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Design and Implementation of Deep Learning Based License Plate Recognition System

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Abstract : With the rapid development of intelligent transportation system, license plate recognition technology, as one of the key technologies, its accuracy and robustness are of great significance to traffic management. This paper proposes a license plate recognition system based on deep learning, aiming at the performance limitations of the existing license plate recognition technology under the influence of environmental factors such as lighting, angle, and site. The system first preprocesses the license plate image, including graying, mean filtering, edge detection and binarization, to improve image quality and reduce noise. Then, the license plate is located by combining geometric and color features, the character boundary area is determined by vertical projection method, and the characters are cut. Finally, by building a convolutional neural network (CNN) model, train and recognize license plate characters. The test and simulation in MATLAB environment show that the system identification accuracy reaches 98.6%, which verifies the effectiveness of the proposed method.

Keywords: License Plate Localization; License Plate Recognition; Convolutional Neural Network; Deep Learning

1. Quote

With the rapid development of social economy and the acceleration of urbanization, cars have become an indispensable means of transportation in people's daily life. The following traffic management problems are also increasingly prominent. How to efficiently and accurately manage the growing number of vehicles has become an important challenge for traffic management departments. As a key component of ITS, license plate recognition technology plays an important role in vehicle monitoring, traffic flow analysis, electronic toll collection, parking lot management and other fields.

License plate recognition system through the automatic identification of vehicle license plate number, to achieve rapid identification and tracking of vehicles. Traditional license plate recognition methods mainly rely on image processing and pattern recognition technology, including image preprocessing, license plate positioning, character segmentation and character recognition and other steps. However, these methods are often difficult to achieve ideal recognition results in the face of complex environments, such as lighting changes, shooting angle, obstruction and defacement.

In recent years, the development of deep learning technology provides a new way to solve this problem. Deep learning, especially convolutional neural network (CNN), has made revolutionary progress in the field of image recognition. By learning the feature representation of a large amount of data, CNN can automatically extract the complex patterns in the image, so as to achieve high accuracy recognition. Applying deep learning technology to license plate recognition can effectively improve the recognition accuracy and robustness of the system.

This paper aims to design and implement a license plate recognition system based on deep learning. The system first preprocesses the collected license plate image to improve image quality and reduce noise interference. Then, the license plate is located by combining geometric and color features to accurately identify the license plate area. Next, the vertical projection method is used to cut each character in the license plate to prepare for character recognition. Finally, the convolutional neural network is used to recognize the characters cut out and realize the automatic output of license plate numbers. The test and simulation in MATLAB environment show that the proposed system can achieve a high accuracy rate of 98.6%, and has good application prospects.

2. License Plate Localization

License plate positioning is a crucial step in the license plate recognition system, which directly affects the accuracy of subsequent character segmentation and recognition. In the complex and changing environment, how to accurately and quickly locate the license plate region from the image is a difficult point in the license plate recognition technology. The license plate localization method proposed in this paper, through a series of image processing techniques, effectively extract the license plate region from the complex background. The following are the detailed step-by-step instructions.

2.1 Image Preprocessing

Image preprocessing is the first step of license plate localization, its purpose is to improve the quality of the image, to lay a good foundation for subsequent processing. The preprocessing steps include.

Grayscale processing: the color image is converted into a grayscale image, which can reduce the amount of calculation and retain the important information of the image. Grayscale processing is achieved by converting the values of the three RGB color channels into a single brightness value, usually using a weighted average method, namely.

Mean filtering: After grayscaling, there may still be some noise in the image, which may interfere with the subsequent edge detection and feature extraction. Mean value filtering is a simple and effective method to remove the noise, it smoothes the image by replacing the value of each pixel with the average of its neighboring pixel values.

2.2 Edge Detection

Edge detection is a technique used in image processing to recognize object boundaries in images. In license plate location, edge detection is helpful to identify the contour of license plate. Canny edge detection algorithm is adopted in this paper, which is a multi-level edge detection algorithm with low false detection rate and good edge location ability. Canny algorithm mainly includes the following steps:

Gaussian Filtering: A Gaussian filter is first used to smooth the image to minimize the effect of noise on edge detection.

