UDC 528.952

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THE AUTOMATED SYSTEM "AMAP" FOR CONSTRUCTING 3D MAPS ACCORDING TO AEROSPACE PHOTOGRAPHY

An information technology underlying the automated system "AMap" described. The information technology includes: using physical maps as initial data for 3D surface; using spatial data interpolation methods; using methods of imposing noise and low-pass filtering to model for better user perception, in particular, reducing the "stairs effect"; using digital image stabilization for improving textures quality.

Introduction. At present, a realistic three-dimensional maps can be use to develop navigation systems, three-dimensional catalogs of maps, to control current status of the airspace, in the movies and more. One of promising area is the modeling of 3D maps, where as textures can be used images obtained by unmanned aerial vehicle (UAV). Spatial models of maps based on UAV data can be components of data storage; data can be detailed or aggregated [1] to solve specific problems, such as modeling the current state of airspace, simulation runway of an airport, etc.

Images obtained from UAV, can have great resolution, which does not allow displaying them in full size. In terms of the concept of data storage, it should be noted that images the Earth's surface is a detailed data. Processing and using of such data has some difficulties. At the same time interactive spatial model is a set of aggregated data and enables the user to interact with the map, look at it from different points and angles, view some detailed fragments or the general scene.

The question of building three-dimensional map includes the construction of a model of the terrain based on geodetic measurements and overlay images of Earth's surface binding to fixed points. Also, the process of creating 3D maps can be followed by a need to solve additional problems:

1) increasing counts of relief model data (based on interpolation techniques);
2) changes in the representation of 3D models which contribute to a better perception of the user (the effects of "noise", "smooth", etc.);
3) procedures for handling texture (quality improvement).

The automated system "AMap" implements the methods to solve the issues described above.

Problem. As mentioned, to create three-dimensional maps need to construct a spatial model of the terrain and to bind it to image the Earth's surface. Steps of constructing 3D map are in Fig. 1:
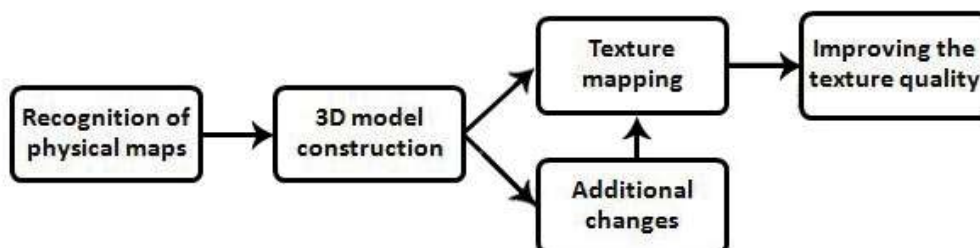

Figure 1. Steps of constructing three-dimensional map.

One of the instruments of the initial data for the model topography is digitizing electronic physical map with the defined heights scale. Physical map is a map that is presented as a schematic diagram of a location and scale heights. In compliance with each color of the heights scale supplied range of heights (Fig. 2).

For definiteness, assume that the physical map presented as bitmap with RGB color model. Denote $p_{i,j}$, $i = \overline{0, W-1}$; $j = \overline{0, L-1}$ - intensity of color pixel component, where W, L - linear dimensions of the image. Let is a digital high resolution image; obtained from remote sensing (e. g.

Landsat) that determines the sample surface of the Earth. Hereinafter we will call this the image texture in terms of texture of 3D model. Denote $p_{i,j}^{*}$, $i = \overline{0, W^{*}-1}$; $j = \overline{0, L^{*}-1}$ - intensity of color pixel component (R, G, or B), where W^{*}, L^{*} - linear dimensions of the texture.

