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# *Elevator Light Curtain Fault Detection System Based on Internet of Things (IoT) Technology*

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***Abstract:*** This paper presents an IoT-based elevator fault detection system. It uses infrared sensors and triaxial accelerometers to monitor elevator door activities and operation status in real time. Data is analyzed via a cloud platform to send accurate fault alerts, improving safety and maintenance efficiency.

## 1. Introduction

With the increasing popularity of high-rise buildings, people's reliance on elevators is growing, and elevator safety is becoming a major concern. Given the complex structure of elevators, using IoT technology to monitor their operating conditions and detect faults is an urgent need for elevator management, maintenance, and safe operation.

Elevator manufacturers usually have their own communication protocols, which are not compatible with each other. To obtain elevator data, the control system needs to be modified for monitoring [1]. The elevator light curtain is an important safety component, and the problem to be solved is:

(1)If elevator faults aren't reported to maintenance staff and users in time, repairs may be delayed. Trapped people might try wrong ways to save themselves and get more hurt.

(2)Traditional elevator maintenance follows a “one-size-fits-all” model. It requires maintenance every 15 days according to the rules, no matter the elevator's quality, usage frequency, or maintenance status. This leads to a waste of resources for well-maintained elevators that are of good quality and used less often.

So, adding IoT features to elevator light curtains and monitoring elevator door areas and running status in real time is very necessary. It can send exact fault alerts right away. This makes maintenance, fault fixing, and rescuing trapped people more efficient and helps prevent safety accidents [2].

## 2. Research Objectives and Main Research Content

### 2.1 Research Objectives

The project aims to create an IoT-based elevator fault detection system. It uses infrared sensors, accelerometers, and a cloud platform to monitor the elevator in real time. It detects door area activity and collects data. If a fault is found, it sends alerts to maintenance staff and property managers for quick rescue and maintenance.

### 2.2 Research Content

(1)The research uses infrared sensors and triaxial accelerometer to monitor the elevator door area and collect data. The infrared sensors detect people or objects entering or exiting. The accelerometers collect data on the elevator's operating status, like sudden stops.

(2)The system analyzes the data to identify faults and sends abnormal information to the cloud platform in time.

## 3. Technical Approach

### 3.1 Signal Acquisition and Data Fusion

Infrared sensors and triaxial accelerometers are connected to the IoT cloud platform to develop an elevator light curtain device. It can monitor the elevator and diagnose faults in real time, making it safer and more reliable.

We research the infrared array sensors. We place 40 pairs of infrared emitters and receivers evenly and use cross-scanning to make a dense detection area. This helps the sensor detect people and objects moving in the elevator door area. With small signal amplification and a dual-CPU circuit, we can collect and process the infrared signals well. Using fuzzy logic algorithms makes the detection more accurate.

The triaxial accelerometer boosts the system's monitoring. It collects data on door status, open or close position, and sudden stops of the door. Analyzing this helps spot faults early.

### 3.2 Signal Processing

As shown in Figure 1, the dual-CPU circuit can handle signals from both the infrared sensor and the accelerometer at the same time. This makes data processing faster and more accurate.The device sends out infrared light. When an object blocks the light, the signal changes. These changed signals are amplified and processed by the circuit, and then sent to the dual-CPU. One CPU collects and filters the data, while the other CPU talks to the PC. Finally, fuzzy logic algorithms help judge the situation, allowing the system to monitor the elevator door area and its operating status.

