

Embedded Remote Video Surveillance System Based on ARM

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Abstract: In this study, an embedded remote video surveillance system based on ARM was build. The hardware system is composed of ARM S3C2440 processor, OV9650 CMOS camera, and mobile phone; and the software platform includes three modules—video capture, video processing, and video transmission. Moreover, an improved moving target detection algorithm was proposed, which combines real-time background updating and three frame differencing to reduce the impact from the gradient and emergency in ambient light when long-term monitoring. The test results showed that, when someone appears in the monitoring scene, the system will send the relevant video information to the user's mobile phone via e-mail, that is, an alarm is sent to the user to complete remote video surveillance. In addition, it can adapt to the changes in ambient light when long-term monitoring and also has a good resistance to the sudden appearance of highlight, having good security and stability.

Keywords: video surveillance system, ARM, embedded system, remote surveillance, moving target detection.

1. INTRODUCTION

The video surveillance system based on computer technology, embedded technology, and network technology can carry on all-day automatic real-time monitoring to the important department or place of the various professions, and it has already become the important component of peaceful guard domain. In recent years, the research on video surveillance system has caused widespread attention of the academic circle and industrial field in home and abroad, which also becomes the front topic of domestic and foreign research (Xing *et al*, 2006; Xiong *et al*, 2009).

In 1997, the first remote monitoring diagnosis workshop was sponsored untidily by the Stanford University and Massachusetts Institute of Technology, and there were more than 50 representors from 30 corporations and research facilities attending the conference. The conference mainly discussed the open style system, the diagnostic message regulations, the transport protocols, and legitimate limit to users, and so on, which are related to remote surveillance system, and made forecast to the future technological development. The next generation remote monitoring diagnosis demonstration system based on Internet was developed by the Stanford University and Massachusetts Institute of Technology, which has been supported and coordinated by 12 big companies about manufacturing industry, computer industry, instruments, and meters' industry, such as Sun, HP, Boeing, Intel, and Ford, and so on. Afterwards, these companies promoted an experimental system named Testbed together. Testbed uses the embedded Web network, the real-time JAVA, and Bayesian Net to form

the information monitor and the diagnosis inference in the scope of Internet (Venetianer *et al*, 2010; Hemetsberger *et al*, 2006). Moreover, many International organizations, such as MIMOSA (Machinery Information Management Open System Alliance), SMFPT (Society for Machinery Failure Prevention Technology), and COMADEM (Condition Monition and Engineering Management), and so on, also carry on equipment monitoring, malfunction diagnosis consultation, and technology extension through network, and they formulated some form and standard on information exchange (Tim Jones, 2002; Sarkar, 2006). Many big companies have also added the Internet function into their products. For example, Bently Corporation's computer online equipment movement observation system, Data Manager 2000, may send the equipment running status information to the remote terminal through network dynamic data exchange (Net DDE) (Li *et al*, 2009). The famous National Instruments corporation has also joined the network communication processing module in the products LabWindows/CVI and LabVIEW, they can transmit the monitor data by the way of WWW, FTP, the Email in the network scope (Yang *et al*, 2010). The research team "ALARM" in France has conducted the long-term research on intelligent warning of production process and the surveillance system, and they have been applicated in many projects.

The research on remote surveillance technology has also developed positively in China (Ruan *et al*, 2006; Lin *et al*, 2010). At present, Xi'an Jiaotong University, Huazhong University of Science and Technology, Harbin Industry University, Nanjing University of Science and Technology,

and so on, have obtained more advanced research results. For instance, the large-scale revolving mechanical computer condition observation system and malfunction diagnosis system RMMD of Xi'an Jiaotong University, and the steam turbine operating mode monitor and diagnosis system KBGMD of Huazhong University of Science and Technology, and micro computerizes the unit condition surveillance and malfunction diagnosis expert system MMMDES of Harbin Industry University, and so on.

