Use of numerical stereophotogrammetry and GIS technologies for description of dynamic surface inhomogeneity

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Stereophotogrammetry and GIS technologies are suggested to describe the dynamic inhomogeneity of the surface for modeling diffusion of aerosols in the atmospheric boundary layer. These technologies provide collecting areal average data on the images of different scales with necessary detail. A general scheme for solution of the problem is presented, and the parameters determining the accuracy are considered.

Introduction

In numerically simulating diffusion of aerosols in the atmospheric boundary layer, considerable difficulties arise on formulating boundary conditions for actual surface inhomogeneity. Such situations arise, as an aerosol cloud propagates over uneven terrain including areas with different vegetation cover (grass, shrubs, trees), ravines, hills, lakes, rivers, etc.

Another case is diffusion of a pollutant under conditions of urban building. In numerical simulation of the diffusion of an aerosol cloud, the boundary conditions are usually set very schematically, that leads to considerable discrepancy between calculated concentration fields and the measured ones.

The use of photogrammetric methods in combination with the up-to-date information technologies could provide for the development of numerical models with necessary detail.

Photogrammetric methods are specific from the viewpoint of immanence to the object of study. This manifests itself in the fact that inherently spatial objects are studied using their spatial models (rather than plane images). The possibility of visualizing the results in the form of combined three-dimensional models with fixed metrics characteristics makes the photogrammetric methods attractive for various users.

The quality of such models from the viewpoint of their accuracy and adequacy is directly connected with the selection of survey parameters, surveying instrumentation, and algorithms for data processing. In this paper we consider some aspects of using photogrammetric technologies for modeling inhomogeneous dynamic surfaces, as well as some examples of their implementation for particular territories.

Technology of photogrammetric method of collecting aerial data

Digital photogrammetric methods provide for efficient solution of the problem of surface modeling from various images. They become especially urgent on the local scale of environmental investigations, in particular, for the problems formulated in previous Section. Depending on the type of the territory studied and characteristics of the initial images, different programming and technological methods can be applied to photogrammetric processing.

Typical procedures of digital photogrammetric processing are implemented in the software of digital photogrammetric stations and, to a certain extent, in full-range raster geoinformation systems (GIS). As for vector GIS, their capabilities of extracting data from images are limited, but they can be used provided that they are complemented with algorithms of photogrammetric processing.

Thus, to process images of a plain terrain, the method of digital plane phototriangulation with the use of GIS tools is developed.[1] This method supplies every image with the needed number of reference points leveled and combined into a common network.

The optimal method providing for the best accuracy is the technology shown in Fig. 1. In this case, extracting data from images is implemented on a digital photogrammetric station (or versatile analytical device), and then the data obtained are exported to GIS for analysis and interpretation.

In studying undulating ground and mountainous territories, the landscape is a significant factor, therefore a digital model of the territory is constructed based on stereopairs of air photos. This is performed at a photogrammetric station, and the data are collected in accordance with the stereoscopic model of the territory. Thus, a digital model of a preset structure that presents any landscape form can be constructed.

The detailed technology depends on the tasks and landscape features of the territory studied. The efficiency of using air photos (or other materials) is determined by surveying parameters, the most important among which is the scale. The selected survey scale should provide for the information content sufficient for the objects studied and, whenever necessary, for joint analysis of

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natural objects of different spatial level from different-scale images. Information content of images depends on the survey methods and instrumentation, as well as on optical, meteorological, and other conditions. It is worth restricting the minimum survey scale based on minimum size of objects or their parts on a photo.

