

# GEOINDEX PROJECT: REAL-TIME ENVIRONMENTAL VISUALISATION FOR GEOGRAPHICAL INFORMATION SYSTEMS

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## ABSTRACT

We describe the architecture of a prototype system for the real-time visualisation of 3D geographical terrain. The prototype system is an open platform that combines a Virtual Reality system and access to traditional Geographical Information Systems (GIS). This prototype is being carried out within project GEOINDEX partially financed by the EU in its IV Framework Programme.

We present the architecture of the system, with special emphasis on the key functional modules, namely the kernel and the 3D flyer. The kernel assures the performance of the overall system in real time and the flyer offers a virtual output of geographical information coming from a GIS, yet in 3D.

Keywords: Geographical Information System, Virtual Reality, environmental visualisation, 3D, real time, man-machine interaction, real time terrain generation.

## 1 Introduction

The combination of Geographical Information Systems (GIS) and Virtual Reality (VR) technology is today not sufficiently exploited. Both fields, separately, have experimented a great boom in the last years, which has been useful for developing some theoretical bases and a solid practice. In a parallel way, many virtual reality systems as well as GIS have been commercialised. However, systems that combine both elements are practically non existent, in spite of the fact that the combination has been demonstrated to improve environmental visualisation, exploratory data analysis and even the marketing of land-based resources such as golf courses or ski resorts.

This paper describes GEOINDEX, a system designed to represent and permit the manipulation of geographical information within a 3D environment and in real time

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(the latter, a key element in virtual reality). Generally speaking, combining GIS and VR involves two key problems: on the one hand, each system traditionally uses its own specific data structures and, on the other hand, it is normally not possible to represent in real time the enormous quantity of information typically handled within a GIS (normally the GIS displays single „snapshots,, of a terrain). It is easy to understand that the systems use different data structures if we take into account the objectives of each [FALBY93]. The prime objective of the geographical information system is to relate various types of information to a given geographical zone, creating a georeferenced database to support fundamentally planning-based activities [CHANCE90; WORBOYS95], many of which are related to environmental problems [GOODCHILD93]. This planning process is, by its very nature, slow and methodical. However, for real time systems such as in VR, a premium is placed on minimising the time required to draw all the information in a realistic way by means of polygons with illumination and textures. This allows a user to not only view a snapshot of a terrain (for example, a mountain), but to fly over it and spin it around to immediately view particular areas in more detail. The frame rate (or snapshots per second) must be at least of 15 frames per second in order to assure a good interaction in real time. Any solution to incorporate VR within GIS must include modules that convert the information originating from a GIS to a most suitable format for its representation in real time [BURROGH92].

VR systems must simultaneously strive to attain maximum realism and interactivity. By realism we mean drawing the greatest possible quantity of lit polygons and with textures: the more and smaller the polygons, the finer the detail may be. Interactivity assumes drawing those polygons with a frame rate of at least 15 frames per second (optimally 25 f /s). Current graphic platforms allow the rendering of thousands of polygons at interactive speeds, however when real geographical information is represented these capacities are widely surpassed. Because of this, it is necessary not only to have a powerful graphical workstation, but furthermore to optimally select the information that is to be rendered in each frame.

## **2 Previous work**

The primary application area of the linking of Geographical Information Systems and Virtual Reality technology has been military simulation, which results in the fact that much of the cutting-edge technology in this area does not reach the public until years after implementation and testing. In past years, the defence industry has contracted the creation of numerous distributed combat simulators for aircraft, helicopters, armoured vehicles, etc. Most of these simulators are connected to GIS --in the sense that the objects are georeferenced, that is the system knows their geographical location-- and additionally they simulate vast areas of terrain with a high degree of

realism. These systems are normally based on powerful workstations and some are interconnected through high speed networks (ATM), allowing distributed simulation.

The Georgia Institute of Technology, within its project VGIS, has developed a system for the connection of GIS and VR. This project is also oriented toward military applications, and by that same motive does not have an adequate interface so that the common user may interact in a friendly way with the system.

