Intelligent Fusion Technology of Crop Growth Monitoring Data Under Wireless Sensor Networks

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Abstract. Using adaptive weighted data fusion technology, the relative error of crop growth monitoring data is relatively large, accuracy is not high, and its fusion is not effective. In view of the above problems, the intelligent fusion technology of crop growth monitoring data under wireless sensor network is proposed. The technology consists of three parts: Using LEACH (Low Energy Adaptive Clustering Hierarchy) protocol to realize rapid processing and transmission of monitoring data. Accurate fusion of monitoring data through BP (Back Propagation) neural network; the two models are combined to construct the data fusion algorithm BPDFA (Back-Propagation Data Fusion Algorithm) model, so as to achieve intelligent fusion of crop growth monitoring data. By using the unique information processing characteristics of BP neural network, multi-information processing and transmission at the same time, the efficiency of processing is improved, and the fusion of crop growth information is realized. The results show that the intelligent fusion technology and adaptive weighted data fusion technology proposed in this study, the relative error is reduced by 3.72 °C, the accuracy is higher, and the fusion effect is better.

Keywords: Wireless sensor network · Monitoring data · Data fusion · LEACH protocol · BP neural network

1 Introduction

Appropriate environment plays an important role in promoting the growth and high yield of crops. Therefore, real-time monitoring of crop growth environment has always been an important task for agricultural development. At present, research on agricultural monitoring technology at home and abroad attaches great importance and has achieved some results. In recent years, wireless sensor networks with low cost, small size, low power consumption and multiple functions have emerged [1]. Wireless sensor network is a data-centric network. Its basic function is to collect and return the monitoring data of the area where the sensor node is located. However, in the process of collecting information, each node transmits data to the convergence node separately, which not only wastes the extremely limited energy of the sensor node, but also reduces the efficiency of information collection. How to reduce data communication, reduce energy consumption of nodes, and extend the network lifetime have become a hot topic in wireless sensor networks [2]. Data fusion technology is one of the key

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technologies to solve the above problems. The research of data fusion technology mainly focuses on fusion algorithm and routing protocol. These two aspects play different roles in data fusion. The former uses neural networks to reduce the amount of data transmitted to sink nodes, reducing communication energy consumption, and prolonging the network lifetime. The latter uses LEACH protocol to select valuable information for the former to merge and transmit. Finally, the two are combined to build a data fusion algorithm BPDFA model to complete the integration of crop growth monitoring data. In recent years, many experts have done a lot of research and achieved some results. Documentation [3] a method of wireless sensor network and sensor fusion is proposed, which effectively improves the data acquisition efficiency, but does not realize the purpose of real-time acquisition. Documentation [4] an adaptive predictive weighted data fusion method based on wireless sensor network is proposed, which can improve the capacity consumption of sensor network nodes, but the processing time is too long. To verify the effectiveness of the fusion technique, comparative experiments were conducted. The results show that compared with the adaptive weighted data fusion technology, the relative average error of the data fusion method in this study is reduced by 3.72 °C, which shows the advantages of this technology.

2 Data Fusion in Wireless Sensor Networks

Data fusion technology is a very important technology in wireless sensor networks. This technology uses a number of algorithms to process a large amount of raw data collected by sensor nodes to perform in-network processing, remove the redundant information, and transfer only a small amount of meaningful processing results to the aggregation node [3, 4]. In other words, the data fusion technology in wireless sensor networks includes two aspects: one is the transmission of fused data to the sink node; the other is the fusion processing of monitoring data.

3 Transmission of Crop Growth Monitoring Data

In the study of this chapter, the crop growth monitoring data was transmitted based on the LEACH routing protocol.

