Three-Dimensional Geographical Information Systems

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Abstract – **The paper describes three-dimensional data models for relief modeling which are used in modern three-dimensional geographical information systems. The paper, also, describes a three-dimensional information system Ginis-3D which is developed in Computer Graphics and GIS Laboratory at Faculty of Electronic Engineering in Niš. Special attention is paid to the three-dimensional relief modeling and visualization. Algorithm for this purpose is described in detail, starting from faces generation for three-dimensional surface to the texture adding and other methods needed for the realistic relief visualization.**

Keywords – **Three-dimensional GIS, Terrain visualization**

I. Introduction

Visual representation of Earth's surface has a long history. Whenever, people tried to represent on drawing the landscape, which surround them. The oldest drawings have been found before 4000 in Mesopotamia. These findings were found on pottery and the drawings depict mountains and rivers in two dimensions [1]. Further evolution of cartography and relief representation was three-dimensional (3D) representation of Earth's surface on two-dimensional medium (paper or screen). During the history, models of relief representation varied from different symbols that depict mountains throw the special technique for represent inclination of terrain using different type of lines, to the wide used abstract symbolization that use contour lines [2]. Computers, and specially Geographic Information Systems (GIS), improve the possibilities for 3D representation of Earth's surface. Early versions of GIS have enabled founding same additional information (attributes) from two-dimensional map. The one of the possibilities is retrieving the additional information about third dimension (altitude) of arbitrary point on the map. Computer's and software's progress enable new opportunities to make the representation of landscape more realistic. The new trend in realistic modeling of real world is Virtual Reality (VR) [3]. The VR is not mature enough, but from the beginning the results are impressive. We witness the amassing progress of new technologies, which provide 3D data representation (such as 3D representation of real world). Naturally, development of GIS has pursued this progress. This was result in development the new generation of 3D GIS, which provides three-dimensional interactive topological maps without spatial, temporal and thematic constraints.

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II. Terrain Modeling

The basic information in three-dimensional relief representation is data of terrain altitude. This data can be acquired in different ways, from digitalization of two-dimensional maps using different software for semi or fully automated detection of contour lines [4] to the usage of Global Positioning Systems (GPS) and conventional gathering of attitude extracted from aero-photos taken from multiple different positions. No matter which method is used, the goal is creating of digital space model as bases for generating 3D representation. During the development of GIS two models for representing 3D spatial data are standardized:

1. Digital Elevation Model (DEM), and
2. Triangulated Irregular Network (TIN).

DEM [5] is regular mesh of points in space and their altitudes (see Fig 1).

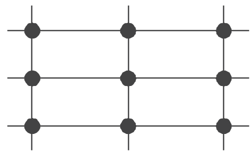

Fig. 1. DEM data model

Using the regular DEM mesh, the triangle and tetragon surfaces are constructed. 3D representation consists of these surfaces. Resolution of points in mesh depends on the generalization level. Usually the resolution of commercial DEM data is 25 meters. Of course, it is always possible to get higher resolution applying different types of interpolations.

The second type of digital representation model is TIN model [6]. TIN uses irregular point mesh with the information about altitude gathered using space triangulation process, i.e. tessellation of the convex hull of some points into triangles (see Fig 2).

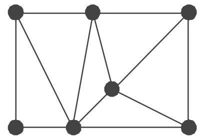

Fig. 2. TIN data model

The second model space is defined by altitude of arbitrary set of points. Usually these points represent the points where the terrain slope is changed. Thereby, the amount of data, which specify particular space, is radically reduced (if it is compared with DEM). This set of points is the bases for creating the triangle and tetragon surfaces as a part of 3D representation.

Frequently, the hybrid model is used. The base of this hybrid model is DEM, and TIN is assigned to it as an extension for generating more accurate terrain representation.

The next step, after creating the triangular and tetragon surfaces, is 3D scene creation. This includes standard procedures from the computer graphics domain (computation of normal on the surface in defined point, light placement and defining the position of camera). In purpose to get a more realistic view, it becomes normal to place two-dimension texture on the surface. The scanned raster maps, orthophotos or satellite images are used as 2D texture for designing the 3D view. The 3D view reality is improved by using one of known shading models, one of color interpolation methods applied on triangular and tetragon surfaces during 3D scene rendering or different kind of texture filtering.

