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The Application of Neural Network in the Heart Pump Bionic Control System Based on Neuroshell

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With the development of the heart pump, more and more products of artificial heart have been applied to the human body, but most of the products produce some discomfort harmful to human body, can't meet the heart pump comfort requirements, need further improvement and enhancement. through the neural network design of bionic control method is one of effective methods to improve the heart pump's comfort.A neural network model was established in this paper according to the relationship of the pressure head of the blood pump with motor power and speed by neural network software Neuroshell2. A lot of data were studied for the neural network model by selecting the appropriate activation function, the parameters of network model was adjusted, the stability of neural network was increased, the error of the neural network measuring values and the actual values to meet the human body comfort was within 5%. Improve comfort after blood pump implantation in the human body

Key words: Artificial heart, Neural network, Bionic control, Neuroshell.

According[1] to the world health organization investigation, at present the cardiovascular disease and heart disease accounted for about 30% of all disease. To 2020, cardiovascular disease and heart disease will account for 40% of all diseases(Sony et al., 2004). Although heart transplant surgery has been a great success, but the donation amount and the patient's own clinical surgery and so on various aspects of the restrictions, natural heart transplantation is very limited. After 50 years' R&D, the artificial heart blood pumps have achieved many progresses, a lot of clinical requirements have been satisfied such as blood compatibility, implantability and durability (Henning et al., 1997; Robert et al., 2002; Hedlund et al., 2001), thus the comfortability of the receiptor with a heart pump becomes more and more important in the future. The key technology to achieve this purpose is to improve the sensitivity of flow rate changing after the pressure head variation in the pump, so as to maintain the flow rate balance between the left ventricular assist pump and the right ventricle(Houghton et al., 2006). Due to limited self-identity of impeller pump, however, it is difficult to do so automatically. In this paper, centrifugal pumps are homemade in Institute of Biomedical Engineering of Jiangsu University as research subjects, A neural network model was established according to the relationship of the pressure head of the blood pump with motor power and speed by neural network software Neuroshell. A lot of data were studied for the neural network model by selecting the appropriate activation function, adjusted the parameters of network model, the stability of neural network was increased, the error of the neural network measuring values and the sensor measuring values was within 5%.Then, through the Neuroshell software got learned weights and bias of the network, according to the excitation function written neural network program realized blood pump head forecast, through head change automatic control flow met the human body comfort

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requirements, achieved the purpose of bionic control.

The establishment of the neural network model

A neural network model includes input layer, output layer and middle layer(Zong et al., 2001). In this paper,the mainly purpose was realize the blood pump head automatic detection through the neural network, so its output layer neuron was head H. The input layer neuron was chosen the parameters has a significant effect for head, it was important significance for the accuracy of detection system. Centrifugal pump's head was affected by various factors, it was known by the pump energy characteristic curve: When the pump speed n = const (constant), a certain function relation between the blood pump's head and input power is H=f(Q), Thus, the input power was chose as a input neuron. Besides, the motor speed also have certain effect, so the speed as another input neuron.

