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A Multi sensor Data Fusion Method for Smart Agriculture

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Abstract

In this paper, the algorithm first performs data level fusion of the same type of sensor data in the weather sensor and soil sensor, mainly including data preprocessing, average weighting method to eliminate the redundancy of the same type of data in time and space. In the specific application, the feature level fusion is carried out according to the application, and the fuzzy comprehensive evaluation strategy is used for feature level fusion.

Keywords

Data level fusion, Average weighting method, Feature level fusion, Fuzzy Comprehensive Evaluation Strategy.

1. INTRODUCTION

As the three foundations of modern information technology, wireless sensor network (WSN), which is formed by the high integration of sensor technology, communication technology and computer technology[1-3], has become a new information acquisition and processing technology. The intelligent agricultural data monitoring network is composed of a large number of intelligent sensor nodes with low energy and low power consumption. It can monitor, perceive and collect various environments in real time cooperatively, collect and process the information of monitoring objects, and obtain detailed and accurate information[4-6]. It is transmitted to the base station host and the staff who need the information through the wireless transmission network[7]. At the same time, the staff can also transmit the instructions to the target node through the network to enable it to perform specific tasks[8-11]. In smart agriculture, the use of multi-sensor data acquisition poses new challenges to data fusion, and the realization of multi-sensor data fusion method has good application value[12-14].

2. MULTISENSOR DATA FUSION METHOD

In farm management, video monitoring, agricultural production environment monitoring, atmospheric environment monitoring, professional system guidance/knowledge base construction, agricultural product anti-counterfeiting traceability, agricultural hardware intelligent control, agricultural materials management, agricultural management and other agricultural activities, information, digital and intelligent technologies need to be used to integrate multi-sensor data. The sensor monitoring system and data fusion method are designed to meet the needs of soil environment monitoring and atmospheric environment monitoring in the agricultural production process[15].

2.1. Design of sensor data fusion algorithm

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The sensors include meteorological sensors and soil environment sensors. The algorithm first performs data level fusion of the same type of sensor data in the meteorological sensors and soil sensors, mainly including data preprocessing, average weighting method to eliminate the time and space redundancy of the same type of data. In the specific application, the feature level fusion is carried out according to the application, and the fuzzy comprehensive evaluation strategy is used for feature level fusion. The algorithm design is shown in Figure 1.

