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Data Acquisition and Remote Monitoring of Geological Parameters for Landslide Prediction using WSN

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Abstract

Aiming at the problems of a large amount of redundant information, low data accuracy and difficulty in system monitoring when wireless sensor network nodes collect data. An efficient technique of data collection and remote monitoring system based on wireless sensor network is proposed. The system uses WSN nodes to real-time collection of external environment parameters. A software design for Wireless Sensor Network formation, data fusion, data transmission and transferring data to the host computer, and use of WIFI/GSM as a means of transmission to build a remote monitoring platform. The test results show that the system can realize remote real-time monitoring of the external environment, geophysical parameters and the use of data fusion algorithms increases the transmission rate and data accuracy between nodes.

Keywords: Wireless Sensor Network, Data Acquisition, Landslides, Remote Monitoring.

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Introduction

The Wireless Sensor Network (WSN) is a multi-hop self-organizing network system formed by a large number of inexpensive micro-sensor nodes deployed in the monitoring area.[1] Its purpose is to cooperatively sense, collect, and process the information of the perceived object in the network coverage area and send it to the observer. The wireless sensor network is mainly composed of three parts: nodes, gateways and software.

With the rapid development of Micro- Electro-Mechanical System (MEMS), System on Chip (SOC), wireless communication and low-power embedded technology, Wireless Sensor Networks brought about a revolution in information perception with its low power consumption, low cost, distributed and self-organizing characteristics.[2] The importance of this technology is comparable to that of the Internet: Just as the Internet enables computers to access all kinds of digital information regardless of where it is stored, sensor networks will expand the ability of people to interact with the real world remotely. It is even called a new type of computer system, because it is different from the hardware of the past, which can be distributed everywhere and the ability of collective analysis.

A vast number of Wireless sensor network products are already in the market, and new products with fascinating features will appear soon. Many types of sensors in wireless sensor networks can detect various phenomena in the surrounding environment, including earthquakes, electromagnetics, temperature, humidity, noise, light intensity, pressure, soil composition, the size, speed, and direction of moving objects. MEMS-based micro-sensing technology and wireless networking technology have given broad application prospects to wireless sensor networks.

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The potential application areas can be summarized as: military, aviation, anti-terrorism, explosion protection, disaster relief, environment, medical care, health care, household, industry, business and other fields.[3,4]

Wireless sensor networks mostly use five-layer protocol standards: application layer, transport layer, network layer, data link layer, and physical layer, corresponds to the five-layer protocol of the Internet Protocol Stack. In addition, the protocol stack also includes an energy management platform, a mobile management platform, and a task management platform. These management platforms enable sensor nodes to work together in an energy-efficient manner, forward data in the sensor network where the nodes move, and support multitasking and resource sharing.

The functions of each layer protocol and platform are as follows: The physical layer provides simple but robust signal modulation and wireless transceiver technology; The data link layer is responsible for data framing, frame detection, media access and error control; The network layer is mainly responsible for route generation and route selection; The transport layer is responsible for the transmission control of the data stream , which is an important part for ensuring the quality of communication services; The application layer includes a series of application layer software based on monitoring tasks; The energy management platform manages how the sensor nodes use energy, and energy saving needs to be considered at each protocol layer; The mobility management platform detects and registers the movement of sensor nodes, and maintains the route to the sink node, so that the sensor node can dynamically track the location of its neighbors; The task management platform balances and schedules monitoring tasks in a given area.[5-7]

Key technologies of sensor networks: Wireless communication technology, Embedded operating system design, Low power consumption design, Routing protocol of multi-hop self-organizing network, establish a data-centric sensor network, Data fusion and data management technology, network security technology, underwater precise positioning technology, convergence node, Network node.[8,9]

