Alexandr DOUDKIN [1], Valentin GANCHENKO [1], Albert PETROVSKY [1], Boleslav SOBKOWIAK [2]
1) UIIP, NAS of Belarus, 6 Surganov str., Minsk, 220012, Belarus
e-mail: doudkin@newman.bas-net.by ; ganchenko@lsi.bas-net.by ; petrovsky@newman.bas-net.by
2) PIMR, 60-963 Poznan, Starolecka Str., 31, Poland
e-mail: office@pimr.poznan.pl

DISEASE AREAS DETECTION ON AGRICULTURAL PLANTS USING FRACTAL AND TEXTURAL FEATURES OF HIGH RESOLUTION COLOR AERIAL PHOTOGRAPHS

Summary

A method of disease areas detection on agricultural plants is proposed based on image processing using textural and fractal characteristics of images. The developed method was implemented in a joint segmentation algorithm of aerial photograph. It is applied in a decision-making system, which is a part of software-hardware complex for agriculture application.

1. Introduction

Remote sensing methods allow effective detecting field areas that are infected by plant diseases. The infection detected on early stages of its development reduces costs of plants protective measures. There are two approaches for detection of the infected areas: spectrometric and optical or visual [1, 2]. Spectrometric approach allows detecting a number of infections on very early development stages. In spite of that fact development of an optical method for infection detection takes place both for an independent system and for spectrometric one that increases quality of the identification. Agricultural fields color images are object of our research (fig. 1).

The purpose of the work consists in development of effective method of processing of vegetative covers color images received with help of high resolution digital shooting, and also their realization as software for computer vision systems. Fractal and textural characteristics of images are used as basis for the detection method under consideration. Essence of the method consists in development and use fractal and textural characteristics with required properties for construction of attributes space and objects detection on agricultural fields color images.

2. Textures

Heterogeneity or repeatability of fine fragments refers as a texture of digital image. A characteristic attribute of a texture is uniformity at a level of vicinities or a local level, i.e. at a level of adjacent pixels groups with various brightness values [8].

Textural images can be divided into two classes: stochastic (or casual) and periodic (or structural) structures. On basis of base elements attributes they are subdivided on fine-grained, coarse-grained, smooth, granulated and hilly.

