Hindawi
Wireless Communications and Mobile Computing
Volume 2022, Article ID 7684586, 13 pages
https://doi.org/10.1155/2022/7684586

Research Article

An Analysis of Internet of Things Computer Network Security and Remote Control Technology

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Received 29 May 2022; Revised 5 August 2022; Accepted 8 August 2022; Published 13 September 2022

Academic Editor: Jun Ye

In order to solve the problem of the specific application of Internet of Things computer network security monitoring technology in infrastructure construction, a method of remote network monitoring system design is proposed, taking tunnel security construction as an example. According to the characteristics of construction tunnel safety monitoring, this method provides theoretical guidance from several aspects, such as computer remote monitoring, data decision analysis, safety control, personnel positioning, and data management. Through experiments, it is found that in the safety detection experiment, when the data is extracted within 2 minutes for detection, the detection accuracy is higher than 80%, and if it is 4 minutes, the detection accuracy is higher than 90%; in the response time test, the local control response time is generally less than 1 s. In the remote control response time test, the response time can generally be within 3 s, and it may be greater than 5 s. The designed construction tunnel monitoring system transmits the collected data to the monitoring terminal remotely. Then, the sensor data is analyzed for timing decision-making. This method can effectively calculate the safety status of each monitoring unit of the current tunnel according to a certain algorithm and formulate corresponding emergency measures according to the safety status.

1. Introduction

With the rapid development of Internet of Things technology, its application scope is becoming wider and wider. At present, the Internet of Things has been widely used in intelligent building, smart city, smart transportation, smart home, logistics system, environmental detection, digital medical, energy conservation, fire protection, and other fields. With the continuous development of the transportation industry, more and more tunnels have been put into use. As the tunnel environment is bad and accidents are easy to happen, the safety of the tunnel has become a big problem of traffic safety. How to ensure the safe operation of the tunnel will have a very important significance. With the increase of China's investment in infrastructure construction, the safety of tunnel construction has been widely paid attention to. Common tunnel disasters include fire, excessive harmful gas, water inrush, and collapse. How to predict the disaster and control the safety after the disaster is a key point of tunnel construction monitoring. Construction of tunnel monitoring system is a huge system, involving multidisciplinary knowledge such as computers, communications, and software development. According to the characteristics of the construction of tunnel safety monitoring, exploratory research was carried on from the aspects of the data decision-making analysis, safety control, personnel positioning, data management, and so on. A construction tunnel safety monitoring solution based on Internet of Things was proposed in the paper. The environmental characteristics, safety protection requirements, and control requirements of the construction of tunnel were analyzed in detail. The disaster characteristics of the tunnel fire, harmful gas exceeding bid, water inrush, collapse, and main protection points were introduced in this paper. Combined with the actual situation of the tunnel construction, the method of combining the local control and remote control of tunnel safety control was put forward. When the level of tunnel disaster was low, the control command was sent through the monitoring software to drive the control execution equipment in the tunnel field for control. When the level of tunnel disaster was high and the onsite danger was beyond local control, the monitoring software requested the remote assistance from the remote 3G terminal and reported the onsite situation. At the same time, in order to manage and monitor the construction personnel better, the construction tunnel monitoring system used ZigBee network to locate the construction personnel. The designed construction tunnel monitoring system conducted timing decision-making analysis of sensor data. The method could effectively calculate the current security status of each monitoring unit of the tunnel according to a certain algorithm and work out the corresponding emergency treatment measures according to the security status.

Taking the tunnel construction as an example in this paper, based on the Internet of Things computer network, timing decision-making analysis of construction tunnel monitoring system and sensor data were conducted. The current tunnel safety state of each control unit was calculated according to certain algorithm. According to the safety state, the corresponding emergency treatment measures were formulated, providing several sets of emergency response plan for the users to choose and implement.

The Internet of Things needs to ensure the security and confidentiality of computer network information transmission during the operation process and strengthen the management of network services. Illegal program codes in the Internet will destroy important data and control functions in the IoT system. Therefore, managers need to strengthen the management of illegal program codes and formulate effective control measures to ensure the security of the code running in the IoT system. IoT managers need to strengthen their awareness of network security prevention, formulate effective solutions for specific problems, and ensure the security of network communications. The application of remote control technology can meet the needs of remote data transmission and acquisition, and managers need to strengthen the management of network codes during the period. Prevent illegal code from damaging the IoT system and affect communication security.

2. Related Works

Shi and Zhou believed that it was of great significance to study remote tunnel monitoring system based on Internet of Things architecture. Ensuring the safe operation of tunnels was not only a management system issue but also required a reliable technical support [1]. Mansour et al. believed that doing a good job in the tunnel safety emergency command, it was necessary not only to establish a perfect safety management organization system but also to establish an efficient and intelligent information management system [2]. Chen et al. believed that the remote tunnel monitoring system could provide data support for management and decision-making for the management. The management could realize real-time monitoring and remote control of the tunnel conveniently, eliminate potential safety hazards in advance, and take emergency rescue measures in case of emergencies, reducing harm and loss and improving the intelligence of the system [3]. Tong and Sun believed that the development of Internet of Things technology in China was still in the initial stage. And various technologies and modes were not mature enough and the application scope was not very wide [4]. Wei et al. believe that the development of the Internet of Things focuses on the world, and China is no exception. The next major target of the information industry is the Internet of Things [5]. Honar Pajooh et al. believed that the application of IoT technology in tunnels not only improves the data level of tunnels but also promotes the development of the entire IoT industry [6]. Wei et al. believed that the safe operation of tunnels was an important part of the safety work of China's transportation construction industry [7]. The safety monitoring and emergency rescue work of tunnel operation can greatly improve the level of safety monitoring and emergency linkage in the whole traffic construction industry. Qiao believed that the research of the application of Internet of Things technology in tunnel remote monitoring system also had reference significance for the Internet of Things research on construction safety in transportation construction industry and the construction of unified safety monitoring and emergency command system [8]. The Internet of Things has grown rapidly since it was first proposed in 1995. Many universities in China have conducted in-depth researches on the automatic monitoring of the Internet of Things. Guo et al. believed that the Internet of Things was applied in various industries constantly and smart cities and smart transportation were advocated throughout the country [9]. At present, China's monitoring system based on the Internet of Things is also developing rapidly, but there are also some problems. Most of the monitoring systems are only simple technical improvements of the traditional monitoring systems, with lacking of the idea of thing-thing connecting. Zhang et al. believed that most monitoring systems only used a single sensor and a single communication mode and the integration degree was not high [10]. The whole process of monitoring system includes the data acquisition, communication, processing, evaluation, and visualization. Part of the link still does not involve the Internet of Things or the function is relatively weak. Most monitoring systems based on the Internet of Things are applied in logistics system, earthquake disaster, and other aspects, but there are few applications in engineering. Due to the limitation of precision, reliability, and durability of Chinese instruments, hardware from different countries and software from China are often adopted by large-scale monitoring systems based on the Internet of Things. And the system is not highly integrated. The traditional tunnel monitoring system in China mostly uses fieldbus technology to transmit the underlying data. There are some disadvantages in this way. The cost of wiring is a great overhead, and the complexity and difficulty of wiring and maintenance bring great trouble to the construction personnel. It cannot meet the requirement of dynamically adding monitoring points in the tunnel. If new monitoring points or monitoring quantity are needed, rewiring is required. The complexity and difficulty is imaginable. According to the characteristics of construction tunnel security monitoring, a construction tunnel security monitoring

