Elevator Safety Monitoring and Early Warning System Based on Directional antenna transmission technology

Ying Huang, Weijia Yu

Abstract—**In order to solve problems of the absence of security protection and the lack of early warning mechanism in the current elevator operation process, elevator safety monitoring and early warning system based on directional antenna transmission technology was proposed. The system includes sensor module circuit, microcontroller module circuit, display module, directional antenna transmission module, remote server and data monitoring system. Design ideas of hardware development, remote server and data monitoring system are introduced. Two version monitoring software are written, one for PC monitor, the other one for mobile phone monitoring. In order to improve data transmission distance, transmission rate and transmission quality, automatic antenna alignment system is designed, which combines the advantages of directional antennas and omnidirectional antennas transmission technique. To overcome problems such as instability of the alignment process, delay and other factors, DMC（Dynamic Matrix Control） algorithm should be used in the system and optimal control of the antenna angular alignment will be achieved. The system can continuously transmit real-time elevator's working status information and environmental information, and it also send commands to notify elevator company managers once an abnormal conditions occur in the elevator, so that people can take urgent measures and maintenance measures. This system can be applied to real-time warning of all-types elevators.**

Index Terms—**wireless sensor technology; safety monitoring; early warning system**

Original Research Paper
DOI: 10.7251/ELS1519101H

I. Introduction

ELEVATOR has become an indispensable equipment in our daily life, and plays an important role in our life. China has a lot of elevator and maintains a rapid growth rate, but a large number of elevator is running in poor condition [1]. Elevator accidents caused by lack of maintenance, lack of safe operating condition monitoring and emergency measures which affected the lives and safety of the people happened frequently. Therefore, the design of elevator safety monitoring and early warning system has practical significance [2]. At present, three methods are mainly used for elevator safety monitoring, they are embedded chip, Zigbee technology and GPRS/GSM technology. Embedded chips monitoring via ethernet cabling has disadvantages such as routing complexity, high power consumption, and difficulty to completely realize different information acquisition. Zigbee technology has advantages of low cost, low power consumption and fast data transfer, etc., but only can be applied in short distance communication. GPRS/GSM technology supported by server with slightly higher cost, is widely applied to various practical fields due to prevalence of cell phone signal [3].

In the wireless transmission process, the transmission speed, transmission distance and transmission quality are limited due to installation location and affected by obstacles. In order to improve data transmission distance, transmission rate and transmission quality, directional antenna transmission techniques is adopted in the system.

A directional antenna is an antenna which radiates greater power in one or several specified directions allowing for increased performance on transmit and receive and reduced interference from unwanted sources [4]. Directional antenna has advantages of far communication distance，strong directional anti-interference ability, which can increase the transmission distance and the transfer speed, reduce the signal transmission delay and power consumption of the node, improve the spatial reuse and high spatial multiplexing rate [5-6]. Far communication distance can be achieved by additional gain, and then improve the WSN network throughput, enhanced reliability and reduce latency [7].

Elevator safety monitoring and early warning system based on directional antenna technology could be applied to monitor working state and environmental parameters of elevators. The data acquired from sensors modules are sent to the receiver module via directional antenna, and then data are sent to a remote server by GPRS technology. Monitoring systems process all data and display it[8].

This research reported in the paper is supported by Guangxi university research project (2015), research project of Liuzhou Railway Vocational TechnicalCollege (2014), the project of outstanding young teachers' training in higher education institutions of Guangxi.

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II. SYSTEM STRUCTURE

Elevator should have not only comfortable environment, but also operate reliably, detect faults quickly as soon as possible and shorten the fault repair time [9-10]. Therefore, it is important to monitor working state and environmental parameters of elevators. These data include voltage, current, acceleration, temperature, humidity, smoke, flames, body sensors and toxic gases, etc. The system is composed of sensor module circuit, microcontroller module circuits, display module, directional antenna module and power module. Software is mainly composed of server systems and data monitoring systems. Various data are collected from Sensor terminal, processed by SCM module circuit and sent to server system by directional antenna module. When server receives a command to read the data, it forwarded the data saved in the database. Data monitoring system processes the data, and notifies elevator company managers once the data is abnormal. The display module is used to display the data collected from Sensor terminal circuit. And the power supply module is provided power to each module. System structure is shown in Figure 1. For easy installation, modular design is adopted in the system, a node is used to detect the elevator working status parameters , another node for detecting elevator environmental parameters. All data are sent by 3G module which embedded TCP / IP protocol stack[11].

