Use of photogrammetry in determination of pollen characteristics

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A technique is proposed for studying morphometry of pollen grains by means of photomicrography using a digital photogrammetric station. The photogrammetric processing of digital images allows determination of parameters characterizing the shape of pollen grains what is important for estimation of their aerodynamic properties.

Introduction

Aerosol biogenic particles are very specific. They are characterized by complex shape, and some of them can change their shape under the influence of ambient factors. Morphology of pollen grains is connected with the methods of their spreading and transport. To determine the concentration of pollen in air and to estimate aerodynamic properties of pollen grains when simulating the dynamics of their spreading, we need quantitative data on their shape, but these data are unavailable now.

The photogrammetry is an efficient method of quantitative interpretation of micro-objects. It can be used to determine any quantitative characteristics of the objects under study using their images and, in the presence of a stereopair, to reconstruct the spatial image (stereo model) of some micro-object in order to derive its spatial characteristics.

1. Technique

To study the morphological characteristics of pollen grains, we propose a technique based on the use of computer photogrammetric technologies (Fig. 1). Micro-images of pollen grains converted into the digital form are subjected to photogrammetric processing at the SDS digital photogrammetric station developed at the Faculty of Photogrammetry and Remote Sensing of the Siberian State Geodesic Academy.[1] The SDS software includes codes for processing of both aerospace photographs (single images and stereopairs) and images recorded from close distances, including microscopic ones. The left and right images, matched on a screen, form a stereo pattern when observed through polarization liquid-crystal glasses with a flicker frequency of 120 Hz.

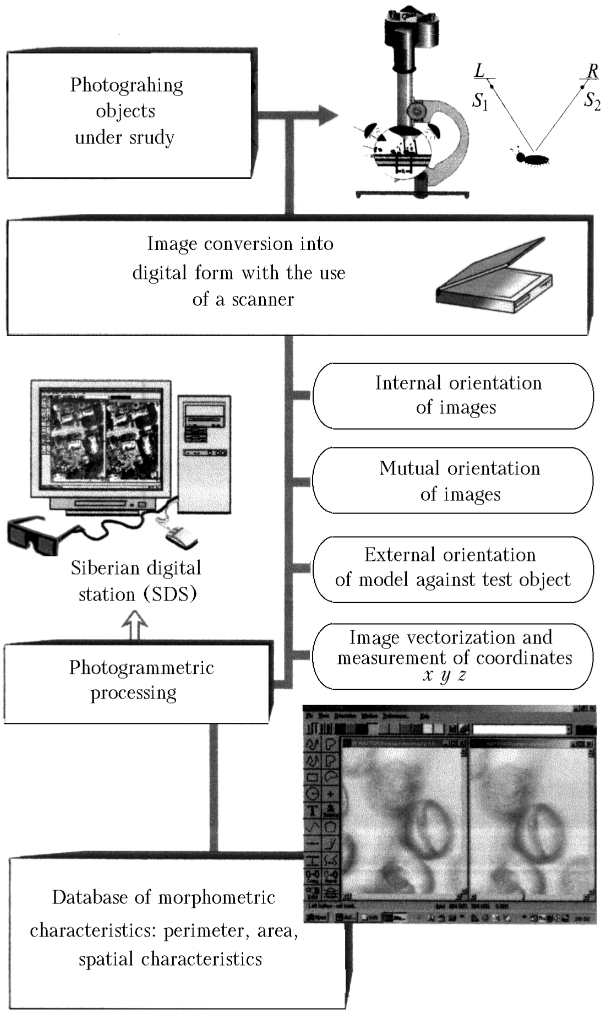

Fig. 1.

The photogrammetric technique of studying morphometry of pollen grains includes the following processes:

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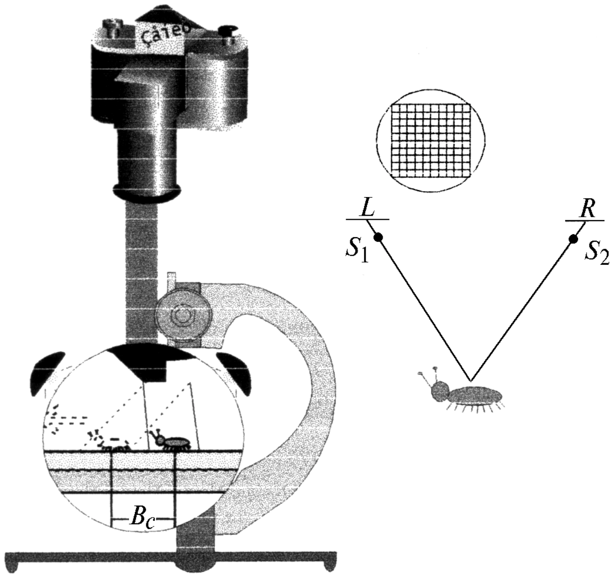
– photographing objects under study;

– converting photographic images into the digital form with the use of a scanner;

– processing mathematically the digital images with the use of SDS programming modules;

– processing statistically the determined pollen characteristics.