Gradient Calculation: Calculate the magnitude and direction of the gradient of the image, the gradient reflects the brightness of the image changes faster or slower, is the basis of edge detection.

Non-maximum suppression: Non-maximum suppression of the gradient magnitude in the gradient direction to refine the edges.

Dual Threshold Detection:Two thresholds are used to determine strong and weak edges.Strong edges are directly considered as edges while weak edges need to be connected to strong edges to be determined.

2.3 Binarization

Binarization is the process of converting an image to contain only two pixel values (usually black and white), which is very useful for subsequent morphological operations and feature extraction. In this paper, adaptive thresholding method is used for binarization, which can automatically adjust the threshold value according to the local brightness of the image to adapt to the image under different lighting conditions, Fig. 1 Binarization diagram.

Figure 1. Binarization Map

2.4 Geometric Characterization

License plates have some obvious geometric features, such as aspect ratio, shape and so on. By analyzing these features, the license plate area can be initially located. For example, the aspect ratio of the license plate is usually within a certain range, and by calculating the aspect ratio of all connected areas in the image, the area that meets the characteristics of the license plate can be filtered out.

1.5 Color Characterization

In addition to geometric features, the color of license plate is also a good location feature. The color of license plates in different countries and regions has certain specifications. Through color clustering algorithm, the regions with similar colors in the image can be grouped to assist in locating license plate regions. Color clustering usually uses the Kmeans algorithm, which can divide the colors in the image into K categories, and assign each pixel to the nearest category according to the similarity of colors.

Through the above steps, the license plate localization method proposed in this paper can effectively extract the license plate region from the complex scene, which provides accurate input for the subsequent character segmentation and recognition.

3. Character Cut

Character cutting is a key link in the license plate recognition system, its purpose is to locate the license plate area after each character segmentation, in order to carry out further recognition. The accuracy of this step directly affects the effect of character recognition. In this paper, we adopt the vertical projection method for character cutting, which is simple and efficient, and can effectively deal with license plate characters of different sizes and fonts. The following are the detailed step-by-step instructions.

3.1 Vertical Projection

Vertical projection is the first step in character cutting, and its purpose is to determine the approximate position of each character by analyzing the pixel distribution in the vertical direction of the license plate area. The specific steps are as follows.

Projection calculation: The image of the license plate area is projected vertically, i.e., the pixels of each column are summed to obtain a one-dimensional array representing the brightness of each column. Each element of this array represents the sum of pixels in the corresponding column, which can reflect the vertical boundary of the character.

Characterization: By analyzing the projection results, it can be observed that the blank areas between characters show low values in the projection array. This is due to the fact that there are no pixels or fewer pixels in the blank areas between the characters, resulting in lower projection values.

3.2 Determination of Boundaries

After obtaining the vertical projection results, the next step is to determine the left and right boundaries of each character based on the projection results. The purpose of this step is to separate the consecutive characters to prepare for the subsequent character recognition. The specific steps are as follows.

Threshold Determination: Based on the statistical properties of the projected array, a threshold value is determined to distinguish between character areas and blank areas. Usually, this threshold can be determined by analyzing the histogram of the projected array.

Boundary localization: The left and right boundaries of a character can be determined by comparing each element of the projection array with the threshold value. When the projection value crosses the threshold from high to low, it can be regarded as the end of a character; when the projection value crosses the threshold from low to high, it can be regarded as the beginning of a new character.

3.3 Character Normalization

After determining the boundary of each character, the next step is to normalize the cut out characters. The purpose of the normalization process is to make all the characters have a uniform size and location, in order to adapt to the subsequent character recognition model. The specific steps are as follows.

Resize: Adjust each character to a uniform size, usually a standard size, such as 28x28 pixels. This step can be achieved by scaling algorithms, such as bilinear interpolation or nearest neighbor interpolation.

Centering: each character is adjusted to the center of the image to reduce the bias of the character recognition model. This step can be achieved by calculating the center of mass of the character and moving it to the center position.

Rotation correction: Characters may be tilted due to the shooting angle. By calculating the tilt angle of the character and performing a rotation correction, the character can be kept horizontal and the accuracy of recognition can be improved.

