Study on Video Intelligent Early Warning and Tracking System Based on ARM

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***Abstract* - Digital video intelligent early warning and tracking system consists of an early warning matrix subsystem and tracking speed dome subsystem. A warning matrix subsystem with dual-core embedded architecture including ARM and DSP are designed. The architecture is used as the basis to design image early warning algorithm based on traffic dynamics. After image early warning, license plate number is located rapidly, then license plate recognition and accident severity level determination are made on the basis of verifying and detailing inclination after location. According to the accident level, the corresponding processes are made such as informing the person on duty or starting tracking speed dome to track. In tracking speed dome subsystem, image tracing model is designed in detail, fuzzy PID controller is used to control speed dome to track suspicious object, real-time monitor is made and the results of simulation experiments are given.**

Keywords - embedded dual-core system, intelligent early warning, accident recognition, tracking and monitoring, simulation

I. INTRODUCTION

In recent years, with the enhancement of economic power in our country, urban area is extending, law-and-order situation is becoming complicated, public safety issues are constantly highlighted, urban crime is becoming evident, and the means is updated and upgraded continuously, which has an urgent demand on accelerate development of digital video intelligent early warning and tracking surveillance system dominated by proactive prevention. In September 2009, Ministry of Public Security in China officially launched urban networking alarm and surveillance system construction (Project 3111) which developed alarm and surveillance system construction pilot projects all over the country to promote the construction of safe city. However, seen from the present urban networking alarm and surveillance system construction, video surveillance system is constructed by simulating monitoring system or adding video capture card to PC, which is difficult to satisfy the requirements of real-time process, stability and reliability, accident recognition and automatic tracing. And it is stilled confined by post-mordem forensics. Therefore, it is urgent to develop new video surveillance system. Rapid development of large-scale integrated circuit and embedded software and hardware technology provides new thought of solving the problem, which means to develop digital video intelligent early warning and tracking surveillance system based on embedded structure.

The innovation of the paper includes: Firstly, analysis of video image is made in video matrix (the chip uses AT91RM920T of ATMEL Corporation), that is, DSP chip is used to make high-seed analysis on large number of data in video pictures and automatically extract key information of video source, which can detect the problems and make timely early warning. After early warning, the license plate is automatically recognized and GPRS is used to send the recognized license plate and accident situation to the person on duty, and then tracing speed dome is used to track abnormal situations until early warning is removed. Secondly, a response algorithm model of early warning condition is designed. The model can make high-speed analysis on large number of compressed video data. The extracted key information is used to judge if it has need to make early warning and implement corresponding operations, for example, making early warning picture display on monitor and opening DVR for recording picture. A hardware structure is designed and fuzzy PID controller is used to control speed dome to track suspicious targets and make real-time surveillance until the early warning is removed.

II. IMAGE EARLY WARNING ALGORITHM OF DYNAMICS VISUAL EVENT RECOGNITION BASED ON DYNAMICS

A. Introduction of Visual Event Recognition Based on Dynamics

For dynamic visual method, all events to be recognized should be defined as verb firstly. We can know from the practice that only three verbs can describe all events. The verbs are: (1) Support, an object Y falls when it is not supported by object X, which means that object X supports object Y. (2) Connection, when two objects contact, it is called connection. (3) Attachment, when two objects move as a community, it is called that an object attaches to the other object.

The events which are described by the above verbs and the combination with logic relationship are used to express a complicated event. The event of the object X catching object Y and throwing it is taken as an example.

（Defining throw（X，Y））

（There are two sub-event （I，J））……I means X catches object Y, and J expresses X throws object Y

（Logics and （when sub-event I, connecting（X，Y））
（when sub-event is I, attaching to（X，Y））
（when sub-event is I, supporting （X，Y））
（when sub-event is J, attaching to（X，Y））
（when sub-event is J, connecting （X，Y））
（Logic＝（I ends）（J begins）））

We can see that the contour features including place, direction, the shape and size of the outline of moving targets can be gained through outline process after achieving traffic information images. The contour features are assigned to joint model and hierarchical model, which can judge if the outline meets the features of traffic accidents and determines if it is necessary to make early warning.

