B-P网络用于环境质量分类研究

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摘要　用全国25个湖泊的水质指标资料作为训练样本，应用人工神经网络B-P算法，分别建立了3参数和4参数的水质分类模型。并用所建立的模型对6个湖泊水质进行分类检验效果。结果表明B-P模型应用于环境质量分类是可行的。且由于B-P网络有自学习、自适应的能力，因而与其它的环境质量分类法相比具有优越性。

关键词　神经网络，B-P算法，环境质量分类。

国内外学者对环境质量分类已提出了指数法、模糊数学法、灰色系统法[1]、层次分析法[2]、主分量法[3]和密切值法[4]等多种处理方法。在上述方法中，多数需要设计各分类指标对各级标准的隶属函数或白化函数及各指标的权值，因而分类结果总会受到人的主观因素的影响。

近年来，人工神经网络的研究受到了极大关注，并已广泛用于模式识别、图文处理、函数拟合和系统控制等方面。环境质量的区划和分类实际上是模式识别问题。因此，本文尝试将人工神经网络应用于环境质量的分类研究。

1　用于环境质量分类的B-P网络模型

人工神经网络是智能模式识别的方法之一。它是在现代神经科学研究成果基础上提出的一种数学模型，是由大量电子元件、光电元件等处理单元广泛互连而成的网络，是人脑功能的某种抽象、简化与模拟。其主要特征有：①它是一个大规模的复杂系统，有大量可供调节的参数；②它有高度并行的处理机制，运算速度快；③它有高度分散的存贮方式，因此具有全息联想特性；④它具有自组织、自学习、自适应和容错性能力[5]。国外有人提出的基于B-P算法的人工神经网络模型（简称B-P网络）已在模式识别和分类问题中得到了广泛应用。

用于环境质量分类识别的B-P网络主要由一个输入节点层、一个隐节点层和一个输出节点层组成[5]，如图1所示。B-P网络的学习过程由正向传播和反向传播组成。在正向传播过程中，指标信息从输入层进入，经隐层传向输出层。每一层神经元的状态——权重和阈值只影响下一层神经元的状态。若在输出层得到期望的分类输出，则停止运行并输出结果。否则转入反向传播，将误差信号沿原来的连接通路返回，通过修改各层神经元的权值和阈值，使误差信号减小。

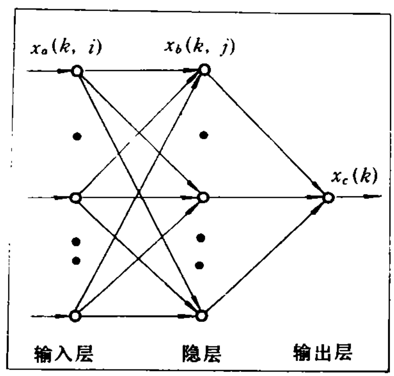

图1　3层B-P网络模型

B-P网络用于环境质量分类时，先将第k个环境样本的M个分类指标值$x_a(k,i)$，$i=1,2,\cdots\cdots M$作为信息，输入网络向前传播，经各层作用函数

$$f(x) = \frac{1}{1+e^{-x}} \tag{1}$$

作用后，在隐节点和输出节点的输出值分别为

$$x_b(k,j) = f\left[\sum_{i=1}^{M} w_a(k,i,j)x_a(k,i) + R_b(k,j)\right] \tag{2}$$

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$$x_c(k) = f[\sum_{j=1}^{H} w_b(k,j)x_b(k,j) + R_c(k)] \quad (3)$$

式中，$w_a(k,i,j)$为输入层 i 节点对隐层 j 节点的权值，$w_b(k,j)$为隐层 j 节点对输出层节点的权值，$x_a(k,i)$为第 k 个环境样本的第 i 个分类指标的输入值，$R_b(k,j)$和 $R_c(k)$分别为隐层和输出层的阈值。网络的输出误差定义为：

$$D(k) = x_c(k)[1 - x_c(k)][c - x_c(k)] \quad (4)$$

其中，c 为期望输出值

$$c=\begin{cases} 1 & \text{环境质量好} \\ 0.5 & \text{环境质量一般} \\ 0 & \text{环境质量差} \end{cases}$$

