Growth and Metabolism Control of Lactic Acid Fermentation Based on Internet of Things

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Abstract: With the development of Internet of Things technology, it drives the new development of most industries. Combining the fermentation industry with the LOT, fermentation is a highly nonlinear process in which operators need to measure and operate regularly. This paper proposes an efficient growth and metabolism control method for lactic acid fermentation based on the Internet of Things, using Internet of Things technology combined with cloud computing. Through neural network and expert system of predicting, the fermentation process can be controlled more accurately and effectively, and the threshold value can be changed in time according to the growth stage of the microorganism, to a certain extent, to avoid the error of manual operation. Show the advantages of combining the Internet of Things.

Keywords: Internet of Things, Neural Network, Fermentation, Cloud Computing.

1. Introduction
The Internet of Things, according to a unified protocol standard connects any item to the Internet for communication and data interaction, and combines various sensor devices with the Internet. Each device acts as a network of "smart nodes" that detect information and perform signal processing. Finally, the node will be sent to the cloud platform in a secure way, store and process "cloud" data [1]. The systematic study of the fermentation process requires the use of models that allow representative kinetics to be processed through mathematical tools [2]. At present, the fermentation industry has single control methods for parameters, and most of them cannot combine environmental factors with the growth and metabolism of specific microorganisms.

In this paper, fermentation process based on LOT and cloud platform is proposed. Optimizing the control of fermentation parameters, BP neural network combined with an expert system is used to set precise temperature and PH and other control parameter thresholds.

The chapter layout of this article: Section 2 introduces the current research status of the Internet of Things combination fermentation; Section 3 introduces the relevant knowledge and specific model scheme of this scheme; Section 4 is a summary of this article.

2. Related work
The uncertainty and nonlinearity of the fermentation process have challenges about the parameter control. Nelson et al. [2] used the neural network to develop a state observer from the experimental data and the Scaglias model, and combined the neural network to estimate the product content from...
the amount of substrate, bacteria, CO2 and ethanol as input; Gianluca Masetti et al. [3] proposed a system based on the Internet of things to monitor the fermentation of wine during the wine brewing process; Xiaoet al. [4] applied the single neuron adaptive PID to the control strategy of the humidity and temperature of the fermentation tank. The simulation result shows that the single neuron adaptive PID algorithm makes the system have stronger adaptive ability and high control ability, the model changes from time to time, but it is necessary to re-experiment to obtain new model parameters, which cannot achieve the convergence with the previous stage; Petreet al. [5] proposed a nonlinear indirect adaptive control strategy based on lactic acid production, and new parameters are obtained through combined linearization control; Wang et al. [6] studied the influence of the culture medium on the yield and biomass of lycopene by using neural network. Combining with genetic algorithm, the optimal medium ratio was obtained.

3. Infrastructure of Internet of Things

3.1. Structure of the Internet of Things

LoT implementations use different technical communications models, each with its own characteristics. [12] As the Fig.1 shows.

![Fig.2 The overall structure of the Internet of Things](image)

3.1.1. Perception layer

Devices connected by the perception layer will generate a huge amount of data, which requires a communication infrastructure with specific functions to meet heterogeneous constraints in real-time data processing, storage, speed, scalability, real-time analysis and other aspects [8].

3.1.2. The network layer

The network layer serves as the hub between the perception layer and the application layer. It is responsible for transmitting the data collected by the perception layer to the application layer, and passing relevant information through the network management center and the information processing center to the cloud and clients in real time and accurately.

3.1.3. Application layer
The application layer is a deep integration with industry expertise, using intelligent technologies such as fuzzy recognition and cloud computing to analyze and process big data and information to achieve intelligent control of objects. [10]

3.2. Lactic acid fermentation control process

3.2.1. Predictive model
In [11], multiple models of staged linearization were applied to fermentation process control. The predictive control model predicts the future value of the output based on the real-time input of the system. Both the production volume and quality can be improved using more precise control of the manufacturing process.[7] All the raw data are first preprocessed by the edge server and then the time-sensitive data are used and stored locally. [9] Combined with the penicillin fermentation process, multi-model predictive function control based on piecewise linearization and predictive function control based on BP network are studied. For each local model, design predictive function controllers respectively, and then use weights to weight the pattern controllers and sum them to get the total controller. The multi-model of multi-stage linearization has three main points: reference trajectory, internal model, and error correction. The fermentation process prediction research connects the output model in series with the neural network, and the output model outputs a fixed structure model, which is the product concentration. According to the carbon dioxide release rate that can be measured online during the penicillin fermentation process, the product concentration of the penicillin fermentation process is estimated.

3.2.2. Data processing
The growth and metabolism curve of lactic acid fermentation has certain errors relative to the standard curve under different factors. Expert system is used to judge the rough stage. An expert system is an intelligent computer program that uses knowledge and reasoning to solve complex problems that only experts can solve. The BP artificial neural network is used to calculate the trend and rate of the number of live bacteria, which is closer to the actual situation of microorganisms, rather than directly using the growth and metabolism mathematical model.

**Fig.3** BP neural network structure
**Fig.4** Expert system structure

The growth and metabolism curve of lactic acid fermentation has certain errors relative to the standard curve under different factors. Experienced fermentation research scholars are required to
judge the stage at this time. This article uses an expert system to predict. The key data required for the number of live bacteria is calculated by the BP neural network. An expert system is an intelligent computer program that uses knowledge and reasoning to solve complex problems that only experts can solve. For the highly non-linear fermentation process, there are too many factors to be considered, the BP artificial neural network is used to calculate the trend and rate of the number of live bacteria, which is closer to the actual situation of microorganisms, rather than directly using the growth and metabolism mathematical model, Which can make the parameter control more accurate and improve the yield.

The neural network and expert system are shown in Fig.2 and Fig.3.

First, the PB neural network is used to predict the change of the number of live bacteria at this time. The input parameters are oxygen content, temperature, PH, pressure, reducing sugar content and time. The output parameter is the rate of change of the number of live bacteria.

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![Diagram: Lactic acid fermentation control process](image)

**Fig.4.** Lactic acid fermentation control process

The BP neural network prediction model outputs the growth rate of live bacteria, and transmits the sensor data to the expert system. The expert system decides which stage the predicted bacterial growth
rate will be in, resets the control parameter threshold value according to the actual situation, and sends it back to the controller to adjust the threshold value of each parameter, and guide the corresponding operation according to the change of the threshold value.

Before the fermentation, it is necessary to sterilize equipment. The sensor transmits the data to the expert system, then the expert system decides that it meets the fermentation conditions based on the existing experience and knowledge, and the fermentation starts when it meets the requirements.

When the fermentation starts, the data from the last phase of the period is passed to the neural network prediction model. According to the reference trajectory, the data beyond the limit can be avoided to prevent judgment errors. When the next stage is about to be reached, according to the fermentation kinetics, the cell concentration, substrate concentration, and product concentration all have changes. There is no clear boundary between the two stages. The rate of cell change predicted by the neural network is transmitted. Enter the expert system, start to adjust the parameter threshold, and send it back to the controller for manipulation. The threshold is compared with the previous stage. If it meets, it will remain unchanged. If it does not, it will change to the current threshold.

Based on the fermentation process control of the LOT, the operation is guided according to the fermentation stage to avoid errors caused by the operation of workers or the use of mathematical models. This article mainly explains the advantages of combining with the LOT and the necessity of future development, using the combination of neural network prediction models and expert systems to track the status of fermentation.

4. Conclusion
This article uses neural networks and expert systems to predict the fermentation process, and the integration with the Internet of Things is a necessary trend for future development.

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