Three-dimensional coordinates will be denoted in the Cartesian coordinate system where axes x and z correspond to the width and length of the map and axis y - height above sea level.
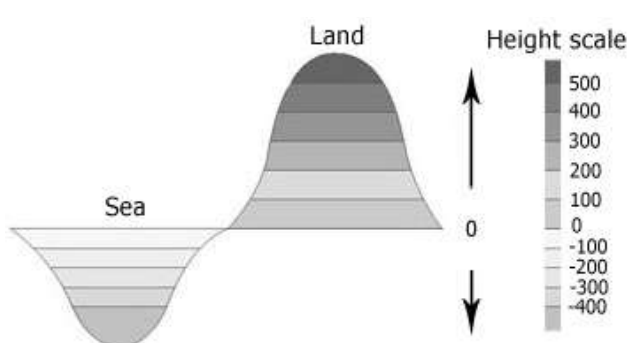

Figure 2. Height scale at a physical map.

There is necessary to develop information technology for construction 3D maps, which allow:

1) recognition of electronic physical map and identification of the heights scale;

2) build a model of spatial locality by using obtained data;

3) binding of realistic textures and the constructed model;

4) improve the quality of overlay texture;

5) changes in the 3D models that contribute to a better perception of the user.

Purpose of article is a description of information that underlies automated system "AMap".

Basic material. As mentioned the issue of building three-dimensional map includes the construction of a model of the terrain based on survey research and the task of overlay a picture of the Earth's surface by binding fixed point. Next, consider the steps to create 3D maps according to the induced (Fig. 1).

Recognition of physical maps. At this stage there is the task of mapping data in a physical map with spatial coordinates. Put w and l - linear dimensions on axis x and z of fragment spatial models that corresponds to one pixel. Analyzing the height scale, each (i, j) pixel ($i = \overline{0, W-1}$; $j = \overline{0, L-1}$) of physical maps with the intensity of color component $p_{i,j}$ match to the height $h_{i,j}$.

Color of an input image pixel may not coincide with the color from heights scale, for example, if the map has conditional tags, pictures of rivers, city names and other symbols. Then recursively analyzes color values of neighboring pixels, until found necessary value of height.

Build a 3D model. There are many graphics accelerators with hardware to paint 3D objects, removing invisible parts, binding texture etc.

In the previous step was obtained $h_{i,j}$; $i = \overline{0, W-1}$; $j = \overline{0, L-1}$ – the set of points which are formed by a uniform grid. Quite easy to build a triangles network on these points:

$$h_{i,j} h_{i+1,j} h_{i,j+1}, ...; i = \overline{0, W-2}; j = \overline{0, L-2}.$$

By using software (DirectX, OpenGL, etc.) these polygonal areas are transferred for further processing accelerator that lets you take advantage of 3D-accelerators [2].

Texture mapping. Rectification may be considered as a transformation process of digital images carried out to obtain distortion of the images. Transformation parameters are obtained by using control points on the uncorrected raw image and their corresponding points on the map. There are three commonly used approaches to perform rectification process. These methods are polynomial, projective, and differential rectifications [3].

