ANALYSIS OF IMAGES OBTAINED BY CAPILLARY DYNAMOLYSIS METHOD

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Abstract

Now the methods of computational image analysis allow us to automate the techniques of routine analysis of digital images in various fields of research. The capillary dynamolysis method reflects the spectrum of organic matter in a biological sample. Last decades it is widely applied in ecology and food industry to study the properties of soil and products.

This paper presents an approach to the analysis and classification of soil samples obtained by capillary dynamolysis. Detectors of brightness differences help to define a special boundary curve on the image, and distances from the central point of the image to the points on the curve are the classifying signs for the image under study.

A set of 128 images is divided into 8 classes, which are used to assess the qualitative properties of soil samples. Computed features make it possible to distinguish samples of the soil of the worst quality and to compare images from different classes

1. INTRODUCTION

From the middle of the last century picture forming methods for investigating organic cultivation products are widely used. They are based on the inner structure of an explored sample which depends on biological processes under study. There are three classes of such methods: cupric chloride crystallization (called also biocrystallization), capillary dynamolysis, and circular chromatography. The main principle of the methods is to place some metal salts in water solution and perform the reaction with the substance to be analyzed. In the capillary dynamolysis method the reaction is taking place on vertically located filter paper with 0.5% solution of a metal salt, usually silver nitrate and ferrous sulfate. The paper absorbs the solution of the salt by capillary taking up, after which 0.1% sodium hydroxide solution with the sample extract is added. The filter paper then is dried and exposed by indirect sunlight. The result is the image with specific patterns and colors. Its characteristics allow us to make assumptions about the quality of samples and type of producing environment.

Picture forming methods have practical applications in the development of agriculture and estimation of plant food quality based on its organic properties. Also they provide an analysis of soil samples. Traditionally trained expert groups are involved in image analysis. They evaluate obtained images through approved criteria for describing differences between tested samples. But with growth of contemporary computational systems the necessity of applying automatic image analysis methods arises. Expert evaluation requires significant practical experience and a lot of time. More than that, a unified methodology for estimating sample properties does not exist. In this way, computational image analysis is able to increase the objectivity and quality of the evaluation results and allow processing large volumes of data.

This article presents an approach to the analysis of images obtained by capillary dynamolysis method. It is based on the assessment of shape and geometrical properties of a specific region of an image considered. The main steps include the image filtering for noise reduction and retrieval of key information, searching for interest area by applying special detectors based on lines approximation, and forming a final feature set depending on the image geometrical properties. The obtained image signs allow us to create a unique description for each tested sample. The paper is structured as follows. Section 2 describes existing approaches to analysis of images obtained by the capillary dynamolysis and other picture forming methods. Section 3 presents major points of the proposed approach for target images analysis. Section 4 discusses results and directions of a future work.

2. RELATED WORKS

Visual evaluation and computational analysis are commonly used to investigate images obtained by capillary dynamolysis and other picture forming methods. Computational image analysis is a nontrivial task, so it requires an individual line of attack which takes into account singularities of image formation.

The paper [11] describes key properties of images obtained by capillary dynamolysis and gives prescriptions for its visual interpretation. In [5] the authors present an approach to visual analysis of wheat images, which is derived from the experiments with capillary dynamolysis and biocrystallization. They use statistical methods for classifying target samples based on visually detected features. Several examples for image computational analysis are introduced for biocrystallization, but not for the capillary dynamolysis. The paper [4] discusses applications of capillary dynamolysis, biocrystallization and circular chromatography for analysis of quality and classification of grape and grape juice samples.

In [1] computational analysis methods are applied to examine impact effects of homeopathic drugs on plants. Images for source samples are generated through biocrystallization, their features are obtained by texture and variance analysis. Additionally, the authors use data representing physical properties of experiments.

The paper [7] presents an approach to visual and computational analysis of soil images acquired by the circular chromatography method. Areas of interest are selected randomly in central zone of an image which is previously transformed to grayscale, then the entropy of texture features in this area is computed. Results are combined with visual characteristics, and on this basis final image features are formed.

