Research on Traffic Monitoring Method of Elevated Road Based on DSP+FPGA

Rong-Bao Chen, Tian-Ze Fei, Ben-Xian Xiao
School of Electrical Engineering and Automation, Hefei University of Technology, Hefei, China
E-mail:crbwish@126.com

Peng Jiang, Dun-Hong Wang, Qian-Kun Zhang, Yu-Bing Pu
Hefei Municipal Design Institute Co., Ltd
E-mail: 36220647@qq.com

Ya-Feng Wu
Anhui Sun Create Electronics Co., Ltd Hefei, China
E-mail: 36220647@qq.com

***Abstract*-Along with the development of the urban rapid transit, the overhead traffic monitoring, and according to the traffic situation in a timely manner to make all kinds of control, management, and induced measures is one of the development trend of urban intelligent transportation. In this paper, the video image processing control platform to build is based on DSP + FPGA structure. DSP takes the core of video image processing tasks, FPGA as the data preprocessing unit, the completion of the interface logic, system interconnection and data channels. An elevated road traffic monitoring algorithm based on virtual detection coil is embedded in the management and control platform. First set up virtual coil in the video image as detection area and complete the image preprocessing. And then adopt the method of superposition averaging extract background. Using the adaptive background update background model, then adopt the background difference method to extract the foreground target; At the same time using a comprehensive color and texture shadow detection algorithm to eliminate the shadow, statistical vehicle flow; Through the traffic and extracting the average speed of adjustment on control platform limits the height of the mast, realizes the elevated road upward ramp traffic, restrictions, and shut down.**

Keywords-elevated road; DSP+FPGA architecture; background update; virtual coil; vehicle flow; limited height pole

I. INTRODUCTION

With the rapid development of our economy and to speed up the process of urbanization, urban car ownership is growing at a rapid speed. Urban traffic is becoming more and more congestion and traffic capacity of road network is facing increasing pressure. Traffic congestion has become a national concern and an urgent problem to solve. It is also the theme of the current intelligent transportation. Intelligent transportation system [1] is the future development trend of urban traffic. Based on the traditional transportation system, ITS implementation of intelligence, information, integration and network traffic, reduce environmental pollution at the same time, guarantee the safety of the transport system to the greatest extent, reliability and flexibility.

Viaduct as an important component of the urban traffic arteries, is not only to reduce the pressure on urban traffic, it is the guarantee of urban rapid transit. Effective monitoring and management of the traffic flow of the viaduct is also an important part of the ITS. When the monitoring to the elevated road traffic jams, timely the elevated road upward ramp current limiting and temporarily closed, ensure unblocked elevated road. However, due to the traffic information is not smooth and elevated road only monitoring is not effective and timely control of traffic flow method, which leads to the urban viaduct often appear congestion phenomenon.

At present mainly used for the viaduct traffic statistics are permanently embedded system based on piezoelectric loop, electromagnetic wave monitoring system and video vehicle detection system based on image processing technology [2]. Permanent embedded type system in the process of embedding a lot of damage to the road, and short service life. Electromagnetic wave monitoring system is not conducive to the detection of multiple lanes traffic flow, if the vehicle overlap, will affect the accuracy of monitoring. The disadvantages of this system are: high power consumption, large size, high technical requirements. Traffic monitoring system based on video images using image processing and recognition technology, access to the road traffic, vehicle, speed, such as traffic flow information, and in a timely manner to the traffic regulation. The system has low cost, easy installation and maintenance, the advantages of wide application range, is widely used. The current vehicle traffic statistics method based on video detection mainly has the target tracking algorithm [3]and the virtual coil detection algorithm [4]. Through analysis and comparison, the complexity of the virtual coil detection algorithm in time performance is excellent, because this system have certain request for real-time performance, finally choose the virtual coil test to obtain traffic information.

The video processing system adopts the embedded system of the multiprocessor architecture to meet the requirements of high real-time performance [5]. In this paper, based on multiprocessor architecture, building hardware control platform based on DSP + FPGA model[6], embedding algorithm of traffic monitoring of elevated road traffic monitoring, through elevated road upward ramp limit block on traffic trends to make timely adjustment.

