

Data acquisition and fusion system based on wireless sensor

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Abstract. In order to further promote the research on the technology of data acquisition and fusion in the process of using the wireless sensor technology and to improve the optimization of the installation, use, maintenance, performance and many other indicators of wireless sensor devices, the requirements of wireless communication field were analyzed, and the fusion algorithm was innovatively adopted with the research background of motor experiment platform and the data acquisition, and the optimal weighting factor of a single wireless sensor which can effectively reduce invalid data and improve the transmission efficiency was obtained in this paper; then, it was applied to the data fusion system, so that a new data acquisition and fusion system based on the wireless sensing was successfully obtained. The experimental results prove that this system model has good effects in aspects of data acquisition, transmission, fusion, low-power consumption, communication test and so on.

Key words. Data acquisition system, wireless sensor, fusion algorithm.

1. Introduction

With the development of microelectronics, machinery, information transmission, wireless sensor networks have been widely used in many fields, such as data acquisition, medical and health care, environmental detection, smart home, and national defense, military affairs and so on. At the same time, data acquisition has also undergone a series of changes with the in-depth research of computer technology, so it has put forward higher requirements in terms of transmission quality, efficiency, accuracy and so on.

In 1990, the United States used wireless sensor networks to carry out military research works to monitor battlefield conditions, locate targets accurately and monitor enemy equipment and so on.) [1]. Zhang Guojun of Beijing Forestry University introduced the wireless sensor network technology with low-power consumption into forest fire monitoring and created a forest fire monitoring system based on wireless

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sensor technology to monitor the temperature, humidity and other related indicators of designated areas in the forest and to send them to the computer for analysis, at the same time, this system achieved the advantages of energy saving [2]. In 2005, the U. S. Military used wireless sensor technology to successfully test the location system based on the gunfire and effectively construct the electronic defense system, so as to provide the technical basis for obtaining the enemy's military intelligence. Melbourne University in Australia and James Cook University constructed a wireless sensor system for detecting the coastal climate, wind direction, water temperature, water pressure, and so on, and realized the promotion of environmental monitoring [3].

The article is arranged in five chapters. In the first chapter, the current international researches on wireless sensor technology to collect data were mainly introduced; in the second chapter, the general design idea of wireless sensor system for data acquisition and fusion was analyzed; in the third chapter, combined with the analysis of some examples, the data fusion algorithm for wireless sensor was studied through the creation of application model; in the fourth chapter, in terms of the data acquisition, communication, data fusion, performance and power consumption, the data acquisition and fusion system of wireless sensor was run and tested; in the fifth chapter, researches of data acquisition and fusion system for wireless sensor were summarized with the prospect of future researches.

2. State of the art

After entering the 21 century, China has made progress in the field of the research of wireless sensor network. At the same time, university teaching has opened courses about the wireless and sensing technology. In addition, our country has provided the financial assistance for some representative wireless sensor projects. Among them, in 2009, China's Ministry of Industry and Information Technology launched a new broadband mobile communications network, and set up the research and development and industrialization of the short distance wireless Internet and wireless sensor network.

In the process of in-service, wireless sensor equipment is often difficult to be maintained due to the effects of the environment and force majeure and other factors, so the security problem becomes the biggest problem. Therefore, with its limited memory spaces and computing powers, it is a breakthrough point to improve the equipment adaptive environment and data acquisition, calculation, transmission and other capabilities [4]. In terms of the data fusion, the number of ports needs to be reduced as much as possible to improve the data inefficiency and to achieve more optimized data fusion. Based on the technology development of wireless sensor network, system detection performances and construction costs have broad prospects for development.

3. Methodology

3.1. Routing algorithm

The network involved in this study can support the mesh routing algorithm and tree routing algorithm of the two algorithms. In which, the tree routing algorithm is mainly applied to the tree structure network in the communication protocol, its principle is the allocation mechanism based on the network address, and each router has a certain address space, which is used to allocate ports. Therefore, the tree routing algorithm was adopted according to the requirements of this study.

Communication protocols usually need to allocate addresses and follow them throughout the device's use cycle to identify devices or send data over the network. In the early stage of network construction, the number of logical port needs to be correlated and constructed, and the sequence relation of solidification needs to be determined. When data is transmitted, this sequence of relationships needs to be strictly followed, and the address should be assigned completely after the completion of the network construction. Assuming that the maximum number that a higher level device may have the next level of equipment isC_m, and the maximum number of routers is R_m, while the maximum depth of the network is L_m. If these parameters are determined by the communication protocol, then the network address offset can be calculated as follows:

$$\mathrm{Cskip}\,(d) = \begin{cases} 1 + C_m * (L_m - d - 1), \;\; R_m = 1, \\ \frac{1 + C_m - R_m - C_m * R_m^{L_m - d - 1}}{1 - R_m}, \end{cases} \tag{1}$$

When a device has an offset of 0, it does not have the ability to redistribute the port address of a lower device. That is, it is unable to access the network through other ports. If the offset is greater than 0, then it can accept other devices as its subordinate and assign the corresponding network address.