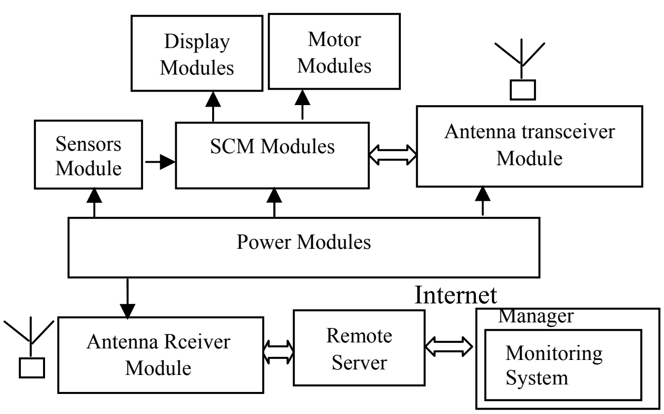

Fig.1. System structure

III. HARDWARE DESIGN

A. Data Acquisition Module

Data acquisition is divided into two categories: one is working state of the operating elevator, such as voltage, current, acceleration etc., and another is environmental parameters inside the elevator, such as temperature and humidity, fire, toxic gases, sensors and body sensors. Current detection module uses ACS712 current sensor module. Voltage detector uses a Hall sensor with UART serial transmission interface. Acceleration module uses three-axis accelerometer ADXL345 module. Flame used in infrared detection module. Smoke detector uses a MQ-2 smoke sensor module. Using temperature and humidity sensor DHT11 module. SCM is used STC89C52 processor.

B. Directional Antenna Module

The nRF905 RF module is chosen as wireless communication module. Its working frequency is 433 ~ 915 MHz. nRF905 RF module has strong anti-interference ability and long transmission distance [6]. Because of distant installation and tall obstacles obstruction, sending node should install gain module to transmit information over longer distances.

C. Directional Antenna Elevation and Azimuth Calculation

Suppose that （x1,y1,z1）is geographic coordinates of elevator antenna, and （x2,y2,z2）is geographic coordinates of server node. They are obtained by GPS module, so the elevation(λ) and azimuth(α) is calculated by the following formulas[12].

$$\lambda = \arctan \frac{z_2 - z_1}{\sqrt{(y_2 - y_1)^2 + (x_2 - x_1)^2}} \qquad (1)$$

$$\alpha = \arctan \frac{y_2 - y_1}{x_2 - x_1} \qquad (2)$$

In addition, Seen as the axis of rotation axis of the antenna, as the starting point to the geographic North Pole, so the antenna azimuth is defined as the axis which clockwise rotation to a predetermined angle. The angle rotation. Assumed that the antenna node and the server node antenna coordinates are（ λ_1, α_1 ）、（ λ_2, α_2 ）， so the azimuth of antenna is calculated by formula (3) [13].

$$\gamma = \arctan \frac{\phi_1 \times \cos \alpha_2}{\phi_2} \qquad (3)$$

Which $\phi_1 = |\lambda_1 - \lambda_2|$， $\phi_2 = |\alpha_1 - \alpha_2|$。

IV. SOFTWARE DESIGN

A. Processor Program Design

Server sends the location and height of the elevator which getting from GPS module, by omnidirectional antenna at 360 angle, and then enters data receive mode after receiving the acknowledgment signal of all the nodes of the elevators. Antenna node rotates at a constant speed and stops after receives the position and height sent from server, and then sends a confirmation signal to the server. Elevation and azimuth of the antenna is calculated with the position and height sent from server and its position and height. Antenna alignment is achieved by driving the stepper motor according to elevation and azimuth.