Projective transformation is defined by eight parameters, which can be derived from four object points lying in a map and their corresponding texture image coordinates. At the end of the geometric transformation, to obtain the pixel values (gray level values, intensities or color values) of the new image, a radiometric resampling is required. For this purpose, interpolation techniques are used (e.g. interpolation methods based on local polynomial splines, which are close to the average [4]). The rectification of image obtained from Landsat satellite [5] is on Fig. 3.
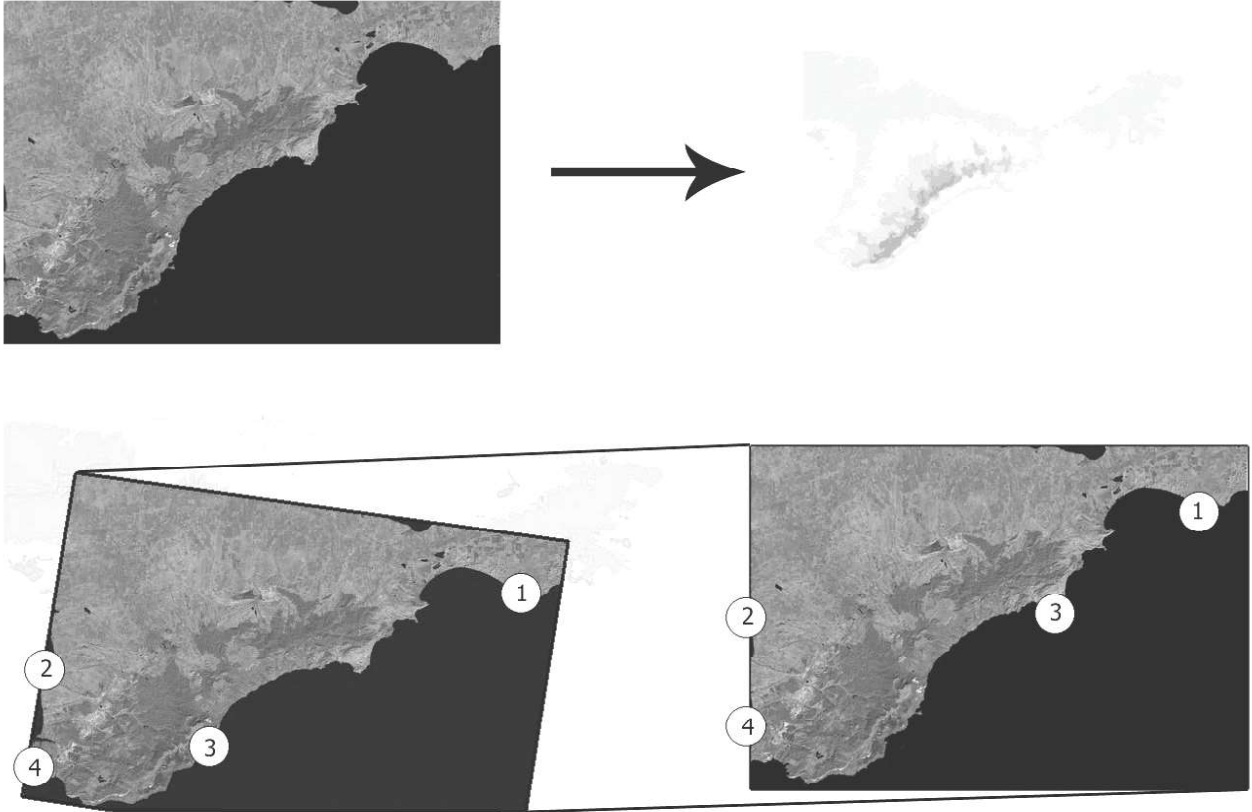
Figure 3. Rectificaton of a texture.

Additional changes. The following changes in the representation of 3D models contribute to a better perception of the user, but not a means of increasing its details. Their use depends on the problem that faces a particular realization of the spatial models.

Imposition of noise. Electronic physical maps contain information about a limited number of sections of height. For visual improvement resulting spatial models, and reduce the "stairs effect" (Fig. 4.a) suggested imposing a random normally distributed noise, which depends on the height of points on which it is imposed, i.e. $\tilde{h}_{i,j} = h_{i,j} + \mathrm{e}_h$, $i = \overline{0, W-1}$, $j = \overline{0, L-1}$ where $\mathrm{e}_h = N(0, \mathrm{y}_e)$ - normalized random variable with mean square deviation $\sigma_\varepsilon = \varphi(h)$ - a function of height, which is chosen so that any values of ε_h didn't go beyond the corresponding section of the heights scale.