For scale selection, the following dependence can be used:

$$m = (2LR/B)\sqrt{-\ln P_B\,\Delta D},$$

where m is the scale ratio of images; L is the linear size of an object; R is the camera resolution; B is the coefficient of recognition of the object's shape; P_B is the probability of object recognition from aerial photos; ΔD is the absolute difference between the optical densities of the object and background.[2]

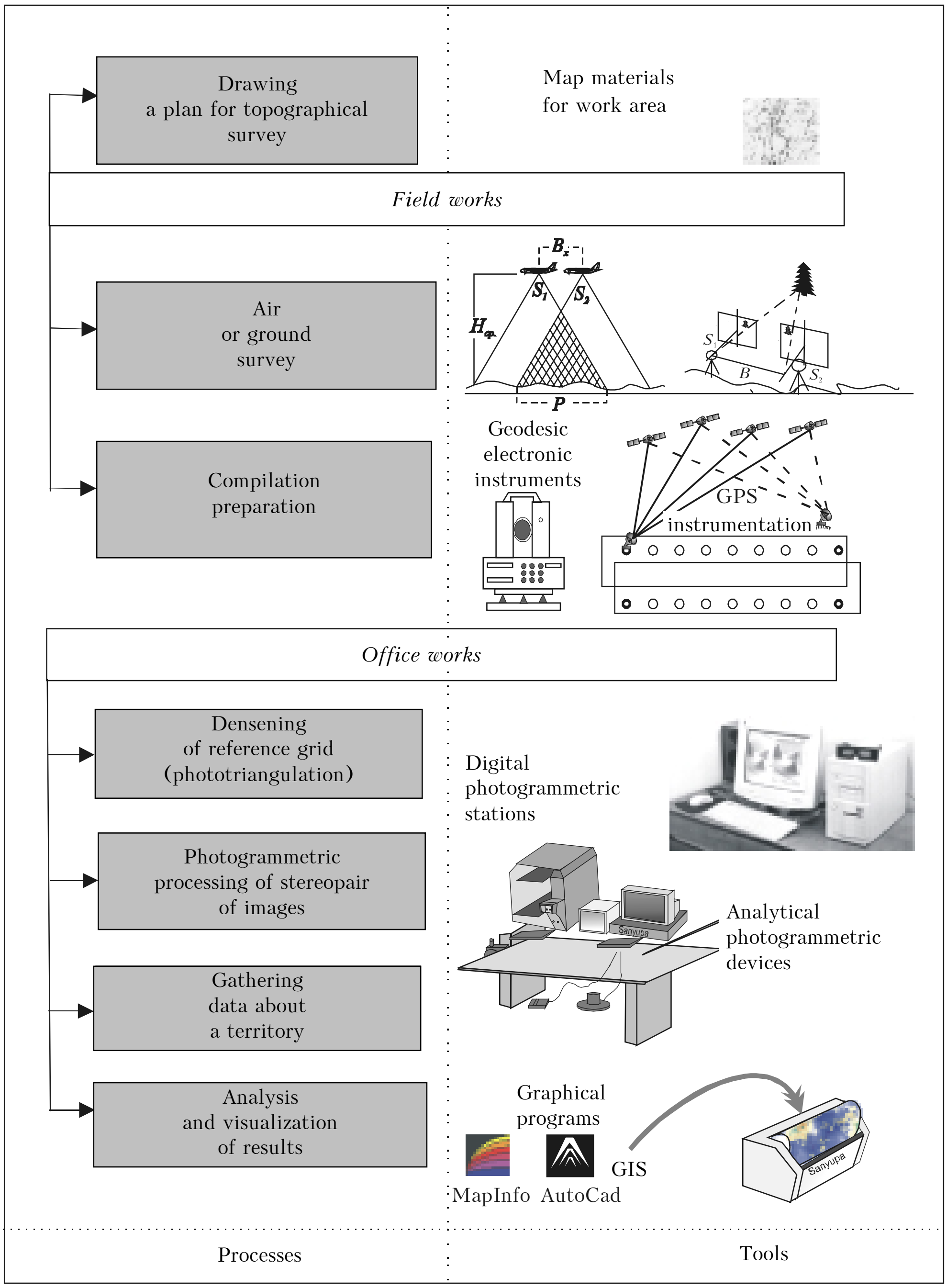

Fig. 1. Functional diagram of collecting photogrammetric spatial data on a territory under study.

