



An Incomplete License Plate Image Intelligent Recognition System Based on the Generated Counter Network

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Abstract. In order to solve the problems of high recognition accuracy and long time-consuming recognition in the traditional incomplete license plate image recognition system, the paper proposes an incomplete license plate image intelligent recognition system based on a generative confrontation network. According to the composition of the recognition system, the framework of the intelligent recognition system for incomplete license plate images is designed. The hardware platform of the system is the S3C6410 embedded development board, which is based on Samsung's ARM11 processor chip, and the CPU is based on the ARM111176JZF-S core design. A powerful multimedia processing unit is integrated inside, which supports hardware encoding and decoding of video files in formats such as Mpeg4, H.264/H.263, and can be output to LCD and TV display at the same time. The 6410 uses a high-density 6-layer board design, which integrates 256M DDR RAM, 256M/1 GB SLC Nand Flash memory. The system software uses a generative confrontation network to repair the incomplete license plate image, and combines the template matching method to complete the license plate image recognition. Experimental results show that the designed intelligent recognition system has high recognition accuracy and can effectively reduce the time-consuming recognition.

Keyword: Generative counter measure network · Incomplete license plate image · Intelligent recognition

1 Introduction

License plate image intelligent recognition system is a special computer vision system, which takes the car photo as a specific target. It is one of the important research topics of computer vision and pattern recognition in the field of intelligent transportation. It can be widely used in traffic flow detection, traffic control and guidance, intelligent community management, automatic toll collection without stopping, red light running and other illegal vehicle monitoring, vehicle security and other fields, and has broad application prospects [1–3].

With the rapid development of China's economy, the scale of highway network is expanding, and effective traffic management technology is extremely necessary and

urgent. The traffic management mode mainly includes artificial traffic management and intelligent transportation system management. Because the latter can save a lot of manpower and material resources, intelligent transportation system has become the main direction of traffic management development. Intelligent transportation system integrates the traffic management system effectively by means of control, communication, computer and optics, and realizes the efficient, accurate and comprehensive transportation management. License plate recognition system, as an important tool of intelligent transportation system, plays an important role in intelligent traffic management. With the rapid development of digital image processing technology, license plate recognition system has been continuously optimized. The main task of license plate recognition system is to process and analyze the license plate image collected by camera, so as to complete the recognition of vehicle license plate information [5–7].

License plate is the unique sign of vehicles, and its recognition is conducive to the accurate and efficient management of transportation. Since the 21st century, the domestic license plate recognition technology has developed rapidly. Researchers have proposed a variety of license plate location and recognition methods based on the characteristics of Chinese license plate, but most license plate recognition systems have many limitations, such as: the resolution of license plate image must be high and clear as a whole; There should be no text advertisements around the license plate; The license plate shall not be seriously tilted or incomplete. Therefore, it is of great significance to study a management system which can locate and recognize license plate efficiently and accurately.

Therefore, this paper proposes an intelligent recognition system of incomplete license plate image based on generative countermeasure network. The overall design idea of the system is: Based on S3C6410 embedded development board, the hardware platform of the system is designed to realize the real-time transmission and display of license plate image, and the software part of the system uses generative countermeasure network to repair the incomplete license plate image, combined with the template matching method to complete the license plate image recognition. Finally, the effectiveness of the designed system is verified by experiments.

2 Design of Intelligent Recognition System for Incomplete License Plate Image

The completed license plate recognition system is generally composed of vehicle perceptron, image acquisition, license plate character recognition, recognition result output and other parts [8].

Vehicle sensor is to sense whether the vehicle has reached, whether to capture and obtain the image. There are external trigger devices commonly used, such as: ground sensor coil sensor, which triggers the signal when the vehicle comes and sends it to the system to capture the license plate image. In addition, there are other trigger methods, such as video stream trigger.

Image acquisition, this process is mainly when there is a trigger signal, the use of cameras and other image acquisition devices to capture the vehicle image, stored in the license plate recognition system, easy to further identify [9–11].

