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Research on Identification System of Aero Engine Blade

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Abstract

This paper mainly focuses on the recognition of engraved code information, including three steps: character image acquisition, character image preprocessing and character recognition. To carry out the research of blade identity information integration technology, and realize the end-to-end identification of blade identity information.

Keywords: recognition of blade code information, aero engine blade, identity information, character, image

1. The Introduction

In aero-engine, blade is one of the most critical components, and the identification efficiency of blade identity information will directly affect the overall processing efficiency. In addition, the blade is the largest number of parts in an aeroengine. Take a turbofan engine of a certain type as an example, the compressor part has 12-13 stages, and there are more than 1000 blades in total. The turbine part has 5-6 stages, with a total of about 600 blades. It can be seen that the identification task of blade identity information is heavy.

At present, blade serial number and blade information are manually recorded in the measurement scale and manually entered into the system. In order to improve efficiency and avoid manual errors, this paper mainly focuses on the identification of blade coding information, including three steps of character image acquisition, character image preprocessing and character recognition, and carries out research on the integration technology of blade identity information to realize the end-to-end identification of blade identity information. This is illustrated in Figures 1 and 2.

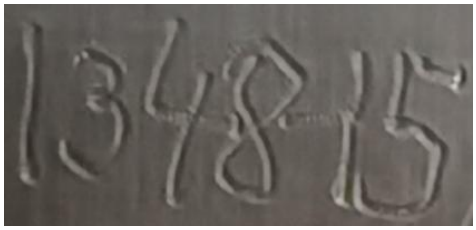

Figure 1. Example 1 of blade code information

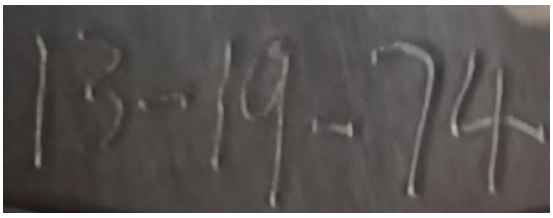

Figure 2. Example 2 of blade code information

The blade coding information has the following characteristics, which makes the image recognition based on traditional methods unable to meet the actual production needs:

(1) Handwritten character forms are complex and diverse, and there is no unified mode. Therefore, pattern recognition methods based on traditional artificial feature extraction can not effectively adapt to a variety of blade identity information.

(2) The scale of handwritten blade identity information changes greatly, and the aspect ratio changes sharply. Therefore, the image analysis and processing methods in general detection methods can not adapt well to analyze the size of the region, so they can not effectively detect the defects of different scales and aspect ratios.

(3) The image of blade identity information is affected by blade material and imaging, and there is a lot of noise interference, and the detection based on visual method is susceptible to dust/light/poor imaging and other problems. Therefore, the existing character methods based on feature or template can not effectively avoid the influence of noise, which is easy to cause false recognition.

Because compared with traditional recognition methods based on statistical or structural features, convolutional neural networks can automatically extract effective abstract features and use them for recognition only by constantly training and optimizing the parameters of the model. Therefore, this research combines the excellent convolutional neural network model to study the recognition of handwritten characters on the mixed data sets of numbers and uppercase and lowercase letters, in order to promote the development of blade identity information recognition.

2. Research on High Resolution Image Acquisition Technology

This topic aims to study the identification technology of blade identity information. Based on this, the first thing to do is to collect and obtain the character image containing blade identity information for the subsequent training of network recognition. The character image acquisition device adopted is shown in Figure 3. A robot manipulator carries specific tooling after scraping blade under test, moving to the front of the industrial camera image acquisition device for high resolution image acquisition. Among them, the image acquisition device is composed of industrial camera, lens and light source, using treated measuring vane is lighting light source to improve the target brightness and to distinguish the background and overcome the interference of ambient light. The lens is used in conjunction with the industrial camera to image the measured blade. Mercury MER series industrial digital camera produced by Dahang Image Company will be selected as the industrial camera. This type of camera adopts Sony IMX252 CMOS sensor with global exposure. Its resolution is 2048×1536, the pixel size is 3.45μm×3.45μm, and the frame rate is 125fps. Standard C interface. Image data is transmitted through USB3.0 data interface, and optical signals are transformed into ordered electrical signals. In order to cooperate with the use of this type of industrial camera, the ML-ST series industrial telecentric lens from MORITEX Company of Japan is planned to be selected. This type of lens has the characteristics of high contrast, high resolution and low distortion, and has a high level of optical recognition ability. Its resolution is 11.2μm, magnification is 3×, and working distance is 108.3mm. The depth of field is 0.44mm. The illumination source is MCEP white LED point light source with a power of 3.0W, which can be directly installed on the lens through the light source interface on the telecentric lens, so as to achieve uniform coaxial falling illumination, which makes the character image obtained with better quality and facilitates subsequent image processing.