Table 1. The testing data in different learning and momentum

Learning rate	Momentum	Min. Average Error	mean absolute error	Percent within 5%
0.1	0.1	0.0009993	4.186	76.056
0.1	0.2	0.000919	4.026	77.465
0.1	0.3	0.0008917	3.749	88.732
0.1	0.4	0.0009939	4.115	80.282
0.1	0.5	0.0008301	4.019	83.099
0.1	0.6	0.0007689	4.063	81.69
0.1	0.7	0.0007326	4.159	77.465
0.1	0.8	0.0007022	3.584	81.69
0.1	0.9	0.0006876	4.701	73.239
0.2	0.1	0.0007617	3.906	81.69
0.2	0.2	0.0007427	3.901	81.69
0.2	0.3	0.0007383	4.029	81.69
0.2	0.4	0.0007296	4.064	80.282
0.2	0.5	0.0007347	4.05	81.69
0.2	0.6	0.0006966	3.581	85.915
0.2	0.7	0.0006598	3.412	84.507
0.2	0.8	0.0007001	4.438	67.606
0.2	0.9	0.0007226	3.993	81.69
0.3	0.1	0.0007481	4.057	78.873
0.3	0.2	0.0007409	4.059	80.282
0.3	0.3	0.0007069	3.812	74.658
0.3	0.4	0.0006757	3.567	83.099
0.3	0.5	0.0006236	3.396	85.915
0.3	0.6	0.0006711	3.453	83.099
0.3	0.7	0.000693	4.448	66.197
0.3	0.8	0.0007582	3.848	83.099
0.3	0.9	0.0006094	4.135	70.423
0.4	0.1	0.0007201	3.677	78.873
0.4	0.2	0.0007174	3.779	83.099
0.4	0.3	0.0006598	3.511	81.69
0.4	0.4	0.0006768	3.544	83.099
0.4	0.5	0.0006914	4.27	67.606
0.4	0.6	0.0007139	3.56	76.056
0.4	0.7	0.0006062	4.525	71.831
0.4	0.8	0.0007631	4.016	78.873
0.4	0.9	0.0006456	4.561	66.197
0.5	0.1	0.0006673	3.532	81.69
0.5	0.2	0.0006836	3.858	78.873
0.5	0.3	0.0006597	3.201	87.324
0.5	0.4	0.0007138	3.628	78.873
0.5	0.5	0.0007373	3.717	76.056
0.5	0.6	0.0007242	4.356	69.014
0.5	0.7	0.0007341	3.905	78.873
0.5	0.8	0.0007096	4.005	78.873
0.5	0.9	0.0005653	2.887	81.69
0.6	0.1	0.000634	3.269	87.324
0.6	0.2	0.0006797	3.176	84.507
0.6	0.3	0.0007121	3.594	77.465
0.6	0.4	0.0007199	3.66	77.465
0.6	0.5	0.000783	3.723	77.465
0.6	0.6	0.0006382	5.039	71.831
0.6	0.7	0.0007334	3.811	76.056
0.6	0.8	0.0006714	4.073	73.239
0.6	0.9	0.0006807	3.98	78.873
0.7	0.1	0.0006753	4.244	76.056
0.7	0.2	0.0007131	3.595	77.465
0.7	0.3	0.0007165	3.653	77.465
0.7	0.4	0.0007617	3.72	76.056
0.7	0.5	0.0007538	3.751	80.282
0.7	0.6	0.0007273	3.923	77.465
0.7	0.7	0.0007075	3.726	77.465
0.7	0.8	0.0006486	4.203	66.197
0.7	0.9	0.0006796	3.993	77.465
0.8	0.1	0.0006918	3.56	83.099
0.8	0.2	0.000716	3.653	77.465
0.8	0.3	0.0007541	3.645	77.465
0.8	0.4	0.0007869	3.844	73.239
0.8	0.5	0.0007064	4.092	73.239
0.8	0.6	0.0007055	3.945	80.282
0.8	0.7	0.0007105	4.016	77.465
0.8	0.8	0.0005363	3.855	69.014
0.8	0.9	0.0005062	2.884	80.282
0.9	0.1	0.0007147	3.651	77.465
0.9	0.2	0.0007418	3.635	78.873
0.9	0.3	0.000713	4.197	71.831
0.9	0.4	0.0007541	4.413	67.606
0.9	0.5	0.0007208	3.992	77.465
0.9	0.6	0.0007679	4.06	77.465
0.9	0.7	0.0006503	4.127	71.831
0.9	0.8	0.0005976	3.066	78.873
0.9	0.9	0.0004803	3.076	83.099

The choice of intermediate layer

According to the demonstration Of Robert Hecht – Nilelson,a three layer BP network can realize arbitrary precision, approximate any continuous function(Liming et al., 1993). Therefore, the majority of practical problems, Choose a middle layer, namely, three layer network.So,in this paper the structure of neural network is also a three layer neural network

The training of neural network system

Training samples obtained

This experiment training specimen collection used experimental device is the blood circulation simulation experiment platform was used to collection the training samples. First, keeped the blood pump input voltage constant, regulated the outlet pressure, got the head of different point, and recorded the test sample.Speed n was obtained from the display screen of blood pump's

Table 2. The testing data in different number of hidden neuron

Learning rate	Momentum	Hidden neuron	Min. Average Error	mean absolute error	Percent within 5%
0.5	0.9	20	0.0003369	3.057	77.465
0.5	0.9	19	0.0003397	2.983	81.69
0.5	0.9	18	0.0003228	3.1	78.873
0.5	0.9	17	0.0003044	2.784	81.69
0.5	0.9	16	0.000323	2.926	83.099
0.5	0.9	15	0.0003523	2.976	80.282
0.5	0.9	14	0.0003299	2.864	83.099
0.5	0.9	13	0.0003454	3.062	74.648
0.5	0.9	12	0.0003027	3.025	80.282
0.5	0.9	11	0.0003355	3.093	77.465
0.5	0.9	10	0.0003298	2.73	80.282
0.5	0.9	9	0.0004359	2.813	80.282
0.5	0.9	8	0.0004209	2.785	80.282
0.5	0.9	7	0.0005888	4.279	73.239
0.5	0.9	6	0.0006222	4.572	69.014
0.5	0.9	5	0.0006757	4.24	78.873
0.5	0.9	4	0.0008704	4.251	81.69
0.5	0.9	3	0.001166	5.097	61.972
0.8	0.9	20	0.0002804	3.178	81.69
0.8	0.9	19	0.0002977	3.169	81.69
0.8	0.9	18	0.0003532	3.113	80.282
0.8	0.9	17	0.0003144	2.896	81.69
0.8	0.9	16	0.0002946	3.113	81.69
0.8	0.9	15	0.0003398	3.258	78.873
0.8	0.9	14	0.0003111	3.072	83.099
0.8	0.9	13	0.0003266	3.035	78.873
0.8	0.9	12	0.000334	3.18	78.873
0.8	0.9	11	0.000679	4.043	76.056
0.8	0.9	10	0.00067	4.186	71.831
0.8	0.9	9	0.0004309	4.047	69.014
0.8	0.9	8	0.0004264	3.043	80.282
0.8	0.9	7	0.000616	4.226	76.056
0.8	0.9	6	0.0006233	4.259	76.056
0.8	0.9	5	0.0006728	3.956	76.056
0.8	0.9	4	0.0011903	4.972	57.746
0.8	0.9	3	0.0013359	4.84	64.789