II. VEHICLE DETECTION OF ELEVATED ROAD

A. Image Preprocessing

Median filter is the most simple and the most typical nonlinear filter [7]. However, it is difficult to meet the requirements of video surveillance in real time because of the large amount of calculation of the median filtering. At the same time, the filtering window size has great influence on the noise suppression, and can not take into account the suppression of noise and the protection of image details. Improved median filtering algorithm is adopted in this paper. Steps are as follows:

The improved median filtering algorithm takes 3*3 as the minimum moving window, and the distance of each move is a pixel distance. When the window moves to the right one pixel, the original is the right side of the middle of a new window into the middle of the new column moved to the right side, the pixel value of x, y, z. At the same time the original one column is removed, the pixel value is i, j, k.

Compare the two column pixel values of the removal and moving, whether to meet the equation i=x, j=y, k=z, if the three equations are set up, do not need to repeat the sort, the output of the original value, otherwise enter the step two;

If any equation is not established, the new pixel value is replaced by the original pixel value, and the average value of the current pixel value is obtained, and get new mean value;

To sort the pixel values of the current window, get a new value;

The mean value obtained from the second step and the median value obtained by the third step are weighted. After a lot of experiments, the mean value is 0.7, the median is 0.3, and the center point is the result of both weighted values.

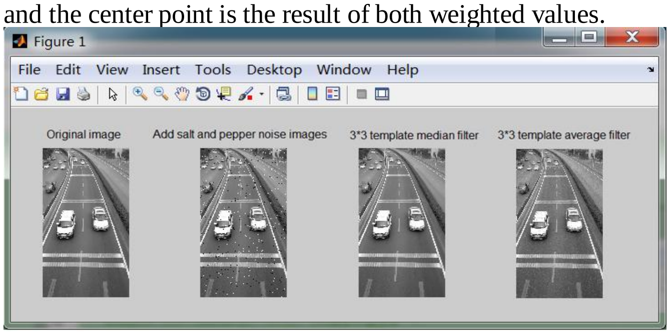

Figure 1. Comparison of image filtering method.

Compared with the simulation results shown in Figure 1, the improved median filter can better remove the noise of the image, and better retain the details and edges of the original image.

The image gray stretch, gray value interval is increased to improve the contrast of the image weakening useless content, while projecting an image of the object of important information, to improve the clarity of the image. The design uses the gray scale piecewise linear stretch [8], namely first divides the gray level chart the output value scope to be many sections, then respectively makes the linear drawing operation.

The linear transformation formula is piecewise linear transformation function. The formula of three segment piecewise linear stretch transformation is as (1):

$$q(x,y)\begin{cases} \frac{y_1}{x_1} f(x,y) & 0 \le f(x,y) \le x_1 \\ \frac{y_2 - y_1}{x_2 - x_1}(f(x,y) - x_1) + y_1 & x_1 < f(x,y) < x_2 \\ \frac{255 - y_2}{255 - x_2}(f(x,y) - x_2) + y_2 & x_2 \le f(x,y) \le 255 \end{cases} \quad (1)$$

$f(x,y)$ in the formula is the gray value of pixel point in(x,y), $q(x,y)$ is the gray value of the corresponding output after linear transformation function.

By adjusting the contrast of the gray image, the image level of the image appears to be enhanced, as shown in Figure 2, the image of the car's clarity has been improved significantly. Experimental results show that the proposed method enhances the useful information in the image, but also weakens some of the less important content, and basically maintained the original image features.

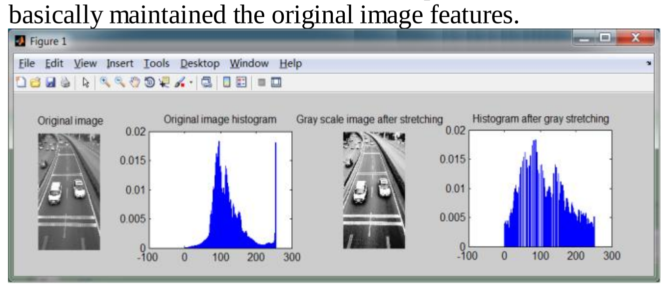

Figure 2. Comparison of the original image and the gray stretch image.