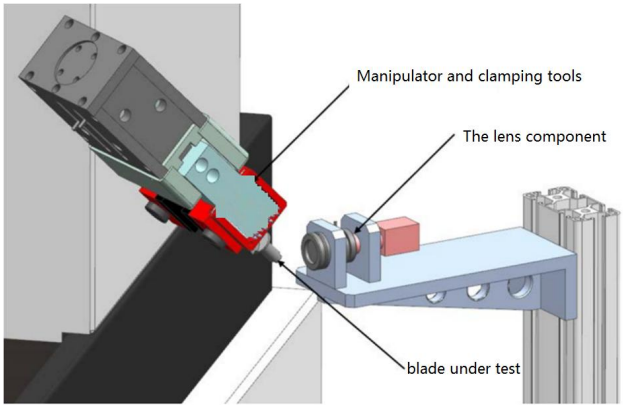

Figure 3. Image acquisition device

3. Character Image Processing Technology Research

The research of character image processing technology is the key link to improve image quality. A good preprocessing algorithm can significantly improve the clarity and discrimination of the image, and bring great convenience to the image location determination and extraction of the identity information of the rear blade. This topic intends to use image processing technology to filter, enhance, thresholding, edge detection, morphological operation and other processing on the original image of blade identity information, so as to obtain the image features of blade identity information. The effect of image and processing process is shown in the figure 4. For the acquired original image, adopt the method of gaussian filtering noise reduction processing in the first place, to remove the interference of the image information. Then, the edge extraction operation is carried out on the denoised image to obtain the specific position of the target character and the edge contour needed in the image. Finally using morphological operations such as corrosion, expansion highlights the image detail characteristics of the target character. It is convenient for the subsequent research of recognition technology.

A. Original image B. Gaussian filtering C. Edge extraction D. Morphological operations

Figure 4. Image preprocessing

3.1 Image Binarization

The purpose of image binarization is to simplify the information of the image, which is represented by two-pixel values of light and dark, which is conducive to the segmentation of the foreground and background area, and is also convenient for algorithm processing and design. To put it simply, the binarization process of an image is to set an appropriate threshold to determine each pixel on the image and classify it as the foreground or background region. Assuming that (x, y) represents a pixel on image F (x, y), the gray value of pixel F (x, y) of point (x, y) is compared with the threshold T. If it is greater than the threshold, it is considered to belong to the detected object; otherwise, it is considered to belong to the background area. The corresponding formula is as follows:

$$g(x,y)=\begin{cases}1 & f(x,y)\geq T\\ 0 & f(x,y)<T\end{cases}$$

3.2 Gaussian Filtering

In the process of target image acquisition of leaf identity information, noise will inevitably interfere with the acquired image, resulting in noise pollution, which will affect the subsequent target image feature extraction and recognition operations. So as to contains blade identity information of character image preprocessing technology research, the key step is to filter the noise reduction. Traditional image denoising methods include mean filtering, median filtering and Gaussian filtering. According to the size of the filter used, the mean filter denoising method takes the target pixel as the center and replaces the pixel value of the target pixel with the average value of the pixel in the neighborhood of the filter size. The median filter denoising algorithm is similar to the mean filter.

According to the size of the filter, the median value of the pixel in the neighborhood of the filter size is taken to replace the pixel value of the target pixel. Gaussian filtering is a linear filtering algorithm, which mainly uses the distribution of two-dimensional Gaussian function to smooth the image and achieve the purpose of noise reduction. Among these traditional filtering methods, median filtering can effectively remove salt and pepper noise in the image, but the filtering effect of Gaussian noise is not very good. Average filtering method and gauss filter method to gaussian noise of the noise reduction result is better, but the average filtering method after noise reduction, image resolution loss is bigger. In the process of filtering, the larger the filter, the more blurred the image will be. Gaussian filtering can effectively remove the Gaussian noise in the image, and effectively maintain the clarity of the image with less loss of details.

