Phytomonitoring in the Phytometrics of the Plants

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Abstract. Phytomonitoring in the greenhouse using non-contact, visual assessment of plants is considered. The basis of the developed visual assessment is the implementation of plant photography by a special electrotechnical complex, after which the stored images are to be recognized by means of applying the technology of wavelet analysis. The use of technology of wavelet analysis of photographs as a means of contactless information acquisition will allow to assess the growth and condition of plants in the greenhouse and predict their development through the mathematical transformations laid down in its basis. This approach will provide an assessment of future yields. When recognizing plant photo images it is also possible to estimate the impression of plants that will detect the disease and then inform the staff about the condition of the a certain plant. The developed algorithm of recognition is also used to recognize biomass in the greenhouse space. The above will allow you to predict the amount of biomass for further use in bioreactors.

1 Introduction

Assessment of plant development (phytomonitoring) is impossible without its visual analysis. It is necessary to constantly control the development of plants with the simultaneous control of the parameters of the microclimate. As an example, one of the successful solutions to the problem of visual inspection is the use of a mathematical apparatus for wavelet analysis of images, which allows for visual inspection of plants throughout the greenhouse area. Observations on the development of plants and their reaction to the effect of microclimatic disturbances provide an opportunity to accumulate knowledge about the plant and predict its further development and yield [1, 2, 5, 8].

The intensive use of greenhouse space leads to the simultaneous presence of plants in several phases, which leads to an increase in the dimension of the task of synthesizing the control system in real time. In the development of systems of this type, as a rule, a method for the formation of local functional intelligent subsystems on an hourly basis is applied [3].

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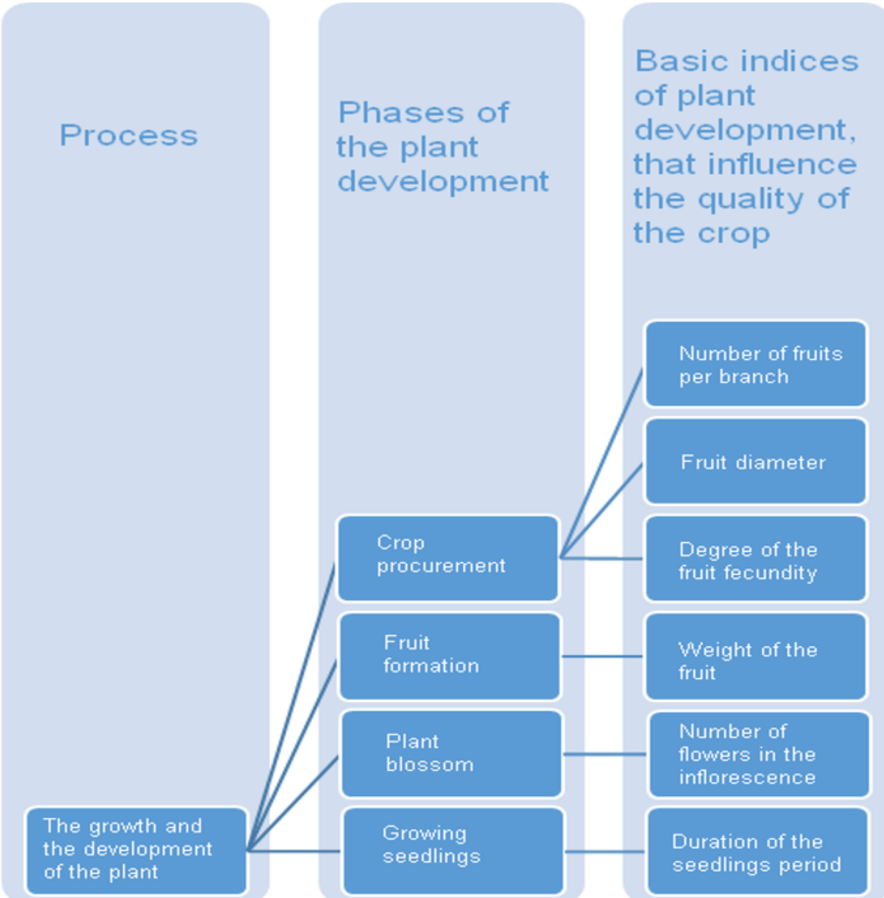

Fig. 1. Classification of basic indices of plant development.

