Research and Design of Intelligent Greenhouse Control System Based on AIoT Fusion Technology

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Abstract. This article designs the entire intelligent Greenhouse system architecture, collects a large amount of data such as temperature, humidity, light, and water through Multi-sensors, and implements an improved fuzzy neural network control algorithm. The advantage of this algorithm over traditional neural networks is that it can express fuzzy and qualitative knowledge, which also improves the overall learning ability of the system. This intelligent system combines advanced technologies such as AIoT, NB-IoT, and 5G and uploads sensor data to the cloud platform. Through this improved learning algorithm, it provides optimized temperature, humidity and lighting conditions for plants in the greenhouse, and optimal growth conditions. In addition, this system design also optimizes NB-IoT power management, which can improve the overall system information transmission rate and decoding efficiency, and better achieve connection between the 5G and NB-IoT in order to link up each operations and for transmissions. That design and research of the intelligent greenhouse control system has improved the function and the value of the traditional greenhouse control system. Through the AIoT fusion technology, the entire intelligent greenhouse system is made more convenient, intelligent and integrated.

1. Overview
The control system of traditional intelligent greenhouse mainly controls all kinds of the parameters, such as temperature, humidity, light intensity, Carbon dioxide concentration and water volume in the intelligent greenhouse. It is mainly accomplished by artificially setting related parameters or according to the experience numbers. The environment of different greenhouses has large differences, it brings many problems for the intelligent greenhouse control system. At present, the more popular AloT technology consists of the artificial intelligence technology (AI) and the Internet of Things (IoT) and it builds a higher form of intelligent ecosystem in order to realize dataization and intelligence of all things through artificial intelligence technology[1]. However, various types of front-end acquisition sensors will generate massive data that needs to be transmitted, and high-speed data transmission processing has always restricted the development and application of this technology, and with the implementation of 5G technology, it has further promoted the application and development of AloT technology. There are various sensors in the intelligence greenhouse control system, and a large amount of monitoring data needs to be quickly uploaded to the cloud for algorithm processing by using 5G technology. This paper designs a intelligent greenhouse control system based on the fusion technology of AloT and NB-IoT, and uses the combination of NB-IoT power optimization and 5G, an improved fuzzy neural network optimization algorithm[2]. The intelligent greenhouse control system based on AloT fusion technology is more intelligent and humane than traditional intelligent...
greenhouse control system, creating an ecological environment more suitable for plant growth.

2. System design

![Overall architecture of the system](image)

The overall architecture of the system is divided into a front-end access layer, a 5G network transmission layer, a narrowband IoT layer, and an intelligent application layer. The front-end access layer mainly includes various types of sensor data collection in the greenhouse, including temperature and humidity collection, water collection, and lighting collection. At the same time, it supports cloud interface to upload data. The network layer mainly realizes the collection and transmission of front-end collected data. The intelligent greenhouse control system perceives the big data platform using narrowband Internet of Things technology (NB-IoT), which can realize the connection of various sensors, then it also has intelligent processing functions by itself, and combining various types of sensors and intelligent processing, analyzing, processing and processing through the massively collected sensor information, and applying them to different application needs[3]. According to plants real needs on greenhouse, the intelligent application layer as an upper layer application can achieve intelligent analysis, environmental decision and control.

3. Improved fuzzy neural network algorithm design

3.1 Principle of improved algorithm

The fuzzy neural network is a new technology that combines the powerful structural knowledge expression ability of fuzzy logic reasoning with the powerful self-learning ability of neural networks. It is the product of the organic combination of fuzzy logic reasoning and neural networks.

The improved model takes the neural network as the main body, divides the input space into several different types of fuzzy inference combinations, first makes fuzzy logic judgments on the system, and uses an improved weighting coefficient defuzzifier to generate fuzzy outputs for multi-sensor sampled data. The improved weighting coefficient defuzzifier output is used as the input of the neural network, which makes this improved fuzzy control neural network have better self-learning control capabilities[4].

According to Figure 2, the entire algorithm design can be seen. Sampling data is first transferred to the fuzzy controller. In traditional average weighted fuzzy control, X1, X2 ... xN are average weighted, and then output by the fuzzy controller. The data collected by the sensor is not a dimension, so weighted fuzzy control will affect the authenticity of the data features, and it is difficult to restore the essence of the data even through a neural network.

Therefore, we sample the improved weighted fuzzy control, and calculate the weight ratio according to the specific collection parameter type. After the multi-sensor data passes the improved
weighted fuzzy controller, it produces more accurate data features, which lays the foundation for the next step of neural network training.