Figure 1: Analysis of Internet of Things computer network security and remote control technology.

solution based on wireless sensor network was proposed in the paper. The analysis of Internet of Things computer network security and remote control technology is shown in Figure 1.

3. Method

The monitoring system of construction tunnel is a concentration of sensor data collection, data analysis and processing, the disaster in situ processing equipment, the 3G remote linkage equipment, mobile positioning multifunction as one whole system, detecting all kinds of disasters in the tunnel real-timely, and reporting the data to the monitoring center. Monitoring software analyzes and processes the data. According to the level of risk, local tunnel processing equipment is called and 3G remote linkage mechanism was started, respectively, to ensure that losses caused by tunnel disasters are minimized. The hardware structure of tunnel monitoring system is composed of sensor network, 3G network, ZigBee network, and monitoring center [11]. Sensor network mainly accomplishes data acquisition. The data of acquisition include temperature, humidity, light, oxygen, carbon dioxide, carbon monoxide, smoke, nitric oxide, nitrogen dioxide, methane, dust, noise, wind speed, liquid level, stress, vibration, and displacement. Because wireless sensor nodes use batteries, the data acquisition is a way of a time interval for a period of time to collect data. Sensor nodes for each data set the alert value. Once the collected data exceeds the alert value, the node enters emergency pass-through mode. The node collects data uninterruptedly, so that policy-makers can timely grasp the change trend of the disaster. When the collected data falls below the safe value, the node exits the emergency pass-through mode. The collected data is sent to the wireless gateway through the WIAPA network and then sent by the gateway to the remote computer network monitoring center through the router [12, 13]. WIA network is an industrial wireless network in full compliance with the national standard for WIA-PA of process automation. A WIA network consists of at least one WIA gateway and one device and a WIA gateway can manage 100 devices at most. The application of WIA-PA technology will help to reduce the risks of the production and use of enterprise-related products, ensure industrial safety, and promote the realization of industrial energy conservation and emission reduction targets. Multiple WIA networks can form large-scale complex networks through Ethernet interconnection [14]. The 3G information is sent by the monitoring center to the 3G terminal equipment supplier through the Internet network, then to the 3G public network by the supplier's server, and finally to the 3G terminal equipment by the 3G public network [15]. ZigBee network consists of master node, mobile node, and anchor node. The host node acts as a network gateway and is responsible for collecting data from streamers and mobile phones. At the same time, the mobile phone counts the data location of the mobile phone together with the anchor point through the data extension. The positioning algorithm of ZigBee wireless positioning network adopts RF-TOF ranging positioning technology, and the position of construction personnel can be calculated by placing the sensor node on the helmet of construction personnel. In recent years, indoor positioning has gradually become a basic function in many terminal applications, including civil use, disaster protection, and peacekeeping missions. Indoor positioning technology has tended to mature. At present, it has been widely covered and applied to many scene management systems, providing cost-effective convenience for all-time managers and users. Compared with the satellite positioning which is only relied on outdoors, signal sources used for positioning are numerous in indoor scene. Due to different indoor location signal sources, a variety of indoor location algorithms are also produced. One of them is the location algorithm based on ranging, which depends on the hardware with direct ranging ability, namely, the location algorithm based on TOF.

The Internet of Things needs to analyze and process data information during the operation process, so as to ensure that the computer has enough space to store the data information. Once the data information in the Internet of Things is damaged, the damaged data can be automatically repaired with the support of the system, and the function of automatic repair can be exerted. There are multiple technical control areas in IoT, and these technical control areas need to be isolated from each other. The effective isolation between technical control areas can avoid the damage to the network system by illegal intruders and ensure the security of the Internet of Things computer system as much as possible. In addition, in order to strengthen the management of Internet of Things computer network security, it is necessary to build corresponding operating norms, implement the responsibility system, and give operators certain operating rights.

In the research, the device provided these functions including signal sending and receiving, time stamp recording, and delay sending. When clocks were out of sync between hardware, single-sided two-way ranging (SS-TWR) could be adopted. The calculation formula of signal flight time was shown in

$$\mathrm{TOF} = \frac{1}{2} * ((T_3 - T_0) - (T_2 - T_1)). \tag{1}$$

This method was not commonly used, because there was a deviation between the clock of the base station and the tag and the standard clock, which was represented by the clock drift rate k ($k = 10\,\mathrm{ppm}$). Assuming that the tag delay time T_d was 3 ms and the signal flight time TOF was negligible compared with the delay time, the ranging error caused by the delay time T_d was shown in

$$|r| = \frac{1}{2} * |k_b - k_t| * T_d * c. \tag{2}$$

$|k_b - k_t| = 5\,\mathrm{ppm}$, and $|r| \approx 2.25\mathrm{m}$. $|k_b - k_t|$ was likely to be higher than 5 ppm in reality, which could bring a big ranging error. To reduce the effect of clock drift on ranging, a double-sided two-way ranging (DS-TWR) method was used. Based on SS-TWR, this method added another sending and receiving of delay and signal. The TOF calculation method of DS-TWR method was shown in

$$\begin{cases} T_{r1} = T_3 - T_0, T_{p1} = T_2 - T_1, \\ T_{r2} = T_5 - T_2, T_{p2} = T_4 - T_3, \\ \mathrm{TOF} = \dfrac{T_{r1} * T_{r2} - T_{p1} * T_{p1}}{T_{r1} + T_{r2} + T_{p1} + T_{p2}}. \end{cases} \tag{3}$$

