

# Number Plate Localization, Correction and Recognition for Intelligent Parking Systems

Tian Huang

School of Electronic Information and Electrical Engineering

Yangtze University

Jingzhou, China

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**Abstract:** To address the challenges in recognizing number plate images in car park environments caused by factors such as lighting and tilt, this paper proposes a method for number plate localization and correction based on morphological analysis, the Hough transform and the minimum variance of projected point coordinates. Character segmentation and recognition are achieved using vertical projection and template matching. First, coarse localization of the license plate is achieved through the top-hat transform and Canny edge detection, followed by fine-tuning using prior knowledge such as area and aspect ratio. Next, the Hough transform is employed to detect straight lines in the border for horizontal correction, whilst vertical shearing correction is performed using the criterion of minimum variance of projected point coordinates. Subsequently, the corrected binary image is vertically projected to segment the characters, and finally, the license plate number is output by matching it against a standard template. A parking management system with toll management functionality was developed in the MATLAB environment. Testing was conducted on 57 real-world license plate images, achieving an overall recognition accuracy of 91.2%, thereby validating the effectiveness of the method.

**Keywords:** Vehicle number plate recognition; Morphological processing; Hough transform; Vertical projection; Template matching

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## 1. INTRODUCTION

With the continuous growth in private car ownership in recent years, the demand for automation and intelligence in car park management has become increasingly urgent. As a core component of intelligent parking systems, automatic number plate recognition technology plays a crucial role in vehicle access control, billing and security monitoring. However, in practical applications, license plate recognition faces numerous challenges: outdoor images are easily affected by changes in lighting and weather conditions, leading to low contrast and increased noise; varying shooting angles and vehicle parking positions can cause license plates to appear tilted or even distorted; furthermore, license plate formats in China are diverse, comprising Chinese characters, letters and numbers, with some characters having complex structures; combined with factors such as stains and wear, these all increase the difficulty of accurate recognition.

In recent years, scholars both domestically and internationally have conducted extensive research into license plate recognition. Early

methods primarily relied on texture, color, or edge detection to localize license plates, subsequently integrating skew correction and character recognition technologies to form a complete pipeline. [1]For instance, localization methods based on edge detection and mathematical morphology exhibit a certain degree of robustness against noise; the Hough transform and Radon transform are frequently employed for skew correction; whilst character recognition primarily utilizes approaches such as template matching, neural networks, and support vector machines. However, a single method often struggles to balance real-time performance with accuracy, and in complex scenarios, it is particularly prone to localization failures or character segmentation errors.[2]

This paper designs and implements a complete vehicle number plate recognition workflow tailored for fixed entry and exit points in car parks: during the pre-processing stage, a top-hat transform is employed to enhance contrast; candidate regions are identified using Canny edge detection and morphological closing and opening

operations, and filtered using prior geometric knowledge of number plates; in the correction phase, horizontal correction based on the Hough transform is performed, followed by vertical correction based on minimizing the variance of projected point coordinates; character segmentation employs the vertical projection method, combining the width and spacing features of the license plate characters to precisely locate the boundary of each character; finally, character recognition is completed through normalization and template matching. On this basis, a parking management simulation system integrating recognition and billing functions was constructed using a MATLAB GUI to validate the algorithm's performance.

## 2. OVERALL SYSTEM DESIGN

The intelligent parking system comprises entrance/exit hardware equipment and a MATLAB software management platform. The hardware includes an integrated number plate recognition unit (featuring a camera, auxiliary lighting, and an LED display), a barrier gate, and ground-loop detectors, all arranged on the same side of the lane in accordance with fixed installation specifications. The software component centers on number plate recognition, supplemented by vehicle information management and charging functions. The overall workflow proceeds as follows: a vehicle triggers the ground-loop sensor; the camera captures an image; the number plate recognition algorithm extracts the number plate; a comparison with the database determines the entry or exit status; the entry and exit times are recorded and parking fees calculated; and parking space information is updated whilst the barrier is controlled.

The specific technical approach of the number plate recognition module involves sequentially performing pre-processing, number plate localization, skew correction, character segmentation and character recognition on the captured color images, ultimately outputting the number plate string for subsequent billing management.

## 3. NUMBER PLATE LOCALIZATION AND SKEW CORRECTION

### 3.1 Image Pre-processing and Number Plate Localization

To reduce computational load and improve image quality, the input image is first resized to 650 pixels in the horizontal direction,

smoothed using Gaussian low-pass filtering, and then converted to a greyscale image. To address the issue of uneven lighting in car park images, contrast is enhanced using the top-hat transform: a 15\*15 rectangular structural element is applied to the greyscale image via an opening operation, and the result is then subtracted from the original greyscale image to highlight bright contours such as the number plate area. Subsequently, the Otsu method is used to automatically determine a global threshold, and the difference image is binarized.

On the binary image, edges are extracted using the Canny operator, followed by morphological closing (with a 12\*20 structural element) and opening (12\*15) operations to connect the edges of the license plate characters and eliminate fine noise, resulting in several connected regions. The minimum bounding rectangles of these connected regions are calculated. Given that the width-to-height ratio of standard Chinese number plates is approximately 3.14, a threshold range of 2.1-3.9 for the width-to-height ratio and an area range of 9,000-25,000 pixel are set. Rectangular regions satisfying both conditions are identified as the true number plate positions, thereby achieving a filtering process from coarse to fine localization. The fine localization of the number plate is shown in Figure 1[5][6].