Related Work

This paper designs environmental monitoring systems that integrate data collection, data fusion, data display, storage, and remote monitoring. The system can be used in Landslides monitoring and prediction. There are many research on wireless sensor networks. Designed a mine underwater water level monitoring and control system to complete mine monitoring,[10] but the system is more complicated. Literature[11] describes the data transmission and wireless sensor network in wireless sensor network, which belongs to theoretical research. Literature[12,13] proposed a specific design scheme of wireless sensor network, and the implementation, outcome needs to be verified by experiments. In another study,[14,15] the data fusion algorithm of wireless sensor network was proposed, the algorithm reduced the data redundancy, but did not conduct practical application research. Literature[16] designed the CC2530 module but did not applied to the node further. Literature[17] gives many basic application examples of ZigBee, and provides program references for realizing ZigBee applications in various occasions. Combined with previous research, this system is designed based on wireless sensor network data acquisition and remote monitoring system, effectively solving the above problems. When traditional wireless sensor network nodes collect data, they usually use a single node to monitor the environment, making the monitored environment parameters inaccurate and difficult to truly reflect the current environment. This system uses multiple network nodes to monitor the same environmental parameters, and then integrates the monitored data, which not only ensures the accuracy of the data, but also reduces the data redundancy and greatly improves the system's efficiency. The display and control on smartphones, by mobile phone application app, to make it more convenient for users to monitor the environment. When connected to the public IP network, the system can be remotely monitored, which facilitates the users to use the system more practically.

System Design

The realization process of the wireless sensor network data collection and remote monitoring system is as follows:

1. A certain number of network nodes are arranged in the external environment, and the network nodes are responsible for collecting external environmental/geological parameters. Then the network nodes are clustered, the nodes in the cluster collect the same kind of data, and the cluster head node is responsible for data fusion.
2. Fused data is transmitted to the sink node and is stored on the local computer, sink node is also equipped with WIFI, GSM to transmit the data to the cloud, to be monitored by the remote server.

The data fusion algorithm is implemented at the cluster head on the data received from the end nodes. The main environmental parameters collected by the system are: temperature, Pore pressure, rainfall intensity and soil moisture.

Overall block diagram of the system is shown in Figure 1. It is mainly composed of network nodes, cluster head nodes, gateway (network coordinator), monitoring computer, and remote monitoring terminals, which can acquire data such as temperature, soil moisture, pore water pressure and Rainfall intensity from the monitored area. The system uses a node clustering mechanism to divide the nodes that collect the same data into the same group. The cluster head node is responsible for data fusion, the cluster member nodes collect various real-time data, and the gateway node is responsible for establishing and maintaining the entire system network.

The working process of the system is, when the node collects the data from the environment sensors, the collected data is sent to the cluster head node for data fusion, and then the cluster head node sends the fused data to the gateway node, and finally, the gateway node transmits the data to

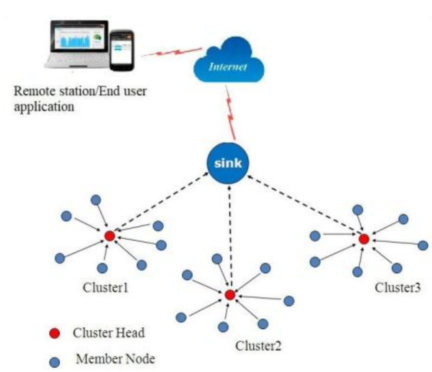

Figure 1: Overall system block diagram

the host computer through the USB data cable for data display and storage. At the same time, the gateway can send instructions to control network nodes connected to external devices, thereby adjusting the external environment. The gateway node also transmits the information to the cloud through GSM network. The data in the cloud storage can be accessed from any place remote computer for analysis.

Data Fusion Algorithm

This system generates a lot of redundant data when the node collects data, which greatly consumes the energy of the node and reduces the transmission rate. Applying the data fusion algorithm to the node effectively solves these problems. In a multi-sensor system, the fusion of uncertain information from each sensor is an uncertain reasoning process. At present, the commonly used data fusion methods are two categories: statistical methods and artificial intelligence. The algorithms used in multi-sensor data fusion mainly include classical inference and statistical methods, Bayesian estimation, cluster analysis, arithmetic mean and recursive fusion estimation, adaptive weighted fusion estimation, DS evidence reasoning, wavelet transform, entropy estimation, Fuzzy set theory and Artificial Neural Networks. Different fusion algorithms have their own advantages and disadvantages and are suitable for different application backgrounds and requirements of different fusion levels.