The approximate calculation formula of ranging error caused by clock drift of the method was shown in

$$|r| \approx \mathrm{TOF} * \frac{1}{2} * |k_b + k_t| * c. \tag{4}$$

Both k_b and k_t were set as 20 ppm. If the distance between the base station and the tag was 200 m and TOF was about 666 ns, the ranging error was obtained, which was shown in

$$|r| = 666 * 10^{-9} * 20 * 10^{-6} * 3 * 10^{8} \approx 0.004\mathrm{m}. \tag{5}$$

That is, the ranging error of DS-TWR method due to clock drift was mm level, so the DS-TWR method should be adopted in the actual TOF working mode. In the paper, ZigBee wireless communication technology was adopted to standardize PLC control system information communication. The filtering algorithm was adopted to filter the redundant noise of the data collected by the gateway. Considering that the state data of the system working environment was distributed discreetly, the system control variable was set to be numerically stable and the production equipment state data in the discrete time domain was represented by the Kalman filter. The expression was shown in

$$s(x) = \frac{As(x-1) + B + W(x)}{S(x) + V(x)}. \tag{6}$$

In the formula, $S(x)$ and $S(x-1)$ were the estimated value of production equipment state data at the moment of x and moment $x-1$, respectively. A and B were the defined parameters of the system. $W(x)$ and $V(x)$ were the noise of the system and the working environment, respectively.

Calculate the covariance $P(x/x-1)$ of the estimated value of state data at at the moment of x and $x-1$. The formula was shown in

$$P\left(\frac{x}{x-1}\right) = \frac{AH(x-1)H(x) + Q}{R}. \tag{7}$$

In the formula, $H(x-1)$ and $H(x)$ were the system observation matrices the moment of x and moment $x-1$, respectively. R was system covariance. Q was the gain coefficient.

$P(x/x-1)$ was further optimized to obtain the optimal estimation value $K(x)$ of the system time. The expression was shown in

$$K(x) = \frac{LK(x-1)}{P(x/(x-1)) + f}. \tag{8}$$

In the formula, $K(x-1)$ was the optimal estimation value of state data at $x-1$ moment. L was the covariance of $K(x-1)$ value. F was Gaussian white noise.

After the original data was filtered, PID controller optimization algorithm was adopted to make the production equipment state variables collected by the system closer to the real value of the environment. Each state data was abstracted as a particle, and the particle space position was determined according to the particle moving speed and inertia, so as to find the optimal path to reduce the system error. The PID controller weighting parameters E_1 and E_2 were defined. The expression was shown in

$$\begin{cases} E_1 = \dfrac{a1e1[I(x) - D(x) + a2e2[O(x) - D(x)]}{gv(x)}, \\ E2 = D(x) + v(x+1). \end{cases} \tag{9}$$

In the formula, a_1 and a_2 were particle accelerations. e_1 and e_2 were random parameters. (x) and $O(x)$ were the

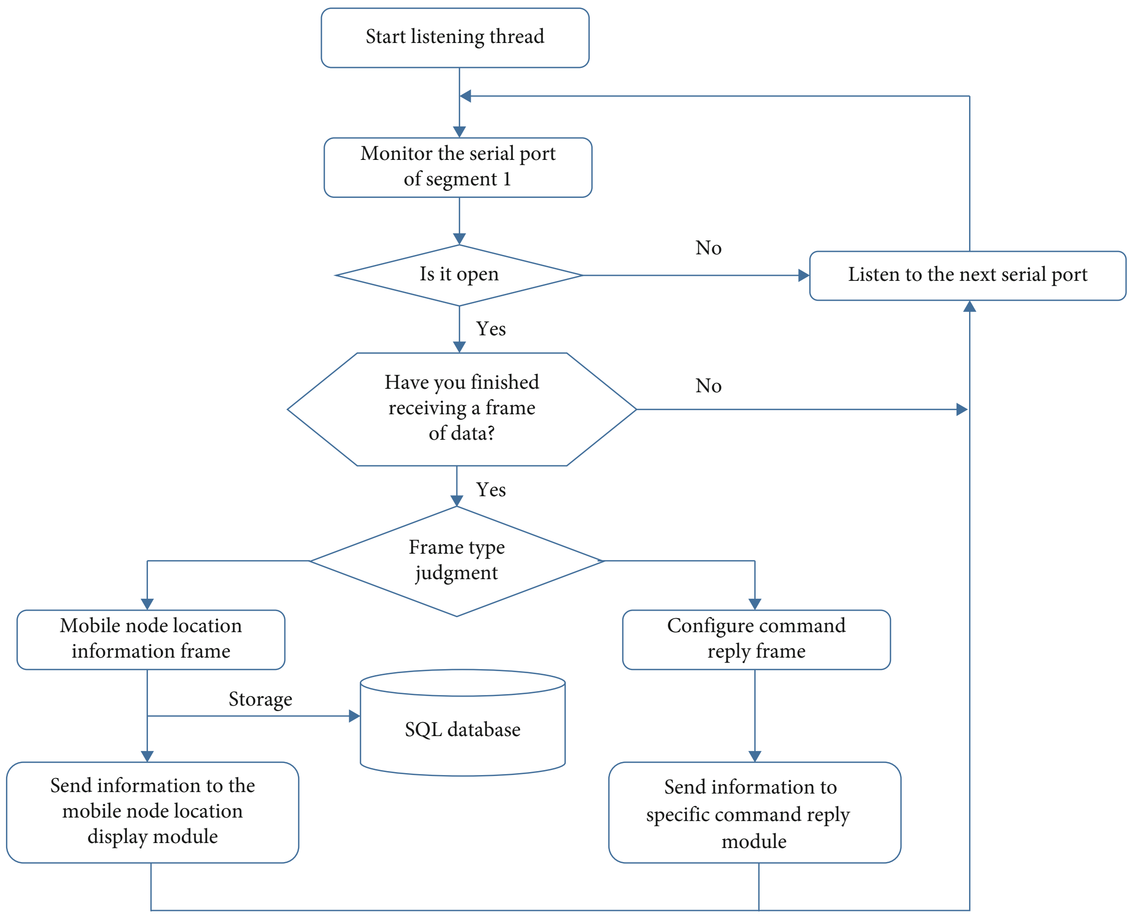

Figure 2: Multiserial port monitoring process.

positions of moment particle and particle swarm, respectively. $D(x)$ was the optimal position. g was inertial parameter. $v(x)$ and $v(x+1)$ were the velocity.