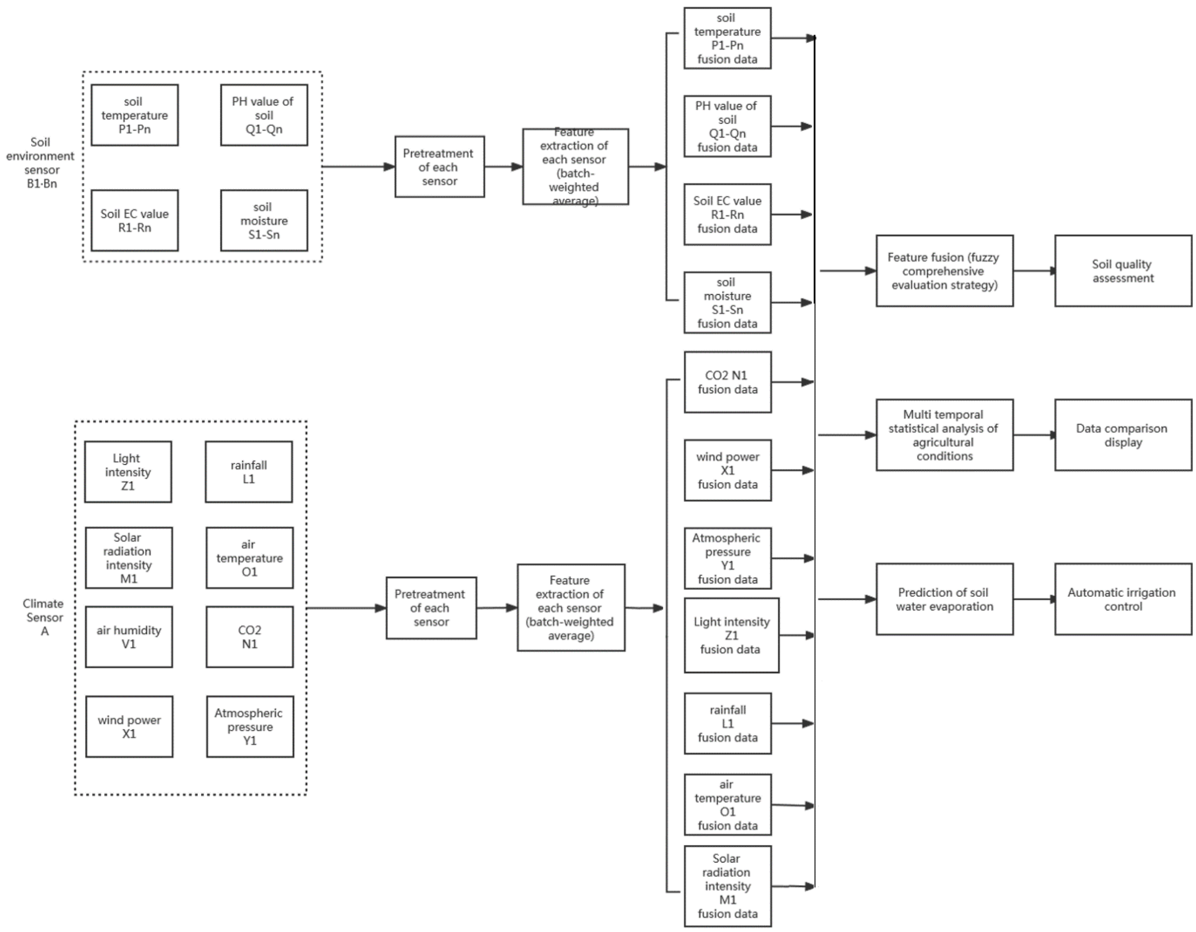

Figure 1: The algorithm design

2.2. Design of multi-sensor data level fusion algorithm

A monitoring area needs to be equipped with n soil environment sensors and 1 weather sensor to form a monitoring system. Therefore, the number of weather sensors and soil sensors in a monitoring system is not equal, and the sensor data must be consistent for a time to describe the current state of the monitoring area. Therefore, the monitoring area time period is taken as the research object, and the system is designed to start at any time The soil sensor collects data at a fixed time, for example, 10 times of flat data collection within 10 minutes starting at 8:15:00 for data fusion of the same type of sensor. The algorithm implementation steps are as follows:

Step1: The collected weather sensors include wind, atmospheric pressure, light intensity, solar radiation intensity, rainfall, air temperature and humidity, CO2; Soil environmental sensors include soil temperature, soil humidity, soil PH value and soil EC value. Take 10 groups of data respectively, and each sensor represents the data according to $X = (X_{1,} X_2 \dots X_{11})$;

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Step2: Judge the threshold value of the collected sensor data, and use the maximum and minimum range values as the threshold value. For example, the maximum range range of the temperature sensor is - 40 ° to 80 °. Therefore, when the data exceeds the maximum range threshold value or is lower than the minimum threshold value, remove the abnormal value, and replace the missing value with the average value in the calculation process;

Step3: Divide 10 groups of sensor data measured by a single sensor into two groups according to the acquisition time sequence， P1=($x_{1,}x_{3,}x_{5,}x_{7,}x_{9}$)、P2=（$x_{2,}x_{4,}x_{6,}x_{8,}x_{10}$）；

Step4: Calculate the weighted average of the two groups of data (P1, P2) according to Formula 1; E_1, E_2;

$$E=\frac{X_1 f_1+X_2 f_2+X_3 f_3+\cdots X_n f_n}{n} \tag{1}$$

Where n is the number of times, and C is the number of f_n occurrences;

Step5: Calculate the variance of two groups of data (P1, P2) according to Formula 2, ${\sigma_1}^2, {\sigma_2}^2$;

$$\sigma^2=\frac{1}{m}\sum_1^m (X_m-E)^2 \tag{2}$$

Where m is the current intra group data and E is the weighted average of the current data group;