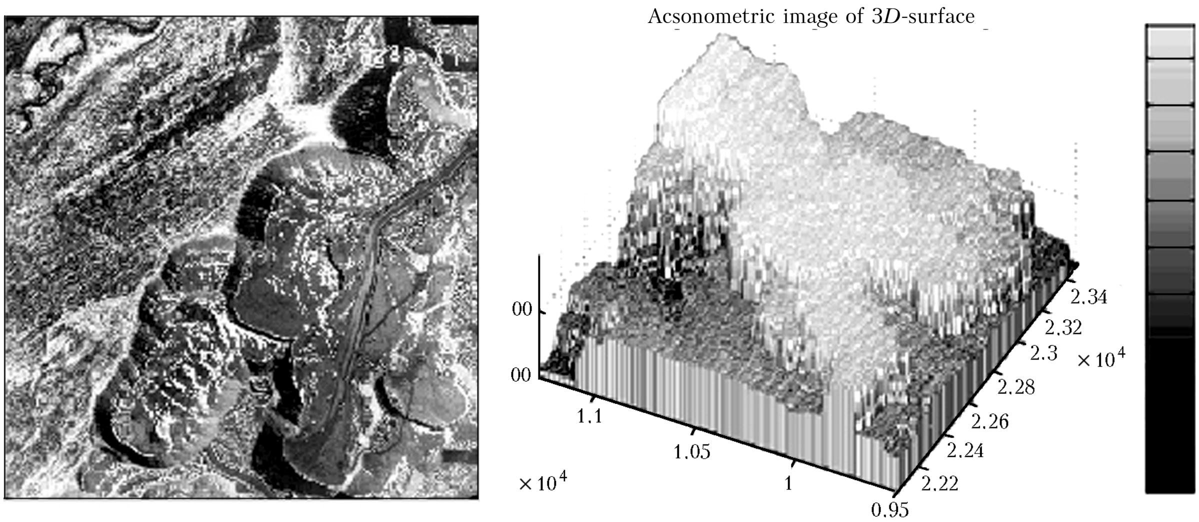

Fig. 2. Three-dimensional surface of a coal pit near Kemerovo.

The parameters entering into this equation, in their turn, are regulated by a rather large number of factors. Thus, ΔD is determined by the character of object boundaries on the territory. Finally the resolution is determined not only by the capabilities of an optical system used, but also by the resolution of a digital image, which can be obtained directly by using a digital camera or through scanning. These factors determine the limitation of the dimensions imposed on an element of a digital image.

Geometric characteristics of images depend also on the camera focal length. In particular, application of short-focus aerial cameras provides the overdone vertical scale of a stereo model and thus improves the conditions for recognition and measurement of microrelief and low-level vegetation. To survey mountainous territories or high-rise built-up areas, long-focal length objectives should be used to decrease geometric distortion of images.

As an example, after calculations by the above equation, we determined that to identify vegetation canopy of trees and shrubs, 1:10000 photos should be used, and for the territory covered by perennial grass, large-scale (up to 1:3000) photos are needed.

Taking the above-said into account, we have developed detailed technologies for extracting data from images of various territories. To finalize these technologies, we used an SDS photogrammetric station developed at the Faculty of Photogrammetry and Remote Sensing of Siberian State Geodesic Academy.[3]

Practical implementation

The developed technologies are applied to making up digital maps of various scales and thematic designation. For example, 1:25000 topical maps of the Zdvinskii District of Novosibirsk Region were drawn. They present the current state of landscape from 1:20000 aerial photos.[4] Digital maps for inventory of land resources with the visualization in the form of three-dimension maps were drawn from 1:6000 aerial photos. Stereopairs of aerial photos were used to form digital models of landscape at different territories. A fragment of such a model of one of Kemerovo coal pits is shown in Fig. 2.

Conclusion

Application of digital photogrammetric technologies and GIS yields spatial data for numerical simulation of an inhomogeneous dynamic surface capable of meeting practical needs in controlling the accuracy and detail of the data collected.

Wide use of computers accompanied by a significant decrease in their cost and the increase in the power and speed, as well as application of digital cameras favor application of digital photogrammetric technologies and continuous increase in their efficiency.

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