Outside the military area, few real efforts have been made in order to link both types of systems; even fewer have aimed at the creation of commercial products.

Schee and Jense [SCHEE95], describe a system that attempts to bridge RV and GIS. They consider that the interaction of both systems must be determined by the following factors:

- The capabilities of the hardware platform that will determine the frame rate and the quantity of information that can be loaded.
- The differences of the information represented in both systems.
- The communication between both systems that determines the speed and the maximum quantity of information that can be loaded.
- The VR system can not be limited by the information transfer speed of the GIS to the VR system. It is inadmissible that the execution of the VR module be interrupted due to lag in the arrival information requested from the GIS.
- Irrelevant information would have to be eliminated or suppressed.
- The conversion of information formats between both systems must be included.

The New University of Lisbon has developed a basic system [NEVES95] following these rules, where the user can interact with geographical information in a virtual environment. Again, we stress that the literature in this field is dominated by either military or research (pilot) applications, partly due to the fact that until very recently the popular hardware/software platforms (PCs running Windows) were not powerful or robust enough to support these applications. This paper demonstrates via the GEOINDEX system that this is no longer the case.

### 3 GEOINDEX

GEOINDEX is the result of a software system definition project partly financed by the European Union within the IV Framework Programme (Esprit EP-25029). Among its objectives was to design a system for the representation of geographical information all over Europe, in 3D and in real time, on PC platforms. The geographical information is comprised of a regular grid of terrain elevations (DTM), upon which are draped satellite images, vectorial information such as communication networks, rivers, lakes, etc., and 3D icons representing points of interest (POI), for example hotels, museums, petrol stations, etc. The sum of this information, opti-

mised for 3D representation in real time, represents a virtual landscape upon which the user is able to fly freely and even query, providing that attribute databases exist and are attached. The user is able to move towards the more interesting zones and to click on an icon located on the virtual landscape, in order to request the associated information, which appears via a multimedia presenter (for example Internet Explorer).

Other important objective of GEOINDEX was to reach the widest audience of potential users, and so it was decided to develop the prototype a PC platform using the Windows NT operating system, discarding UNIX platforms like for example Silicon Graphics, due to its superior cost and reduced market share.

The GEOINDEX system is characterised by the following features:

- It is an open software module providing Geographical Information Visualisation in 3D and in real time.
- The geographical information is taken from standard GIS formats, but is then preprocessed for optimum representation in real time.
- It translates the specific GIS data structures to those needed for the 3D representation in real time.
- The system optimally manages the information using spatial indices --quad-tree structures for polygons as well as for terrain pages (files).
- The user can perform interactive flights with a high degree of realism, over virtual landscapes, controlling altitude, camera angle, speed, etc.
- The system is scale-independent: users may fly over terrain from neighbourhood to global scales, depending on the data sources available.
- During a flight in the virtual environment, the user can request multimedia information about interesting points represented by 3D icons and located on the virtual landscape.
- The System has been designed to run on popular PC platforms under Windows NT with standard AGP graphics boards.
- The final result of GEOINDEX will be twofold: (1) a toolkit to be used by multimedia developers to incorporate into their own applications some key GIS functions as well as 3D real time graphics output, and (2) specifically packaged terrain flyovers of constrained areas, available on CD-ROM for direct viewing.

#### **4 Architecture of GEOINDEX**

The system is comprised of four main modules, represented in figure 1:

- The base of the system (kernel).

- An interactive 3D flight module, which permits to the user to fly over a virtual landscape (flyer).
- A data base management module that manipulates the geographical information and the rest of the information ( DBM module ).
- A multimedia presenter module, where results of user queries, associated with 3D icons, is presented (Presenter Module).