Step6: Calculate the variance values of ${\sigma_1}^2$、${\sigma_2}^2$ respectively in step 3, and update the variance combination according to formula 3.

$$\sigma=\frac{{\sigma_1}^2 * {\sigma_2}^2}{{\sigma_1}^2+{\sigma_2}^2} \tag{3}$$

Step7: According to σ、E_1, E_2, update the fusion data E according to Formula 4. At this time, E is the sensor value after batch weighted average.

$$E=\frac{{\sigma_1}^2 * E_2}{{\sigma_1}^2+{\sigma_2}^2}+\frac{{\sigma_2}^2 * E_1}{{\sigma_1}^2+{\sigma_2}^2} \tag{4}$$

2.3. Application model design

2.3.1 Multi temporal statistical analysis

Carry out statistical analysis of different sensor data at the same time for the same monitoring area, obtain daily meteorological data of farmland plots such as solar radiation, temperature, humidity, wind speed and CO2 in the monitoring area according to sensor distribution, and make thematic maps that can be read clearly, provide data reference for planting the same kind of crops, and also make corresponding decision support for later crop planting. Through the analysis of environmental changes such as air temperature, air humidity, wind speed, CO2, solar radiation and rainfall of similar sensors at different times, historical data support is provided for improving crop growth environment. The platform can timely analyze abnormal data to provide the best environment for agricultural crop growth.

2.3.2 Prediction of soil moisture difference

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In the process of crop growth, how to predict crop water demand and obtain soil moisture content is the key point to realize automatic farmland irrigation. Therefore, the project predicts and estimates the soil moisture difference through weather forecast data and HS model formula 5:

$$E_i = 0.0023R\left(\frac{T_{max}-T_{min}}{2} + 17.8\right)\sqrt{T_{max} + T_{min}} \tag{5}$$

Where: E_i is soil moisture, T_{max} is the daily maximum temperature, T_{min} is the daily minimum temperature, and R is the solar radiation.

Predict the water E required by plants in the next cycle through the variable data of weather forecast such as air temperature and humidity, solar radiation intensity, rainfall, etc.Set the parameters in combination with the environment required by the current crop growth stage, that is, determine the soil moisture E_i and E_{max}, drought E_{min} and the optimal value, water cutoff point E_p and water supplement point E_s of the crop according to the growth coefficient of different crops. According to the current soil moisture measurement E_c and E_i Judge whether to start water supplement irrigation according to Formula 6, so as to realize intermittent irrigation of water and fertilizer, so as to reduce the irrigation amount and cost. The control method is shown in Figure 3

$$\begin{gathered} if[(E_c - E_i) < E_s] = true : \text{Hydration} \\ if(E_c > E_p) = true: \text{Water cut off} \end{gathered} \tag{6}$$

2.3.3 Soil quality evaluation method

After the first level fusion algorithm, the fused values of each sensor are represented by X=(X_1,X_2 ...X_n). The fused data are used for heterogeneous sensor data fusion, and fuzzy comprehensive evaluation is used. The specific implementation steps are as follows:

Step1: Obtain 10 groups of fused data of wind, atmospheric pressure, light intensity, solar radiation intensity, rainfall, air temperature and humidity, soil temperature, soil humidity, soil PH value and soil EC value during Tj period. Determine the set of evaluation factors, U={U_1,U_2...U_4}={Soil temperature, soil humidity, soil PH value, soil EC value }， The monitoring and selection of these four factors can comprehensively cover the evaluation of the current regional crop growth environment。

Step2: The quality of crop growth environment in the monitored area is represented by four levels, including four states of good, medium and poor, soV={v_1,v_2, v_4, v_4}={excellent good average poor }， According to the physical indicators of soil quality and the chemical indicators of soil quality, the specific standard of V corresponding to each factor in the evaluation factor set U is established.

