Design of Intelligent Pedestrian Flow Detection and Security Alarm System based on Ethernet

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ABSTRACT

For real-time monitoring the area around the bank or other special places where unexpected incidents occur occasionally and making timely pedestrian flow counting, we designed a pedestrian flow detection alarm system based on Ethernet. The system will issue a warning to the server if the abnormal phenomenon such as prolonged retention occurs. This paper introduces the system composition, working principle and hardware system of the alarm controller. The parameter setting system based on Web Server and workflow of this alarm system are also presented. The system can real-time monitor and find abnormal information, interact with the remote web server through Ethernet, perform the effective supervision of special areas.

INTRODUCTION

In recent years, incidents caused by the use of ATM at night have occurred frequently. In April 8, 2017, a ATM robbery occurred in Shantou city of Guangdong Province which caused serious social harm with 2 deaths and 1 injury[1]. In January 25th, 2017, another ATM robbery incident occurred in Fengcheng city of Liaoning Province. A security on duty just witnessed the crime on the monitor screen and issued a warning by the ATM alarming client which forced the robber to flee the scene and prevent the occurrence of a malignant incident[2]. Since the robbery usually takes place during the night, it is very meaningful to design a pedestrian flow detection alarm system which has the functions of real-time monitoring the area around the bank or other special places where unexpected incidents occur occasionally and making timely pedestrian flow count. Besides, the system must issue a warning to the server if the abnormal phenomenon such as retention occurs.

Nowadays, there are two kinds of commonly pedestrian flow measurement systems. Normally solution is mainly made up of microprocessor, photoelectric and acoustic electric sensor modules[3]. It is low cost and can be widely used, but the counting accuracy is poor when it is used for large flowrate. The other method is based on image processing technology[4]. The system can track the moving target and count the flowrate by analyzing the characteristics of human face, which extremely avoids the occlusion problem [5]. But the complex structure, difficult technology, and high cost restrict its popularization and application even though it can detect dynamic targets and count them accurately.
This paper introduces an intelligent pedestrian flow detection and alarm system based on Ethernet which has the characteristics of low cost, convenient installation and wide application. It is suitable for monitoring the ATM area at night particularly.

SYSTEM COMPOSITION

The pedestrian flow detection and alarm system consists of two parts: locale alarm controller and web server. Data transmission is carried out through Ethernet (see Figure 1).

![System Composition Diagram](image_url)

Figure 1. System composition.

The alarm controller monitors the pedestrian flow in real-time and sends the flow data to the web server. If a suspicious phenomenon such as prolonged retention is found, a warning will be issued to the web server. This alarm controller is mainly composed of Ethernet communication module, pedestrian flow detection module, alarm output module and parameter setting module of web server.

The web server is mainly composed of device registration module, trigger alarm module, reset alarm module and heartbeat mechanism module. The server registers the online alarm controllers and sends the alarm operation or reset-alarm operation to the alarm controller according to the flow data.

The alarm controller will initialize after booted and then theregistration information will be sent to the web server. Once registered, the controller will monitor pedestrian flow automatically. If abnormal data occur, it will submit alarm data to the web server which will determine whether to trigger local alarms. If the local alarm is triggered, the web server will issue an alarm command to the alarm controller and its Alarm Output Port will be enabled. The warning messages include DevType (type of the alarm controller), AlarmTime, AlarmNum, AlarmPeople and so on. The web server will return the confirmation information to the alarm controller after it receives the alarm information.

The alarm controller needs to be reset after alarm or abnormal triggered. It sends registration request to the web server until the registration is successful. The heartbeat message will be sent to the web server after registration and once it's invalid, the alarm...
controller must be registered again. Some registration information such as Version, Controller Device ID, IP Address, Controller Port, Bank Name, Store Name will be saved to the controller to avoid losing after the registration is complete.

The Heartbeat Mechanism is built to ensure the reliability of communication and check whether the alarm controller is online. The alarm controller shall send heartbeat message to the web server according to the heartbeat period in the registration information. The controller shall be set to offline status and need to re-register once the heartbeat message has been invalid. Figure 2 shows the System workflow.

![System workflow diagram](image)

**Figure 2. System workflow.**

**ALARM CONTROLLER**

The STM32F207 chip that processes the input data of sensors is utilized to be the microcontroller of the alarm controller. It is made up of Ethernet communicating module, pedestrian flow detection module, alarm output module and parameter setting module. The output data will be sent to the web server through the Ethernet communicating module.

**Pedestrian Flow Detection Module and Alarm Output Module**

The pedestrian flow detection module includes two parts: the human detection module that consists of a pyroelectric infrared sensor and the flow counting module which is made up of two infrared diffuse reflection switches.

One pair of infrared diffuse reflection switches that utilize for collecting pedestrian flow information integrate emitter and receiver. Their working voltage is 12V DC and detection range is 5-100cm adjustable. When the detected object passes the detector, the infrared ray emitted by the emitter is received by the receiver, then the sensor generates a switching signal[6]. During operation, the switch outputs low-level if no one goes through it. When the switch detects that someone has passed, the output jumps to a high-level, with a rising edge producing. Figure 3 shows that one person passes through the flow detection module.
Figure 3. Working scheme of infrared diffuse reflection switches.

