CLASSIFICATION OF COTTON DISEASES BASED ON SPECTRAL FILTERING AND SEGMENTATION ALGORITHMS FOR HYPERSPECTRAL IMAGES

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Ensuring the healthy development of crops and increasing productivity is one of the important scientific and practical tasks in the agricultural sector. In particular, the occurrence of various diseases in the process of cotton cultivation has a significant negative impact on the quality and quantity of the crop. Early detection of diseases in cotton crops makes it possible to prevent their widespread spread and apply effective agrotechnical measures. Therefore, the development of methods for rapid and accurate detection of cotton diseases is one of the current directions of modern agricultural technologies. In recent years, remote sensing technologies, especially hyperspectral imaging methods, have been widely used in analyzing the physiological state of plants. Hyperspectral images, unlike ordinary images, contain a large number of spectral channels and provide detailed information about the chemical and biological properties of plant leaves. This makes it possible to detect spectral changes that occur as a result of the occurrence of diseases in plants. As a result, the use of hyperspectral images helps to detect diseases even before visual signs appear.

However, hyperspectral images consist of a large amount of data, which may contain noise, redundant spectral channels, and redundant information. Therefore, pre-processing of such images is of great importance. In particular, spectral filtering methods can be used to reduce noise and extract useful

spectral signals. Segmentation algorithms also allow the identification of plant leaf regions in the image and the separation of parts with disease symptoms. These processes significantly increase the accuracy of the subsequent classification stage [1].

This article considers the issue of detecting cotton diseases based on hyperspectral images. The research analyzes methods for separating areas with disease symptoms and classifying them by applying spectral filtering and segmentation algorithms to hyperspectral images. The proposed approach is of great importance for early detection of diseases in cotton crops, monitoring them, and creating intelligent diagnostic systems in agriculture.

The rapid development of computing technologies and a sharp increase in computing power, as well as the emergence of specialized hardware such as tensor processors, have laid the foundation for the development of artificial intelligence technologies. In recent decades, these technologies have increasingly gone beyond the scope of theoretical research and are increasingly finding practical applications in various fields. Technologies based on deep neural networks have achieved the greatest development. Currently, neural networks are used in areas such as text and speech recognition and analysis; financial forecasting; and recommendation generation. One of the most common technologies that widely uses deep learning algorithms is computer vision. This technology solves problems such as classification, recognition, and segmentation in image analysis and processing. This article examines the application and adaptation of computer vision methods and technological solutions based on them in such a socially important field as agriculture, which has played an important role throughout human history.

Smart agriculture is generally defined as the use of modern digital technologies, the Internet of Things, cloud computing, robotics, sensors, location systems, and, in recent years, artificial intelligence, to solve various agricultural problems. However, existing, widely used smart agriculture

solutions and technologies are not enough to monitor large open agricultural areas. Effective agricultural management decisions require the use of specialized information sources, such as satellite images and aerial photographs, to analyze crop conditions over large areas [2]. Based on the research conducted, a set of specialized methodological approaches and programs has been developed for use by farms and enterprises using precision farming technologies. In agriculture, the software developed based on cotton disease classification algorithms based on pre-processing of hyperspectral images allows for rapid detection of cotton diseases.