Along with the research on remote monitor, its application domain also has been gradually transited from technical grade and commercial level to civil level. The video surveillance system based on embedded technology can not only be applied in some professions needed to carry on video remote supervisory, transmission, memory and management, such as the real estate, the chain-like system, the transportation system, and the financial profession, and so on, but also be widely applied in construction of safe campus, safe city, and safe society. With the unceasing enhancement of life's quality, the family safety protection has been paid an increasing attention. The development of the wide band technology enables the family remote monitoring technically achievable. However, the alarm system applied to family safety protection is static and based on the signal at present, so the video information is unable to be viewed. The merit of the embedded system makes it suit the family monitoring. Therefore, in the study, the embedded video surveillance system and the alarm system was integrated, and the embedded remote video surveillance system based on the ARM was studied and designed. The system of this study realized real-time monitoring to the family security.

2. SYSTEM DESIGN

2.1 Design of Hardware System

The hardware system includes processor, video-capture devices, and user's mobile phone to receive video information. In this study, ARM920T-based S3C2440 processor is chosen to complete the core control; OV9650 CMOS camera is used as a video-capture device; and the user's phone is connected to the Internet to receive video information to achieve real-time monitoring. As shown in Fig.1, it is the block diagram for overall design of the hardware system.

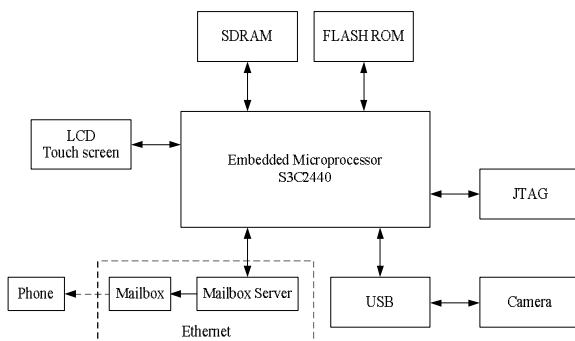


Fig.1. The block diagram of overall design of the hardware system

(1) Processor: S3C2440 processor based on ARM920T architecture is selected in the system; its expansion board provides the IO resources associated with our design (Huang *et al*, 2010):

① LCD Interface: It provides all the signal lines needed by TFT LCD screen interface, and supports 1, 2, 4, 8, 16, and 24bpp, at the same time, with TFT LCD screen of a maximum 16M colour and resolution up to 640×480 pixels.

② 2 USB interfaces: It can be switched to the Slave mode by the toggle switch, in our design, the USB interfaces are used as important ports for synchronization, communication, and downloading.

③ Nor Flash: It provides 1MB NorFlash, mainly used for the storage of initiator. It plays a very important role in the environment building of the beginning design.

④ Ethernet interface: It provides chip CS8900A with 10M Ethernet, chooses integrated isolation transformer RJ4 interface, and with the ACT, LINK indicator. In this design, it has dual role: used as the port for downloading the WinCE operating system in the design progress, and the carrier of the transmission channel after the system design.

⑤ Digital camera circuits: It provides the standard digital camera interfaces, used to link a variety of camera modules externally.

(2) Camera: OV9650 (Zhang *et al*, 2010) CMOS camera with 1.3 million pixels is selected in the built system. Particularly in poor light, the speed of CMOS camera is slower, but its price very low, and CMOS has power consumption only when the circuit is connected, it is generally used low-end cameras, digital cameras and toys. There is a 20P plug with 2mm pitch in ARM used as extension to connect the camera.

(3) User's mobile phone: User's mobile phone: The connection between the processor and the mailbox server is realized achieved by programming; and the theme and video attachments are sent to the mailbox linked to the phone through the mailbox server. When the mailbox receives the mail from the system, the relevant message will be sent to the user's mobile phone automatically.

2.2 Design of Software Platform

The embedded WinCE operating system (Pang *et al*, 2009) is selected in the design, and there are mainly three function modules, that is, video capture module, video processing module, and video transmission module. The schematic diagram of system software platform is shown in Fig.2.

The main function of each module is as follows:

(1) Video capture module: Camera captures video frames and sends them to video processing module.

(2) Video processing module: Use Moving target detection to process each video frame to determine whether there is moving target in the monitoring scene.

(3) Video transmission module: Send video information containing the moving target to the user's mobile phone via e-mail, to complete the remote video surveillance.