A1 and A2 represent the two infrared diffuse reflection switches and the distance between these two detectors is 50cm. Assume that the person is moving at 2 meters per second, the TDOA (Time Difference of Arrival) between the rising edges of the two switches is 250 milliseconds according to equation 1 (\(v=c\)).

\[
    t = \frac{S}{v}
\]

(1)

If the rising edge of A1 is received before A2 by the microcontroller, it is judged that one person have entered with the counter adding 1 (see Figure 4(a)). On the contrary, it is judged that one person have left with the counter subtracting 1 (see Figure 4(b)).

![Figure 4. Electrical level change diagram of Infrared diffuse reflection switches.](image)

The human detection module is realized by pyroelectric infrared sensor. Human body will radiate infrared light with 10\(\mu\)m wavelength because of the steady body temperature of 37 centigrade based on the basic knowledge of infrared radiation[7].

Some piezoelectric materials, such as lithium tantalate and barium titanate, will be polarized with the increase of temperature, thereby releasing part of their electric charges[8]. This phenomenon is called pyroelectric effect. These materials are made into thin sheets which electrodes are disposed on the upper and lower surfaces thereof. Assuming that the polarization charge is \(\Delta P\) and the component has an equivalent capacitance value of \(C\), when the infrared radiation to the surface of the sheet causes the temperature of \(\Delta T\) to change, the upper and lower surface electrodes of the wafer will produce a polarization voltage of \(\Delta V\) according to equation 2.
\[ \Delta V = \frac{\Delta P}{C} \]  

(2)

Considering the fact that wavelength sensitivity of pyroelectric infrared sensor generally remains within the range of 0.2-20µm. The optical filter need to be added\[9\] to ensure detecting infrared from the human body. According to our test, the normal average time of using ATM is 5 minutes at night. Therefore, if the microcontroller receives a high-level signal constantly for more than 5 minutes, a warning message will be sent to web serve in order to alert the operator in charge, the operator can use surveillance equipment to check if there is potential danger. Figure 5 shows the interface circuit diagram of pedestrian flow detection module.

IN1-IN4 connect with the output of external alarm switches, U2 is a quadruplex optocoupler, R3-R6 is the current limiting resistor of the optocoupler input side, C1-C4 is the hardware filter capacitor. INPUT1-INPUT4 is the detected signal after isolating the optocoupler and connected to the input ports of STM32 F207\[10\]. 8 inputs including 5 alarm inputs, 1 double check signal input and 2 flow count inputs have been designed. The channel assignment and switch type can be set according to the parameter setting module.

The alarm output module that uses the relay output is utilized to drive the sound and light alarm devices. The alarm output port which possesses normally open model and normally closed model is connected to the general output port of the STM32. The relay coil is driven by the signal of alarm output port that has been isolated by the optocoupler TLP521 through a triode. A parallel freewheeling diode is used for protecting the relay coil.

**Ethernet Communication Module**

An independent Ethernet controller ENC28J60 is utilized to design the interface circuit of the Ethernet communication module, it has SPI interface, integrates MAC and 10 BASE-T PHY, includes receiver and conflict suppression circuit, supports an 10BASE-T port with automatic polarity detection and correction, supports full-duplex and half-duplex mode, and also supports programmable filling, CRC generation and programmable automatic rejection of error packets. Figure 6 shows the interface circuit diagram of Ethernet communication module.
WEB SERVER

The web server exchanges data with the alarm controller through Ethernet and provides data storage, parameter setting and Web application services[12]. It is consist of device registration module, trigger alarm module, reset alarm module and heartbeat mechanism module.

Enter the IP address of the alarm controller in the browser to log in the Web settings interface, the alarm controller parameter setting based on Web Server can be completed easily. It mainly includes alarm controller network parameter setting, remote server network parameter setting, input port setting, output port setting, person detection setting, device ID setting and so on.

The alarm controller network parameters are stored in the FLASH of the system, parameter setting is utilized for configuring the local network parameters of the alarm controller such as IP address, subnet mask, default gateway, DNS server, MAC address and so on.

The remote server parameter setting is used for configure network parameters of the web server, including web server IP addresses, web server port numbers, unit name and branch name.

The subfunction of the remote server parameter setting is as follows:

```c
Static void html_ServerParmSet(char *data)
{
    chartmp[100];
    charc_tmp[33];
    .......
    read_flash(HtmlSizeAddress+2*1024,(u16 *)htmlreadbuf,2048);
}
```

The subfunction reads the server parameters from the 'Flash', extracts and updates the server IP address and branch name from the array 'data'.

CONCLUSIONS

Some tests have been done in several sites and the result is shown as Figure 7.
When one person follows another one closely into the ATM area, the parameter N1 (alarm times of being followed) will be increased by 1, once the prolonged retention has occurred, N2 (alarm times of retention) will also be increased by 1. The large false negative rate is mainly caused by unsuitable installation of the system and this ratio must be ameliorated in our later study. Nevertheless, the prototype has been run in a bank of Sichuan, China for two months. According to the feedback of the bank, the system is stable and reliable, which can be widely used and worth further popularization. Figure 8 shows the prototype of the alarm controller.

![Prototype of the alarm controller](image)

Figure 8. The prototype of alarm controller.

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