controller, input voltage U and current I directly was obtained from the screen of special stabilized voltage supply, import and export pressure was measured from the ECG monitor. Then, adjusted blood pump input voltage, and repeated the above step, collected the sample data.The training sample collected must be as possible as comprehensive and reflect blood pump all run characteristic. The 474 groups sample data was obtained after analysis and processing of all collection sample.

The training of samples data by neuroshell

Use of Neuroshell Software created a neural network model and trained network, steps are as follows

1) By neuroshell software created the neural network file abc.dsc
2) Input 474 group samples
3) Determine the network input/output parameter.

Two input neuron respectively named n,p.An output neuron named H. According to the range of each input and output neuron data value, maked sure their maximum and minimum value. The Neuroshell software can also own determind each neuron's maximum and minimum value according to all input sample data.

Defined network structure and parameters

Network's input neuron and output neuron number can be determined directly by the network input and output model ,the selection of Middle layer neuron number, learning rate and momentum factor have guiding principles,but more rely on the experience and try to scrape.Here, the number of network's input neuron was 2, the output neuron was 1, the number of training data set 332, the default value of hidden neuron number was 20 (hidden neuron number m = 0.5 * (input neuron number a + output neuron number b)+(training data groups c) ^ 0.5), initial value of Learning rate and momentum factor respectively was 0.1, 0.1.

The training of the neural network

The sample data was repeatedly used in the training process of network. All the sample data forward running once, and reverse modify the connection weights was called a training (or a learning), This training requires repeated proceed until to obtain the appropriate mapping results. The neural network was trained make use of sample databy neuroshell software shown in Figure 1.

The weights and bias of the neural network system obtained

In order to find the best network structure, obtain the weights and the bias of neural network, the network according to the following structure and parameters to training.

(a) First, the network was trained 50000 cycle (all samples data training once for a cycle) make use of sample data in hidden neuron was 20, Learning rate was respectively 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, momentum factor was respectively 0.1, 0.2, 0.3, 0.4, 0.5,

Table 3. Neural network connection weight table

	Input layer		Output layer	
Bias	Input neuron p	Input neuron n	Bias	Output neuron H
-313.69821	182.1772156	174.4667511	-0.2678869	3.7672966
-281.60095	168.3149567	160.0802002		-4.3699317
41.5032387	-16.1979008	-53.6158791		-0.8251047
-19.335791	16.4929638	9.5172873		1.2248807
18.0708942	42.1791878	-65.3564987		-0.4378157
-31.988176	-17.9307613	40.3417473		0.5269365
-0.9263492	16.8904419	-13.7951546		-1.9933515
-44.255558	-54.0436707	97.5596466		0.2065557
-88.602547	18.0028419	77.8679199		0.4788347
-5.8911762	-27.8347816	40.185112		2.8738878
-102.89402	-158.9948425	233.063797		8.4132767
-136.77435	81.0107651	75.3964844		-4.6838851
-317.27115	219.7969055	149.279068		5.1524267
-10.591471	-8.6721048	47.5416832		-1.7797954

