Navel Orange Pest Image Recognition Based on Convolution Deep Neural Network

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Abstract — A navel orange disease & pest image recognition algorithm based on conventional neural network is proposed. Firstly, characteristics of navel orange diseases & pests are described on the basis of various colors and forms of diseases & pests and their data are collected and extracted. Secondly, the Convolutional Neural Network (CNN) is described: i) input data are expressed in two-dimensional array and CNN operates in the input image window in the training and test stages, ii) the characteristics are observed by weight via the window in the input data, and iii) CNN training and recognition of navel orange disease & pest image are realized. Finally, the effectiveness of the method is verified by experiments.

Keywords - convolution neural network; navel orange disease & pest; image recognition; characteristic extraction

I. INTRODUCTION

In recent years, global climatic deterioration is accelerated, environmental conditions become more weaken and burst of crop diseases & pests is rising (disease & pest spreading speed depends on environmental conditions and susceptibility to infection of plants). Prevention measures can be effectively taken only by promptly and accurately recognizing crop diseases & pests. Traditional disease & pest detection and recognition completely rely on personal experience and visual observation and it has disadvantages of slow speed, strong subjectivity, high misjudgment rate and bad real-time property.

As precise agriculture is emerging, a new thinking pattern for crop disease & pest recognition is provided when information technologies are used to assist agricultural production and image processing technology is one of them. Image processing is the process that image signal is transferred into corresponding digital signal and processed by the computer. Navel orange disease & pest image recognition technology is the application of image processing technology in crop disease & pest recognition and a technical approach to replace traditional manual recognition. This method is faster, more accurate and more real-time the tradition method in navel orange recognition. It can promptly and accurately recognize category of disease & pest before the disease bursts out and provide essential information for farming people to take measures to control and prevent disease and pest spreading. Chinese and foreign experts and scholars have done a great number of researches in this field and research contents mainly include navel disease & pest image segmentation, characteristic extraction and category recognition.

Convolution neural network is applied in the thesis to recognize the image of navel orange diseases and pests on the basis of various colors and forms of navel orange diseases & pests and disease & pest characteristic description and finally effectiveness of the method mention is verified in the experiment.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Pest</th>
<th>Orange thrips</th>
<th>Phyllocoptruta oleivora ashmead</th>
<th>Polyphagotarsonemus latus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Early stage</td>
<td>Middle stage</td>
<td>Late stage</td>
</tr>
<tr>
<td>Training sample/PCS</td>
<td>9</td>
<td>10</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>Test sample/PCS</td>
<td>8</td>
<td>11</td>
<td>3</td>
<td>9</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample</th>
<th>Disease</th>
<th>Anthrax-dry</th>
<th>Anthrax-tear stain</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Early stage</td>
<td>Middle stage</td>
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<tr>
<td></td>
<td></td>
<td>Early stage</td>
<td>Middle stage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mechanical injury</td>
<td></td>
</tr>
<tr>
<td>Training sample/PCS</td>
<td>13</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Test sample/PCS</td>
<td>12</td>
<td>5</td>
<td>7</td>
</tr>
</tbody>
</table>
II. EXTRACTION OF NAVEL ORANGE DISEASE & PEST CHARACTERISTICS

A. Experiment Material

Newhall navel orange is native to America and it is the bud mutation of Washington navel orange in California, USA. Because of its beautiful appearance, superior meat and good commodity characteristic, it was introduced to China in 1978 and has become one of the major cultivation species of oranges. 324 Newhall navel oranges with diseases & pests were picked in the orange plantation in the first ten days of October. Considering typical characteristics of early-stage, middle-stage and late-stage disease & pest, 138 training samples and 122 test samples are selected from 4 common disease & pest categories. To calibrate recognition accuracy of machine, samples with mechanical injury are selected and number of each category of samples is shown in Table 1. In the natural lighting, take pictures of the oranges successively by camera and then segment the image and remove the background by blue component threshold to prepare for disease & pest edge detection and characteristic extraction.