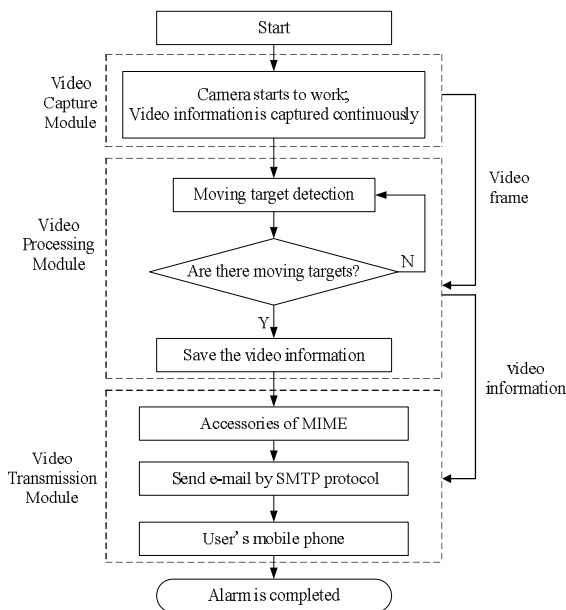


Fig.2. The schematic diagram of system software platform

3. DESIGN OF MAIN FUNCTION MODULES

3.1 Video capture module

CMOS OV9650 camera is selected to capture video frame, the video format is RGB565, which represents a pixel by 16-bit (2 bytes). The lowest 5 bits denote blue component, the middle 6 bits denote green component, and the highest 5 bits denote red component. The masks corresponding to the three components are: 0xF800, 0x07E0 and 0x001F. In order to extract the desired colour component, after reading a pixel, use the respective mask "and" on the pixel value. The flow chart of video capture is shown in Fig.3.

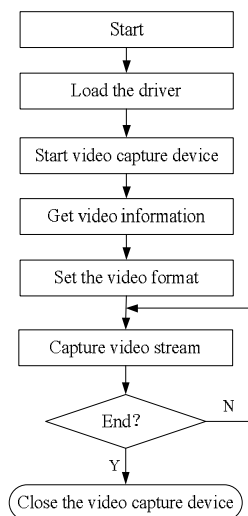


Fig.3. The flow chart of video capture module

Firstly, load the prepared driver of the camera to start the video equipment; secondly, get the video information by the reading function and set the image formats of system display and video storage; finally, extract the video frame by frame and sent them to the next processing module.

In the system, "DeviceIoControl" function in API is mainly used to access to the camera driver to complete the corresponding operation—obtaining information, sending commands, and exchanging data. Use this interface function to send the correct control code and data to the specified device driver, and then analyze its response, the appropriate purpose can be achieved.

3.2 Video Processing Module

This module handles video information from video capture module, that is to say, detecting whether there is an intruder appearing in the monitoring scene.

In order to improve accuracy and stability of the system, on the basis of background subtraction, an improved moving detection algorithm is proposed. The main idea is: in background subtraction, the background image is fixed, so in the case of long-term monitoring, the changes of ambient light will reduce the accuracy of moving detection. To overcome this drawback, the adaptive background updating method is introduced, which can real-time update the background to reduce the impact of the ambient light. However, it has poor adaptability to the sudden changes in the environment, such as sudden exposure, which can also result in error detection. Thus, the three frame differencing is used to filtrate these sudden changes, which can make the system better adapt to environmental changes and have better stability when long-term monitoring. In summary, the presented algorithm combines the background subtraction, the adaptive background updating method, and the three frame differencing, which can reduce the impact resulting from the gradient and emergency in ambient light when long-term monitoring.