3.1 Cluster Head Selection

LEACH protocol cluster head selection method: In the initial stage of each cluster, each node randomly generates a number between [0.1]. If this number is less than the set threshold S(n), the corresponding node will be selected as Cluster heads, thus broadcasting their episodes of becoming cluster heads. When passing through the cluster head, the threshold S(n) is set to zero. The threshold S(n) is expressed as:

$$S(n) = \begin{cases} 0 & n \notin \theta \\ \frac{\alpha}{1-\alpha^{*}[r \bmod (1/\alpha)]} & n \in \theta \end{cases} \tag{1}$$

In the formula, α represents the percentage of the number of cluster head nodes in the number of all nodes of the wireless sensor network, r represents the number of "rounds" performed by the current cluster head election, θ represents a set, and elements in the set are The cluster head sensor nodes have not been selected in the $1/\alpha$ round.

3.2 Cluster Initialization

The initial stage of the cluster is also the establishment stage of the cluster, which is to prepare for the monitoring data transmission in the stable stage. This stage mainly includes the determination of the cluster head node and forms a cluster structure with its neighboring nodes; in each cluster structure, the cluster. The head node allocates TDMA (Time Division Multiple Access) time slices for other intra-cluster nodes.

3.3 Cluster Stability

After the establishment of the cluster is completed, the sensor node transmits the collected data to the cluster head node in the assigned time slot; the cluster head node first performs information fusion after receiving all the data packets from all the member nodes in the cluster, and the received data is received. The data packets of the packet and cluster head node are compressed into a packet of equal length. The fused data packet is then transmitted to the sink node using different CDMA (Code Division Multiple Access) codes to reduce the communication traffic. After the sink node receives the data of the cluster head node. The data is transmitted to the monitoring center for data processing. After a period of time, the network re-enters the cluster establishment phase and performs the next round of cluster reconstruction. Figure 1 is a visual data flow chart.

3.4 The Choice of the Optimal Number of Cluster Heads

In the LEACH protocol, the number of cluster heads can find the optimal value range. The idea is to minimize the total energy consumed by the network in each round, and the number of cluster heads in the corresponding network is optimal, that is, the number of cluster heads [5].

The total energy consumption Z of a cluster head node in a frame is:

$$Z = [LE\ (N/K - 1) + LF\ (N/K - 1)] \cdot M \tag{2}$$

In the formula, L is the number of bits of information for each data; E is the energy consumed for data fusion; N is the number of sensor nodes; K is the number of cluster head nodes; F is the distance from the cluster head node to the base station; M is each The average coverage area of clusters.

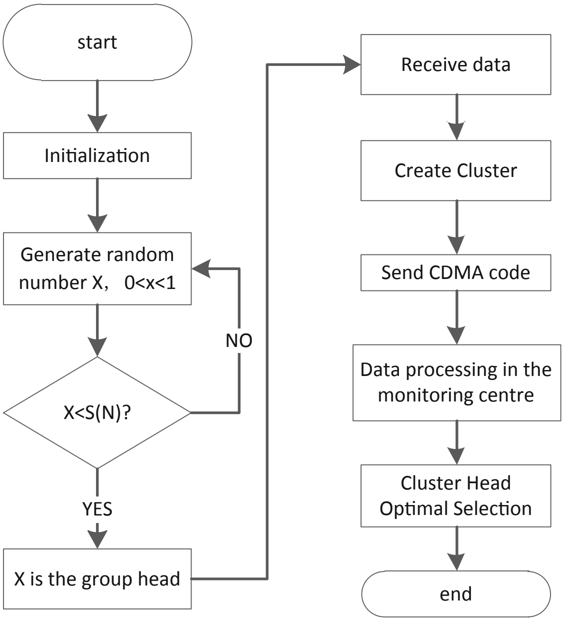

Fig. 1. Flow chart of visual data transmission

4 Fusion of Monitoring Data

Due to the limited energy of the wireless sensor network, in order to extend the life cycle of the WSN (Wireless Sensor Networks), the LEACH routing protocol was used in the previous chapter, and the optimal number of cluster heads was selected in conjunction with the efficient use of energy [6]. This chapter mainly introduces the data fusion technology in the cluster selection of the LEACH routing protocol in the previous chapter. That is, the BP neural network algorithm is used in each cluster structure to process the data collected by node crop growth monitoring so as to reduce the data transmitted to the sink node. Quantity, reduce communication energy consumption, reach the purpose of prolonging network life cycle [7].