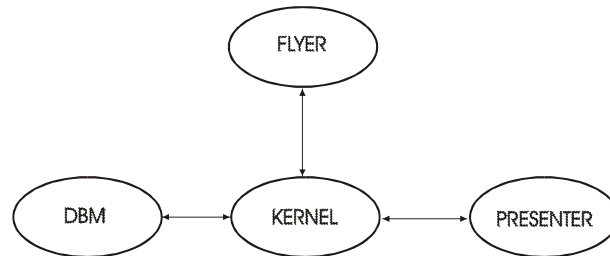


Figure 1. Basic design of GEOINDEX

#### 4.1 The Kernel

The kernel is responsible for message passing and can be considered the heart of the system. It establishes communication with the other modules through channels (object linking and embedding) [DENNING97], receives queries from other modules and replies to the corresponding calls. Among other things it optimally provides the flyer with the geographical information it needs: the relevant part of the terrain model, the vectorial information (highways, rivers, etc.) and the icons. In the event of a user query, the kernel obtains additional information about the corresponding points, communicating to the DBM module the icons that have been selected and then passing to the presenter the information to be shown.

Besides its role as an internal interface, the kernel must optimise system resources to make possible visualisation in real time given the quantity of information typically handled by geographical information systems [COSMAN90].

In the basic operation cycle of whole system, the kernel attends to the data demand coming from the flyer, requesting that the DBM load into memory the zone of the virtual landscape that the user over-flies at each moment.

The basic tasks of the kernel are as follow:

1. to initialise the system.
2. to establish communication channels for the exchange of messages and data between the different modules.
3. To assure that the system is working in a optimum way.

The third task is focused on assuring that the flyer provides a quality presentation in real time (of at least 15 frames per second). The kernel monitors the state of hardware resources and distributing processing times and then reduces, when needed, the level of detail of the information that is represented in the flyer. Furthermore, the kernel assures that the information needed by the flyer will be available in memory and does produce a lag during the loading of such information. The system anticipates, in function of the current position of the user and of his/her speed vector, which will be the next zones to be displayed. Once the next zone has been identified, the kernel requests that the DBM module load that information into memory. As the RAM memory is limited and the time spent in the loading must not affect the presentation of the flyer, it is critical to determine at which moment and what data should be loaded in memory. Therefore, the system builds and maintains in real-time a priority list that establishes the loading order of the information.

From a logical point of view, inside the kernel we can highlight the following parts:

- An scheduler of the Entries,
- a scheduler of the outputs,
- a processing time module,
- a system state controller,
- an internal controller.

The entry scheduler is the part of the kernel that receives the messages coming from the rest off the modules. The messages are of two types: requirements and data. The output scheduler passes the messages that the kernel sends to the rest of the modules.

The state controller is in charge of examining the state of the system if required by the internal controller. This module generates a report with the current state of all the resources of the system, verifying which is the current state of the memory and CPU.

The processing time module is in charge, if required the internal process module, of distributing the available CPU cycles among the different modules of the system. It works by means of a list of priorities associated with the different processes. The internal process module judges which is the best way of managing the resources of the system in order to maintain a frame rate of at least 15 frames per second. With this purpose, the internal process module will examine the current state of the system and will decide, with all the available information, how to distribute the process times among the modules, as well as to decide the zones loaded in memory and at what resolution.

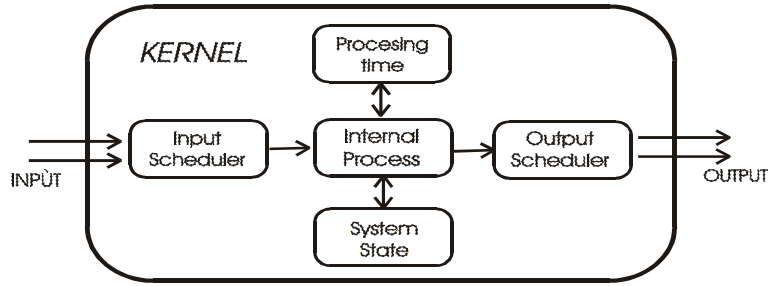


Figure 2. Design of the Kernel

## 4.2 Presenter module

The presenter module displays to the screen in multimedia format all the available information about the point of interest (POI) that has been selected by the user. This information can originate of several sources. It can be available in the GIS attribute database or can be found in an alternate multimedia data base or may even be accessed through web pages.