2 Topicality of the research

Figure 2 shows an example of a stationary plant monitoring system without the use of a camera.

It is proposed to observe the plant with the help of a camera for visual inspection of the plant with the possible determination of the fecundity of the fruits by the color and size of the fruit and stem of the plant, as well as to detect the diseases that struck the plant. Appropriate measurements can be made for all plants in the greenhouse, and are not limited to a single plant.

Implementation of such phytomonitoring is possible due to the use of a complex that visually inspects plants in a certain area and presents results in the form of images, which is respectively a new approach to solving the problem because existing phytomonitoring systems determine the state of plants directly in a contact way [7-11].

The obtained images of plants are stored in the form of photo images. Analysis and processing of the corresponding data carried out through wavelet transformations, in which each photo will decompose into wave functions (wavelets) [4, 6].

The main task in this case is to recognize images of the photo images, which will find the contour of plant blossom to determine the phase of plant development and future yields.

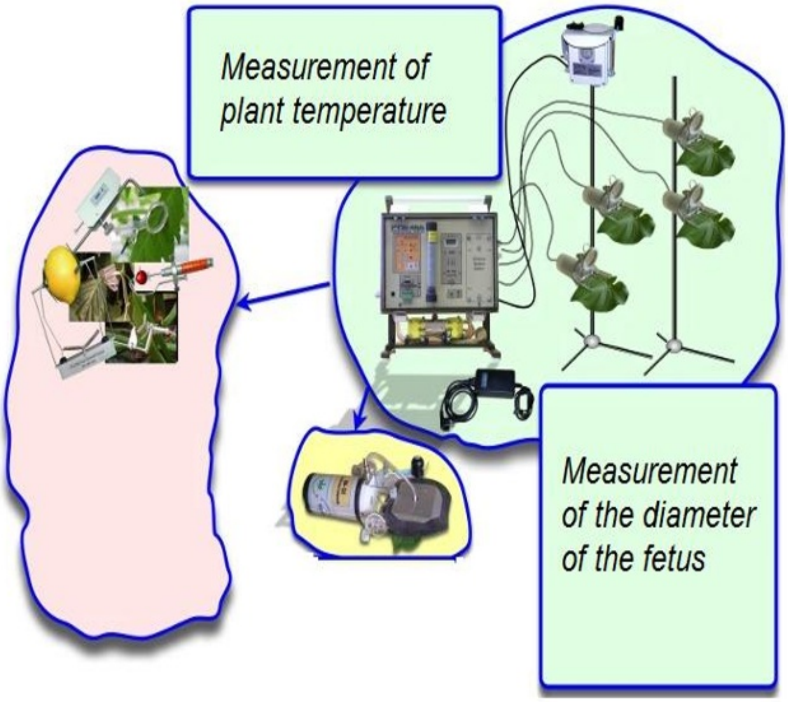

Fig. 2. The structure of the stationary plant phytonomonitoring system.

The purpose of the research is to develop algorithms for image recognition to assess the condition and phase of plants development in the greenhouse through applying wavelet analysis.

3 Materials and methods of research

We received 100 images of tomato at different stages of fecundity in the block greenhouse of the PJSC "Greenhouse Plant", while processing the received images (Fig. 3).

The task of selecting an object from an image is finding the boundaries of the required object. In our case, finding the contours of an object is performed by finding the boundary points of a sharp transition of brightness.

