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The Design of Intelligent Image Sensor Applied to Mobile Surveillance System

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Abstract

Brightness obviously affects the pixel value of an image sensor. Image identification from a traditional sensor may generate a bias and surveillant misunderstandings because of weather. The purpose of the research is to develop an intelligent image sensor with mobile communication function applied to Vehicle surveillance system. The proposed intelligent image sensor integrates an optoelectronic converting circuit and an embedded system and can convert the brightness to an analog voltage. From the voltage value, we can establish a contrast list to show the relationship of the analog voltage and image pixel values. Using the list and applying the linear interpolation method, we can eliminate the effect of the brightness and raise the identification rate. The intelligent image sensor is able to largely decrease the image identification bias, send a live alarm instantly by its mobile communication function, and save storage space and costs compared to the traditional solution.

Keywords: *Embedded System, Intelligent Image Sensor, Image Identification, Intelligent System.*

1. Introduction

Most traditional security systems record a continuous image from the sensors. It means that the modern security system records all images from cameras 24 hours a day and seven days a week, such as in the systems in banks, shops, residential communities, etc[1]. Therefore, the traditional security system requires a great mount of storage space and high costs. In addition, many unnecessary images are recorded in the system.

Based on the definition of the International Electrotechnical Committee (IEC), the sensor is an inductive element in the measurement system for converting the input signal to the measurable signal. Generally speaking, the sensor comprises the sensing element and the transduction element. The sensing element is for sensing the changes in the object, and the transduction element is for transduction of the signal from the sensing element to a communicable and measurable signal[2]. The future sensing technology is the important base of context awareness. The most difficulty in developing the future sensing technology is to capture all environmental changes and generate the correct feedback. A good sensor is not only has high accuracy, high stability, fast feedback, firmness, and high anti-interference but is also equipped with intelligent algorithms for analyzing and integrating massive amounts of signals [3]. Intelligentization and multi-functionality is the future trend in sensing technology. Relying only on the improvement of materials technology, it is difficult to reach the target. We need to add the micro-computing function for data analysis and operation in the sensor to complete the sensor's functions. Nowadays, the so-called intelligent sensor means a sensor with embedded microprocessor for data detection, operation, memorization, and diagnosis [3].

Products based on the application of the embedded system technology generally integrate the functions of sensing, network, and intelligence. Most of them appeared in the market in recent years and mainly in the digital home appliance and consumer electronics categories [4]. With the integration of Internet connection and automation functions, the embedded system is used widely in many digital home appliance products, such as the Internet refrigerator from LG Group, the intelligent vacuums, etc. Compared to the traditional products, the digital home appliance products have more automated functions, including the integration of communications, artificial intelligence, sensors, and actuators. During these years, many consumer electronic products, no matter removable or irremovable, provided users with the functions of fast data retrieving, monitoring, and management of digital contents by integrating different communication technologies. The digital home appliance can be divided into two major categories: the Digital Home Server (DHS), and the Digital Home Renderer (DHR)[2]. The DHS provides the users with the functions of data retrieval, recording, storage, and content protection. The DHS generally has some DHR functions, such as smart operation and management interface, multimedia management, collection, and broadcasting, etc. Other DHR devices include personal video recorders (PVR), stereos with storage devices, home theater systems, cameras, cellular phones, etc.

Based on the embedded system technology, the research tries to develop an intelligent image sensor with mobile communication function for image identification. By applying a simple optoelectronic converting circuit design and integrating the embedded system, the research tries to eliminate the effect of brightness that generates errors in image identification, and to decrease the average rate of incorrect image identification by the digital security system, and actually decrease the installation costs and storage requirements the traditional security system. The research has five parts, including: (1) general introduction, (2) general introduction of embedded system, (3) the research structure and the applied method for the improvement of image identification, (4) the experimental data and the research analysis, and (5) the conclusion.