The basic cycle of the presenter module is the following:

- module determines which is the POI requested,
- determines the sources from the which to obtain the requested information,
- connects and compiles the information,

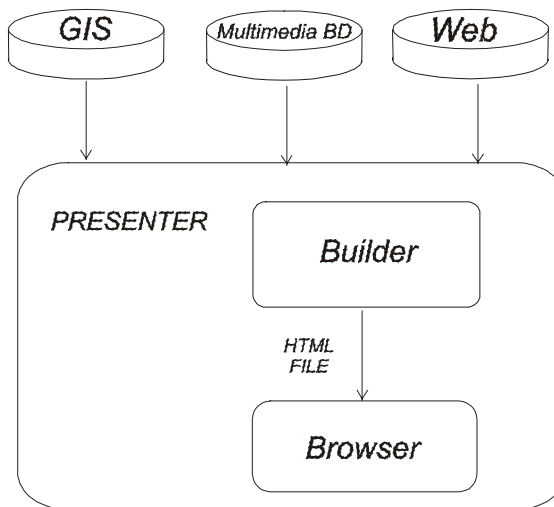


Figure 3: Internal structure of the Presenter.

- if this information is not available in HTML format, generates a HTML file with the compiled information,
- sends request to an available browser (Netscape or MSIE), which presents the information using all the necessary means (text, sound, images, animations, etc.).

### 4.3 DBM Module

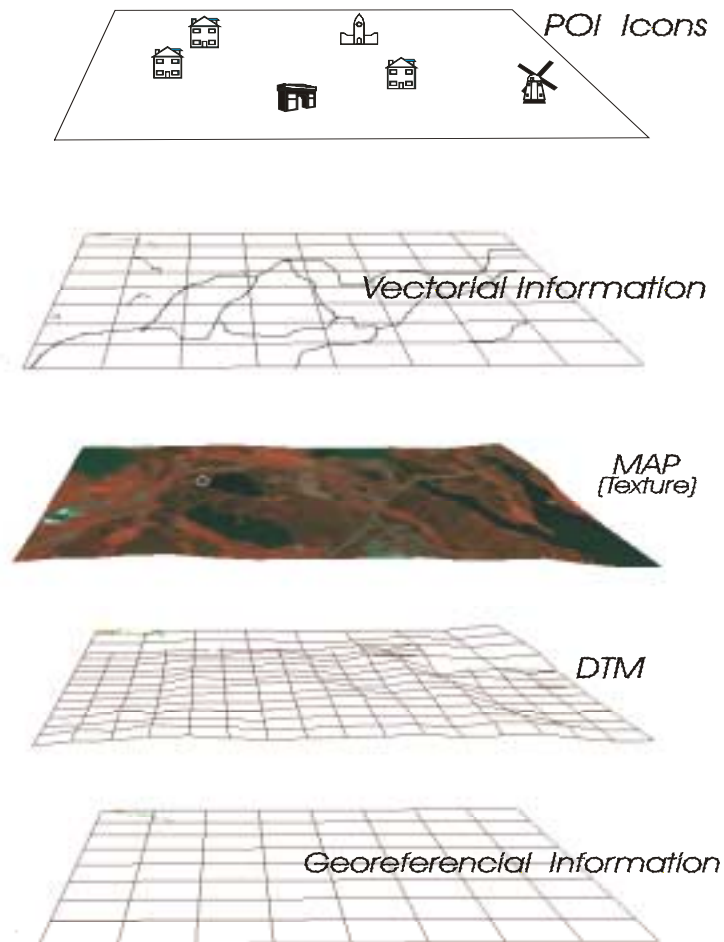


Figure 4. Layer terrain model

The DBM, or database manager module is in charge of supplying the flyer with information both geographic and nongeographic. The information that must be supplied to the flyer includes a regular grid with the terrain elevations (DTM), images of the same terrain taken by satellite or aerial photos, 3D icons that represent interesting points (POI) and (optionally) vectorial data such as highways, lakes, rivers, green zones, etc. The combination of these information layers is what has been called "virtual landscape" [SCHRODER94]. GEOINDEX assumes that this information will be stored in a modern GIS (supporting OLE) and in one of several well-known formats; the DBM module connects to and reads this information. Additionally, the DBM module handles preprocessing of this information into a suitable real time 3D format.

