Special areas detection using fractal and textural characteristics of high resolution images

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Abstract: *Aerial photograph processing methods based on textural and fractal characteristics of images are considered in the paper (on an example of agricultural field images). ASM, Contrast and Entropy are used as textural characteristics. Calculation of fractal signature is based on fractal dimension. Results of joint segmentation based on proposed methods are tested at processing potato field aerial photographs.*

Keyword: fractal, texture, agricultural field, high resolution image

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. For example, a change of reflective characteristics of potato plants in infra-red area allows identifying phytophthora even before appearance of visual features [1, p. 409]. 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).

100 meters — 50 meters — 15 meters — 5 meters

Fig. 1 – Examples of initial aerial photographs.

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 method under consideration.

The scientific idea of the investigation consists use textural and fractal characteristics with required properties for attributes space construction and objects detection on agricultural fields color images.

As a result of the analysis of methods and algorithms of allocation of objects on images with use textural and fractal characteristics basic textural characteristics are allocated: 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. Fractals construction ways and textural and fractal characteristics application in images processing are also considered.

2. TEXTURES

A texture is one of the major characteristics used for identification of objects or areas on the image. It represents two-level structure:

- at the top level –a set of base elements connected by some spatial organization;

- on bottom – base elements representing casual aspect.

Structures on the basis of base elements attributes and interactions between them are subdivided on fine-grained, coarse-grained, smooth, granulated and undulating.

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

Textural basic characteristics are given below:

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

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

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

The example of textural characteristics calculation result is resulted on fig. 2.

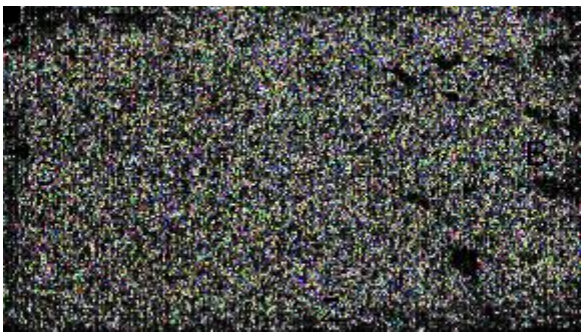

Fig. 2 – Result of textural characteristics calculation for a field aerial photograph executed from height of 15 meters.

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:

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

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.

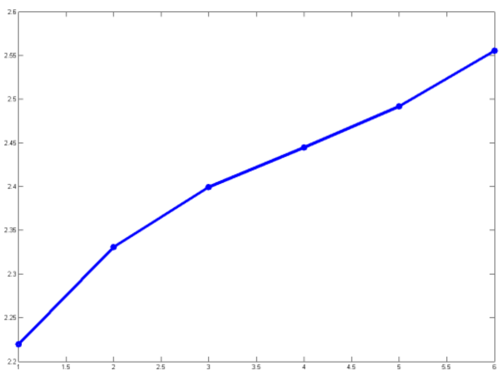

Fig. 3 – Forest fractal signature.

Fractal dimension *D* (*i*, *j*) at a finding of pixel (*i*, *j*) on all scales is evaluated as a weighed sum of local fractal dimensions F_ε (*i*, *j*):

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

where

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

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

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

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

after finding the logarithm, we obtain:

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

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

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

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.

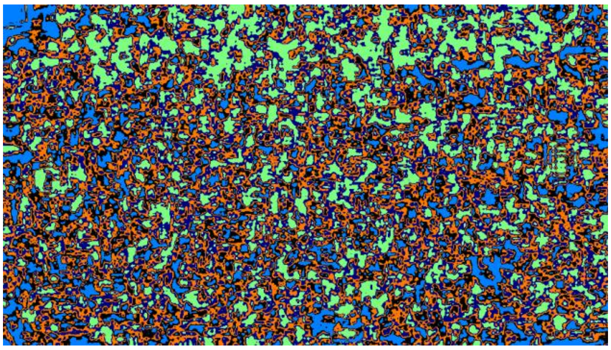

Fig. 4 – Fractal signatures of various image areas.

4. RESULTS

Results of application of the algorithms considered in the paper can be used for joint segmentation [4] applied to additional information channels supplementing an available initial image. Such processing example is resulted on fig. 5.

Obtained segmentation result allows in an automatic mode to detect areas on which there is a disease development. The knowledge of an allocation of such areas allows determining requirement of those or other agricultural fields areas for fertilizers and other chemicals. It allows making agricultural works more effective and less expensive.

Fig. 5 – Joint segmentation result example.

5. CONCLUSION

The scientific importance of the obtained results consists in capability of creation of new highly effective methods and high-efficiency algorithms of no anthropogenic origin objects images processing and fractal nature objects allocation.

The practical importance consists of application of the developed methods and algorithms for natural origin objects allocation that allow increasing essentially accuracy and reliability of functioning of computer vision systems, monitoring and decision-making.

Possible area of application is remote sensing of the Earth (in forestry, geology, agriculture).

6. 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.