To improve data accuracy and reduce redundancy, this system uses multiple sensor nodes to collect the same kind of data, and performs the same kind of data fusion at the cluster head node. For this system fuzzy closeness data fusion algorithm is selected, the algorithm is described as follows:

The sensor measurement value is random and generally obeys a normal distribution. For a certain parameter (such as temperature), let the measurement value of the i- th sensor be x where $i = 1,2,3,\ldots,ni = 1,2,3,\ldots,n$ and the specific fusion process of n parameters is as follows:

- Calculate the mean $x_0 x_0$ and variance of the measured n parameters of the same type by using $\sigma_0\sigma_0$

$$x_0 = \frac{1}{n}\sum_{i-0}^{n} x_i x_0 = \frac{1}{n}\sum_{i-0}^{n} x_i \text{ ------(1)}$$

$$\sigma_0 = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - x_0)}\sigma_0 = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - x_0)} \text{ ------(2)}$$

- Find the relative weight $\omega_i\omega_i$. First find the $x_0 x_0$ fuzzy closeness between the raw data of each sensor and the mean value of this parameter $\zeta_i\zeta_i$, the specific formula is given in equation (3), and then it will be $\zeta_i\zeta_i$, brought into formula (4) to obtain the weight of the fusion $\omega_i\omega_i$,

$$\zeta_i = \frac{1}{1+|x_i - x_0|}\zeta_i = \frac{1}{1+|x_i - x_0|} \text{ ----- (3)}$$

$$\omega_i = \frac{\zeta_i}{\sum_{i=1}^{n}\zeta_i}\omega_i = \frac{\zeta_i}{\sum_{i=1}^{n}\zeta_i} \text{ -------------(4)}$$

- Obtain the data fusion result of the parameter after calculation

$$\overline{xx} = \sum_{i=1}^{n}\omega_i\zeta_i\sum_{i=1}^{n}\omega_i\zeta_i \text{ ------------ (5)}$$

- Obtain the feature vector. Repeat the above three steps to fuse the temperature, Pore pressure, rainfall intensity and soil moisture data to obtain the fusion value. The fusion value of the four parameters constitutes the feature vector T = [T1, T2, T3], where T1, T2 and T3 represent, respectively, the result of each type of data fusion. Data fusion block diagram is shown in Figure 2.

System Software Design

Thesoftwaredesignofdata acquisition andremotemonitoring system is divided into lower-level code programming, upper-level software design and remote monitoring-side software design. After the lower level completes the collection of external environmental parameters and data fusion, the cluster head node transmits the data to the coordinator node, i.e., to the upper level, and sends it to the host computer software for real-time display and storage. The entire system can also be remotely monitored by remote control software via Ethernet, displaying various data in real time.

Node-side Code Programming

The node-side code programming of the entire system mainly includes: network establishment, sensor drive, manual clustering, and data fusion. The program software uses IAR to program each terminal node and coordinator first to form a system network. The system uses multicast communication to cluster homogeneous sensor nodes and drive their corresponding sensors at the same time. Then perform data fusion at the cluster head nodes of each group, and complete the programming of the corresponding data fusion algorithm. Finally, complete the programming of the sink node, and the sink node assumes the data collection center and network manager role in the entire network. In order to ensure that the nodes can carry out data fusion and can be displayed correctly on the computer, the nodes are numbered three times during programming, as shown in Table 1.

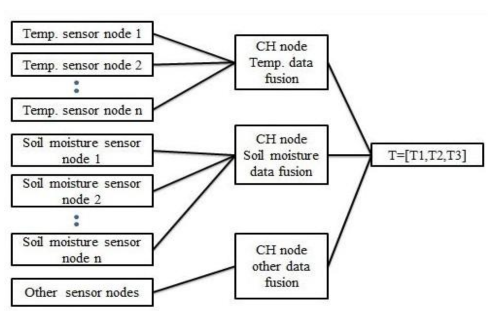

Figure 2: Structure of the data fusion

Table 1: The node categorization.

Sl#	*Node category*	*Group number*
1	Cluster member number	ID:1-4
2	Cluster head node number	Number: 0x01 – 0x04

Host Computer Software Design

The Host computer software should meet the following requirements: the results of data fusion can be viewed, which is convenient for users to store and process the data. At the same time, the host computer software can also be used as a server to facilitate client access. In order to realize these functions, the host computer software of this system uses C+ programming language. C+ has advantages over other languages when writing desktop applications. At the same time, the C+ programming language is closely connected with the database, which greatly facilitates the storage of data. When using C+ to design the host computer, the entire host computer includes: data display module, server module, instruction module, data storage module. The entire design framework is shown in the Figure 3.

Remote Monitoring Terminal Software Design

Introducing the remote-control terminal allows users to view the system in real time and solve the distance problem on the ground. To facilitate users to monitor the entire system, this system uses JAVA language to design mobile phone APP software. With the popularization of smartphones, APP software on smartphones has long been integrated into people's lives and studies. The development of APP corresponding to this system can help people. The system can be monitored anytime, and the user uses the ground facilities. Use the client's mobile phone to connect to the public IP of the wireless router. The mobile app has complete access to the server and realizes the remote monitoring function of the system.

