RFID Based Electronic Toll Collection System Design and Implementation

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Abstract. Electronic toll collection system (ETC) is usually used in Open road tolling (ORT) or free-flow tolling. In this project, ETC system is designed both in software and hareware. Radio frequency identification (RFID) technology is used to further improve performance of this system. This ETC system can be installed without tearing up the road, also this system can collect the data from the passing vehicles, identify the license plate and vehicle model and RFID electronic tag, retrieve the related registration informatiom from database, match registration information with the data ETC system collected, prevent switching license plates, collect the tolls automatically without having vehicles to slow down to pay.

Keywords: ETC · Vehicle recognition · License plate · RFID

1 Introduction

People's living standards continue to increase, the number of private cars is also increasing, the vehicles through the toll station will be substantially increased, which need to wait in line, the automobile exhaust in parking in a line brings much more damage than running on the road. And starting the car again makes the fuel consumption to increase. So it is urgent to develop completely open road tolling system suitable for toll road.

RFID is the technology of radio frequency identification, it uses the road test reader to identify the electronic tags on the vehicles. The cost of electronic tag is now relatively high, so the use of identification is limited to only on the license plate. If the electronic tag could be cheap enough that many most drivers would like to equip their cars with it, RFID may get the full use to provide more accurate informaiton and show more benefitail features. RFID technology is applied to a number of fields, without direct contact with the identified objects, or even completely blocked objects can also be identified, it uses electromagnetic waves to transmit data, fast, accurate and very useful.

2   Identification Technology

(1) Vehicle Identification

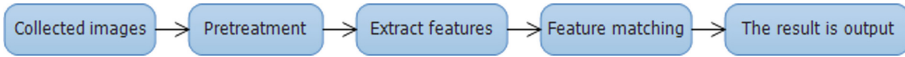The main steps to achieve vehicle identification are shown in Fig. 1.:

Fig. 1. Vehicle identification

The photos taken by the camera are preprocessed, the quality of the pretreatment affects the extraction and matching. So, pretreatment is important. Color photos use a large storage space black and white photos use less storage space, the general pretreatment is to take the color photos in gray scale. Use the preprocessed images to extract information, the identified vehicles' side view is processed to extract the features, calculated the following data by the calculation: the length of the roof and body; the roof length and height of the vehicle; the ratio of the two parts to the length, the body is divided by the vertical line into two parts. Using these features to distinguish. The eigenvalue of the standard model (car, bus, train) is calculated and then the features are brought together to do matching work, and then output the vehicle results.

Install the camera above the lane, the background is the lane, set the gray scale of the background as $b(x, y)$, set the gray scale of identified vehicle and the background as $f(x, y)$, set the gray scale of the identified vehicle as $d(x, y)$:

$$d(x, y) = f(x, y) - b(x, y) \tag{1}$$

The vehicle movement is calculated by comparing the difference between the gray image of the camera and the background image, the pixel of the moving vehicle is calculated, and the resulting video is framed, the background of each frame is constant, segmenting the identified vehicle, filter out the interference and noise in the image, to get a higher quality image, the image is scanned through the calculation, get three feature ratio.
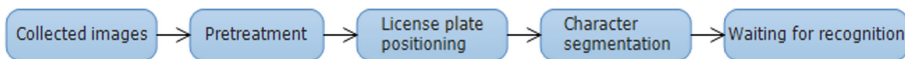
(2) License Plate Recognition

Fig. 2. License plate recognition

The main steps to achieve license plate recognition are shown in Fig. 2.:

The image acquired by the camera is pre-processed, and the image quality acquired by the camera may be affected by the factors of is greatly reduced by the influence of

the environment such as fog, rain, etc., the efficiency of license plate recognition is reduced. Since the license plate is a regular rectangle, the aspect ratio of the inner contour is about 4.5:1, the subgraph calculates the gray scale approximation of the pixels in the image. The lateral convolution factor is:

$$\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \tag{2}$$

The vertical convolution factor is:

$$\begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \tag{3}$$

$$G = \sqrt{G_x^2 + G_y^2} \tag{4}$$

$$
\begin{aligned}
G_x &= (-1) * f(x-1, y-1) + 0 * f(x, y-1) + 1 \\
&\quad * f(x+1, y-1) + (-2) * f(x-1, y) + 0 * f(x, y) + 2 \\
&\quad * f(x+1, y) + (-1) * f(x-1, y+1) + 1 * f(x+1, y+1) \\
&= [f(x+1, y-1) + 2 * f(x+1, y) + f(x+1, y+1)] \\
&\quad - [f(x-1, y-1) + 2 * f(x-1, y) + f(x-1, y+1)]
\end{aligned} \tag{5}
$$

$$
\begin{aligned}
G_y &= 1 * f(x-1, y-1) + 2 * f(x, y-1) + 1 * f(x+1, y-1) \\
&\quad + 0 * f(x-1, y) + 0 * f(x, y) + 0 * f(x+1, y) + (-1) \\
&\quad * f(x-1, y+1) + (-2) * f(x, y+1) + (-1) * f(x+1, y+1) \\
&= [f(x-1, y-1) + 2 * f(x, y-1) + f(x+1, y-1)] \\
&\quad - [f(x-1, y+1) + 2 * f(x, y+1) + f(x+1, y+1)]
\end{aligned} \tag{6}
$$