2. Introduction of Embedded Systems

As mentioned in the last paragraph, the embedded system is widely used in many fields, such as digital home appliances, consumer electronics, video security, home care, etc. In the application of image identification, the research in reference [5] tries to develop an embedded system to capture correct images in all brightness conditions and generates the driveway picture. The research in reference [6] develops a DHCP-Cam that works separately on the Internet based on the embedded system technology and requires only network and power cables. In reference [7], the research demonstrates a complete web camera based on the Samsung's SNDS100 module. The microprocessor integrates an Ethernet MAC Chip in the module that can compress the external image and output the result to the SNDS100 module. In reference [8], the research uses a Java-base embedded system to develop a homecare structure and remotely monitor a patient's condition. In reference [9], the research designs a simple e-Life security system by a GPRS/GPS module.

From the research, we can conclude that the brightness indeed raises the rate of incorrect identification. Therefore, based on the brightness effect upon the image identification, the research will develop an intelligent image sensor based on an embedded system application and with an economic and effective optoelectronic converting circuit design to largely decrease the rate of incorrect image identification by the security system.

By integrating a GPRS/GSM module and the embedded system, this research proposes an intelligent image sensor with mobile communication function. The sensor is able to not only improve the image identification bias but also send a live alarm instantly.

3. The Design for Intelligent Image Sensor with Mobile Communication Function

The research proposes a design of intelligent image sensor for a surveillance system based on the integration of 32-bit embedded system development kit with integrating an optoelectronic converting circuit, a GPRS/GSM module, and an image sensor to develop an intelligent image sensor in a vehicle surveillance system

3.1. Embedded System Hardware Structure

In the research, we used the Samsung S3C4510 ARM7TDMI embedded system development kit as the development base. We used the A/D converting module of the development kit to retrieve the analog voltage values from the optoelectronic converting circuit and convert them to digital values. Then we can generate the relationship between the brightness and the analog voltage values. We also use the image-sensing module of the development kit to get the monitoring image pixel values under different brightness and analog voltages. After analyzing and comparing the pixel difference under different brightness conditions, we can build a contrast list of optoelectronic converting voltage values and pixel difference. Fig.1 shows the embedded system development kit. The kit is equipped with a Samsung S3C4510 ARM7TDMI micro-processor, a 32-bit RISC IC, 2MB Flash ROM and 16MB SDRAM, two 9-pin D-Type UART Ports, a RJ-45 10/100 Base-T Ethernet Port, and USB 1.1 Device ports,. In addition, the kit also has hardware interfaces such as the recording and speaker interface, a 128×128 graphical LCD module (4 gray level), 4×4 Key Pad, and a Camera Module interface. The camera used in the research is 352 × 290 pixels with 352 × 288 effective pixels and can be reset to the CCM mode of 160 × 120 pixels or 320 × 240 pixels by the CMOS Camera Module Controller (CCM Controller). The rest relative hardware functions include 4 Digits 7 Segment LED, 8 bits LED Lamp, JTAG connector for ARM ICE (20 pins), and FPGA Board interface. See Fig. 2 for the related hardware infrastructure of the embedded development kit. The CCM controller on the peripheral development kit can reset the image size of 160 × 120 pixels on the CCM display. The image module can connect to the JP13 connection in the development kit. The retrieved images are shown in the LCD (128× 128 4 level) on the development kit or saved and displayed in the server via the Ethernet port. The image sensor module is equipped with a CMOS camera for Color Image Sensor (100K) image detection. Its effective view area is 352 × 288 pixels. The CCM module is driven by a 50Mhz CPU and can record 5 images per second. See Fig. 3 for details about display operation and hardware setup.

