Corrosion Detection for Large Steel Structure base on UAV Integrated with Image Processing System

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Abstract. Large cranes and other outdoor large steel structures need to be checked regularly to ensure their safety, and corrosion detection is one of the most important inspection item. Traditional manual inspection has many disadvantages including high labour intensity, low efficiency and low detection accuracy. In this paper, a novel corrosion detection method based on UAV intelligent image recognition is proposed. The six-rotor UAV can collect the photos of the steel structure device safely and reliably. With the intelligent corrosion recognition algorithm proposed in this paper, infection such as background noise can be eliminated, and the corrosion area in the image can be identified automatically with high precision. A test device has been built and the results show that the device and method can identify the corrosion area effectively.

1. Introduction
Crane implemented in ports and other places are always exposed in salty sea wind environment and working with heavy loads. Their metal materials are easily to be corroded, and cracks are generated. This may bring big risks to lifting operation, and also very harmful for the on-site working staff and the mission loads. Detecting the corrosion and cracks situation is one of the most important routine work for safety production.

In the traditional detection method, engineers should climb up to the cranes and check if there is any unaccepted corrosion or cracks. Auxiliary detection equipment is always needed for the large steel structure, which makes the detection process complicated, time consuming, difficult and often dangerous for the engineers. Also, there are always many hard-to-reach positions with limited manual detection and make the detection less effective. A new detection method with UAV(unmanned aerial vehicle) comes into use recently, with many advantages including higher efficiency, safer for inspectors and higher accuracy [1-4].

In 2016, an UAV was used in a crane structural detection [5], during the 20-minute flight, multiple sets of high-altitude pictures were shot by a CCD camera, then these pictures are transferred to the ground station and post-processing were performed. Since there was no ultrasonic ranging module in this detection platform, and it is difficult to quantify the defects in the post-processing. In 2017, another UAV was used in the disposal of special equipment and hazardous chemicals [6]. The aerial photography and infrared imaging technologies were used to test and evaluate the safety status of equipment. Also, UAVs were used to inspect large-scale playground facilities and other equipment to detect high-altitude corners that cannot be reached by inspectors [7-14].
Although the UAV detection method mentioned above improves safety and reduces labor intensity compared with manual detection method, there are also some problems to be solved. The UAV is only used to take pictures during the detection process, and the actual corrosion check is mainly finished by the experienced engineers after the detection. The results cannot be achieved in the real-time way, and some corrosion areas needs to be confirmed repeatedly, therefore, experienced engineers are still needed.

In this paper, an automatic corrosion detection device based on real-time image processing technology of UAV is designed, with the corrosion image real-time processing technology, the labor intensity of corrosion detection can be further reduced, the accuracy and effectiveness of detection can be improved.

2. Structure of the corrosion detection system
The structure of the corrosion detection system is shown in Figure 1, which is mainly composed of a six-axis UAV platform, image sensor modules and a ground station.

(1) six-axis UAV platform
According to the requirement of special equipment inspection, the UAV intelligent detection system has been improved. The platform is designed with the features of intelligent obstacle avoidance, positioning, stable hover and other flight characteristics when used in the unstructured special equipment detection environment. The multi-axis UAV can take off and land vertically at any place, and has low requirements on the working place, also, its simple mechanical structure is easy to maintain. Therefore, a six-axis UAV is used in the platform, some technical data is shown in Table 1.

By carrying a variety of sensor modules such as visual sensing, ultrasonic sensing and laser sensing, the platform is based on the multi-sensor information fusion system. The corresponding rules are designed and the information obtained by sensors is complemented and processed to improve the intelligence of the whole system.
Table 1 Technical data of the six-axis UAV platform

| Item                                | Value |
|-------------------------------------|-------|
| Flight mass/kg                      | 8.5   |
| Wheelbase/mm                        | 800   |
| Duration of flight/min              | 20    |
| Classification of wind resistance   | 5     |
| Blade diameter/cm                   | 15    |

(2) Image sensor modules

The UAV cradle system is equipped with a high-definition CCD camera and an infrared video camera, some technical data is shown in Table 2. The focal length is adjustable and high-definition image data can be accessed instantly in the stable flight. Also, a machine vision processing unit is embedded in this system. the potential structural failure of steel structure can be suspected and recorded, and this information can be shown on the station system. After analyzing of image data, it is convenient for the inspectors to locate structural defects and analyze the fatigue and powerful connection parts effectively, making the evaluation and testing more intuitive and clear.