若输出误差未小于指定精度，将误差信号 $D(k)$沿原来的连接通路反向传播，按递推公式依次修正各层的权值和阈值。定义输出层的阈值增量为：

$$\delta R_c(k) = A \times D(k) \quad (5)$$

定义隐层的误差为：

$$E(k,j) = x_b(k,j)[1 - x_b(k,j)][\sum_{j=1}^{H} w_b(k,j) \times D(k)] \quad (6)$$

定义隐层的阈值增量为：

$$\delta R_b(k,j) = B \times E(k,j) \quad (7)$$

(5)、(7)两式中的 A、B 均为学习参数，一般取为0.2—0.5。输入层和隐层的权值修正的递推公式分别为：

$$w_a(k+1,i,j) = w_a(k,i,j) + x_a(k,i) \times \delta R_b(k,j) \quad (8)$$

$$w_b(k+1,j) = w_b(k,j) + x_b(k,j) \times \delta R_c(k) \quad (9)$$

隐层和输出层的阈值修正递推公式分别为：

$$R_b(k+1,j) = R_b(k,j) + \delta R_b(k,j) \quad (10)$$

$$R_c(k+1) = R_c(k) + \delta R_c(k) \quad (11)$$

分别赋予各层权重和阈值为(−1,1)间的一个随机小初值，将训练样本集中的一个样本输入网络学习，按(2)、(3)式作用函数作用后正向传播，若在输出层得到的误差信号 $D(k)$达不到精度要求，则在 $D(k)$的反向传播过程中，网络按(5)—(11)式产生修正后的权值和阈值，并将其又赋予进入网络的下一个样本，依次往复。若训练样本集中所有样本都已学习一遍，输出误差 $D(k)$仍未达到指定精度，可将样本集中最后学习的一个样本产生的权值和阈值再赋给最初的那个样本，让训练样本集重复学习，直到对于一个给定的样本输入 $x_a(k,i)$产生的实际网络输出 $x_c(k)$与期望输出值 c 的误差信号达到指定精度要求为止。

2 B-P网络用于水环境质量分类实例

2.1 指标选取和样本数据处理

对湖泊水质分类，选取有代表性的叶绿素(chl-a)、总磷(TP)、总氮(TN)和透明度(SD)4个分类指标。31个湖泊4个指标测值列于表1。表中前25个湖泊为训练样本，后6个湖泊做检验样本。每个样本的各指标测值均按下式规格化。

$$x_a(k,i) = \frac{\lg[x(k,i)] - \lg[\min_k(x(k,i))]}{\lg[\max_k(x(k,i))] - \lg[\min_k(x(k,i))]}$$

式中，$\max_k(x(k,i))$和 $\min_k(x(k,i))$分别为 N 个样本中第 i 个指标的最大值和最小值。

2.2 B-P网络对湖泊水质分类结果

赋予网络各层的初始权值和阈值为随机小量后，令学习参数 $A=B=0.3$，用25个样本分别选取前3个指标和全部4个指标学习建模。学习次数采用全部 $N=25$ 个样本学完一遍后，以其均方误差$\frac{1}{N}\sum_{k}^{N}[c_k - x_c(k)]^2 < 1\times10^{-3}$控制。$k$ 为迭代次数。对3参数和4参数分别学习了277遍(6925次)和300遍(7500次)后达到指定精度。此时得到网络各层的最佳权值和阈值。根据最佳权值和阈值由公式(2)、(3)可从网络得出各样本的实际输出值 $x_c(k)$。划定下列阈值作为水质的分类标准

$x_c(k)$	[0,0.25)	[0.25,0.75)	[0.75,1]
水质类别	差"C"	一般"B"	好"A"

