Research on automatic segmentation and recognition of single characters in original rubbings based on intelligent recognition of oracle bone inscriptions

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Abstract. This paper proposes an effective segmentation and recognition method using YOLOv8 to solve the problem of segmentation and recognition of Oracle rubbings images. Draw sub-pixel edge contours through spot detection, corner detection, and edge detection (such as Canny and Sobel), and combine grayscale, opening operations, binarization, and Gaussian filtering to remove noise and repair contours, extract image features, and establish preprocessing Model. Use this model to preprocess the original oracle rubbing image and train it based on YOLOv8. The results show that this method can effectively segment and identify oracle bones characters.

Keywords: Oracle recognition, YOLOv8, image segmentation, edge detection.

1. Introduction

Entering the 21st century, with the rapid development of computer science and artificial intelligence technology, the identification and interpretation of oracle bone inscriptions has ushered in new opportunities. The application of technologies such as deep learning, image processing, and natural language processing makes it possible to automatically identify and analyze oracle bones. In recent years, oracle bone inscription recognition technology has gradually shifted from traditional feature extraction to methods based on deep learning, and the recognition accuracy has been significantly improved [1]. For example, in 2017, Liu Yongge [2] used support vector machine to identify 1290 oracle bone characters. Although a certain accuracy was achieved, there were still shortcomings. In 2018, Gu Shaotong [3] proposed an oracle-bone glyph recognition method based on fractal geometry. By calculating the fractal dimensions of the glyphs and their quadrants, the oracle-bone glyphs were formalized into a set of fractal description codes, and registered with the fractal feature library. Identify oracle bones glyphs. In 2020, Liu Guoying [4] proposed an oracle bone inscription detection and recognition method based on deep learning. In 2021, Liu Fang [5] used the triplet loss function and rotation angle regression technology to optimize the accuracy of oracle bone text classification based on the Mask R-CNN algorithm. In 2022, Wang Mei [6] and others proposed a Structural Construction Separation Network (STSN). A large number of experiments on the Oracle-241 data set showed that STSN was superior to other adaptive methods and successfully improved the recognition of scanned data. Performance, even when contaminated by prolonged burial and careless excavation. In 2023, Mao Yafei [7] proposed an oracle bone character recognition method based on an improved ResNeSt network, achieving a recognition accuracy of 93.53% on the OBC306 data set, achieving the best recognition effect at the time. In 2024, Bi Xiaojun [8] proposed a small-sample oracle-bone inscription recognition method based on supervised contrastive learning, which effectively solved the problem of poor recognition accuracy of oracle-bone inscriptions that appear frequently. Although some progress has been made, oracle bone rubbing images are still affected by various interference elements such as point noise, artificial textures and inherent textures, and the recognition process faces many difficulties. In addition, how to quickly and accurately segment independent text areas from complex backgrounds with numerous interferences is still a challenging problem that needs to be solved. To this end, this study proposes an automatic segmentation and recognition method for Oracle rubbings based on YOLOv8 [9], which realizes the rapid and accurate recognition and segmentation of Oracle rubbings, and provides a reference for the automatic segmentation and recognition of Oracle rubbings.

2. Establishing a preprocessing model for Oracle rubbing images

A large number of oracle bone inscriptions have been excavated, but their identification is quite difficult. This is mainly because oracle bone inscriptions are very old and are often engraved on tortoise shells and animal bones. After years of being buried underground, oracle bones are severely damaged and have low-definition rubbings. First of all, this article performs grayscale processing, denoising, opening operations, and binary processing on the Oracle image to reduce the interference of interference elements on subsequent processing, thereby making the image clearer and the text more complete.

