GIS And Virtual Reality Systems Integration

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***Abstract* - The paper describes virtual reality and geographical information systems integration methodology. Described virtual GIS is based on OO methodology and uses original continuous georeferenced raster map, developed by CG&GIS Lab, as texture source, and DEM obtained from georeferenced raster map. While VR part uses Microsoft DirectX technology, GIS functionality is based on the original GIS framework developed by CG&GIS Lab.**

***Keywords* – VR, GIS, Integration, Virtual GIS**

I. INTRODUCTION

The representation of the world surrounding us have been changed during past centuries from drawings on the pottery, through geographic paper maps, to the electronic maps. The representation becomes more realistic as humans improved their knowledge. Nowadays, it is made possible to improve these representations, in such way that they look more realistic, due to the hardware and the software evolution. The new trend of reliable modeling of real world is known as ***Virtual Reality*** (***VR***). Virtual Reality is still on its beginning, but the results are already impressive. The development of ***Geographic Information Systems*** (***GIS***) follows this progress. Nowadays, the scientific researches are oriented to exploring new virtual **three-dimensional** (***3D***) GIS systems, which provide 3D interactive topographic maps, without space, time or context limitations.

The two-dimensional (2D) GIS and 3D ***CAD*** (***Computer Added Design***) systems are the most common systems that use spatial data. CAD systems are usually designed to work with small 3D models, but the performance of their execution on huge 3D models is very poor. One example of this is a terrain modeling. From the GIS point of view, the CAD and the VR systems have two major disadvantages: lack of the semantic metadata and limited 3D analyses.

One way of enhancing CAD and VR systems is to add capability of working with databases and assigning attributes to the geometric objects [1,2]. However, these new systems cannot perform complex analyses using the object's attributes.

Further enhancement can be achieved by integrating GIS, CAD and VR, i.e. their geometric and semantic data in order to enable complex 3D analyses and more realistic visualization and the interactivity.

The rest of the paper is organized in the following way. The second part contains the existing solutions and current research efforts to improve geometric and semantic data integration. Third section describes the methodology of GIS and VR systems integration into a monolite Virtual GIS, developed in Computer Graphics and GIS Laboratory (***CG&GIS Lab***) on the Faculty of Electronic Engineering, Niš. The usability of VR GIS and the short description of its appliance are described in the fourth part. The conclusions and directions for further research are presented at the end of the paper.

II. EXISTING SOLUTIONS AND RESEARCH TRENDS

First attempts to solve the problem of GIS and VR integration are appearance of hybrid systems such as AutoCAD, ArcView and ArcCAD. The drawback is isolation of database due to different data formats, causing either incomplete analyses or inefficient visualization. Intensive researches are performed in the computer graphics and GIS area to overcome this problem. In the computer graphics area, the research is focused on discovering the algorithms and structures for processing huge amount of 3D data (geometry and texture) in real time, photorealistic visualization, algorithms for 3D data generalization and manipulation of the ***Level of Detail*** (***LOD***).

The objectives of research provided in the GIS domain are:

1. Development of conceptual 3D GIS models,
2. Data acquisition,
3. Spatial analyses,
4. Visualization, navigation and user interface.

The development of conceptual 3D models capable to integrate semantic data, 3D geometry and 3D topology, mostly consider 3D topology or 3D visualization in real time, and only some of them consider 3D analyses and visualization integration.

The 3D data acquisition is more complex and costly in comparison with 2D data acquisition. Some successful methodologies and algorithms for automatic 3D data acquisition are presented in Gulch et al. [3]. However, the manual approaches are still predominant.

3D GIS should make possible measuring operations (distance, length, area, volume, etc.) and set operations (intersection, union, difference, etc.). Third dimension increases complexity of spatial relations. The researches in this domain are involved in discovering the formalisms for detecting spatial relationships [4] and definition of spatial query languages for 3D analyses or extending existing 2D languages [5].

Advances in the area of visualization, navigation and user interface have made visual media a major ingredient of the current interface and it is likely that graphics will play a dominant role in the communication and interaction in the future. Researches in this area are focused on revelation the new modes for 3D spatial analyses visualization, tools for navigation through large 3D models in real time and texture the geometry [6].

CG&GIS Lab has also taken part in solving problems mentioned above. The main objective of the researches is integration of the Virtual Reality systems and 3D GIS. There are four levels of integration [7]:

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1. Rudimentary level.
2. Operational level.
3. Functional level.
4. Complete integration.