Table 1. Network depth and offset

Network depth	Offset
0	21
1	5
2	1
3	0

3.2. 3.2 The self-processing mechanism of routing failures

In the network of meshed structures, routers usually have two operating states: the network operating state and the backup standby state. For the network, the most important problem is the switching of the two states. If the normally operating router has not consumed all of its energy or has not yet completed the task, the backup port will replace it, but which will waste energy and reduce the network lifespan. However, when the router uses up energy, the backup route is started, which will also cause some data loss [5].

In general, the tree routing algorithm in communication protocols takes a passive maintenance mechanism. When it can communicate but cannot transmit data, it attempts to resend data; when it is completely unable to transmit data, it will try to re-establish the connection. As a result, the quality of data transmission can be seriously affected. In order to solve this problem, a self-processing mechanism for feedback information needs to be created [6].

During the process of network operation, whether the routing port is normal can be determined according to the detected link quality indexes, so that whether to carry out the conversion between different states can be determined.

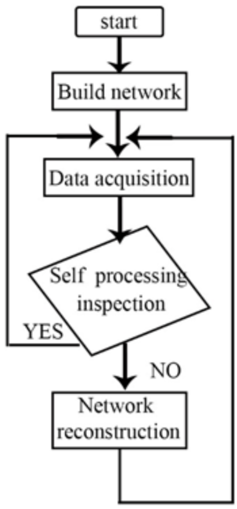

Fig. 1. Self-processing mechanism model

When an abnormal network is determined, the communication protocol will clear the fault port from the network through the coordinated processing, and then it will inform the standby port in time to switch to the working state. Prior to this, the lower port of the faulty port will also switch to the working state. On this basis, the network structure table will be updated and the fault information will be cleared [7].

3.3. Data fusion algorithm

Due to the different measuring data accuracies and measuring environments of the wireless sensor, there will be errors in the measurement. Therefore, each sensor data needs to be computed, and arithmetic averages should be taken to reduce the accuracy of the results. The adaptive fusion algorithm can adjust the original data measured by each sensor and fuse the minimum variance data fusion value. The mean square deviation after fusion is less than the mean square deviation of one or more sensors [8]. Assuming that there are n sensors to collect data, and then

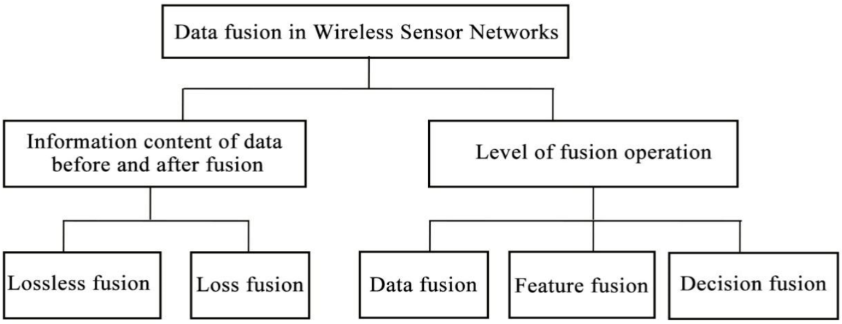

Fig. 2. Classification of data fusion in Wireless Sensor Networks

the adaptive weighted fusion algorithm is to find the corresponding factors of each sensor as $W1$, $W2$ and $W3$ under the condition that the total mean square error is minimum, so as to make the fused $\hat{x}$ reach the optimum.

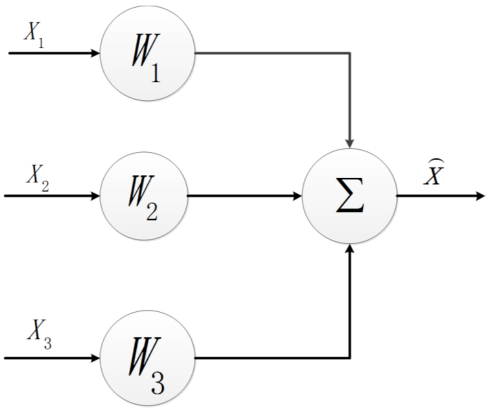

Fig. 3. Adaptive weighted fusion algorithm model

In the above model, the wireless sensor will produce a large number of related data on the mining network, and its terminal system will collect the data in time. Taking the collected humidity as an example, the terminal node will collect data every once in a while and store the collected data into memorizer according to the changes of humidity. When multiple data is collected, the fusion calculation can be carried out, and the mean and variance can be obtained, finally these mean and variance can be sent to the router. When the router receives the mean and variance of multiple sensor nodes, the optimal values and fusion values of each sensor can be calculated and sent to the coordinator.