Figure 2. Structure of fuzzy neural network

The first, multi-dimensional sensor data collected is stored, and then the fuzzy control output of the multi-dimensional data is completed by using the optimal proportional weight according to the fuzzy control algorithm. The purpose of multi-sensor data weighted fuzzy output is to make the estimation accuracy of the target parameter higher, but the sensor data comes from different dimensions, then the influence of the sensor on the weight of the fuzzy output should be considered when performing fuzzy output. The weight of the fuzzy controller is 

\[ i\alpha (i=1,2,\ldots,n) \]

Therefore, according to the weighted fuzzy control algorithm, specific formulas (1) and (2) are given.

\[ U_i = F(X_1, X_2, \cdots, X_n) \]  

\[ U(i) = \sum_{i=1}^{n} \alpha_i X_i \]  

Restrictions: \[ \sum_{i=1}^{n} \alpha_i = 1 \] (i = 1, 2, \ldots, n)

According to the output characteristic parameters of the weighted fuzzy controller obtained in the first step, then \( U(1), U(2), \ldots, U(N) \) are brought into the neural network for training. Then according to the following formula 3, the forward propagation calculate errors are performed to gain the weight coefficient.

\[ Y(x) = \sum_{i=1}^{N} W_i G_i (m_i, n_i, x) = H(x)W_0 \]  

Among them, \( m_i \) is the weight vector between the i-th neuron in the hidden layer and the neuron in the input layer, \( W_i \) is the weight vector between the i hidden neuron in the middle hidden layer and the output neuron, \( n_i \) is the i-th neuron offset in the hidden layer. \( W_0 = [w_1, w_2, \cdots, w_N] \) The goal of the neural network is to minimize the training error of the data samples, that is, \( \text{MIN} \ Y(x) \).

3.2 Improved fuzzy neural network algorithm steps and simulation

According to the formula algorithms are derived and the steps are also presented.

1. The collected sensor data, such as temperature, humidity, light intensity, and water measurement values, then they are input to the fuzzy controller.

2. For each type of sensor input into a fuzzy controller, according to a set of fuzzy rule fuzzy
inference is performed, finally we can obtain its corresponding fuzzy output.

3. The fuzzy output value uses the value as the input of the neural network. In the control process, the influence of each rule on the output can be changed by changing the weight factor Wi according to the change of the situation, so as to achieve the goal of adjusting the performance of fuzzy control[6].

According to the algorithm steps, a large amount of sensor data collected by us is transmitted to the weighted fuzzy controller, which is processed through matlab.

According to the designed neural network structure, the pre-processing data is trained through the neural network, and finally the optimized weight value is obtained through algorithmic operation. Figure 3 shows the convergence effect of the fuzzy neural network after data training is completed.

According to the algorithm simulation analysis, the characteristics of the improved fuzzy neural network structure are obtained:

1) Make the structure and weights of the network have a clear setting range. The structural design of the network and the initialization of the weights have a theoretical basis, which prevent the network from falling into the inability to find the optimal solution[7].

2) The learning ability of neural networks can be used to adjust the control rules and fuzzification methods of fuzzy control, so that fuzzy control has a certain adaptive ability.

3) Fuzzy neural network combines qualitative knowledge expression and quantitative numerical operations well, and has a good control effect.

![Figure 3](image.png)

**Figure 3. Convergence effect of trained fuzzy neural network**

### 4. NB-IoT power management optimization design

This system optimizes the design of NB-IoT power management, which can ensure a better and seamless connection between 5G and NB-IoT, so that information can be successfully and quickly decoded. Because NB-IoT does not have a fast closed-loop power control process, it needs to be adjusted by Power through a large number of actual measurement data, and selects the best path loss compensation to achieve the optimization process.

For the uplink power control, the NPDCCCH channel can be detected and the compensation coefficient of the road loss can be adjusted by sending different content or format information during the actual measurement and setting process[8].

For the uplink power adjustment, the following two derivation formulas can be used to optimize the debugging:

The derived transmission power formula for the MSG format is as follows:

\[ P_{\text{NPUSCH}}(i) = 10 \log_{10}(M_{\text{NPUSCH}}(i)) + PL + \Delta \text{NPDCCH} + A_{c} \]  \hspace{1cm} (3)

For the format transmission power formula

\[ P_{\text{NPUSCH}}(i) = 10 \log_{10}(M_{\text{NPUSCH}}(i)) + N_{\text{NPUSCH}}(i) + PL + \Delta \text{NPDCCH} + A(j) + PL \]  \hspace{1cm} (4)

Through constant adjustment of formula parameters, it was found through actual
testing. $M_{\text{NPUSCH}}$ the value range is 0.25, 1, 0.5, 8, 12; $\Delta_{\text{NPDCCH}}$ the value ranges from -1 to 10dB, and the uplink transmit power reaches the optimal state.

For the downlink transmit power of each channel is fixed, no power control is required, and the offset value is 0, so the code is written through software testing as follows:

\[
\begin{align*}
\text{NBPCHP} &= \text{NRS POWER} + 0; \\
\text{NPDCCH P} &= \text{NRS POWER} + 0; \\
\text{NPDSCH P} &= \text{NRS POWER} + 0;
\end{align*}
\]

![Signal Power Spectrum](image1.png) ![Optimized Signal Power Spectrum](image2.png)

Figure 4. Comparison of nb-iot power optimization

According to the comparison chart of the optimized power spectrum density of Figure 4, by optimizing the design of the NB-IoT power management simulation, you can see that the right figure is the optimized power spectrum density chart, and the theoretical optimization effect can reach 66.7%. The information transmission rate and decoding efficiency are significantly higher than the traditional NB-IoT without compensation optimization by about 18%, which can better achieve 5G and NB-IoT connection and transmission[9].

5. Conclusion

In this paper, the research and optimization design of AIoT, NB-IoT, 5G and other technologies are applied to the intelligent greenhouse control system. The system design is advanced, scientific, reliable, and economical. By improving the fuzzy neural network algorithm So that artificial intelligence technology can be better played in the intelligent greenhouse control system.

The research and design of this system will promote the further development of smart greenhouses in the future.

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