The realization process of the algorithm is as follows:

Step 1: Save the current video frame as the background image;

Step 2: Continue to capture video, get the difference image between the background image and the first frame, and record the number of pixels in the continuous region of the difference image, M_1 . If M_1 is less than the threshold T , it proves that there is no moving target invasive monitoring scene, and then change the background image with the current frame, the judge concluded; if M_1 is greater than the threshold T , there may be a sudden change in lighting or a moving target invasion, put this frame into the dynamic memory, and go to "Step 3";

Step 3: Capture the second video frame, get the difference image between it and the current background, and record the number of pixels in the continuous region of the difference image, M_2 . If M_2 is less than the threshold T , it proves that there is an instant change in light, without any response,

replace the background of the current frame; If M_2 is greater than T , put it into another dynamic memory for further determination, and go to “Step 4”;

Step 4: Capture the third video frame, get the difference image between it and the background image, and record the number of pixels in the continuous region of the difference image, M_3 . If M_3 is less than the threshold T , it proves that there is a moving target invasion, change the background image with the current frame, and send the current frame to the next processing module; If M_3 is greater than T , get the difference image between the second frame and the first frame, and the difference image between the third frame and the second frame, and then record the number of pixels in the two difference images, N_1 and N_2 , and go to “Step 5”;

Step 5: If all of N_1 and N_2 are greater than T , it proves that there is a moving target invasion, send the current frame to the next processing module; If all of N_1 and N_2 are smaller than T , it shows that there are some changes in the environmental background, update the background with the third frame, and the system continues to monitor; Or that it can be considered there are sudden changes in ambient light and moving target in the monitoring scene at the same time, replace the first frame with the third frame, and detect again.

The flow chart of video processing is shown in Fig.4.

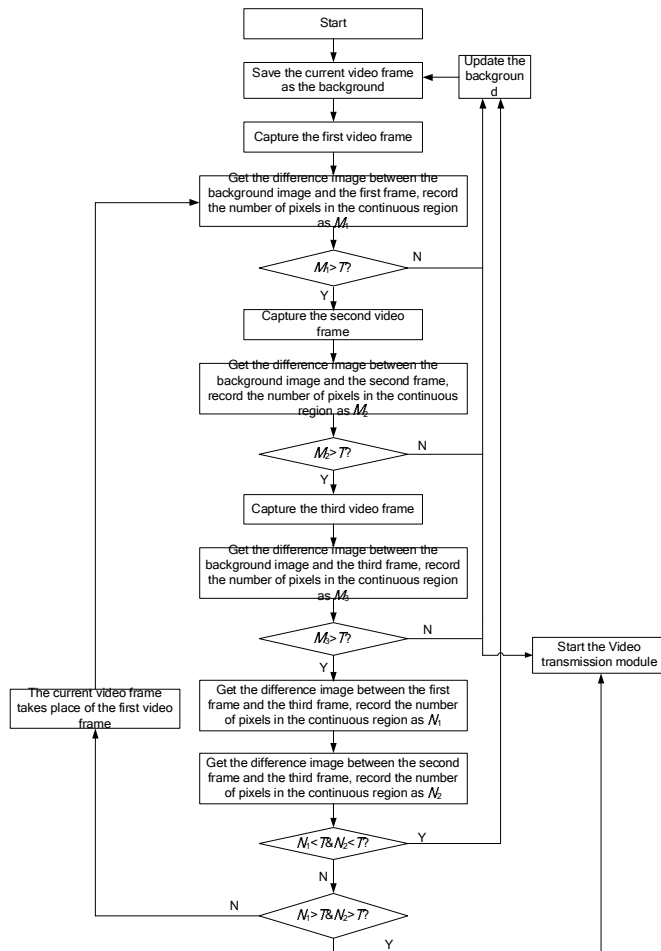


Fig.4. Flow chart of image processing module

The proposed moving target detection algorithm combines background subtraction and frame difference, which inherits some good characteristics, such as “accurately monitoring object” of background subtraction method and “strong adaptability to light” of frame difference method, and so on. What is more, jointing multi-frame judgment and adaptive background updating can further enhance the stability of the surveillance system.

In addition, the algorithm can update the background adaptively and monitor the scene if there are moving targets, and since being designed on the basis of the background subtraction, it has faster detection and response speed. As soon as someone brakes into the scene, the system will immediately send alarm message to the users’ mobile phone, and then monitor the scene again. Thus, the system has real-time and remote monitoring function.

3.3 Video transmission module

This module sends the video information needed being alarmed to the user’s mobile phone via e-mail, and then the remote monitoring is completed. The diagram for transmission of video information is shown in Fig.5.