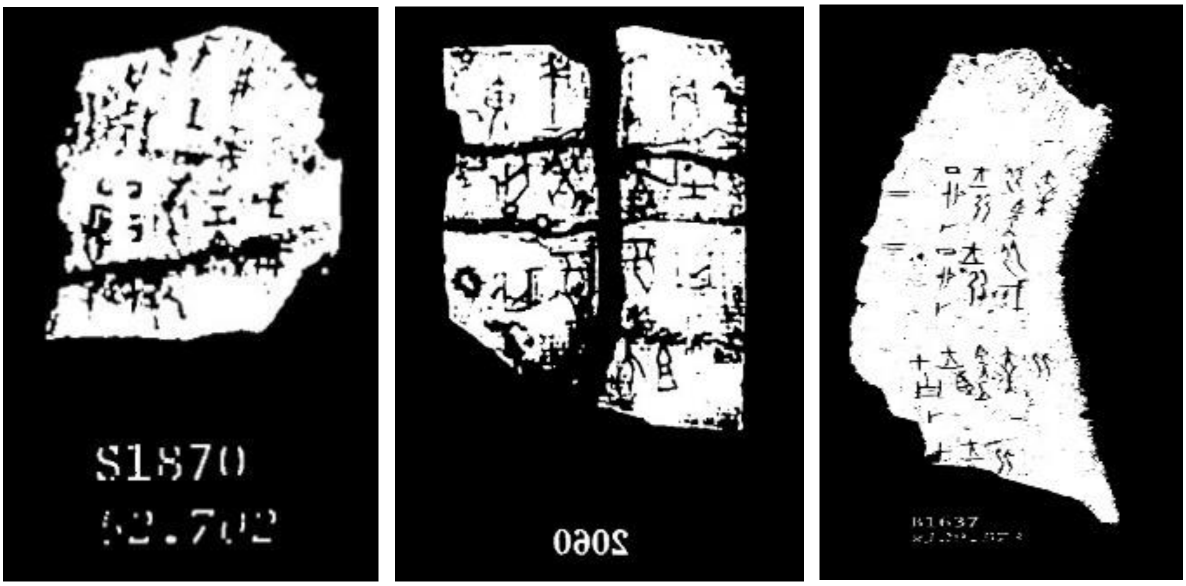


Figure 1. Binarization results of three oracle bone rubbings images.

2.1. Establishment and analysis of image preprocessing model of Oracle rubbings

(1) Edge detection

Canny edge detection is a widely used edge detection algorithm that combines multiple steps such as Gaussian filtering, gradient calculation, non-maximum suppression, and double threshold processing. The following are the main principles of the canny edge detection algorithm:

First, the image is smoothed using a Gaussian filter to reduce the impact of noise on edge detection. The kernel function of the Gaussian filter is:

$$G(x,y)=\frac{1}{2\pi\sigma^2}e^{-\frac{x^2+y^2}{2\sigma^2}} \tag{1}$$

Among them, (x,y) are the pixel coordinates, and σ is the standard deviation of the Gaussian function, which controls the degree of smoothing. Controls the level of smoothing. Next, the gradient intensity and direction of each pixel is calculated, usually by applying the Sobel operator. Non-maximum suppression refines edges and suppresses the gradient strength of non-local maxima to zero. Finally, double threshold processing is used to determine the final edge point, setting the high threshold Th and the low threshold Tl. If the gradient intensity is greater than Th, the edge point is determined; if it is less than Tl, it is suppressed; if it is between the two, check whether there is a determined edge point in its neighborhood, and if so, retain it, otherwise suppress it.

(a) Original picture (b) canny edge detection (c) Sobel edge detection

(d)Prewit edge detection (e) roberts edge detection (f) log edge detection

Figure 2. Edge detection results of oracle bone rubbing images using different methods.

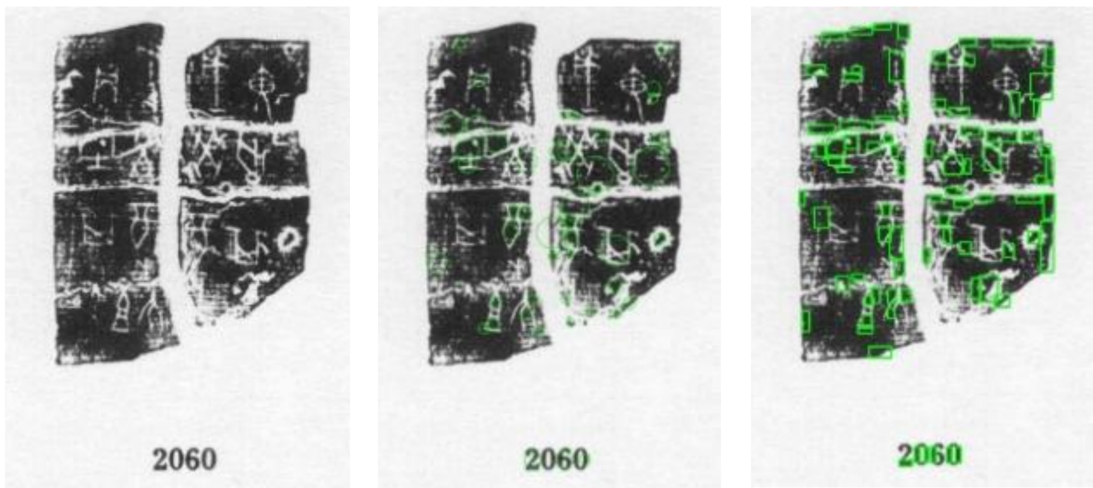
As shown in Figure 2, edge detection can identify the contour, shape and structural features in the oracle bone rubbings image. These are the basis for subsequent image processing and analysis and help to understand the content of the oracle bone rubbings.