The system variance state equation was shown in

$$H(x) = E_1 \int_0^x P\left(\frac{x}{x-1}\right) dx + E_2 \frac{dp(x/(x-1))}{dx}. \tag{10}$$

In the formula, $P'(x/(x-1))$ was the optimized system variance.

The positioning system was completed by ZigBee network data collection management module. Due to the system to monitor three sections of the subway construction site at the same time, so the network also was composed of three subpositioning networks. Each network consisted of a master node, a reference node, and a mobile node. The master node was equal to the gateway to complete the work of the data receiving and sending of the reference node and mobile node. At the same time, the upward computer sent data through the serial port [16].

This system performs computer network remote monitoring for multiple construction threads at the same time. The subway construction site did not connect. Therefore, WIA network and ZigBee network were composed of three subnetworks, with collection and management of various blocks, respectively. They can resist various electromagnetic interferences used in industrial field, home automation control, and industrial telemetry remote control. And the data was sent to the PC at the same time. So the data collection and management module was composed of three different network management modules. The structure of data acquisition and management module is shown in Figure 2.

After the monitoring system collects the data, it stores the sensor data in the database of the remote computer. In order to get what the current state of the tunnel was, data fusion and the analysis of the state of the tunnel were necessary. The tunnel construction monitoring system is designed to show the real-time and automatic statistics of the construction site conditions and personnel activities to the management personnel. As an auxiliary means of construction safety management, it adds more guarantee for the safety of the tunnel construction. A block of the tunnel was long. Even if the sensor data of the tunnel was analyzed, which position was in danger could not be known according to the results [17].

The computer network remote control system can meet people's various needs and has been widely used in various fields, such as network monitoring, network automation management, and computer-aided teaching. The remote control system consists of different parts, such as server terminal, communication network, user terminal, and controlled

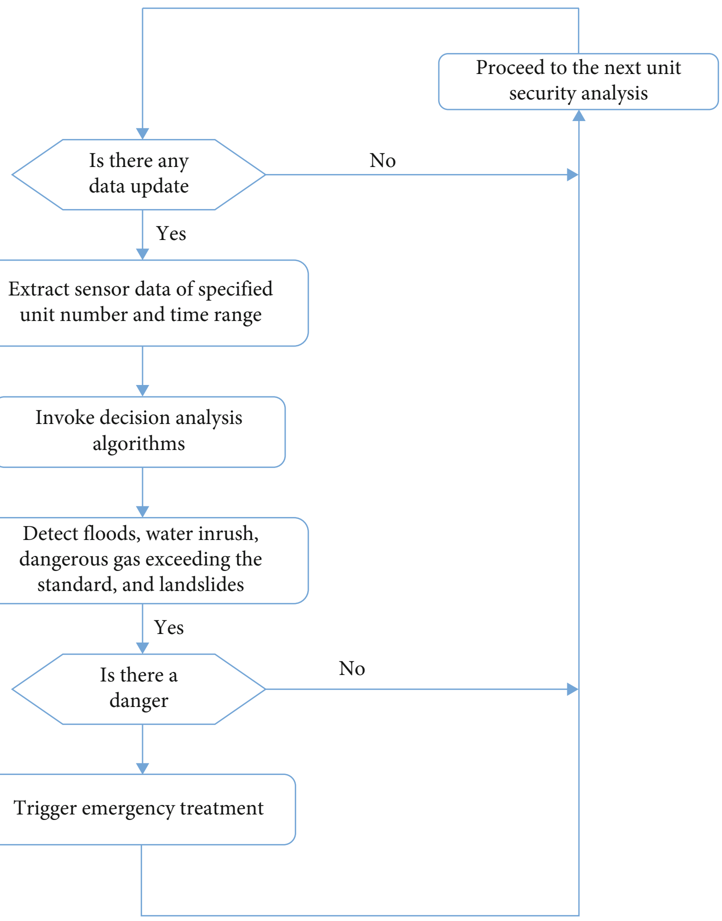

FIGURE 3: Flow chart of decision-making analysis and processing.

network. The main function of the controlled network is to receive commands issued by the master network and distribute them to each device. The operating systems of the master network and the controlled network can be Windows 7, Windows 8 or Windows XP.

Therefore, the system adopts the decision analysis method based on the computer network remote monitoring unit. A block of the tunnel is divided into a number of monitor units. Each unit could collect all kinds of sensor data and store the data in the database. Decision-making analysis was the analysis of a single state of monitoring unit. Decision analysis system is generally composed of interactive language system, problem system, database, model library, universal library, and knowledge base management system. This system detected four kinds of dangerous situations in the tunnel, including fire, dangerous gas exceeding bid, water inrush, and collapse and outputs the grade of the four kinds of danger of the unit. When the danger level exceeds the normal level, the computer will trigger corresponding emergency measures by itself, so as to respond to the dangerous situation as soon as possible. The flow chart of decision-making analysis is shown in Figure 3.

Monitoring software regularly carried out safety detection on the tunnel under construction, which mainly detected fire, harmful gases, water inrush, and collapse disaster. According to the data of different sensors, the tunnel disaster was divided into different levels, which were divided into five grades including normal, existence of hidden danger, danger treatment, emergency avoidance, and disaster relief. Correct and reasonable prevention and control measures will play a role in inhibiting or reducing the degree of disaster harm. On the contrary, if no attention or take wrong countermeasures, this will aggravate the degree of disaster and even play a role in inducing disaster. According to different levels of disasters, different measures were taken. Tunnel emergency treatment was to take different countermeasures for different categories and levels of disasters [18].