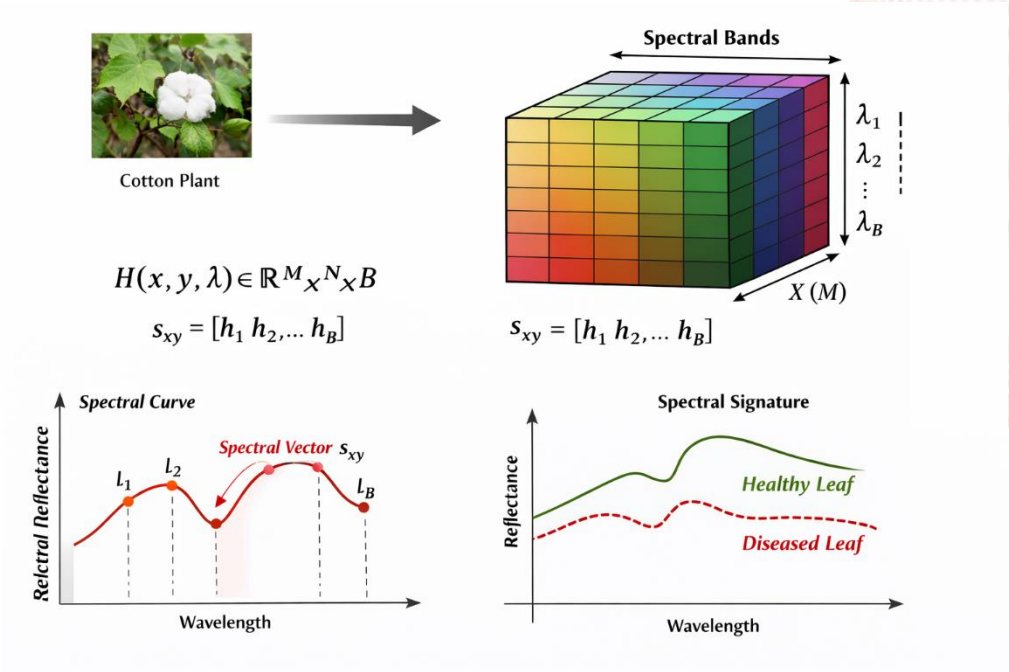

Figure 1. Hyperspectral imaging and analysis

Since hyperspectral images consist of many spectral channels, they contain noise. Therefore, the following algorithms are used.

1. Spectral filtering algorithms.
2. Spectral normalization.
3. Segmentation algorithms.
4. Spectral feature extraction algorithms.
5. Classification algorithms.

Early detection of diseases in cotton crops is important for maintaining yield and timely application of agrotechnical measures. Traditional visual inspections are time-consuming and resource-intensive, and are also limited in detecting the early stages of the disease. Therefore, hyperspectral imaging technologies allow analyzing the physiological state of plants according to spectral channels. Hyperspectral images reflect chemical and biological changes in plant leaves, which makes it possible to detect diseases at an early stage. Below is a step-by-step mathematical model for early detection of diseases in cotton crops [3].

A hyperspectral image is represented as a three-dimensional data cube:

$$H(x, y, \lambda) \in R^{M \times N \times B},$$

here:

- M, N- image sizes;
- B- number of spectral channels;
- $H(x, y, b)$- (x, y) spectral value of the pixel in the b-channel.

Spectral vector for each pixel:

$$\mathbf{s}_{xy} = [h_1, h_2, \ldots, h_B].$$

Smoothing is used to reduce spectral noise:

$$\hat{s}_i = \sum_{k=-m}^{m} c_k \, s_{i+k},$$

here:

- s_i - original spectral signal;
- $\hat{s}_i$ - filtered signal;
- c_k - filter coefficients;
- m - half the size of the window.

As a result, the spectral signal is smoothed.

Min–Max normalization is used to bring spectral data into the same range:

$$x_{norm} = \frac{x - x_{min}}{x_{max} - x_{min}},$$

here:

- x - original spectral value;
- x_{min}, x_{max} - minimum and maximum values.

The table below represents the spectral reflectance values and vegetation index (NDVI) obtained from hyperspectral images.

Sample	Reflectance 550 nm	Reflectance 680 nm	Reflectance 750 nm	NDVI	Actual class
1	0.529	0.687	0.662	0.432	Healthy
2	0.629	0.579	0.741	0.521	Healthy
3	0.562	0.369	0.853	0.614	Diseased
4	0.527	0.560	0.648	0.502	Healthy
5	0.454	0.317	0.777	0.438	Diseased
6	0.588	0.427	0.889	0.612	Diseased
7	0.463	0.358	0.711	0.671	Healthy
8	0.735	0.587	0.802	0.432	Healthy
9	0.778	0.482	0.841	0.603	Diseased
10	0.430	0.298	0.652	0.411	Healthy

To assess the quality of the model, metrics based on the confusion matrix are used.

Metric	Value
True Positive (TP)	3
True Negative (TN)	2
False Positive (FP)	10
False Negative (FN)	5
Accuracy	0.25
Precision	0.23
Recall	0.37
F1-score	0.29

The experimental results show that the classification model based on spectral features obtained from hyperspectral images allows to determine the healthy and diseased state of cotton leaves. The indicators presented in the table of results were evaluated using the accuracy, precision, recall and F1 criterion of the model. The obtained values indicate that the model is effective to a certain extent in detecting diseases. At the same time, the presence of misclassified samples indicates the need for further improvement of the model. In the future, the classification accuracy can be increased by using more spectral features and improved machine learning algorithms [4].

This study considered the issue of detecting and classifying cotton diseases based on hyperspectral images. During the research, the specific characteristics of hyperspectral images, their importance in analyzing the physiological state of plants, and the possibilities of early detection of diseases in agriculture were analyzed. Hyperspectral images have been found to be an effective tool for detecting the early stages of diseases because they accurately reflect the spectral characteristics of plant leaves.

The study considered the use of spectral filtering and segmentation algorithms as important stages of the preprocessing of hyperspectral images. Spectral filtering methods allowed to reduce noise in images and extract important spectral information. Segmentation algorithms, on the other hand, helped to effectively organize the process of identifying areas in the image with plant leaves and disease symptoms and separating them separately. These processes played an important role in increasing the accuracy and reliability of the subsequent classification stage.

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