B. Background Extraction and Update

In real-time traffic image sequences, the background of a set of images can be divided into two parts, the Stationary Region and the mobile Region. In this system, only need to calculate the traffic road area in the image. Adaptive threshold method is used to get the the Stationary Region and the mobile Region.

The system uses the method of the average value of the method to extract the background model, the experiment shows that the selection of 150 images to get the background of the effect is better, as shown in figure 3. Its principle can be expressed by (2):

$$BI(x,y) = \frac{\sum_{i=1}^{j} PI_i(x,y)}{n} \quad (2)$$

In the image sequence, $PI_i(x,y)$ is the pixel value of the point (x,y) in the image of the I frame in the type(2). $BI(x,y)$ represents the pixel value of the point (x,y) position of the background image.

Figure 3. Background image.

Due to the change of weather, lighting and other external environment, the background is in a dynamic change. To accurately detect the vehicle, must be dynamically updated background. By using adaptive background model, the background can be updated effectively [9]. Detailed approach for: Based on the extraction of the background model, calculate the difference between each pixel $CI_t(x,y)$ in MR and each pixel $CB_t(x,y)$ in MR of the current background for the t-th frame input image. If the difference is less than the threshold value TD, then the pixel $CI_t(x,y)$ belongs to the background, then with the value of the pixel as the instantaneous background of the corresponding pixel value. Otherwise, the pixel belongs to the foreground object, with the current background pixel value $CB_t(x,y)$ as the instantaneous background of the corresponding pixel value. The background of the image is obtained by the weighted average of the instantaneous background and the current background as the next frame.

In the current frame image, the moving object is included in the current frame, and the foreground and background of the image in the current frame are used to update the background image. Classification formula as shown in (3).

$$CurI_t(x,y) = |CI_t(x,y) - CB_t(x,y)| \tag{3}$$

In the formula (3), t calculated from zero, when t is zero, $CB_t(x,y)$ is the initial extraction of the background frame $BI(x,y)$ .TD is determined by the method of Otsu. When the value is greater than the threshold value, updates the current background of the pixel, otherwise not updated. As shown in the formula (4).

$$Tar_t(x,y) = \begin{cases} 0 & CurI_t(x,y) \le TD \\ 1 & CurI_t(x,y) > TD \end{cases} \tag{4}$$

$Tar_t(x,y)$ determines which pixels in the current frame image are used to update the current background. According to the formula (5) to obtain the instantaneous background $IB_t(x,y)$

$$IB_t(x,y) = \begin{cases} CI_t(x,y) & Tar_t(x,y) = 0 \\ CB_t(x,y) & Tar_t(x,y) = 1 \end{cases} \tag{5}$$

Update the current background according to the formula (6):

$$CB_{t+1}(x,y) = \partial * IB_t(x,y) + (1-\partial) * CB_t(x,y) \tag{6}$$

In formula (6), $IB_t(x,y)$ is Instantaneous background, ∂ is weight factor. Through a large number of experiments, T=0.1 is the most suitable.

C. *Vehicle Detection and Shadow Elimination*

Detection based on background subtraction [10] can better to extract the target image. But the effect of the foreground object is dependent on the selection of threshold value through the background subtraction. Due to the change of the road environment, the fixed threshold can not be very good to detect the target. Otsu algorithm [11] can determine an optimal threshold for binary image processing, effective extraction of vehicle targets. However, the existence of the shadow will lead to false detection, which will cause a large error count of vehicles. Common shadow detection methods are based on texture and SNP shadow detection algorithm [12], however, the two can only be in a specific environment to have a better effect of shadow detection.

This paper adopts a comprehensive color and texture shadow detection algorithm. Firstly, the foreground object Q is extracted by background subtraction and Otsu, then get Q_m by Corrosion of the foreground. Then use $(Q-Q_m)$ to get the foreground edge information Q_c .At this time, the foreground object is composed of Q_m and Q_c . For Q_m respectively the shadow detection method based on texture and shadow detection method based on SNPS, the results of the two methods to do "and" operation. The edge image Q_c just to do SNP shadow detection based on color. Finally, the results of the detection of two kinds of shadow algorithms are combined to detect the shadow area of foreground blocks. Based on two methods of the shadow judging standard [13]to mark image points. In the end, the pixels of the mark of the shadow pixels are removed from the foreground, and fill the hole of the vehicle target, and the foreground object of the vehicle is shown in Figure 4.