The emergency response measures were divided into the following kinds: rewrite the monitor view area color, send local control command, and start the remote linkage. The latter two needed to send control commands to the field and remote, with a relatively complex processing logic. In local control, monitoring center sent control commands to execution nodes by WIA gateway. After the transmission was completed, it was necessary to wait for the execution result of the terminal device. And then, the next control action was taken according to the execution result. The flow chart of local control and remote linkage control in tunnel emergency treatment is shown in Figure 4.

WIA Ethernet interface commands provided a software interface for managing and configuring the WIA network and sending and receiving data information of terminals

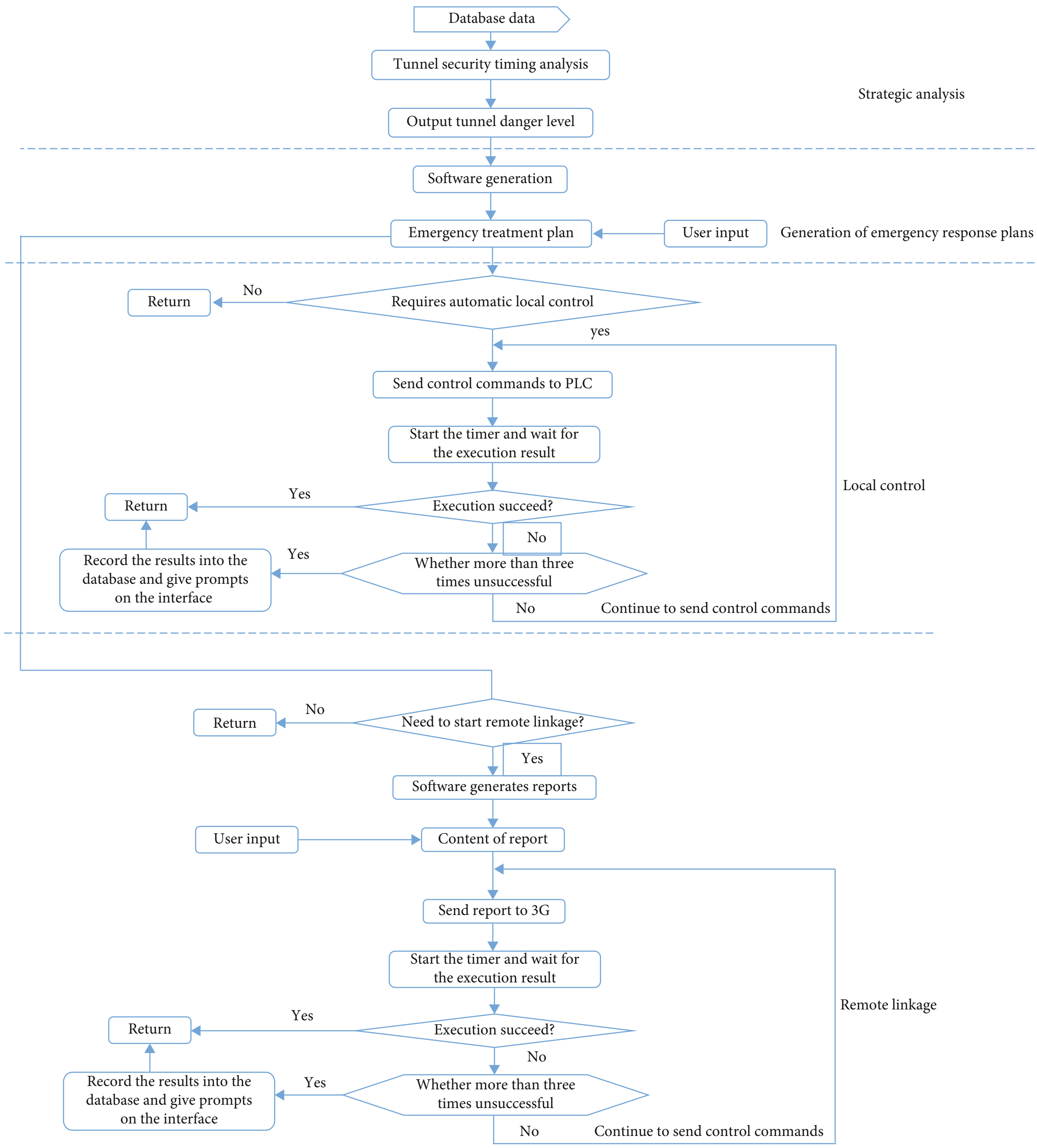

FIGURE 4: Flow chart of emergency processing.

over the Ethernet. WIA network information could be obtained by using Ethernet interface commands. The process of the specific processing is shown in Figure 5.

Construction tunnel safety inspection was based on a single unit for the unit. By analyzing all the extracted data uploaded by the unit node for a period of time in the database, the security level of the unit was concluded, in order to ensure the rapidity and accuracy of the data analysis. Choose to extract the data uploaded by the sensor nodes within 2-10 minutes from the field information collected through the monitoring network. If the time span is too long, it will take too long, and if the time span is too short, the results will be inaccurate and errors will occur. In terms of the weight of data, the closer the data was uploaded, the greater the weight should be [19, 20]. At the same time, in the analysis of tunnel danger, it should be analyzed according to the analysis of multiple sensor data. Each sensor data could represent the different importance. In fire detection, for example, temperature, humidity, oxygen, carbon monoxide, carbon dioxide, and smoke should be tested at the same