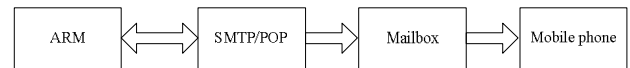


Fig. 5. The diagram for transmission of video information

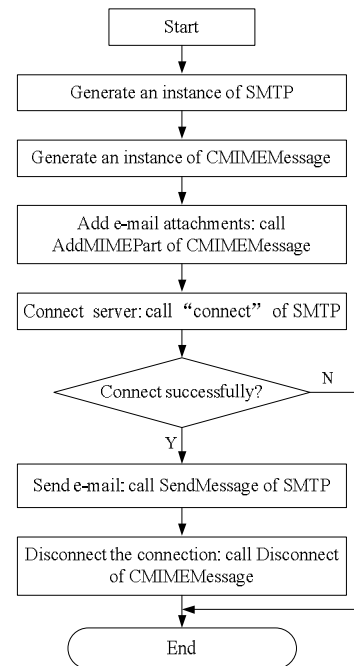


Fig.6. The flowing diagram of sending video information

In the design of video transmission module, the following two aspects should be considered:

(1) Information costs: some companies, such as China Mobile, have opened mailbox service for their users; when

there is a new mail arrival, it will freely send remind information to the user's mobile phone;

(2) Information: it is needed to send video information containing intruders to the mailbox of user's mobile phone in the form of an attachment, so the message should be able to carry a large amount of information and can carry attachments, thus, users can download and view the surveillance video via mobile phone accessing Ethernet.

SMTP and MIME protocols are selected to achieve the process of sending video information, the flowing diagram is shown in Fig.6.

Firstly, the system connects "126 mailbox server" through Socket interface, then the envelope and message content are sent using SMTP protocol, and attachments of video frame containing intruder are loaded by MIME protocol, thus, the process of sending monitoring information is completed.

4. SYSTEM EVALUATION AND EXPERIMENTAL

Use "eMbedded Visual C++ (eVC++) 4.0" to develop the local applications, and select "Intelligent Control and Embedded System Laboratory, College of Computer Science and Technology, Jilin University" to be as the monitoring scene. On this basis, the performance of our embedded remote video surveillance system is tested. In the test program, set the output format to be YUV422, the rate of capturing frame to be 25f/s, and the resolution to be 320×240 . As shown in Fig.7, it is the interface map of our system starting.

In the system, each video frame is saved with the fixed size, and in the video processing module, by comparing the number of pixels in the continuous region of the difference image and the threshold T , it can be determined whether there is someone braking into the monitoring scene. After several experiments, the threshold T is chosen to be a fixed value 92.



Fig.7. The interface map of our system starting

The system real-time detects whether there are moving targets in the monitoring scene. When someone breaks into the monitoring scene, the video processing module will detect out the moving target in the captured video frame, and then the video transmission module will send alarm message to the user via mobile phone e-mail, as shown in Fig.8, it is one of the test results of our system.

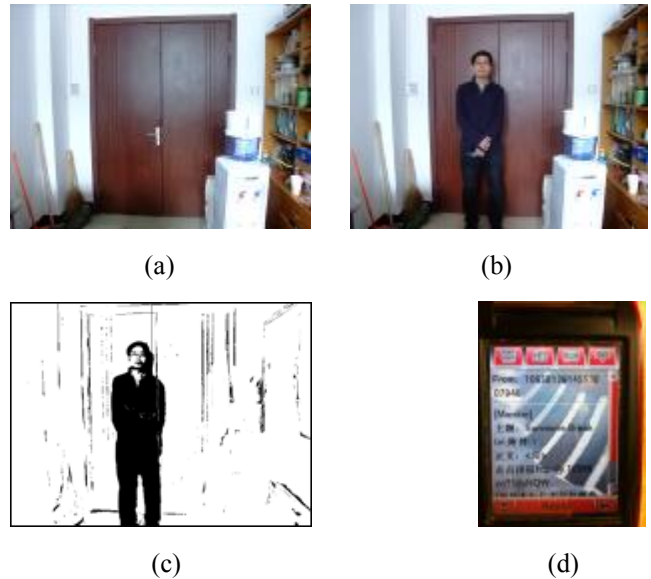


Fig.8. Test result of our system: (a) is the current background; (b) is the captured video frame containing intruder; (c) is the result of moving target detection; (d) is the received alarm message.