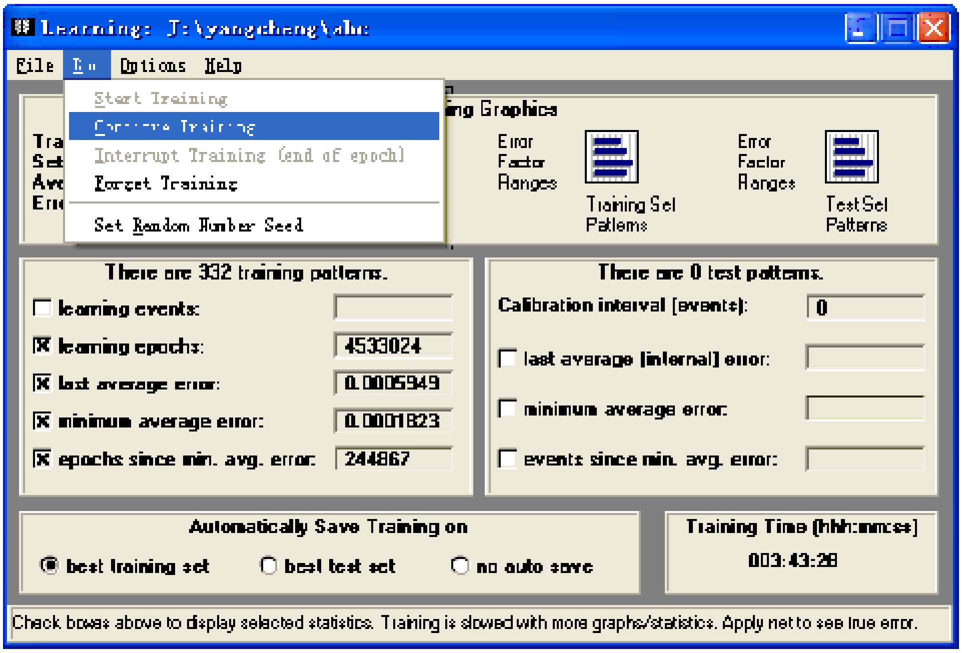

Fig. 1. The training of network by neuroshell

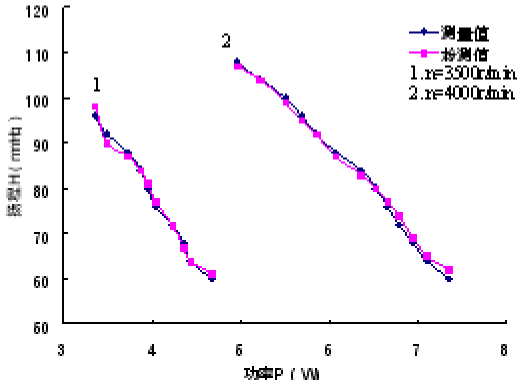

Fig. 2. The compare curve of Neural network detection and actual measured

0.6, 0.7, 0.8, 0.9, found the best learning rate and momentum factor in training.

(b) Next, the number of hidden neuron as little as possible when the error is similar. So the network was trained 100000 cycle in hidden neuron was respectively 3~20 when learning rate was 0.5, momentum factor was 0.9 and learning rate was 0.8, momentum factor was 0.9

After training to draw the mean absolute error of the network was minimum when learning rate 0.5, momentum factor 0.9 and learning rate 0.8, momentum factor 0.9. All testing data were shown in table 1

After training can be seen the resolution of network was highest when hidden nuit was14, learning rate was 0.5, momentum factor was 0.9. therefore, in this paper using 2-14-1 network structure, composition of three layer forward neural network of the input layer 2 nodes, hidden layer 14 nodes and output layer 1 node. All testing data were shown in table 2.

Setting learning rate was 0.5, momentum factor was 0.9, the number of hidden neuron was 14, trained more cycle again by neuroshell, found the cycle of the minimun of the mean absolute error and the maximum of test error within 5% data ratio,obtained the each layer network's Weight and bias.

In this paper, the sample trained 5000000 cycle, finally obtained the data was best in 1695440 cycle, the mean absolute error was 2.679, the test error within 5% data ratio was 85.915, obtained the weights of each layers connected in this error were shown in Table 3.

The analysis of the neural network testing data

The c language program was generated using the value of weight and bias by neuroshell software. This program can be directly used to bionic control system.Taken a group of input data, detected the output value by the neural network compared with the output value of the actual measurement was shown in figure 2

By above figure shown, the output value of the neural network and the actual measured were very close, the error was very small. This shows that neural network has mastered the blood pump's characteristic curve change trend by training, established a good mapping relation, each input value (speed, power) matched a output value(head), and achieved a certain accuracy in atucal detection.

Summarize

In this paper, the neural nerwork model was established by neuroshell software, and trained using many sample data, achieved the automatic measurement of the blood pump's head, the error of the detection and atucal measurement was controlled within 5%, mainly satisfied for with design requirements. The blood pump bionic control system was designed by neural network, achieved the flow blance with right ventricle in left ventricle assistant, and reduced the blood pump's volume of implantation in the human body part, increased the implantable, Meanwhile reduced the probability of Receptors infection, It is a very important tool for the heart pump a long-term used in clinical to lift vertricle assistant.

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