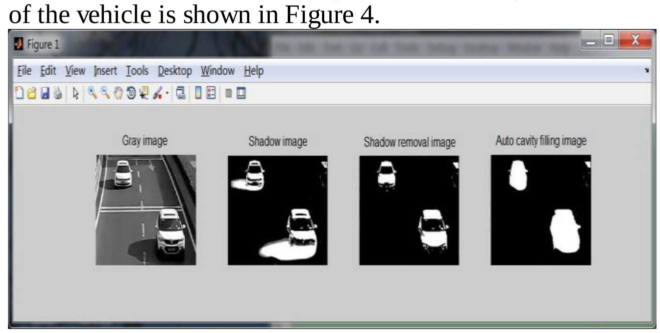

Figure 4. Vehicle shadow detection and shadow removal.

III. ELEVATED ROAD VEHICLE COUNTING ALGORITHM

A. Virtual Coil Settings

When vehicles through virtual coil, the corresponding regional characteristics in image will change, when tested the change information in virtual coil match the motion characteristics of the vehicle, can determine a vehicle pass. Through the analysis of the characteristics of the changes and the use of correlation algorithm to carry out the extraction of vehicle counting and speed. In order to ensure the accuracy of vehicle detection, the virtual coil must be set to the appropriate location and size, usually the virtual coil perpendicular to the direction of the road. Coil is arranged in the proximal end of the image, width coil and single lane width is basically the same, the distance between the two detection lines is about two thirds of the length of the car and based on each lane angle in the video set separately. As shown in Figure 5.

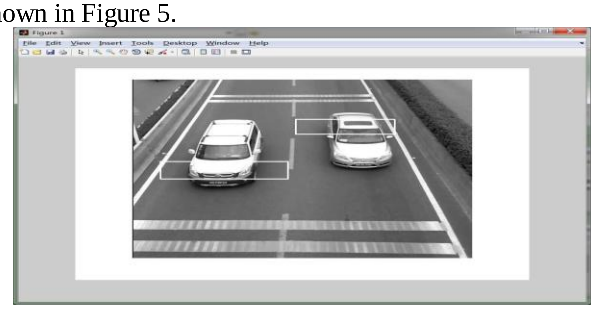

Figure 5. Vchematic diagram of detection area.

B. V Ehicle Flow Counting Algorithm Based on Virtual Coil

On the single lane of the virtual coil pixel real-time scanning, according to the changes in the status of the virtual coil to determine whether there is a vehicle to enter and leave. Assuming the total number of pixels in the detection area is N, the total number of pixels of the vehicle target of the two value image is Q, and the judgment formula is shown in (7).

$$Dst = \begin{cases} 1 & Isum > N/2 \\ 0 & Isum \le N/2 \end{cases} \qquad (7)$$

When the vehicle enters the virtual coil, the pixel value of the detected area will change. The above formula shows that if the target on the binary of image pixel number more than half of the total number of pixels detection area, it indicates that the current coil in the vehicle, Dst is set to 1, otherwise it is set to 0, an indication that the region detection is car free state. At the same time, the marker variable $flag$ is introduced, and the auxiliary state variable Dst is carried out to count the vehicle, to avoid a car statistics for many times. Assuming that $Count$ is the number of vehicle statistics. The simulation results as shown in figure 6, specific algorithm processes are as follows:

- Initialize variables, $Count$ set 0, marking variable $flag$ set 0;
- To detect the current frame area to determine whether a vehicle binary image pixels satisfy conditions $Isum > N/2$ .If the condition is satisfied, it indicates that there is a vehicle in the current detection area, and the state variable Dst is set to 1, otherwise, the current frame is in a state of no car, and the variable Dst is set to 0;
- If the current frame status $Dst = 0$, said the detection area no car exists, the vehicle does not count;
- State variable Qst is used to show the presence of a vehicle in the previous frame of the detection region, if it is 0 and the state of the current frame of Dst is 1, it indicates that there is a car into the detection area. At this time the introduction of tag variables $flag$. If $flag$ is 0 indicates that the vehicle has not been counted, the count plus 1 at the same time $flag$ set 1, if $flag$ is 1, then said that the vehicle has been statistics, count value is constant, the vehicle does not count;
- If the current frame detection area without vehicles, Dst is zero, and previous frame have vehicles namely Qst is 1, indicates the vehicle leaving the region detection, $flag$ is set to 0, the value of $Count$ remains unchanged, the vehicle does not count. At the same time by detecting the vehicle through the virtual coil number of frames to extract the vehicle's speed v ;
- Update the status of the previous frame, the state of the current frame Dst assigned to the state of the previous frame Qst , according to the above steps to the next round of vehicle statistics and speed extraction.

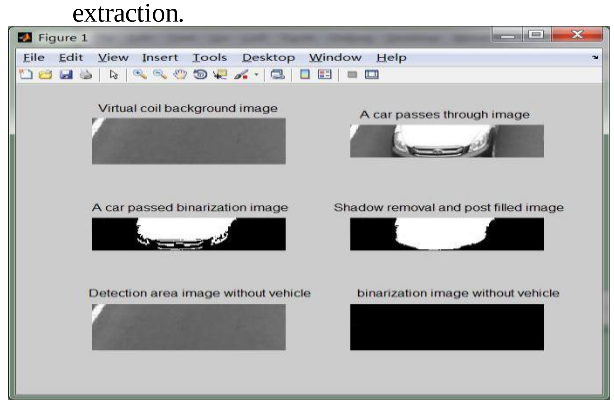

Figure 6. Comparison of the results of two cases of vehicle and non vehicle detection area.

In the MATLAB environment, the use of the algorithm on the viaduct shot on the two video of the vehicle count, the experimental results as shown in table 1.

TABLE I. STATISTICAL RESULTS OF TRAFFIC FLOW MONITORING ALGORITHM

video	Algorithm count	Manual counting	accuracy rate	average velocity
1	43	44	97.7%	38km/h
2	38	39	97.4%	41km/h

The system statistics traffic flow of the elevated road, when the elevated road traffic tends to congestion and promptly closed elevated road ramp or adjust the ascending ramp high height limit, limit (or decrease) of the new vehicle, in order to ensure the smooth of the elevated road.

Merely by the number of vehicles passing over a period of time to determine the ramp closed or limiting is not scientific, night vehicle less at this time by the average velocity to assist the judge, vehicle statistics through the coil frames to calculate vehicle speed. That is to set a unit of time the vehicle through the threshold Thd and the average speed threshold Vd, when the count value is bigger than Thd and less than Vd, limit the elevated road traffic.

IV. THE ELEVATED ROAD TRAFFIC CONTROLLER PLATFORM IMPLEMENTATION

A. *Software Design of Traffic Control Platform of Elevated Road*

The software design flow of the elevated road traffic control platform is shown in Figure 7. After reading the video frame, the virtual coil is set as the detection area of the vehicle, so as to reduce the amount of computation to ensure the real-time performance of the system; The collected images are preprocessing (for image filtering and gray stretching), the hardware is completed by FPGA; The background is extracted by using the method of superposition of averaging, and the background is updated by the adaptive background model; Background subtraction method is used to extract the foreground object and then to eliminate the shadow. Finally according to the moving objects in virtual coil binary image pixel number and state variables complete vehicle counting. The core algorithm of this part is completed by DSP.

B. *Elevated Road Traffic Monitoring System Hardware Structure Design*

In the hardware system of the elevated road traffic monitoring system, DSP (TMS320DM642) mainly receives the data from the FPGA pretreatment, and then uses the data to realize the algorithm. At the same time, DSP is also responsible for the configuration of all kinds of peripheral interface configuration (the coordination of all kinds of interfaces to ensure the normal operation of the entire system). IIC bus is responsible for the video capture chip SAA7105H initialization configuration; When the video data is processed, the communication module inside the FPGA is sent to the DSP to send an interrupt signal INT0, and the DSP receives the data; DSP after processing the data through the LXT972 transfer to the host computer for display and storage. The hardware structure of the system is shown in Figure 8.