Most of the image noise is Gaussian noise, so Gaussian filter is usually used to denoise the image. Gaussian filter is a linear smoothing filter, which is suitable for eliminating Gaussian noise and is widely used in image denoising. The algorithm mainly uses the distribution of two-dimensional Gaussian function to smooth the image, takes the value of a pixel as the core, uses the convolution check to carry out the weighted average of the surrounding neighborhood pixels, and the obtained value is used as the new value of the current pixel. Finally, the weighted average processing of the whole image pixel value is realized.

In the actual process of Gaussian filter denoising, if the two-dimensional Gaussian distribution used is among, is the point coordinate, which can be considered as an integer in the image processing process, and is the standard deviation. Then the corresponding Gaussian function image distribution is shown as follows in the figure 5. It can be seen that the position close to the origin has a higher terrain, and the farther from the origin, the lower the terrain. That is, the template coefficient of the Gaussian filter decreases with the increase of the distance from the template center, so that the image after the Gaussian filter processing is less blurred.

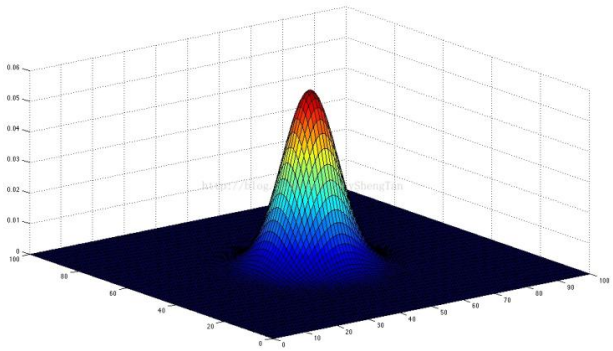

Figure 5. Two-dimensional Gaussian filter

If a 3×3 Gaussian filter template is to be generated, and the central position of the template is taken as the coordinate origin to sample the image pixel value, the coordinates of the template at each position are shown in the figure 6. The X-axis is horizontally to the right, and the Y-axis is vertically down. The coordinate values of each position are put into the Gaussian function for calculation, and the obtained value is the coefficient of the corresponding template.

(-1,1)	(0,1)	(1,1)
(-1,0)	(0,0)	(1,0)
(-1,-1)	(0,-1)	(1,-1)

Figure 6. Example of Gaussian filter

Then, the corresponding template is used to scan each pixel in the image, and the weighted average gray value of the pixels in the neighborhood determined by the template is used to replace the value of the center pixel of the template, so as to realize the Gaussian filter denoising processing of the image.

In the process of noise reduction of Gaussian filter, the most critical is the adjustment and selection of standard deviation in Gaussian filter, which has a great effect and influence on the smoothing ability of Gaussian filter. The larger is, the wider the frequency band of the Gaussian filter will be, and the better the image smoothing effect will be. Finally, by adjusting the standard deviation parameter, Finally, by adjusting the standard deviation parameter, it can effectively balance the suppression of image noise and the degree of blur after image processing, and obtain the better solution after filtering and noise reduction.

3.3 Edge Extraction

Edge detection is a multi-stage algorithm, as shown in the schematic diagram of the algorithm process, it is shown in the figure 7, which mainly includes four steps: image noise reduction, image gradient calculation, non-maximum value suppression and threshold screening.