(2) Spot detection

Threshold-based spot detection is one of the simplest methods that determines which pixels belong to spots by comparing image pixel values with a threshold. Its core formula is:

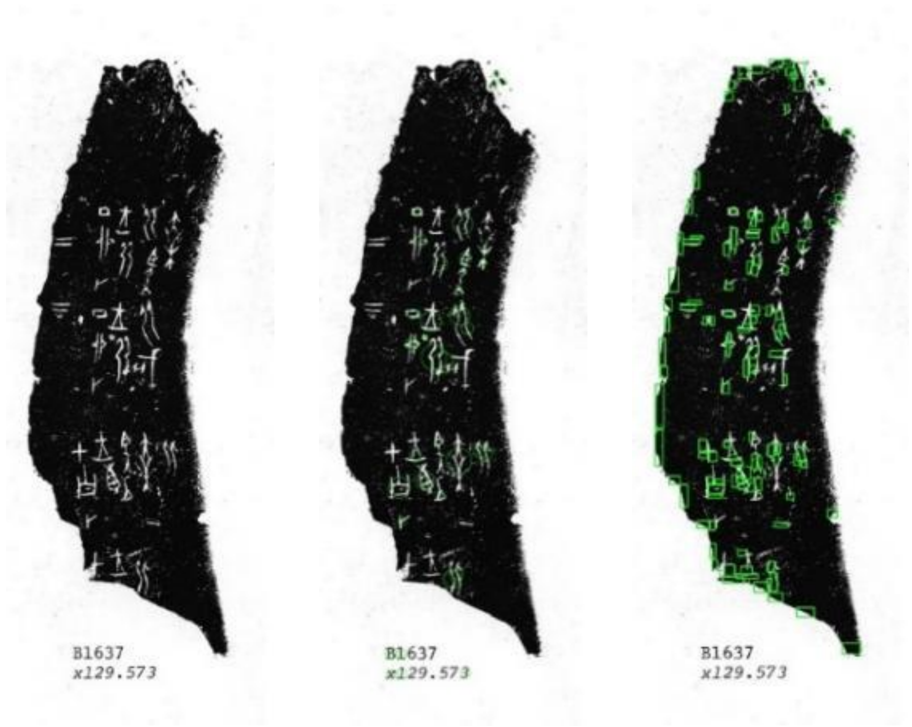
$$Blob = \{p|f(p) > T\} \quad (2)$$

Threshold-based spot detection compares the pixel value f (p) with the threshold T. When f (p)>T, the pixel p is considered to be part of the spot.



(a) Original picture (b) blob spot detection (c) log spot detection

Figure 3. Spot detection results of different methods on the h02060 oracle bone rubbing image.



(a) Original picture (b) blob spot detection (c)log spot detection

Figure 4. Spot detection results of different methods on the image of oracle bone rubbing No. w01637.