When approving the proposed technique, we used an MBI–11 microscope equipped with a photographic attachment. For metric calibration of images together with the studied samples, a specially manufactured test object (Fig. 2) made as a grid on barite glass was used as a substage. To obtain the stereopair, a sample was photographed twice, and between two exposures it was displaced by the length of a base. The test object was moved by the substage. Taking into account that objectives of light microscopes have low depth of focus, a series of experiments was conducted in order to choose the illuminating conditions and photographic materials providing a good stereo effect.



Test object

Fig. 2. Experimental setup and photomicrography technique: L is position of the object for the left picture; R is that for the right picture; B_c is the base.

Images obtained under the above conditions were digitized with the help of a scanner (the negative image was scanned). The recommended resolution of a digital image is no less than 600 dpi.

Processing the photomicrographic images at the digital photogrammetric station includes the following processes:

– calibrating initial raster images to take into account their geometric and scale distortions using the image of the test object;

– constructing the spatial model of the photographed objects (mutual orientation of the left and right images and external orientation of the model against points at the test object image);

– measuring the coordinates of points of the model in the stereo mode (for single images in the mono mode), interactive drawing of the object's boundaries if necessary, and representing the spatial shape as isolines.

2. Experimental results

At the first stage, we processed single images of pollen grains of different cultures by the technique described above. Figure 3 shows the fragments of digital images ($100^{\times}$-fold magnification) of pollen grains of couch grass and pine tree. At these images, grain boundaries, which are needed for determination of their area and perimeter, are identified.

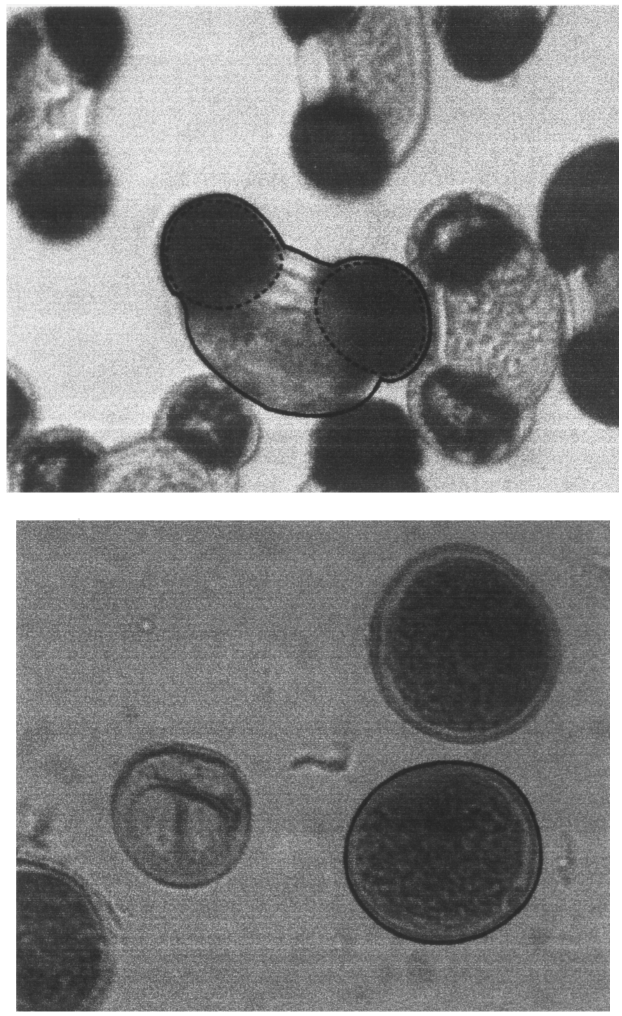


Fig. 3.

The couch grass pollen is an example of pollen grains of the simplest (close to spherical) shape. The pine tree pollen grains ($i = 4$) have a complex shape, and more complex procedures are needed for its quantitative description. A grain consists of a body of the pollen grain ($i = 3$) and two air bags ($i = 1, 2$). The pollen grain's contours are outlined by solid line, and the air bags are shown by dashed lines. Table 1 presents the measured parameters of pollen grains for three kinds of plants, whose pollen shapes are close to the spherical ones. Pollen grains of these plants have the shape of plane disks, whose cross sections are approximated by ellipse. In this case, the perimeter (P) and area (S) of pollen grains are expressed through the large ($2b$) and small ($2a$) axes as follows:

$$2b = \frac{P}{2E(e)}, \quad 2a = \frac{4S}{2\pi d}, \tag{1}$$

where

$$e = \sin\alpha = \sqrt{(b^2 - a^2)/b^2}, \tag{2}$$

and $E(e)$ is the total elliptic integral.

Table 1. Characteristics of pollen grains of some plants

Characteristic	Timothy-grass		Couch grass		Siberian larch	
	P, μm	S, μm^2	P, μm	S, μm^2	P, μm	S, μm^2
Mean value	75.4	412	134	1430	249	4840
RMS deviation	5.4	58	12.5	260	12	460
Number of pollen grains	100		66		88	
Parameter R	0.6075		0.6362		0.63072	
$2b$, μm	29		45		88	
$2a$, μm	18		40		70	

N o t e . Parameter R is calculated by Eq. (3).