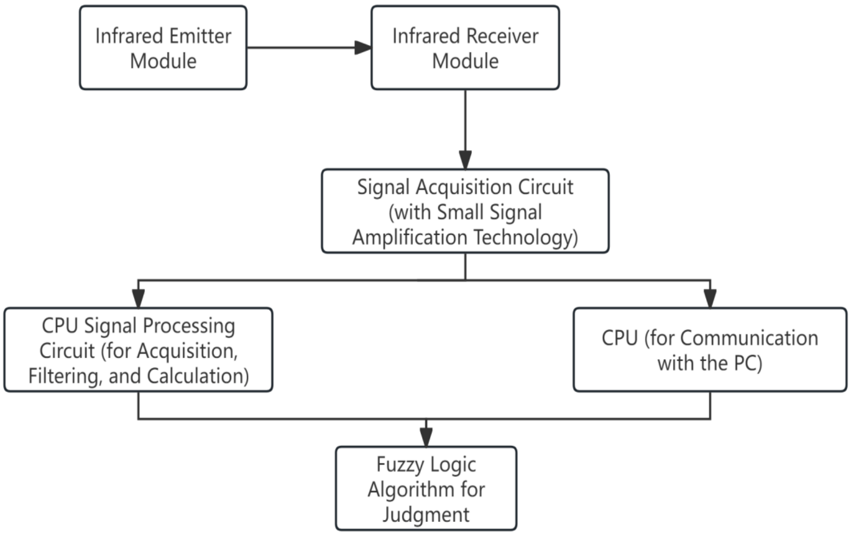


*Figure 1: Dual-CPU Signal Processing Block Diagram*

To look at the data from the sensors, we use methods like spectrum analysis, power spectrum analysis, and PCA. These help find important features in the accelerometer signals and spot frequencies that might cause faults. This lets us predict and warn about elevator may has problems.

### 3.2.1 Spectrum Analysis

Spectrum analysis uses Fourier transform to change signals from the time domain to the frequency domain. It shows the frequency information in the signals. For example, if the signal collected by the accelerometer is x(t), its Fourier transform is: $X(f) = \int_{-\infty}^{\infty} x(t)e^{-j2\Pi ft}dt$ . Through spectrum analysis, we can get the amplitude spectrum and phase spectrum of the signal. This helps identify specific frequency components. If the amplitude of a frequency suddenly increases, it might mean there is abnormal vibration in the elevator parts.

### 3.2.2. Power Spectrum Analysis

Power spectrum analysis is used to estimate the energy distribution of the signal. For the accelerometer signal x(t), its power spectrum can be calculated by the following formula: $P(f) = |X(f)|^2$ Here, X(f) is the Fourier transform of the signal. Power spectrum analysis can find the high-energy frequency parts in the signal. These parts might be related to elevator faults.

For example, if the power spectrum of the elevator is stable in a frequency range (like 10-20 Hz) when it's working normally, but there's a big change in that range, it might mean a part like the motor or bearing is faulty.

### 3.2.3. Principal Component Analysis(PCA)

PCA is a dimensionality reduction technique used to extract the main features from data. Suppose the signal collected by the acceleration sensor is a multi-dimensional dataset X. PCA can extract key features through the following steps:

(1)Centralize the data by subtracting the mean value from each column.

(2)Calculate the covariance matrix: $C = \frac{1}{n-1} X^t X$

(3)Perform eigen-decomposition on the covariance matrix to obtain eigenvalues and eigenvectors.

(4)Select the eigenvectors corresponding to the k largest eigenvalues to form the projection matrix P.

(5)Project the original data onto the principal component space: $Y = XP$

The key features extracted through PCA can be utilized in subsequent fault diagnosis models. For instance, when the eigenvalues after principal component analysis show significant variations in a certain dimension, it may indicate that the operating state of the elevator has deviated abnormally.

Practical application case: Suppose the elevator is operating normally, and the signals collected by the acceleration sensor mainly concentrate in the low-frequency band (such as 0-10 Hz). However, when the elevator malfunctions, the amplitude of the signals in the high-frequency band (such as 50-100 Hz) significantly increases. Through spectral analysis and power spectrum analysis, these abnormal frequency components can be identified; combined with the key features extracted by PCA, a fault prediction model can be constructed, thereby achieving early warning for elevator faults.

