

# Intelligent Digital Recognition System Based on Vernier Caliper

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**Abstract:** The detection and recognition of information in natural scenes has always been a difficult problem in computer vision. Digital instrument character recognition is one of the more representative and valuable things. In recent years, there is a lot of research work on this problem, but the solutions rely on string location, character segmentation and other preprocessing processes, the results of these preprocessing processes directly affect the final character recognition results. In contrast, the character recognition method of digital instrument based on convolution neural network (CNN) omits the complex preprocessing process through graph to graph prediction, and the character recognition result is obtained directly. And has a strong generalization ability, can identify multiple types of instruments. At the same time, through the weighted fusion of multi-scale and multi-level features in the CNN, a better ability of feature extraction and information integration is obtained. The experimental results show that the method can directly and accurately recognize the characters in the Vernier caliper.

**Key words:** Digital recognition, convolution neural network, detection, computer vision.

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## 1. Introduction

Nowadays, digital instruments are widely used in various industries [1]-[5]. Due to historical reasons, cost control considerations, design requirements and other factors, there are still a considerable number of instruments do not provide a data communication interface with the computer, but also need to manually input instrument data. Manual input of instrument data consumes a lot of manpower and time, and the results are easily disturbed by human factors. In contrast, it is more convenient to capture the instrument image according to the real-time monitoring and capture the instrument image, and then use the character recognition method to recognize the data in the instrument image [6]-[9].

The data in the digital instrument usually contains multiple characters. The traditional method first determines the position of the character by positioning, and then divides the character into a single character for recognition [10]-[13]. The whole process is complicated, and the recognition results are easily affected by the localization and segmentation results in the preprocessing process. If we realize the pixel level prediction of the digital instrument image, and the prediction result contains both position information and category information, we can synthesize the two directly to get the character result [14]-[18]. In this paper, a character recognition method of digital instrument based on convolution neural

network (CNN) is proposed. In this method, the pixel level prediction from graph to graph is realized by CNN algorithm, and the location, extraction and segmentation of characters are realized at the same time. Though the weighted hybrid feature learning, the multi-scale and multi-level features of the CNN are fused, so that the prediction results can be well integrated with the location information and classification information, and the accurate character recognition results can be obtained. The experimental results show that this method can omit the complex preprocessing process and obtain the recognition results of the characters in the instrument directly from the digital instrument image.

## 2. Structure and Principle of CNN Model

The common CNN is mainly divided into two parts: the display layer and the hidden layer, the display layer includes the input layer and output layer, and the hidden layer includes the convolution layer and the pooling layer [19]. In each layer, a two-dimensional plane is composed of multiple neurons, and then a layer structure is formed by these planes. Fig. 1 is a common CNN structure diagram.

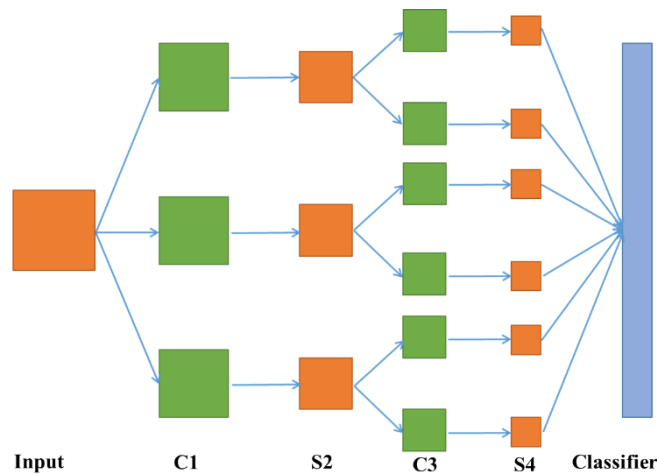


Fig. 1. CNN structure.