Through the above steps, the character cutting method proposed in this paper can effectively segment each character from the license plate region and normalize it, providing high-quality input for the subsequent character recognition. This method is robust to different sizes, fonts and styles of license plates and can be adapted to various complex environments.

4. Character Recognition

Character recognition is the core of the license plate recognition system, whose purpose is to accurately recognize characters from the cut character images. With the development of deep learning technology, convolutional neural network (CNN) is widely used in character recognition because of its excellent performance in the field of image recognition. This paper uses CNN to recognize license plate characters. The following is a detailed description of the steps:

4.1 Data Set Construction

The dataset is the basis for training deep learning models, and a high-quality dataset is crucial for the generalization ability of the model. In license plate character recognition, the construction of the dataset includes the following aspects.

Data collection: Collect a large number of license plate images, which should cover different types of license plates, character styles, shooting angles and lighting conditions to ensure that the model can adapt to a variety of real-world scenarios.

Data annotation: the captured license plate images are manually labeled, and the characters in each image are extracted and converted into corresponding labels. This step is the key to data preprocessing, and it is necessary to ensure the accuracy of the labeling.

Data enhancement: In order to improve the generalization ability of the model, more training samples can be generated by data enhancement techniques. Common data enhancement methods include rotation, scaling, cropping and color transformation.

Data partitioning: The labeled dataset is partitioned into training set, validation set and test set. Usually, the training set is used for model training, the validation set is used for model selection and hyper-parameter tuning, and the test set is used to evaluate the final performance of the model.

4.2 Modeling

An appropriate CNN model is crucial to the accuracy of character recognition. The CNN model designed in this paper includes the following main parts:

Input layer: Receive the normalized character image, usually a fixed-size grayscale image.

Convolution layer: extract image features through multiple convolution layers. Each convolution layer is usually followed by an activation function (such as ReLU) to introduce nonlinearity and enhance the expression ability of the model.

Pooling layer: Reduce the spatial dimensions of features by pooling layer (e.g., maximum pooling), while retaining important feature information.

Fully Connected Layer: After convolution and pooling layers, features are mapped to the output space through a fully connected layer. The output dimension of the fully connected layer is usually equal to the number of categories.

Output layer: The output layer usually uses the softmax activation function to convert the output of the full connection layer into a probability distribution, representing the prediction probability of each category.

4.3 Model Training

Model training is a key step in deep learning, the purpose of which is to adjust the model parameters through the optimization algorithm, so that the model can accurately recognize the characters in the training data. The model training methods used in this paper include.

Loss function:A cross-entropy loss function is used to measure the difference between the model predictions and the true labels, and the gradient is computed by a back-propagation algorithm.

Optimization algorithm: Adam or SGD and other optimization algorithms are used to update the model parameters according to the gradient to minimize the loss function.

Hyper-parameter tuning: the hyper-parameters of the model (such as learning rate, batch size, etc.) are tuned through the validation set to improve the performance of the model, Fig. 2 Error value change curve.

Regularization: to prevent over fitting, regularization techniques such as dropout or weight attenuation can be introduced in the training process.

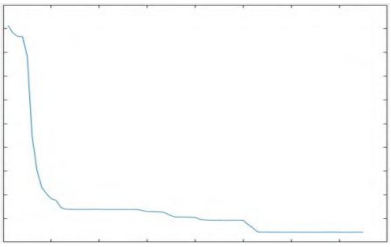

Figure 2. Variation Curve of the Error Value

4.4 Model Testing

Model testing is an important part of evaluating the performance of a model, and its purpose is to assess the generalization ability of a model on an independent test set. The model testing methods used in this paper include.

Performance evaluation: Evaluate the trained model using the test set and calculate the recognition accuracy, precision, recall and other indicators.

Confusion matrix: analyze the performance of the model on different categories through the confusion matrix to identify the strengths and weaknesses of the model.

Error analysis: analyze the samples that are wrongly identified by the model, find out the shortcomings of the model, and propose the improvement plan.

Model deployment: deploy the tested model to the real application for real-time license plate recognition task.

