Moisture Content in Food Production Process Based on Wavelet Neural Network

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Abstract. Water content not only affects the taste and hardness of food, but also affects the shelf life of food, which determines the profit and loss of enterprises to a certain extent. Therefore, in the process of food production, the detection of moisture content is very necessary. In this paper, wavelet theory and wavelet neural network are introduced briefly, and make necessary modification on this basis, it is applied to the actual food production process to achieve real-time prediction of food moisture content. The alarm is raised when the predicted value exceeds the pre-set moisture range, so as to remind staff to adjust raw material ratio in advance. Finally, through a group of data in MATLAB programming environment to study the feasibility of the algorithm, we can find that the error between the prediction results and the actual results is small, the method can better achieve the prediction of food moisture content. In this way, the rate of defective products in the production process can be reduced as much as possible. Meanwhile, the waste of raw materials can be reduced and the economic benefits of enterprises can be improved.

Keywords: wavelet neural network; moisture content, food production process; prediction

1. Introduction

From the biological point of view, there are two forms of water in food, one is crystal water, the other is free water. Among them, the content of free water not only affects the hard or soft degree and taste of food, but also it is the indispensable condition for the growth and reproduction of microorganisms [1]. In a certain range of moisture, the moisture content is positively correlated with the growth rate of microorganisms. At this time, the higher the water content in the food, the shorter the shelf life; but if the moisture content in the food is too little, the food will become too hard, affect the taste of food. Therefore, the moisture content in food must be kept in a reasonable range. That is to say, detecting and even predicting the moisture content in the production process are of great significance. At present, according to different use scenarios, a variety of moisture detection methods have been proposed in the world, such as drying method, capacitance method, infrared method, etc. [2], but these methods can only detect the moisture content in the finished product, cannot realize the prediction of moisture content. In this paper, the wavelet neural network is modified and applied to the actual food product process to achieve the real-time moisture detection and prediction. The defective products will be killed in the production process at the cradle-before the finished product, so it can reduce the economic loss of enterprises and the waste of raw materials, improve the production efficiency in the production process and increase the economic income of enterprises benefit.
2. Wavelet Theory
Fourier transform is a powerful instrument in signal processing and analysis. It builds a bridge between spatial domain and frequency domain. However, this method abandons the time factor in the process of transformation, so it has great limitations in time analysis. In order to solve this problem, in 1974, French engineer J. Morlet put forward the idea of wavelet analysis on the basis of Fourier transform for the first time. This method is an improvement of Fourier analysis. It successfully overcomes the shortcoming of Fourier transform which can not analyze local signal \cite{3}. It is a perfect combination of theoretical mathematics and applied mathematics. It was called “Mathematical microscope” vividly \cite{4,5}. At present, this method is used in image processing, geological survey and many other modern scientific fields \cite{4,6}. As we all know, Fourier transform only has three transform function, they are sin(x), cos(x) and exp(x). Different from the Fourier transform, the types of wavelet functions have a lot of wavelet transform function, and there are still various wavelet functions proposed continually. The commonly used wavelet functions include Haar wavelet, Daubechies wavelet, Mexican Hat wavelet, Meyer wavelet, Morlet wavelet, etc. Their respective function graphs are shown in Figure 1:

![Figure 1. Five common graphs of wavelet functions.](image)

The continuous wavelet transform function can be expressed by the equation shown in formula (1)

\[
f(x) = a^{-\frac{1}{2}} \int_{-\infty}^{\infty} x(t) \cdot \varphi(\frac{t-x}{a}) \, dt \quad a>0
\]

Among them, \(\varphi(t)\) is the wavelet basis function, \(a\) is the stretching factor, which is equivalent to making the lens close to or away from the target, and \(\tau\) is the translation factor, which is equivalent to horizontally moving the lens. At the same time, from formula (1), we can find that the function has a time factor in the calculation, so this method can analyze the local signal.