BP network is a forward neural network using BP algorithm. It is based on multi-layer perceptrons and adds back propagation signals. It can better deal with non-linear data information and has good generalization ability. Applied to system model identification, prediction or control BP. BP neural network obtains learning guidelines, feedback data collected through learning criteria standards, extract sign information, and under the role of reasoning machines, matches the sign with knowledge in the knowledge base, and then obtains key information for Fusion. Complete the processing of data information. The combination of BP neural network and wireless sensor network can tell the state of real-time response data transmission.

The excitation function in the neuron model in a neural network is usually a nonlinear Sigmoid function:

$$f(x) = \frac{1}{1 + e^{-x}} \tag{3}$$

Only when the system characteristic changes between the positive and negative regions, the excitation function selects a symmetric Sigmoid function, also known as a hyperbolic function:

$$f(x) = \sin \frac{e^{-x}}{1 + e^{-x}} \tag{4}$$

The network structure of the BP neural network consists of an input layer, an output layer, and an implicit layer. The hidden layer may have multiple layers, but the most commonly used is a single hidden layer three-layer BP network, as shown in Fig. 2.

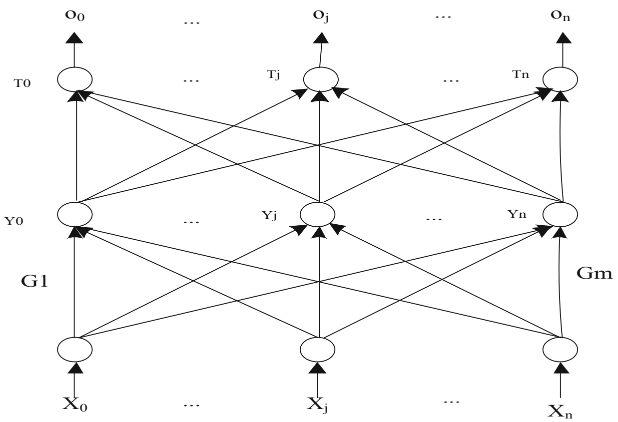

Fig. 2. Network structure of BP neural network

Each layer vector is X, Y, O, where the input vector is: X = (X0, …, Xj, …, Xn)T, and the hidden layer vector is: Y = (Y0, …, Yj, …, Ym). The output layer vector is: O = (O1, …, Oj, …, Ot). The connection weight matrix G = (G1, …, Gj, …, Gn) between the input layer and the hidden layer neurons. The connection weight matrix T = (T1, …, Tk, …, Th) between the hidden layer and the output layer neurons. The relationship between the input layer signal x_i and the hidden layer signal y_i is shown in Eqs. (5) and (6).

$$net_j = \sum_{j=1}^{n} G_{jn} x_j \quad j = 1, 2, 3, \cdots, n \tag{5}$$

$$y_j = f\left(net_j\right) \tag{6}$$

The relationship between the hidden layer signal and the output layer signal is shown in Eqs. (7) and (8).

$$net_k = \sum_{k=1}^{m} T_{kn} y_j \quad k = 1, 2, 3, \cdots, h \tag{7}$$

$$O_k = f(net_k) \tag{8}$$

The error function β is shown in formula (9).

$$\beta = \frac{\sum_{k=1}^{1}}{2} O_k^2 y_j^2 \tag{9}$$

It can be known from formula (9) that the error function is changed by the connection weight value Δ between layers, as shown in formula (10). μ represents the learning rate, which is generally a constant of (0, 1).

