Research on Vision-based Intelligent Vehicle Safety Inspection and Visual Surveillance

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***Abstract*—Vehicles' safety surveillances have been paid more attentions on by the governments with increasingly rampant terrorist activities like car bombing attacks and illegal immigrations. Lots of terrorists may hide the bombs under the vehicles to avoid the searches by the workers. Illegal immigrants usually adopt the same tricks. Hence, vehicles' bottom will be one of the most important searching places in the safety inspection. However, traditional bottom inspections are accomplished manually with hand-held security mirrors. This method has poor efficiency, limited searching areas, unbearable reliability and large consumption of human resources. So computer vision and intelligent transportation technologies are led into the safety inspections and surveillances according to these critical defects. Line scanned and area scanned CCD cameras are trigged by the vehicle detection apparatus to grab images of the vehicles' bottom and license plates respectively. These images will be processed by the industrial computers real-timely. Sounded alarms can remind the workers there are existing doubtable foreign goods under the bottom. The experimental results indicate preliminarily that the proposed method not only have good performances on detection rate and low false alarm rate, also can improve the reliability effectively.**

Keywords-vehicle safety inspection; visual surveillance; machine vision; license plate recognition

I. INTRODUCTION

Nowadays, vehicles' safety surveillances have been paid more attentions on with vehicles' popularization, especially the increasingly rampant terrorist activities like car bombing attacks and illegal immigrations [1~3]. To guarantee the social stability, people's lives and property safety, each government enhances the important places' safety inspection level like government departments, airports, customs, military bases and etc. Lots of the terrorists may hide the dangerous objects like bombs under the vehicles to escape inspector's searching. Illegal immigrants usually adopt the same tricks. Hence, bottom of the vehicle will be one of the most important searching places in the safety inspection [4].

Nevertheless, most situations of the current vehicle bottom inspection are accomplished manually with hand-held security mirrors in China due to limitations of the technology development, shown in Figure 1. This method has poor efficiency. It may cost 2~3 minutes to finish one small car's detection. To middle or large vehicles, it needs more time. Due to hand-held security mirror's limitation, the inspection area is incompleteness which leads to poor reliability and large consumption of human resources.

Figure 1. Manual bottom inspection with hand-held security mirror

During the Chinese "two Conferences" and Beijing Olympic Games in 2008, one kind of vehicle bottom inspection robot were arranged to detect the doubtable objects under the vehicles [5]. Cameras and wireless communication devices were installed on the robot. The operator sent the instructions through the remote controllers controlling robot's moving directions, speed and camera's capturing angels. Images grabbed by the camera will be sent to the controller and displayed on the screen. Although this kind of inspection robot improved a lot, it still have some shortcomings like time-consuming (6~8 minutes for the small cars), stopping for the inspection and judging by the workers.

Hence, computer vision and intelligent transportation technologies are led into the safety inspections and surveillances which can improve the inspection accuracy, reliability and reduce the consumption of human resources. Intelligent vehicle safety inspection system, combing with line scan imaging, image processing, network transmission and database technologies, has characteristic like high speed, high accuracy and high intelligence. System's vehicle detection, illumination control, imaging parts can run coordinately which construct the whole entirety. This system also can be popularized to community defense and security, road surveillance and bank monitoring. It has broad market prospects and research space.

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II. Intelligent Vehicle Safety Inspection and Visual Surveillance System

A. Architecture and functions

This system inherited the traditional safety inspection system's basic functions and improved its realization methods, which can enhance the inspection efficiency and the accuracy. Based on this, it realized the remote image transmission and image database indexing. The architecture of the system is shown in Figure 2.

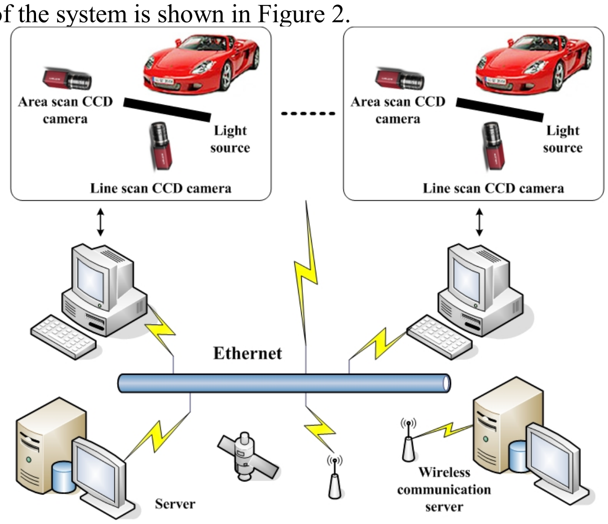

Figure 2. Architecture of the vehicle safety inspection system

Intelligent vehicle safety inspection system's functions including:

- Vehicles' bottom and license plate images should be displayed fully and real-timely on the monitor. Inspection software judges correctly if there are hiding bombs or illegal immigrants.
- Recognizing the characters of the license plate, these data combing with the bottom image will be transmitted to the remote controlling server through the Ethernet.
- The remote controlling server receives each workstation's images then constructs large-content image database. These vehicles' data should be stored more than 3 months in case of investigations. These data should be fast indexed according to the time or contents of the license plate.

B. Combination of the system

System's combination figure is shown in Figure 3. The main functional modules including vehicle detection part, bottom imaging part, bottom inspection and license plate recognition part, image compressing and transmission part and image database part.

- Vehicle detection part is mainly in charge of detecting the moving cars passing through the inspection site. If there is a vehicle coming into the area, signals must be sent to the monitoring computer by this apparatus, and then the line scan CCD camera will be triggered to acquire an image in time. The grabbed image will be processed by the inspection software.
- Bottom image acquisition is the key of the security inspection system. This part includes frame grabber, high precision line scan camera and high luminance flashing light source. When it received a signal "vehicle arriving" from the vehicle detection apparatus, bottom image scanning must be started. After the vehicle passed the inspection site, the line scan camera will be stopped.
- The captured bottom image and license plate image are processed by the inspection software. License plate is located and recognized with steps like color space conversion, vertical projection and fuzzy neural networks training. Bottom objects judgment is accomplished with image comparison method. It depends on calculating the normalized cross-correlation C between images. According to C, the accumulation of the difference image then can give an alarm signal if there is a doubtable object under the vehicle.
- Image compression and transmission is the key for the remote surveillance. This part compressed the captured bottom image and license plate image with JPEG standard for static image compression. It can get a satisfied compression ratio and the precondition is that the image quality meets the inspection requirements. Real-time image transmission can be realized combing the client/server and Winsock programming.
- Image database part manages the images sent by each sub-system and offers the image indexing function. The core of the database should include image displaying control, historical data processing, image indexing and management.

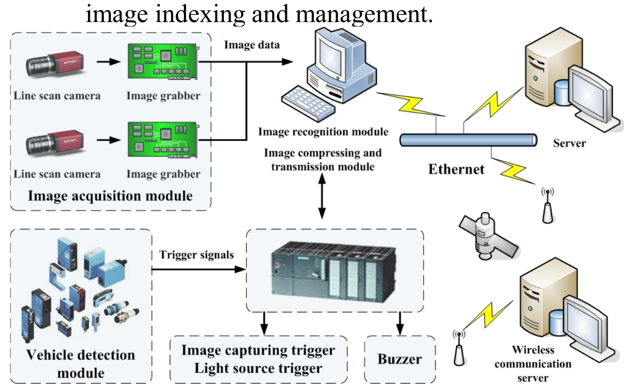

Figure 3. functional modules of the inspection system

III. Hardware Implementation of the Intelligent Vehicle Safety Inspection System

A. Vehicle detection apparatus

This apparatus should judge the vehicles coming into the inspection area or not so as to start or stop the cameras. Laser measurement device like LMS-211 is widely used abroad on highways serving as the electronic police to detect the vehicles [6]. This device can detect accurately and reliably, nevertheless it is too expensive to be widely popularized in China. Hence, sense coils based approaches [7] are applied to detect the passing vehicles. In this system, sense coils serving as the trigger source are buried under the road of the inspection site. If there is a vehicle passing through the coils, magnetic flux will change accordingly. This small change will be sent to the signal converter and output the level signals. Vehicle detection apparatus structure is shown in Figure 4.