Step3: According to the theory of fuzzy mathematics, each evaluation factor u_i， i∈ [1, 4], in the evaluation factor set U is evaluated, Determine the degree of membership of the evaluation object to each evaluation factor grade, and realize the fuzzy mapping f: U→ $f(v)$ ∈ [0,1] , between evaluation factor U and evaluation grade V, Then the set of single factor evaluation membership of the ith element in U is expressed as: Ri=(r_{i1}, r_{i2}, ... r_{i4}), Then all elements in set U form a fuzzy evaluation matrix:

$$R_{4*4} = \begin{matrix} r_{11} & r_{12} & r_{13} & r_{14} \\ r_{21} & r_{22} & r_{23} & r_{24} \\ r_{31} & r_{32} & r_{33} & r_{34} \\ r_{41} & r_{42} & r_{43} & r_{44} \end{matrix}$$

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Step4：Determine the factor weight value W=(w_1, w_2, w_3, w_4), which is used to represent the weight of each factor in U, and use expert scoring to determine the weight using frequency statistics.

Step5：After determining the single factor evaluation matrix R and factor weight vector W, the fuzzy vector A on U is changed into the fuzzy vector B on V through fuzzy change, B= $W_{1*4}.R_{4*4} = (b_1, b_2, b_3, b_4)$. The V value corresponding to the final evaluation result A, A=max (b_1, b_2, b_3, b_4). This method can be used to evaluate the soil environmental quality in the current monitoring area.

2.4. Data integration and analysis

Based on the specific needs of environmental monitoring, pest control, fertilizer and water integrated irrigation, expert remote guidance, traceability of agricultural crops, intelligent control, big data analysis, etc., integrate multi-source, massive, high-dimensional health file data, label and structure agricultural information data collected from the park, build an index, and finally store it, so as to realize the standardization of agricultural product information for subsequent processing and analysis. Data mining technology is used to conduct in-depth analysis and mining of data, provide users with convenient classification and prediction, provide users with favorable agricultural decision-making, and improve the utilization rate of agricultural data.

3. EXPERIMENTAL ANALYSIS

In this paper, sensor data fusion analysis experiment is carried out, and the experimental environment parameters are shown in Table 1 below.

Table 1 Experimental Environment Parameters

Test environment name	Test environment parameters
Data transmission mode	
operating system	Windowns 10
Host frequency	CPU 2.4G Hz
Sensor model	
data format	

The weather sensors collected in this experiment include wind, atmospheric pressure, light intensity, solar radiation intensity, rainfall, air temperature and humidity, CO2; Soil environmental sensors include soil temperature, soil humidity, soil PH value and soil EC value. Take 10 groups of data respectively, Determine the threshold value of the collected sensor data, and use the maximum and minimum range values as the threshold value, In the multisensor data fusion test, data from 100 nodes are used for the fusion experiment. The experimental data parameters are shown in Table 2.

Table 2 Data Fusion Experimental Parameters

Test content	Test parameters
Number of different data nodes	100
Number of different data types	4
Tolerance of difference data	Within the setting range, the standard deviation is less than 1
Processing method of variance data	Equal and differential treatment

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4. CONCLUSION

The method in this paper collects weather sensors including wind, atmospheric pressure, light intensity, solar radiation intensity, rainfall, air temperature and humidity, CO2; 10 groups of data, such as soil environment sensor, to judge the threshold value of the collected sensor data, use the maximum and minimum range values as the threshold value, when the data exceeds the maximum threshold value of the range or is lower than the minimum threshold value, remove the abnormal value, and replace the missing value in the calculation process with the average value; The 10 groups of sensor data measured by a single sensor are divided into two groups according to the collection time sequence. The soil moisture difference is predicted and estimated through the weather forecast data through the HS model, and the air temperature and humidity, solar radiation intensity, rainfall and other variable data are predicted. According to the current soil moisture measurement value, whether to start water supplement irrigation is judged, so as to achieve intermittent irrigation of water and fertilizer, so as to reduce the irrigation amount and cost. At the same time, data mining technology is used for in-depth analysis and mining of data to provide users with convenient classification and prediction, provide users with favorable agricultural decisions, and improve the utilization rate of agricultural data.

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