$f(a, b)$ indicates the gray scale of the image point (a, b), the gray scale of a pixel is made by formula $G = \sqrt{G_x^2 + G_y^2}$.

Find and scan the approximate location of the license plate, extract the license plate information quickly. Cut each character on the license plate, then wait for the computer to identify the characters.

License plate number can be used to retrieve the owner's and vehicle's information. After the gray scale processing, the license plate change into black and white two colors, the pixel is 0 or 1, the degree of the brightness on character projection is different, according to the darkness to write the bit, separate each character, the computer identifies characters' feature. Just like before the Spring Festival the Ailpay had an activity called scan the "Bless", the similar characters can be identified. For example, when we use the Alipay to scan "Blass" can also be identified as correct, that is the proof of the bug in Ailpay. The system designed here already considered this problem of all similarities, such as: "8" "B" and other words, so that error won't happen in this system.

3   RFID Technology

(1) RFID Hardware Design

It consists electronic radio frequency tag design, reader module design, power module and serial port design, antenna design.

Radio frequency identification can provide high accuracy data by identify the objects in long distance, so the electronic tags should use active electronic tag design to get the full benefit of RFID, passive electronic tag can only be recognized within near distance, also the accuracy is relatively low. The reader module mainly identify the electronic tags information, the electronic tags can be input the information about license plate and vehicle. The reader can read the information in the tag and write information to the tag to collect toll. The power module mainly provide the RF voltage, use bridge rectifier, use large capacitance for voltage regulation. Serial port do send and receive, and the antenna should be chosen according to the application, to achieve the best performances.

(2) The Overall Framework Design

When the RFID system is working, the vehicle with the electronic tag come into the area with a specific frequency of the RF signal launched by the reader. The electronic tag will produce the induced current and activate itself, send the data to the reader through the network, and the reader transmit the information to the computer, after computer's operation to achieve the identify on the vehicle's information, and then the computer send the command to the reader, complete the task of tolling.

When vehicles are passing the reader, if there are two or more tags appear at the same time, they will interfere each other, cause that electronic tags can not be accurately read, so the use of the electronic tag anti-collision method is important. The reader selects one of the tag groups, then inquire the tag one by one. If there is no tag, the counter is 0, only one tag counter shows 1, there is no collision, if there are multiple tags, the counter shows greater than or equal to 2, then there are many tags collide, at the moment the reader come into next round to send the inquire adjustment command, all the tags in the magnetic field are receiving this command, identify the tags one by one, to avoid missing any tag that should be identified.

The information identified through RFID and the images acquired in camera are send to the database server and image recognition server through the network and then return the electronic tag to collect the toll through the network. Identify the system flow chart as shown in Fig. 3.
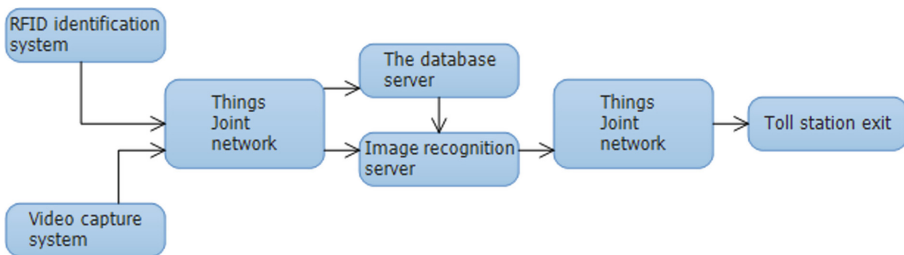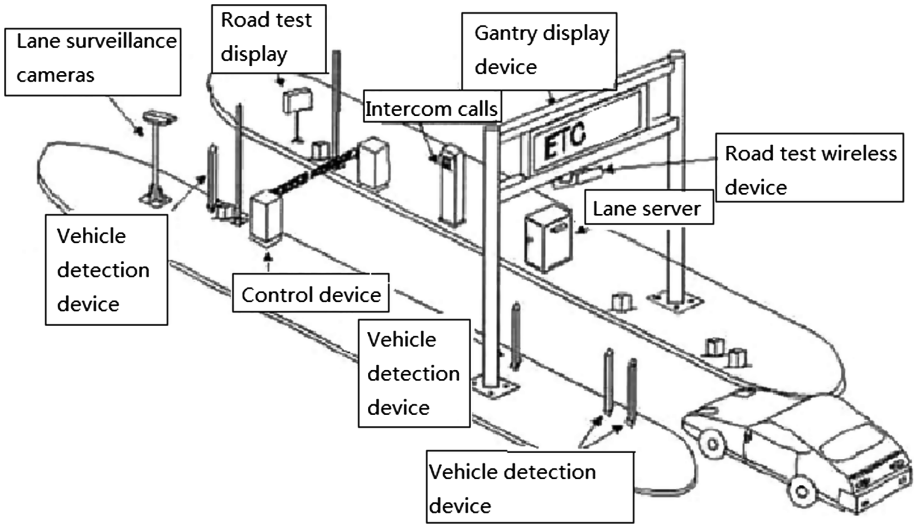