Minimal data sharing between two technologies is provided on the rudimentary integration level. On the operational level the data consistency between VR and GIS is established, and the redundancy is minimized. Communication transparency between GIS and VR technologies was achieved on the functional level. The fourth level represents merged system – a complete integration of the technologies into monolite Virtual GIS. The cost-effective alternative of Virtual GIS is usage of WWW and VRML technologies.

The examples of systems with high level of integration are:

1. ***Virtual 3D GIS*** [8], which is not real 3D GIS, because it uses 2.5D data,
2. ***3D GIS*** [9], which performs fast 3D visualization and gives the contribution to real time navigation, but it hardly can be classified as 3D GIS.

Currently, in this area, the most important competitors on the commercial market are:

1. ***ArcView 3D Analyst***, product of ESRI that uses only 2.5D data and is oriented to the 3D visualization, but not to 3D analyses.
2. ***Imagine VirtualGIS***, product of ERDAS, which provides excellent 3D visualization, fly-through functionality, but 3D GIS function are still on the rudimentary level.
3. ***GeoMedia Terrain***, product of Intergraph Inc. that provides 3D terrain model generation using DEM data, fly-through functionality and some simple 3D analyses.

In general, there are a lot of software environments that visualize 3D terrain efficiently, but 3D GIS functions are at rudimentary level. 3D data structures, 3D data manipulation and 3D GIS analysis has been neglected. Current researches attempt to offer monolithic Virtual GIS that provides complete 3D GIS functionality and the capability of visualization and interactive work like the VR systems. The popularity of this topic is confirmed by the numerous projects that are developed in last few years. Most of those projects have appliance in the telecommunication domain, mainly in the propagation of electromagnetic waves through space, prediction and visualization. These applications can be found in FP5 (finished in 2002.) and FP6 (will be finished in 2006.) founded by European Union, as the topic in the most preferential research domain – IST (Information Society Technologies).

III. VR AND GIS INTEGRATION METHODOLOGY

CG&GIS Lab has also given its contribution to the efforts mentioned before developing its own methodology. This methodology is based on the original continual georeferenced raster map, developed in CG&GIS Lab [10] that is used for the terrain textures and 3D digital elevation model. The elevation model is result of digitalization of contour according to preset grid from the continual georeferenced raster map. The software is built on object-oriented paradigm. A VR part of the system is implemented using Microsoft DirectX technology. GIS functionality is based on original GIS framework developed in CG&GIS Lab. Graphical representation of the global system architecture is shown in Fig. 1.

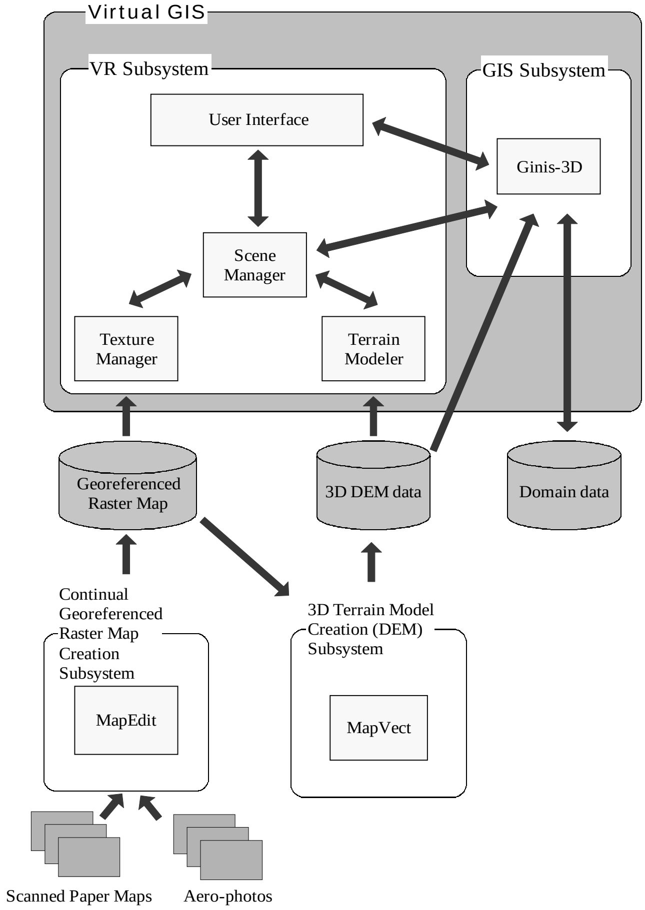

Fig. 1. VR and GIS integration methodology

The complete methodology is developed and it starts from geographic data acquisition. This can be done using commercially available DEM data and georeferenced raster data for the texturing. If these data are not available, the methodology offers the possibilities to create them from the scanned raster maps or orthophotos. These data are the input to the subsystem for continual georeferenced raster map creation, which major component is ***MapEdit***, software for georeferencing and rectification of the raster data. The output of the subsystem is georeferenced raster map divided in small sections for easier manipulation in texture creation process and DEM data computation.

