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An Autonomous License Plate Detection Method

Hsiao-Chen Kuo
Department of Management Information Systems
Far East University
Tainan, Taiwan, R.O.C.
ginkoo@cc.feu.edu.tw

Jiann-Shu Lee
Department of Computer Science and Information Engineering
National University of Tainan
Tainan, Taiwan, R.O.C.
cslee@nutn.edu.tw

Sho-Tsung Kao
Department of Information and Learning Technology
National University of Tainan
Tainan, Taiwan, R.O.C.

***Abstract*—Detection of license plate is an important process in intelligent transportation systems before license plate recognition. In this paper, we proposed an autonomous license plate detection system with computer vision instead of sensors. Using characteristics of dynamic images, our system rapidly identifies the license plate region. The system consists of two subsystems: car detection subsystem and plate extraction subsystem. Car detection subsystem uses MMADR and NDDR of dynamic images to find the location of cars on the screen. Plate extraction subsystem uses the characteristics of the plates and plate searching algorithm to extract plate image. Experimental results show that our system can effectively detect vehicles and locate the plates under different environments.**

Keywords-license plate detection; computer vision;

I. INTRODUCTION

As a result of rapid economic development, quantity and traffic of vehicles has substantially grown up. With an increasingly complex environment there is a serious bottleneck in the management of traffic. Intelligent Transportation System (ITS) has now become the main development direction of traffic management, and license plate detection and recognition system is an important role in the ITS.

License plate detection and recognition system can be widely used in automated management systems, such as: automated car parking management, automated toll station, as well as the stolen cars detection. Because the failure rate of employees who work in toll stations or in car park would increase when they engaged in monotonous and repetitive work for a long time, a stable and reliable automated management system not only can do unmanned control, but also can save the cost of management.

The existing license plate detection and recognition systems can be divided into two major categories: on lane and on road. Those on road applications have wide fields of vision, and therefore the region of plate is small within captured image. Less information causes difficulty to detect plate and recognize. And those on lane applications often used at car park or entrance of place. Many of those are using some sensors to determine the car has been stopped in the appropriate place before capturing image, and then detect plate on predefined area. The plate would not be detected if the car is not at proper position.

To avoid the drawback due to sensor failures and avoid poor performance of detection system that caused by uncertain location of parking on restricted lane, this paper presents an autonomous license plate detection system without using other sensors. The system determines whether a vehicle stop only by visual information, and dynamically determines plate location especially on open lane. Therefore, our system can be applied to the place with an open lane such as hotel or community.

The rest of this paper is organized as follows. Section 2 surveys the related plate detection methods. Section 3 introduces the proposed car detection method and plate extraction algorithm. Section 4 presents the experimental results and performance of our system. Finally, we have conclusion remarks in Section 5.

II. RELATED WORKS

Some papers have been proposed for license plate detection or extraction. Yong[1] makes use of edges in horizontal and vertical of image and properties from binary image to find out the location of plate. Bai[2] generates edge density map by Sobel mask at first. Dilation operator is done after binary and nonlinear filtering on edge density map. Then, the plate area is located. Gray-scale image is used as a source in Yong's and Bai's method.

On the other hand, some approaches take advantage of color features. In [3], Zhu firstly confirms the background color of license plate by way of linear combination of R, G and B and make it as the candidate license plate area, then uses the mathematical morphology like erosion, dilation, opening and closing, gets certain position of the plate region finally. Wu[4] and Wei[5] take HIS components of 9 pixels from each 3×3 region on captured plate image as inputs of Multi-Layer Perceptron Networks (MLPN) to determine whether the pixel is point of the license plate or not.

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III. AUTONOMOUS LICENSE PLATE DETECTION SYSTEM

Our proposed system consists of two subsystems: car detection subsystem and plate extraction subsystem. Car detection subsystem uses Minimum Moving Amount Decision Rule (MMADR) and Nearest Distance Decision Rule (NDDR) of dynamic images to find the location of cars on the screen. Plate extraction subsystem uses the characteristics of the plates and plate searching algorithm to extract plate. The details will be described in the following subsections.