With the humidity as an example, the humidity data of 4 sensor nodes is collected. In order to verify the effectiveness of the adaptive weighted fusion algorithm in eliminating error data and improving the accuracy, one of the nodes is artificially intervened to simulate the occurrence of the fault.

Table 1 shows the five humidity data collected by the five sensor nodes during a collection cycle in summer (unit: %rh).

Table 2. Five sets of humidity data

	The first time	The second time	The third time	The fourth time	The fifth time
node 1	40	50	45	49.9	50
node 2	45	45.7	46	50	51
node 3	60	59	59.5	60	60
node 4	75	74.1	74.9	70	70
node 5	50	52.3	53	55	50

3.4. Data fusion algorithm in the system

In the adaptive weighted fusion algorithm, the adjustment of weighting factors can effectively eliminate the impact on the final results, and calculate the average value of the data collected by the sensor. In order to make the results more accurate, the more accurate results of wireless sensor nodes must be obtained finally to achieve the most accurate final estimate. In this research, the fractional operation of the sensing measured data was carried out, and the corresponding values were calculated. On this basis, the overall measurement variance was estimated through the weighted calculation [9].

In the wireless sensor data acquisition system designed in this paper, the data measured by each sensor was fused. The estimated value and variance were calculated by the batch estimation fusion algorithm, and then the adaptive weighted fusion algorithm was used to obtain the measured estimated value and variances of the individual sensors, so that the optimal weighting factor of each sensor was calculated, and the final results were calculated. Thus, even in the presence of error data, the two steps of using batch estimation and adaptive weighting fusion can also gradually weaken the influence of error data on the final result and obtain more accurate data.

4. Result analysis and discussion

4.1. Hardware design of low-power network nodes

Wireless sensor network data acquisition system is composed of low-power network nodes, and it mainly includes coordinator and router and many other different terminal nodes with different functions. In general, a system composed of wireless communication, sensors, power supplies, processors and other auxiliary modules has the characteristics of low-power consumption. The corresponding module can be selected according to the different types of low-power network nodes. For example, the coordinator node sends the data sent by the terminal node to the host computer and select different modules according to different requirements [10].

Wireless sensor network nodes in the wireless sensor data acquisition and fusion system use the latest chip CC2430 launched in the United States, the chip has the characteristics of low energy consumption, so it can realize the signal transmission with low-power. Semiconductors fabricated with metal oxide materials can meet the needs of this application, thus achieving low-power requirements and reducing costs [11]. Chip CC2430 integrates a low-power video front-end, microcontroller, and memory on a single chip; in addition, it also has powerful peripheral resources, so the current consumption is low in the pick-up mode. Chip CC2430 has the function of low-power consumption and high performances. The current consumption is small in the resting state, and a large number of circuits are integrated in the interior. There is serial port circuit on the low-power coordinator node of data collection. In the design, the serial port is used to realize the data transmission between PC and chip CC2430.

In the design process, the problem of level switch needs to be solved to achieve the communication between the chip CC2430 and the PC serial port, and the driver is responsible for the level switch.

In the research of the system, the sensor circuit design mainly includes the sensors in the voltage, the current, and the temperature of the three aspects. For the voltage sensors used in voltage collection, the circuit board of a welded voltage sensor in the process of using needs to pay special attention to the problem of zero drift of voltage sensor, and which needs the timely compensation. Therefore, in the process of using, zero point circuit also needs to be designed to ensure the accuracy of measurement data. The use and design of the current sensor are the same as the voltage sensor, because it also requires the actual zero point circuit to ensure that the system output is 0 without output. The temperature sensor sends or receives information via a single wire interface, so it only needs one interface.

4.2. System software design

In the software design of this system, the cross compiler and debugger are the most perfect development tools, including the optimizing compiler, assembler, connection locator, and editor, and so on. The integrated compiler has the characteristics of efficient code, fast interrupt processing and optimization of memory mode. The C/C+ compiler of EW can generate efficient and reliable executable codes, and its applications are large with obvious results. Compared with other development tools, the system can use both global and specific chip optimization techniques [4].