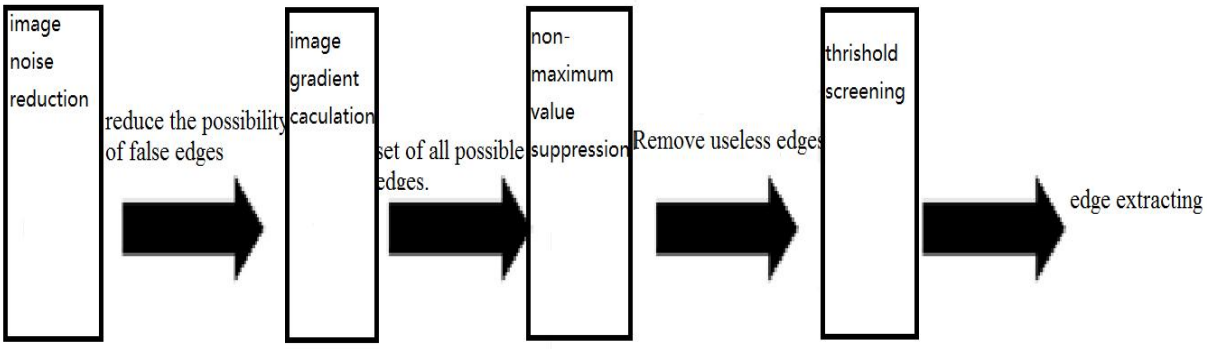

Figure 7. Flowchart of edge detection algorithm

First, the image should be de-noised. Gradient operators can be used to enhance the image, essentially by enhancing the edge contour, that is, the edge can be detected. However, they are all highly affected by noise. So, the first step is to think of removing the noise. Because the noise is the gray level changes a lot, it is easy to identify as a false edge. Therefore, this step is to perform noise reduction on the image to reduce the possibility of false edges in the process of image target edge extraction.

In the second step, the image gradient is calculated to obtain the possible edges. The edge of the image can be obtained by calculating the image gradient. Because the gradient is the place where the gray level changes obviously, while the edge is also the place where the gray level changes obviously, the gray level changes may be the edge or not. So this is the set of all possible edges.

The third step is non-maximum suppression. Usually, gray change places are concentrated. Therefore, according to this feature, the place with the largest gray level change in the gradient direction in the local range can be retained, and the others are not retained, so that a large part of the edge points can be removed, and the edge with multiple pixels wide will become a single pixel wide edge, that is, the “fat edge” will become “thin edge”.

The fourth step is double threshold screening. After non-maximum suppression, there are still many possible edge points. Therefore, a double threshold can be further set, namely low threshold (low) and high threshold (high), for screening possible edge points, so as to finally determine the edge contour of the object in the image. In the process of threshold screening for these possible edge points, if the gray level change is greater than high, it is set as strong edge pixel. Those lower than low are excluded and it is set as a weak edge pixel between low and high. Further judging, if there are strong edge pixels in its field, it would be retained. If not, it would be eliminated. The reason for this is that if only the strong edge contour is kept, some edges may not be closed and need to be supplemented from the point between low and high to make the edges as closed as possible.

3.4 Morphological Operation

Morphology generally refers to the branch of biology that deals with the structure of animals and plants. The basic idea is to measure and extract the corresponding shape in the image by using the structural elements with certain forms to achieve the purpose of image analysis and recognition. The mathematical basis and language of morphological image processing is set theory. The application of morphological image processing can simplify

image data, preserve their basic shape properties, and remove irrelevant structures.

The basic operations of morphological image processing include: expansion, corrosion, open operation and close operation, hit and miss transform, top-hat transform, black HAT transform and so on. Morphological applications: noise elimination, boundary extraction, region filling, connected component extraction, convex hull, refinement, coarsing, etc. Separate independent image elements, or adjacent elements in the image; Obtain the obvious maximum region and minimum region in the image; Find the image gradient.

Corrosion operation and expansion operation are the operational basis of all morphological operations. The combination of corrosion and expansion can realize open operation, closed operation, morphological gradient and other various forms of operations. Therefore, the following mainly introduces the realization principle of corrosion and expansion operation.

The core content of expansion and corrosion operation is structural elements, and the following opening and closing operation is also important to the design of structural elements. A suitable design of structural elements can bring good treatment effect. Typically, structural elements are matrices with elements of one or zero. The region with structural element 1 defines the domain of the image, and the pixels in the domain are taken into account when performing morphological operations such as expansion and corrosion. In general, the structural elements of a two-dimensional or planar structure are much smaller than the image being processed. The center pixel of the structure element, the origin of the structure element, corresponds to the pixel value of interest in the input image, which is the pixel value to be processed. Structural elements in three dimensions use 0 and 1 to define the range of structural elements in the X-Y plane, and use height values to define the third dimension.

3.4.1 Corrosion

Corrosion is an algorithm that eliminates some boundary points of the target graph under the constraints of structural elements and makes the boundary shrink inward, which has the function of shrinking the target region.