In [12] the authors describe a method based on neural networks to analyze images obtained by capillary dynamolysis. They notice that in literature there are no approaches to computational analysis of target images. The task of binary classification of organic and non-organic food images is considered. A source image is transformed to grayscale and convolved to a one-dimensional vector. To reduce the dimension of the vector the Gram-Sharle coefficients are computed, which form the resultant feature set. It should be noted that at the moment there are few methods of computational image analysis, because visual interpretation acquires more wide using both experience and practical applications.

The papers [9,10] describe our previous results concerning to analysis of images obtained by the capillary dynamolysis method. The proposed approach for feature selection was described in [9]. In paper [10] we presented the results of evaluation and clusterization on the dataset containing 31 images of soil.

3. THE ANALYSIS OF IMAGES OBTAINED BY THE CAPILLARY DYNAMOLYSIS METHOD

This method may be applied to obtain images when analyzing liquids, soils, food, plants [4,7]. One should note that digital images of different objects may have rather similar structures, which prevents us from visual comparing [11]. Besides that in practice we often have to deal with a small number of images. Our goal is to reveal characteristics of images obtained by the capillary dynamolysis method and use them as classifying signs of the objects under study. The proposed approach allows us to find the most informative areas on an image and define their geometric properties, such that these properties are unique for an object to a great extent. To find these areas and delete noise we use the filtration algorithms based on differential operators. We apply special detectors to find the points of the brightness difference, which helps to find the boundary of the area of interest. Then we calculate the distances from the centum of the image to the boundary. These distances are used as characteristics of the image. For testing the method, the experimental data consisting from 128 soil images obtained by capillary dynamolysis method [2] were used. All images have holes in the center and two areas – brawn and gray. The boundary of the fist area is smooth, and the second one has sharp edges. The example of an image obtained by the capillary dynamolisys method is shown on the Fig. 1.

Figure 1. Image of soil sample obtained by the capillary dynamolysis method

In experiments each image corresponds to one of metal salts: Ag, Au, Pb, Sn, Fe, Cu, Hg. To analyze biological preparation images one often apply spectral analysis [3] and statistical methods [6]. For data described above we calculated spectral signs and second order statistics. But the experiments showed that for different samples results differ on 10-20%, which is insufficient for further classification. Hence these methods should not be applied for unique identification of such objects. Thus, the demand arises to filter noise and reveal the most informative signs for classification. In [11] the methods of visual interpretations of chromatogram are described. They may be applied for analysis of soil images obtained by capillary dynamolysis. The author underlines the need to pay attention to rings between external and internal zones and to the edge of the external zone. Visual interpretation leads to the conclusion that the area of interest is inside of external gray zone, because the main change of intensities is concentrated on the boundary, and edge contours are not similar for different images. To localize the position of the contour and calculate numerical signs the following steps are performed:

- filtration by application of binarization (the threshold is defined experimentally) and the Sobel differential operator;
- finding the image center: we use "sliding line detectors" which searches a group of close white pixels inside the black contour;
- search the curve on the image. We construct the line from the image center with a given angular coefficient and take the point on the line, which is the point of the brightness difference, as approximation for the point on the curve. The process is repeated for the next angle value.

The obtained sequence of coordinate values is an approximation of the curve. The signs are the distances from the center of the image to the points on the curve. Thus, in the results of our transformation the closed curve (in polar coordinate system) turns into a curve in Cartesian coordinates, being all its geometrical properties are saved. It is easy to understand that the dimension of the obtained vector of signs depends on the step by the angle.