As Among them, C1 and C3 are convolution layers, and the function of convolution layer is to extract the corresponding features of convolution cores by sliding convolution cores on the previous feature map. The output of the previous layer is taken as the input, and the convolution operation is carried out according to the number of convolution cores in the convolution layer. The input of each neuron in the convolution layer is connected to the local receptive field of the previous layer, and the local receptive field is convoluted with the convolution nucleus [20]. Then, after an activation function (usually a sigmoid function), the local features are extracted, as shown in formula (1).

$$\text{conv}(x) = S(\sum \sum \sum \theta_{ijk} \cdot x_{ijk} + b) \quad (1)$$

where  $S(x)$  is the Sigmoid function, the meaning is shown in formula 2.  $\theta$  and  $x$  are the parameter values in the convolution core,  $b$  is the bias,  $i$  and  $j$  are the size of the convolution core, and  $k$  is the number of characteristic graphs in the upper layer. The reason for using the activation function is that it is a nonlinear function, and its output is nonlinear to the input. If there is no activation function, there will be no mathematical difference between multiple convolution layers and a single convolution layer [21]. The essence of convolution layer is to select a small piece from a large size feature map as a sample, and then through training to learn a lot of different features from this small sample. Then these features are used as detectors and applied to other parts of the image to make convolution, so as to obtain the activation values

of many different features from the local regions of different positions of the feature map.

$$S(x) = \frac{1}{1 + e^{-x}} \quad (2)$$

Layers S2 and S4 are pooled layers. It can be regarded as a fuzzy filter, which plays the role of quadratic feature extraction, and it can also reduce the feature dimension. The pooling layer aggregates the features that pass through the convolution layer at different locations, and calculates the average value of a specific feature in a region of the feature graph. These summary statistical characteristics not only have much lower dimensions, but also improve the results. The operation of this aggregation is called pooling, which is divided into average pooling and maximum pooling according to the pooling function. For the pooling layer, if there are N input feature graphs, there are N output feature graphs, but each output feature graph is reduced by the pooling function [22]. Pooling operation is to select the output feature graph of the upper layer does not coincide with the region, the average pooling calculation of the average value of the region as the output, and the maximum pooling to select the maximum value of the region as the output [23].

### 3. Results and Discussion

The work flow of CNN model algorithm is divided into two stages, one is the location of Vernier caliper digital display area, the other is digital character recognition. Before recognizing the Vernier caliper reading, it is necessary to locate the position of the digital display area of the Vernier caliper instrument, which affects the accuracy of the subsequent character recognition to a great extent. As shown in Fig. 2, we randomly collected a number of Vernier caliper images in different situations. From the Fig. 2, it can be seen that the Vernier caliper image has the phenomena of tilt, position, focal length, lillumination difference and so on, which increases the difficulty of character recognition. The background of figure a is different. The position of picture c is different, and the focal length is far away. This paper intends to construct s set of CNN model which can accurately and efficiently recognize Vernier caliper characters.

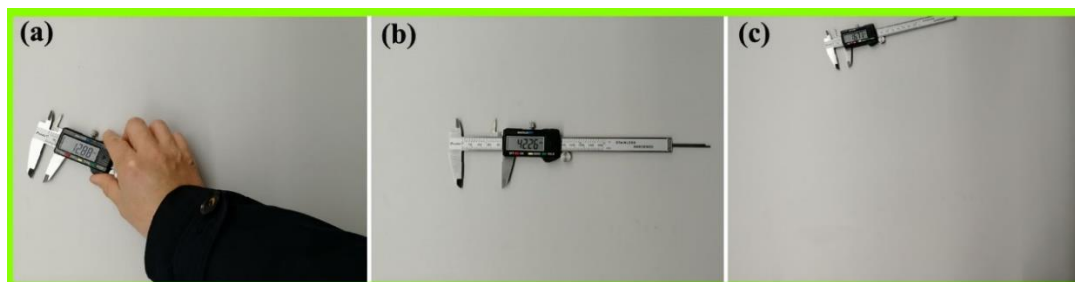


Fig. 2. Vernier caliper images in different scenes.

Because the background environment of the Vernier caliper is very complex, it is necessary to eliminate the background interference of the instrument in order to obtain high recognition accuracy and stability. In this paper, the CNN model is used to extract the characteristics of the digital display area of the Vernier caliper to locate it. First of all, the digital display area of the Vernier caliper is calibrated as the candidate region, and 10000 random image samples are selected for calibration, and the calibrated Vernier caliper samples are put into the CNN model for training. Let the computer learn the characteristics of the candidate area by itself. After the training is completed, a structured CNN model is obtained. As shown in Fig. 3, the yellow box is a candidate area calibration map for a variety of Vernier caliper samples. In order to verify the positioning effect of the model, several Vernier caliper image samples are randomly selected for practice experiment, and the correct rate is more than 99%. Thus, the constructed model is verified.

