DECISION SUPPORT FOR PRECISION FARMING COMPLEX

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In the article algorithms for decision support for hardware and software complex are described. The complex is used for few precision farming tasks: data mining, data processing, decision making and control of fertilizers applying. The complex is designed to reduce costs and environmental burden on potato. The complex is based on processing aerial images photographs of potato fields.

Introduction

Modern methods of thematic cartography and resource management are demanded more and more for remote sensing data (RSD) processing. These data are used in areas such as cartography and land cadastre [1], agronomy and precision agriculture [2,3], a forestry [4], a development of water systems [5], an environmental monitoring [6] etc.

One of the most important areas of image processing is a precision agriculture area. Efficient processing of raw data allows reducing material and other costs in problems associated with crop cultivation and forecasting, a monitoring of level of crops germination and many other applications.

The basic concept of precision agriculture is the fact that a vegetation cover is not uniform within a single field. Up-to-date technologies are used to evaluate and detect these irregularities: global positioning systems (GPS, GLONASS), special sensors, aerial photographs and satellite imagery, as well as special software systems based on GIS. RSD are used for a more accurate evaluation of the seeding density, calculation of application rates and crop protection, more accurate prediction of yield and financial planning. Also, it must take into account local peculiarities of soil and climatic conditions. In some cases it may make it easier to determine the reasons for the deterioration of vegetation.

There are a number of systems for precision agriculture tasks: The Monitoring of Agriculture with Remote Sensing (MARS), Variogram Estimation and Spatial Prediction plus ERror (VESPER), Ag Leader Insight etc. These systems are based on remote sensing processing methods, which allow effective detecting field areas that are infected by plant diseases. Detection and recognition of an infection on early stages of its development reduces costs of plant protective measures.

1. Functions and structure of the complex

The main task of developed hardware and software complex is preparing of morbidity maps of agricultural vegetation (potato) for fertilizer application for healing and prevention of plant diseases.

A series of algorithms for additional feature extraction and processing for agricultural fields images of different spatial resolution are developed by the author [7]. These algorithms can be used to create a technique of data processing which is used as basis for developing of decision making support system (DMSS) for the complex for precision farming tasks. The DMSS is used as a core of the developed complex.

To make decisions about state of the vegetation and amount of applied fertilizers, following steps should be performed:

1. Performing of pre-processing: filtering, white balance correction, data georeferencing.
2. Calculation of the additional features for each processed image: texture, fractal (fractal dimension) and color (ranges saturation and hue of different classes of objects, the normalized reduced histogram for training set of neural network classifier).
3. Performing of multi-criteria threshold and joint segmentation of color, texture and fractal features to detection of different areas of the original image: vegetation (affected and healthy), soil, vegetation and soil boundary, foreign objects.
4. Training of the proposed neural network classifier and recognition of aerial photographs to forming morbidity map which shows areas of soil, healthy and diseased plants and used as a basis for calculation of statistical indicators of productivity.

5. Forming of maps of morbidity rate which is input for control subsystem, which carries out application of plant protection products for their treatment.

The proposed hardware and software complex is designed for monitoring of beginning and development of diseases of vegetation as a part of GIS for precision farming. Structure of the complex is shown in fig. 1.