In Fig.8, (a) is the current background, (b) is a captured video frame when someone breaking in, for this frame, moving target is detected by video processing module, and (c) is the result. At this time, it is considered that there is an intruder having broken into the monitoring scene, and then an alarm message is sent to user's mobile phone by video transmission module, as shown in (c), and the video frame containing the intruder is sent to mobile mailbox as attachment, the user can download it to view.

In the system, the background of the monitoring scene is updated real-time, being able to adapt to changes in ambient light when long-term monitoring, and avoid the impact of detection for gradual changes in lighting, as shown in Fig.9, they are backgrounds updated in three different time.



Fig.9. Backgrounds updated in three different time: (a) is the background updated in about 9 am; (b) is the background updated in about 12; (c) is the background updated in about 14 pm.

In addition, the moving target detection algorithm in video processing module combines background subtraction and frame difference, having good resistance to the sudden appearance of highlight. When there is sudden change in ambient light, our system will filter out the frame with sudden exposure and select the latter one to be the updated background, and moving target detection is done on this time, thus, the false detection rate can be reduced, which is resulted

from mistaking the exposure region to an intruder. As is shown in Fig.10, they are treatment results when sudden bright lights into the monitoring scene. As is shown in Fig.11, they are treatment results when there are sudden bright light and intruder at the same.



Fig.10. Treatment results when sudden bright lights into the monitoring scene: (a) is the first frame; (b) is the frame with sudden bright lights; (c) is the updated background.

From Fig.10, it can be known that, when there is no intruder but sudden bright lights in the monitoring scene, our system can filter out the video frame with sudden bright lights and update the background.

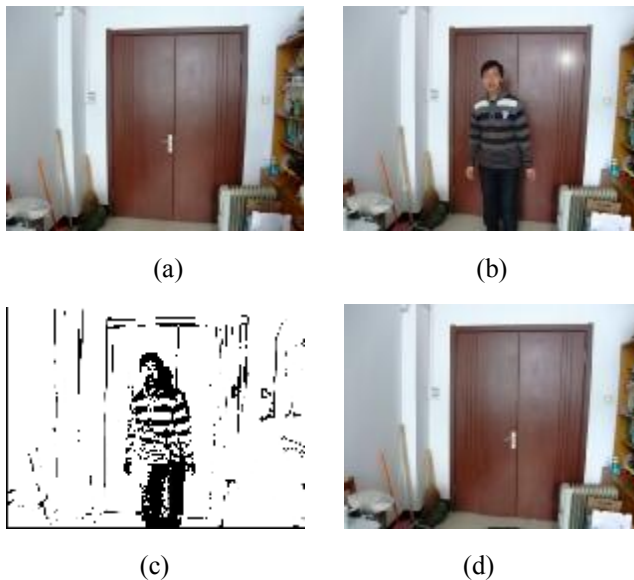


Fig.11. Treatment results when there are sudden bright light and intruder at the same time: (a) is the current background; (b) is the frame with sudden bright lights and intruder; (c) is the detect result; (d) is the updated background.

It can be seen from Fig.11, when there are sudden bright lights and an intruder at the same time in the monitoring scene, our system can accurately detect the intruder.

The above test results showed that our system has completed the main functions, such as front-end video capture, real-time moving target detection for monitoring scene and sending alarm message, and so on. What is more, the built system can adapt to the changes in ambient light when long-term monitoring; and it also has a good resistance to the sudden appearance of highlight.

5. CONCLUSIONS

In this study, an embedded remote video surveillance system based on ARM was built, embedded WinCE operating system was selected; the video capture device is made up of S3C2440 processor and CMOS camera (OV9650) with 1.3 million pixels, and the alarm message is sent to the user's mobile phone via e-mail. In addition, combining with background subtraction, frame difference and real-time background updating, an improved moving target detection algorithm was proposed, which enhances the stability and accuracy of our system.