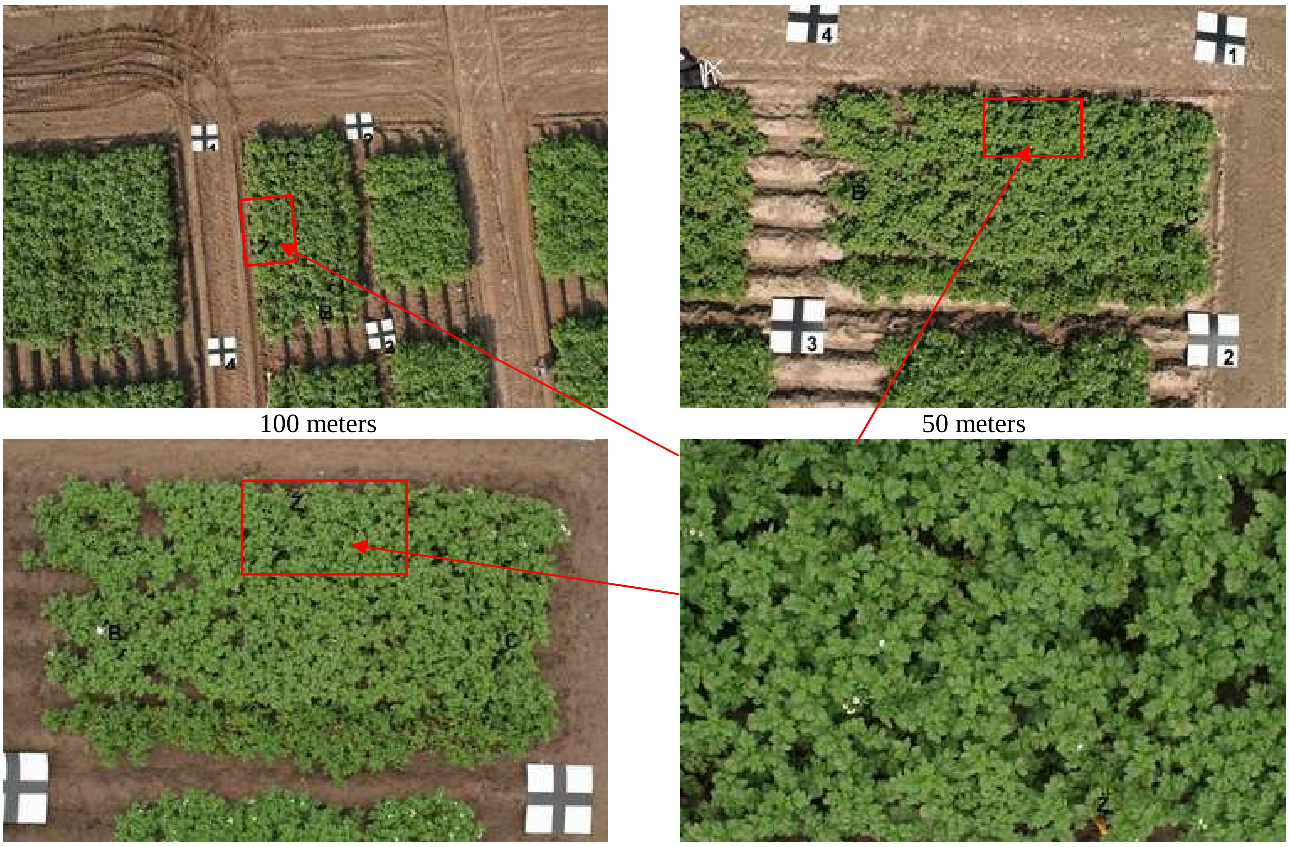

Fig. 1. Examples of initial aerial photographs

On basis of a base elements interaction degree are subdivided on strong (interaction submits to some rule) and weak (interaction has casual character).

Based on the analysis of methods and algorithms of image processing following textural characteristics: ASM (Angular Second-Moment feature) – a measure of image uniformity; Contrast – a quantity measure of local variations on the image and Entropy – a measure of image pixels disorder:

$$ASM = \sum_{i=1}^{N_g}\sum_{j=1}^{N_g}\left(\frac{P(i,j)}{R}\right)^2, \qquad (1)$$

$$Contrast = \sum_{n=0}^{N_g-1} n^2 \left(\sum_{\substack{i=1 \\ |i-j|=n}}^{N_g}\sum_{j=1}^{N_g}\left(\frac{P(i,j)}{R}\right)\right), \qquad (2)$$

$$Entropy = -\sum_{i=1}^{N_g}\sum_{j=1}^{N_g}\left(\frac{P(i,j)}{R}\right)\log\left(\frac{P(i,j)}{R}\right), \qquad (3)$$

Selection of the specified characteristics is based on results of the lead visual expert analysis and bases on presence of visible differences between diseased and healthy fields areas. The example of textural characteristics calculation result is resulted on fig. 2, where visualization of calculated values ASM is resulted. ASM approximates 1 at a small variation of initial data, and it vanishes at greater variation.

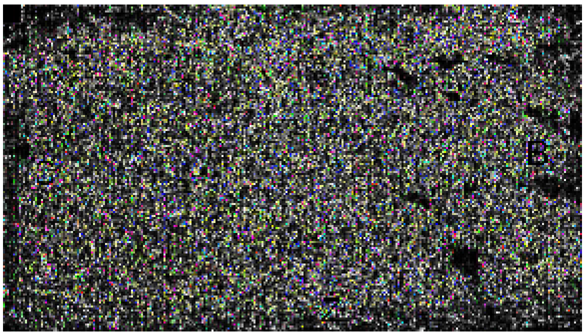

Fig. 2. Result of textural characteristics (in this case – ASM) calculation for the field aerial photograph executed from height of 15 meters

3. Fractals

An essence of the proposed method consists in calculation of separate channel images signatures with their subsequent association with use of factors which values depend on vegetation type and condition.

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. Top surface U contains a set of points which values always exceed an intensity of the initial signal. Bottom surface L has values of points which always are lower of the initial image.

The top and bottom surfaces are defined for at a zero point of origin as the following:

$$U(i,j,0) = L(i,j,0) = g(i,j); \quad (4)$$

where: $g(i, j)$ – initial image.

Generally we have:

$$U(i,j,\varepsilon+1) = \max\left\{U(i,j,\varepsilon)+1, \max_{k,m\in\eta}[U(k,m,\varepsilon)]\right\}; \qquad (5)$$

$$L(i,j,\varepsilon-1) = \min\left\{U(i,j,\varepsilon)-1, \max_{k,m\in\eta}[L(k,m,\varepsilon)]\right\}; \qquad (6)$$

$$\eta = \{(k,m) \mid d[(k,m),(i,j)] \le 1\}; \qquad (7)$$

where d – distance function.