#### 4.4 The FLYER Module

The flyer module is designed as an OLE control [DENNING97] [HRUNGLISHI95] programmed to be executed under Windows NT. The aim of the module is to provide a real-time flyover of a 3D virtual landscape. The user may select the starting point and be able to move along the landscape in real time, as well as to stop and select an icon in order to request information about the object.

The flyer offers the following innovations:

- Flyovers controlled in real time by the user, whereas most PC must be pre-programmed and visualised thereafter,
- Flyer works on any area and with any level of detail,
- The terrain modelling and the visualisation of the simulation have a quality only obtained, up to now, by powerful Unix workstations,
- The user can interact with the icons visualised during the flight, in such a way that all the information associated with each icons is displayed.

The specific features of this module are as follow:

- Automatic terrain generation using advanced data structures based on rectangular grids, quaternary trees (quadtree), etc., commonly used for graphics applications in real time,
- The 3D representation based on a spatial division of quadtrees permits the dynamic generation and management of levels of detail (LOD), with less detail in those zones far from the point of view of the scene,
- Interpolation and dynamic transformation, in real time, of the elevation points of the terrain, in order to maintain the continuity and obtain a soft visualisation between levels of details,

- Automatic texture mapping with satellite imagery in order to increase the grade of realism of the scene.
- Import and export of 3D formats.
- Generation and placement of 3D icons on the terrain.

#### 4.4.1 Terrain generation and spatial division

A major part of development was devoted to code that obtains information from the GEOINDEX geographic data base and generates a 3D terrain with several levels of detail. This work is based on the idea of using terrain data provided by a common GIS. Internally, the data preprocessing includes reorganisation of the 3D vertices that form the terrain in a quadtree data structure [SAMET84]. The level of detail depends on the distance from the terrain to the point of view of the user and on the roughness of the terrain [BERG95].

The polygonal description of the 3D terrain (including the level of detail) is divided according to a spatial criterion in order to produce a hierarchical representation of the data in the form of quadtree.