In order to achieve better elevation and azimuth, angle sensor is installed on controller and taken as feedback, and dynamic matrix control algorithm (DMC) is adopted to adjust optimal antenna elevation and azimuth. When power-up, data are collected after the completion of the initialization successfully and antenna alignment is completed. The data including voltage, current, acceleration, temperature, humidity, smoke, flames, body sensors and toxic gases, etc., will be transferred into the appropriate format and then send to receiving module through a directional antenna.

Server receives the data and determines the accuracy of the data format, and then saves it to the database and displays on the screen. The data format is shown as following:

cs1:00;cs2:00;cs3:0.00;cs4:0.00;cs5:000;cs6:0;cs7:0;cs8:0;

The parameters are described in Table I.

Meanwhile, text messages are sent to notify managers as soon as possible when data collected exceeds the set limit.

B. Antenna Angle Adjustment Algorithm

In order to improve data transmission distance, transmission rate and transmission quality, automatic antenna alignment system is designed, which combines the advantages of directional antennas and omnidirectional antennas transmission technique. To overcome the instability of the alignment process, the delay and other factors of system, DMC (Dynamic Matrix Control) algorithm can be used in the system and optimal control of the antenna angular alignment will be achieved.

TABLE I
SCM DATA FORMAT MEANING AND VALUE

Sring	Meaning	Value
cs1	Temperature	Specific values
cs2	Humidity	Specific values
cs3	Voltage	Specific values
cs4	Current	Specific values
cs5	Acceleration	Specific values
cs6	Human Detection	1 or 0
cs7	Smoke	1 or 0
cs8	flames	1 or 0

The angle value of angle sensor output is used as feedback correction parameters, and scroll to optimize the current angle value and the back control amount, and then the expected output angle meets the requirements, adjustment process is shown in Figure 2.

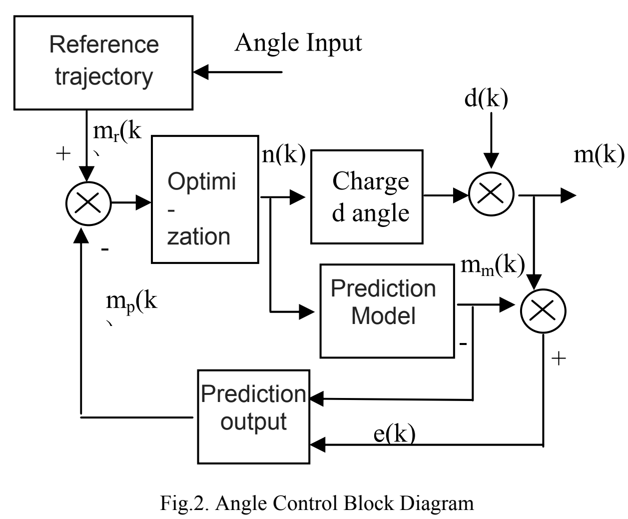

Fig.2. Angle Control Block Diagram

Angle control specific steps as following [14]:

First step: measured angle values of angle sensor, and then discrete sampling data of unit step response is obtained. The discrete sampling data is used as predictive model parameters and combined with the default input control increment, so that angle predicted output values are achieved.

$$\min J(k) = \sum_{i=1}^{p} q_i [w(k+i) - \hat{y}_M(k+i/k)]^2 + \sum_{j=1}^{M} r_j \Delta u^2 (k+j-1) \quad (4)$$

Second, the control amount of the N sampling periods is determined using optimization criterion, and then output value of next M time was closer to the expected output value, which calculated by the calculation value of the angle.

Third step is data feedback correction. For each acquisition time, the actual angle is collected with angle sensor is corrected by prediction model. This process is continuous cycle, and then the final result is closer to the calculated values.

For the actual system functional requirements, in order to achieve the best output and ensure the accuracy of the antenna alignment, DMC algorithm parameters were repeatedly tested.

C. PC Monitoring Software Design

Monitoring software is used to achieve lift working conditions and environmental status data, which includes network connectivity, data start and stop functions, data display and curve drawing composition. Monitoring software designed by VB software, connects to remote server using Winsock control and exchanges data via UDP/TCP protocol.

