The Machine Recognition of Wheat Crop Features from Images Based on Back Propagation Neural Network

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Abstract

A recognition system based on a self-learning back propagation (BP) neural network was designed to extract wheat crop features such as total green area and areas of individual leaves from digital images. It is discussed here along with some techniques to create favorable conditions for image recognition. These comprise: (1) the method of collecting images with a digital camera and associated equipment under natural conditions in fields, (2) an algorithm of pixel labeling to segment images and extract crop features, and (3) a high pass filter based on Laplace transformation to strengthen image information. The results of the study show that the Artificial Neural Network (ANN) system is capable of image recognition of wheat population features.

Media summary

> A recognition system with high accuracy for identifying wheat crop features, such as areas of green leaves and leaf area index, from images was established using a back propagation neural network.

Key Words

Wheat, population, digital image, leaf areas, recognition, back propagation (BP), neural network

Introduction

Features of wheat crops, such as areas of green leaves and total leaf area, are important to proper crop management. Presently, these characteristics are usually obtained by manual measurement at great cost of labor and time. The information is so limited that advanced management and planting technology are not utilized extensively because of variation due to location, seeding, and time during wheat growth. With computer technology developing in recent years, image recognition has provided many methods to resolve this problem on a large scale. Related reports have shown that the area of a side image of a maize plant was linearly related to total biomass (Li SK et al.1997) and there was also a high correlation between the hue of an image of a wheat crop and leaf area index as well as biological production in the booting-mature stage. Such values of hue can be used to monitor growth trend in the booting-mature stage (Wen XY et al. 2001). In recent years, image identification and analysis have been improved by using neural network technology in the simulation of human vision. Relevant examples include distinguishing the shape of corn kernels (Liao et al.1992) and fruits (Liu H et al. 1996). In this paper, we have used artificial neural network technology to develop a method to investigate individual leaf areas and total crop green leaf area of wheat.

Methods

1. Sample images of wheat and data collection

A high-yield experimental wheat crop was planted in 1998-2001 at four densities, 900, 1800, 2700, and 3600 thousand plants per hectare, respectively. Digital images were taken vertically and at 45^{o} from the horizontal at various stages of wheat growth and development. Areas of leaves, stem sheaths, and spikes were measured at the same time with a leaf area detector (Licor-1600). These data were used as the information resource for learning by an Artificial Neural Network (ANN). To ensure consistency of the images, a technical specification was established to maintain constant shooting angle, distance, and angle of incidence light.

2. Equipment and software

The hardware comprised a digital camera and portable computer operated by Windows95/98/NT. Software included the Access97 data base and specialized programs that were written in Microsoft Visual C++ for readability, reliability, and transportability.

Results

1. Image processing and 2feature extraction

The wheat image, together with a referencing icon, a red circle, were separated from the background and marked with a pixel-labeling algorithm. By comparing several processing methods, it was shown that a high pass filter based on Laplace Transformation was optimal to strengthen the image information. The edges of the wheat image were clearly outlined once the segmented wheat image was strengthened. The projected area of green wheat was calculated by adopting a pixel-labeling and segmentation algorithm. The red circle icon provided a size reference for computing total green area and green areas of leaves in the whole processing system.

2. Self-learning artificial neural network information processing

The extraction of projected area of a wheat crop by image processing was used as a learning excercise and then the exact value of total green areas and green leaf areas were output by using self-learning ANN system. The input-output of sample information can be transformed into non-linear problem by a BP algorithm of gradient decline. A BP neural network consists of an input layer, one or more hidden layers, and an output layer. The input layer fans out the input data without making calculations. The data flow along the connection towards the hidden and the output layers. Each unit in the hidden layer transforms the incoming data by executing specified functions and then outputs the transformed data to the next layer. Each unit in the output layer makes a similar transformation on the data from the hidden layer and, optionally, from the input layer. The final result is the mapping of the input vector into a corresponding output vector at the output layer. In this study, key technology is as follows:

2.1 Original data standardization processing

The unit value in the neural network is between 0 and 1. If the value in the input layer equals 0, there is no transformation of data to the hidden and output layers. In order to avoid this occurrence, the input vectors should be standardized as shown by Eqn (1), where V_i is a variable of unit i, and V_{imin} and V_{imax} are maximum and minimum values of unit i, respectively.

$$S_i = 0.8\,\frac{V_i - V_{imin}}{V_{imax} - V_{imin}} + 0.1 \qquad (1)$$

2.2 Number of units in hidden layer

The number of units in the layer is directly related to the recognition result in the BP neural network. As shown In Fig. 1, when the number of units in the hidden layer equals 5, the root mean square (RMS) error of the testing set and training set reaches a minimum thus avoiding “over-training”.