Smoothing. After the imposition of noise possible to conduct smoothing of sequence $\tilde{h}_{i,j}$, $i = \overline{0, W-1}$, $j = \overline{0, L-1}$ using of low-frequency filters, to provide "realistic" look of the model. For example [6]:

$$\tilde{h}^*_{i,j} = \sum_{ii=i-r_i}^{i+r_i} \sum_{jj=j-r_j}^{j+r_j} \gamma_{ii-i, jj-j} \tilde{h}_{ii,jj} , \quad i = \overline{r_i, W-r_i-1}; \quad j = \overline{r_j, L-r_j-1};$$

$\left(2r_i + 1\right) \times \left(2r_j + 1\right)$ - size of mask of low-frequency filter; γ - filter mask.

Increasing the number of samples. In general, the number of pixels electronic physical map does not match the number of pixels of a texture: $W \neq W^*$ and $L \neq L^*$. Accordingly, the dimension sequence of h is less than the dimension of texture overlay. To increase the number of periods h is a need for methods of interpolation. To ensure the performance of calculations it is expedient to use
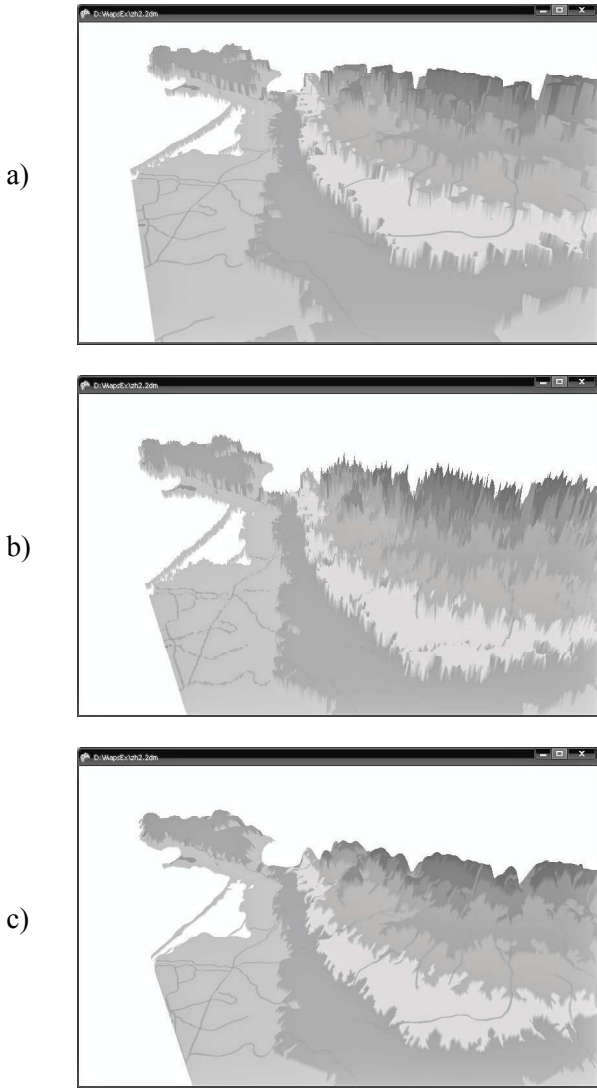
2.28

a)

b)

c)

Figure 4. Constructed 3D model with mapped texture: a) intact; b) noisy, c) noisy and smoothed.

the local approximation methods, in particular, to apply local polynomial splines of two variables based on B-splines that, on average, are related to interpolar [4], which can complement the array of vertices of the spatial model to the image size. Algorithms based on these splines have a great performance due to the low number of arithmetic operations and can operate in real time.

Improving the texture quality. The texture obtained by spacecraft may be distorted due to camera movement. This defect is a common on not fixed shooting or shooting from a platform that can be subject to some mechanical effects, such as microvibrations. The result of such defects can be eliminated or at least greatly reduced, not only hardware but also the mathematical processing procedures that operate in real time.

Assume that the distortion caused by the camera movement, i.e. impose a random low-pass filter:

$$p_{i,j}^{*} = Low(p_{i,j}^{0}) \, ; \; i = \overline{0, W^{*}-1}; \; j = \overline{0, L^{*}-1},$$

$p_{i,j}^{0}$ – color components of the ideal undistorted image.