B. Image Early Warning Algorithm

Based on the above description of traffic vehicles, we design an algorithm. When DSP polls all images of input audio and video matrix, the vehicles and pedestrian of images are for outline operation and for dynamic comparison of traffic incidents. If it conforms to the above instruction, it means traffic incidents happen.

III. EVENT NOTIFICATION CONTENT: LICENSE PLATE NUMBER LOCATION METHOD

A. Binarization of license Plate Image

It is not difficult to discover grey-level features of license plate area. The characters and background pixels of license plate have even gray values which have no great difference. But there is great difference for average gray of two pixels. In addition, there are rich edges in rectangular area that license plate belongs to. There are regular intervals between strokes of each character, which is not common in rectangular area of license plate. In order to make full use of the features, the paper firstly makes level difference accumulated operation on the original gray-level image to highlight the upright edge of image. And the selected method is:

$$HD(x,y)=\sum_{d=0}^{2}|\ f(x+d,y)-2f(x+3+d,y)+f(x+6+d,y)\ | \tag{1}$$

$f(x,y)$ is gray value of image, $HD(x,y)$ is difference accumulated result, x and y express the value of horizontal and vertical coordinate, and d means offset. The achieved difference image can highlight edge features of images and expand the number of pixels, which provides basis for the extraction of license plate.

Figure 1 Gray level of license plate

Adaptive threshold method is used to make binarization processing on the difference image which is achieved by accumulation, which can get edge image including region area of license plate. The concrete method is:

$$f(x,y)=\begin{cases}0 & f(x,y)<T\\ 255 & f(x,y)>T\end{cases} \tag{2}$$

T is Bayes means to use minimum error criterion as convergence condition to get the threshold of segmenting images. Lastly, the image which is processed by the above algorithm is shown in Figure 2.

Figure2 License plate binarization

B. Acquirement of License Plate Candidate Area

Although license plate area has rich and concentrated edges, the edges may not be interconnected to form connected continuum, which is not conductive to vertical location of license plate. So the achieved binarization edge image needs to make horizontal mathematical morphological dilation, which makes license plate area become connected area and can use the license plate as a

whole and non-division region for analysis. While making dilation operation, the interference of noise on edge image causes many pseudo lines. In order to effectively filter license plate area, these lines need to be filtered. Under the premise of not breaking the existing connected region, the paper scans from vertical and horizontal direction, and filters the influence of the lines by restricting the length of all white lines. And the algorithm is:

(1） Scanning one column (line), and counting the number of continuous nonzero pixels, NUM。

(2）If NUM<T_{col1}（T_{row1}） or □NUM>T_{col1}（T_{row1}）, the pixel in the part is set to be zero or keeps invariant.

(3) NUM is cleared. The column (line) continues to be scanned and counted, and turning to (1) until the scanning on the column (line) is over, and turning to (4).

(4) Entering the next column (line) and turning to (1) until the scanning on image is over.

T_{col1}（T_{row1}） is the length threshold which is preset according to priori knowledge.

After processing, several connected regions are achieved as the candidate license plate area. In order to make further process, the connected regions of the image need to be marked, and the leftmost, rightmost, uppermost and nethermost coordinates of each connected region is respectively marked as $Left_i$ $Right_i$ Top_i and $Bottom_i$, and is defined as a candidate rectangular region. And the length and width of each rectangular region can be calculated as:

$$W_i = Right_i - Left_i, \quad H_i = Top_i - Bottom_i \tag{3}$$

The image after processing is shown in Figure 2.

Figure 3 License candidate region.