Table 2 Technical data of the CCD camera

| Item                                | Value                          |
|-------------------------------------|--------------------------------|
| Size/mm                             | 105*95*98                      |
| Working temperature/℃               | -10～50                         |
| Pitch control Angle/°               | ±90, accuracy±0.02             |
| Roll control Angle/°                | ±45, accuracy±0.02             |
| Pointing control Angle/°            | ±150, accuracy±0.03            |
| Mass/g                              | 400                            |
| Optical zoom/mm                     | F4.9～49 (10X zoom)             |

(3) Ground station and remote control

A ground monitoring and controlling platform system is designed to enable the UAV platform system communication. During the flight period, the flight status data including GPS position, flight direction, the battery level, can be transmitted in a real-time and reliable way. The station can display a variety of flight data, capture the image data and process these data. The data processing system can analyze and process a large number of image point cloud data. The suspicious structural defects can be identified and reported early.

3. Automatic corrosion detection algorithm

(1) Conventional image processing methods

Using conventional image processing methods, it is possible to obtain acceptable detection results on pictures with strong contrast between background and corrosion. However, from the HSV color space shown in Figure 2, the contrast between the background of the object and the corrosion color is not obvious. At the same time, some photos are affected by the sunlight, which leads to unsatisfied results when using this conventional processing method, as shown in Figure 3.
A new image processing method based on deep learning theory is proposed for the corrosion area detection. This framework can be built in an efficient C++ language with built-in Python and MATLAB interfaces. It has been widely used in a range of applications in video or image processing.

The target detection neural network uses Faster RCNN, which is based on R-CNN and was first proposed in 2015. The innovation is the network integrated with feature extraction, candidate frame selection, border regression and classification. In order to obtain a better result, VGG16 model is designed, as shown in Figure 4. The detection accuracy and detection efficiency can be effectively improved with this network. Therefore, this method is improved and applied in the image processing for corrosion detection.

**Figure 4.** The designed VGG16 model

4. Experimental result and analysis

1. Experimental setup and data preparation

Since a lot of images are needed for the neural network training, a long-time data collection should be conducted firstly. With the UAV platform as mentioned above, more than 100 pictures were captured during a one-hour flight around a frame crane. On these pictures, a lot of dust areas can be seen. Also, the distance information was obtained by the radar sensor when taking the pictures.

After kicking off some repeated pictures and unaccepted pictures, 63 pictures were chosen as the train objects.

2. Neural network training

With the help of the Labellimg-master® software, the corrosion area data was scaled as shown in Figure 5. Both the corrosion area and its location information were extracted for every picture. After this treatment, different small corrosion area pictures are generated as shown in Figure 6.
Figure 5. Data scaling

Figure 6. small corrosion area and its location xml-format files

Then with these small corrosion area pictures and xml-format files, an auto neural network training process was carried out. In order to get a better and fast result, a pre-training model was loaded, some of the training parameters were configured as shown in Figure 7.

Figure 7. Training parameters configuration

(3) Results and analysis

After using some pictures and more 20k training cycles. The learning results can be verified with the rest pictures which have not been used for training. The corrosion area can be marked with red box and labelled automatically, the “corrosion” indicates the corrosion area and the number means the probabilities.

From the picture shown in Figure 8, most corrosion areas are marked and labelled correctly, almost no omission or wrong marking. Therefore, this corrosion detection method can be proved to be effective and can be used in a real-time mode.

Figure 8. Corrosion detection experimental results

5. Conclusion

In this paper, a novel corrosion detection method based on UAV intelligent image recognition is proposed. Firstly, a corrosion detection system is designed, which is mainly composed of a six-axis UAV platform, image sensor modules and a ground station. The experiment has proved that this
system is very solid and reliable for taking clear pictures and collecting other information of the large steel structure. Then, a new image processing method based on deep learning theory is proposed for the corrosion area detection. With this method, the experimental results show that the detection accuracy and detection efficiency can be effectively improved after the deep neural network training. Finally, since this method can be programmed and applied in the ground station, the corrosion detection process can be carried out automatically, which will be a great progress for intelligent detection.

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