用25个样本的3参数和4参数B-P网络学习后得到的最佳权值和阈值对这25个样本水质

分类结果与水质实况拟合率达95%以上，用最佳权重和阈值对表1中后6个湖泊水质的实际分类检验效果如表2所示，其实际符合率达100%。

表1 31个湖泊的水质参数

序号	湖泊名	chl-a (mg/L)	TP (mg/L)	TN (mg/L)	SD (L/m)	序号	湖泊名	chl-a (mg/L)	TP (mg/L)	TN (mg/L)	SD (L/m)
1	邛海	0.510	0.132	1.772	0.657	17	麓湖	119.510	0.372	3.038	2.985
2	高州水库	1.495	0.046	0.358	0.581	18	东山湖	158.620	0.428	5.350	4.608
3	镜泊湖	4.958	0.316	1.270	0.556	19	流花湖	323.507	0.643	6.777	6.536
4	博斯腾湖	3.515	0.023	0.932	0.668	20	海西海	2.260	0.045	0.318	0.286
5	慈湖	14.470	0.077	1.000	1.292	21	荔湾湖	162.92	0.743	7.337	3.279
6	淀山湖	3.720	0.029	1.086	1.488	22	墨水湖	215.757	0.316	15.692	4.651
7	巢湖	30.890	0.115	1.786	3.546	23	玄武湖	168.14	1.630	4.073	4.566
8	南湖	1.798	2.244	2.349	1.230	24	草湖	298.867	0.931	7.378	4.329
9	固城湖	4.996	0.052	2.374	4.405	25	达赉湖	7.237	0.153	1.671	2.105
10	蘑菇湖	54.770	0.289	2.206	1.908	26	洱海	1.857	0.022	0.246	0.360
11	紫碧湖	0.950	0.049	0.520	0.667	27	于桥水库	10.797	0.025	1.220	0.707
12	南四湖	3.777	0.194	3.201	1.980	28	外海	44.480	0.108	1.309	2.033
13	密云水库	2.273	0.017	0.113	0.549	29	云南西湖	2.720	0.033	0.503	0.625
14	杭州西湖	58.955	0.161	2.478	2.358	30	武汉东湖	56.000	0.125	1.830	0.500
15	甘棠湖	75.693	0.141	1.417	2.632	31	乌梁素海	4.450	0.079	2.268	1.429
16	天池	3.600	0.023	0.620	0.833						

3 结论

(1)B-P网络具有自组织、自学习和自适应能力。它用于环境质量分类不需要确定各分类指标对各级环境质量标准的判别指标值，只要把训练样本的分类指标数据输入B-P网络，用学习结束后的最佳权值和阈值就能对新的样本进行分类。这种分类法消除了主观因素，运算速度快，与其它分类法相比，具有优越性。

(2)B-P网络用于环境质量分类的效果取决于分类指标对各类样本是否具有显著的分辨性和建模样本是否具有代表性。只有选取分辨效果好的指标和对各类环境质量分别有代表性的样本进行建模，才能得到拟合和检验效果均好的B-P网络环境质量分类模型。

(3)该方法用于湖泊水质分类实例结果表明B-P网络用于环境质量分类是可行的。

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表2 6个湖泊水质分类检验效果

序号	湖泊名	水质实际类别	3参数B-P网络法			4参数B-P网络法		
			网络输出值 $x_c(k)$	分类	与实况符合情况	网络输出值 $x_c(k)$	分类	与实况符合情况
26	洱海	B	0.654	B	+	0.642	B	+
27	于桥水库	C	0.169	C	+	0.181	B	+
28	外海	C	0.015	C	+	0.015	C	+
29	云南西湖	B	0.511	B	+	0.506	B	+
30	武汉东湖	C	0.012	C	+	0.013	C	+
31	乌梁素海	B	0.287	B	+	0.297	B	+

"+"表示B-P分类结果与实况结果吻合

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Key words: beryllium, morin, flluorescence.

Study on the Determination of Arsenic in Wastewater by Using Single Valve FIA combined with Hydride Generation Spectrophotometry. Liu Guoquan and Wang Chunxu (Dept. of Environ. Eng., Hebei Institute of Chemical Technology and Light Industry, Shijiazhuang 050018), He Yuaping (Shijiazhuang Chemical Fertilizer Factory, Shijiazhuang 050018): *Chin. J. Environ. Sci.*, **15** (5), 1994, pp. 71—72

A Single Valve FIA (Flow Injection Analysis) system with hydeide generation spectrophotometric detection was designed for the determination of the trace arsenic in wastewater. This FIA system had no need for any carrying gas. The new hydride generator and the absorbing device made by the authors were used in the FIA system. The KBH_4 solution and the mixed silver nitrate- polyvinyl alcoholethanol solution were used for the generation and absorption, respectively, of arsenic hydride. The experimental results show that this method was very good for the determination of trace arsenic in wastewater. The FIA system had main advantages, including simple equipment, easy operation, high sensitivity, rapid determination (30 samples/h), good reproducibility (R. S. D = 3. 04%) and low detection limit (1.82×10^{-9} g/ml).