License plate recognition, the main function is to process the captured license plate image, including image binary, license plate positioning, character segmentation and other parts. The special feature of the system is to use the generated counter network to recover incomplete images, and finally output the license plate recognition results through character recognition [12, 13].

The output of recognition results, the identified string shall be output to other systems or devices through other interfaces for other systems.

The system framework structure is shown in Fig. 1.

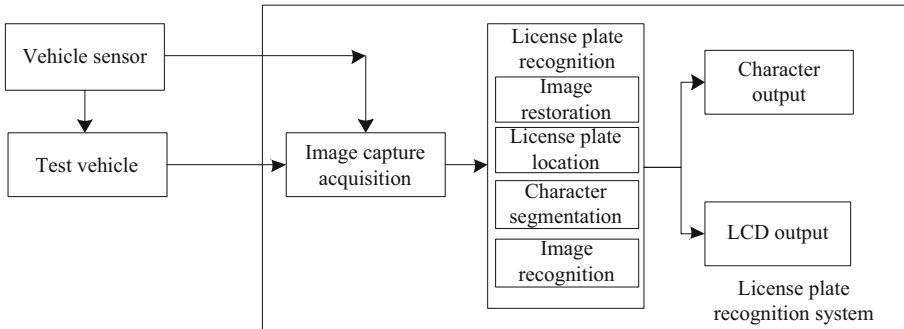


Fig. 1. Frame structure of license plate recognition system

The working principle of the system is: when the vehicle passes through the monitoring area, the vehicle monitoring unit is triggered, the signal is transmitted to the camera, the camera collects the vehicle license plate image and transmits the image to the recognition processing unit for license plate recognition, and the recognition results are displayed on the LCD.

2.1 System Hardware

The hardware platform of the system is the S3C6410 embedded development board, which is based on Samsung's ARM11 processor chip, the CPU is based on the ARM111176JZF-S core design, and a powerful multimedia processing unit is integrated inside. Supports hardware encoding and decoding of video files in formats such as Mpeg4, H.264/H.263, and can be output to LCD and TV display at the same time. The 6410 uses a high-density 6-layer board design, which integrates 256M DDR RAM, 256M/1GB SLC Nand Flash memory. It adopts 5V power supply, realizes various core voltage conversions necessary for the CPU on the motherboard, and also has a professional reset chip. It has the characteristics of high performance, rich interfaces, small size and low power consumption. It is suitable for the secondary development of various mobile handheld devices. The camera uses a USB camera to obtain license plate images, and the LCD display is a 4.3-in. touch screen.

The software operating environment for license plate image recognition is an embedded Linux operating system, and the development environment is Qt. Qt is used

for visual programming. At the same time, the machine vision library OpenCV is used for image processing when processing images.

2.2 System Software

Incomplete Image Restoration Based on the Generated Counter Network

The generative confrontation network was designed and proposed in 2014. It is a generative model. Its core idea is a two-person zero-sum game. The generative confrontation network model is composed of a generative network G and a discriminant network D . The generative network G generates new data by continuously learning the probability distribution of real data and using the learned distribution model. The role of the discriminant network D is to optimize the mutual parameters of the real data and the generated network without much prior knowledge of the image. Improve their respective generation judgment ability, and finally make the data generated through the generation network very close to the real data. The original model framework of the generative confrontation network is shown in Fig. 2.

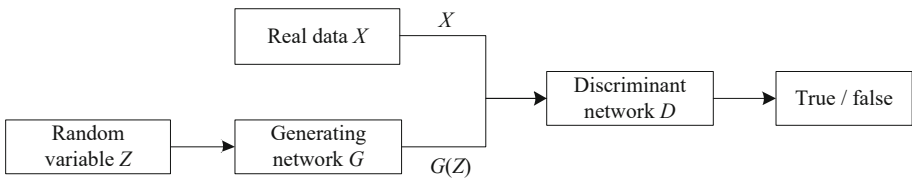


Fig. 2. GAN structure

The random noise vector Z is input to generate the network G and output $G(z)$. When the input data of the discrimination network D is $G(z)$, D outputs 0. The purpose of network countermeasure training is to make $G(z)$ close to the real data distribution P_{date} . After continuous confrontation training and iterative optimization, when D is unable to identify the data source, it is considered that the generated network has learned the real data distribution [14–16].