In the process of corrosion, structural elements are usually used to scan the image to be corroded pixel by pixel, and the corrosion result is determined according to the relationship between structural elements and the corroded image. The schematic diagram of corrosion operation is shown in the figure 8. Assuming that the structure element is a 3×1 matrix, the structure element is used to traverse all the pixels in the image, that is, the pixels in the original image are respectively placed in the center of the pixel element. If the structure element completely coincides with the pixel of the original image, the pixel value of this position is retained, which is 1. Otherwise, set the pixel value at that position to the minimum value of all pixel values in the range of the structure element template, 0. In the final corroded image, only the pixel values in the red box are retained. Therefore, the corrosion operation is mainly to corrode the peripheral protruding points in the image, such as burrs, so as to “shrink” or “refine” the target part of the image.

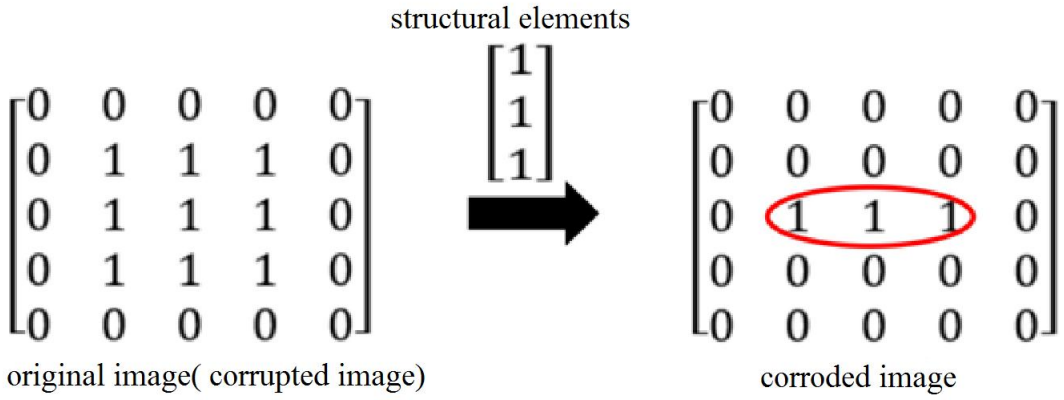

Figure 8. Schematic diagram of corrosion operation principle

3.4.2 Dilation

Dilation is the dual operation of corrosion operation. Its function is to merge the background in contact with the target area into the target object under the constraints of structural elements, so that the target boundary expands outward and the area of the object increases by a corresponding number of points. The dilation operation is similar to the corrosion operation, and it also needs to use the structural element template to traverse all the pixels in the expanded image, as shown in the schematic diagram of its principle, figure 9. Assume that structural

elements are a 3 x 1 matrix, using structure element traverse all the location in the original image pixels. That is, the pixels in the original image are respectively placed in the center of the pixel element. If the structure element coincides with the pixel of the original image, the position is recorded, and the pixel value of this position is set as the value with the largest pixel value within the range of the structure element matrix, that is, 1. Otherwise, the pixel value at this position will remain unchanged as the original value, which is 0. In the final image after dilation, the pixel value in the red box is expanded by dilation operation. Therefore, the dilation operation is mainly to connect or extend outward to the peripheral points of the target area in the image, so as to realize the expansion of the target boundary.

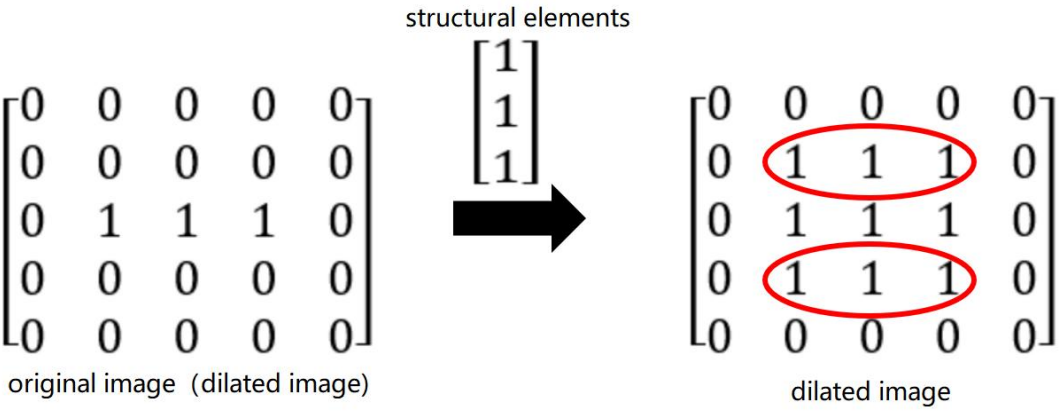

Figure 9. Schematic diagram of expansion operation principle

4. Research on Character Extraction and Recognition Technology

This paper intends to use deep learning method to solve character extraction and character recognition successively. Deep learning-based methods mainly have the following two difficulties:

(1) The formulation of data sets, deep learning-based text character detection and character recognition methods, depends on a large number of data support.