The basic part of the subsystem that computes 3D data for particular terrain is software MapVect, which perform vectorization of georeferenced raster map data [11].

The data computed in such way (georeferenced raster map and 3D DEM data), altogether with data from the problem domain, are the input data for Virtual GIS.

Virtual GIS is monolithic application that integrates VR subsystem and GIS subsystem. The basic component of the GIS subsystem is **Ginis-3D** – 3D GIS, developed in CG&GIS Lab [12]. This component performs georeferencing of all data in system and 2D and 3D spatial query processing. Ginis-3D is hybrid GIS (georeferenced raster map + vector layers) with possibility to generate 3D terrain representation, gathering information about altitude of arbitrary point and some aspects of 3D analyses (e.g. terrain profile).

VR subsystem consists of the following components:

1. User Interface.
2. Scene Manager.
3. Texture Manager.
4. Terrain Modeler.

User Interface component provides user-system interaction on the VR manner. This means that user can "jump" to certain position in the space and to analyze the perspective. Moreover, the VR interface provides flying over the terrain and six degrees of freedom: moving upward, sliding along the scene, rotation and three-dimensional translations. This component also provides possibility of visual motion and 2D and 3D spatial queries that are parameterized and passed to the GIS subsystem. The GIS subsystem executes queries and retrieves 2D and 3D results needed for visualization.

Scene Manager is main component of the VR subsystem. The role of the component is dynamic scene creation, depending on position of camera. During scene rendering, Scene Manager use the texture formed by the Texture Manager, 3D terrain model created by the Terrain Modeler and data from problem domain, which are georeferenced by the GIS subsystem.

Texture Manager is component that dynamically creates texture after the Scene Manager request. For the texture creation, Texture Manager uses continual georeferenced raster map.

Terrain Modeler creates the terrain model using the 3D DEM data when Scene Manager requests it.

The complete algorithm of 3D representation generation is as follows:

1. According to the user request, the User Interface computes the region, which will be created the 3D model, and forward the request to the Scene Manager.
2. The Scene Manager forwards the request to the Texture Manager, Terrain Modeler and GIS subsystem.
3. The Terrain Modeler extracts the DEM data of the specified region and constructs the regular grid.
4. The Texture Manager extracts the part of the georeferenced raster map defined by the region specified earlier and use it as a texture.
5. The GIS subsystem performs spatial query on the domain data, georeferences the data and forwards them to the Scene Manager.
6. The Scene Manager performs space triangulation, i.e. calculate triangular surfaces as details in the 3D representation.
7. The Scene Manager locates the parts of the texture corresponding to the each of the triangular surfaces and applies them to the particular surfaces.
8. The Scene Manager calculates the normal for each node in the grid that will be used later in the rendering of the scene.
9. The Scene Manager does the rendering using Gouraud rendering model. The color and intensity of the adjacent nodes are interpolated along the surfaces among them and the created representation is seamless.
10. The Scene Manager performs the color interpolation inside the triangles. The linear interpolation is used among all three points.
11. The Scene Manager is involved in texture filtering. It uses linear interpolation among four adjacent pixels, which improve the quality of the representation.
12. The Scene Manager places the light. Two types of light are used: directional and ambient.
13. The Scene Manager locates the viewing point.
14. The Scene Manager renders 3D terrain model using the parameters that have been computed earlier and if it is needed adds some visual elements to create more realistic representation (e.g. fog).

At the end, user can see the visualization results (3D model of the terrain as well as 3D data from the problem domain). The terrain model provides capability to change the real time position of the light and the camera. This feature makes the impression of flying over the terrain. The GIS subsystem provides 3D model with the current geographical location, azimuth and elevation, in real time.

The outlined methodology integrates VR and GIS subsystems forming one monolith application. In this way, the forth level of integration – Merged systems (according to [7]) is reached. This enables both subsystems to use the same set of data. The complete data integration is achieved by developing the both subsystems as single application. The overall communication between the subsystems is carried out throw the local procedure calls, which represent the component interface. The realization performed in that way ensures fast system response and reduce the environment influence to minimum.