C. Vertical and Horizontal Location of License Plate

Each candidate rectangular region image needs to be made vertical-direction difference operation. Te vertical-direction projection $VP_i(x)$ of vertical difference image needs to be solved:

$$VP_i(x) = \sum_{x=0}^{W_i-1}\sum_{y=0}^{H_i-1} |f(x+Left_i, y+Bottom_i+1) - f(x+Left_i, y+Bottom_i)| \tag{4}$$

If Max^i is the maximum of element of $VP_i(x)$, as the width of license plate characters of images is variant in certain interval, and license plate characters have no evident regularity because of noise interference. Therefore, when we use horizontal scanning line y=Scan to scan $VP_i(x)$ from 0 to Max^i in the interval [0，Maxi] according to certain $Interval^i$, the number of continuous elements in $VP_i(x)$ which are greater than the scanning value of the scanning line is recorded and characterized as the length of multiple scanning lines. Then the length of all lines in [0，Max^i] and the frequency is accumulated. Only the area in which the frequency of the lines with specific length is greater than a specific number is real license plate area. Through the processing, each non-license plate area can be eliminated, which completes screening and location of license plate area in vertical direction and can gain mean width of license characters of images.

Horizontal location process of license plate is the process of determining the left and right boundary of license plate. In order to determine the left and right boundary of license plate, we can use the proportional relationship between the length and width of license plate and concrete width of license plate of the achieved figure to speculate the concrete length of license plate, which uses the interval of the length of license plate as sliding window, and makes accumulated statistics on the projection in vertical direction of the license plate. When the accumulated value is the maximum, the left and right boundary of the window can be as the left and right boundary of license plate in the image. The processing image is shown in Figure 4.

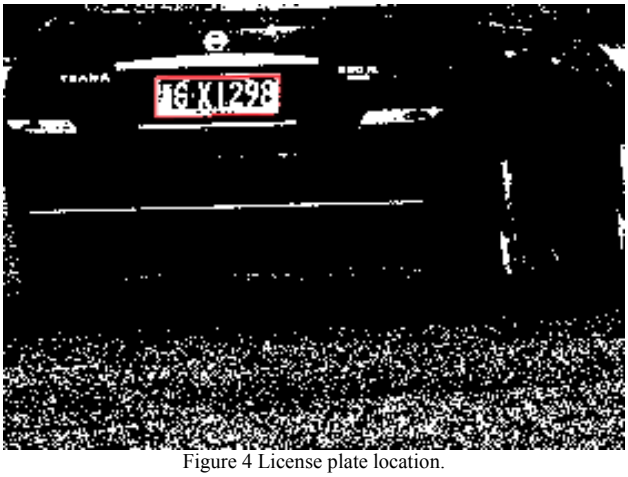

Figure 4 License plate location.

IV. EVENT NOTIFICATION CONTENT-LICENSE PLATE NUMBER RECOGNITION ALGORITHM

After license plate location, we can enter the process of license plate recognition. The recognition principle of number, character and English letters of license plate is the same to that of printed characters.

A. Refinement of License Plate Images

After obtaining binary images after inclination correction, the features of numbers, characters and English letters are extracted. In order to make feature extraction easy, the images should be refined.

Refinement is that binary images with width area are for operations and becomes a framework with only one pixel width. It is an important operation for image analysis and mode recognition. The framework image which receives refined process provides a simple expression for image processing and analysis of the subsequent image, which is conductive to making detailed analysis on images. Refinement algorithm has the following requirements. (1) Image skeleton must keep connectivity and topological structure of the original images, (2) Image skeleton should be the central line of the original image. (3) The result of refinement should be a line image with a pixel width. (4) Processing speed should be rapid. (5) Anti-noise performance is good.

The design uses the improved and refined algorithm proposed by Y.Y.ZHANG and .S.P.WANG in Computer College of Northeast University in America, as follows.

The algorithm uses 4X4 formwork：

P10	P11	P12	P13
P9	P2	P3	P14
P8	P1	P4	P15
P7	P6	P5	P16

Pixels of binary images are expressed by 0 and 1. 1 represents prospect, and A (pl) means the number of 01 in P2, P3, P4, ……P9 and P2 around point P1.Function BP1) is used to mean the number of nonzero in the connected area from P1 to 8. When P1 satisfies the following requirements, it will be deleted from the original image: （1）P1=1；（2）2<=B(Pl)<=6；（3）A(Pl)=1；（4）P2*P4*P8=0 or P11=1；（5） P2*P4*P6=0 or P15=1.