From Eq. (2) we can derive the following relation between the experimentally determined values of P and S and the value of e:

$$R = f(e) = \frac{\sqrt[4]{1 - e^2}}{E(e)} = \frac{4\sqrt{S/\pi}}{P} \,. \tag{3}$$

The values of the function of R are given in Table 2.

The volume of spheroid (V_i) can be found from the following equation:

$$V_i = (2\pi b_i a_i^2)/3, \quad i = 1, \dots, 4. \tag{4}$$

The diameter of the equivalent sphere, i.e., spherical particle, whose volume is equal to the volume of some particle of non-spherical shape, is described by the following equation:

$$d_{\text{shp}}^{\text{eq}} = \sqrt[3]{2b_i(2a_i)^2}. \tag{5}$$

From Eq. (5) we have $d_3^{\text{eq}} = 26$ μm and $d_4^{\text{eq}} = 41$ μm. At the same time, the volume of a pollen grain $V_4 = 2V_{1,2} + V_3$. Based on this value, we have obtained the value of the equivalent diameter $d_4^{\text{eq}} = 34$ μm. According to the experimental data from Ref. 2, the weight of a pollen grain of pine tree is $1.4 \cdot 10^{-8}$ g. Thus, the volume equivalent diameter of pollen grains of pine tree is equal to 30 μm. This value is situated between the values of d_3^{eq} and d_4^{eq}, and it is close to d_4^{eq} (the equivalent is calculated by the weight of the pollen grain).

At the second stage of our study, we optimized the technique of stereo photography of pollen grains in order to obtain the quality of the images sufficient for photogrammetric processing. Based on the experiments, we have found the optimum conditions: simultaneous illumination by incident and lateral transmitted radiation and the base length from 10 to 15 mm. These conditions are favorable for achievement of the limiting resolution and display of the grain surface texture. Stereopairs obtained with allowance made for these requirements were processed at the digital photogrammetric station by the technique described above.

The conducted experiments confirm the possibility of observation and measurement of the stereo (volume) model of pollen grains. Figure 4 shows the image of larch pollen on the test object (the line separation is 100 μm). When photogrammetric processing, we have drawn isolines of equal heights with the interval of 5 μm. The surface of the test object was taken as the initial (zero) one. The obtained isolines represent the spatial shape of the visible part of the photographed pollen grains. These data allowed us to estimate the volumes of the surface of the visible part of the pollen grains as $4.1 \cdot 10^{-8}$ and $4.3 \cdot 10^{-8}$ cm^{-3}, respectively. The obtained results allow the conclusion that the proposed method is, possibly, promising in determination of the pollen grains shape. The accuracy is expected to be within 10%.

Table 2. Function $f(e)$

α, deg	$f(e)$	α, deg	$f(e)$	α, deg	$f(e)$	α, deg	$f(e)$
0	0.63662	25	0.63547	50	0.61441	75	0.47263
5	0.63662	30	0.63414	55	0.60169	80	0.39808
10	0.63659	35	0.63190	60	0.58385	85	0.29023
15	0.63646	40	0.62827	65	0.55859	90	0
20	0.63616	45	0.62261	70	0.52291		

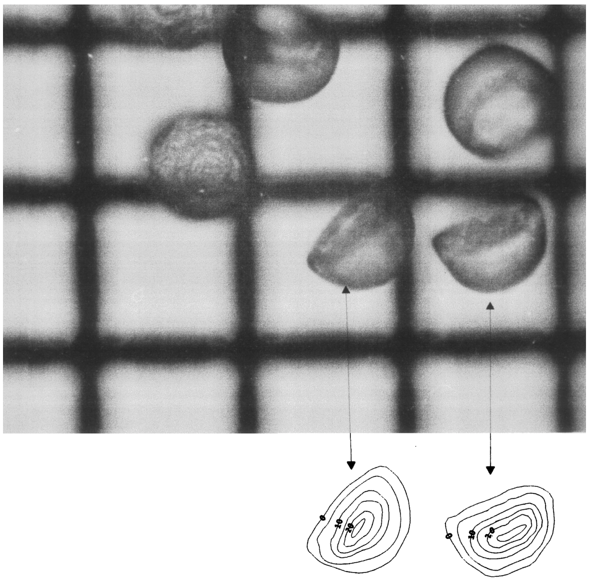


Fig. 4.

Conclusions

Thus, the photogrammetric method of pollen grain images processing at the digital photogrammetric station allows the morphometry of pollen grains of various cultures to be studied. Application of the test object and rigorous mathematical algorithms allows one to separate out the boundaries of objects of any configuration with the needed accuracy and detail and determine such quantitative characteristics of the separated objects as area and perimeter, and (in the presence of stereo images) their spatial characteristics.

References

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