Identification of plants condition using digital images

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Abstract. The paper deals with the problem of evaluation of the current state of plants by digital images using color and morphological descriptors. The above mentioned problem is widely used in automated greenhouse control systems. The paper presents a procedure for identification of the state of plants. The questions of segmentation and morphological image processing are considered. Self-organizing Kohonen networks and feed-forward networks are used as classifiers of RGB images and geometric descriptors. The use of the approach described in the paper allows remote assessing the condition of plants in greenhouses, increasing productivity and reducing the percentage of crop losses.

1. Introduction
Nowadays, when creating modern agrotechnological systems (greenhouses, "intelligent" farm, etc.), there is a need for remote analysis of the condition of plant crops (for example, by digital images) [1-4]. Due to this, there is a need to solve the problem of identification of the condition of plants using digital images. That is, the detection of a healthy, oppressed, sick plant caused by a variety of negative factors (non-compliance with plant nutrition, lack of lighting, the defeat of microorganisms, etc.).

Currently, the market offers a large number of applications for plant identification by photos, but in the investigated systems it is necessary to take into account the condition of plants, diagnose them, evaluate germination, etc. [3-11]. In addition, based on the analysis of digital images of plant crops, it is necessary to decide on the feasibility of performing the specified agrotechnical procedures (for example, changing the pH concentration, micronutrients, etc.).

2. System architecture identification of the condition of the plants
The authors propose to use a multi-level system of identification of plant cultures. Figure 1 shows a diagram of plant identification and diagnosis of conditions of plants.

At the first stage, the original image is pre-processed, which increases the contrast, eliminates interference, reconstruction of the blurred image [5].

Having some representative samples of vectors having the color the authors are interested in (leaf color), they obtain an estimation of the mean value of the color to be selected [4-9]. Let this mean value color be indicated by the RGB column vector $\mathbf{m}$. The segmentation classifies each RGB pixel of an image and determines whether it belongs to the selected mean value color class or not. It is possible to use the Euclidean distance between $z$ (an arbitrary pixel) and $\mathbf{m}$ to map arrays. If the values $J_R, J_G, J_B$ falls in the region $D \leq T$, the points lying inside the ball or on its spherical surface satisfy the given color criterion, and the points lying outside this ball and its boundary sphere do not satisfy. If the values 1 (white) and 0 (black) are assigned to the two corresponding image sets, it is possible to get a binary image that is the result of image segmentation.
The image segmentation RGB $J_R, J_G, J_B$. Image registration tool

Original RGB image $J(\cdot, \cdot, \cdot)$ at time $t_0$. 

Image preprocessing
Contrast enhancement, noise elimination, etc. 

The image segmentation RGB $J_R, J_G, J_B$. 

The procedure of dilation of binary images 

The formation of the geometric descriptors of the image 

Neural network classifier 

RGB database for plants $J_R(t), J_G(t), J_B(t)$. $t$ - the life time of the plants. dB of geometric descriptors of cultures: the skeleton of the plant, code Freeman. 

Classification result $X(t)$: healthy/sick/ oppressed plant; type of disease/cause of plant oppression. Location of plant disease; estimate of biomass. 

Figure 1. Steps in the identification of biological cultures. 

The result of the detection of the region of interest (plants) is shown in Figure 2. 

Figure 2. Result of the segmentation procedure of plants. 

In addition, the color can identify the disease of a plant, the lack of trace elements in the nutrient medium, the lack of lighting. Figure 3 shows the formed samples of healthy and diseased cultures that form the corresponding clusters H1 and H2 in RGB space.
Figure 3. Distribution of healthy and diseased plant clusters in RGB color space.

The result of detection of plant disease is illustrated in Figure 5. White color marked in Figure 4 b) areas that correspond to the \( H_2 \) area. The artificial neural network of direct distribution is used as a classifier in the present work.

Figure 4. Image of a diseased plant: a – initial color image of the plant; b – the result of detection of plant disease.

Morphological image processing is used to determine the geometric characteristics of plants [12]. The procedure of dilation and erosion of objects in a monochrome image allows obtaining a closed contour of plants. Further, for the above closed objects, descriptors (geometric dimensions, area) are estimated, which with the color parameters of the plants are fed to the neural network.

Figure 5 shows a diagram of neural network classification of plant conditions.

Figure 5. Neural network diagram of cluster analysis of the condition of the plants.
It is proposed to use Kohonen self-organizing neural network [13]. The number of neurons is determined by the number of states (healthy/sick/oppressed plant). The number of neural network inputs is determined by the number and dimension of geometric and color descriptors. The neural network is learning for a test sample for both healthy and diseased plants. Each neural network solves the problem of detecting only one plant species. In addition, the percentage of oppressed plants is calculated from a digital image.

3. Conclusion
In the paper the principles of identification of the condition of plants by digital images are considered. The implementation of this task will increase the efficiency of automation in the agricultural sector. During the process of the solution of the problem of identification of the condition of plants, further research is needed in the field of synthesis of procedures that allow clarifying the condition of plants and revealing the root cause of the deviation, taking into account the growing season and plant species caused by various reasons: micronutrient deficiency, viral diseases, lack of lighting, etc. It is also necessary to form the procedure of an assessment of biomass, the forecast of a condition of development of plants, etc. Due to a number of features of identification of the condition of crops associated with the ambiguity of the solution of this problem, it is proposed to use a neuro-fuzzy system of identification and decision-making by the operator [14] of the automated control system of greenhouses.

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