B. Character Recognition

The features of the number and letters of the refined license plate should be analyzed before recognition, which makes it differentiate from various numbers and letters. The principles of feature extraction are as follows. (1) Distinguishable. The features of different categories of objects have evident difference. (2) Reliability. The characteristic values of different objects are similar. (3) Independence. There is no relationship between the features which are used. (4) Small number. Complication of pattern recognition system increases with the dimension of the system.

Figure is taken as an example for analysis. According to the configuration of figure, we select four features. (1) Horizontal line, XR=nR/widthR. nR is the number of continuous pixel points in horizontal direction, and widthR is the horizontal pixel of single letter image. When XR>0.5, there is a horizontal line. (2) Vertical line, YC=nC/widthC. nC is the number of continuous pixel points in vertical direction, and widthC is the vertical pixel of single letter image. When YC>0.5, there is a vertical line. (3) Number of horizontal lines. A line is drawn in some horizontal position of image, and it is the number of the image crossing with the horizontal line. (4) Number of vertical lines. A line is drawn in some vertical position of image, and it is the number of the image crossing with the vertical line. The following is the judgment process. Firstly, it can be divided into two categories according to the number of horizontal lines, A here is the number of horizontal lines （2、4、5、7）and B there is no the number of vertical lines （0、1、3、6、8、9）. A can be differentiated by horizontal position and the standard if there is vertical line. B is differentiated by the standard if there is vertical line, the number of horizontal lines and vertical lines.

C. GPRS Message Event Notification

When we acquire early warning of traffic accidents, it is not enough to only make the images display through the client side. If the personnel on duty leave because of something, or the accident is so serious that the personnel can't manage it, the information needs to be sent to senior-level personnel. And we should use SIM100-E GSM/GPRS dual-frequency module of SIMCOM Corporation which provides wireless interface for messaged and data service. SIM100-E provides standard RS-232 serial interface. The users apply AT order to complete the operation of module through serial interface, as shown in Figure 5.

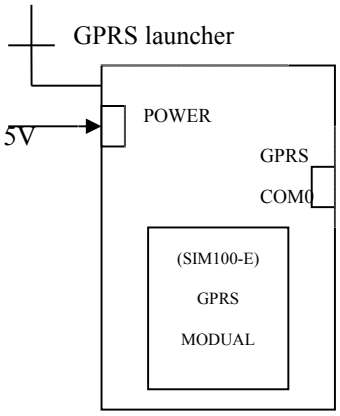

Figure 5 Basic structure diagram of SIM100-E

We use the serial interface 2 of hardware platform of video and audio matrix to realize the communication between GPRS module and audio-video matrix. GPRS sets the traffic rate of audio and video matrix to be 115200. The information transfer task of SIM card is set to be ready. And it is set to be protected while executing the task. We send AT orders to GPRS module through serial interface 2. AT orders are realized by function GPRS_Cmd(char *cmd). GPRS_Cmd is a function which sends characters to serial interface 2, cmd character string which is sent by serial interface 2 is received by GPRS module which manages orders.

V. IMAGE TRACING MODEL AND SIMULATION

A. Mathematical Model of Three-Dimensional Tracking Path

Cameras based on speed dome can be applied to all-round surveillance and demands to make coordination control on multi-axis stepper motor to drive cameras, which makes it can track motion objects.

Therefore, we need at least 3 stepper motor to realize the traction of x axis, y axis and z axis, which realizes spatial location. In order to deduce the mathematical model of tracking path, we suppose the basal coordinate of any locus function $f(x,y,z)$ is (x_1,y_1,z_1), each coordinate changes with time parameters, and suppose T is geometric mapping operator, $f(t_1)=T\{x_1(t_1),y_1(t_1),z_1(t_1)\}$.