In the whole low-power wireless communication technology network, the coordinator can create a new network. Works that the coordinator node needs to complete include: firstly, the coordinator node needs to establish a new network to accept other nodes and allocate the specific network address for them; secondly, the coordinator node needs to accept the data sent by each sensor node and send it to the PC machine through the serial port, and uses serial port to debug the data, so as to show the data. The establishment of a short-time and low-power wireless communication network is mainly initiated by a network coordinator. A fully functional node device with the coordinator capability can effectively monitor scanning and the possible interferences, thus establishing a short-time and low-power wireless communication network. When a suitable channel is selected, the network address, coordinator, network address, network identifier and topological parameters of the network can be determined. After each parameter is determined and the network is established successfully, the coordinator node can accept other nodes to join the network [12].

After the router node in the system is initialized, the relevant parameters can be set up, so as to search the network, join the network and get its own network address as well as determine its working states. It is important to note that the backup nodes do not perform data forwarding. Routers can receive new nodes and add them into the network to find the corresponding network address. As required, the router node which works normally can complete the data forwarding, at the same time, in order to obtain more accurate data and reduce the amount of data sent to the coordinator, the router node also needs to complete data fusion. Data acquisition nodes can join the network via routers and send the data collected by sensors [13].

4.3. Low-power design

In the wireless sensor network data acquisition system, once the energy of the data acquisition node is exhausted, the node will be ineffective and the system life cycle will be terminated. Therefore, under the premise of ensuring the normal operation of the system, minimizing the power consumption and prolonging the life cycle are the key aspects of the system design. The coordinator node which is responsible for data collection is powered by mountain power, so there is no need to consider the energy consumption, but the nodes which are responsible for data acquisition need to be taken into account. Among them, the energy supply module is responsible for providing energy to other three modules to ensure their normal operation. Energy consumption is mainly divided into three parts: the energy consumption associated with communications, the energy consumption of sensor module data acquisition and the energy consumption of the processor module for data processing [14].

4.4. Running and testing

In view of the model designed and researched in this paper, the network construction, operation and test works on the aspects of data acquisition, communication and integration and so on were carried out.

Firstly, 9 nodes were constructed under laboratory conditions, including 2 serial modules which can be used for coordinating data acquisition and transmission, 3 sensor modules which can be used to collect data and the routers and terminals that can be used to test content.

Secondly, a tree based network which consists of 1 coordinated port, 2 router ports, and 5 terminal ports was constructed, as shown in Fig. 4.

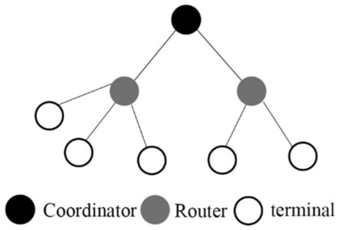

Fig. 4. Network structure diagram

After the completion of the network structure, the terminal port can collect relevant data periodically according to the pre-set command. In the process of data transmission, the data loss often occurs due to the far distance, obstacles, interference and other reasons. In order to solve this problem, the data transmission cycle needs to be limited, and the reasonable acquisition cycle should be set.

After the test, it can be seen that through the formation of the overall system, each port can operate stably and achieve efficient and reliable data transmission; loss phenomenon can be greatly reduced; the power consumption can be effectively reduced; and the working time can get a greater degree of protection.

The whole process of data acquisition and fusion of the wireless sensor is shown in Fig. 5.

Fig. 5. Data acquisition and fusion of wireless sensor

5. Conclusion

In order to better study the popularization work of wireless sensor, the wireless communication technology with low-cost and low-power was selected in this paper. By understanding the current development situation of wireless sensor in data acquisition and fusion, the basic situation of data acquisition and fusion system generated by wireless sensor was analyzed. Based on the use of these two technology systems, the core products of the hardware platform were determined. In view of the deficiency of this protocol, appropriate improvements were carried out, and an active detection mechanism that can effectively reduce the failure rate was designed. At the same time, weighted algorithms for data fusion were added, and related performance tests were carried out. The result reached the basic expectation. Finally, the overall test of the system was carried out on the basis of the completion of the functional modules, and the expected effect of this research was achieved.

The above functions were implemented in this paper. However, in order to promote the technology to more areas, there are few places that can be improved: the first is how to effectively expand the sensor power supply ways to extend the service life; the second is to consider the address optimization and try to reduce the waste phenomenon in the network design; the third is to improve the human intelligence development of the system, so as to maximize the role of remote control and role management functions.

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