Implementation of a remote real-time surveillance security system for intruder detection

Jiang Landa, Chu Jun, Miao Jun

Institute of Computer Vision Nanchang HangKong University, Nanchang, Jiangxi Province, 330063
Email: 1063096577@qq.com

***Abstract*—Family security is one of the key goals of a digital home system. At present, webcams are widely used in home remote monitoring systems. This is due to the fact that its passive monitoring nature leaves a potential security problem and cannot be used for providing proactive security. To solve this problem, this paper proposes the design of a remote embedded intelligent security monitoring system based on the background modeling algorithm in computer vision which can proactively detect intruders. The system uses the ViBe algorithm to model the background image which is acquired from the camera, and then carries out the object detection in the monitored environment. If a moving object (including people) is detected, the system will automatically sound an alarm, while sending a message or calling the user to take preventive measures. Users can log in to the server through the mobile application to detect the intruder from the intercepted picture, and to get a better understanding of the situation. After testing, the system can accurately determine whether there is something intruding the monitoring area or not. It is robust, real-time, and with a good practical application value.**

Keywords- background modeling, embedded technology, remote monitoring, ViBe

I. INTRODUCTION

With the development of social economy and the improvement in the quality of life, family safety has become one of the most important aspects of life. Cameras are being used to monitor both public places and homes in order to enhance safety and security. However, the traditional method of using cameras with human observers has some drawbacks. Research shows that human beings have a short attention span. When a person stares at a screen for more than 20 minutes, his attention drops by 30%; and for periods over an hour, this drop can reach 70%. Also, another disadvantage of traditional systems of security monitoring is that it leads to the unnecessary storage of data in DVR (or other storage forms) resulting in the wastage of a large amount of bandwidth and storage resources. At the same time, such a system lacks any intelligence. It can only monitor and cannot take any proactive measure to improve the security - it cannot help people by providing a response rapidly.

Obviously, the traditional video surveillance systems based on manual operation cannot meet the security needs of the modern society. In recent years, the development of computer vision and artificial intelligence has opened up new channels to provide advanced support for home security [3]. Intelligent video analysis technology, which comes from the field of computer vision, applies automatic analysis of video content by using intelligent algorithms. The core technology is to identify and analyze video content to extract specific behaviors of some specific events or targets. Intelligent video analysis technology can perform the task of the real-time monitoring using a computer and search targets and events fast even from massive amounts of video data. So it has attracted the attention of the researchers [4] in this domain.

In light of the need for applying intelligent monitoring techniques to home security, this paper studies and designs an embedded remote monitoring smart system based on the background modeling algorithm. The intelligent video analysis technology is installed on an ARM processor with an embedded Linux operating system. The System has a camera to record images and uses the embedded ARM development board for real-time background image modeling for intrusion detection. This system has a GPRS communication module to inform the user in case an intrusion is detected. Once the system detects an intrusion, it dials or sends a message to the user through the GPRS module. At the same time the system automatically intercepts the images. Then the users can login to the embedded ARM server and download the intercepted images to see the specific circumstances of the house for taking effective measures in time.

II. SYSTEM OVERVIEW

Modern criminals have resorted to the use of advanced technology for carrying out their crimes. Studies have shown that many criminals use advanced equipment, instead of people, to execute criminal activities. Therefore, for the situations when the owner is not at home, if there is an intrusion, there is a need for a system that can detect such abnormal activity and take appropriate action. The use of target detection to conduct intruder detection, can not only save time and reduce space complexity, but also provide a guarantee for the realization of a robust detection function which is in line with the needs of modern family security [5].

The purpose of this paper is to design an economical and practical remote intelligent monitoring system based on the background modeling algorithm. When the user is out, the task of the whole system is to decide whether there is a break in. In cases where such events are detected, the system will record and save the key images for the user to download and view, to understand what happened in their house. This method avoids the problem of network security, for the embedded ARM development board, which not only solves the problem of the bandwidth of data transmission, but can also reasonably utilize the storage space [6]. The structural design of the system is shown in Fig.1.