(2) The diversity and similarity of writing. Although numbers and letters are simple strokes, some characters have different degrees of similarity in structure.

Aiming at the problem of insufficient data, this paper plans to use data augmentation technology to expand the available samples, and use public data sets for transfer learning. It mainly includes MNIST handwritten digit dataset and CHROME handwritten mathematical formula dataset.

In order to solve the problem of writing diversity and similarity, bidirectional long term memory network is proposed in this paper. Bidirectional long term memory network can make full use of the context information of the character for comprehensive discrimination of character categories, which can well solve the problem that the recognition accuracy is affected by the diversity and similarity of writing characters.

4.1 Character Extraction

In the case of natural scenes without processing, the efficiency of character extraction will be greatly reduced, and the accuracy will be greatly reduced. Therefore, before character extraction, natural scenes can be distinguished into text blocks and non-text blocks by graph, region, block, pixel and other attributes. The text area is composed of multiple consecutive text blocks. The character extraction model is constructed to extract the characters in the text area. The model realizes the character extraction through the following three steps:

(1) The gray image of the natural scene is binarized, and the characters in the text area are segmented from the background;

(2) Make a projection in the vertical and horizontal direction, analyze the peak and trough of the projection curve so as to determine the frame position of each character;

(3) Formulate filtering rules to filter out non-characters.

The text area localization technology realizes the text area from the background image stripping. However, how to realize character recognition, it is necessary to accurately locate the character, find out the boundary of each character, in order to identify the character to the recognition module. Projection segmentation is a mature

technique to determine the boundary of characters. It is realized by Otsu binarization of rectangular block image in text area. However, the natural scene image is affected by exposure or illumination, and the characters may have uneven brightness. When Otsu algorithm is used for binarization, the characters will stick to the background, and the character boundary location cannot be carried out. To solve this problem, a segmentation algorithm based on local overlap threshold is proposed. The image binarization algorithm flow based on local overlap threshold is shown in the figure 10.

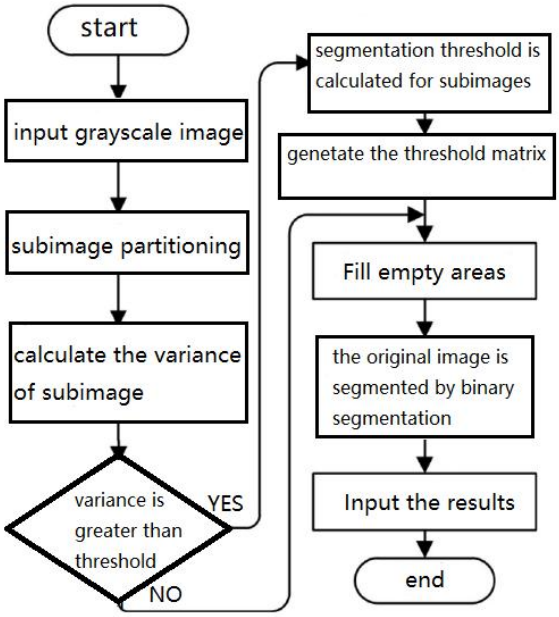

Figure 10. Image binarization algorithm flow based on local overlap threshold

The algorithm is the improvement of global Otsu segmentation algorithm, combined with the local threshold segmentation algorithm, then add grayscale average variance of the statistical characteristics of image, whether the subsidiary image containing the character and the background to determine these two goals. If it is YES, the Otsu algorithm is applied to estimate the sub image threshold, and the threshold value in the threshold matrix. For the sub-images that do not use the Otsu algorithm to calculate the threshold, a threshold filling algorithm is used to fill the blanks in the threshold matrix, so as to obtain the threshold matrix for each pixel. Finally, according to the threshold matrix, the original image can be binary segmentation. The algorithm can be divided into five steps:

(1) Sub-image division;

(2) Calculate subimage variance and variance threshold;

(3) Calculation of local overlap threshold;

(4) Fill the blank area;

(5) Binarization according to the threshold.