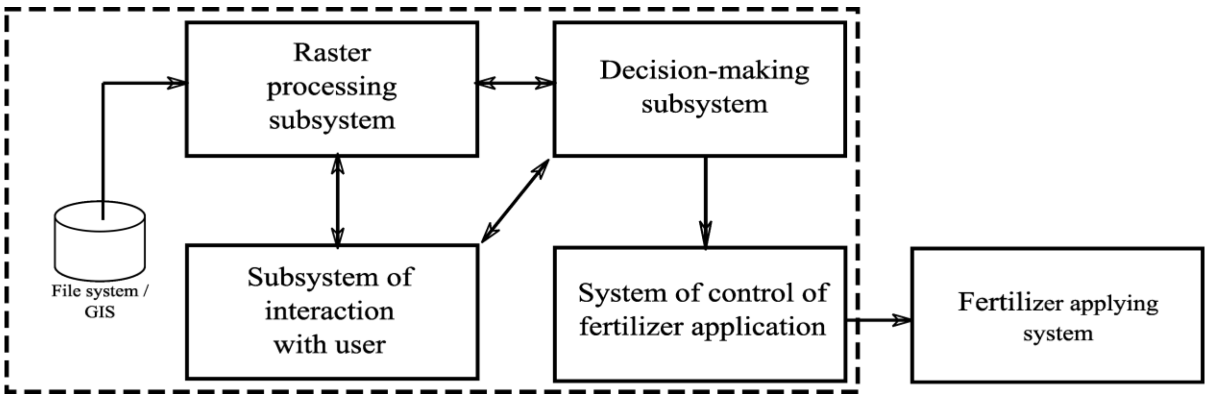

Fig. 1. The scheme hardware and software complex for precision farming tasks

2. Original Data

Agricultural field color images received with help of high resolution digital shooting are an object of our research (fig. 2). Lower value of this quantity equals higher spatial resolution of the image. In this article, if a side of a square is less than 0.6 cm, a spatial resolution is considered as high, otherwise – as low. We need to solve the problem of recognition for mapping of a disease. This can be done by recognizing the original image or by recognizing the received special area.

15 meters 50 meters

Fig. 2. Examples of original aerial photographs

3. Textures and Fractals

A texture is one of the major characteristics used for identification of objects or areas on the image [8]. The structures are subdivided into fine-grained, coarse-grained, smooth, granulated and undulating in according with used base attributes and interactions between them. In view of interaction degree of the base elements the structures are subdivided into strong (interaction submits to some rule) and weak (interaction has casual character).

An essence of the proposed method of textural characteristics calculation consists in calculation of separate channel images signatures with their subsequent association with use of factors which values depend on vegetation type and condition. An example of the obtained textures is shown in fig. 2. The example of textural characteristics calculation result is resulted on fig. 3, where visualization of calculated values Contrast is resulted. Contrast approximates 1 at a small variation of original data, and it vanishes at greater variation [9].

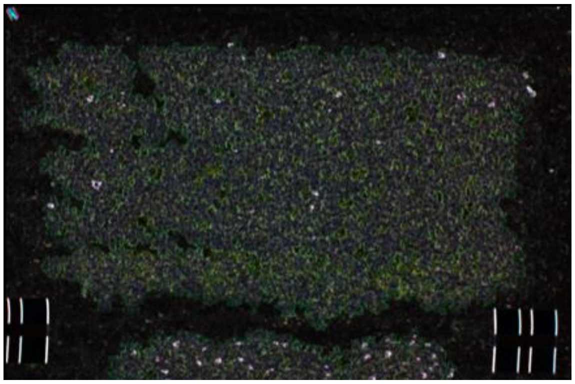

Fig. 3. Textural characteristics for the photograph shown in fig. 2 (15 meters)

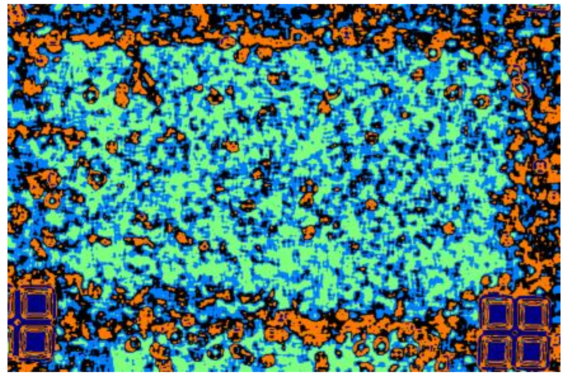

Fig. 4. Fractal signatures of various image areas

Fractal signatures calculation is based on the fact that quantified values of bidimentional signal intensity are located between two functions named the top and bottom surfaces [10]. Top surface U contains a set of points which values always exceed an intensity of the original signal. Bottom surface L has values of points which always are lower of the original image.

Results of fractal signatures calculation algorithm are presented in fig. 4 (visualization of the calculated values fractal signatures is resulted).

4. Joint Fuzzy Segmentation

Joint segmentation algorithm is based on co-processing of the source images and their fractal and textural features (i.e., an original color image is complemented by images of texture and fractal features).