The designed covering, formed by two specified functions, has thickness 2ε. For a bidimentional signal the area of a surface is the volume occupied with a covering, and divided on size 2ε. The intensity A(ε) "surface" area within the limits of a supervision R window calculate by subtraction of bottom "surface" points from top with further summation on all window:

$$A(\varepsilon) = \frac{\sum_{i,j\in R} U(i,j,\varepsilon) - L(i,j,\varepsilon)}{2\varepsilon} = \frac{V(\varepsilon)}{2\varepsilon}. \qquad (8)$$

Fractal dimension is defined on an inclination *log A*(ε) as function *log* ε. The example of fractal signature is represented on fig. 3.

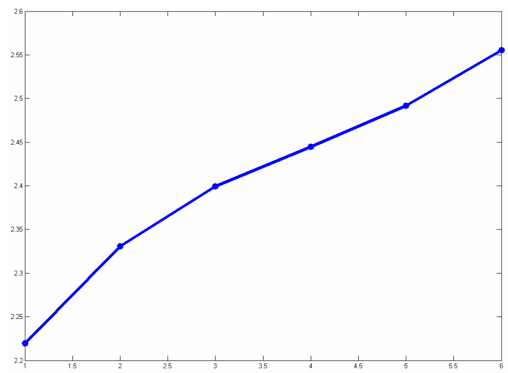

Fig. 3. Fractal signature of plant cover

Fractal dimension D (i, j) at a finding of pixel (i, j) on all scales is evaluated as a weighted sum of local fractal dimensions $F_\varepsilon(i, j)$:

$$D(i,j) = \frac{\sum_\varepsilon C_\varepsilon F_\varepsilon(i,j)}{\sum_\varepsilon C_\varepsilon}; \qquad (9)$$

where:

$$C_\varepsilon = \frac{\log\varepsilon - \log(\varepsilon-1)}{\log 2}; \qquad (10)$$

$$F_\varepsilon = \frac{\log A(i,j,\varepsilon) - \log A(i,j,\varepsilon-1)}{\log\varepsilon - \log(\varepsilon-1)}. \qquad (11)$$

Size $F_\varepsilon(i, j)$ is division A (i, j, ε) on A $(i, j, \varepsilon - 1)$ [3]:

$$\frac{A(i,j,\varepsilon)}{A(i,j,\varepsilon-1)} = \frac{K\varepsilon^{(2-D)}}{K(\varepsilon-1)^{(2-D)}} = \left(\frac{\varepsilon}{\varepsilon-1}\right)^{(2-D)}; \qquad (12)$$

after finding the logarithm, we obtain:

$$\frac{\log A(i,j,\varepsilon) - \log A(i,j,\varepsilon-1)}{\log\varepsilon - \log(\varepsilon-1)} = 2 - D = F_\varepsilon(i,j). \qquad (13)$$

Having substitution in expression (13) values composed (11) and (12) we obtain:

$$D(i,j)=\frac{\log A(i,j,\varepsilon)-\log A(i,j,1)}{\log\varepsilon-\log 1};\qquad(14)$$

It is possible to build fractal dimensions evaluations with the help of expression (14).

Results of fractal signatures calculation algorithm are presented on fig. 4 (visualization of the calculated values fractal signatures is resulted). The quantity 1 $<D<$2 more, than cut more up and non-uniform is image area.

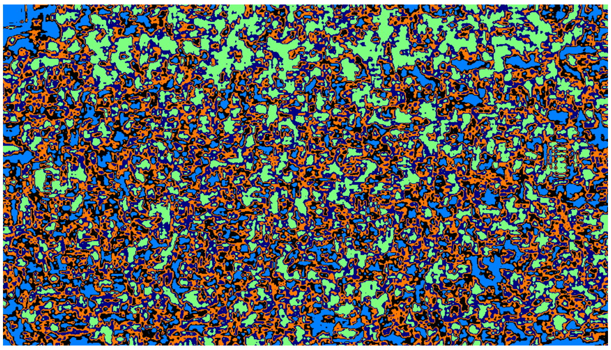

Fig. 4. Fractal signatures of various areas for the field aerial photograph executed from height of 15 meters

4. Processing method

An essence of the method of processing consists in joint segmentation [4], using them as the additional information channels supplementing an available initial image.

Calculation of fractal signatures and textural characteristics of images is carried out for separate channels with their subsequent combining using of factors which values depend on type and a condition of vegetation.