B. Disease & Pest Edge Detection

Disease & pest is corresponding to the disease & pest. Precision of edge detection directly affects the disease & pest recognition accuracy so it is a common method in image segmentation to improve watershed algorithm and overcome disadvantage of excessive segmentation of traditional watershed algorithm. Steps of the algorithm are as follows:

1) Disease & pest color characteristic extraction. The navel orange diseases and pests vary in colors and forms, two categories of parameters are used in the thesis to describe the characteristics of diseases and pests.

2) Disease & pest fractal characteristic extraction. In the over 30 years since fractal was proposed, it has developed into an emerging mathematical branch rapidly and is widely applied to process and analyze natural phenomena with complex detailed characteristics. Disease & pest hazard has such characteristic. Therefore, fractal concept is introduced in the thesis and highly steady and small-deviation perimeter-area method is used in the thesis to calculate the fractal dimension of disease & pest hazard.

Suppose binary function \( f(x, y) = \{f(i,j)\}_{x,y} \) is navel orange disease & pest image, \( i,j \) are the row number and line number of the image matrix, \( M \) and \( N \) are the maximum row and line of the image matrix, \( \delta \) and \( L \) are the boundary and perimeter of disease & pest hazard and \( A \) and \( A \) are disease & pest hazardous region and area. Calculate perimeter \( L \) and area \( A \) with pixel count as measurement unit:

\[
L = \sum_{x=1}^{M \times N} \text{pixel}(i,j)
\]

\[
A = \sum_{x=1}^{M \times N} \text{pixel}(i,j)
\]

According to B. Mandebrot fractal theory, navel orange disease & pest perimeter-area fractal dimension \( D \) is:

\[
D = \frac{\ln L - \ln \delta}{\ln A}
\]

Where, \( \delta \) is the factor of navel orange disease & pest and is related to the category of navel orange diseases and pests.

III. NAVAL DISEASE & PEST RECOGNITION BASED ON CNN

A. Network Mapping Construction

In the model recognition algorithm based on CNN, input data shall be expressed in form of characteristic mapping. Input data are expressed as the input two-dimensional array and presented in horizontal \( x \) and vertical \( y \) pixels. CNN operates in the input image window in training and test stage so network weight can observe characteristics of navel orange diseases and pests via the window in input data.

At present, there are many types of DNN matrix input forms. Under such circumstances, two-dimensional convolution computation can proceed and frequency and time can be normalized at the same time. Or, only frequency is normalized here. Under such circumstances, the same navel orange disease & pest characteristics are classified into one-dimensional characteristic mapping. Once input characteristic vector is constructed, implement activation in convolution layer and aggregation layer. Similar to input layer, convolution layer and aggregation layer of the unit can be expressed as mapping matrix. In CNN terms, convolution layer and aggregation layer can be expressed as one CNN layer.
B. CNN Convolution Layer

As shown in Figure 1, for each input characteristic mapping, suppose $I$ is total mapping numbers, \( O(i = 1, \ldots, I) \) is connected to multiple characteristic mappings (suppose total number is \( J \)), \( Q(j = 1, \ldots, J) \), convolution layer based on local weight matrix is \( I \times J \), \( w_{ij} \). Mapping can be expressed as the convolution computation in the signal processing. Suppose input characteristic mapping is one-dimensional and characteristic mapping of each neutral convolution layer can be figured out:

\[
q_{j,m} = \sigma \left( \sum_{i=m}^{m+s} o_{i,m} w_{ij} \right) \quad (j = 1, \ldots, J)
\]

Where, \( o_{i,m} \) is the characteristic mapping \( O \) of neuron \( m \) input at the \( i \)th time; \( q_{j,m} \) is the neuron \( m \) of convolution layer characteristic mapping \( Q \) input at the \( j \)th time; \( w_{ij} \) is the \( n \)th element of weight vector \( w \); \( F \) is the size of filter and its value depends on the band number of characteristic mapping input by each convolution layer.