4.2 Character Recognition

After character extraction from processed images, it is necessary to conduct research on automatic recognition technology for extracted character information to replace the time-consuming and labor-intensive manual recording method at the current stage, so as to lay the foundation for subsequent research on blade identity information integration technology and realize automatic identification of blade identity information.

The traditional recognition method of handwritten string is carried out in stages. Firstly, the string is divided into single characters, the category of single characters is identified, and then the recognition results are combined. However, the phased approach has two obvious disadvantages: segmentation errors can affect recognition performance, and single-character recognition fails to consider context information.

In order to solve these problems, this paper intends to design a handwritten string recognition model based on the encoder-decoder framework, which can realize the end-to-end recognition of handwritten strings. The flow chart of the recognition algorithm is shown as follows in the figure 11. In the encoding stage, in addition to the

traditional convolutional neural network for feature extraction, bidirectional long short-term memory network (BLSTM) is used on the convolutional layer of the convolutional neural network to encode features according to lines, so that the obtained features can fully consider the context information. BLSTM is derived from the combination of Long short-term memory network (LSTM) and bidirectional RNN (BRNN). Both LSTM and BRNN are variants of RNN. LSTM can learn the long-term dependence of data, and BRNN can train the network in both forward and backward directions. Therefore, the BLSTM method obtained by combining the two methods can better deal with the problem of gradient disappearance and explosion, and obtain context-related long-term information, which has a good effect on solving the problem of single character recognition that fails to consider the context information in the recognition process. In the decoding stage, the attention mechanism is used to complete the implicit alignment between the input features and the recognition results, avoiding the explicit segmentation of strings, and then the obtained intermediate vectors are input into the LSTM for decoding.

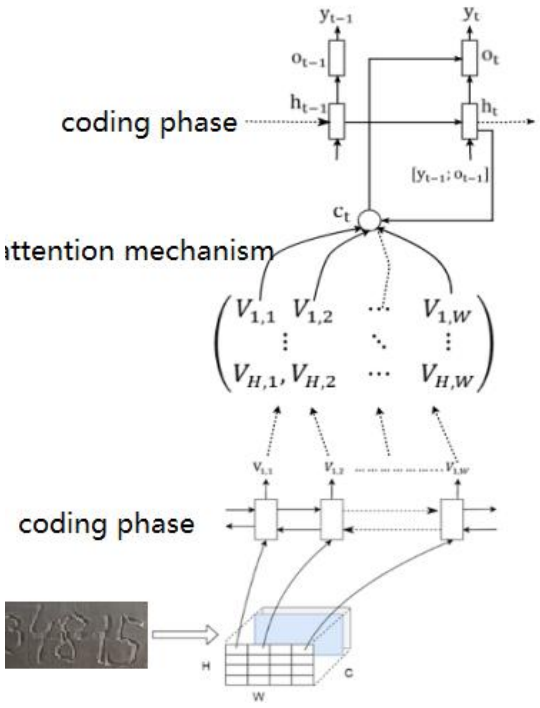

Figure 11. Character recognition flow

Image data needed in the model training process include:

(1) Single numbers and letters inscribed on blade material samples by all engraving personnel on the production site;

(2) Multiple images collected from actual blades.

4.3 Transfer Learning Techniques

The training of convolutional neural network requires a large number of training set images to extract sufficient and diverse features, and only in this way can the accuracy of model recognition be improved. Moreover, the deeper the network is, the more training data are needed. When fewer images are available for network training, the model is prone to overfitting. That is, the trained network is more inclined to recognize the images with similar features in the training samples with a small amount of data. In practical application, the recognition results are often difficult to meet the requirements in the face of complex and diverse image data. Therefore, this project studies the feature transfer of the model through transfer learning method, and obtains knowledge that can help improve the generalization of neural network from similar learning tasks, so as to assist the network model to more accurately recognize character images containing blade identity information.