4. EXPERIMENTS AND DISCUSSION

For testing the proposed algorithm, we used the set of 128 soil images, obtained by the capillary dynamolysis method. These images were produced in four different laboratories with various conditions. Samples were taken from 7 distinct soil types, and NaOH sample was additionally included in the experiment. Dataset is supplemented by the information about the nature of soil samples such as id of sample environment (sampleID), dates of extraction and experiment and the laboratory identifier. The results of exploratory analysis clearly showed that initial parameters of experiments influence the inner structure of obtained samples. Therefore we performed the analysis of each group individually to reveal both generalizing and differentiating signs. We implemented three different clusterization techniques for analysis of each group of samples. Hierarchical clustering and Kohonen self organizing map (SOM) were preferred because of simple visual interpretation and lack of requirement to define initially the number of clusters. We acquired results of both methods for each laboratory and compared the fragmentation obtained with the information about the nature of soils. In this case the conclusions about the suitability of features were drawn basing on the quantity of soil samples from single environment (SampleID).

Besides that the attention was paid to the differences in results of SOM and hierarchical clustering. The distribution of objects from single sampleID turned up into one cluster (for one of four laboratories) is shown in Table 1. Two numbers written in a table through a slash are the number of images from one sampleID in one cluster and total amount of objects in target sampleID respectively.

Table 1. The results of clusterizations

	Kmeans	Hierarch	Som
12-1	3/5	4/5	3/5
12-2	3/6	4/6	3/6
67-1	3/7	4/7	2/7
67-2	4/6	4/6	3/6
91-1	3/6	3/6	1/6
91-2	3/6	4/6	6/6
91-3	3/6	6/6	4/6

Table 2. Cross-correlation between 12-1 and 67-2 SampleIDs

	12-1	12-2	67-1	67-2
12-1	0.524	0.453	0.424	0.459
12-2	0.418	0.381	0.329	0.274
67-1	0.361	0.288	0.456	0.256
67-2	0.325	0.283	0.389	0.548
91-1	0.323	0.356	0.380	0.440
91-2	0.343	0.380	0.403	0.442
91-3	0.488	0.386	0.422	0.466
NaOH	0.281	0.256	0.248	0.148

Table 3. Cross-correlation between 91-1 and NaOH SampleID

	91-1	91-2	91-3	NaOH
12-1	0.351	0.343	0.384	0.267
12-2	0.224	0.355	0.397	0.237
67-1	0.336	0.381	0.404	0.235
67-2	0.392	0.478	0.327	0.252
91-1	0.493	0.415	0.288	0.238
91-2	0.312	0.517	0.488	0.260
91-3	0.454	0.430	0.553	0.266
NaOH	0.263	0.267	0.256	0.502

Further we propose to estimate the ability of extracted features to differentiate the objects of one class from the objects of another (without regard for the conditions of the experiment). Tables 2 and 3 show values of cross-correlation coefficients between randomly select objects in each class.

It is a standard method to estimate the degree of correlation between two series. This characteristic is invariant regarding rotation (for example 2 similar chromatograms may be rotated by different ways). Values close to 1 imply high degree of similarity between objects, values close to 0 signify no dependencies. For assessment we can use Chaddock scale, that make week connections for correlation between 0.1 and 0.3, moderate for values between 0.3 and 0.5 and noticeable between 0.5 and 0.7. It is clear that the correlation between NaOH class and all other classes is week in terms of the Chaddock scale. This allows us to assume that obtained features help to detect samples with the worst soil quality.

Hierarchical clustering shows the best results and collects more the half of objects from same samples into one class. But evaluation of final split seems not to be accurate enough to clearly distinguish samples from one laboratory. The directions of future work will include an exploring of new additional features that could be combined with existing ones and demonstrate a higher degree of similarity between objects from one class.

5. CONCLUSION

In this work we proposed an approach to the analysis of images obtained by the capillary dynamolysis method. It is based on the estimation of the image form and geometrical properties of the boundary curve. The main goal is to find key characteristics which may be used as classification signs. As such a sign we considered the vector of distances from the image center to the points on the boundary curve. The method was tested on the set of 128 soil images. To estimate the effectiveness of these signs the clusterization was performed, and cross-correlations between different classes were calculated. This method may be considered as a promising tool for further investigations

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