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Efficient detection of internal infestation in wheat based on biophotonics

Weiya Shi [a,b,*], Keke Jiao [a], Yitao Liang [a,b], Feng Wang [a,b]

[a] School of Information Science and Technology, Zhengzhou 450001, China
[b] Grain Information Processing and Control Key Laboratory of Ministry of Education, Henan University of Technology, Zhengzhou 450001, China

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ABSTRACT

In the process of grain storage, there are many losses of grain quantity and quality for the sake of insects. As a result, it is necessary to find a rapid and economical method for detecting insects in the grain. The paper innovatively proposes a model of detecting internal infestation in wheat by combining pattern recognition and BioPhoton Analytical Technology (BPAT). In this model, the spontaneous ultraweak photons emitted from normal and insect-contaminated wheat are firstly measured respectively. Then, position, distribution and morphological characteristics can be extracted from the measuring data to construct wheat feature vector. Backpropagation (BP) neural network based on genetic algorithm is employed to take decision on whether wheat kernel has contaminated by insects. The experimental results show that the proposed model can differentiate the normal wheat from the insect-contaminated one at an average accuracy of 95%. The model can also offer a novel thought for detecting internal infestation in the wheat.

1. Introduction

The grain quantity and quality can be largely diminished in its storage procedure for the sake of insects. The grain insects, especially internal infestations, such as maize weevil, and Olivier are very harmful to the storage of grain. Therefore, it is essential to find a rapid method to detect internal infestations in grain. However, internal infestations are difficult to detect because they are hardly visible from exterior of the wheat. This makes the detection process very time-consuming and laboursome [1,2]. The grain price may seriously fluctuate for the sake of the quality of grain reserves [3]. Therefore, grain safety is one of the most concerned issue which attaches great importance in many countries.

At present, the researches of detecting internal infestation are paid great attention at home and aboard. The common stored-grain insect detection technology consists of screening [4], trap catching [5], voice detecting [6], computer vision recognition [7], electronic nose [8], and so on. However, most of these methods have one or more weaknesses. For example, some methods have the strong subjectivity, destructiveness and inaccuracy. In addition, these methods are only fit to detect external infestations while failing to the discovery of internal infestations. In recent years, many advanced methods, such as nuclear magnetic resonance spectroscopy (NMR) [9], X-ray image analysis [10] and the Near-Infrared Reflectance spectroscopy (NIR) [11,12], have been introduced to deal with the problems. But, NMR and X-ray are unsatisfied due to radioactivity and high cost. NIR cannot be employed widely because of its inconvenient operation and unaffordable cost. Therefore, it is necessary to explore some rapid, objective, non-destructive and effective detection method. The appearance of Biological Photon Analysis Technology (BPAT) [13–17] offers an opportunity of detecting internal infestations in the wheat kernels.

Biophoton emission, which is a universal biological phenomenon, exists in a variety of animals, plants, and microorganism system. The phenomenon firstly discovered in an onion experiment by A.G. Gurwiitsh in 1923 [18]. It is metabolic process of lives indicating the state transition from high energy state to lower energy state. Then, a large number of experiments show that biophoton emission change evidently with interior changes of biological system, such as pathology, and injury. With the development of optoelectronic detection technology, researches about biophoton emission have been increasingly concerned in many applications like medicine, pharmacology, and environmental science [19–21]. In agriculture, there are also many researches about the freshness, seed resistance and relation with the ultraweak photon emission [22,23]. However, it remains tentative in internal infestation detection in the field of grain.

Combining Biophoton Analytical Technology and pattern recognition, this paper innovatively proposes a detecting model for internal infestation in the grain. The model firstly utilizes the ultraweak photon detection system to separately measure the spontaneous photons emitted from the normal and insect-contaminated wheat. Then, position, distribution and morphological features are respectively extracted for the construction of distinguished feature vector. Backpropagation (BP) neural network is employed as the classification algorithm. However, BP algorithm converges slowly and easily falls into the local optimum. In this paper, the GA–BP neural network (Genetic Algorithm–Backward Propagation neural

* Corresponding author.
E-mail address: wyshi@fudan.edu.cn (W. Shi).

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network) is introduced to optimize the weight and bias of the neural network. The model can distinguish the normal with the insect-contaminated wheat, which can acquire the recognition accuracy of 95%.

The remainder of the paper is organized as follows: Section 2 describes basic BP neural network based on Genetic Algorithm. Section 3 gives some introduction about materials and methods. In Section 4, feature extraction and data processing are presented. Section 5 shows the experimental results and discussion of the proposed method. The paper is finished with conclusion in Section 6.