The loss function of generating network G is as follows:

$$\min_G(D, G) = E_{z \sim p_z(z)}[\log(1 - D(G(z)))] \tag{1}$$

The loss function of network D is as follows:

$$\max_D V(D, G) = E_{x \sim p_{date}(x)}[\log(1 - D(x))] + E_{z \sim p_z(z)}[\log(1 - D(G(z)))] \tag{2}$$

The total loss function of the model is as follows:

$$\min_G \max_D (D, G) = E_{x:p_{date}(x)}[\log D(x)]J + E_{z:p_z(z)}[1 - D(G(z))] \tag{3}$$

In the formula, E is the function of distribution function, p_{date} is the real data distribution, p_z is the noise distribution.

Incomplete license plate image restoration is an attempt to use the prior knowledge of the degradation process to restore the original appearance of the degraded image, that is, according to the causes of degradation, analyze the environmental factors causing degradation, establish the corresponding data model, and restore the image along the reverse process of the degradation of license plate image.

In practical application, it is usually assumed that the transmission system is a linear system, and the original image $f(x, y)$ passes through the system $h(x, y)$. $h(x, y)$ is a system function obtained by integrating all degradation factors, which is called impulse response or point spread function in urban-rural system. The structure of the basic degradation model is shown in Fig. 3.

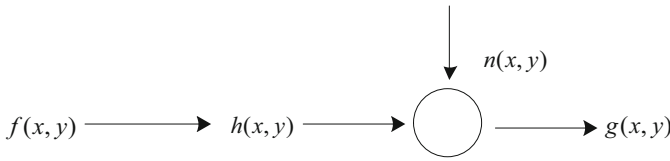


Fig. 3. Degradation model

In Fig. 3, $g(x, y)$ is the actual degraded image, and $n(x, y)$ is the incomplete noise model.

According to the degradation model shown in Fig. 3, the problem of image restoration can be regarded as a process of estimating the original image $f(x, y)$ and making the estimated image as close as possible to the real image $f(x, y)$ according to the obtained incomplete image $g(x, y)$, the prior knowledge of $h(x, y)$ and some statistical properties of incomplete noise $n(x, y)$. If there is no prior knowledge of PSF, incomplete image restoration is more difficult.

According to the image degradation block diagram, the degradation model can be expressed as:

$$g(x, y) = f(x, y) * h(x, y) + n(x, y) \tag{4}$$

In practical applications, all digital images are processed, and the above formula is expressed in discretized form as follows:

$$g(x, y) = \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} f(m, n)h(x - m, y - n) + n(x, y) \tag{5}$$

In the formula, $x = 0, 1, 2, \dots, M - 1, y = 0, 1, 2, \dots, N - 1$.

In practical applications, image integrity restoration is often carried out without knowing the PSF, and blind deconvolution restoration is proposed in this context. Blind deconvolution restoration is an image inpainting method that uses the original incomplete image to estimate PSF and complete image at the same time.