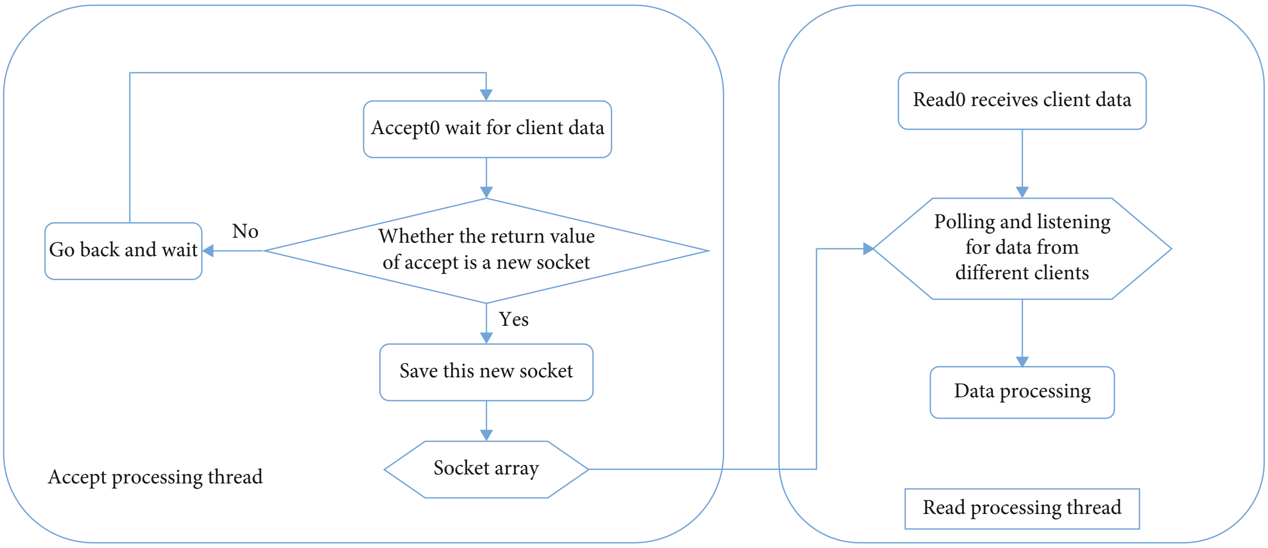

Figure 5: The flow chart of multiterminal network data processing.

time. Among them, temperature, carbon monoxide, carbon dioxide, and smoke for the effectiveness of temperature test were larger. Therefore, different types of sensors accounted for different weights. The decision-making algorithm of construction tunnel safety analysis is shown in Figure 6.

The calculation formula of tunnel danger level K was shown in

$$K = 0.2 * \frac{1}{n1} \sum_{t>0}^{t<80\%T} M_i \alpha + 0.8 * \frac{1}{n2} \sum_{t>80\%T}^{t<100\%T}. \quad (11)$$

n_1 was the number of sensors in the first 80%. n_2 was the number of sensors in the latter 20%. α was the weight value of sensors. And M_i was the warning level corresponding to the sensor value. The tunnel monitoring system adopted SQL Server 2005 for data management, which mainly completed system parameter saving, external data record storage, database data transfer function, data printing, and print preview function [21, 22]. The database management module managed the system data and stored the sensor network data, the location information of mobile nodes, and the system parameters in real time. At the same time, the data management module also provided data query interface. The users can query most of the data stored in the database, using reports or charts to describe the data.

There are two common communication protocols, namely, IP protocol and TCP protocol. Among them, the safety factor of the TCP protocol is relatively high, which can ensure the stability of the system operation. However, the protocol needs to occupy a lot of resources, and long-term operation will affect the system processing rate. When the TCP protocol runs, it needs two computers to transmit the data to be transmitted in the form of packets. If there are multiple network terminals, the IP protocol can be used at this time. The combination of the two protocols is a collection of network protocols.

4. Results Analysis

The main components of a controlled network are hardware and software, which work together to provide control services. The core of the controlled system is the control of the data collection, and the control system is centered on the computer. When designing a controlled system, it is necessary to adhere to the principle of security, pay attention to strengthening the protection of user information, and repair it immediately once a problem occurs. In order for the controlled network to function, it is necessary to strictly follow the prescribed operation steps and send the content of the remote transmission to the main control terminal. Remote control technology can realize the control of computer hardware equipment and software equipment and complete file transmission and management tasks.

Because fires and landslides were difficult to simulate, the method of field burning paper was used in the process of the tunnel danger simulation. Sensors were placed around the combustion for detection. Landslides could not be simulated in the laboratory environment. Therefore, the test method adopted was to simulate the change characteristics of support subplane during collapse by pressurizing the pressure sensor and changing the displacement value of the sensor. When testing whether harmful gases exceeded the standard or not, the analysis method of each gas exceeding the standard was similar. So the detection of harmful gases exceeding the standard was carried out according to the concentration of carbon dioxide [23]. Computer remote network monitoring security analysis test extracts data within 2 minutes and 4 minutes for decision analysis. In the decision-making analysis algorithm, it was concluded that the weight of the historical data and the data within 80% of the current time accounted for 80%. Therefore, when data of within 2 minutes was taken for testing, the detected disaster time was 24~30 s in theory. The detection accuracy was higher than 80%. The test results are shown in Table 1.

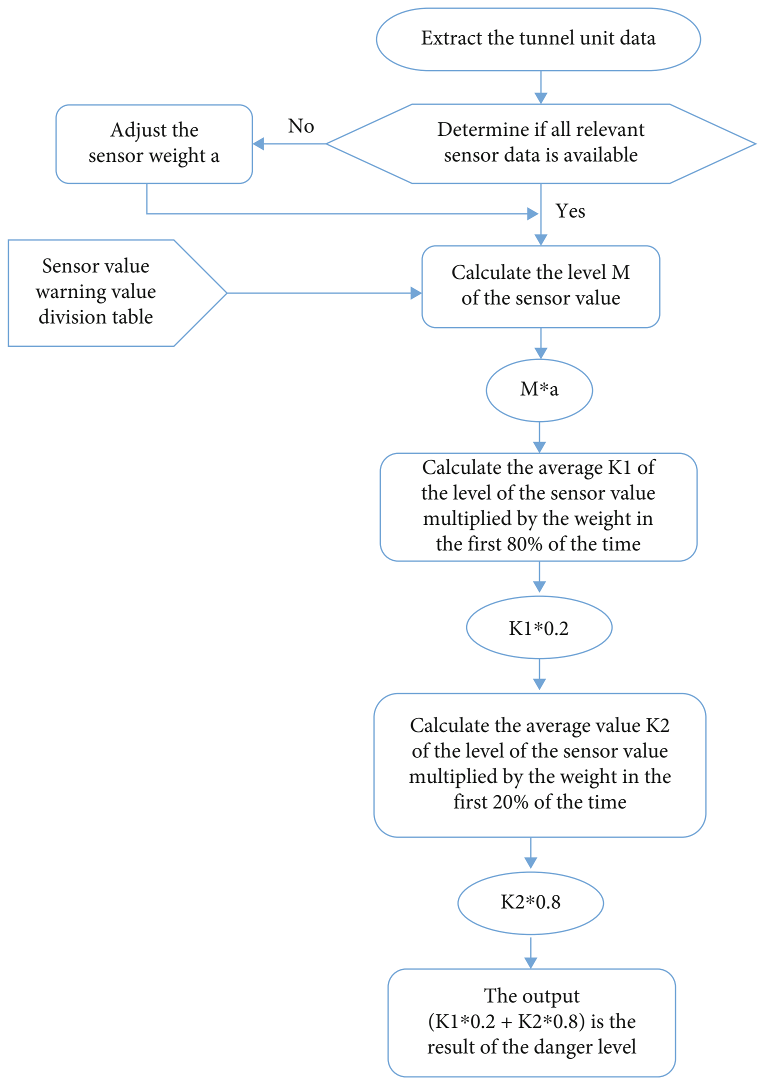

Figure 6: Decision-making algorithm for analysis of construction tunnel safety.