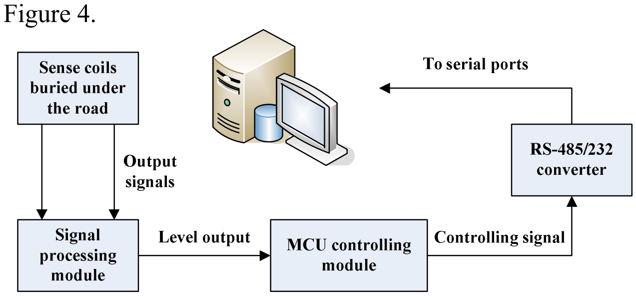

Figure 4. Structure of the vehicle detection apparatus

B. Image acquisition and processing

In traditional surveillance system, area scan cameras are usually adopted as the image grabber. However it is infeasible to be used in vehicle bottom inspection. The main reasons are: (1) Object distances will change according to different type of the vehicle; (2) The acquisition speed can not meet the requirements of fast moving vehicles under the circumstances that object distance is small while the passing speed is high. Some frames may be lost. (3) Some vehicles are too long to be grabbed in one image with area scan camera. Image mosaic method may be useful for them; nevertheless the running speed will decline sharply. Hence, line scan cameras are selected to construct the image capturing system based on the reasons mentioned above. Image acquisition and control principle can be seen in Figure 5. Bottom line scan system includes line scan CCD camera, lens, light source, frame grabbers and etc.

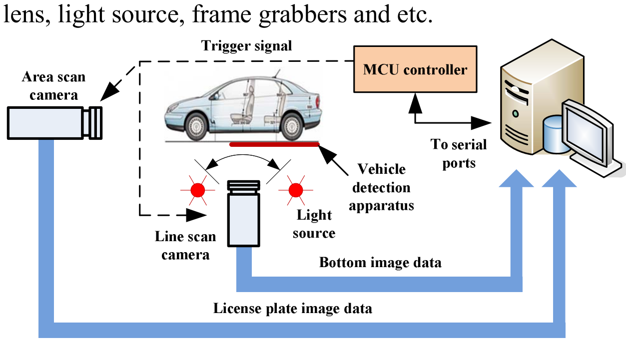

Figure 5. Image acquisition and control principle

C. Experiments and analysis

To verify the effectiveness and reliability of the vehicle safety inspection system, some experiments are carried out depending on the imaging apparatus installations. The construction scheme's side view and top view are shown in Figure 6.

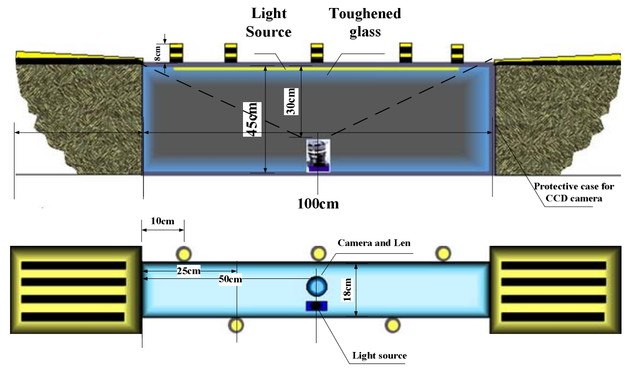

Figure 6. Side view and top view of the camera installation scheme

Experiment 1: License plate image recognition

After the whole vehicle's image including the license plate is captured by the area scan CCD camera, characters on the plate should be recognized and matching with the bottom image. These data will be transmitted to the remote controlling server through the Ethernet. License plate image recognition algorithm is shown in Figure 7.

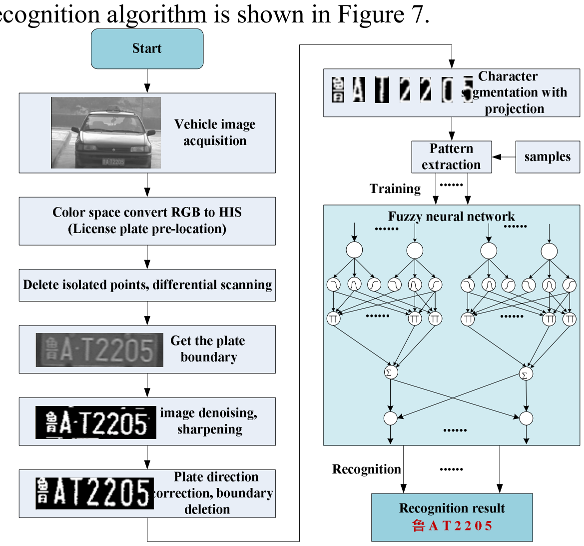

Figure 7. Float chart of license plate image recognition

After license plate edge extraction and binarization, vertical projections for character segmentation are shown in Figure 8. Here, (c) and (d) show the vertical projections of (a) and (b) respectively.