III. Ginis-3D

Ginis-3D is three-dimensional GIS developed in Computer Graphics and GIS Laboratory on Electronic Faculty in Niš. This system is hybrid GIS (georeferenced raster map + vector layers) with capability of terrain 3D view generation, finding information about altitude of arbitrary location and some three-dimensional analysis (3D profile of terrain).

DEM is used as 3D model. The resolution is 100 meter created with altitude digitalization from paper maps. The georeferenced raster map is used for texture generation [7]. Microsoft DirectX [8] is used as 3D graphics engine.

In two-dimensional mode Ginis-3D provides information about altitude of arbitrary location on the raster map. That value computes continually and display depending on current mouse position (see Fig 3).

2D mode provides a possibility to generate 3D terrain profile. The mouse is used to select point on raster map that define the path on which user want to analyze 3D profile. When the points are selected 3D profile is displayed (see Fig 4).

3D profile view enables user to measure distance from the start point of the path to an arbitrary position on the profile. Two types of measurement are provided: measure the strait distance or the real distance (include information of terrain altitude). The information of an arbitrary position altitude is, also, displayed in the profile view.

Three-dimensional mode in Ginis-3D provides a lot of information. In this mode 3D terrain model is displayed. To create 3D view, these steps must be followed:

1. In 2D mode user defines the rectangle that contains the area for 3D model that will be formed.
2. Software retrieves the DEM data about selected area and creates regular grid.
3. The part of raster map, which will be used in 3D view, is insulated, based on the defined rectangular area.