Table 1: Extracting historical data within 2 minutes for decision-making analysis.

Test items	Number of tests	Analysis time less than 30 s	Analysis time more than 30 s	Not to be detected	Detection accuracy
Fire (simulation)	25	13	8	4	84.00%
Water inrush	32	28	4	0	100%
Excess of harmful gas	42	34	6	2	95.23%
Landslide (simulation)	19	11	7	1	94.74%

However, if it was within 4 minutes, the results of the detection were obtained from 48 to 60 s normally. The detection accuracy was higher than 90%. The test results are shown in Table 2.

The local control command was executed by the controller PLC at the construction site. The monitoring software sent the control command to the WIA gateway through Ethernet and the WIA gateway sent the message to the underlying executing node according to the format of writing command. After receiving the data, the executing node sent the data to the serial port of RS232 to 485. Finally, data would be sent to the 485 interface of controller PLC to reach the end of each control device [24].

When the number of network nodes was 10, 20, and 40, the statistical results of the test were divided into four situations: response time less than 1 s, response time more than 1 s, response time less than 3 s, and no execution. The test results are shown in Table 3 and Figure 7.

Seen from the above results, the local control of the response time was generally less than 1 s. With the increase of network size, there would be a control command delay phenomenon of execution. And the larger the network size

Table 2: Extracting historical data within 4 minutes for decision-making analysis.

Test items	Number of tests	Analysis time less than 60 s	Analysis time more than 60 s	Not to be detected	Detection accuracy
Fire (simulation)	25	14	9	2	92.00%
Water inrush	32	26	6	0	100%
Excess of harmful gas	42	25	16	1	97.62%
Landslide (simulation)	19	11	8	0	100%

Table 3: The test results of local control response time.

Network scale (number of network nodes)	Number of tests	Response time less than 1 s	Response time more than 1 s less than 3 s	No execution
10	35	35	0	0
20	36	34	2	0
40	35	30	4	1

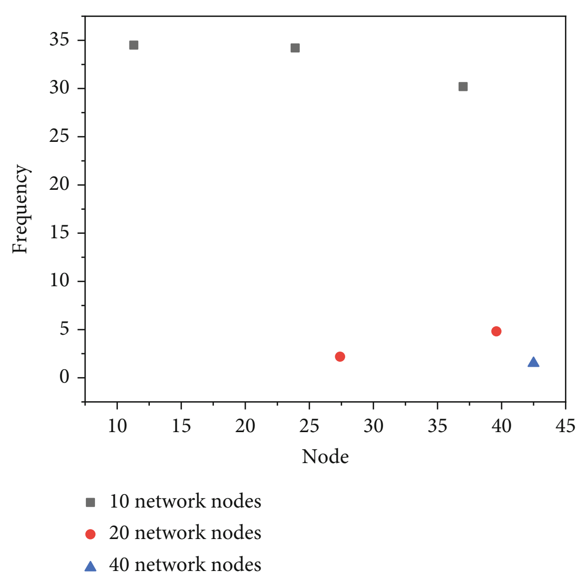

Figure 7: The test results of local control response time.

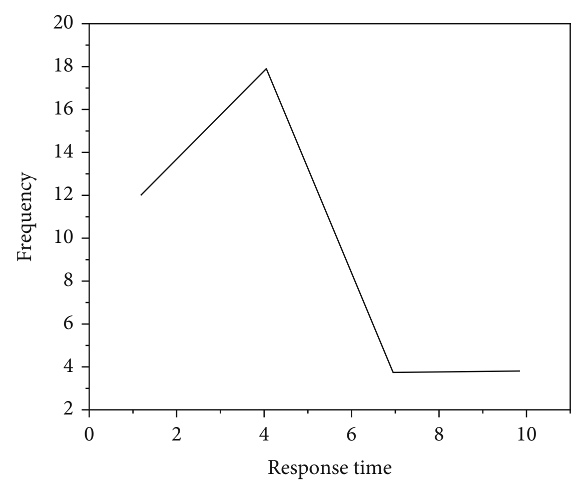

Figure 8: The test results of remote linkage network response time.

was, the delay phenomenon is more serious. The main cause was with the increase of network nodes, node processing capacity is limited: it includes node computing power configuration, backplane bandwidth, and forwarding buffer. The slice of time obtained by each node was smaller. When the network size reached 40 nodes, the control command would be executed (it was not executed within 30 s). Complex network is a special network structure, which is a network structure model that abstracts the elements in a complex system into nodes and the relations between the elements into edges. Therefore, the scale of the network should be reasonably considered when the network was laid out. And the sensor nodes in each bidding section should not be too many when the tunnel was managed and constructed by bidding section [25]. Remote linkage was that the scene situation was reported to the remote 3G terminal equipment. The communication process was that the information to be sent was packed by the monitoring software and was sent to the 3G terminal server through the Ethernet interface. Then, the message was sent to the terminal device by the server through 3G network. Therefore, in the process of testing remote linkage response, the time when the terminal receives the packet was recorded through sending a command to the terminal several times [26]. In the process of testing the response speed of 3G network, the data was sent to the 3G terminal device by hand and the response time from sending data to 3G terminal was calculated. The characteristics of response time and the distribution of response time are shown in Figure 8.