A. Car Detection Subsystem

We use dynamic images from gray-scale video camera as input of our system. First of all, we define DI_t as the difference between two adjacent image frames I_{t-1} and I_t, that is

$$DI_t(x,y)=\left|I_t(x,y)-I_{t-1}(x,y)\right|. \tag{1}$$

Otsu's method is used to automatically perform image thresholding on DI_t, we have

$$BI_t(x,y)=U\left(DI_t(x,y)-Th\right) \tag{2}$$

where

$$U(v)=\begin{cases}1 & if \quad v>0\\ 0 & otherwise.\end{cases} \tag{3}$$

Binary image BI_t can be used to determine frame rate for car detection subsystem. Essentially the greater the frame rate, the better the effect of detection, but the more calculation of system. However, reducing the frame rate can reduce the calculation, but would decrease the effect of detection. We want to find the lowest frame rate with acceptable effect of detection. Signal to Noise Ratio (SNR) is chosen for this purpose. Suppose that the greatest frame rate is 30. SNR is defined as

$$SNR^n=\frac{\sum_x\sum_y BI^{30}}{\sum_x\sum_y\left(BI^{30}\otimes BI^n\right)} \tag{4}$$

where BI^n is BI_t at frame rate of n. Table I compare 4 SNR values at frame rate 1, 5, 10, 15. SNR^{10} and SNR^{15} are very close. Because of the performance considerations we chose 10 as the video frame rate in our system.

Let VP_t and HP_t be the vertical and horizontal projection of BI_t, defined respectively as

$$VP_t(x)=\sum_{y=0}^{N-1}BI_t(x,y) \tag{5}$$

and

$$HP_t(y)=\sum_{x=0}^{M-1}BI_t(x,y). \tag{6}$$

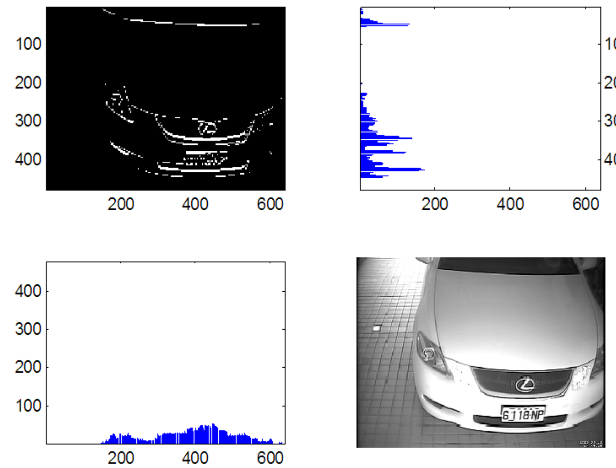

Figure 1. Example of $VP_t(x)$ and $HP_t(y)$ from a captured image.

TABLE I. COMPARISON OF SNR AT DIFFERENT FRAME RATE

Frame rate (Frames/second)	SNR
1	0.2383
5	0.3953
10	0.8614
15	0.8695

Taking the largest component in $VP_t(x)$ and $HP_t(y)$, we have VP_t^S as left border, VP_t^E as right border and HP_t^S as front border at I_t frame. For example, Fig. 1 is a captured image at time t, and BI_t , $VP_t(x)$ and $HP_t(y)$ are shown. Fig. 2 shows VPtS, VP_t^E and HP_t^S on captured image. Therefore image surrounded by VP_t^S, VP_t^E and HP_t^S is car image.

Next, we introduce how to detect whether a vehicle has entered the vision and whether the vehicle has stopped.

1) Minimum Moving Amount Decision Rule (MMADR):

Moving Amount is defined as

$$MA_t=\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}BI_t(x,y). \tag{7}$$

Observing a sequence of MA_t we can find that if MA is more than Th_{ce} (3000 in our system) for a while, it means a car is entering. Then, if MA less than Th_{cs} (close to 0) for a while, it reflects the car is stopped. Fig. 3 shows an example. However, some signal interferences such as turning signal can result in a situation shown in Fig. 4. To overcome the problem opening operator can be applied to this histogram

Figure 2. VP_t^S, VP_t^E and HP_t^S on captured image.