It can be seen from the above formula that deconvolution must be performed to solve f . Using the method of least squares constraint, constrain f and h at the same time, and choose $r(f) + r(h)$ as the penalty function, which can be obtained by the above formula:

$$n = g - h * f \tag{6}$$

and:

$$E\left(\int n^2 dx\right) = \sigma^2 \tag{7}$$

and there are:

$$H_1(u) = \int |\nabla u|^2 dx dy \tag{8}$$

So:

$$|h * f - g|^2 = E\left[\int (h * f - g)^2 dx\right] \approx E\left(\int n^2 dx\right) = \sigma^2 \tag{9}$$

Then the image integrity repair problem can be attributed to the following minimum constraint problem:

$$\min[\partial_1 r(f) + \partial_2 r(h)] \tag{10}$$

When

$$\|h * f - g\|^2 = \|n\|^2 \approx \sigma^2 \tag{11}$$

The corresponding Lagrangian form is:

$$\min L(f, h) = \min\left[\|h * f - g\|^2 + \alpha_1 r(f) + \alpha_2 r(h)\right] \tag{12}$$

The α_1 and α_2 are coefficients after the Lagrangian multiplier. The key to the problem is the selection of $r(f)$ and $r(h)$. If ∇ is gradient operator in H_1 rule, the above equation can be written as follows:

$$\begin{aligned} \min L(F, H) &= \min \left[\|h * f - g\|^2 + \alpha_1 \int |\nabla f|^2 dx dy + \alpha_2 \int |\nabla h|^2 dx dy \right] \\ &= \min \left[(h * f - g)^2 dx dy + \alpha_1 \int |\nabla f|^2 dx dy + \alpha_2 \int |\nabla h|^2 dx dy \right] \\ &= \int \min \left[(h * f - g)^2 + \alpha_1 |\nabla f|^2 + \alpha_2 |\nabla h|^2 \right] dx dy \end{aligned} \tag{13}$$

The partial derivative of the part within the integral sign in the above formula can be obtained as follows:

$$0 = h(-x, -y) * (h * f - g) - 2\alpha_1 \Delta f \tag{14}$$

$$0 = f(-x, -y) * (h * f - g) - 2\alpha_2 \Delta h \tag{15}$$

In the formula, Δ is Laplace operator. In the practical application, the processing is all digital images, and the corresponding discretization form is as follows:

$$H * (Hf - g) - \alpha_1 \Delta f = 0 \tag{16}$$

$$F * (Fh - g) - \alpha_2 \Delta h = 0 \tag{17}$$

After finishing the above formula, we can get:

$$[H * H + \alpha_1(-\Delta)]f = H * g \tag{18}$$

$$[F * F + \alpha_2(-\Delta)]h = F * g \tag{19}$$

Let $F(\xi_x, \xi_y)$ be the Fourier transform of $f(m, n)$, $h(\xi_x, \xi_y)$ be the Fourier transform of $h(m, n)$, $G(\xi_x, \xi_y)$ be the Fourier transform of $g(m, n)$, and $R(\xi_x, \xi_y)$ be the Fourier transform of $(-\Delta)$, then the frequency domain form of the above two equations is:

$$F(\xi_x, \xi_y) = \frac{H * (\xi_x, \xi_y)G(\xi_x, \xi_y)}{|F(\xi_x, \xi_y)|^2 + \alpha^2(\xi_x, \xi_y)} \tag{20}$$

$$H(\xi_x, \xi_y) = \frac{F * (\xi_x, \xi_y)G(\xi_x, \xi_y)}{|F(\xi_x, \xi_y)|^2 + \alpha_2 R(\xi_x, \xi_y)} \tag{21}$$

Here is an empirical formula for R :

$$R = (\xi_x, \xi_y) = 4 - 2 \cos(2\pi\xi_x/M) - 2 \cos(2\pi\xi_y/M) \tag{22}$$

In order to improve the accuracy of restoration, the iterative method is adopted. First fix h^k , solve $f^{(k+1)}$, and then solve $h^{(k+1)}$ according to $f^{(k+1)}$. In this way, the iteration formula is as follows:

$$F^{(k+1)}(\xi_x, \xi_y) = \frac{H^{k^m}(\xi_x, \xi_y)G(\xi_x, \xi_y)}{|H^k(\xi_x, \xi_y)|^2 + \alpha_1 R(\xi_x, \xi_y)} \tag{23}$$

$$H^{(k+1)}(\xi_x, \xi_y) = \frac{F^{(k+l)^m}(\xi_x, \xi_y)G(\xi_x, \xi_y)}{|H^{(k+l)}(\xi_x, \xi_y)|^2 + \alpha_2 R(\xi_x, \xi_y)} \tag{24}$$

Through the above formula, the incomplete image restoration is completed by generating the anti network.