As attributes space on basis of which decision makes, weighed matrixes of color characteristics of initial image, and also textural and fractal characteristics calculated for each color channel of an initial image are used.

As color attributes color ranges defined by expert corresponding healthy and diseased sites of fields are used. The values of ranges of color of diseased areas of a plant are resulted [9, 10] in table 1

Table 1. Color ranges values

Segments	hue range	saturation range
healthy plant (green)	[1,4; 3,14]	[40; 200]
infected plant (yellow)	[0,9; 1,4]	[80; 200]
infected plant (brown-green)	[1,5; 1,8]	[14; 55]

The hue and saturation values are calculated according to the following formulas:

$$Hue=\arctan\left(\frac{\sin(\frac{2}{3}\pi)\cdot g-\sin(\frac{2}{3}\pi)\cdot b}{r+\cos(\frac{2}{3}\pi)\cdot g+\cos(\frac{2}{3}\pi)\cdot b}\right),\qquad(15)$$

$$Sat=\max(r,g,b)-\min(r,g,b),\qquad(16)$$

where r, g, b are red, green and blue color components.

Thus, the algorithm of initial images processing for special areas maps building looks as follows (see figure 5):

1. processing of initial images for receiving of additional information channels representing matrixes of textural and fractal characteristics of each initial image color channel separately;
2. joint segmentation performance of the received matrixes of textural and fractal characteristics and initial images color channels;
3. special areas maps building on basis of a task in view and results of carried out joint segmentation.

The given algorithm is intended for performance of segmentation of initial bidimentional data representing matrixes of various initial image characteristics (in our case as these attributes color channels, textural and fractal characteristics are used). Thus, work of algorithm is carried out in N-dimensional space of attributes (where N is quantity of used characteristics) where each dimension can be considered from the some people in weight factor. Directly segmentation is carried out one of widespread segmentation algorithms (for example, K-means or ISOMAD). The scheme of the algorithm is presented in figure 6.

5. Results of experiments

The purpose of experiments carrying out was check of working capacity of the developed algorithm on available initial data, and also an evaluation of an error of its work.

As initial data for experiment images of site of potato field, executed with different heights from July, 2 till July, 6th, 2007 are used. In figure 1 examples of the initial images executed from height 100, 50, 15 and 5 meters are resulted.

Example of result of the algorithm work is resulted in figure 7 (initial image executed from height of 15 meters, it is resulted in figure 1).