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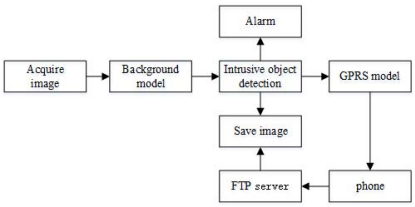

Fig. 1. The structure design of system

III. THE HARDWARE DESIGN

The system's hardware equipment mainly includes a USB camera, LCD touch screen, a OK210 development board and a GPRS module. The development board captures the image from the camera to model the background, and then starts the target detection function. The LCD screen displays the image acquired by camera, and provides the user an option to select the notification methodology in case any abnormal activity is detected in the house. According to the user's choice, the GPRS module can call or send messages to the user's mobile phone. The hardware structure of the system is shown in Fig.2.

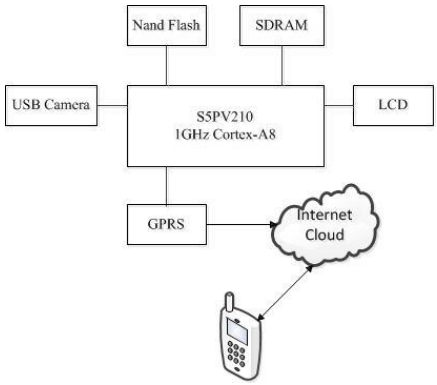

Fig. 2. The structure of hardware design

The system uses the OK210 as the main processor. It supports DDR2 and multiple types of NAND Flash, has strong internal resources and the ability to process video. The development board is based on S5PV210 (the processor of S5PV210 is Cortex-A8). Cortex-A8 has excellent graphics decoding performance and supports multi-standard video coding. As one of the most popular ARM processors, S5PV210 is the ideal choice for many applications. Due to the OK210's computing performance and its relatively low price, this security system uses OK210 as the main processor. The core block diagram of the development board is shown in Fig.3.

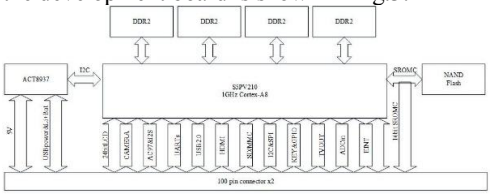

Fig. 3. The core block diagram of OK210

IV. THE IMPLEMENTATION OF THE SYSTEM SOFTWARE

This system was developed in Ubuntu 15.04. The main development tool used is QT4.8.6. The system captures video frames based on V4L2 (Video for Linux Two) APIs. We use the ViBe algorithm for the background modeling and foreground detection. The vsftpd server on the ARM processor, allows the users to log in to the server using the Android FTP client. Once logged in, the user can download the pictures which the system saved when an unknown intruder appeared in the surveillance area. The system uses OpenCV and QT, so these libraries must first be transplanted on the ARM development board [7].

A. Build development environment

Prior to the OpenCV cross compilation, the first task to be completed is the installation of the cross compiler chain. After cross-compiling all the dependent libraries such as yasm, x264 and xvid, the OpenCV transplant can be started. We use CMake to perform the compilation. After transplantation, the generated library should be copied to the ARM development board.

For the design of an interface, QT will also need to be transplanted to the ARM development board. For this, the Tslib library needs to be compiled first. In order to develop conveniently, we compiled two versions of the QT library files: for the PC and ARM. The program was simulated and debugged on a PC. After that, it was cross compiled as an ARM program, and was then run on the ARM.

In order to make users clearly understand what happened in the house, the vsftpd server is transplanted on the ARM development board. Users can login to the server using their mobile phone, and download the picture which the system saved when someone appeared in the monitoring area.

B. Capture image

This system acquires the video frames based on V4L2. There are five steps to acquire the captured pictures [8]:

(1) Open the device file, initialize the parameters of the video data, set the collection window and format of the video/image;

(2) Apply the frame buffer for video capture. The frame buffer is mapped from the kernel space to the user space, which makes it convenient for the system to read and process video data;

(3) Put the frame buffer in the queue, and start the video capture;

(4) The driver starts to capture video frames. The system gets frame buffers from the video acquisition output queue. After processing, the frame buffer goes back into the video input queue and continues the video data acquisition cycle;

(5) Stop the video capture.