## 3.3 Systematic Design

Figure 2 illustrates the working principle of the IoT elevator photo curtain device, and Figure 3 describes the structural composition of the device. The functions of each part in Figure 2 are as follows:

Power supply part: 220V AC is converted to 12V DC by the photo curtain power converter. 12V DC is further converted to 3.3V and 4.2V by the DC/DC converter, which are respectively supplied to the MCU and the NB_IoT module.

MCU (Microcontroller Unit): The MCU is the control center of the system, responsible for processing sensor data and controlling other components. It receives 3.3V power through the VCC pin and connects multiple sensors through the I2C interface for data acquisition. In addition, the MCU communicates with the NB_IoT module through the UART interface.

NB_IoT module: The NB_IoT module communicates with the MCU through the UART interface to achieve wireless data transmission. The NB_IoT module connects to the cellular network through the ESIM card to realize remote communication. The NB_IoT module also connects a 12MHz crystal to provide a clock signal. The Debug interface is used for debugging and monitoring the status of the NB_IoT module.

Sensors: Multiple sensors (such as infrared sensors, acceleration sensors, etc.) are connected to the MCU via I2C interface, and are used to collect data on the elevator's operating status and obstacles in the door area.

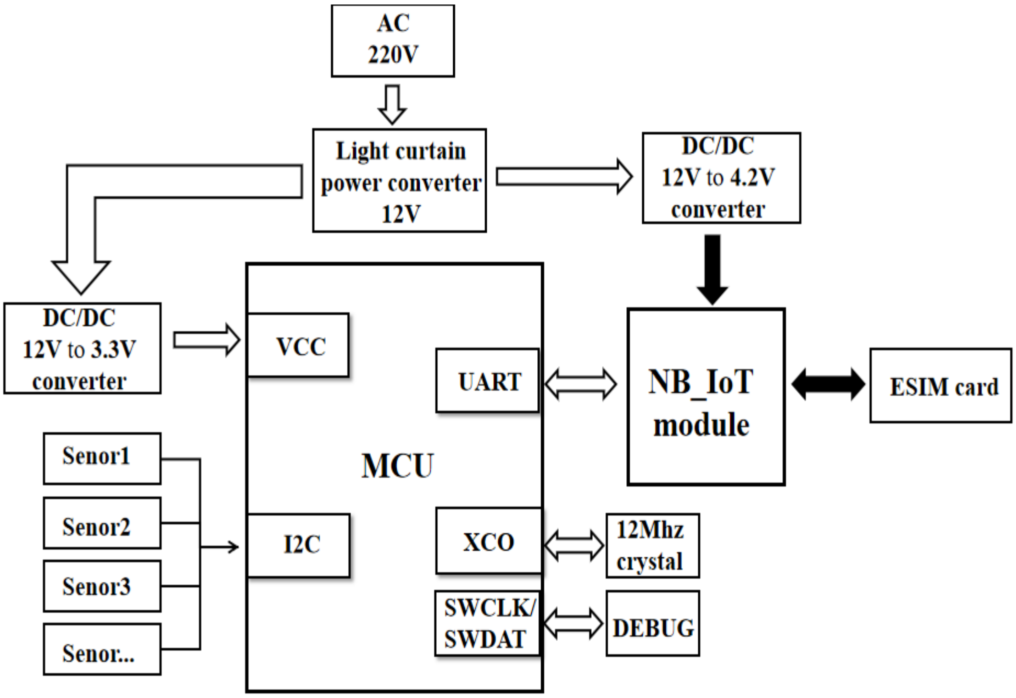


*Figure 2 :The working principle of the IoT elevator photoelectric curtain device*

Figure 3 presents a basic architecture of data flow and its processing in an Internet of Things (IoT) system. The functions of each module are as follows:

Data collection: Infrared sensors are used to detect whether there are obstacles in the elevator door area. The layout of the infrared array sensor adopts 40 pairs of infrared tubes arranged at equal intervals and scanning in an alternating sequence, forming a dense detection area to achieve detailed monitoring of the elevator door area [3].