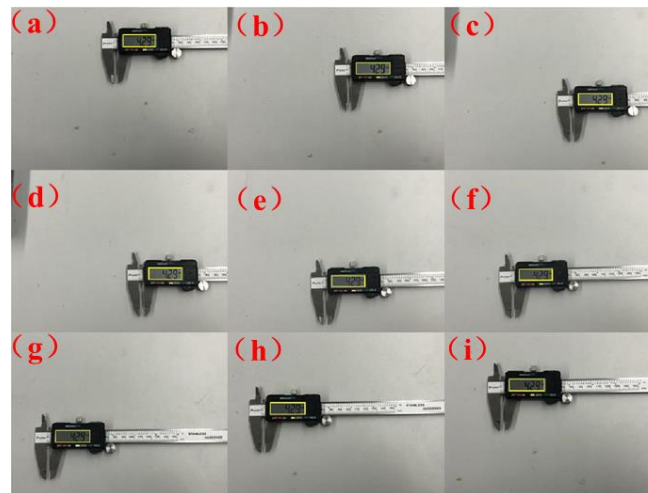


Fig. 3. Vernier caliper candidate area marking effect diagram.

In the process of Vernier caliper image acquisition, due to the randomness of the operation process, it will inevitably lead to the acquisition of inclined images. After locating the candidate area of the inclined image, the digital display part of the image is inclined and the characters are slanted, as shown in Fig. 4(a). In this case, the character noise obtained by the subsequent character segmentation will obviously increase, reduce the correct rate of character recognition, tilt too large image will even appear unable to carry out character segmentation. Therefore, it is necessary to correct the tilted Vernier caliper image. For the horizontal inclination of Vernier caliper, there are two main correction methods, Hough method and Radon method. Compared with the Hough method, the calculation of the Radon method is simple and the dependence is small. In this paper, Radon method is selected to correct the tilt of the Vernier caliper image, as shown in Fig. 4. Fig. 4(a) shows an image obtained by anticlockwise operation, and Fig. 4(b) shows an image obtained by clockwise operation. The tilt angle cannot be greater than 45 degrees, otherwise the reverse rotation will occur.

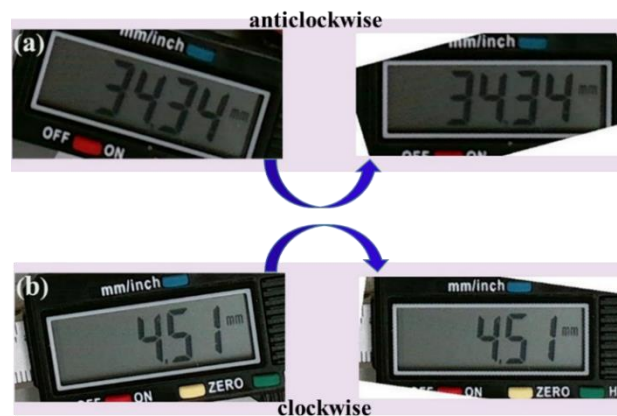


Fig. 4. Schematic diagram of Vernier caliper tilt correction.

The binary image contains only black and white, and the gray value is only 0 and 1, and the image data is further reduced. The purpose of binarization of candidate image is to divide the image into two parts: target and background. The target is the information we need, that is, the character part, and the background is the unneeded part, including the background information of Vernier caliper characters. The binarization process is roughly divided into two steps, first determining a reasonable threshold, and then comparing the gray value of each pixel with the value we set. If the gray value is less than the threshold, the pixel is

converted to black, otherwise to white, as shown in Fig. 5(b). The focus of binarization processing is how to determine the threshold, too small threshold may get too much interference information, which brings difficulties to the subsequent character processing. If the threshold is too large, it will damage some of the target information, resulting in the lack of valid character information and unable to carry out character recognition.

In addition, the image sample also needs to be processed for edge detection, as shown in Fig. 5(c). The edge usually refers to the obvious step transformation between the pixel and the surrounding pixel, and the edge contains rich information such as direction, step property and shape. The purpose of this method is to detect the points with obvious luminance changes in the image, which reflect the local characteristics of the image. There is also unnecessary or redundant interference information with the image data, which will seriously affect the quality of the image, so corrosion noise processing must be carried out, as shown in Fig. 5(d). The basic principle is to replace the value of a point in the image with the average of the points in a certain area. The main function is to make the pixels with large differences in the gray values of the surrounding pixels become close to the surrounding pixels, thus eliminating the isolated noise points. As shown in Fig. 5(e), the closed operation can connect the close area of the image, amplify the discontinuous noise, the structure elements are different, the magnification degree is also different. The closed operation makes the pixels of the image adhere, which can fill the close area of the image and make up for the small cracks. In order to eliminate the noise in the image more thoroughly, we carry out the secondary corrosion noise processing, as shown in Fig. 5(f). After a series of image post-processing, we obtained a very clear Vernier caliper character, which provides a basis for our further image character location.