Denote $\left\{ \tilde{p}_{i,j}^{*} \right\}_{i=\overline{0,W^{*}-1}, j=\overline{0,L^{*}-1}}$ – sequence of the color component raster after stabilization. In [7] presented linear operators such that $\tilde{p}_{i,j}^{*} = C(p_{i,j}^{*})$, and implemented: $\tilde{p}_{i,j}^{*} \approx p_{i,j}^{0}$; $i = \overline{0, W^{*}-1}$; $j = \overline{0, L^{*}-1}$, for random mask χ :

$$C(p_{i,j}^{*}) = \sum_{ii=i-r_i}^{i+r_i} \sum_{jj=j-r_j}^{j+r_j} \chi_{ii-i, jj-j} p_{ii,jj}^{0} \, ; \; i = \overline{r_i, W-r_i-1};$$

$j = \overline{r_j, L-r_j-1}$.

Software. An automated system "AMap" designed to detect patterns of digital physical maps, identifying the height scale and build three-dimensional models by using obtained data. The system consists of two separate applications, which can operate independently of each other. The first application MapCreator (Fig. 5) implementing electronic identification of physical maps in JPEG or BMP image and save data in file 2dm format.

The second application Map3DBuilder (Fig. 4) allows you to read data from a file 2dm format and implements methods of construction and transformation of the spatial model (blending textures, noisy, smoothing, etc.). System requirements for the second application: CPU: Pentium with a clock speed of at least 1GHz or equivalent processor, RAM: at least 96 MB (256 MB recommended) Operating System: Windows XP Service Pack 3 or higher; screen: resolution 800 x 600, 256 colors, graphics card: DirectX 9.0c with support and support for pixel shader version 1.1. Required Components: Microsoft. NET Framework 3.5 or higher; Microsoft XNA Framework Redistributable 3.0 [8].
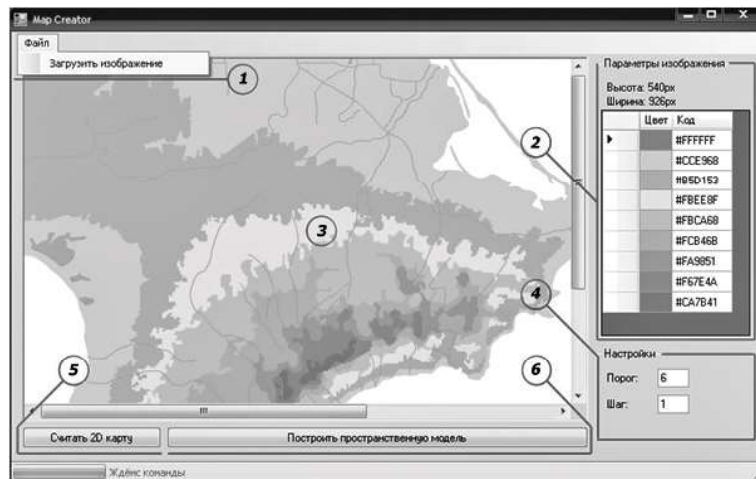
Figure 5. The main window of the first application (1 - home page 2 - picture settings;
3 – workspace; 4 - adjustment; 5 - map reader, 6 - build a 3D model)

Conclusions

An automated system "AMap" implements information technology that includes: using of digitized data of physical maps as maps heights 3D surface; using spatial data interpolation methods based on local polynomial spline interpolation close to the average increase in the number of periods for which there is modeling 3D surface; the methods of imposing noise and low-pass filtering methods to better model the user perception, in particular, reducing the "stairs effect"; using digital image stabilization for improved overlay textures.

The results may have application in developing aircraft simulators for training pilots, navigation systems, three-dimensional catalogs of maps for quick display of remote sensing, monitoring the current status of the airspace and so on. Further research may suggest the development of automated air traffic navigation systems, weather simulation, modeling take-off and landing aircraft, and more.

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