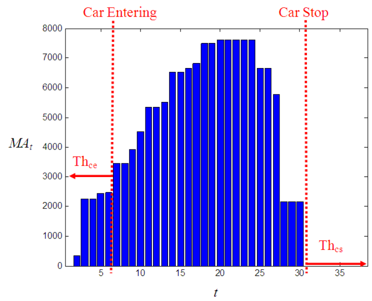

Figure 3. An example of car detection by MMADR.

and yield *OMA* shown in Fig 5. But MMADR still fails to function properly in some situations such as people get off after car stop. In the next section additional rule is used to solve this kind of problem.

2) Nearest Distance Decision Rule (NDDR):

Because vehicle is moving down from top of the screen until it stopped. Fig 6 shows a sequence of HP_t^S. HP_t^S is getting bigger until car stopped, i.e. car is stopped at the time with biggest HP_t^S, called NDDR. However, NDDR will make a mistake if car backs on a slope lane before stop. The mistake is shown in Fig. 7.

Although either MMADR or NDDR has a little bit of minor problems, we can use both of them within detection. At first, MMADR is used to determine whether the vehicle is entering: if OMA_t is bigger than Th_{ce}. Then, as long as one of the following conditions satisfied, vehicle is considered stopped. One is if OMA_t is less than Th_{cs} by MMADR (as Fig. 8 show), the other is SHP_t^S at local minimum by NDDR where SHP_t^S is result of smooth filtering on HP_t^S (as Fig. 9 show.)

B. Plate extraction subsystem

The car image which is determined in car detection

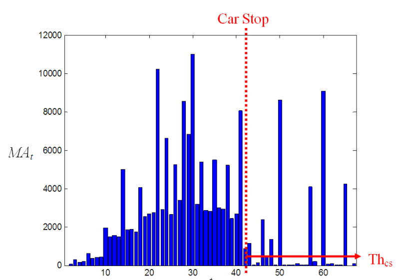

Figure 4. MA_t with signal interference.

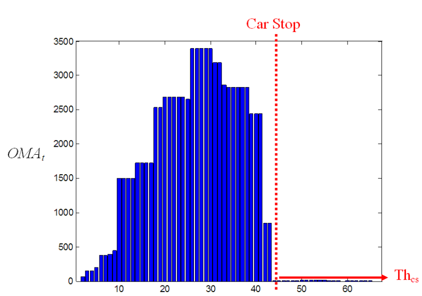

Figure 5. After opening operation.

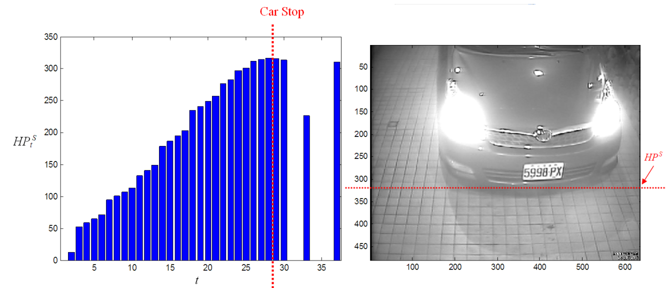

Figure 6. An example of car detection by NDDR.

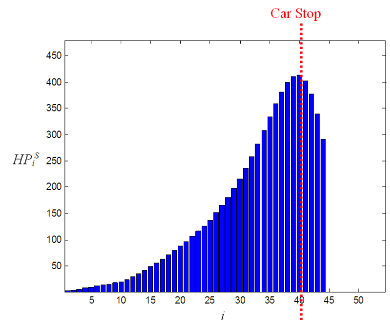

Figure 7. NDDR make a mistake.