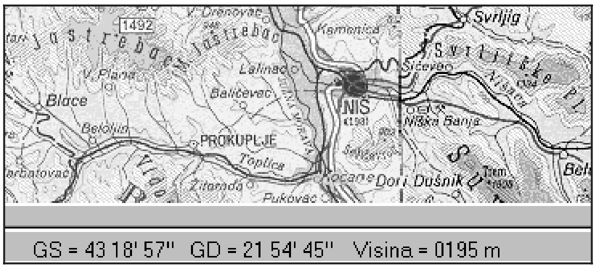

Fig. 3. Altitude information in Ginis-3D application

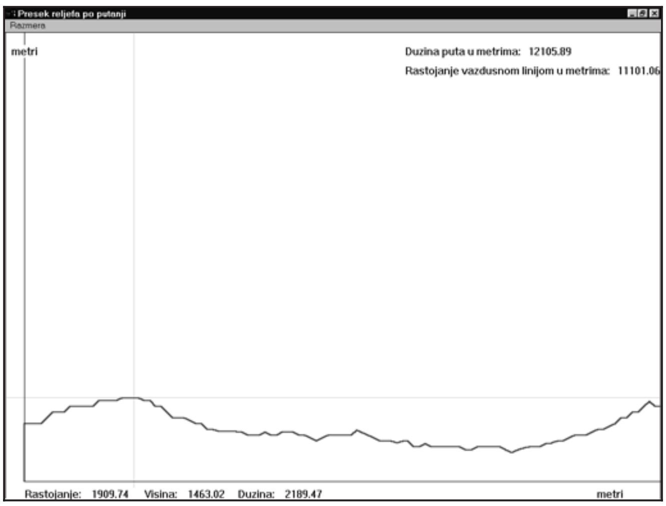

Fig. 4. 3D terrain profile in Ginis-3D application

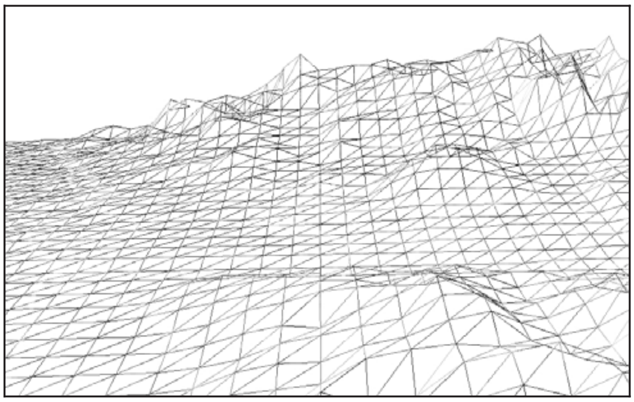

Fig. 5. Creating of 3D surface using space triangulation in Ginis-3D application

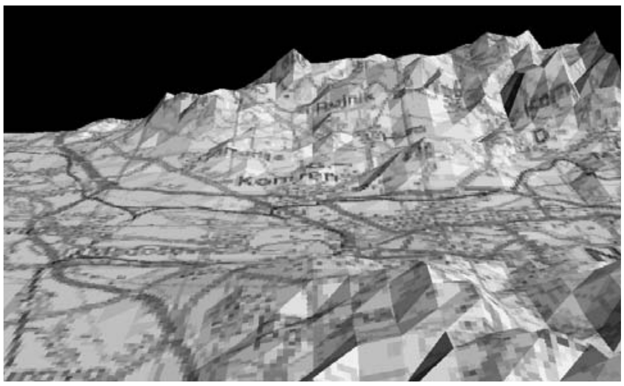

Fig. 6. Dropping the texture over 3D surface

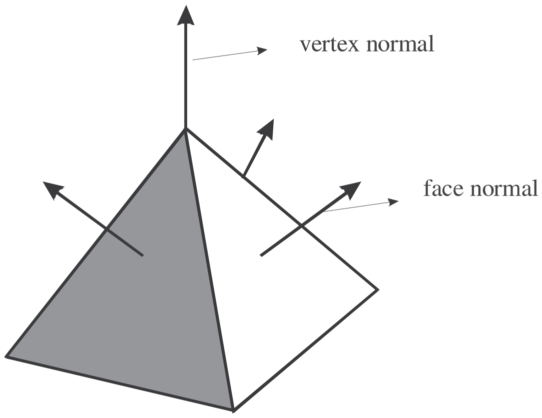

Fig. 7. Normal calculation

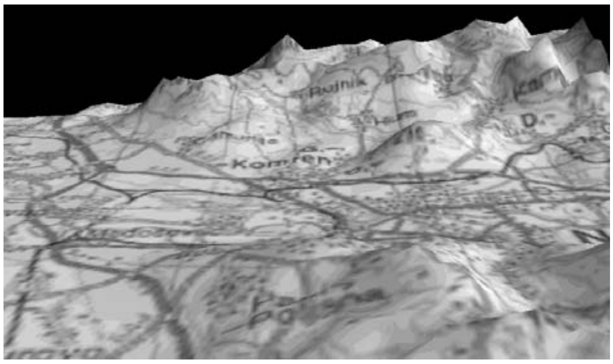

Fig. 8. 3D view made using Gouraud shading and texture filtering

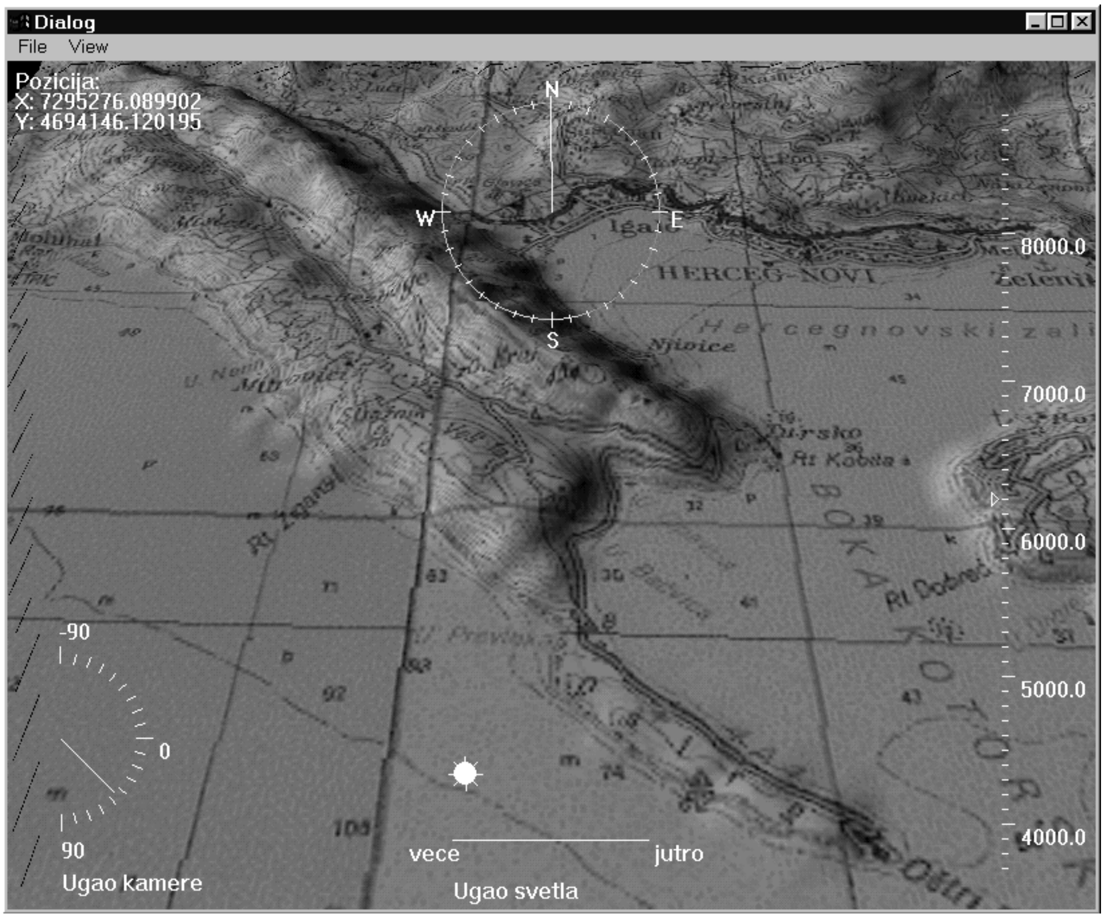

Fig. 9. 3D terrain view in Ginis-3D application

4. The space triangulation is performed and 3D surface is produced from the triangular faces (see Fig 5).
5. For each triangular face of surface the patch of the raster map is computed and dropped over it (see Fig 6).
6. The normal on each vertex on surface and each face of surface is computed (see Fig. 7). These normal are used later for shading.
7. The type of shading is defined. Ginis-3D uses Gouraud type of shading. The normal are used in purpose of generating the smooth surfaces (see Fig. 8). The color and intensity of adjacent vertices are interpolated along the space between them and generate seamless view.
8. The type of color interpolation is determined. Ginis-3D use linear interpolation of color among three vertices on each face.
9. The type of texture filtering is determined. Ginis-3D use linear interpolation among four adjacent pixels that significantly improve the quality of representation.

10. The type and location of the light is determined. Two types of light are used: direct and ambient light [8].
11. The position of the camera is determined (the perspective view of 3D terrain).
12. Using previously defined parameters 3D terrain rendering is performed.

Result of algorithm is 3D scene of terrain. The user has possibility to change the light position and camera position in real time. The effect is flying over the terrain. The system provides information about current location, azimuth and altitude of camera (see Fig 9).

IV. Conclusions

The old human desire, to represent the surrounding world in a realistic way, finally begins to realize. The progress of computer hardware and software with discovering the new powerful technologies for spatial data acquisition (scanning satellites with 1m resolution) provide appearance of three-dimensional geographic systems. These systems can generate 3D terrain model with great efficiency and ability to perform different types of 2D and 3D analysis. The new generation of GIS has improved quality and expanded the application domain (specially in military domain, domain of hydrometeorology and telecommunication domain). Ginis-3D, three-dimensional information system is developed following the actual trends in Laboratory of Computer graphics and GIS on Electronic Engineering Faculty in Nis. This system is natural extension of existing Ginis system that was standard two- dimensional hybrid GIS. Ginis-3D has all functionalities of standard 3D geographic systems (3D terrain generation and 3D analysis) and represent the base on which can be made systems applied in different domains (telecommunications, military service etc.).

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