One of the known methods, which are effective within the framework of geometric transformations, is normalization [4], which consists of automatically identifying unknown transformation parameters to which the input image is subjected, and then bringing it to the reference form. In the process of normalizing the image is replaced by an image equivalent to it.

The task of image recognition is to compare the coefficients obtained from the wavelet decomposition of the test image, with the coefficients obtained in the decomposition of several reference images. When analyzing the maximum number of coefficients, the test image is considered identical to one of the reference images.

Fig. 3 The image of the tomato flower in the greenhouse

The wavelet tree decomposition of the image will look in the following way (Fig. 4): (0.0) – input image; (1.0) – the 1-st level of wavelet decomposition of the image; (2.0) – the 2-nd level of wavelet decomposition of the image; (3.0) – the 3-rd level of wavelet decomposition of the image.

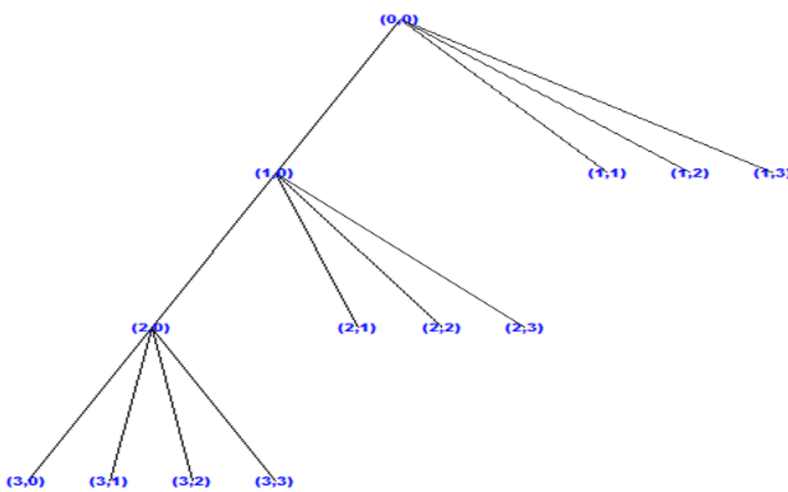

Fig. 4. The wavelet tree decomposition of the image.

Recognition of a tomato plant by photographic images of their fruits follows the following algorithm. For the input image f(x,y) wavelet transforms are performed to find the wavelet coefficients [4, 6]:

$$f(x,y)=\sum_{i=-\infty}^{\infty}\sum_{j=-\infty}^{\infty}\lambda_{r,i,j}^{HH}\phi_{k,i}(x)\phi_{r,j}(y)+\sum_{y=r}^{\infty}\sum_{i=-\infty}^{\infty}\sum_{j=-\infty}^{\infty}(\lambda_{y,i,j}^{HV}\phi_{y,i}(x)\psi_{y,j}(y)+$$

$$+\lambda^{VH}_{y,i,j}\psi_{y,i}(y)\phi_{y,j}(x)+\lambda^{VH}_{y,i,j}\psi_{y,i}(y)\psi_{y,j}(x)), \quad (1)$$

$$\varphi_{y,i}(x)=2^{y/2}\varphi(2^y x-i),\ \ \psi_{y,j}(x)=2^{y/2}\varphi(2^y x-j),$$

r is depth of the wavelet decomposition function; $\lambda^{HV}_{y,i,j}$, $\lambda^{VH}_{y,i,j}$, $\lambda^{VH}_{y,i,j}$ – coefficients of wavelet transformation.

Schematically, the wavelet transform of the image is as follows [4] (Fig. 5).