$$\Delta = \mu \left(\sum_{k=1}^{1} O_k^2 y_j^2 \right) y_j \left(1 - y_j\right) x_n \tag{10}$$

Assuming that the weights of this and the next hidden layer and output layer are T_{kh} and G_{jn} respectively, there are formulae (11) and (12).

$$T_{kh} = T_{kn}^{n-1} + \Delta T_{kn}^{n} \tag{11}$$

$$G_{jn} = G_{jn}^{n-1} + \Delta G_{jn}^{n} \tag{12}$$

The BP neural network algorithm is trained through the above calculation cycle. Each training will re-adjust the weights and thresholds of each layer. The termination condition of the loop is that the overall error is less than the preset value or the number of network training reaches a preset number of times. The value and threshold are also determined [8]. After training through the network, the data to be fused are input. The neural network will perform fusion processing on the trained thresholds and weights to extract the eigenvalues of the data. When processing data, because wireless sensors apply the information conduction characteristics of BP neural networks and apply the excited mode of neuron transmission information, this dynamic process is carried out simultaneously with information processing and information transmission to reduce the transmission of data information. Effective control of time, increased efficiency.

5 Data Fusion Algorithm BPDFA Model

The data fusion technology is applied to the routing layer of the wireless sensor network. Based on the routing protocol, the BP neural network is introduced and a new data fusion algorithm (abbreviated as BPDFA) is proposed. The BPDFA data fusion algorithm selects the optimal cluster head through the LEACH routing protocol and forms a stable clustering structure. In each clustered structure, the cluster sensor nodes collect a large amount of raw monitoring data for preprocessing, and then transmit it to the cluster head node performs data processing again in the cluster head node and sends it to the sink node [9]. BPDFA data fusion algorithm is to use BP neural network algorithm to process data between cluster sensor node and cluster head node. The model of data fusion algorithm BPDFA is shown in Fig. 3.

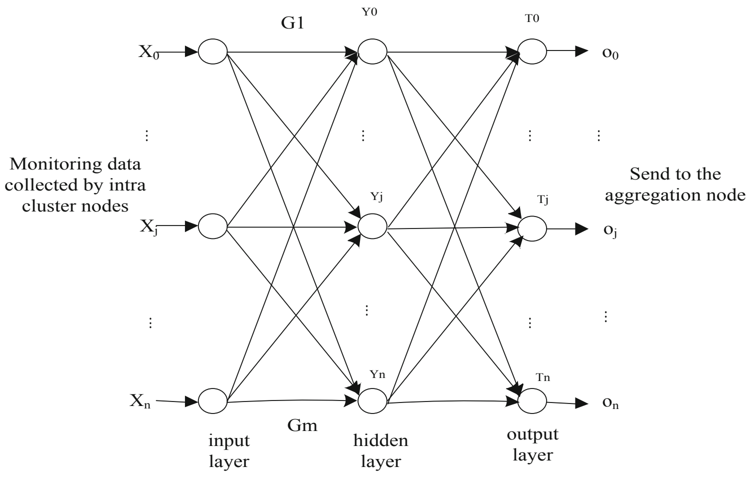

Fig. 3. Data fusion algorithm BPDFA model

According to the BPDFA algorithm model in Fig. 2, the data collected by the nodes in the wireless sensor network can be fused. In the wireless sensor network networking, the status of the nodes in the network and the position of the nodes are determined first. After the status of the network nodes is determined, the wireless sensor network starts to select the optimal cluster head. At this time, the cluster head obtains the information of all nodes in the cluster. After the clustering structure is stable, the cluster head node sends the relevant information of all cluster nodes to the aggregation node. The aggregation node constructs a BP neural network structure based on the obtained network information and collects a sample training neural network matching the node information in the cluster in the sample database, thereby obtaining related neural network parameters. The aggregation node sends the parameters of each layer of the neural network to the corresponding cluster node. The clustering structure of wireless sensor networks can use the trained BP neural network model to process the data fusion. Finally, the processed data is transmitted to the aggregation node in the shortest path, so the BPDFA algorithm completes the data fusion in the wireless sensor network deal with.