Acceleration sensors collect real-time dynamic data of the elevator, such as the elevator's start, stop, door opening and closing status, and whether there is an emergency stop, providing accurate data support for the elevator's operating status.

The data collected by the sensors is then sent to the IoT gateway.

IoT gateway: The IoT gateway is an intermediate device connecting sensors and the cloud platform. It is responsible for the preliminary processing of data. In local real-time pre-analysis, the IoT gateway can perform edge computing, that is, process data near the data source to reduce latency and bandwidth usage. Edge computing also includes security measures to ensure the security of data during transmission.

Transmission and storage: The processed data by the IoT gateway is transmitted to the IoT platform. The IoT platform can receive data from sensors in real time and utilize big data technology for storage and analysis, providing real-time monitoring and early warnings.

IoT Platform: The IoT platform is a centralized system that offers a variety of services, such as big data analysis, security measures, device management, and connection management. The platform interacts with other systems or applications through APIs (Application Programming Interfaces), enabling data to be accessed and utilized by third-party services.

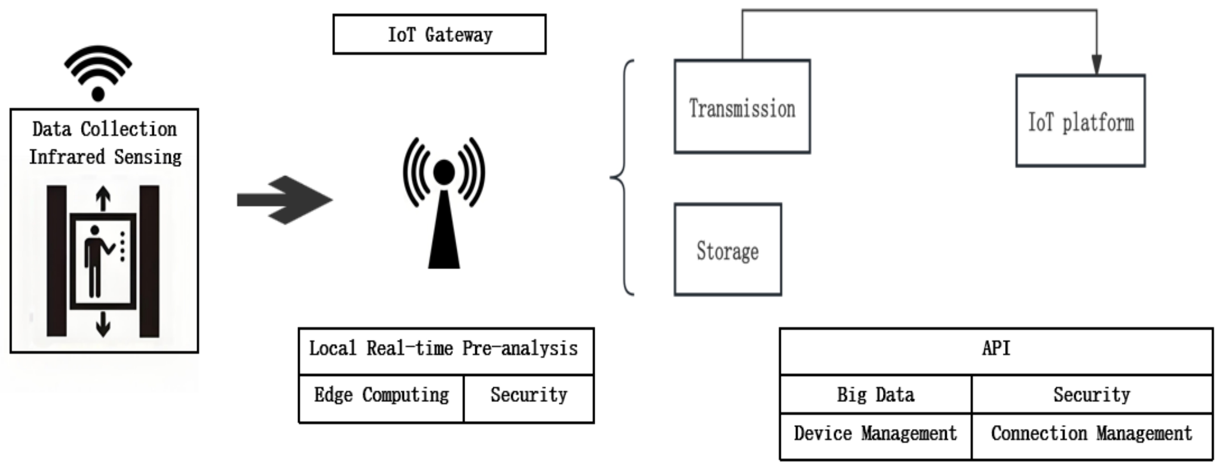


*Figure 3:The schematic diagram of the composition of the elevator photoelectric curtain device based on the Internet of Things*

As can be seen from Figures 2 and 3, this elevator photoelectric curtain platform architecture can realize real-time monitoring of the elevator's operating status and fault early warning, thereby enhancing the safety and reliability of the elevator.

## 5. Conclusion

### 5.1 Main technical indicators of the elevator photoelectric curtain:

(1) Minimum detectable object: 50mm;
(2) Protection height: 20 - 1855mm;
(3) Anti-light interference: 120,000 Lux;
(4) Response time: no more than 69ms;
(5) Time from detecting a fault to transmitting to the cloud platform server: less than 3 seconds.

### 5.2 Conclusion

The elevator photoelectric curtain fault detection system based on Internet of Things technology can monitor the real-time activity information of the elevator door area and the operating status data of the elevator. It can achieve early warning of elevator faults, significantly improve the safety and reliability of elevator operation, and reduce accidents and downtime caused by faults. In addition, it will optimize the maintenance mode and realize on-demand maintenance, thereby reducing maintenance costs and improving efficiency.

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