Key words: flow injection analysis, hydride generation, spectrophotometry, arsenic, wastewater.

Reversed-phase High Performance Liquid Chromatographic Determination of Methomyl in Soils. Chen Yanjun et al. (Jining Medical College, Jining 272113): *Chin. J. Environ. Sci.*, **15** (5), 1994, pp. 73—74

A reversed- phase HPLC method was discribed for determination of methomyl in soils. The detection limit of methomyl in soils was 0. 1μg, and the linear range was 1. 0—20μg/ml. The average recovery of methomyl as standard added to soils as in the range of 96. 1% — 100. 2%. The relative standard deviations were below 5%. This method was simple with a higher sensitivity and a bether accaracy.

Key words: methomyl, reversed-phase, HPLC, soil.

Study on Environmental Quality Classification Based on B- P Neural Network. Li Zuoyong (Chengdu Institute of Meteorology, Chengdu 610041): *Chin. J. Environ. Sci.*, **15**(5), 1994, pp. 75—77

Based on the back-propagation (B-P) algorithm of neural network, the classification models of water quality with 3 and 4 parameters were developed by taking the data on water quality indexes of 25 lakes as training samples. The verification of models for water quality classification of 6 lakes indecated that B-P neural network possessed not only good practicability, but also superiority over other classification methods of environmental quality because of its self-learning and self-adaptabity.

Key words: neural network, B-P algorithm, environmental quality classification.

Qualitative Analysis on the Urban Vehicular Emission Pollution Model. Zhou Hongchang and Yang Peikun et al. (Dept. of Road & Traffic Eng., Tongji University, Shanghai 200092): *Chin. J. Environ. Sci.*, **15**(5), 1994, pp. 78—82

Based on the physical process of the vehicular emission dispersion in the urban street canyon, the monitored data of CO concentration near the urban traffic roads were analysed. The microscale near field dispersion model was particularly discussed, including the initial conditions, boundary conditions and the scope of the model as well as the problems that the model might deal with.

Key words: urban trasportation, air pollution model, dispersion.

Current Status of Hazardous Waste Pollution and the Strategy for Its Control in China. Chen Liqiu (Dept. of Science and Technology, National Environmental Protection Agency, Beijing 100035): *Chin. J. Environ. Sci.*, **15**(5), 1994, pp. 83—87

Hazardous waste pollutions in soils, waters, air and organisms are very serious in China, have caused negative effects and threats to human health in some parts of China, and have become a major environmental problem which urgently need to be solved at present. This paper deals with the current status of hazardous waste pollution in China, a comprehensive analysis and comparison on the pollution control technologies and management competencies for hazardous wastes in home and abroad, and the response strategies and recommendations on pollution control of hazardous wastes which are proposed according to the local conditions in China.

Key words: hazardous waste, pollution control, response strategy.

Development of Catalytic Oxidation Technology for the Treatment of Highly Concentrated and Refractory Organic Wastewater. Wen Donghui, Zhu Wanpeng (Dept. of Environ. Eng., Tsinghua Univ., Beijing 100084): *Chin. J. Environ. Sci.*, **15** (5), 1994, pp. 88—91

Four branches of the catalytic oxidation process have been formed, i. e., wet catalytic oxidation; photocatalytic oxidation; homogeneous catalytic oxidation and heterogeneous catalytic oxidation. substantially, they all catalyze the decomposition of oxidant so as to speed up the chemical reactions between organic matters and oxidant in wastewater. Some powerful oxidants can produce much stronger radicals by catalysis to oxidate and decompose some highly concentrated and refractory organic matters. Therefore, catalytic oxidation becomes important as a new technology for the treatment of highly concentrated and refractory organic wastewater.

Key words: catalytic oxidation, organic wastewater, oxidants.