Through the above steps, the license plate character recognition method based on CNN proposed in this paper can effectively recognize the license plate characters in various complex environments, providing an accurate character recognition capability for the license plate recognition system. This method has good robustness and generalization ability in practical applications, and can meet the needs of intelligent transportation systems.

5. Simulation

Simulation test is an important part of verifying the performance of license plate recognition system. The effectiveness and robustness of the system in practical application can be evaluated by simulating the system in the MATLAB environment. The following are the detailed steps of the simulation test:

5.1 Test Data Preparation

The quality and diversity of test data directly affects the results of simulation testing. To ensure the comprehensiveness and accuracy of the tests, the following types of test data need to be collected and prepared.

Images under different lighting conditions: including license plate images taken under strong light, backlight, shadow and other conditions to test the performance of the system under light changes.

Images from different angles: Including license plate images taken from front, side, top and top view, in order to test the adaptability of the system to the shooting angle.

Images under different site conditions: including images of license plates taken at different sites, such as highways, city roads and parking lots, in order to test the performance of the system in different application scenarios.

Images of different license plate types: including license plates issued in different regions and years, as well as temporary license plates and special vehicle license plates, etc., in order to test the system's ability to recognize different license plate types.

Contains occluded and defaced images: This includes images of license plates that are occluded or defaced by dirt, dust, scratches, etc. to test the robustness of the system in the face of imperfect conditions.

5.2 System Testing

System testing is to input the prepared test data into the license plate recognition system and record the recognition results of the system. The testing process includes the following steps.

Data input: import the test data set into the MATLAB environment, and preprocess according to the system processing order, including graying, filtering, edge detection, etc.

Figure 3. Edge Detection Graph

License plate localization: use the license plate localization algorithm implemented in the system to process each image and extract the license plate region.

Character cutting: cut the characters of the localized license plate area and extract the image of each character.

Character recognition: input the cut character image into the trained CNN model for character recognition.

Record of results: Record the recognition results of the system for each test image, including the sequence of recognized characters and recognition time and other information.

5.3 Performance Evaluation

Performance evaluation is the process of analyzing the performance of the system under different conditions and counting the recognition accuracy of the system. The evaluation process consists of the following steps.

Accuracy statistics: Calculate the recognition accuracy of the system on the entire test dataset, i.e. the ratio of the number of correctly recognized license plates to the total number of tests.

Performance analysis: Analyze the performance of the system under different lighting, angle and site conditions, and identify the strengths and weaknesses of the system.

Error analysis: Samples of system recognition errors are analyzed to find out the recognition errors of the system under specific conditions and to analyze the causes of the errors.

Robustness test: Evaluate the robustness of the system in the face of imperfect conditions such as occlusion and contamination, and test the reliability of the system in practical applications.

Real-time testing: Evaluate the time required by the system to process each test image, and test whether the system meets the demand for real-time processing.

Through the above simulation test steps, the performance of the proposed license plate recognition system can be comprehensively evaluated in practical applications. The simulation results will provide an important reference for the optimization and improvement of the system, and lay a foundation for the practicalization and industrialization of the system.

6. Conclusion

The deep learning based license plate recognition system proposed in this paper achieves high accuracy recognition of license plates in complex environments through a series of innovative technical means. The following is a summary of the main conclusions and future research directions of this paper's work.

Main conclusions

1. High accuracy recognition: The simulation test in the MATLAB environment shows that the system can achieve a recognition accuracy of 98.6%, which proves the effectiveness of the depth learning model in the task of license plate character recognition.
2. Robustness: The system can maintain high recognition accuracy under different lighting, angle and site conditions, showing good robustness. This is mainly due to the design of image preprocessing and license plate localization algorithms, which can effectively cope with the changes of the complex environment.
3. Automated process: from image pre-processing to license plate positioning, to character cutting and recognition, the whole process is automated, reducing manual intervention and improving the efficiency of the recognition process.
4. Advantages of deep learning model: The convolutional neural network (CNN) model used can automatically learn image features without manually designing feature extraction algorithms, which simplifies the development process and improves the accuracy of recognition.

In conclusion, the deep learning-based license plate recognition system proposed in this paper has achieved certain results in theory and practice, but it still needs to be optimized and improved in practical applications to achieve wider commercialization and practicality.

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