IV. Virtual GIS Application

The Virtual GIS can be used in every domain in which the traditional GIS are used – urbanism, aqueduct, mining, hydrology, telecommunication etc. The Virtual GIS can also have a military application, for example for monitoring dynamic battlefields. Also, these systems are irreplaceable for different kind of trainers and simulators.

VR GIS make available real representation of the data without leaving the office, which minimize the frequency of the terrain work, and also the cost. This is especially significant in the telecommunication domain, where this kind of systems perform different type of simulations in the process of development wireless telecommunication networks (mobile telephone network, radio-relay links, radar networks etc.).

In the purpose of testing and verification of developed methodology, one system is designed in the CG&GIS Lab. The system provides the prediction of the radar coverage zone and verification of radar network configuration. The system uses the model of the radar, the parameters of the target, which can be discovered by the radar, model of atmosphere and 3D terrain model to precisely determine the coverage zone of particular radar. Besides, the system creates reliable 2D and 3D visualization of the calculated zone, and possibility of interactive work between user and the system. The examples of 2D and 3D visualization are shown in Fig. 2 and Fig. 3.

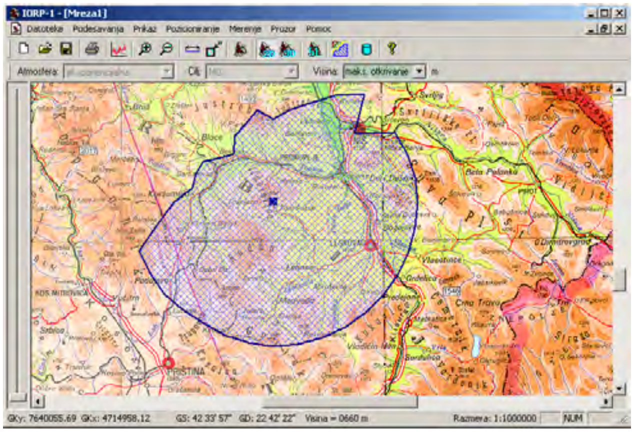

Fig. 2. 2D visualization of radar coverage zone

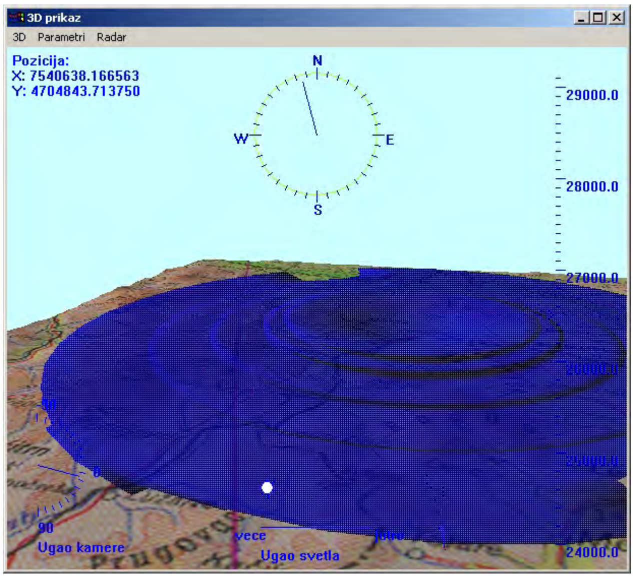

Fig. 3. 3D visualization of radar coverage zone

V. Conclusions

The earlier version of the GIS provided the information about third dimension – the altitude of arbitrary point on the map. The further evolution of the computers and adequate software has created the new possibilities for improving the representation of the world surrounding us. The Virtual Reality has been introduced into the GIS application allowing more reliable representation of the real world. The researches in the GIS domain are immediately oriented to the closer integration of two technologies. The researches on this topic are carried out in the CG&GIS Lab. The result of the researches is the integration of VR and GIS into monolite Virtual GIS. The complete methodology is developed and it begins from the spatial data acquisition and ends with the creation of reliable 3D representation. This paper presents detailed description of the methodology and overview of the application of the Virtual GIS in the telecommunication domain, developed in order to verify the developed methodology.

Further research trends in this domain are involved in improvement of the performance of the developed methodology. The component capable to predict user movements through the scene and dynamically prepare the 3D scene according to these movements prior to its visualization is under development. This component will afford the impression of the continuous motion through the scene in real time, regardless to the size of the scene, giving the user more natural way of viewing the surrounding space, which is the final goal of the Virtual GIS.

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