Crop Nutrition Diagnosis Expert System Based on Artificial Neural Networks

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Abstract

This research aims at designing an intelligent and carry-home diagnosis expert system (ES) to help inexpert farmers detect crop nutrition disorders in time. To ensure the reasoning veracity of the system, artificial neural networks (ANN) were proposed, and a single chip computer was applied for spot using possibility. Two subsystems and their corresponding ANN clusters were created according to the location where the nutrition disorders first took place. The symptoms of six crops were collected. The confidences and conclusions of symptoms diagnosis by field experts were used as input and output neurons of ANN. Study results were saved as a knowledge base in a flash memory. Using MCS-51C language, single chip computer diagnosis was realized. Field validation indicated that diagnosis errors were less than 8%. Moreover, the combination of ANN and ES can make up traditional expert system defects and improve the systems intelligence and diagnosis efficiency.

1. Introduction

Agricultural chemicals have a risk to impair people's health, which could result in the disruption of ecosystem. Therefore, it should be indispensable to employ farming methods, which can minimize the use of such chemicals, as well as technologies for environment conservation. It should be important to diagnose the plant conditions in using the environmentally-friendly production technology. It would become possible to conduct early protection and treatment if we can diagnose whether plants are normal or abnormal as well as the cause of abnormality. Traditionally, a lot of experts were expected to do this, but only a few experts had the ability to do this, and each expert had his own specific domain. To retain expertise and to make it more generally accessible, an intelligent and carry-home diagnosis expert system (ES) was designed, which can help inexpert farmers detect crop nutrition disorders in time. This approach could form the basis for the development of precision farming.

Expert system technology has been applied in many agricultural disciplines, and many expert systems have been built for diagnosing diseases in plants. Yialouris et al. invested a multilingual expert system for the diagnosis of pests, diseases and nutritional disorders of six greenhouse vegetables [1, 2]. M. A. Kramers et al. designed an expert system for diagnosing flower bulb diseases, pests and non-parasitic disorders [3]. Ghosh and Samanta developed an expert system for insect pest management in tea [4]. Yutaka SASAKI and Masato SUZUKI developed an automatic diagnosis system of plant disease using genetic programming [5]. Landry designed an expert system for the control of potato storage environments [6]. However many of them were traditional expert systems, which were based on personal computers. So they had inferior self-study abilities and possessed many deficiencies:

- It has difficulty in providing the correct diagnosis with insufficient input information, and the rule based knowledge presentation is difficult to simulate the expert reasoning process.
- Self-study ability is very low. So it has difficulty in solving the complicated problems. The effort, manpower and time are required to design and develop an expert system. Moreover it will cost a lot of time to search the possible fault hypotheses.
- Expert systems tend to be rigid, in the sense that, the working system adaptability to a new environment is not very well.

The objective of this research was to design an intelligent and carry-home diagnosis expert system to help inexpert farmers identifying and treating nutrition disorders in time. It will be helpful for inexpert farmers

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to minimize losses and employ fertilizer exactly. To ensure system reasoning veracity, artificial neural networks (ANN) were proposed. Microcomputer as a new technology was also applied in this system to satisfy spot using.

2. Artificial neural networks

Artificial neural networks are non-linear mapping structures based on the function of the human brain. They are mathematical modeling tools that are especially useful in the field of prediction and forecasting in complex settings. ANN use a large number of highly interconnected processing neurons, working in unison to solve specific problems, such as forecasting and pattern recognition. Each neuron is connected to certain of its neighbors with varying coefficients or weights, which represent the relative influence of the different neuron inputs to other neurons. ANN have been widely used in the agricultural field. Chris Gliever, David C.Slaughter applied ANN to distinguish crops from weeds [7]. Holger R. Maier and Graeme C.Dandy applied neural networks to predict and forecast water resources variables [8]. Wu, L.Y applied neural networks for fault diagnosis [9]. Among the many computational models of neural networks, the back-propagation network (BP network) has been shown to be theoretically sound and has demonstrated excellent capability for various complex classification and prediction problems [10]. Back–propagation uses a learning process to minimize the global error of the system by modifying node weights. The weight increment or decrement is achieved by using the gradient descent rule. The network is trained by initially selecting the weights at random and then presenting all training data repeatedly. The weights are adjusted after every trial using external information specifying the correct result until the weights converge and the errors are reduced to acceptable values. Figure.1 shows the basal BP network structure. It has input layer, hidden layer, and output layer.