Fig. 3. Identify the system flow chart

Fig. 4. Identify the diagram

The camera shoot on the vehicles to identify the vehicle models, license plates and other information is compared with the RFID tag (Tag), the same is normal, different is abnormal, when the comparison shows normal, it can finish toll collecting through the RFID reader (Reader) and the antenna on the electronic tag (Fig. 4).

4   Tolling System Software

Tolling system software functions consist a few sub-system: user login interface, login interface, sub-management login, owner login. Management personnel can carry out user management, toll station intersection query, vehicle traffic query, vehicle violation view, a single owner information, the owner can do the basic information query, violation of detailed inquiries, consumer information query and other functions. As shown in Fig. 5.
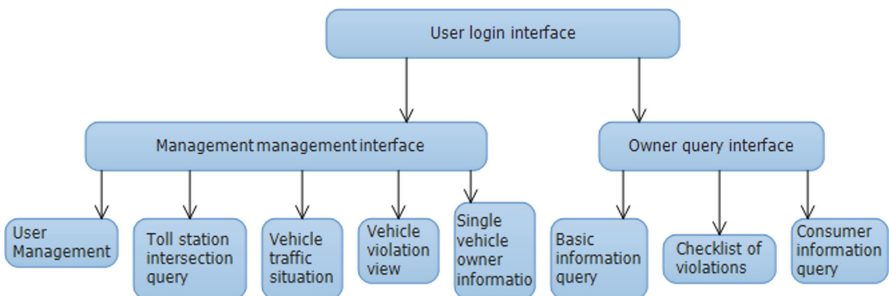

Fig. 5. system function flow chart

5   Conclusion

With the rapid development of China's economy and the continuous increase in car ownership, the highway brings people convenient travel, at the same time is also facing enormous problems. The electronic toll collection system is an automatic tolling system for roads, bridges and tunnels that are being developed and promoted internationally. This technology prevents some speculators to change large vehicle license plates to small car license plates secretly, and it prevents a lot of payment loopholes. Electronic toll collection system is a huge system, the popularity of electronic tags is a problem yet to be solved, vehicle license plates recognition technology also need to be improved by use higher technology. Now Alipay and other software launched a credit live, consume first and then pay for it, prepaid is a good trend, sesame credit deposit, these all have brought great convenience, so this technology needs to be developed in this area.

ETC technology has the obvious characteristics and advantages of eliminating cash transactions, eliminating the need for slowing down, effectively improving the road capacity, greatly enhance the service level, simplify the process of tolling and reduce environmental pollution. Without vehicles' slowing down to pay and manully process tolling, this system can autoamticaly collect toll, especially through network environment, help to improve the road network of integrated transport capacity and service levels.

Electronic toll collecting system (ETC) use radio frequency identification technology (RFID), road test reader and camera to identify the electronic tag, take photos of vehicle license plate, do the corresponding match, if the matching is correct, the tolling system will be able to access the reader, the reader write information of tolling into electronic tags to finish process of tolling.

The cost of RFID tags are high now. The current software like WPS, CAJViewer 7.2 can convert image into characters then into text files, we can also develop such software, read the characters in the image and write to text by using file functions in C language., collect toll of vehicles that are not equipped with electronic tag by using Visual Studio 2012, this is practible and achievable, the quality of acquired data will be affected by the factors of enviroments like fog or other extrem weather.

Radio frequency identification (RFID) is a non-contact, long distance technology, it can identify the tag that is even being blocked, coupled with the image to match, it would be more efficient electronic toll collection system (ETC) with electronic tags being widely used in the future.

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