Figure 1 Precise License Plate Localization

### 3.2 License Plate Tilt Correction

Due to the shooting angle, the localized number plate often exhibits horizontal and vertical tilt. In the horizontal direction, utilizing the property that the number plate borders are parallel, the Sobel horizontal edge operator is employed to extract lateral edges, which are then enhanced through dilation. A Hough transform is applied to the processed binary image to detect straight lines within the range  $\theta \in [-90^\circ, 89^\circ]$ , thereby obtaining the tilt angle corresponding to the longer border. To prevent upside-down orientation caused by large-angle rotation, when the absolute value of the calculated angle exceeds  $50^\circ$ , the angle is rotated in the opposite direction by adding

180°. Finally, bilinear interpolation is applied to rotate the original grayscale image of the number plate, thereby achieving horizontal correction.

Horizontal correction can only address overall rotational tilt; the characters on the license plate may still exhibit shearing (vertical tilt). To perform vertical correction, the horizontally corrected image is first binarized again. Morphological operations are then applied to remove small objects such as horizontal connecting lines and rivets, and noise is filtered out using the open operation (threshold 50 pixels), yielding a binary image containing only the characters. Using horizontal and vertical projections, the top, bottom, left and right borders are cropped to retain a clean character region. The center of gravity coordinates are calculated for each connected component (character), calculate the shearing angle for each character, and take the average of all character shearing angles as the shearing angle for the entire image. An affine transformation is applied to the borderless image to perform shearing correction, followed by the removal of any excess black borders resulting from the transformation.[3] This ultimately yields a well-aligned, border-free binary license plate image, laying a solid foundation for character segmentation. The shearing-corrected binary license plate is shown in Figure 2.



Figure 2 License plate after shearing transformation

## 4. CHARACTER SEGMENTATION AND RECOGNITION

### 4.1 Character Segmentation Based on Vertical Projection

The license plate image, following skew correction and border cropping, exhibits a regular character arrangement, allowing direct application of the vertical projection method for segmentation. By counting the number of black (or white) pixels in each column of the binary image, a vertical projection histogram is obtained. Ideally, as there are no connecting strokes between characters, the projection image will form distinct peaks (character regions) and troughs (spacing regions), with projection values at the troughs approaching zero.

During segmentation[4], the projection curve is scanned from left to right. When the projection value in a given column changes from zero to a non-zero value, this is recorded as the left boundary of the character; when it changes from a non-zero value to zero, this is recorded as the right boundary. Once the boundaries of all candidate characters have been obtained, they are verified and filtered using prior knowledge of number plates: based on standard number plate dimensions, the character width is approximately 45 mm, whilst the total plate width is approximately 409 mm. Consequently, the width of a single character should be greater than 1/10 of the total plate width (particularly for wider Chinese characters such as ‘川’) and greater than 1/25 of the total width (taking into account narrower characters such as ‘1’). Furthermore, utilizing the characteristic that the first character (Chinese character) is located at the far left of the number plate, the first character is locked within its possible position range, with the remaining characters arranged sequentially. Ultimately, the 7-character region satisfying the width constraints is retained and normalized to a size of 110 \* 55 for recognition purposes. The image of the character segmentation and normalization is shown in Figure 3.



Figure 3 Character segmentation and normalization

### 4.2 Template Matching Character Recognition

Given that the shapes of the characters on the number plate are relatively standardized following rigorous correction, this paper employs a simple and efficient template matching method[7]. A standard character template library is pre-established, comprising the digits 0-9, the letters A-Z (excluding easily confused characters such as ‘I’ and ‘O’), and the Chinese abbreviations for the 31 provincial-level administrative regions. All templates are stored as binary images with dimensions of 110 \* 55[8].

During recognition, the binary image of the character to be recognized is compared sequentially with samples of the corresponding type in the template library. The proportion of pixel values that match at corresponding positions between the two images is calculated as a measure of similarity. To avoid the time-consuming process of a full-library search, the positional constraints

of the license plate characters are utilized: the first character must be a Chinese character, so only Chinese character templates are matched; the second character must be a letter, so A-Z is matched; the third to seventh characters are either numbers or letters, so the corresponding subsets are matched. The similarity between each character at its respective position and the corresponding template is calculated sequentially, and the character with the highest similarity is selected as the recognition result, ultimately forming the license plate number string.

## 5. EXPERIMENTAL RESULTS AND ANALYSIS

The experimental environment was MATLAB R2021a, running on a computer configured with an AMD Ryzen 5 5500U processor and 16 GB of RAM. Test images were captured using a mobile phone's rear camera at the entrance and exit of a car park, comprising a total of 57 license plate images taken under varying lighting conditions and angles. Within the GUI simulation system, vehicle entry and exit were simulated to trigger recognition, whilst simultaneously managing the number of parking spaces and parking fees. In this system, both character recognition and segmentation results for the license plate recognition were correct. Out of the 57 test images, 52 were successfully recognized, yielding a positioning and recognition accuracy rate of 91.2%. The images where recognition failed were primarily those with severe damage or where the shooting angle was too extreme, resulting in characters being severely smudged together. Overall, the method described in this paper achieved a high accuracy rate in the pre-defined car park environment, and the processing time per image was low, meeting real-time requirements. Furthermore, the integrated fee management function in the system charges at a rate of 2 yuan for every 6 hours. Upon entry and exit, the system automatically generates records containing the license plate number, entry and exit times, and the fee, thereby validating the system's engineering feasibility.

## 6. CONCLUSION

In response to the license plate recognition requirements of smart car parks, this paper has designed a method for license plate localization and correction that combines morphological processing, the Hough transform and minimum variance projection. Character segmentation and recognition are achieved through vertical projection and template matching. Experiments demonstrate that

this method can accurately extract license plate information in approximately 92% of real-world scenarios[9], meeting the application requirements for car park management. Future work could further incorporate deep learning methods to enhance recognition robustness under conditions of similar characters and complex distortions, whilst optimizing hardware-software coordination to achieve more intelligent parking management.

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