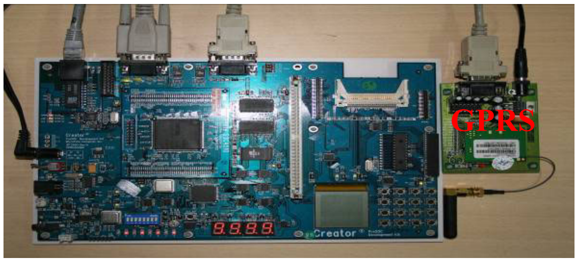

Figure 1. The Embedded System Development Kit

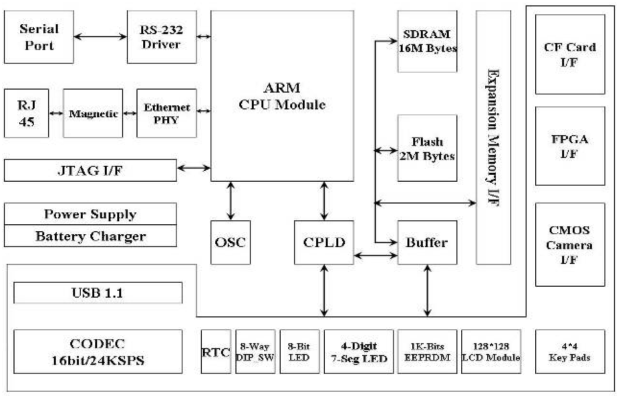

Figure 2. The Infrastructure of the Embedded System Development Kit

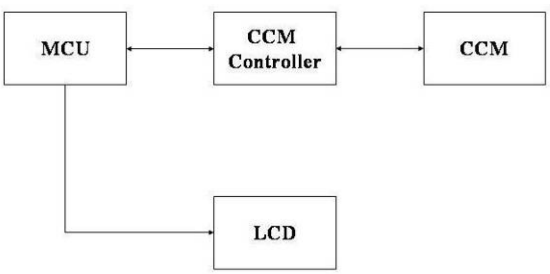

Figure 3. The Hardware Layout of the Image Display

3.2. Embedded System Hardware Structure

The GSM SMS network architecture is illustrated in Fig 4. In this architecture, when a Mobile Station (MS) sends a short message, this message is delivered to the GSM radio system, that is, a Base Transceiver Station (BTS) and then a Base Station Controller (BSC). The radio system then forwards the message to a Mobile Switching Center (MSC) called SMS Inter-Working MSC (IWMSC). The IWMSC passes this message to a Short Message Service Center (SM-SC). The SM-SC then forwards the message to the destination GSM network through a specific GSM MSC called the SMS Gateway MSC (SMS GMSC). Following the GSM roaming protocol, the SMS GMSC locates the serving MSC of the message receiver and forwards the message to that MSC.

This MSC broadcasts the message to the BTSs, and the BTSs page the destination MS (receiver) [10].

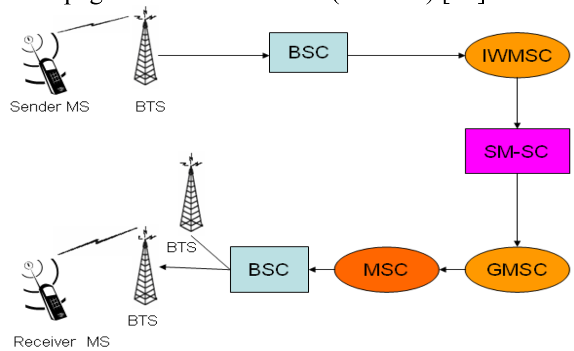

Figure 4. GSM SMS Structure

3.3 GSM/GPRS Module

The GSM/GPRS module used in this research is SIMCOM SIM300. The SIM300 supports the EGSM900/GSM1800/1900 dual frequency socket baud rate 1200~115.2Kbps, set manually by the users and controlled by AT commands, and equips with a RS-232 connector. The following is the specification:

- Broad Power Supply Range: DC 5V~12V/2A
- Weight: 130g
- Size: 98x54x25mm
- Power Consumption: 2000mA at the peak; standard: 200mA; Sleep Mode: 10mA
- GPRS mobile station class B

When the intelligent image sensor of the security system detects the abnormal image, the sensor sends a short message through the GPRS/GSM module to the user immediately for the live monitoring effect.

3.4. The Proposed Intelligent Image Identification Method Applied to Remove the Change of Brightness

This research proposes a simple optoelectronic converting circuit to determine the brightness and convert the voltage value for analysis. See Fig. 5 showing the integration of the relative circuit and embedded system development kit.