C. Moving object detection

This system uses the ViBe algorithm to detect moving object. The main feature of ViBe[10] algorithm is the update strategy of the background model. The pixels of the sample that need to be replaced and the neighboring pixels to be updated are randomly selected. When it is not able to determine the model of the changed pixel, a random update strategy is chosen to simulate the uncertainty of the pixel's changes to a certain extent.

a. The principle of ViBe

In the ViBe model, each pixel includes a sample set, which contains the past value of the pixel and the values of its adjacent pixel. In such a sample set, for a new pixel, it's value will be compared with the collection point of sample to determine whether the new pixel belongs to the

background or not. This is the process of pixels' classification.

Formally, let's denote $M(x) = \{v_1, v_2, \ldots, v_N\}$ as the background sample set of pixels located at x in the image (the size of sample is N); $v(x)$ represents the pixel's value at x. As shown in Fig.4, v_i(i=1,2,... 6) is the sampling point of the sample set of point x. It is defined as a sphere $S_R(v(x))$ of radius R centered on $v(x)$. By computing the intersection of $S_R(v(x))$ and $M(x)$, if the intersection number satisfies the given threshold #min, as show in (1):

$$\#\left\{S_R(v(x)) \cap \{v_1, v_2, \ldots, v_N\}\right\} \geq \#min \qquad (1)$$

then point x is classified as belonging to the background, otherwise, point x is a foreground point.

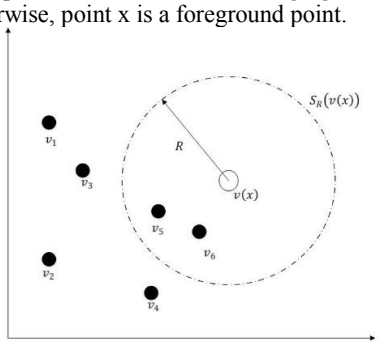

Fig. 4. Comparison of a pixel value with a set of samples in a 2-D Euclidean color space.

b. The initialization of ViBe

Initialization is the process of building a background model. A general background modeling method usually needs to cache a certain length of the video sequence to complete the background model initialization, which consumes a few seconds of time. On the ARM development board, due to the limitation of the calculation speed the time required is higher. This greatly affects the real-time intruder detection. ViBe uses only one frame image to complete the initialization of the background model. ViBe initializes the background model by using the characteristics of the adjacent pixels that have a similar distribution, so it can fill the sample set of pixels.

The initialization method for a pixel at location x - N times randomly selected pixel values from the 8 neighborhoods of x as its model sample values, as shown in the formula (2) are chosen.

$$M^0(x) = \{v^0(y|y \in N_G(x))\} \qquad (2)$$

t=0 indexes the first frame and $N_G(x)$ is a spatial neighborhood of a pixel at location x. This initialization method, though sensitive to noise, requires a small amount of calculation and hence leads to a fast execution speed, enabling it to detect moving objects quickly.

c. The updating mechanism of ViBe

ViBe combines the conservative update strategy and foreground point counting method to update the background model. When a pixel is classified as background, it has a probability of $1/\varphi$ to randomly select a sample pixel in the sample set to update. It also has a probability of $1/\varphi$ to update the sample set of its neighboring point. In addition, when a pixel is classified as a foreground point K times continuously, it will be determined as the background point. There is also a probability of $1/\varphi$ to update its model sample.

ViBe updates the sample randomly, to ensure a smooth life cycle of the sample value. Because of a random update mechanism, the probability of any sample value to be updated at time t is $(N-1)/N$. Assuming that time is continuous, the probability that the sample value is still reserved in dt is

$$P(t, t+dt) = \left(\frac{N-1}{N}\right)^{(t+dt)-t} \qquad (3)$$

This indicates that since the sample value to be replaced has no relationship with time t, ViBe's random strategy is suitable.