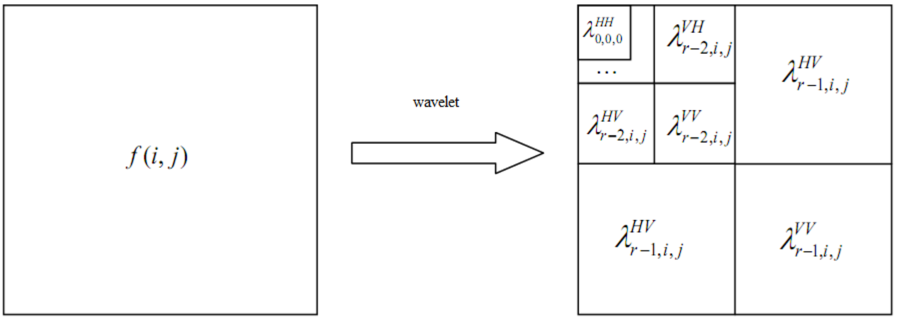

Fig. 5. The wavelet transform.

The found wavelet coefficients decompose in the space of their own vectors:

$$\tilde{a}_j=\sum_{k=1}^{S}\lambda_k x_{jk} y_k+\Delta_{js}, s<r, \Delta_{js}=\sum_{k=s+1}^{r}\lambda_k x_{jk} y_k\ . \quad (2)$$

In this way, the vector of signs for the incoming w image is obtained.

Next, we find distances between the received attribute vectors and each of the vectors of the study sample, using the Euclidean metric [5]:

$$d^i=\sqrt{\sum_{i=1}^{s}(w_i-w_i^j)^2}, i=\overline{1,M}. \quad (3)$$

The normalized vectors of the matrix for the Euclidean metric have the following form:

eigenvecs(T) =

	0	1	2
0	0.039	$-5.444\cdot10^{-3}-0.018i$	$-5.444\cdot10^{-3}+0.018i$
1	0.039	$-0.01-6.861i\cdot10^{-3}$	$-0.01+6.861i\cdot10^{-3}$
2	0.039	$4.035\cdot10^{-3}-4.164i\cdot10^{-3}$	$4.035\cdot10^{-3}+4.164i\cdot10^{-3}$
3	0.039	$0.012-1.662i\cdot10^{-3}$	$0.012+1.662i\cdot10^{-3}$
4	0.039	$-3.989\cdot10^{-3}-1.714i\cdot10^{-3}$	$-3.989\cdot10^{-3}+1.714i\cdot10^{-3}$
5	0.039	$-0.012+5.514i\cdot10^{-3}$	$-0.012-5.514i\cdot10^{-3}$
6	0.04	$5.033\cdot10^{-3}+0.023i$	$5.033\cdot10^{-3}-0.023i$
7	0.04	$-0.015+0.025i$	$-0.015-0.025i$
8	0.041	$-0.022+0.013i$	$-0.022-0.013i$
9	0.04	$-7.513\cdot10^{-3}+0.02i$	$-7.513\cdot10^{-3}-0.02i$
10	0.039	$-3.318\cdot10^{-3}+9.773i\cdot10^{-3}$	$-3.318\cdot10^{-3}-9.773i\cdot10^{-3}$
11	0.041	$-0.012+5.696i\cdot10^{-3}$	$-0.012-5.696i\cdot10^{-3}$
12	0.04	$-0.022+0.03i$	$-0.022-0.03i$
13	0.041	$-0.035+0.037i$	$-0.035-0.037i$
14	0.04	$-0.03+0.038i$	$-0.03-0.038i$
15	0.039	$-0.021+0.039i$	...

An object that corresponds to w^m vector (in which the distance d^m meets the condition $d^m = \min\{d^i\}, i=\overline{1,M}$) will be called a recognized image.

The research of the recognition of tomato flower was conducted on the images with the resolution 2048x1536 (Fig. 6).

Fig. 6. Recognized image of the tomato flower.

By this technique it is possible to recognize and evaluate the plants on the whole greenhouse area.

The phytometric evaluation procedure is as follows: the robotic complex performs a visual inspection of the plants, these results are transmitted to an intelligent system that analyzes the phytometric parameters of the plant (Fig. 7, 8).