Considering the portability of the system, mobile client monitoring software is also designed to achieve the data based on the Android platform, which sends and receives data through Socket. It is necessary to know the host IP address of the server (IP must be a public address) in order to make sure that the application software communicate properly.

V. EXPERIMENT RESULTS

After the completion of the system design, each sensor is attached to the specified location inside the elevator car. The data transfer accuracy rate and packet loss rate of 6 sets of samples were tested. Each sensor node periodically sends data to the server, and the data received by the server were stored in the database. PC monitoring software periodically reads data from the server and displays.

Assumed that sensor sends packets every 30 minutes and 10 packets per time, so total of packets is 480 per day. The systems were constantly monitored for 3 days, Therefore, the cumulative total data packet is 1440 .The data transfer accuracy rate and packet loss rate of the system is shown in Table II.

TABLE II
DATA TRANSFER ANALYSIS TABLE

NO.	Send data packets	Received data packets	Data transfer accuracy rate	Packet loss rate
1	1440	1344	93.3%	6.7%
2	1440	1333	92.6%	7.4%
3	1440	1236	85.8%	14.2%
4	1440	1404	97.5%	2.5%
5	1440	1420	98.6%	1.4%
6	1440	978	67.9%	32.1%

As shown in Table II, Data transfer accuracy rate of No.3 and No.6 is 85.8% and 67.9%, and the other's were higher than 90%.Affected by factors of GPRS network, natural environment, antenna interference and transmission loss, etc., the data transfer accuracy rate can not achieve 100% accuracy. Analysis show that the data transfer accuracy rate of No.3 is relatively low just because of Poor mounting position of directional antenna and imperfect of antenna rotation angle. After calibration, the data transfer accuracy rate of No.3 can reach more than 90%; GPRS network dropped since the telephone charge is overdue, so The data transmission is affected. That is why the data transfer accuracy rate of No.6 is low.

Open the PC monitoring software, PC monitoring software can properly receive and display data, as shown in Table III.

TABLE III
SENSOR DATA ACQUISITION TABLE

data	time	Humidity /%RH	Temp /℃	Voltage /V	Current /A
2014/6/5	7:42:35	60	31	223.36	74.11
2014/6/5	7:42:51	61	31	223.36	73.88
2014/6/5	7:43:07	61	31	223.36	73.98
2014/6/5	7:43:22	62	31	223.36	74.07
2014/6/5	7:43:38	62	31	223.36	73.98
2014/6/5	7:43:54	63	31	223.36	74.01
2014/6/5	7:44:10	63	31	223.92	74.07
2014/6/5	7:44:25	64	31	223.28	74.05
2014/6/5	7:44:42	64	31	223.36	73.98

data	time	infrared	smoke	flame
2014/6/5	7:42:35	1	0	0
2014/6/5	7:42:51	1	0	0
2014/6/5	7:43:07	1	0	0
2014/6/5	7:43:22	0	0	1
2014/6/5	7:43:38	0	0	0
2014/6/5	7:43:54	1	0	0
2014/6/5	7:44:10	1	0	1
2014/6/5	7:44:25	0	0	0
2014/6/5	7:44:42	1	0	1

In the Table III, when the value of infrared, smoke and flame is 1, a text message is sent to elevator company managers to notify that an abnormal conditions occur in the elevator, infrared value indicates that someone in the elevator, smoke value indicates that there is smoke in the elevator and the flame value indicates that there is flame in the elevator. If the range of voltage, current, temperature and humidity are set, a text message also sent to elevator company managers when the value collected from sensor module exceeds the range.

Data acquisition is consistent with the work of running the elevator data and environmental data. As shown in Table III, data is correct, errors-free, communication smooth and stable.

VI. CONCLUSION

Monitoring of working state and environmental parameters of elevator can be achieved real-timely by directional antenna technology. Exception or failure can be responsed in time and notification can be sent to manager rapidly. The system can ensure the normal functioning of the elevator to the maximum extent more scientifically and effectively. The system has many advantages such as simple line installation, easy maintenance, scalability, easy construction and so on. Phone-based monitoring method eliminates time and place restrictions and provides more human-based management for staff. The system has practical significance and it can be applied to a variety of elevator monitoring, highlights the social and economic benefits.

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