D. The implementation of FTP Client

In the moment that an unknown intruder enters the monitoring area, the system will automatically save the image on the server. Users can download the images by logging in to the vsftpd server. This will help the users to know what exactly happened in their house and also keep the key evidence.

The development process of the Android FTP client is shown in Fig.5. Firstly, set up a connection with the server via the IP address and port number. Secondly, log on to the vsftpd server using your username and password. After a successful login, you can perform various operations with the pictures - such as upload, download, delete and rename the images. After the operation is completed, disconnect the connection to the server.

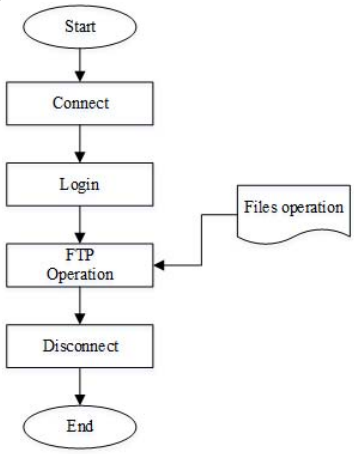

Fig. 5. Flow-process diagram of ftp client.

V. Experiments

The hardware platform of the system is shown in Fig.6. After transplanting the program to development board, the system starts the task of background modeling and moving object detection. If an intruder is detected in the monitoring area, the system will call or send text messages to inform users that there is some abnormal activity at the house. On the left of the LCD screen shows the video images. During the initial setup of the system, the user can input the phone number by using the touch keyboard on the right of the screen or click on the phone

or SMS icon on the middle of the screen to make the system call or send messages to trigger the remote alarm function. When the user chooses to send a message to inform, he can edit the text box below the two icon and write the content of the messages to be sent.

Fig. 6. The hardware platform of system

When users receive telephone or SMS alerts, they can log in to the server to download and view the pictures the system has saved, and then adopt corresponding measures; Fig.7(a) shown the Android FTP client login interface. After entering the relevant information, users can connect and login to the vsftpd server. Fig.7(b) shown the folder of the pictures which the system had saved; Fig.7(c) shows various operations the users can perform on a picture - such as download the image or rename it by long pressing upon the filename; Fig.7(d) display the image files that was downloaded from the server to the user's mobile phone, so that even if the front-end equipment of the system is broken, the user can still maintain the key evidence; Fig.7(e) shows a picture that the user downloaded from the server, so that the user can clearly know who broke into the house, and take the corresponding measures.

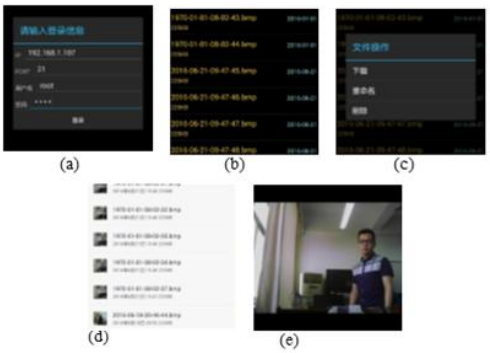

Fig. 7. The experiment of ftp client

VI. CONCLUSIONS AND FUTURE WORK

In this paper, we research the application of background modeling algorithm for remote intelligent monitoring. We implement an intelligent video analysis technology and embedded technology to implement safety and security at homes and other environments. This system has the advantage that the traditional monitoring system do not have with respect to its being intelligent in detecting intruders, and its ability to integrate with other systems. In the ARM development board, the ViBe algorithm processes the real-time video image, and inspects the monitoring area intelligently. If a moving object is detected, the development board will sound an alarm, which can play a deterrent role to the intruder. At the same time, the system will automatically save the pictures to the server which has been transplanted to the development board. If the house is intruded, users can choose the system to inform them by phone or SMS, and then users can download the pictures through the mobile phone to know more clearly the situation of house. However, in the case of light changes drastically, this system is prone to making errors in detection. When the system has just started to run, the background modeling algorithm cannot handle ghost regions quickly. Moreover, this system is not combined with other sensor technologies to realize an integrated security system. To solve the above problems, we need to do more work on the system for further improvement.

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