The test results showed that the response time of the 3G network distribution was relatively dispersed. Generally, the situation of within 3 s could appear. The cause was the external network information received by 3G terminal. Since the median value can only reflect problems with the median value, there is no more feedback, for example, I want to know within how many ms of 80% of the service's requests take, which require additional data metrics. The situation of more than 5 s could also appear. At the same time, the phenomenon of no response also could appear. The stability of the external network demand was high. So the phenomenon of receiving nothing could appear. Therefore, in the

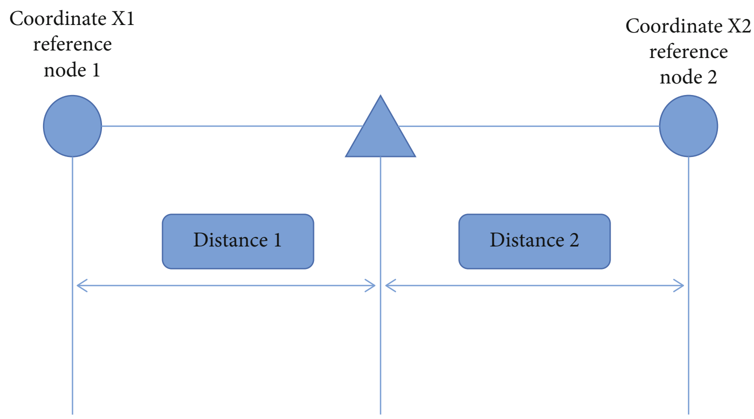

Figure 9: Schematic diagram of localization algorithm.

Table 4: The test results of positioning.

The test conditions		Valid data (within 3 m range)	Deviation from normal value (3 m)	Total test data	Minimum error (cm)	Maximum error (cm)	Valid data percentage
The square measure	Two reference nodes	31	6	37	4	293	83.78%
	Three reference nodes	24	4	28	12	225	85.71%
Corridor measuring	Two reference nodes	38	2	40	27	275	95.00%
	Three reference nodes	26	7	33	9	295	78.79%

design of the software, it was necessary to add a resending mechanism. When the information of the 3G terminal devices was not received within a certain period of time, the control command needed to be resent. In the construction tunnel, the tunnel was usually linear structure and the localization algorithm was relatively complex to implement, especially the two-dimensional localization system, which had a long algorithm development cycle. Therefore, the system currently adopted the one-dimensional localization system, which outputs the segment number of the moving node and the corresponding one-dimensional coordinate value [27, 28].

There are many researches on sensor network localization technology. And the basic localization algorithm is to locate the unknown location node through the known location node. ZigBee communication protocols were used in positioning network. Ranging algorithm used the time pulse to measure the distance (TOF). Mobile node sent waves to the reference node. Calculate the time to recover from the wave. Since the transmission time is proportional to the distance, the distance between the reference node and the mobile node can be calculated through the time difference, and finally, the location information of the mobile node can be obtained. For the location of the phone, determine the exact location of the data. The positioning diagram is shown in Figure 9.

The test was divided into corridor test in the experimental building and outdoor square environment test to test the positioning effect in different environments. The distance between the two reference nodes was 30 m. Due to the current conditions, the positioning effect was only tested in the case of 2 and 3 reference nodes. If the test result deviated too much from the true value (the error was more than 3 m), it was considered invalid. During the test, the deviation error value and the percentage of valid data were recorded. The test results of positioning are shown in Table 4.

In the test results, due to hardware instability and other factors, the measured results could appear the phenomenon of error more than 3 m. Seen from the test results of positioning, the test accuracy and test environment and the number of reference nodes had no connection. The environmental impact on positioning system was relatively small. But if the precision of positioning system was only about 80%, the precision was also needed to further improve.

5. Conclusion

The Internet of Things technology is the development trend of China's future society. The effective use of the Internet of Things in enterprises can improve the efficiency of resource sharing. During this period, technicians need to strengthen the management of the operating environment of the Internet of Things and further improve the functions of the remote control system to ensure its operational safety, and stability will better promote the long-term development of China's Internet of Things technology.

With the intensification of road traffic construction in China, more and more attention has been paid to the monitoring of construction tunnels. Common construction tunnel disasters include fire, harmful gas exceeding the standard, water inrush, and landslides. Computer remote construction tunnel monitoring system based on wireless sensor network collects 17 kinds of sensor values through the wireless sensor network to monitor the running state of the construction tunnel in real time. By analyzing the sensor data, the safety state of the tunnel is obtained. When the tunnel is in different levels of danger, the monitoring software will take different measures. For emergency treatment plan, carry out local control and remote linkage control of construction tunnels and eliminate or reduce tunnel disasters. This paper mainly studies the following aspects:

(1) The analysis of tunnel safety: the safety analysis of each unit of the construction tunnel was carried out regularly. By extracting the recent historical data from the database, different weight values were allocated to the data of different time and data of different sensor types. And the status of each monitoring unit was calculated by decision-making analysis algorithm

(2) Network communication management based on multiterminal: construction tunnel monitoring system was composed of multiple network, including WIA sensor network, ZigBee positioning network, and 3G remote linkage. Monitoring system was based on multiple bid monitoring, with each bid being a subnetwork, so the multiple network management was one of the focuses of this system. The communication system with network multiple terminal system was studied. Finally, the multiterminal multinetwork management was realized

(3) Tunnel emergency treatment: in the construction tunnel monitoring, different emergency treatment measures need to be taken when the detection tunnel is in different danger levels. In this paper, according to the actual situation of the tunnel, a reasonable tunnel emergency treatment scheme was developed and the software emergency treatment process was designed and realized

(4) Remote linkage control: when the risk of construction tunnel is at high level, relying on control equipment of the field cannot control the situation effectively, with the need to send the remote linkage request. The integrated remote control scheme based on 3G communication was adopted in this system. Through the Ethernet interface, the report was sent to the equipment placed in fire department, emergency department, government department, etc.

(5) System monitoring view management: as the construction tunnel monitoring software, it is necessary to monitor the tunnel running condition in real time to understand the running state of each section of the construction tunnel as well as the running state of the fan and water pump and other execution equipment, realizing the graphical monitoring

(6) Database management: in the computer network remote monitoring system based on wireless sensor network, sensors continuously collect various sensor data, which is the basis for tunnel safety analysis on the one hand and the basis for postevent accident analysis on the other hand. Provide data dump, data query function, and data printing function

Data Availability

The datasets used during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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