Matrices of color features of original image, as well as the textural and fractal features computed for each color channel of the original image are used as the feature space.

Color ranges of corresponding healthy and diseased parts of potato fields obtained from an expert are used as color features. The algorithm is intended for segmentation of two-dimensional data representing matrices of various features of the original image such as color channels, textural and fractal features. Thus, the segmentation algorithm is executed in an N-dimensional space of attributes (where N is the number of characteristics used) where each dimension can be taken with a certain weight coefficient.

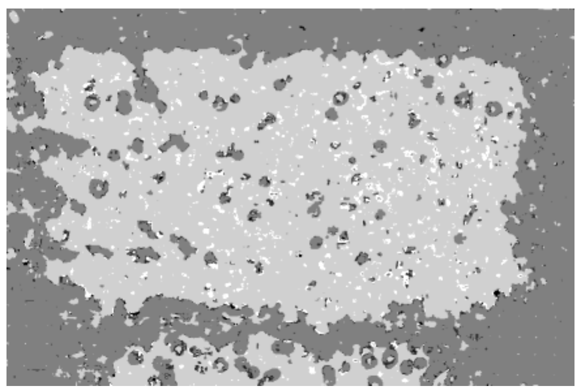

Fig. 5. Joint segmentation result example

Obtained segmentation result (fig. 5) allows in an automatic mode to detect areas on which a disease is developed. The knowledge of an allocation of such areas allows determining requirement of fertilizers and other chemicals. It allows making agricultural works more effective and less expensive.

5. Color Features

Next step of processing is image recognition based on analysis of color features of various objects types. The analysis showed that within the same type, the features are differed slightly and are independent of spatial resolution. At the same time these features have some differences for different objects types. These differences in color features for each color channel (*R*, *G*, *B* or *H*, *S*, *V*) are offered to use for processing.

Color features of images are represented as normalized reduced histograms. A number of individual brightness elements is decreased and can be equal to zero for a small images. It creates distortions of a histogram. To reduce influence of the distortions it is proposed to use a histogram of intervals of brightness – the histogram based on a set of elements of brightness in each segment. Such histogram is called a reduced. To ensure interoperability between the histograms of various sizes of images we use a normalization procedure.

6. Perceptron as a Classifier

To classify image areas a multilayer perceptron [11] is used with $N \times L$ inputs, where: N – number of segments of the normalized histogram, which is input of the perceptron, L – number of channels. One hidden layer contains 32×3 neurons (number of neurons is chosen experimentally), and an output layer containing three neurons corresponding to object types. A logistic activation function with sigmoid shape is used for each of the neurons. Data sample for classification is formed by a window of size $K \times K$ pixels scanning the original image.

Back-propagation algorithm is used to adjust weights of the perceptron. The normalized histograms of objects selected by operator are used as training sets. More than 1000 images are used for each class.

7. Evaluation of Quality Recognition

The results of evaluation of recognition based on described algorithms are shown in table 1.

Table 1

Recognition algorithms evaluation

Algorithm	Error, %	Algorithm	Error, %
Fuzzy C-Means	18.7	Gustafson-Kessel	11.7
Gath-Geva	15.5	C-Means	15.9
SVM (HSV)	13.3	SVM (RGB)	16.7
Random Forest (HSV)	9.5	Random Forest (RGB)	15.4
Developed algorithm using HSV	**4.9**	**Developed algorithm using RGB**	**4.8**

Conclusion

The technique of recognition of vegetation state for decision support system for monitoring agricultural fields was proposed. The proposed algorithms for image segmentation, identification of specified areas and neural network classification are used as a core of the decision support system. These algorithms allow to build additional features and to configure algorithms for processing specific images in order to reduce time complexity and improve reliability of identification.

The structure of the complex was developed, that is based on the proposed technique of recognizing the state of vegetation from aerial photographs stored in GIS. The results of data processing can be used in the control system of fertilizers applying mechanisms for treatment and prevention of diseases of potato.

Scientific significance of these results consists in detection disease areas of agricultural plants fields which, which can be used in problems of precision farming. Practical importance consists of application of the developed complex for cultivation of green products at reduced cost. Possible area of application is remote sensing of the Earth (in precision farming, forestry).

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