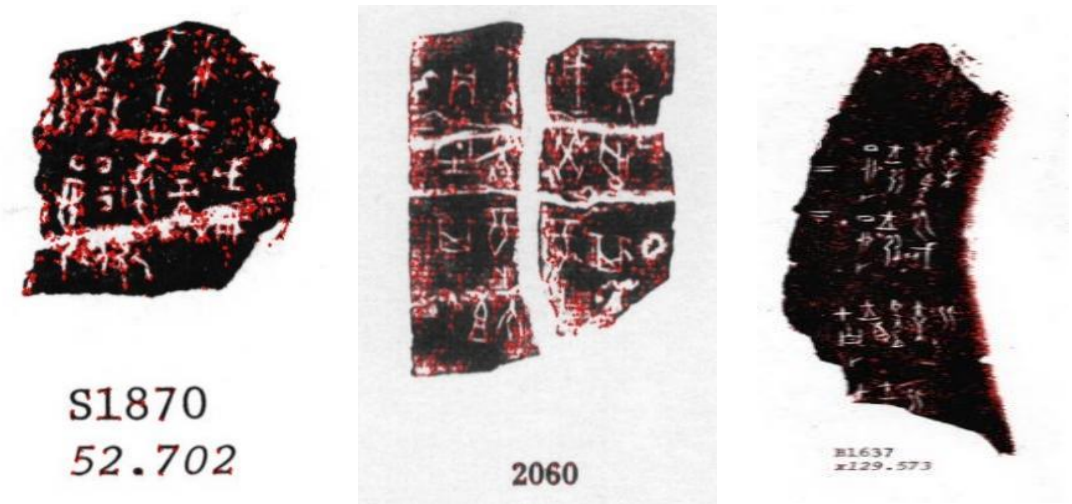
From Figure 3 and Figure 4, the specific location of the spots in the image can be clearly determined.

(3) Diagonal detection

In image processing, diagonal detection is often combined with edge detection and Hough transform. The Hough transform maps points in image space to curves in parameter space, and straight lines map to points in parameter space. Straight line detection is usually represented by polar coordinates. The straight line is defined by two parameters: distance ρ and angle θ. In polar coordinates, a straight line can be expressed as:

$$\rho = x\cos\theta + y\sin\theta \tag{3}$$

Among them, (x, y) is a point in the image space, ρ is the distance from the origin to the straight line, and θ is the angle between the vertical line and the positive direction of the x-axis.



(a) Image No. w01870 (b) Image No.h02060 (c) Image No.w01637

Figure 5. Diagonal detection results of three oracle bone rubbing images.

3. Detect and segment Oracle based on YOLOv8

Because oracle bone inscriptions are very old and are often engraved on tortoise shells and animal bones. After years of burial, the oracle bones are severely damaged and have low-definition rubbings. This article first performs grayscale, denoising, opening and binary processing on the Oracle image data set to reduce interference elements and improve image clarity and text integrity. The YOLOv8 [10] model is used for oracle detection and segmentation, and the images are cleaned and enhanced to ensure data quality. Configure YOLOv8 model parameters according to requirements, use the training set to train the model, and use the validation set for performance verification and parameter adjustment. Finally, the model performance is evaluated, indicators such as precision and recall are calculated, and the model parameters are optimized based on the results to improve the performance and accuracy of the model.

3.1. Model establishment

First, clean the collected photos to remove poor quality, damaged, blurred photos. Then, the images are enhanced, such as resizing, normalizing, and scaling, to enrich training samples and enhance model generalization capabilities. Divide the annotated data set into training set, verification set and test set in a ratio of 4:1:1. The core principle of YOLOv8 [11] is to treat the object detection task as a single regression problem and directly predict the category and location of objects in the image, which is suitable for real-time detection applications. It uses the anchor-free CenterNet target detection method to directly predict the center point position, width and height of the object. Let us directly predict the center point coordinates (x_c, y_c) of the target and the target width w and height h. Its loss function usually includes position loss and classification loss. Position loss:

$$PositionalLoss = \frac{1}{2}((x_c - x_c, g_t)^2 + (y_c - y_c, g_t)^2) \tag{4}$$

Where x_c, y_c, g_t are the true center point coordinate classification loss of the target?

$$ClassificationLoss = -\,log(p(c|x_c, y_c)) \tag{5}$$

Where $p(c|x_c, y_c)$ is the predicted target category probability? Divide the input image into a grid cell array, perform multi-scale detection, construct and fuse multi-scale feature maps, and set up the detection head to detect objects of different sizes. Smaller feature maps detect larger objects, and larger feature maps detect smaller objects. Each grid cell predicts multiple bounding boxes and their confidence and class probabilities. The confidence reflects the credibility of the objects contained in the predicted boxes and how closely they match the actual objects.