Viewer

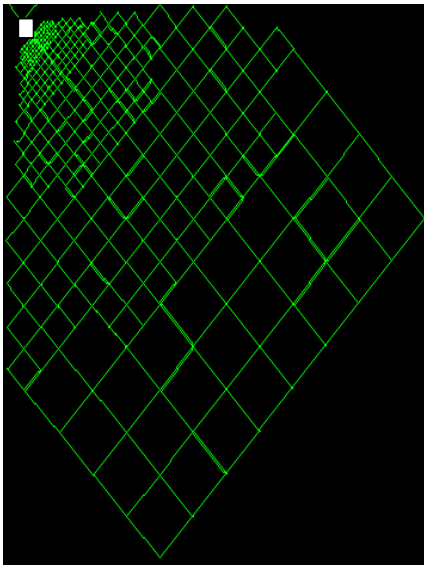


Figure 5. The level of detail is higher around the viewer

The level of detail is maintained in areas of high roughness

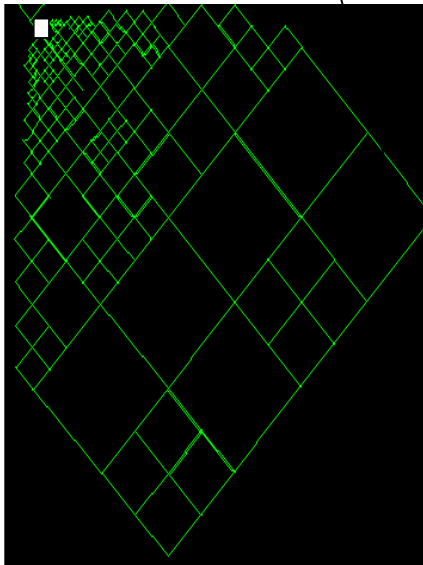


Figure 7. Areas of low roughness are simplified

#### 4.4.2 Dynamic control of terrain

The dynamic control of the terrain, aimed at maximising frame update speed, is based on the selection techniques of levels of detail and pruning of data, used frequently in 3D applications. However in 3D terrain representation the refinement of such techniques is necessary in order to maintain the visual continuity of the terrain between different levels of detail. There are 3D graphics libraries oriented to systems in real time that have solved that problem (i.e. Performer 2.1), but generally these graphic libraries have been designed to be executed only on high-end hardware platforms with great processing capabilities. Thus, we have developed algorithms for the representation in quadtree data structure of the terrain, in order to improve access and provide visual continuity of the surface and a quick rendering of the scene.

#### 4.4.3 3D edition, modelling and texture mapping

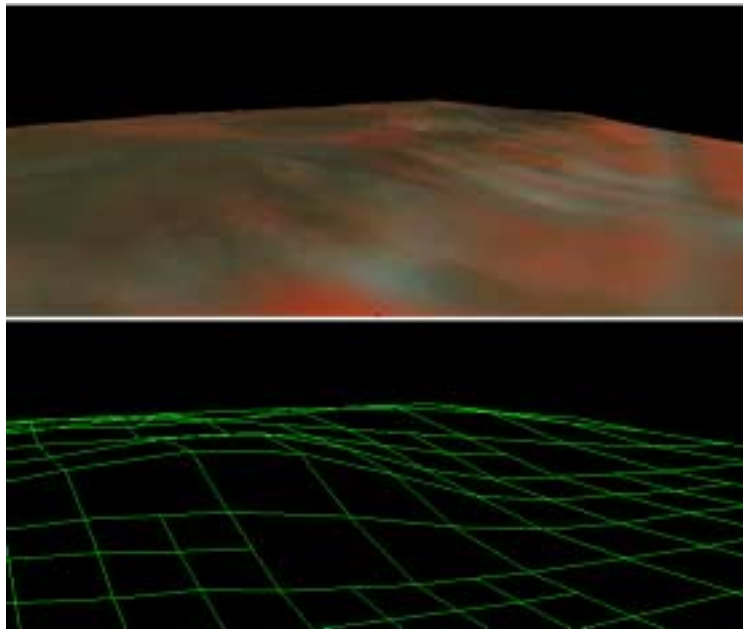


Figure 6. Calculation of texture co-ordinates and application of the same.

GEOINDEX incorporates a very simple modeller for the creation of 3D icons that are positioned on the terrain. The system permits the use of models coming from other 3D modellers, importing file formats such as OBJ and DXF. The different types of icons are then linked to information sources. If this information is refer-

enced to a web page, the owner of the information (on the server side) will be in charge of updating it. In other cases, GEOINDEX connects via ODBC and then generates a HTML file with the information associated with each icon for visualisation using any browser.

Regarding texture mapping of satellite imagery, the Flyer calculates automatically the texture co-ordinates, having previously made perspective corrections and co-ordinate adjustments in order to obtain a good visual result. In the following figure we show an area in the north of Denmark, with and without texture. The texture mapping and calculation of texture co-ordinates is carried out in real time.

## 5 Conclusions

GEOINDEX demonstrates the combination of classic Geographical Information Systems functions alongside Virtual Reality techniques, to obtain enhanced 3D output for a wide variety of environmental visualisation applications. The architecture described in this article is based on the novel functionality of two of the defined modules: on one hand the „flyer,, which creates the virtual environment for flying and on the other hand the „kernel,, which manages and co-ordinates the different modules of the whole system in order to assure its operation in real time.

GEOINDEX may be considered a tool for developers who want to introduce geographical information in their multimedia developments and, on the other hand, as an additional module for the users of the classic GIS which fills the vacuum as far as real-time visualisation of data in 3 dimensions.

GEOINDEX is being developed under the perspective of a project whose objective is to define a prototype architecture. As future work is intended to extend the architecture so that the used information can belong to a great variety of formats distributed by an information network.

More information GEOINDEX may be found at URL:

<http://glup.irobot.uv.es/lisittome/artec/cas/artec.html>

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