C. CNN Aggregation Layer

As shown in Figure 2, apply aggregation operation in CNN convolution layer to generate corresponding aggregation layer. Aggregation function is separately applied to each convolution characteristic mapping. When the maximum aggregation function is used, CNN aggregation layer can be defined as [14]:

\[
P_{i,m} = \max_{j=1}^{G} q_{i,j-i+p+s}
\]

Where, \( G \) is scale of aggregation layer and \( s \) is displacement to determine the contact ratio of adjacent aggregation windows. Similarly, if average function is used, the output is:

\[
P_{i,m} = \frac{1}{r} \sum_{j=1}^{G} q_{i,j-i+p+s}
\]

Where, \( r \) is scale factor that can be learnt. Generally in image recognition application, when constraint \( G = s \) and aggregation windows do not overlap, there is no space between. In this situation, maximum aggregation characteristic mapping is better than the average aggregation characteristic mapping. In the text work, \( G \) and \( s \) are adjusted separately. In addition, non-linear activation function is used to generate final output. Figure 3 is the aggregation process diagram when size of aggregation layer is 3. Each aggregation layer size would be one third of size of convolution layer.

IV. EXPERIMENT RESULT AND ANALYSIS

Disease & pest hazard edge detection is carried out in the thesis by improved watershed algorithm, diseases and pests are marked and the widest distributed category is
Phyllocoptruta oleivora Ashmead. Three double color component averages of training samples of oranges with 4 diseases and pests and mechanical injury are shown in Table 2. According to equation (4), calculate fractal dimension of 151 training samples, including oranges with mechanical injury. Table 3 is the statistical distribution of fractal dimension. Hazardous area of Phyllocoptruta oleivora Ashmead is large and complex and fractal dimension is big; hazardous area of anthrax and polyphagotarsonemus latus is small and they are relatively concentrated and simple and fractal dimension is relatively small; mechanical injury is mainly concentrated on one point, form is simple and fractal dimension the is minimum.

Detect the test samples in the navel orange disease & pest recognition model that has learnt in training samples and recognition performance is shown in Table 4. Color and form of pest varies greatly in the different hazardous period of phyllocoptruta oleivora Ashmead and recognition accuracy is the lowest; although color of mechanical injury changes in the early and late stages, the form is simple and recognition accuracy is the highest; average recognition accuracy of oranges with 4 disease and pests and mechanical injury is 85.51%.

<table>
<thead>
<tr>
<th>TABLE 2. DISEASE &amp; PEST COLOR CHARACTERISTICS</th>
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<tbody>
<tr>
<td>Sample</td>
</tr>
<tr>
<td>Orange thrips</td>
</tr>
<tr>
<td>R</td>
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<tr>
<td>G</td>
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<td>B</td>
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<tr>
<th>TABLE 3. FRACTAL DIMENSION DISTRIBUTION</th>
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<tbody>
<tr>
<td>Sample</td>
</tr>
<tr>
<td>Orange thrips</td>
</tr>
<tr>
<td>R</td>
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<tr>
<td>G</td>
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<thead>
<tr>
<th>TABLE 4. PERFORMANCE OF NAVEL ORANGE DISEASE &amp; PEST MAPPER</th>
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<tbody>
<tr>
<td>Sample</td>
</tr>
<tr>
<td>Orange thrips</td>
</tr>
<tr>
<td>Misjudgment/PCS</td>
</tr>
<tr>
<td>Recognition accuracy/%</td>
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</tbody>
</table>

V. CONCLUSIONS

A navel orange disease & pest image recognition algorithm based on CNN is proposed in the thesis. Disease & pest characteristics are described based on various colors and forms of navel orange diseases and pests and navel orange disease & pest characteristics in two-dimensional array are trained and predicted by NCC. Experiment result demonstrates effectiveness of the method mentioned. Technologies of ultrasound, infrared ray, laser and frequency spectrum are integrated to complement disease & pest characteristics and improvement of disease & pest recognition accuracy is the major research content in the next stage.

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REFERENCES