In order to remove redundant boxes, YOLOv8 uses non-maximum suppression (NMS) to filter the final detection results. The loss for object classification is a measure of how accurately the network predicts the object category. Classification loss is calculated using cross-entropy loss in YOLOv8. The formula of Cross-Entropy Loss is as follows:

$$CrossEntropyLoss = -\sum_{c=1}^{C} y_c\, log(\, p_c + \epsilon) \tag{6}$$

Where y_c is the one-hot encoded value of the true label on category c. p_c is the probability that the model predicts that the sample belongs to category c. The loss function is summed over all categories c. Add a small value ϵ to p to avoid log (0). Object location loss, also known as object presence confidence loss, is a measure of how accurately the network predicts the presence or absence of an object. Computed by binary cross-entropy loss.

$$BinaryCross - EntropyLoss = -(y\, log(\,p) + (1-y)\, log(\,1-p)) \tag{7}$$

Where y is the true label (0 or 1). P is the positive class probability predicted by the model. Log is the natural logarithm. Object size loss measures the accuracy of the network's prediction of bounding box location and size, typically calculated using the mean squared error. Threshold and dilate the segmentation results to optimize the final segmentation mask. Evaluate the model detection effect and calculate indicators such as precision (P), recall (R), F1 value, average precision (AP), and mean average precision (mAP).

3.2. Model solution

Configure the YOLOv8 model parameters: the batch size is 16, and the number of training rounds is 100. Using the preprocessed training set, the model is trained via stochastic gradient descent, enabling it to accurately detect oracles. After training is completed, use the validation set to evaluate model performance and adjust parameters based on the results to achieve satisfactory performance. In the test phase, a new oracle image is input, and the model will output a prediction box containing the oracle area.

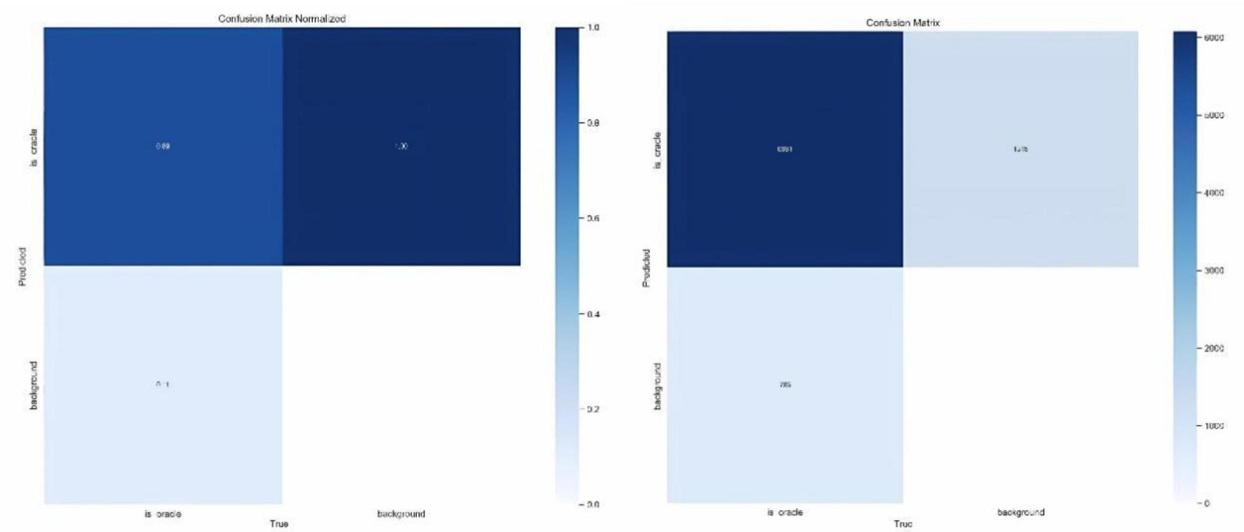


Figure 6. Normalization.

As shown in Figure 6, 6081 pictures can be accurately segmented, and 786 pictures cannot be accurately segmented under prediction conditions.