License Plate Character Recognition

The purpose of character recognition is to transform image into text information, which is an important branch of pattern recognition. As the last part of license plate recognition system, character recognition accuracy directly affects the performance of the whole license plate recognition system. In addition, the accuracy of character recognition method is seriously affected by the result of character segmentation. If the method of character recognition is based on machine learning, its recognition accuracy is also affected by the completeness of the training set.

The main steps of the character recognition algorithm based on template matching are:

First, compare the characteristics of the character to be recognized with the characteristics of the standard character; then, find the most similar expression form, then the recognition result is the character corresponding to this expression form.

The essence of the character recognition method based on template matching is to calculate the similarity between the training sample and the test sample. The category of the training sample with the greatest similarity to the test sample is the category of the test sample. Using character characteristics and matching principles to recognize character images is to judge test samples and training in a classification model. A character recognition algorithm for template matching will be described in detail below.

Suppose that the function $f(x, y)$ represents the input character, the function $F(x, y)$ represents the standard template, and the output result is $T(x, y)$. Now, using the correlation quantity x_1 and x_2 to represent the random variable, the output result is as follows:

$$T(x_1 - x_2, y_1 - y_2) = \iint f(x, y)F(x + (x_1 - x_2), y + (y_1 - y_2))dxdy \quad (25)$$

When $x_1 = x_2, y_1 = y_2,$

$$T(0, 0) = \iint f(x, y)F(x, y)dxdy \quad (26)$$

When $f(x, y) = F(x, y),$

$$T(0, 0) = \iint f(x, y)f(x, y)dxdy \quad (27)$$

That is, the correlation function of the test sample, and $T(0, 0) \geq T(x, y)$. $T(0, 0)$ is the main peak of $T(x, y)$, and there will be some sub peaks which are not equal to the main peak in other characters. Then, the character category can be determined by setting the threshold.

The size of the test image and the training image is normalized, and then the similarity between the template and the character image is calculated. Suppose that the image to be detected is represented as $F(m, n)$, the image sub image to be detected is represented as $F_{xy}(m, n)$, the coordinates of the upper left corner pixel of the sub image in the image are (x, y) , and the template image is $T(m, n)$, then the correlation operator $R(x, y)$ is:

$$R(x, y) = \frac{\sum_{m=1}^M \sum_{n=1}^N F_{xy}(m, n) * T(m, n)}{\sqrt{\sum_{m=1}^M \sum_{n=1}^N (F_{xy}(m, n))^2 \sum_{m=1}^M \sum_{n=1}^N (T(m, n))^2}} \quad (28)$$

The best matching template is the corresponding template with the largest correlation operator. Since the original image is a binary image, the above formula can be simplified to:

$$D(x, y) = \sum_{m=1}^M \sum_{n=1}^N F_{xy}(m, n) \oplus T(m, n) \quad (29)$$

In the formula, the smaller the value of $D(x, y)$, the better the repair effect of incomplete license plates.

3 Experimental Verification

In order to verify the practical application performance of the proposed intelligent recognition system of incomplete license plate image based on generative counter-measure network, simulation and comparative verification experiments are carried out.

3.1 Experimental Scheme

System experiment environment:

Hardware: Intel Core i5@2.6 GHz, RAM 8 GB.

Software: Windows 10 64-bit operating system, Microsoft Visual C++ 2017 (v141), Qt 5.10.1 (Open Source License).

Experimental data: There are few publicly available incomplete license plate image databases. In order to better carry out simulation experiments, 3000 pairs of images have been collected from the network image library and the GoPro data set to form a data set. Each pair of images contains an incomplete image and a corresponding complete image. Therefore, the number of images used in the experiment is 1500, and the resolution size of the image pair is set to 256×256 . The sample image is shown in Fig. 4.