Different from the traditional machine learning algorithms, transfer learning helps the network model reduce the over-dependence on the target domain data by transferring the generalizable knowledge from the related learning tasks to the target tasks. It is not strict with the source domain and target domain data is identically distributed,

only need two data exist certain similarity, it can extract the characteristics of the direct data on the source domain as the initial characteristics of the target domain data, and then automatically in the process of training target domain data characteristics of the initial screening and retention, the common features of and will be effective for the target domain data classification task, to improve overall performance on the classification task. Transfer learning for convolutional neural networks is not only the reuse process of common features in the source domain data, but also the reuse process of the model trained on the source domain data. The algorithm flow chart is shown in the following figure 12. According to experience, the structure of the convolution part in front of the model is generally selected to be retained, and the convergence parameters of the model in the source domain are used to initialize it, that is, the migration of model features. However, the structure of the fully connected part of the model can be kept or customized according to requirements, but the parameters of this part are randomly initialized to fine-tune and fit the features on the data in the target domain.

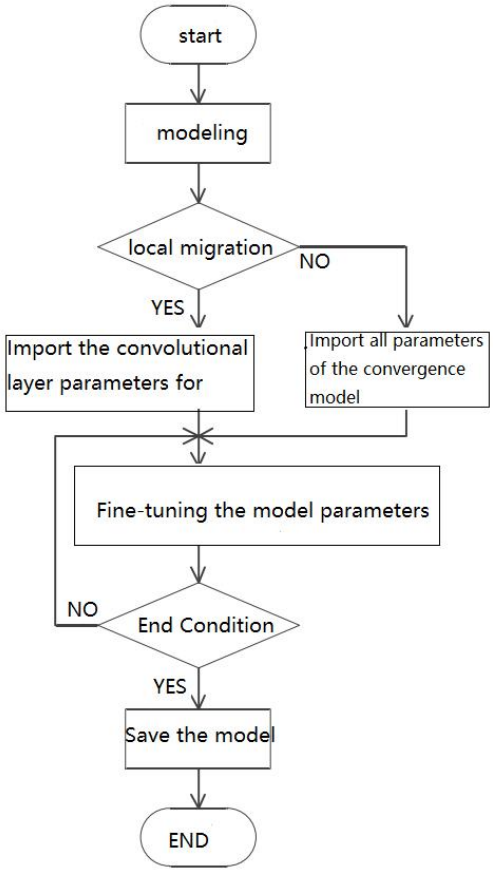

Figure 12. Transfer learning process

5. Research on Blade Identity Information Identification Integration Technology

5.1 Hardware System Integration

The integrated system consists of six-axis robot, optical detection platform, blade identification module, automatic clamping station, feeding frame, automatic screening device, electronic control system and measuring software, etc. Six axis robot manipulator with specific tooling after scraping blade under test, moved to the image acquisition device for high resolution image acquisition. The image acquisition device is composed of industrial camera, lens and light source, using the optical image visual identification system will first serial number of the component under test and the product information to identify automatically after inputting special central integrated control system, to obtain recognition results. The measurement results are automatically uniquely corresponding to the product identification code and product number, and the coded image data is collected and saved at the same time to facilitate the subsequent manual inspection of the identification results. It greatly facilitates the collection and management of measurement data and avoids the risk of misoperation. The whole system covers an area of about 3.5m×3.8m.

5.2 Blade Identity Identification Structured Data Interface

A complete text extraction system is as follows: Firstly, the text localization technology is used to localize the scene text under the given natural scene image, that is, to obtain a single text area box; Secondly, the text area box is selected to be corrected and corrected to a horizontal text image. Finally, text recognition technology is used to recognize the corrected text. Therefore, it is necessary to carry out the research of blade identity information integration technology, provide a structured data interface for blade identity information recognition, complete the integration and deployment of image preprocessing, character extraction and recognition model, and realize the end-to-end recognition of blade identity information.

6. The Conclusion

In order to meet the urgent needs of the digital recognition of the aero-engine blade code information, the research on optical character acquisition, character image processing, automatic character extraction and recognition is carried out. By studying the automatic detection and recognition algorithm based on depth study, software engineering, systems integration and other technology, developed with independent intellectual property rights of blade identity information automatic recognition software, the realization of digital identification of blade carved code information. At the same time, it completes the research of graphic database technology, and realizes the standardized storage of coded graphics, annotated files and recognition results. The research results can replace the current methods of manual identification and manual input of blade identity information, improve the operation efficiency and establish valuable data sets at the same time, so as to facilitate the subsequent iterative optimization research on the accuracy of digital identification of blade identity information.

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