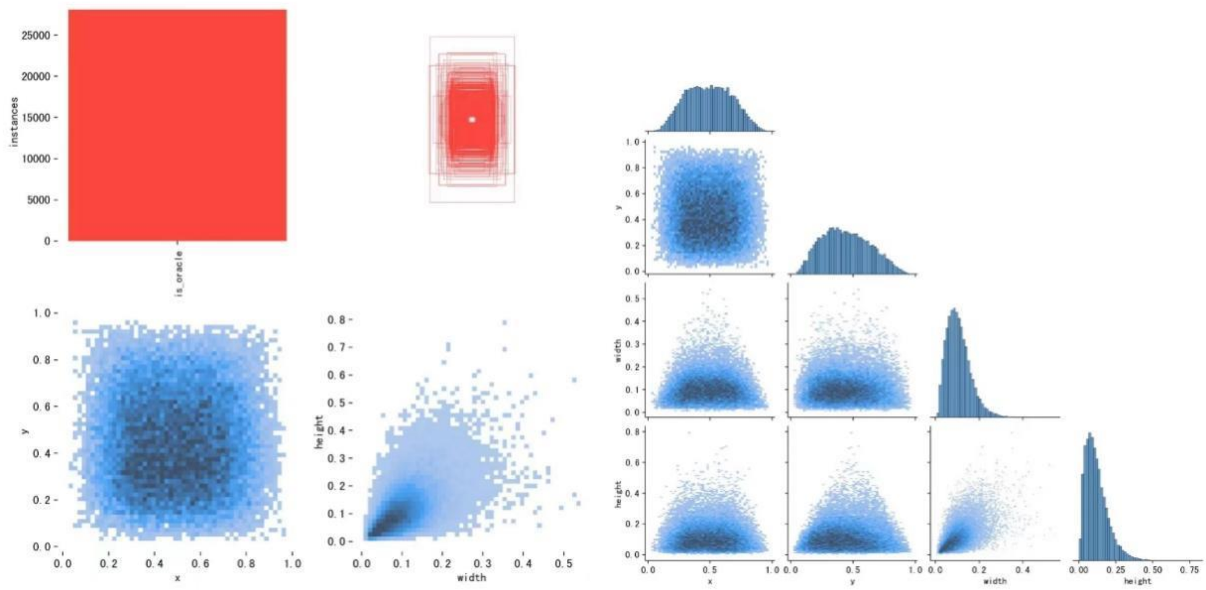


Figure 7. Label statistics chart.

From Figure 7, the paper can clearly see the size and number of the segmented oracle bone rubbing images.

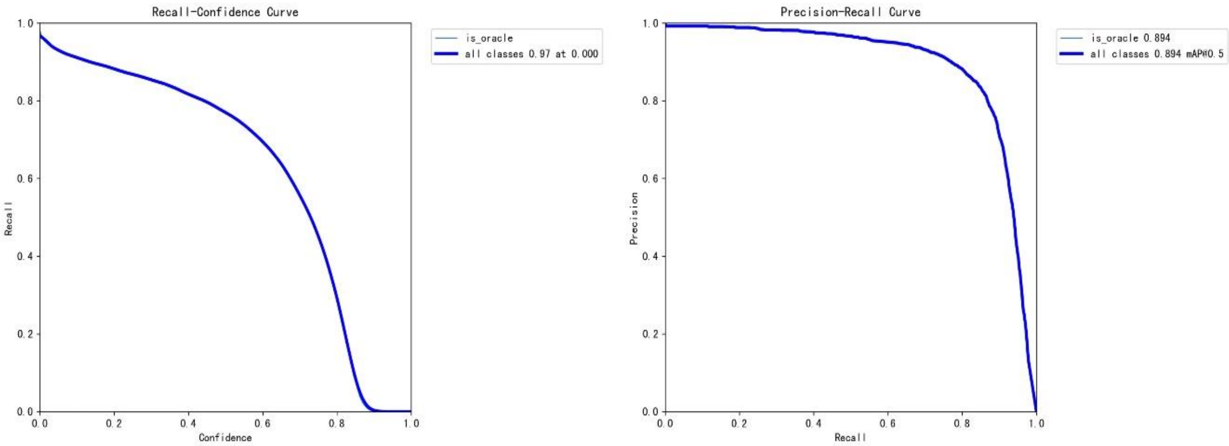


Figure 8. Precision-Confidence Curve.

As can be seen from Figure 8, the confidence gradually approaches 1.0, indicating that the detection is accurate.

