The PID control based on CHAOS-RBF in stove application

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Abstract: Introduces the ceramic stove controlling system controlled by MSP430 single-chip computer. The system ameliorate the PID control method, adopts CHAOS-RBF, improves the accuracy of temperature control largely. There are two parts in this system, the lower machine measures the data and the upper machine with responsibility for data processing, displaying data and so on. Meanwhile, using the serial communication RS-485 to realize the control of principal and subordinate station.

Keywords: stove temperature control ;chaos optimize ;neural network; single-chip

0 Forward
In industrial production, the fields such as metallurgy, steel, etc. all need to use the stove heating device, temperature has become a kind of very important index in industrial control target. Need to control temperature while measure temperature constantly. Serious lagging exists in the measurement and control of temperature, regulate time, exceed adjusting amount, self error all asks to be in the certain range inner under the control of[1].

Digital PID control in the production process is one of the most common control method[2]. Although the proportional control can quickly reflect the temperature error, but it is also very easily lead to over-regulation, is not easy to conduct online PID adjustment. Using neural network to improve the CHAOS-RBF algorithm to replace the general PID control, automatic adjustment through training PID parameters.

The single chip is small in size, has high speed and low price, which is widely used in various control systems, can be convenient for data acquisition, data test. In this paper, one of the powerful 16 bit MSP430 MCU, is a product of TI company, it’s notable feature is the extremely low power consumption[3].

1 The main structure and function
Upper machine: An ordinary PC computer
(1) Real-time monitoring of various stove temperature;
(2) Setting the purpose temperature;
(3) As the main station communicate with the eight point by RS-485.

Lower machine: Using MSP430X1232 single chip
(1) Real-time measurement of various stove temperature;
(2) As Secondary station responsible for the data collection;
(3) Receive PC control orders to regulate the temperature.

2 The lower machine design
The lower machine system is composed by the SCM system, temperature measurement, temperature control, alarm and keypad input, LED display, power modules and communications modules.

Because of measuring the temperature need a large range in this system, and thermocouple temperature sensor has a wide temperature range, high precision, simple structure features, it is a very strong applicability of the sensor. So in this system it is the first-selected[4]. Temperature control circuit use the electromagnetism valve to control the importation and the output of natural gas, adjust the heating power. In the temperature measurement and temperature control modules are used CHAOS-RBF algorithm to improve the measurement accuracy and ease the overshoot, fluctuations caused by sudden change in temperature.

System hardware structure as Fig.1.
3 The upper machine design

The upper machine as the principal, it’s task is that watch and control the data that the lower machine collects, display nodes temperature on time. Using the Serial Communication to exchange of data and control the lower machine. The host computer sends the control signal, receives inquiries from the lower machine. There are eight states, gives them different address codes. The host computer according to the codes to decide which point should be controlled.

4 The stove temperature mathematical model and PID control based on CHAOS-RBF

CHAOSEE-RBF network tuning PID controller consists of two parts: PID controller and CHAOS-RBF network identifier. RBF network identifier through the input and output data to determine the approximate model, and use this model to replace the relation between input and output; PID controller parameters through CHAOS-RBF network identifier achieve adaptive tuning [5].

4.1 CHAOS - RBF network identifier

Chaos exists in the nonlinear system, is a more general phenomenon, with its characteristics of campaign ergodicity, random, to a certain extent according to their own laws do not repeat the traversal of all state [6].

CHAOS - RBF algorithm through Chaos logic, sent to the neural network. Then neural network’s output will be considered as the optimized PID control parameters.

Can know that network output is: $y(X) = \sum_{j=1}^{M} w_{j}G_{j}(||X-C_{j}||), i=1,2,\cdots,N$ (1)

In the type, $X=[x_{1},x_{2},\cdots,x_{L}]$ is input vectors; $C_{j}=[c_{j1},c_{j2},\cdots,c_{jL}]$ is the concealed unit center.

This paper only has one output, so the relation of the input and output is:

$$y_{m} = \sum_{j=1}^{M} w_{j}G_{j}(||X-C_{j}||) = \sum_{j=1}^{M} w_{j}e^{(-\frac{||X-C_{j}||^{2}}{2y_{j}^{2}})}$$ (2)

The network’s capability index function is: $E(k)=\frac{1}{2}(y(k)-y_{0}(k))^{2}$ (3)

The chaos dynamics function is Logistic mapped [7];

$$x_{n+1}=f(u,x_{n})=ux_{n}(1-x_{n})$$ (4)

To optimize the error function, take the steps as follows:

1. Give different initial value to $x_{i}$ put into the Logistic mapped, we may get i different chaos track vectors.

2. The selected i-chaotic variables in Step 1 will be mapped to the (0,1), according to the value of variables, the corresponding optimization of chaotic variables $x_{i,n+1} = c_{i}+d_{i}x_{i,n+1}$, $c_{i},d_{i}$ is the magnify multiple.