2. BP Neural Network Based on Genetic Algorithm

2.1. BP Neural Network

Backpropagation (BP) is a traditional algorithm in the region of artificial neural networks, which has been widely used in signal processing, pattern recognition, adaptive control and so on [24,25]. In general, BP neural network consists of input layer, hidden layer and output layer, as illustrated in Fig. 1. Input layer is responsible for receiving the external input information, hidden layer is in charge of the internal information processing, and the output layer gives the ultimately processed result. The algorithm is composed of forward and back propagation, which is successive learning process. In the procedure of forward propagation, the input information is dealt with to produce the output. When the output is inconsistent with desired result, back propagation of error begins. In the learning procedure, the weights and bias values of neural network, which denote the leaning parameters of the neural network, are continuously updated until error is less than a predefined value.

In Fig. 1, x denotes the input information of network, y is the output of hidden layer, z is the final output and f is the transfer function. Each layer has its own weight matrix $\overrightarrow{W}$ and threshold vectors θ, and γ. In the training process, some parameters (weights matrix and threshold vector) need to be learned gradually.

However, BP neural network has some shortcomings. For example, it converges slowly and is easily trapped in the local optimum. In addition, its initial weights and bias values are randomly selected so that the optimal values cannot be necessarily obtained after a number of training and learning.

2.2. Genetic Algorithm

Genetic algorithm (GA) is a searching method, which is inspired by evolutionism. It was always used to find exact or approximate solutions of some problems. The fundamental procedure can be outlined as follows.

i. Some candidate solutions (called individuals) of some problem are firstly represented by a population of abstract representations (called chromosomes).
ii. The representations are updated, based on the idea of mutation, selection, and crossover, evolving toward optimization solutions.

The evolution generally starts from a population of randomly generated individuals. In each procedure, the fitness value of every individual in the population is evaluated. Multiple individuals are randomly selected and modified to form a new population. The new population is then treated as the next iteration. The algorithm terminates when either a satisfactory fitness level has been reached, or a maximum number of generations has been produced. In recent years, it has been used to computational science, economics, chemistry, manufacturing and other fields [26,27].

2.3. GA–BP Algorithm

Combining the learning ability of BP algorithm and the global search ability of genetic algorithm, the GA–BP neural network [28–31] (Genetic Algorithm–Backward Propagation neural network) can be used to improve the performance of BP algorithm. The whole procedure consists of two steps:

i. Genetic Algorithm is firstly used to optimize the weight and bias value of BP network.
ii. Then, BP algorithm is used to explore the optimum classifying result in the solution space.

In the computation of GA–BP, several issues need to be considered, which consist encoding method, fitness function and evolutional operation.

A. Encoding method.

Coding is one fundamental step in the design of GA, which represents the input data with some code. At present, there are many encoding methods, such as binary encoding, real coding, gray coding and so on. This paper uses real coding method, which can improve the accuracy and running speed of algorithm.

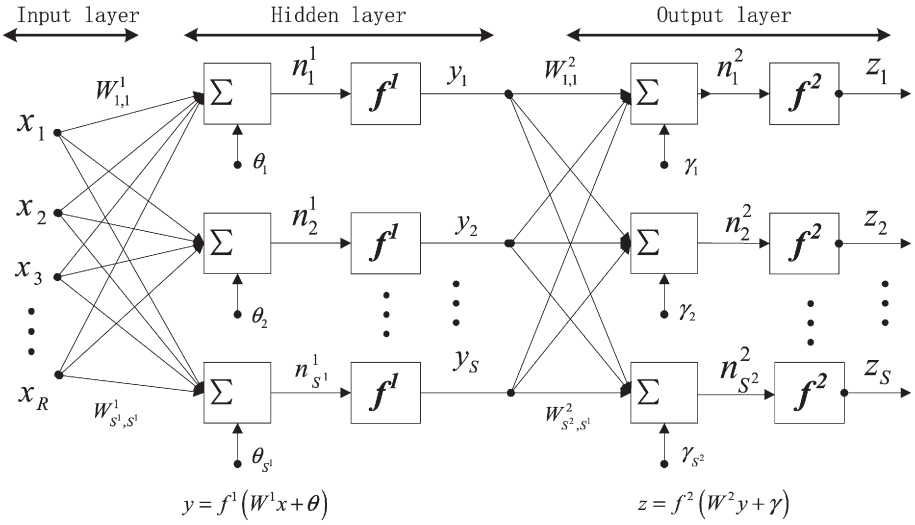

Fig. 1. Three-layer BP network structure.