable advantages over traditional image recognition. The average accuracy of deep learning algorithms based on convolutional neural networks in millions of imageNets is above 80%, and the accuracy of small-scale image recognition is almost Close to 100%. Since the acrylic board in this project is a small transparent object, SSD algorithm and YOLO

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V4 are generally used for small target detection. Through actual detection, the SSD cannot capture and identify the acrylic board far away from the blade hub, and the response speed cannot reach the standard of real-time detection of the video stream. Therefore, we use the YOLO V4 algorithm.

Use the built potorch deep learning platform to train our processed data set. The network structure of yolo V4 includes BackBone (CSPDarknet53) and Neck (SPP+PAN) backbone to extract image features, and neck to fuse feature information of feature maps of different sizes.

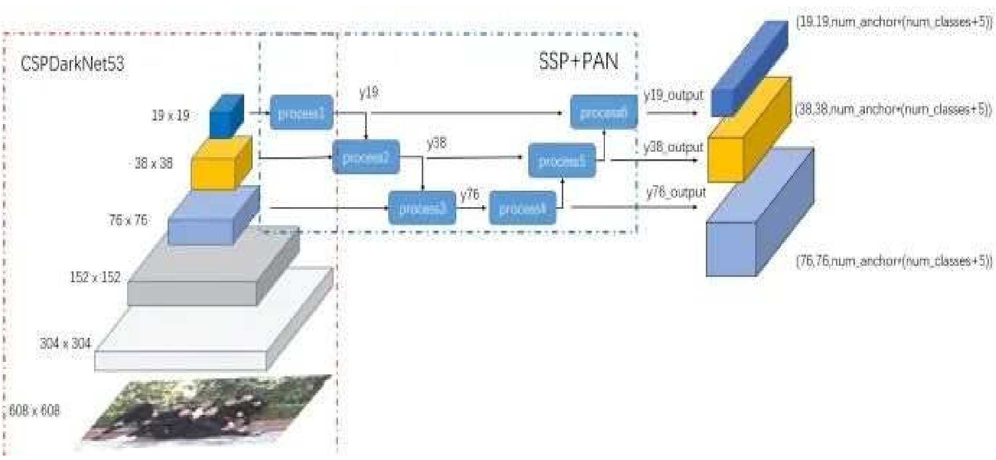

Fig. 4 The network structure of yolo V4

First, collect the image library. Use glass sheets of different thicknesses to be placed at different positions of the blade to collect images. There are images of a single ice cube, as well as images of multiple ice cubes, with a total of more than 150 images. The data is marked with the partition where the ice cubes are located.

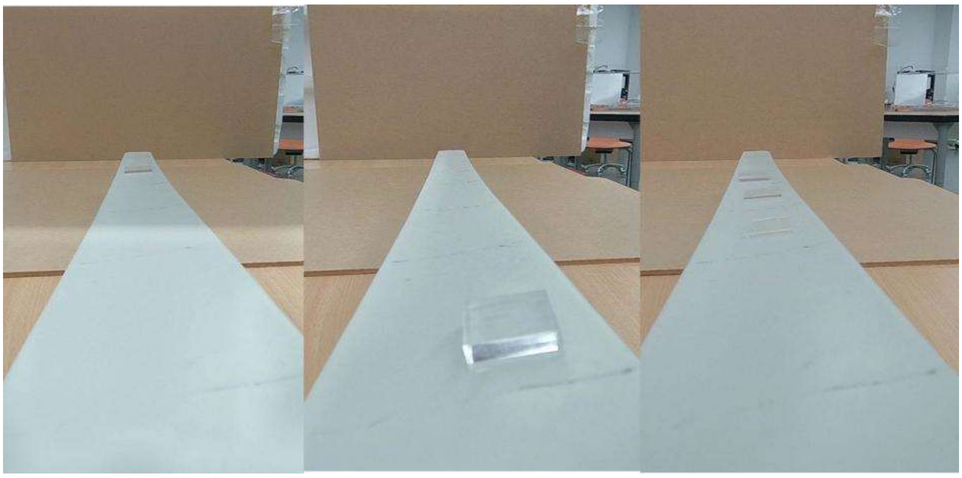

Fig. 5 Image acquisition and annotation

Since the accuracy of deep learning largely depends on the data set, it is necessary to expand the data set to expand the training samples to improve the accuracy of network recognition. We transform thousands of collected photos (horizontal flip, vertical flip, mirror symmetry, affine change, rotation, Gaussian noise, contrast change, scale change, and translation), and the image size is from 2G to 30G. Use the built-up deep learning platform for data set training, and use one part as the test set and the other part as the verification set. After cross-validation, the final algorithm accuracy rate is 88%.