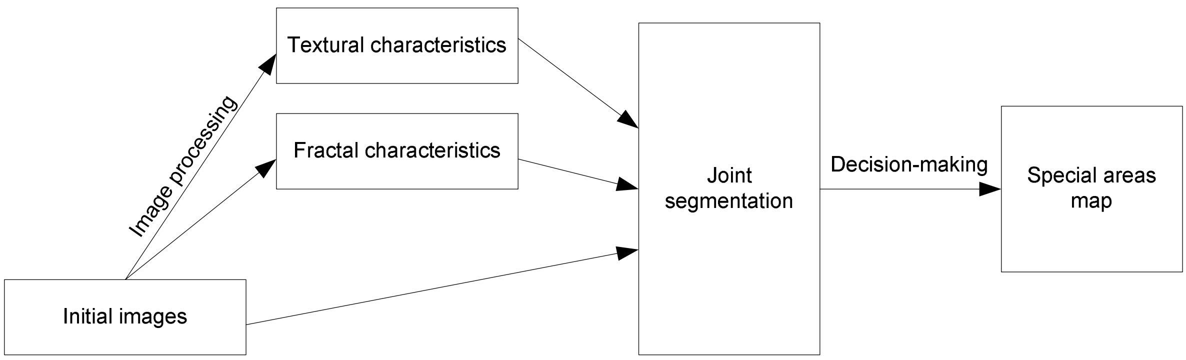

Fig. 5. Processing algorithm scheme

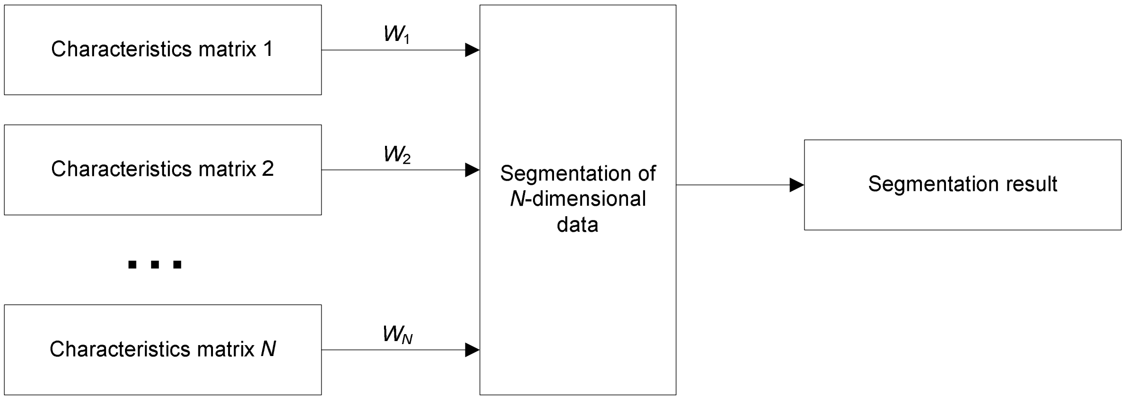

Fig. 6. Scheme of joint segmentation algorithm(W_i – weight ratio)

Fig. 7. Example of the result of the developed algorithm work

Received segmentation result allows detecting areas on which there is a disease development in an automatic mode. Knowledge of a location of such sites will allow determining need of those or other sites of agricultural fields for fertilizers and other chemicals. And it will allow making agricultural works more effective and less expensive.

At the decision of special areas maps building probably occurrence on a map of areas wrongly detected as special areas. It is connected in particular to degradation of borders between parts of the initial image (for example, arising transition of color to border of images of separate plants and soil) which can appear, for example, as a result of JPEG-compression of the initial data.

Table 2. Evaluations of errors for various resolutions data

Height of shooting, meters	100	50	15	~5
Experiment number	Numerical value of error evaluation, %			
1	44,7	6,6	24,8	2,2
2	4,6	26,6	4,6	3,9
3	31,9	5,4	2,7	5,1
Middle value	21,2	10,2	9,5	3,4

The specified error is evaluated as relative area of erroneous areas received on the initial image, not containing special areas, and depends on initial data resolution (evaluations for various resolution are resulted in table 2, for each experiment various images from the initial images set are used).

6. Practical application

On the basis of the developed algorithm the hardware-software complex for mineral fertilizers and other chemicals application on agricultural fields has been proposed.

The scheme of the proposed complex is resulted in figure 8.

At work under the proposed scheme chemicals application is carried out as follows:

1. with use of the proposed algorithm special areas maps (for example, sites with developing disease of plants) are calculated;
2. the ready-built maps receive a geographical binding and are kept in base GIS for further use;
3. the received maps are used at decision-making on necessity of application of this or that amount of fertilizers on that or other site of farmland;
4. the chemicals application control system on the basis of available maps and real-time data, supervises amount of chemicals brought in soil and directs a corresponding command to chemicals application system.

As real-time data can be used:

– data of global navigating satellite system. In this case the control system, determining with help of navigating system, on what site of a field is is, calculates necessary amount of chemicals, proceeding from the special areas map;

– data from color camera of a seen range. In this case the control system can correct in real time the given special areas maps, thus, making of more exact decisions that increases efficiency work.

7. Conclusion

The received results on calculation fractal and textural features of images of agricultural fields allow receiving additional information on condition of a vegetative cover. Thus the result to a lesser degree depends on conditions of illumination and presence on image of extraneous subjects, than at use only color attributes. However use only these attributes does not allow detecting diseased sites precisely enough. For decision of this problem the joint segmentation algorithm, which for detection of special areas uses as well color characteristics of images for reception of more exact result, is entered. On basis of this approach hardware-software complex for mineral fertilizers and other chemicals application on agricultural fields also is under construction.