Our system has the following advantages: (1) in ARM system, use CMOS image sensor to capture images, their color and quality are acceptable, although imaging permeability and color reproduction are not as CCD, it has advantages at low power consumption, price and integration; (2) the video processing module has good real-time processing performance and the saved video frames have high quality; (3) taking the amount of information transmission and different types of mobile phones, and using mobile mailbox to send alarm message, is better in adaptability, faster at speed and lower at price.

Of course, there are still some shortcomings in the system: (1) the robustness has not yet reached the requirements of a complete intelligent monitoring system, for example, when the speed of the moving target changes sharply, there may be error detection; (2) the system was designed based on wired network, there may be wiring problems, if being extended to wireless network, its application will be more convenient; (3) using mobile mailbox to send alarm message is slightly inferior to phones with good performance and full function, the communication with mobile phone by GPRS will be more direct and convenient.

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REFERENCES

- Hemetsberger, H., Kogler, J., Humenberger, M., Zinner, C. and Kubinger, W. (2006). Workflow for Development and Testing of an Embedded Vision Application. In: *International Conference on Visualization, Imaging, and Image Processing*, Palma de Mallorca(ES), 28-30 June 2006, 499-504.
- Huang, Y., Huang, C. and Jia, X.T. (2010). Design of the Indoor Alarm Based on S3C2440. In: *the 2th International Conference on Information Science and Engineering(ICISE), Forum on Information Technology and Applications*, Hangzhou, China, 2010, 6545-6547.
- Li J. and Xu, Y. (2009). Remote Monitoring Systems Based on Embedded Database. In: *The 3th International Conference on Genetic and Evolutionary Computing*, Guilin, China, 14-17 October 2009, 381-384.

- Lin, L.Z., Zhang, H.T. and Duan, L.Y. (2010). Designed of New Embedded Network Video Surveillance System. *Manufacturing Automation*, 32(10), 151-153.
- Pang, Z.F., Yang, H.L. and Gao, J.L. (2009). An Embedded Image Processing System Based on WinCE. In: *Proceedings of the 2009 2th International Symposium on Computational Intelligence and Design*, Changsha, Hunan, China, 12-14 December 2009, 355-358.
- Ruan, S.X, Qiu, C.L. and Tian, D. (2006). Research and Design of Meteorological Data Collection System Based on ARM. *Journal of Jilin University(Information Science Edition)*, 24(2), 220-224.
- Sarkar, D. (2006). A Concurrent Multipart TCP and Its Markov Model. In: *Proceeding of the Communications*, 2, 615-620.
- Tim Jones, M. (2002). TCP/IP Application Layer Protocols for Embedded Systems. CHARLES RIVER MEDIA, INC.
- Venetianer, P.L. and Deng, H. (2010). Performance Evaluation of an Intelligent Video Surveillance System--A Case Study. *Computer Vision and Image Understanding*, 114(11), 1292-1302.
- Xing, J.P., Zhang, J. and He bin, C. (2006). GPS Real Time Vehicle Alarm Monitoring System Base on GPRS/CSD using the Embedded System. In: *Proceedings of the 6th International Conference on ITS Telecommunications*, Chengdu, China, June, 2006, 1155-1158.
- Xiong, X.Y., Wang, B. and Wang, D.X. (2009). Research of Event-based Emergency Video Surveillance System. In: *Proceedings of the 2009 International Workshop on Information Security and Application (IWISA 2009)*, Qingdao, China, 21-22 November 2009, 572-575.
- Yang, L., Jiang, L.Y., Yue, K. and Pang, H.M. (2010). Design and Implementation of the Lab Remote Monitoring System Based on Embedded Web Technology. In: *2010 International Forum on Information Technology and Applications*, 172-175.
- Zhang, M., Sun, J.G. and Wang, S. (2010). Research and Implementation of the CMOS Camera Device Driver Based on S3C2440. In: *Proceedings of the 2010 International Conference on Intelligent Computation Technology and Automation*, 1039-1042.