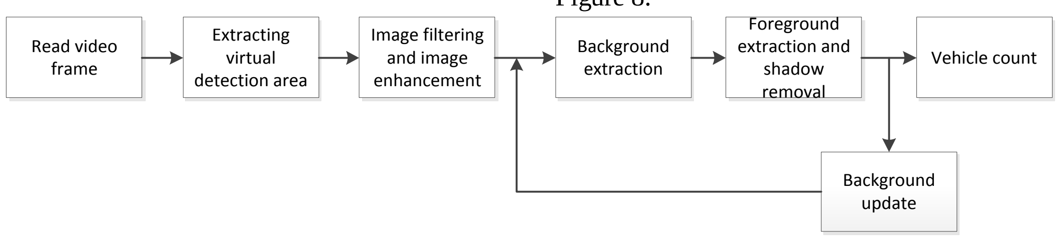

Figure 7. The flow chart of traffic statistics based on virtual coil.

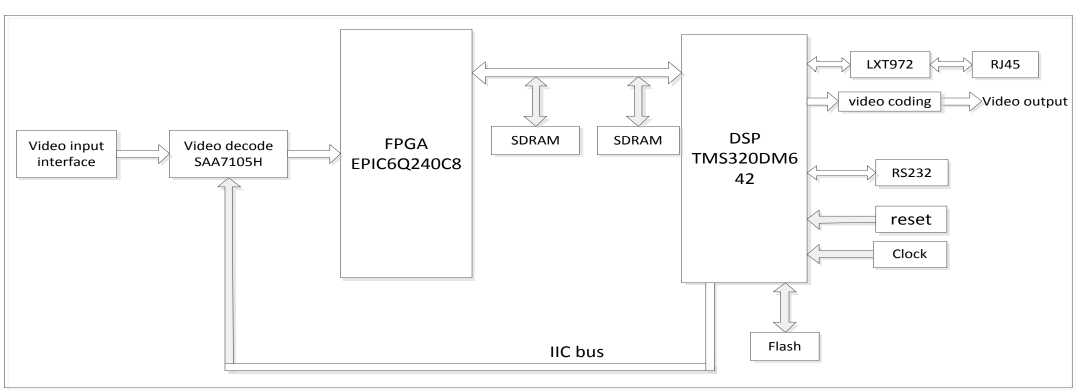

Figure 8. Hardware structure of the system.

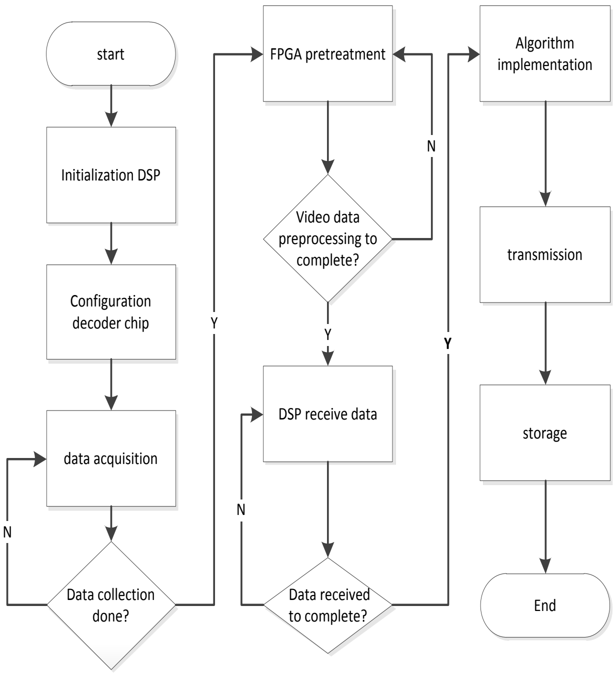

Figure 9. DSP+FPGA processing video data flow chart.

