Leakage analysis of campus water supply system based on MLP neural network

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Abstract. Water supply system is an important part of campus public facilities, and the water supply pipeline will leak, not only increase the cost of water supply, but also cause water waste. This paper collects water consumption data of water meters at all levels in a school's water supply system, establishes MLP multilayer perceptron neural network model, determines the water leakage rate according to the fluctuation of predicted value and actual value, so as to analyze the leakage situation of each school's water supply system. When the fluctuation between the actual and predicted water consumption exceeds a certain threshold, water leakage occurs on that day. Through solving the model, the following conclusions are finally drawn: (1) the annual water leakage rate of the school is 10.74%, and the water leakage is 29131.418L. (2) The water leakage rate in the first quarter is the highest, and the water leakage in the second quarter is the highest. (3) The school aquaculture area is the most serious leakage phenomenon, and the maximum water leakage rate of each water meter node is more than 10%.

Keywords: campus water supply system, MLP multilayer perceptron neural network model, leakage detection.

1. Problem Analysis

1.1. Background
Water supply system is an important part of the campus public facilities, the school needs to spend a lot of manpower, material and financial resources in the process of ensuring the normal campus water supply. At the same time, the part of the water supply pipeline leak would happen, both increase the cost of water supply, the school also caused the waste of water resources, therefore, in order to make logistics management department can timely discover and solve the problems of water supply system, this paper, based on the data of schools at all levels of the intelligent water meter, establish the corresponding mathematical model, analysis of the water and leakage of the school.

The research in this paper is based on the hierarchical relationship of water meters in a school district and the water consumption data of all water meters in four quarters, mainly to solve the following problems:
Problem one: leakage of water delivery network is a serious problem, the average water loss of public water supply network is about 5%. According to the data of water meter, a mathematical model is established to analyze the leakage of water supply network.

Problem two: establish a suitable mathematical model, according to the real-time data of the water meter to find and determine the location of leakage in time.

1.2. Modeling ideas
For the first question, it is required to analyze the specific leakage situation of the campus water network according to the display data of water meters at all levels. In this paper, the annual water consumption of the school is predicted according to the daily water consumption data of each water meter by using the prediction method of multi-layer perceptron neural network. When the fluctuation between the actual and predicted water consumption exceeds a certain threshold, water leakage occurs on that day. Where, Water leakage is equal to the predicted value minus the actual value. Subsequently, the annual water leakage rate of the school was calculated and the leakage loss of the campus water network was analyzed.

For the second question, it is required to find and determine the location of leakage in time according to the real-time data of water meters. Based on the neural network model established in question 1, this paper predicts the daily water consumption data of water meters at all levels of the school throughout the year, calculates the water leakage rate of water meters at all levels every day, and determines the area with high water leakage rate for timely maintenance of the school.

2. Model assumptions
1. It is assumed that the data recorded by water meters at all levels can accurately reflect the water consumption of the school and there is no omission of data.
2. Assume that the school water supply system remains stable without damage.
3. Assume that the difference between the predicted value of the water meter and the actual value is the water leakage of the water meter.

3. Symbol description

| symbol | meaning |
|--------|---------|
| $f_j$  | The activation function |
| $b_j$  | The offset vector |
| $W_j$  | The weight vector |
| $y$    | The output vector |
| $P$    | Maximum leakage ratio |

4. Problem 1: Establishment and solution of the model

4.1. Establishment of MLP neural network model
MLP, as a forward neural network with deep learning ability, contains a large number of neurons in a multi-layer network, which can map a set of input vectors to a set of output vectors and theoretically approximate any linear function with arbitrary accuracy. Multilayer perceptron introduces one to multiple hidden layers on the basis of single-layer neural network, and MLP deep learning network model is generally three or multiple layers.

In this paper, the annual daily water consumption of each water meter is used as training data, and the MLP neural network model is established to predict the annual daily water consumption of the school. Its model structure is shown as follows:
After the data enters the MLP from the input layer, the neurons of the hidden layer analyze and transfer it, and finally the data is output by the output layer, so as to realize the multi-layer optimization processing of the data.

In the MLP model, the output of the upper layer is the input of the next layer. For the neuron in the hidden layer and the output layer, the output formula of the JTH neuron in the I layer is:

\[ y_j^{(i)} = f_j^{(i)}(W_j^{(i)}y^{(i-1)} + b_j^{(i)}) \]  

Where, \( W_j^{(i)} \) is the weight vector of layer i and neuron j; \( y^{(i-1)} \) is the output vector of layer i-1; \( b_j^{(i)} \) is the bias vector of layer i and neuron j; \( f_j^{(i)} \) is the activation function of layer i and neuron j.

Sigmoid function is selected as the activation function in this paper, and its expression is as follows:

\[ f_j^{(i)} = \frac{1}{1 + e^{-x}} \]

The weight vector and bias vector are determined by the training process of MLP.

MLP neural network can carry out self-learning and feedback adjustment in training, so as to modify and adjust the weight and bias of each neuron. In this process, algorithm can be used to optimize the weight and bias of MLP, and improve the prediction accuracy of MLP model in the later stage.

4.2. Model solution

According to the annual daily water volume data of each water meter, Python was used to solve the MLP neural network model, and the predicted results are as follows:
According to the prediction results of the model, the daily water leakage and water leakage ratio of all water meters can be calculated as follows:

![Figure 3. Daily leakage of all water meters](image)

![Figure 4. Daily leakage rate of all water meters](image)

As can be seen from the figure, with the arrival of summer, water consumption reaches its peak and water leakage gradually increases. But in terms of the leakage rate, the relative leakage of water in the first quarter was more serious, even in One day in February, the leakage of water reached 50% of the total water consumption. According to the calculation results, the annual water leakage rate of the school reached 10.74%, much higher than the average water loss rate of the public water supply network, indicating that the water supply system of the school has major problems, and the management department needs to find out the problems and repair them in time.

5. Problem 2: Establishment and solution of the model
According to the neural network model established in question 1, we predict the daily water quantity of each level of water meter. If the predicted value differs greatly from the actual value, it is regarded as the serious water leakage area, and the water leakage rate of this area is calculated, so as to timely identify the area with the maximum leakage rate and take corresponding measures. Due to space limitation, this paper only presents partial identification results, as shown below: (From top to bottom: water leakage, water leakage rate).
Figures 5. Prediction of leakage in dormitory area and teaching building

Figure 6. Leakage prediction of aquaculture area
According to the prediction results of the neural network model, the maximum leakage rate of each area is determined as follows:

**Table 2. Maximum water leakage rate in each region**

| Area                  | Maximum leakage ratio |
|-----------------------|-----------------------|
| The teaching building | P<5%                  |
| The dining room       | 5%<P<10%              |
| Dormitory area        | 10%<P<15%             |
| Culture zones         | P>15%                 |

According to the calculation results of water meter water leakage rate, it can be seen that the leakage loss in aquaculture area is serious, the maximum water leakage rate of each water meter node is more than 10%, and the maximum water leakage rate is more than 15%. In addition, in the first quarter of the breeding area, a number of pieces of leakage occurred, which may be caused by old pipelines or pipeline series in the breeding area. The school should replace the pipelines or repair them in time.

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