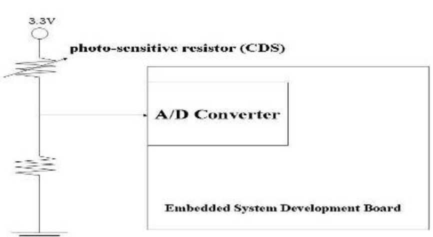

Figure 5. The Optoelectronic Converting Circuit

As shown in Fig. 5, we connected the optoelectronic converting circuit to the A/D converting connection of the development kit. By using a CDS that changes its resistance value following a change in light levels, we can get the analog voltage value under different brightness levels. The CDS we used in the research can change its value in the range of 8K and 12K Ohm. The current of the optoelectronic converting circuit is 3.3V and offered by the development kit. Then we built the relationship list of the voltage value of the optoelectronic converting circuit and the relative pixel difference in Table 1. Because the brightness range is too wide to get all analog voltage values, we use the linear interpolation method and the contrast list of the analog voltage of the brightness and the pixel difference to quickly generate the target analog voltage and the relative pixel difference. The formula of the linear Interpolation method is showed in Equation 1. The variable x in the formula is the new analog voltage value from the optoelectronic converting circuit. The function f(x) represents the relative pixel difference from the new analog voltage value. The variables a and b are the known voltage range in Table 1. Functions f(a) and f(b) are the two relative pixel differences of the analog voltage range. Using the Interpolation formula in Equation 1, we can generate the pixel difference of the new analog voltage value from the optoelectronic converting circuit. For example, assume that variable x is 0.75, which is between 0.7 and 0.8. Set the variables a as 0.7, and variable b as 0.8. We can get the result of f(0.7) as 8 and the result of f(0.8) as 20. Use these two values in Equation 1, and we can get the pixel difference f(0.75) as 14.

Table 1. The Contrast List of the Voltage and Pixel Difference

Analog Voltage Value	Pixel Difference
0.7	8
0.8	20
0.9	29
1.0	42

$$f(x) = \frac{b-x}{b-a} f(a) + \frac{x-a}{b-a} f(b) \tag{1}$$

The flow chart of the intelligent image identification mechanism that integrates the mobile communication function is shown in Fig. 6. The intelligent image identification combines the optoelectronic converting circuit with the linear insertion method. The mechanism generates pixel difference values when the level of brightness changes. We use the value to eliminate the effect of brightness on the image pixels. The process of the image identification is to determine the contrast list of the optoelectronic converting voltage and pixel difference from the optoelectronic converting circuit. From the list, we can use the linear interpolation method to calculate the relative pixel value of the voltage retrieved from the optoelectronic converting circuit. After we delete the difference from the original image pixels, we can get a new value. We compare the new value with the old value, and we can judge whether the result is normal or not. If the new value is abnormal, an alarm is raised by the system and sends a short message to the specific user/users, and the intelligent image sensor saves the images in the server. Otherwise, the system continues monitoring.

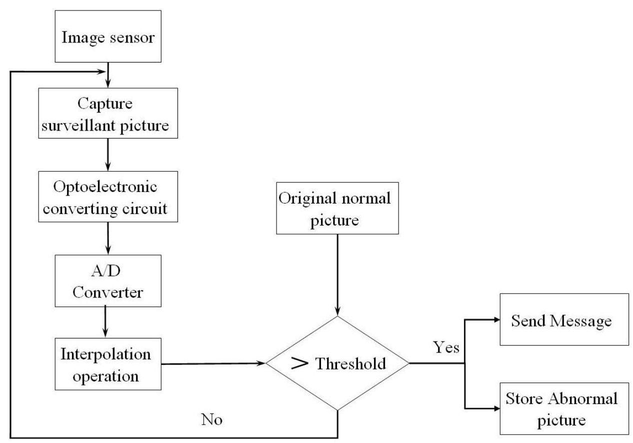

Figure 6. The Infrastructure of the Intelligent Image Identification Surveillance System

4. The Experimental Results

Fig. 7 shows the infrastructure of the intelligent image identification system of the mobile communication. When the pixel value exceeds the default value in comparison with the image pixel value from the monitoring camera, the system shows an alarm. The intelligent image sensor saves the abnormal images in the server via the GPRS network. See Fig. 8 for the demonstration of the continuously abnormal images. The system then sends an alarm message to the user immediately. See Figure 9 for the process. The image size from the image sensor is 160 × 120 (shown in Fig. 10), with a total of 19200 pixels. During the observation, we found that the main factor in image identification bias is from the changes in brightness. When we eliminate the effects from brightness, we need not compare all 19200 pixels of the full image. Focusing on the pixel value of some critical regions of the image, we can generate an effective and fast identification result. The critical regions mentioned in the research include the upper-left, upper-right, lower-left, lower-right corner, and the five central areas of the image. Each area is composed of 9 pixels, as shown in Fig. 11. From Table 2, we can understand that the experiment generates an incorrect image identification result if we do not eliminate the effect of brightness this is no matter whether in the 19200 pixels of a full image or the 81 pixels of all 9 critical areas. After eliminating the effect of brightness, we can get a more correct identification result. Even if we compare only the 81 pixels of the 9 critical areas, we find the average rate of incorrect identification is only 6%.