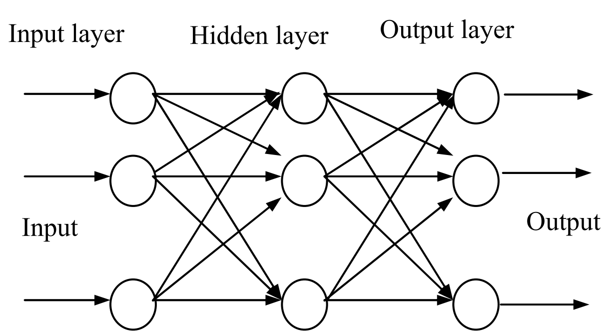

Figure1.**Structure of artificial neural network**

The delta rule was used as the learning rule, which specifies how connection weights are changed during the learning process. The sigmoid transfer function was chosen as the non–linear function that transfers the internally generated sum for each node to a potential output node.

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

The main reasons for using artificial neural networks are:

- Neural networks can realize parallel reasoning; it will be beneficial to the reasoning efficiency.
- Their generalization capability lets them deal with partial or noisy inputs.
- Neural networks can be trained instead of explicitly programmed allow a practical system to be built with much less effort than a functionally equivalent expert system. So it can solve some traditional expert system questions such as the knowledge presentation and knowledge acquisition.

Artificial neural networks can make up traditional expert system deficiencies, so the combination of the ES and ANN will be greatly close to human intelligent capability. Furthermore, advanced computer technologies have made it possible to develop an expert system using affordable single chip computer [11]. The application of single chip computer has been extensively demonstrated that it is very convenient for spot using. Figure.2 is the structure of this system.

2.1. ANN study algorithm and process

The learning steps of BP network are as follows:

(1)Establish initial weight and threshold value $w_{ij}(0)$, $\theta_j(0)$ as nonzero random number.

(2)Select some training input patterns x_p *(p=1, 2… P)*, with corresponding output patterns T_p *(p=1, 2… P)*, and feed them into the network.

(3)Compute the states of the hidden neurons and output neurons using

$$o_{kj} = f_j(\sum_i w_{ji} o_{ki} + \theta_j) \tag{2}$$

(4)Compute the training error by following rules:

$$\delta_{kj} = (t_{kj} - o_{kj}) \cdot o_{kj}(1 - o_{kj}) \tag{3}$$

$$\delta_{kj} = o_{kj}(1 - o_{kj}) \sum_m \delta_{km} w_{mj} \tag{4}$$

Where t_{kj} is the anticipant output value; k is the node number of the j layer

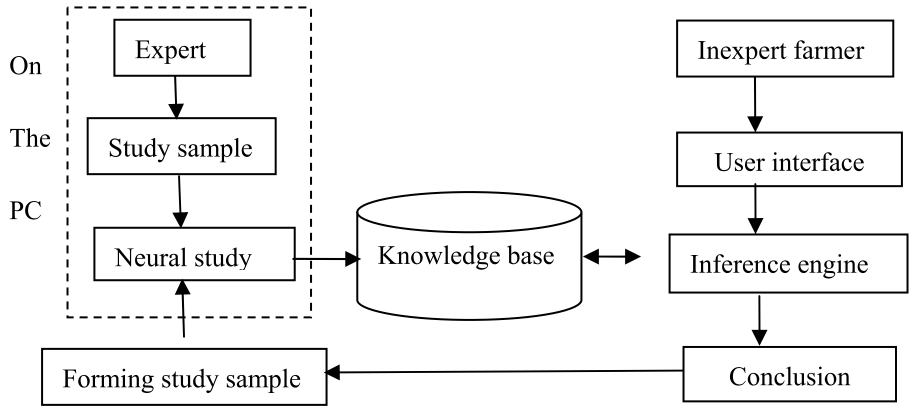

Figure2. **The structure of the crop nutrition diagnosis expert system**

(5)Update the weight vectors

$$w_{ji}(t+1) = w_{ji}(t) + \eta\delta_{kj}o_{ki} + \alpha[w_{ji}(t) - w_{ji}(t-1)] \quad (5)$$

$$\theta_j(t+1) = \theta_j(t) + \eta\delta_j + \alpha[\theta_j(t) - \theta_j(t-1)] \quad (6)$$

Where η is the study pace, here η is equal to 0.5; α is the increment or decrement tendency, here α is equal to 0.5.