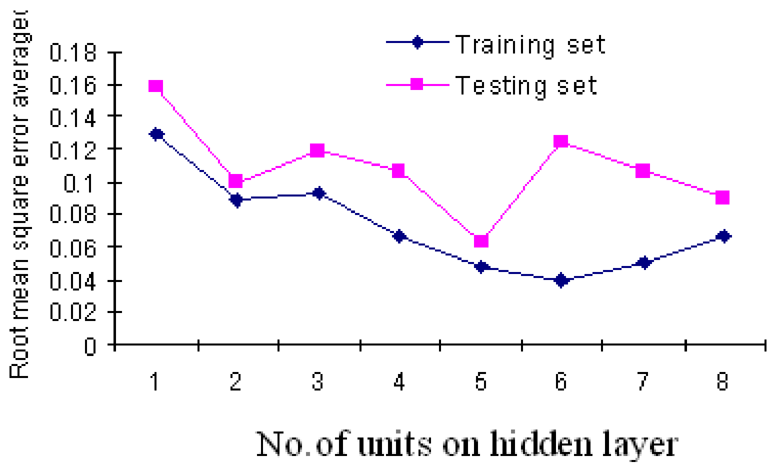

Figure 1. Effects of number of units in hidden layer of BP network on the results of image recognition for population feature of wheat

2.3 Iteration times

In order to avoid "over-training", the method uses the r.m.s error of the testing set to monitor the r.m.s. error of training set. It is shown in Fig.2 that during the network training, r.m.s. error of the training set declines and while r.m.s. error of the testing set declines from the outset it may then remain level or increase. It is also shown that when the learning rate equals 0.25 and the iteration time equals 300000, that the r.m.s. error of testing set approaches a minimum value and iteration should cease regardless of the increae or decrease of the r.m.s error of the training set. As a result, the correspondence weight values are used to fix recognition network model of wheat crop characteristics.

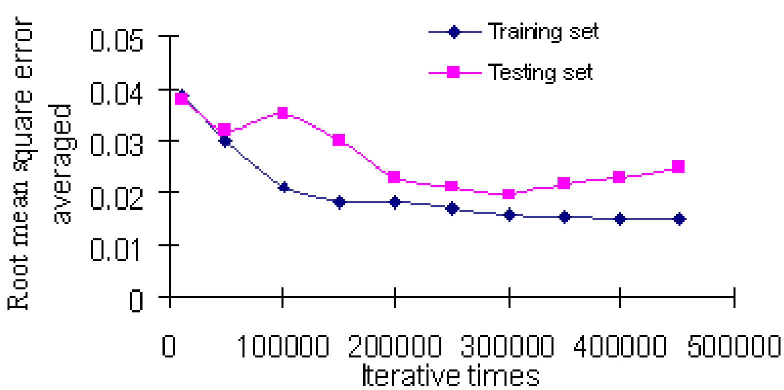

Figure 2. Effects of number of iterations on the results of network training

3 Identifying total green areas and leaf areas of a wheat crop

Thirty-six images of wheat at the heading stage were selected as the training set for the construction of the ANN recognition model. The recognition results for sixteen images that were selected at random ar shown in Table 1. Compared to traditional geometric methods, recognition precision of wheat total green area and leaf area averages by using ANN are 85.4 and 86.4%, respectively. This shows that the method using a BP neural network is able to identify total green areas and leaf areas of wheat crops.

Table 1. Comparison of ANN image recognition and manual measurement

Code[1]		Total green areas (cm^2)			Areas of green leaves (cm^2)			
	Image areas of wheat shadow (cm^2)	Manual measuring	Image recognition	Relative error (%)	Manual measuring	Image recognition	Relative error (%)	LAI
				Training set				
001(H)	7156.6	15232	15239.3	0.05	10559	10662.1	0.98	4.26
002(H)	8227.8	18142	18970.1	4.56	13487	13386.1	0.75	5.35
003(H)	7576.6	16864	16391.8	2.80	11730	11544.7	1.58	4.62
004(H)	8087.3	18064	18392.1	1.82	12311	12475.8	1.34	4.99
005(H)	9558.3	18538	19913.9	7.42	13760	14025.3	1.93	5.61
006(H)	8025.0	17885	19305.5	7.94	12339	12596.8	2.08	5.04
007(S)	8179.4	18142	16942.4	6.61	13487	12998.6	3.63	5.20
008(S)	8160.7	18538	19426.8	4.81	13760	13682.3	0.57	5.47
Means	8121.5	17676	18072.7	4.50	12679	12671.5	1.63	5.07
				Testingset				
009(H)	5837.4	18820	15409.1	18.12	13152	10284.3	21.80	4.11
010(H)	6707.3	17712	15172.6	14.34	12307	10686.1	13.17	4.27
011(H)	7297.7	22950	17955.4	21.76	17046	13712.1	19.56	5.48
012(S)	7518.1	18064	16690.0	7.61	12311	11754.7	4.52	4.70
013(S)	6058.5	17885	14145.8	20.91	12339	9805.8	20.54	3.92

014(S)	6882.6	18820	17419.0	7.44	13152	12268.2	6.72	4.91
015(S)	5640.3	17712	13614.9	23.14	12307	9784.6	20.50	3.91
016(V)	7912.3	18142	18732.2	3.25	13487	13193.0	2.18	5.28
Means	6731.8	18763	16142.4	14.57	13263	11436.1	13.62	4.57

1H,S,V in parentheses represents wheat images taken from the angle of horizontal level ,45 degree, and verticality, respectively

Conclusion

This result was achieved for wheat plants growing in a high density crop of over one million stalks per mu, with leaves touching or overlapping. Successful crop management systems require more real-time crop data than can be obtained at present. In this paper, a system with high recognition accuracy for identifying wheat crop image features, such as green area and leaf area index, was established using BP neural network. The work showed that a self-learning BP neural network could readily identify the features and this was an important part of the high-yield wheat crop intelligent image recognition using a multi-media expert system. As the methods presented are not restricted to a single species, they should be easily transferable to other crops, disease incidence, the shape of individual plants, quality, and aspect etc. Meantime it also provides technology to create an expert system for the diagnosis of the condition of wheat crops.

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