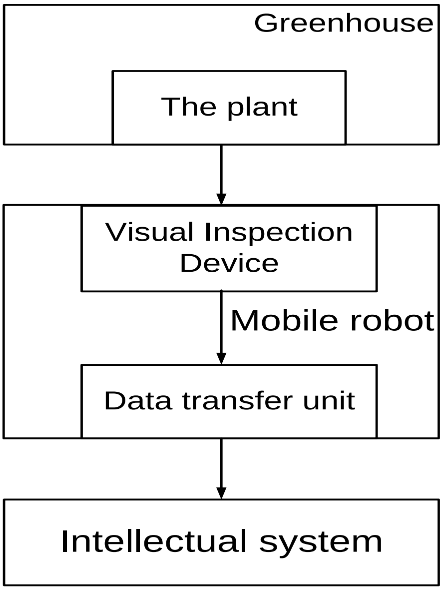

Fig. 7. Phytomonitoring in the greenhouse.

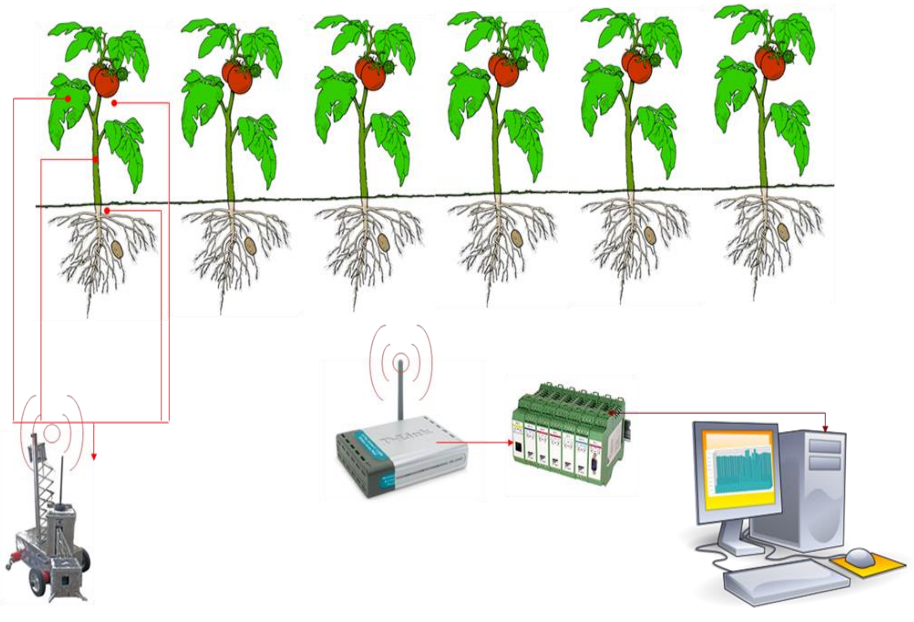

Fig. 8. The proposed system of fitomonitoring.

Scientists have been successful tests of development in PJSC "Combine" Teplichny "of the Kyiv region (Fig. 9).

Fig. 9. Photo of a mobile robot test in a greenhouse.

The aforementioned approaches are also used to determine the biomass by photographic image. This approach is realized through the use of a camera located on a robot platform that moves in the greenhouse space. By recognizing the image, determine the amount of biomass, which allows you to predict the amount of dry matter of plants for use in obtaining alternative energy from bioreactors.

4 Conclusions

We developed the scheme of conducting wavelet analysis of plant images in determination of their phytometric parameters, as well as assessment of the condition and phase of plant development. We carried out the decomposition of the image of the tomato flower to wavelet coefficients, which enables us to recognize the object.

On the basis of image processing, it is possible in the future to identify and detect diseases that struck the plant. By recognizing the image, determine the amount of biomass, which allows you to predict the amount of dry matter of plants for use in obtaining alternative energy from bioreactors.

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