(6) All steps above are applied again and again until the networks can class all the training patterns correctly, such as $E=\sum E_p<\varepsilon$, where $E_p=\sum (t_{pj}-o_{pj})^2/2$, and ε is the precision, here ε =0.0001

(7)Ending

3. Knowledge acquisition and system realization

3.1. Knowledge acquisition

Knowledge acquisition is the most critical and problematic phase in the development of an expert system. It is obvious that experts play a determining role in the system's knowledge accumulation, where the role of the knowledge engineer is important for the systems' efficiency. In this sytem, documents, such as books, pictures and papers, concerning the crop nutrition disorders and diagnostic procedures were collected. Classification and analysis of symptoms is very important stage in the process of building an ES. In this system, According to the location where the nutrient disorders first took place, the crop element deficiency was divided into two groups: N, P, K, Mg, or Mo deficiency (the symptoms first take place on the old leaves); Ca, B, Fe, Cu, S, or Zn deficiency (the symptoms first take place on the yong leaves). So two subsystems and their corresponding ANN clusters were founded.

The reliability of an ES depends mainly on the quality of knowledge that it handles. During the knowledge acquisition procedure, particular attention was paid to the accuracy of description of the symptoms and related factors associated with the nutrition disorders of the crops. In most cases, the problems which occur during growth can be identified on the basis of visual symptoms alone. This enables this system to provide users with a diagnosis on the basis of a brief description of the external appearance of the affected plant. So in this system, visual symptoms that can be easly identified by inexpert farmers were collected and their descriptions were standardized. All the symptoms of six crops (wheat, corn, cucumber, tomato, apple tree, and pear tree) were analyzed from the following five parts: macroscopically phenomenon, stalk (root) symptoms, leaves symptoms, fruit symptoms and crops pathogenesis or other causal factors. The main reason considering from these five parts is that although simple language is used to represent the symptoms in this system, a certain degree of knowledge of the plant is also required, i.e. a completely untrained user would have to learn the basic vocabulary essential to identify the various plant parts, and must learn to distinguish the subtle changes of leaf color associated with certain disorders. For example, the transition from green to pale green to pale yellow associated with element deficiency of crop, it may cause some difficulties in practical use. So from another point of view, macroscopically phenomenon, stalk (root) symptoms, and fruit symptoms were considered in this system. This did not prove a serious problem since the diagnosis in question did not depend on color alone but on other factors such as plant vigor, stem thickness and other factors. Additionally, if the nutrition disorders took place in the initial stages, another four parts can be used to diagnosis. So these five parts have pareller relationships. All symptoms were saved as the one part of the knowledge base.

3.2. System realization

Field experts were invited to diagnose from the five parts. The confidences and the corresponding conclusions they inputted were as ANN study samples. The detailed steps were as follows:

(1) Analyze and discuss with the field experts, and ask them to diagnose from the above five parts. The confidences and conclusions of symptoms diagnosis by field experts were used as input and output neurons of ANN.

(2) Train them on the PC, the connected weights were kept or written into the storage, as one part of knowledge base.

(3) Realize the single chip computer diagnosis by using MCS-51C language.

For example, in case of nitrogen deficiency of wheat, the symptoms, together with a diagnosis, were presented as follows. Simple language was used at this stage so as to assist the subsequent homogenization and ordering of information. Plant: wheat

Symptoms:

x_1（macroscopical phenomenon）: The plant is dwarf, emaciated, erect, and a little spout

x_2（leaves symptoms）: Lamina is short, narrow, and the order leaves first become yellow

x_3（stalk (root) symptoms）: Root is slight and has little root number

x_4（fruit symptoms）: Ear little and small

x_5（nosogenesis）: Too early to plant, sandy soil, fertilizer deficiency

Conclusion:

y_1: nitrogen deficiency possibility

Field experts were invited to diagnose the five symptoms. Table 1 shows some training samples of this system. From Table 1, we can see that if the actual symptoms are very alike with the five presentation symptoms, that is, the confidences are all 1, so the possibility of the nitrogen deficiency is 100%. If the respective confidences are 0.6, 0.8, 0.8, 0.4, 0.8, it represents that the analogical possibility is 60%, 80%, 80%, 40%, 80% respectively, and the possibility of the nitrogen deficiency is 95%. So in this system, five input neurons and one output neuron were got, and then training them on PC with Visual Basic 6.0 programming. After standardizing the data, selecting three hidden layers, and training 526 times, the study results were collected (Table 2, Table 3). Keep them in storage, and save as knowledge base, then program by using C language of MCS-51 to realize the single chip computer diagnosis.