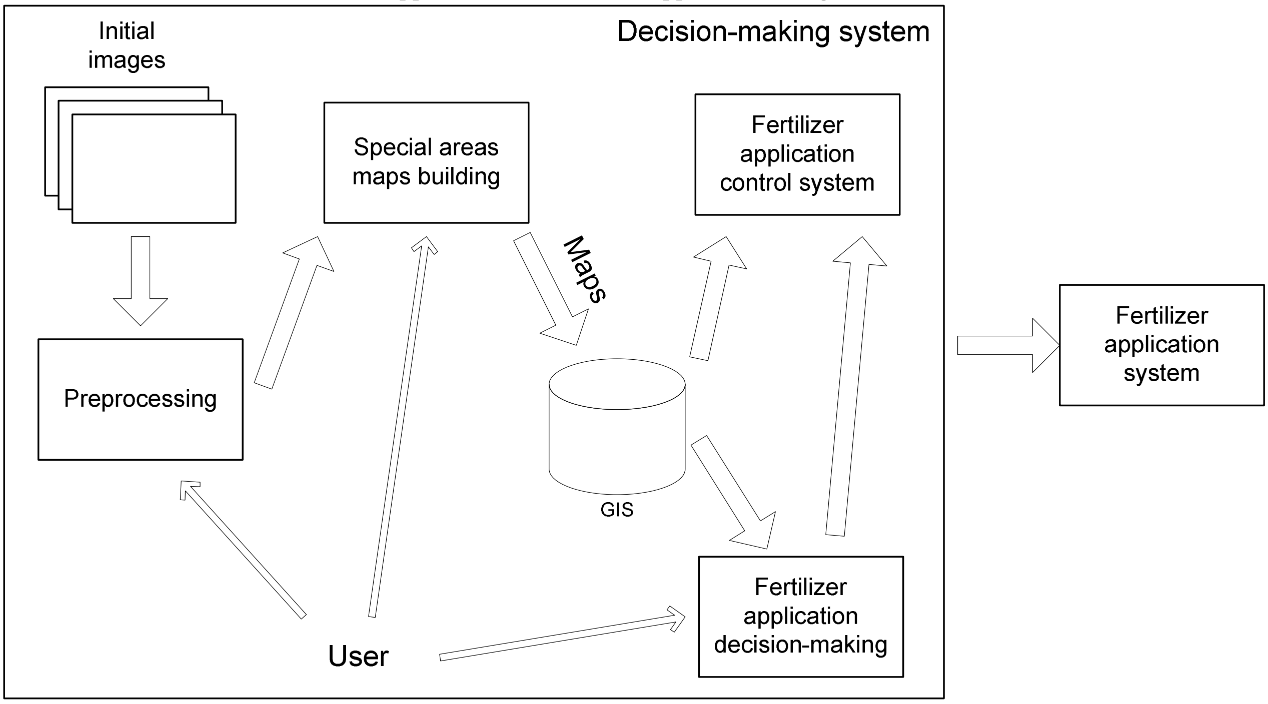

Fig. 8. Scheme of the hardware-software complex for mineral fertilizers and other chemicals application on agricultural fields

8. References

[1] Belyaev B.I., Katkovsky L.V. Optical remote sensing. – Minsk: BSU, 2006. – 455 p. [In russian].

[2] Chao, K., Y.R. Chen, and M. S. Kim. Machine vision technology for agricultural applications // Elsevier science transactions on computers and electronics in agriculture. – 2002. – Vol. 36.– P. 173-191.

[3] Feder E. Fractals / E. Feder. – Moscow.: Mir, 1991. – 254 p. [In russian].

[4] Ganchenko, V. Joint segmentation of Aerial Photographs with the Various Resolution / V. Ganchenko, A. Petrovsky, B. Sobkoviak // Proc. of the 5th Int Conf on Neural Networks and Artificial Intelligence ICNNAI 2008, May 27-30, 2008, Minsk, Belarus – Minsk, 2008. – P. 177-181.

[5] Francis S.Hill. Computer Graphics. // Macmillan Publishing Company. – 1990.

[6] Foley, van Dam, Feiner, Hughes. Computer Graphics: Principles and Practice. – Addison-Wesley Publishing Company, 1990.

[7] Haralick R.M., Shanmugam K., Dinstein I. Textural Features for Image Classification // IEEE Transactions on Systems, Man and Cybernetics. – 1973. – No.6. – P. 610-621.

[8] Starovoytov V.V. Local geometrical methods of digital processing and the analysis of images. // Starovoytov V.V. – Minsk: Institute of technical cybernetics BAS, 1997. – 284 p. [In Russian].

[9] Sobkowiak B., Analysis of colour images of infested crop fields. Part 1. Carrying out of the test and assessment of its results / B. Sobkowiak, T. Pawlowski // Wybrane zagadnienia ekologiczne we współczesnym rolnictwie. Monografia, tom 2; pod red. T. Pawłowskiego. – Poznan: Industrial Institute of Agricultural Engineering. – 2005. – Vol. 2. – 128 p.

[10] Vatkin, M. Isolating of informative features of potato diseases on the basis of colour characteristics of leaves / M. Vatkin, V. Ganchenko, A. Doudkin, A. Petrovsky, B. Sobkowiak // Journal of Research and Applications in Agricultural Engineering, Poznan, 2007. – Vol. 52 (4). – P. 98-99.