3. Wavelet Neural Network
Wavelet neural network\cite{7} is one of the important applications of wavelet theory. Based on BP neural network, the wavelet function is introduced as the hidden layer. When the signal propagates to the output layer, the calculated error is back propagated. The structure of wavelet neural network is shown in Figure 2.
Figure 2. Structure of wavelet neural network.
In the above figure, X represents the input layer parameter, Y represents the output layer parameter, \( \omega_{ij} \) represents the weight of the input layer and hidden layer, and \( \omega_{jk} \) represents the weight between the intermediate layer and the output layer.

When the input layer is known, the hidden layer can be obtained by formula (2)

\[
h(j) = h_j \left[ \sum_{i=1}^{l} \omega_{ij} x_i - b_j \right] / a_j \\
\text{j=1,2,...,l}
\]  

(2)

Where \( h_j \) is the wavelet basis function, \( b_j \) is the translation factor and \( a_j \) is the scaling factor.

Furthermore, we can get the value of output layer of wavelet neural network by formula (3)

\[
Y(k) = \sum_{i=1}^{l} w_{jk} h(i) \\
\text{h=1,2,...,m}
\]  

(3)

At the same time, the wavelet neural network will carry on the reverse transmission of the error, and then constantly modify the parameters to improve the accuracy of prediction. The calculation formula of error is as follows (4)

\[
e = \sum_{k=1}^{m} y_{n(k)} - y_{(k)}
\]  

(4)

Where, \( y_{n(k)} \) is the expected output value, \( y_{(k)} \) is the predicted output value of the network.

When using wavelet neural network to predict, we first need initialize parameters, and then give enough data to train the network, so that the system can automatically correct the weights in the process of learning, and detect whether the training results meet the requirement. If the requirement has been met, we started with experimental predictions; otherwise, the network will be trained again and again until reach the requirement. The specific working process can be represented by the flow chart shown in Figure 3.

Figure 3. Work flow chart of wavelet neural network.
4. Realization of Water Prediction Mechanism

In the process of food production, we collect the moisture content of food at equal intervals, and transmit it to the system for storage. When the number of collected data reaches the requirement of training network \( n \), we start training network and give the predicted value. In the next time, we get the \( N+1 \) data. We discard the original first group of data and modify the other data label. The second data is changed to the first one, and the third data is changed to the second one, finally, a new data sample will be formed. The process of data storage and update can be shown in Figure 4.

![Figure 4. Storage and update of sample data.](image)

In the production process, we set a moisture content standard \( S_0 \) in advance. We consider that there is a certain error in the moisture detection equipment, and the general food moisture content requirements are not very strict, allowing moisture to change in a certain range, so we can set a allowable change width \( SW \), we set the moisture content of produced food in the range of \( S_0 \pm SW \) is up to the requirements. However, if the predicted or detected moisture content is not within the set range, the system will send an alarm to remind the on-site staff that the moisture content of the food currently produced may not be up to standard. To tell staff adjust the raw material ratio in advance\(^{[8]} \). The implementation process is shown in Figure 5. below:

![Figure 5. Water prediction and alarm flow chart.](image)
5. Feasibility Verification of Thinking Method
In order to verify the feasibility of the above ideas and methods, we carried out the following experiments in MATLAB programming environment to study the feasibility of the ideas and methods. First of all, we set up a series of necessary data samples, and the data samples should meet the following conditions:
1) The sample data are independent of each other, and all data are generated randomly;
2) In order to be close to the actual life and production, we set the moisture content in food to be basically stable between 10% and 30%, and there are very few data between 30% and 40%;
3) The data content should include input data and output data.
The following table 1 and table 2 shows the data samples we set up:

| Table 1. The input data. |
|--------------------------|
| 0.17 0.18 0.17 0.19 0.21 0.22 0.17 0.18 0.22 0.23 0.17 0.18 0.22 |
| 0.22 0.18 0.21 0.23 0.24 0.11 0.18 0.19 0.22 0.25 0.24 0.26 0.22 |
| 0.26 0.19 0.21 0.23 0.15 0.17 0.21 0.18 0.15 0.21 0.31 0.18 0.22 |
| 0.23 0.32 0.17 0.45 0.31 0.12 0.16 0.26 0.25 0.34 0.26 0.18 0.35 |
| 0.15 0.22 0.22 0.26 0.25 0.24 0.21 0.26 0.17 0.22 0.17 0.26 0.16 |
| 0.29 0.17 0.33 0.18 0.21 0.16 0.45 0.15 0.22 0.17 0.22 0.18 0.26 |
| 0.32 0.17 0.15 0.26 0.14 0.32 0.33 0.26 0.15 0.17 0.18 0.21 0.51 |
| 0.12 0.17 0.22 0.17 0.23 0.22 0.26 0.15 0.14 0.19 0.16 0.26 0.26 |
| 0.28 0.25 0.21 0.21 0.23 0.21 0.19 0.25 0.19 0.32 0.15 0.16 0.26 |
| 0.19 0.19 0.17 0.29 0.18 0.26 0.26 0.21 0.13 0.25 0.17 0.29 0.23 |
| 0.19 0.17 0.21 0.19 0.21 0.23 0.15 0.18 0.17 0.21 0.23 0.19 0.12 |
| 0.15 0.21 0.30 0.21 0.16 0.19 0.23 0.26 0.28 0.19 |

| Table 2. The output data. |
|---------------------------|
| 0.19 0.21 0.22 0.17 0.18 0.22 0.23 0.17 0.11 0.15 0.16 0.12 0.18 |
| 0.23 0.24 0.11 0.18 0.19 0.22 0.25 0.24 0.26 0.22 0.30 0.28 0.22 |
| 0.25 0.26 0.24 0.22 0.31 0.17 0.19 0.21 0.22 0.15 0.16 0.18 0.26 |
| 0.23 0.15 0.17 0.21 0.18 0.15 0.21 0.31 0.18 0.22 0.19 0.22 0.23 |
| 0.45 0.31 0.12 0.16 0.26 0.25 0.34 0.26 0.18 0.35 0.19 0.13 0.15 |
| 0.26 0.25 0.24 0.13 0.17 0.22 0.17 0.26 0.16 0.14 0.16 0.29 0.17 |
| 0.18 0.21 0.16 0.45 0.15 0.22 0.17 0.22 0.18 0.26 0.17 0.17 0.32 |
| 0.26 0.14 0.32 0.33 0.26 0.15 0.17 0.18 0.21 0.51 0.19 0.21 0.21 |
| 0.17 0.23 0.22 0.26 0.15 0.14 0.19 0.16 0.26 0.26 0.15 0.24 0.28 |
| 0.21 0.23 0.21 0.19 0.25 0.19 0.32 0.15 0.16 0.26 0.29 0.27 0.19 |
| 0.29 0.18 0.26 0.26 0.21 0.13 0.25 0.17 0.29 0.23 0.19 0.19 0.17 |
| 0.19 0.21 0.23 0.15 0.18 0.17 0.21 0.23 0.19 0.12 0.32 0.32 0.15 |
| 0.21 0.16 0.19 0.23 0.26 0.28 0.19 0.19 0.19 0.17 |

Here, we take the first 120 groups of data in the above two tables as our initial data samples, and the following 70 groups of data as our test data samples, and update the data according to the above scheme before each prediction. In addition, we select Morlet as the mother wavelet basis function of the algorithm, and its mathematical expression is shown in formula 5:

\[ y = e^{-\frac{x^2}{2}} \cdot \cos(1.75x) \]  

(5)

After a series of necessary operations, the result of the above data after running in MATLAB programming environment is shown in figure 6:
As can be seen from the above figure, the error between the prediction result of the method and the actual output result is small, which can well realize the data result prediction.

6. Summary
This paper takes wavelet neural network as the starting point, and necessary improvements are made on this basis. Then it is applied to the actual food production process to realize the real-time moisture content prediction, which makes it more quickly to find the problems in the production process, and to avoid the waste of raw materials and economic loss. Then, the experimental results show that the algorithm can accurately predict the experimental data. This method will have wide application value in improving production efficiency and yield.

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