subsystem is used for plate extraction. Since plate is always at front of car, the region of interest (ROI-car) can be defined as the forefront of car image and region height is set to one fourth of width. Fig. 10 shows the interesting region of car image. It is obvious that vertical edges of plate region are more than others. Fig. 11 shows vertical edge (VE) image by using Sobel operator. After observation of vertical edge images, the amount of edge pixels at plate region is the most and even. A pre-defined box (PB) suitable for the size of

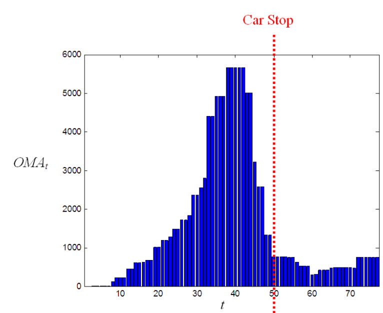

Figure 8. Car stopped if OMA_t is less than Th_{cs}.

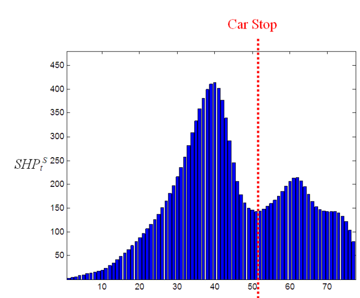

Figure 9. Car stopped if SHP_t^S at local minimum.

Figure 10.The interesting region of car image.

plate is used to search a region with the most edge information and gravity of edge pixels in this region locate at center. Finally, plate image will be extracted by the following potential car plate region (PCPR) algorithm.

- For a ROI-car image, do raster scan every 2 pixels as the upper left corner of PB.
- Calculating total pixels of vertical edge image inside each PB by the equation

$$PN(u,v)=\sum_{x=u}^{u+L}\sum_{y=v}^{v+H}VE(x,y), \quad (8)$$

  where L and H are width and height of PB, $VE(x,y)$ is vertical edge image.
- Gravity of vertical edge pixels inside each PB is defined as

$$MC(u,v)=\left(\frac{\sum_{x=u}^{u+L}\sum_{y=v}^{v+H}xVE(x,y)}{PN(u,v)},\frac{\sum_{x=u}^{u+L}\sum_{y=v}^{v+H}yVE(x,y)}{PN(u,v)}\right). \quad (9)$$

- Region of plate will be at the position with maximum PN and at which MC is closest to the center of PB. That is,

$$PCPR(m,n)=\arg\max_{(u,v)}\{PN(u,v)\}$$
$$\cap\arg\min_{(u,v)}\left\{\left\|MC(u,v)-\left(u+\tfrac{L}{2},v+\tfrac{W}{2}\right)\right\|\right\}. \quad (10)$$

Fig.12 is extracted image of license plate.

IV. EXPERIMENTAL RESULTS

Our system is build with HP Compaq DX7200, Intel P4-630 3.00GHz CPU, 2GB RAM and TTIC-3321 CCD camera. The resolution of capture image is 640×480 pixels. In the experiments, we use 500 dynamic images which contain 450 of car and 50 of others without license plate (e.g. motorcycle or people.) These were captured at different environment conditions including day, night, raining, or sunshine. A part of captured images after car detection are shown in Fig 13. The average time expended at plate extraction is 0.16 second.

Figure 11. Vertical edge image.

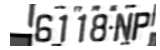

Figure 12 Extracted plate image.

Figure 13. Samples of captured images.

Table II shows efficiency of our proposed system.

TABLE II. SYSTEM EFFICIENCY

Detection Result	**Accuracy Percentage**
No plate detected of car with plate	4.22% (19/450)
Plate detected of car with plate	95.78% (431/450)
Plate detected of others without plate	12.00% (6/50)
No plate detected of others without plate	88.00% (44/50)

V. CONCLUSIONS

In this paper, we introduced an autonomous license plate detection method and system. Two subsystems were proposed. Car detection subsystem can automatically determine whether a vehicle is entering the lane and is stopped by described methods of MMADR and NDDR. Plate extraction subsystem can locate the plate from captured image by proposed method of PCPR algorithm. The experimental results show our system can effectively detect vehicles and locate the plates under different environments.

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