6 Comparative Experiment

To verify the effectiveness of the intelligent fusion technology of crop growth monitoring data under the wireless sensor network in this study, a monitoring area was selected in the laboratory, and 30 temperature sensor nodes and 3 sub-layer routing nodes constitute a wireless sensor network. Temperature sensor node number 1–30, each node collected 10 times a single test data, 10 tests at different temperatures, the baseline true values were 13.5 °C, 17.20 °C, 20.80 °C, 23.70 °C, 25.0 °C, 27.0 °C, 29.0 °C, 31.0 °C, 33.0 °C, 35.0 °C. The three sub-layer nodes are numbered 1–3. Each sub-layer node is connected to five ordinary nodes, which correspond to sensor nodes 1–10, 11–20, and 21–30 respectively.

Taking the 10 experimental data as an example, the experimental data are processed using the data fusion technology and the adaptive weighted data fusion technology respectively, and the experimental data fusion results are displayed. The results are shown in Table 1.

Table 1. Contrast of two kinds of technical data fusion values with true values

Number	1	2	3	4	5	6	7	8	9	10
True value (°C)	13.6	17	20	23	25	27	29	31	33	35
Data fusion technology in this paper (°C)	13.6	17.2	20.1	23	25.1	27	28.9	31	33	35.1
Adaptive weighted data fusion technology (°C)	13.2	16.5	20.3	22.8	25.5	27.4	28.5	30.7	32.5	34.6

In order to visually show the degree of approximation between the fusion value and the true value of the two calculation methods, the true value is normalized to 0, and the obtained relative value of the fusion value is shown in Fig. 4.

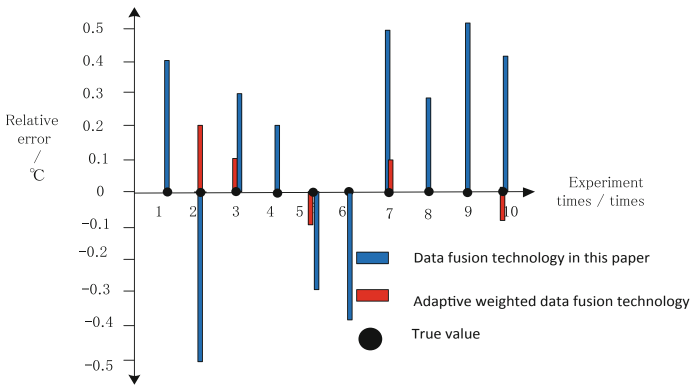

Fig. 4. Relative error of fusion value

In the experiment, the relative average error of the monitoring data fusion technique in this study was smaller than the relative average error of the adaptive weighted fusion technique. The relative average error of the former was only 0.06 °C and the latter was 3.8 °C. The relative error of the two was relatively different 3.74 °C. It can be shown that the monitoring data fusion technology of this study is superior to the adaptive weighted fusion method. It is more stable, mainly because the layered adaptive weighted fusion method does not remove gross errors at the beginning, resulting in large calculation bias.

7 Conclusion

With the constant intelligence of modern society, wireless sensor network technology has gradually attracted the attention of various industries, and data fusion technology can comprehensively process a large amount of information collected by multiple sensors and obtain final decision based on the fusion result. The BP neural network is combined with the LEACH routing protocol to handle the data fusion and transmission problems in wireless sensor networks. Compared with the past, the fusion has high accuracy, good stability, and is simple and easy to implement. While satisfying the real-time requirements of data fusion, the accuracy of the measurement data is improved. Although the calculation amount is increased, the amount of data transmission is reduced theoretically. It can save the energy of wireless sensor nodes, extend the life span of wireless sensor networks, lay a foundation for the development of crop growth data monitoring technology, and promote the sustainable development of China's agriculture.

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