The motion equation only includes registration parameter and is the same to common geometric function, which has corresponding geometric features such as the slope of a tangent, curvature and torsion. And it indicates important motion information which means dynamic relationship of motion displacement. The differential equation can express the relationship between motion parameters. Deriving the time t_1 of Formula (8) can get:

$$v_f=\frac{df}{dt}\frac{dt}{dt_1}=\frac{\partial T}{\partial x_1}\frac{dx_1}{dt}\frac{dt}{dt_1}+\frac{\partial T}{\partial y_1}\frac{dy_1}{dt}\frac{dt}{dt_1}+\frac{\partial T}{\partial z_1}\frac{dz_1}{dt}\frac{dt}{dt_1}$$

We can see from the formula that each item only relates to geometric mapping operator T, which means that motion speed of $f(x,y,z)$ is equal to the multiplication of geometric parameter and time rate of change. Therefore, if locus function is known, we can solve motion parameter of any point.

5.2 Model simulation

MATLAB language is used to make simulation comparison test on control system which uses and doesn't use fuzzy adaptive controller. In the experiment, the transfer function of controlled object (stepper motor) is:

$$G(S)=\frac{17.534}{S^2+5.9629S+17.534}$$

The unit step response results of the system are shown in Figure 6 (the curve ① is the system output of fuzzy adaptive PID control, and curve ② is the system output of the conventional PID control).

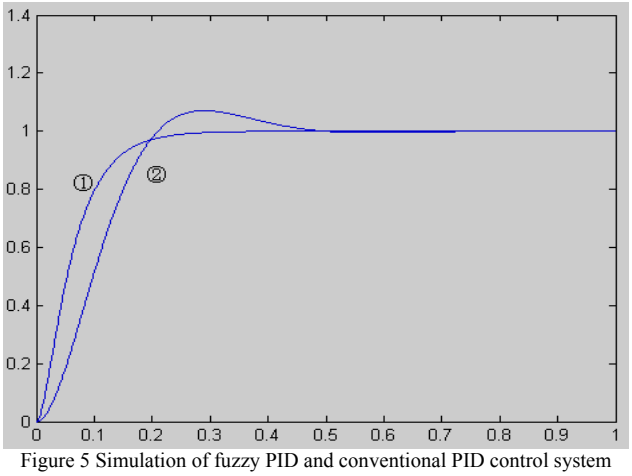

Figure 5 Simulation of fuzzy PID and conventional PID control system

We can see from simulation curves that when fuzzy adaptive PID control is used, the dynamic response of the system is rapid, there is no overshoot, and there is no state error, so it has good controlling effect. But when

conventional PID control is used, the response speed is low, and there is overshoot and vibration which is between 0.5 seconds and 0.75 seconds.

VI. SUMMARY

Based on studying digital video intelligent early warning and tracking surveillance system at home and abroad, the paper studies the existing problems of digital video intelligent early warning and tracking surveillance system in our country, and proposes a digital video matrix structure based on ARM and DSP dual-core structure and speed dome based on fuzzy PID automatic tracing.

The innovation of the paper includes: dual-core embedded structure is used to make digital video intelligent early warning and tracking surveillance system, which not only realizes the analysis and comparison of various images, but also improves the overall performance of the system. Using dynamic incidents fuzzy recognition and GPRS incidents not only greatly reduces false alarm rate of the system, but also makes the work of monitoring personnel reduce. Fuzzy PID automatic tracing is used in combination with simple fuzzy control and conventional PID control. According to the size of error e and error change Δe, fuzzy rules can be modulated automatically, and proportional factors K_e, $K_{\Delta e}$ and K_p, K_i can be corrected adaptively, which makes natural frequency and damping ratio of the system transferring functions regulate automatically, which makes the system realize reducing positive fixed torque and increasing reverse braking torque, which can overcome nonlinearity of speed dome, instability of parameters and influence of various interferences on the system, for example, conventional PID control and simple fuzzy control have higher outline tracing accuracy, positioning accuracy and robustness on disturbance.

In short, I learned a lot about hardware design from the paper. From the paper work, I not only accumulate rich experience about software and hardware system design, but also feel that the knowledge is endless. Only working harder can make progress.

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