Table1. **Training sample of the wheat nitrogen deficiency diagnosis**

Symptom	Confidences (expert suggest %)									
	1	2	3	4	5	6	7	8	9	10
x_1	1	0.6	0.6	0.7	0.6	0.8	0.5	0.7	0.5	0.5
x_2	1	0.8	0.7	0.6	0.5	0.4	0.4	0.4	0.8	0.8
x_3	1	0.8	0.4	0.6	0.7	0.4	0.8	0.7	0.7	0.5
x_4	1	0.4	0.5	0.8	0.6	0.4	0.6	0.6	0.4	0.3
x_5	1	0.8	0.6	0.8	0.8	0.6	0.8	0.8	0.6	0.6
y_1	1	0.95	0.75	0.80	0.65	0.45	0.55	0.60	0.70	0.30

Table2. **The weight from hidden layer unit to input unit**

Hidden layer \ Input layer	1	2	3	4	5
1	-1.398	0.154	-0.336	-2.411	-2.269
2	1.607	-1.128	-1.915	-2.299	-0.975
3	2.245	4.959	-1.474	-3.026	-1.314

Table3. **The weight from output layer unit to hidden layer unit**

Output layer \ Hidden layer	1	2	3
1	-7.983	-3.658	4.049

Table4. **Testing sample of the wheat nitrogen deficiency diagnosis**

No.	x_1	x_2	x_3	x_4	x_5	y_1（Expert diagnosis %）	System diagnosis (%)
1	0.6	0.8	0.4	0.4	0.6	0.65	0.646
2	0.4	0.5	0.6	0.5	0.6	0.35	0.349
3	0.7	0.8	0.6	0.5	0.6	0.90	0.905
4	0.8	0.5	0.7	0.6	0.7	0.80	0.788
5	0.5	0.7	0.4	0.3	0.6	0.35	0.398

3.3. System validation

This system has a high veracity after spot using by inexpert farmers. Table 4 is the comparison of system diagnosis and expert diagnosis. An expert was invited to diagnose the nitrogen deficiency. The conclusion was that the nitrogen deficiency possibility was 65%. When the inexpert farmers analyzed from the five parts and inputted that the macroscopically phenomenon analogical possibility was 60%, and others were 80%, 40%, 40%, and 60% respectively, the system diagnosis was 64.6%. For another field, the expert diagnosis was 80%, and the system diagnosis was 78.8 %. The diagnosis errors were less than 8% of that performed by a human expert. So the conclusions are very close.

3.4. Hardware

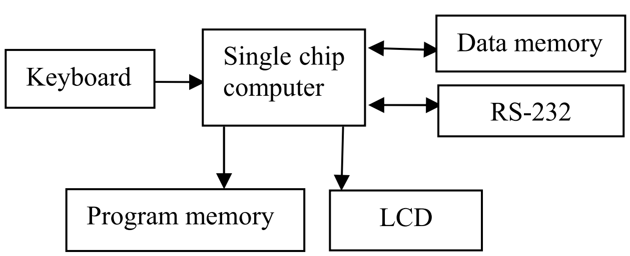

Figure3. **The structure of the hardware**

The system consisted of the following hardware (Figure3): Single chip computer, program storage, data storages, LCD, and keyboard. The central part of the system- microprocessor, determines the hardware and software performance. The 8bit microprocessor, DS80C320 was selected for its price, input and output running rate. LCD and keyboard are designed for realizing user interface. 4×4 keyboard was chose in this system. RS-232 was applied to realize communication with personal computer (PC) which will be beneficial to the knowledge base expansion.

4. Conclusion

The combination of ANN and ES can make up traditional expert system defects, and improve system intelligent levels. During the practical use, a few conclusions were obtained based on the results obtained from theoretical analysis and experimental testing:

System was designed on a single chip computer, it broke through traditional designing patterns on the PC, and it was much easier for carrying and spot using than traditional model.

The results showed that diagnosis errors were less than 8%. It indicated that the model was practicable and it provided a new pathway for nutrition diagnosis expert system.

The application of ANN made system really have the “expert” capability from the reasoning and self-studying.

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