3. Using the chaos variables to dispose repeatedly. Provided that $x_{i}(k)=x_{i,n+1}(k)$, $f_{j}(k)$ is the capability index.

And order $x_{i}^{*}=x_{i}(0),f^{*}=f(0)$. 

![Fig.1 The drawing of the system hardware structure](http://www.elecfans.com)

![Fig.1 The drawing of the system hardware structure](http://bbs.elecfans.com)
if \( f_i(k) \leq f^* \), then \( f^* = f_i(k) \), \( x^* = x_i(k) \).

Else if \( f_i(k) > f^* \), then discards \( x_i(k) \). \( x^* \) is the most excellent answer at present.

4. \( k = k + 1 \).

5. \( x^*_{i,n+1} = x^*_{i,n+1} \), adjusting the result.

6. Provided that \( x_i(k) = x^*_{i,n+1}(k') \), \( f_i(k') \) is the capability index.

If \( f_i(k') \leq f^* \), then \( f^* = f_i(k') \), \( x^* = x_i(k') \).

Else if \( f_i(k') > f^* \), then discards \( x_i(k') \). \( x^* \) is the most excellent answer in the whole system.

4. **2 PID controller tuning parameters Principle**

   Incremental classic PID control algorithm using differential equation is expressed as:
   \[
   \Delta u(k) = u(k) - u(k-1) = k_p \Delta e(k) + k_i \int_0^k \Delta e(t) dt + k_d \frac{\Delta^2 e(k)}{2}
   \]  
   \((5)\)

   In the formula \( k_p, k_i, k_d \) are the quotients of proportion, integral and differential coefficient.

   PID controller tuning parameters principle is:
   \[
   J(k) = \frac{1}{2} \frac{\partial^2 J(k)}{\partial \theta^2}
   \]  
   \((6)\)

   Neural networks through self-study, the weight coefficient adjustment it corresponds to a state of stability in a law under optimal control parameters of a PID controller. \( k_p, k_i, k_d \) are the output. Take \( k_p \) for example,

   \[
   k_p(k) = k_p(k-1) - \frac{\partial J(k)}{\partial k_p}
   \]  
   \((7)\)

   In the formula \( \theta \) is the study efficiency.

   \[
   \frac{\partial J(k)}{\partial k_p} = \frac{\partial J(k)}{\partial \gamma(k)} \frac{\partial \gamma(k)}{\partial \Delta u(k)} \frac{\partial \Delta u(k)}{\partial k_p} = -e(k) \frac{\partial \gamma(k)}{\partial \Delta u(k)} \Delta e(k)
   \]  
   \((8)\)

   And \( \frac{\partial \gamma(k)}{\partial \Delta u(k)} \) receives from CHAOS - RBF network identifier, sequentially obtains the intention of optimize.

   \[
   \frac{\partial \gamma(k)}{\partial \Delta u(k)} \frac{\partial m(k)}{\partial \Delta u(k)} = \frac{M}{\sum_{j=1}^{M} w_j G_j} \frac{C_j 1 - \Delta u(k)}{b_j^2}
   \]  
   \((9)\)

4. **3 Simulation research**

   Suppose the temperature object’s approximately mathematics model as:
   \[
   y(k) = \frac{1.2(1-0.8e^{-0.1k})(k-1)+u(k-1)}{1+y^2(k-1)}
   \]

   the study speed is 0.25 and the inertia quotient is 0.04. In the Matlab, the simulate result as Fig.2.
We apply 200 groups of data to CHAOS-RBF train the good network, judge the precision. Take out 10 groups among them at random now. Such as Table 1. Can find out from the table, adopting CHAOS-RBF to control the temperature can meet demands of system.

<table>
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<tr>
<th>C</th>
<th>∆C</th>
<th>error</th>
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<td>100.35</td>
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</tr>
<tr>
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<td>158.97</td>
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<td>160.55</td>
<td>170.92</td>
<td>-0.19</td>
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<tr>
<td>190.73</td>
<td>192.65</td>
<td>-0.18</td>
</tr>
</tbody>
</table>

5 Conclusion

The innovation of this text lies in the system adopting CHAOS-RBF algorithm, optimize neural network output parameter, automatically adjust through training PID parameters. Temperature control lagging is reduced greatly, and can control the temperature of each stove at the same time in the control room, the system is furnished with the warning system of temperature, there is very strong practicability.

References

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创新点：将混沌技术、神经网络 RBF 算法与 PID 控制结合起来用于陶瓷窑炉温度控制系统中，大大优化了系统的控制性能。

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