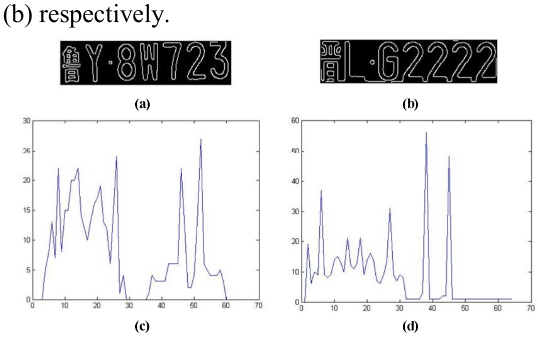

Figure 8. Vertical projection of the binary license plate

Experiment 2: Doubtable objects' visual inspection under the vehicle

To judge if there are doubtable objects like bombs under the vehicle, image comparison method is adopted in the vehicle safety inspection system. Inspection software running on the industrial computer will calculate the vehicle's length and width coarsely according to the captured bottom image which help reducing the comparison times effectively (from several hundred times to several times). Doubtable objects' visual inspection flow chart is given in Figure 9. The operating interface of the system is shown in Figure 10.

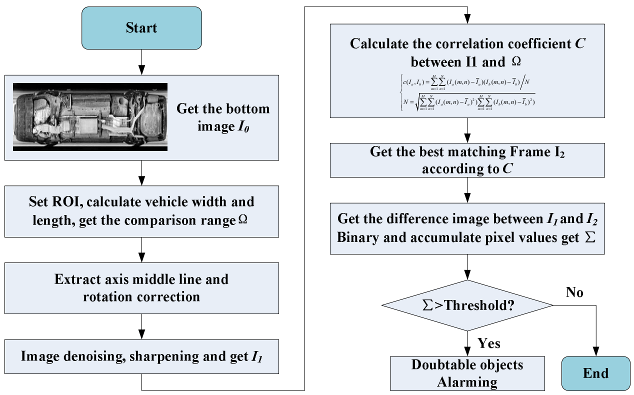

Figure 9. Doubtable objects' visual inspection flow chart

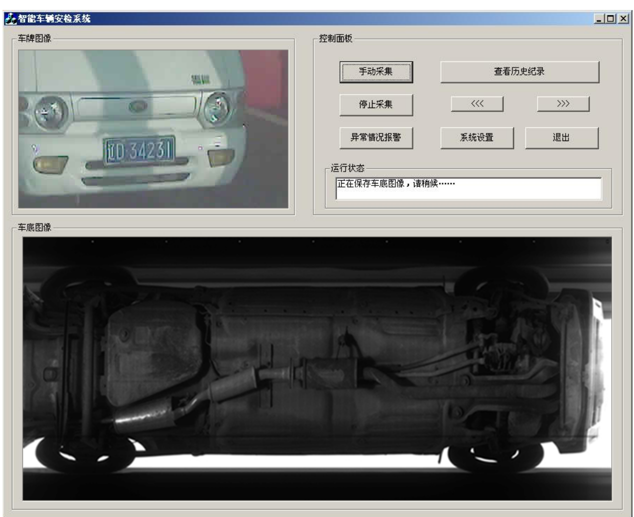

Figure 10. Operating interface of the security inspection system

Lots of methods like mean absolute difference (MAD) [8] or the sum of absolute differences (SAD) to evaluate the difference between images. Here the normalized cross-correlation is used to describe the correlation between two frames [9]. Normalized cross-correlation has the advantage of not being affected significantly by global changes. The correlation coefficient C is defined by

$$\begin{cases} C(I_a, I_b) = \dfrac{\sum_{m=1}^{M}\sum_{n=1}^{N}(I_a(m,n)-\bar{I}_a)(I_b(m,n)-\bar{I}_b)}{N} \\ N = \sqrt{\sum_{m=1}^{M}\sum_{n=1}^{N}(I_a(m,n)-\bar{I}_a)^2 \cdot \sum_{m=1}^{M}\sum_{n=1}^{N}(I_b(m,n)-\bar{I}_b)^2} \end{cases} \quad (1)$$

where $\bar{I}$ is the mean of I, N is the normalized coefficient. This method is sensitive to differences between frames which can describe the matching degree efficiently. The smaller the matching degree, the larger difference between the images is.

IV. CONCLUSION

With vehicles' popularization, especially the increasingly rampant terrorist activities like car bombing attacks and illegal immigrations, vehicles security surveillance is paid more attentions on by the governments. Due to hand-held security mirror's severe defects like low efficiency, poor reliability, incomplete inspection area and large consumption of human resources, computer vision and intelligent transportation technology are introduce into the vehicle safety inspection and visual surveillance. According to the experiments, this system can recognize the license plate and judge the doubtable objects under the vehicle effectively and accurately.

ACKNOWLEDGMENT

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