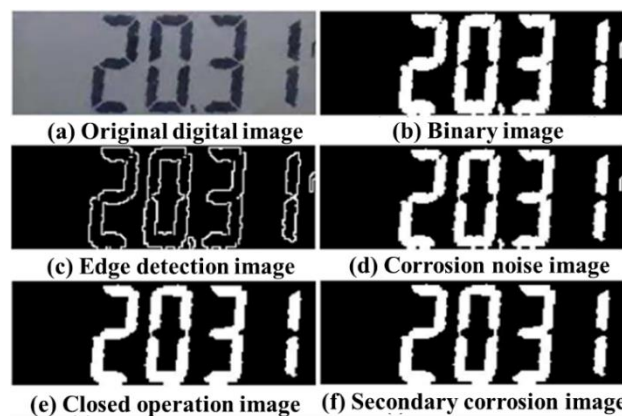


Fig. 5. Post-processing of Vernier caliper candidate region image.

Before the image data recognition based on the CNN algorithm, a training stage must be added [24]. In this algorithm, the appropriate training samples should be selected during the training. After the sample is input into the network, the output and ideal output of each layer of neurons are calculated. Then feedback is carried out, and the network model adjusts and modifies the weights and thresholds of the network according to the difference, and recalculates the difference between the output and the ideal output. And so on, after a lot of learning, the weights and thresholds are constantly modified until the network weights and thresholds are determined, and finally a classifier is formed. This process is the training period of the algorithm [25]. Only after the training is over can we start to work normally. As shown in Fig. 6, we integrate the positioning, post-processing, secondary positioning and recognition of the candidate regions of the Vernier caliper image, and set up a man-machine interface. The recognition result is shown in the lower left corner of the Fig. 6, through the test of 5000 Vernier caliper images, the recognition accuracy is more than 95%.

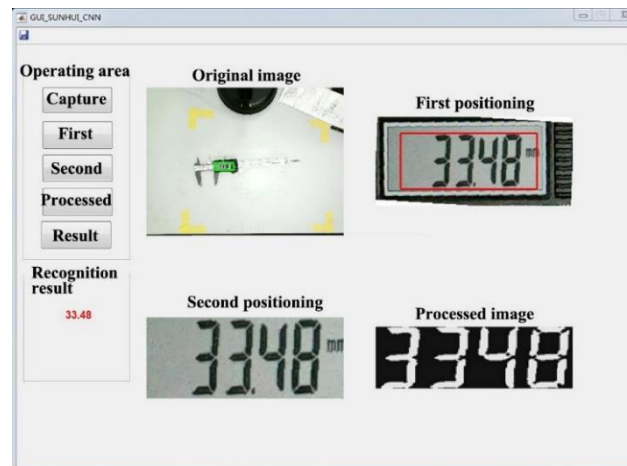


Fig. 6. The man-machine interface of the intelligent identification system.

#### 4. Conclusion

In this paper, the flow and algorithm of Vernier caliper recognition system are analyzed, and the related technologies are summarized. After summary and consideration, the technologically advanced CNN algorithm and the post-processing with excellent performance are selected, and the intelligent recognition system of Vernier caliper is developed on the basis of MATLAB software. After using the CNN algorithm to locate the candidate region of the Vernier caliper, the image is processed by binarization, corrosion noise and closed operation, which removes the cluttered and meaningless small parts of the image and retains the main features of the image. Then the image of the Vernier caliper is corrected by Radon transform. According to the information such as the width and height occupied by the number and the distance between the character, it is projected longitudinally, and according to the projection result, the individual characters of the candidate region are obtained and normalized. Finally, the more popular and technologically advanced CNN algorithm is used for character recognition, and the recognition accuracy is more than 95%.

#### Conflict of Interest

The authors declare no conflict of interest.

#### Author Contributions

Hui Sun conducted the research; Feng Shan built the model; Weiwei Shi analyzed the data; Xiaoyun Tang drew the pictures; Xiaowei Wang wrote the paper; Xiaofeng Li validates the model; Yuanfang Cheng counted the identification data; Haiwei Zhang supervised the paper; all authors had approved the final version.

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