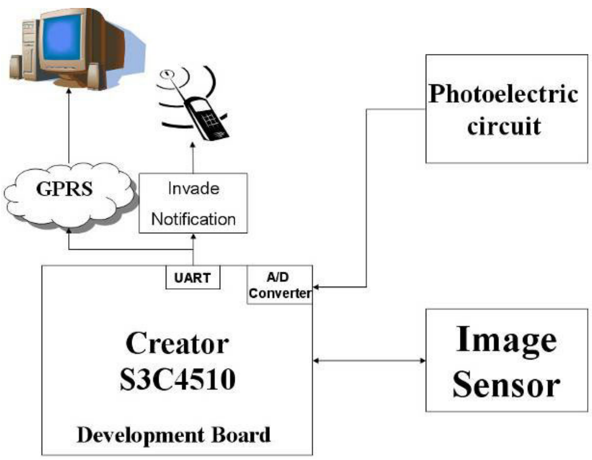

Figure 7. The Infrastructure of the Intelligent Image Identification Surveillance System

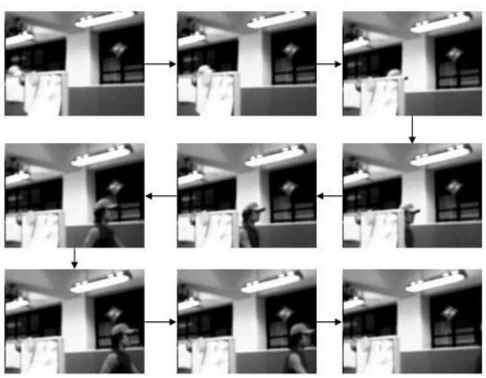

Figure 8. The Abnormal Images

Figure 9. Alarm message

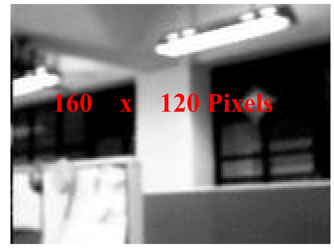

Figure 10. The Figure of 160 x 120 Pixels

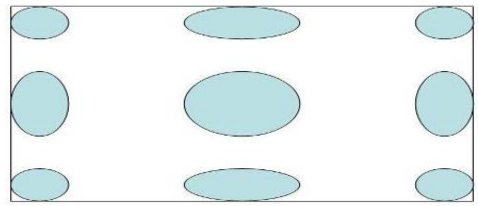

Figure 11. The 9 Critical Regions of the Image

Table 2. The Analysis Result of the Image Identification

Number of Pixels	Threshold Setting	Remove the Change of Brightness	Average d Error Rate
19200	6400	No	100%
19200	6400	Yes	4%
81	27	No	100%
81	27	Yes	6%

5. Conclusions

The research proposes an intelligent image sensor for surveillance systems with mobile communication function. By combining the simple optoelectronic converting circuit design with the linear Interpolation method, the research eliminates the effects of brightness that we supposed to be the main reason for incorrect image identification. The research has conducted an image identification and comparison analysis in a full image of 19200 pixels and the 81-pixel critical region. We have found that the image identification becomes faster and more effective after eliminating the effect of brightness, and this is even when we just compare the critical regions of the image. To instantly warn the user about the alarm, we integrate a mobile communication module to the sensor. It lets the sensor to be able to send an alarm message to the user when a live alarm is triggered. The research suggests using an embedded system development kit with a simple optoelectronic converting circuit to develop an intelligent image sensor in the surveillance system. Not only exploring the fast development environment from the powerful peripheral interface of the embedded system development kit, the research also concludes how to eliminate the effects of brightness upon identification and do a fast identification thus decreasing hardware costs.

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