Fig. 4. Sample image

Experimental scheme: Taking the incomplete license plate recognition accuracy and recognition time as the experimental comparison index, this method is compared with the traditional method.

3.2 Analysis of Experimental Results

Recognition Accuracy

Because the license plate images are incomplete, it is necessary to verify the recognition accuracy of incomplete license plate images. The comparison results of the recognition accuracy of incomplete license plate image between the proposed method and the traditional method are shown in Fig. 5.

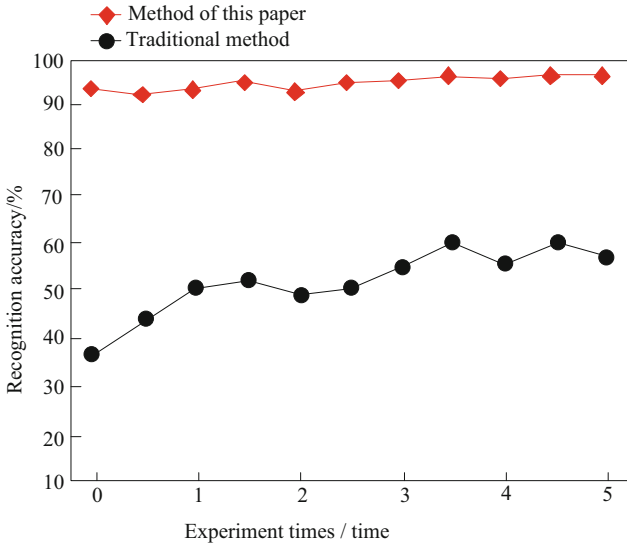


Fig. 5. Comparison of image recognition accuracy of incomplete license plates

The results of the comparison of the image recognition accuracy of incomplete license plate shown in Fig. 5 show that the recognition accuracy of this method is basically kept at more than 90%. Although the traditional method can keep the fluctuation rising state, the maximum recognition accuracy is still not 70%.

Identification Time

In the process of recognizing incomplete license plate image, it is necessary to restore the incomplete license plate image, so it is necessary to verify the recognition time of incomplete license plate image. The results of time-consuming comparison between the proposed method and the traditional method for recognition of 1500 license plate images are shown in Table 1.

Table 1. Comparison results of incomplete license plate image recognition

Experiment times/time	Identification time/s	
	Method of this paper	Traditional method
1	1423	1898
2	1412	1941
3	1429	1967
4	1408	1983
5	1431	2011
Mean value	1420.6	1960

From the time comparison results of incomplete license plate image recognition shown in Table 1, it can be seen that when there are 1500 incomplete images to be recognized, the average recognition time of this method is 1420.6s, while the average recognition time of traditional method is 1960s. Therefore, this method can effectively reduce the recognition time.

4 Conclusion

License plate recognition is one of the research hotspots in the field of modern computer vision and pattern recognition. With the wide application of intelligent transportation system and the rapid growth of vehicle data, it is more and more important to use license plate recognition system for vehicle management and road dredging. License plate recognition is paid more and more attention by domestic and foreign scientific research institutions. In the context of the popularity of mobile office and mobile commerce, the mobile license plate recognition is also on the agenda. However, the current license plate recognition system used in complex background, its recognition accuracy is not high enough. Therefore, it is of great significance for traffic management to develop a license plate recognition system with perfect functions and high recognition accuracy. In this paper, the incomplete license plate image recognition system based on generative countermeasure network is comprehensively designed. The recognition performance of the designed system is verified by experiments. The method has high recognition accuracy and efficiency in incomplete license plate image recognition.

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 2. Project name: The work was supported by the Science and Technology Research Program of Chongqing Municipal Education Commission, project number: KJZD-K201801901
 3. roject name: research and design of intelligent manufacturing cloud platform system based on Internet of things, project number: KJQN201801902

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