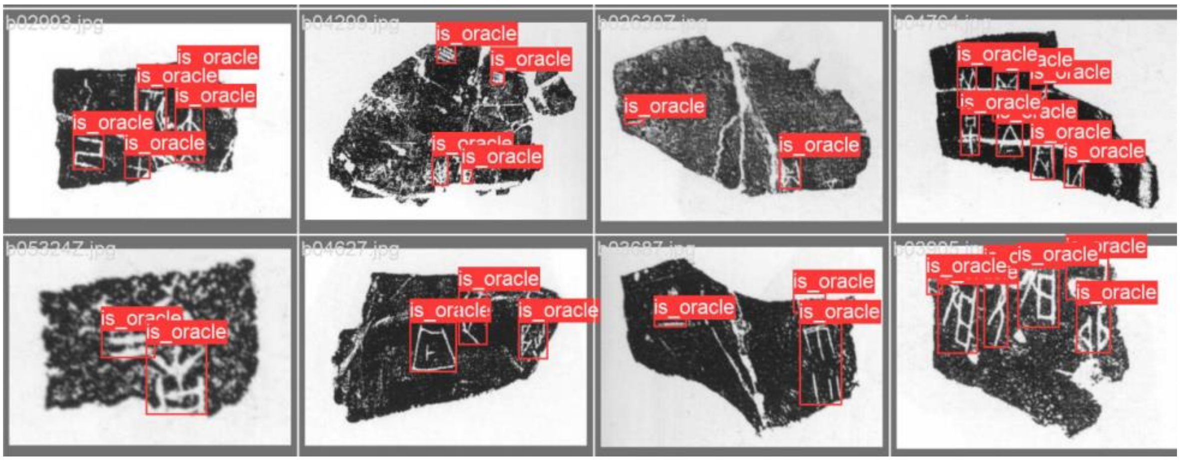


Figure 9. Segmented Oracle rubbing image.

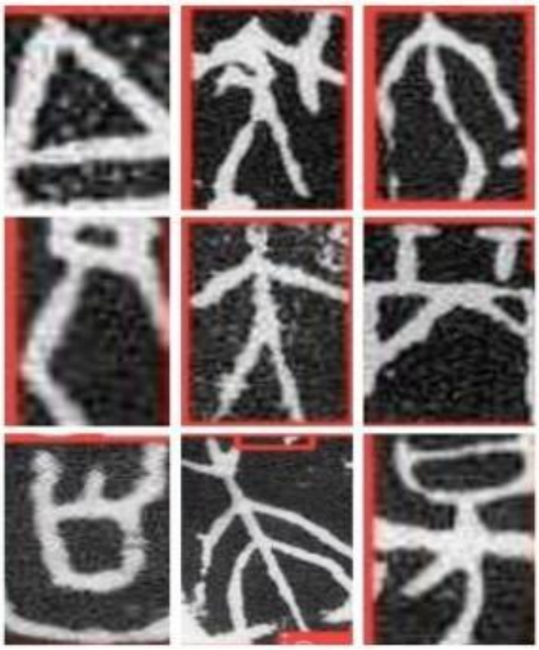


Figure 10. Oracle rubbing image after single character segmentation.

As shown in Figures 9 and 10, the segmented oracle bone inscription image is clearer, making it easier to observe the oracle bone inscriptions and discover their characteristics.

4. Conclusions

This study proposes an automatic segmentation and recognition method for single characters in Oracle rubbings based on YOLOv8, which solves the problems of image complexity and noise interference. Through preprocessing steps such as grayscale, denoising, open operation, binarization and Gaussian filtering, the key features of the oracle image were successfully extracted, noise was effectively removed, contours were repaired, and the accuracy of segmentation and recognition was improved. Experimental results show that training using YOLOv8 can effectively segment and recognize Oracle characters. Edge detection methods such as Canny, Sobel, Prewit and Roberts enhance the structural feature recognition of images and improve recognition accuracy and efficiency. The YOLO algorithm demonstrates high speed and simplicity in real-time object detection tasks, capable of detecting multiple objects simultaneously. To sum up, the method in this paper performs well in segmentation and recognition of oracle bone inscriptions images, and has high practical value and application prospects. Future research can further optimize model parameters and preprocessing steps to improve recognition accuracy and robustness.

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