Result and Analysis

To ensure successful operation of the system, the selected geological data is monitored without human interference. The environmental/geological parameter have been monitored using the developed system, the selected parameters are temperature, pore pressure, soil moisture, and amount of rainfall.

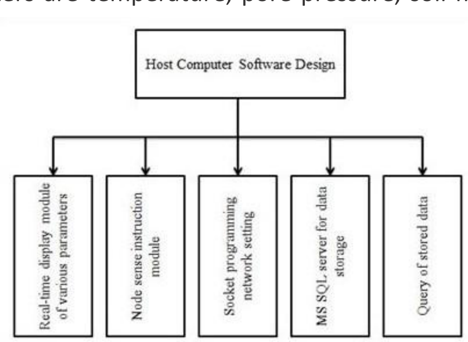

Figure 3: Host computer software design.

Table 2: Packet statistics

Sl#	*Time (ms)*	*Cluster head type*	*Number of data packets received*	*Actual number of data packets transmitted*
1	8000	Temperature cluster head	3	1
2	8000	Pore pressure cluster head	3	1
3	8000	Soil moisture cluster head	3	1
4	8000	Rain fall info cluster head	3	1

A certain number of Zigbee nodes are arranged in the environment, and the nodes are clustered. The member nodes in each cluster are homogeneous sensor nodes for temperature, pore pressure, soil moisture, and amount of rainfall. The cluster head node is responsible for data fusion and counts the number of data packets arriving within a certain period. The fused data is transmitted to the host computer through the coordinator for display and storage, and the mobile phone is connected to the public network IP for remote monitoring. The experimental results are as shown in Table 2.

The number of data packets arriving at the cluster head node is three temperature data packets, three soil moisture data packets, three pore pressure data packets, and three Rainfall intensity data packets, at every 8000 ms. After data fusion of the respective cluster head nodes, it becomes one data packet, which reduces data redundancy and greatly improves data accuracy.

As depicted in Figure 4, the server is turned on and the port COM9 is selected at this time. It can display the present status of all the nodes for environmental/geological parameter monitoring. Figure 5, shows the data received after data fusion. Data received after fusion has a higher accuracy than the individual measurement, also, it reduces the time for data transfer, which reflects the real-time data of the external environment.

In Figure 5, server window displays, the current temperature 27.4 degrees Celsius, the Pore Pressure 0.065 Mpa, the Rainfall intensity 10.00 mm, and the soil moisture 42.2 % rh. At the

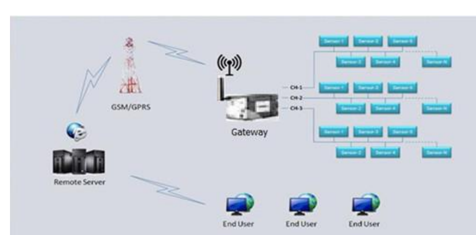

Figure 4: The PC display of multi node monitoring

Figure 5: The PC display of the aggregated data.

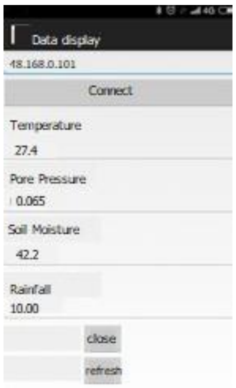

Figure 6: The display on mobile phone

same time, we can send commands to activate the alarm, and change the status of the lights connected to the node. The Figure 6 mobile display shows the measured parameters from the coverage area, which is connected to the public IP of the wireless router in the system, to remotely monitor the system. The mobile terminal serves as the client to access the server (host computer), and its display status is same as that of the host computer

Conclusion

As a novel type of intelligent monitoring system, the wireless sensor network can not only collect the required data information, but also process the information, and finally transmit the accurate information to the control center, which has become one of the research issues that people are currently paying close attention to. This paper designs a data acquisition and remote monitoring system based on a wireless sensor network for a landslide prediction application. On the one hand, it uses a fuzzy closeness data fusion algorithm to improve the transmission rate and data accuracy. On the other hand, it acquires geological data from landslide-prone areas to predict slope failures to mitigate landslide hazards. The whole system has achieved the expected results during the implementation and testing. The next step will be to continue the research of this subject to improve the system’s deficiencies.

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