Video decoder receiving from installed on the elevated road camera video analog signal, through SAA7105H decoding is converted into digital video signal to the FPGA chip. EPIC6Q240C8 chip as a coprocessor to complete the cache and video frame of the video signal synthesis, reduce the DSP computation. The FPGA through double SDRAM ping-pong structure to ensure the integrity of video frames [14]. FPGA for data preprocessing, and then the processed data is sent to the DSP, using DSP to complete set of traffic monitoring algorithm and the processed video data for storage and transmission, through the EMAC interface of DSP by LXT972 access Ethernet and PC for data transmission. In the hardware platform for algorithm design and transplantation, DSP+FPGA processing video data flow as shown in figure 9.

V. CONCLUDING REMARKS

As part of intelligent transportation, elevated road is smooth or not is vital for the city's traffic. The purpose of the elevated road construction is fast, but need to run after construction, need to control the traffic based on the statistics of the traffic flow on the elevated road. According to the requirement, this paper puts forward a set of feasible solutions to the elevated road traffic monitoring, and has carried on the simulation algorithm for the vehicle counting, the simulation results show that this algorithm can effectively to monitor the overhead traffic. The experimental results show that the accuracy of the vehicle count is more than 97%. Aiming at the special application environment of the elevated road, embedded design scheme based on DSP+FPGA architecture in hardware. The scheme is simple and reliable, high real-time performance, can effectively applied to the elevated road traffic management.

REFERENCES

[1] XIA Yang. Intelligent transport system based on video stream. Information technology, 2007(9):61-63.

[2] Wu Yabin, CHEN Shurong. A vehicle identification and traffic detection algorithm based on surveillance video[J]. Microcomputer and Application, 2015, 34(7):45-48.

[3] ZHANG Ning, SHI Yi, HE Tiejun. Vehicle Module Recognition Based on Virtual Loops[J]. Traffic and computer, 2008,26(6):69-72.

[4] DONG Chunli, DONG Yuning. Survey on Video Based Vehicle Detection and Tracking Algorithms[J]. Nanjing University of Posts and Telecommunications (NATURAL SCIENCE EDITION), 2009, 29(2): 88-94.

[5] J. H. Duan, Y. L. Deng, K. Liang. Development of Image Processing System Based on DSP and FPGA. The Eighth International Conference on Electronic Measurement and Instruments, Xi'an, Shanxi, China, 2007:791-794.

[6] PENG Yu, JIANG Honglan, Yang Zhiming .Design of general digital signal processing system based on DSP and FPGA[J]. Foreign electronic measurement technology, 2013, 32(1):17-21.

[7] YANG Jing, WANG Yuanqing. Implementation of Improved Median Filtering Algorithm in Real-time and High-speed[J]. Computers and modernization, 2013(8):30-32.

[8] TIAN Wang, TAO Qingchuan. A Fusion based Night Image Enhancement Algorithm[J]. Computer security, 2013 (10): 43-46.

[9] WANG Aili, DONG Baotian, WANG Zesheng. Adaptive Background Updating Based on Optical Flow and Background Difference[J]. China Railway Science, 2014, 35(6):131-137.

[10] LUO Donghua, YU Zhi, Li Xiying. Application of edge-based background difference in traffic volume extraction[J]. Opto-Electronic Engineering, 2007, 34(11): 70-73.

[11] Philippe Salembier. Morphological multiscale segmentation for image coding[J]. Signal Processing,1994,38:359-386.

[12] JIANG Ke, LI Aihua, SU Yangzhao. An Adaptive Shadow Detection Algorithm Using Edge Texture and Sampling Deduction[J].JOURNAL OF XI'AN JIAOTONG UNIVERSITY. 2013, 47(2):39-46. Processing,1994,38:359-386.

[13] LU Qinghua, WU Zhiwei, FAN Yanbin. Shadow Detection Algorithm for Moving Vehicles Based on Color Space and Texture[J]. JOURNAL OF TEST AND MEASUREMENT TECHNOLOGY, 2013(2): 252-254.

[14] KANG Yanxia, CAO Jianzhong, TIAN Yan. Ping-pang Cache Structure in Real-time Video Processing System[J]. Journal of Projectiles, Rockets. 2007, 27(4): 218-221.