Intelligent system for agricultural crops defective areas monitoring and visualization based on spectral analysis of satellite high-resolution images

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Abstract. The article deals with the aspects of designing and software implementation of an intelligent system for monitoring and visualizing defective areas of agricultural crops based on the spectral analysis of high-resolution satellite images. The structure of the designed intelligent system, modules and procedures used in its software implementation, as well as a UML-diagram of user interaction with the components of the software system are presented.

1. Introduction
The productivity of agricultural crops is one of the most important indicators of the efficiency of the entire agro-industrial complex, taken into account when planning import and export operations in the agricultural market. Standard methods of collecting information on crop yields at the level of the country and its administrative units are often subjective and do not provide the necessary speed and advance. With the development of technologies for remote sensing of the Earth from space, it became possible to monitor the state of crops in large areas quickly and with minimal financial costs.

2. Materials and methods
The problem of increasing the productivity of crops and crop yields is due to the quality of field work, timely fertilization of plants, as well as operational monitoring using various remote sensing tools. The use of large aircraft for this purpose is expensive and not always possible. Satellite images are not always relevant and have a low resolution. In small farms, control can also be carried out manually, but the area of the sown fields does not always allow this to be done quickly. Most of the assessments made in such cases are made on the ground by visiting the fields of the expert group, but the expert group, spending a lot of time on monitoring, may not get the whole picture of the state of the crops as a whole.

The most reliable crop forecasts are made on the basis of plant bioproductivity modeling, taking into account the main physical and biological processes in the «soil-plant-atmosphere» system (photosynthesis, respiration, organ growth and death, carbon influx into the soil, soil respiration, evapotranspiration, etc.). When combining models of the plant production process with models of radiation transport and remote sensing data, it becomes possible to adjust and refine the model parameters by comparing the calculated reflective characteristics of the vegetation cover with the results of their remote measurements.

To speed up this process, it is necessary to use aerial photography, including flying robots-unmanned aerial vehicles. Remote monitoring using unmanned aerial vehicles allows you to quickly, without unnecessary costs, get information about the state of crops and implement precision farming technologies. Within the framework of project studies devoted to the problems of increasing the productivity of agricultural systems, an intelligent system for monitoring defective areas of agricultural crops is being
developed (Figure 1). The software implementation of the system is based on a framework using the Python language Django with an integrated OpenCV library for recognizing defective soil areas.

OpenCV is a great library with lightweight algorithms that can be used in 3D rendering, advanced image and video editing, tracking and identifying objects and people in a video, finding identical images from a set, and for much, much more. This library is very important for those who develop projects related to machine learning in the field of images.

In the process of designing the software system, the OpenCV library was used, which is a computer vision system with easy and developer-friendly algorithms that can be used in 3D rendering, advanced image and video editing, tracking and identifying objects and people in the video, searching for identical images from a set, and for much, much more. This library is very important for those who develop projects related to machine learning in the field of images.

During the program implementation, the following modules and procedures were used:
- opencv_core - the main functionality. It includes basic structures, calculations (mathematical functions, random number generators) and linear algebra, DFT, DCT, input / output for XML and YAML, etc;
- opencv_imgproc - image processing (filtering, geometric transformations, color space transformation, etc.);
- opencv_highgui - simple UI, image and video input/output;
- opencv_ml - machine learning models (SVM, decision trees, stimulated learning, etc.);
- opencv_features2d - recognition and description of flat primitives (SURF, FAST, and others, including a specialized framework).

Figure 1. Structure of the designed intelligent system.

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3. Results and discussion

The intelligent decision support system developed during the research is implemented in the form of a software package designed for recognition, processing and analysis as objects of identification of data from satellite monitoring and on-board remote sensing of agricultural crops based on the use of an ensemble of implemented multi-layer deep learning neural networks, as well as for research and study of the features of crop cultivation in different soil and climatic zones, taking into account the differentiated placement of crops.

Figure 2. UML-diagram of interaction between the user and the components of the software system.

Figure 3. Module for segmentation of images of agricultural crops from digital aerial photographs.

Figure 4. Module for recognition and visualization of problem areas of agricultural crops based on satellite and remote sensing data.
4. Conclusion
The developed software package is designed for recognition, processing and analysis as objects of identification of aerial photographs of agricultural crops based on remote sensing and satellite monitoring data using an ensemble of implemented multi-layer deep learning neural networks, as well as for research and study of the features of crop cultivation in different soil and climatic zones, taking into account the differentiated placement of crops.

The developed software package includes:
- module for recognizing and classifying objects in agricultural fields;
- module for identifying defective and problematic areas of plantings;
- module for assessing the degree of humidity based on satellite monitoring data;
- module for recognition and visualization of problem areas of agricultural crops;
- module for segmentation of images of agricultural crops based on digital aerial photographs.

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