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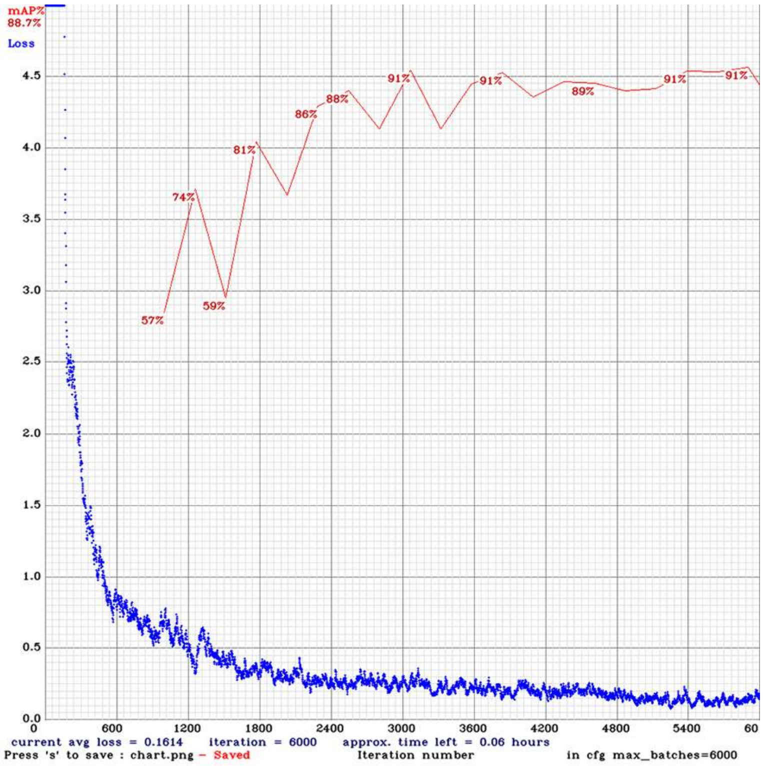

Fig. 6 Convergence curve of loss function

After training, repeated experiments are performed on multiple sets of targets, and ultimately all have a higher accuracy. Of course, at the boundary of two areas, or when there are multiple ice-coated areas at the same time, the accuracy of the system will be reduced.

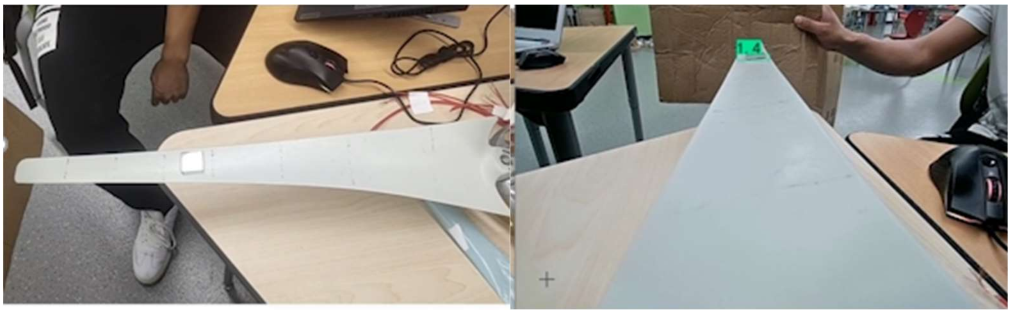

Fig. 7 Real-time partition detection of video stream

In order to ensure that the icing of the blades can be detected at any time during the operation of the wind turbine. Completed the real-time partition detection of the video stream, as shown in Fig. 7. It can be seen that the acrylic board is located in area 4 at this time, and the displayed recognition result is also 4, and the recognition accuracy is higher.

4. Conclusion

This paper first completed the modeling of the wind turbine platform. The camera was placed at the hub position, and the control plate was embedded in the hub. Then the effect of the traditional image recognition algorithm was tested, and finally based on the deep learning platform, the real-time monitoring of the icing of the blades was completed. The monitoring results show that image recognition can reduce downtime and increase wind turbine power generation time and power generation efficiency compared to traditional manual deicing and ultrasonic deicing. Compared with

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the traditional deicing method, the deicing method based on image recognition provides a new approach, which has certain reference value for the icing problem of wind turbines in the industry.

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