The Aksum project: a VR GIS for a 3D inclusive interaction with an archaeological landscape

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Abstract
The Aksum Project is a joint research project between Boston University, IUO (Istituto Universitario Orientale of Naples, Italy), CNR-ITABC (Istituto per le Tecnologie Applicate ai Beni Culturali, of Rome, Italy) and CINECA Supercomputing Center (Visit Lab, of Bologna, Italy) supported by Agenzia 2000 CNR, aimed to the virtual reconstruction of the archaeological landscape throughout paleo-environmental data, GIS and remote sensing applications. The project started in 2001 and we expect to complete the first phase of software development within 2003.
In this context, after a long and complex archaeological fieldwork activity, a VR system consisting in the 3D inclusive interaction with the archaeological landscape has been created according to a multiplatform approach. In fact the application is developed for desktop virtual reality systems (inexpensive PCs) and for Virtual Theatres based on Unix-SGI systems. The application is planned using Java instead of C++, the language used for the main application. The choice of the Java language has been made for two reasons: 1) the perfect portability of Java application across different platforms, which represents a great help for the development of a multiplatform application, and 2) the availability of a powerful and complete library for the creation of GUIs.
We can define the final result a first fundamental step for the realization of a VR GIS with a specific interface dedicated to all the 3D data: layers, themes, movies, archives, DEMs, maps, etc, everything connected in a 3D space. The faculty to query and to interact the system in 3D opens new perspectives for the next generation of VR applications oriented towards the virtual reconstruction of archaeological landscapes or, better, "mindscapes"(perceptual condition to interpret the anthropic landscape).

Keywords:
Virtual Archaeology, Immersive Virtual Environment, 3d User Interfaces.

1 Introduction

The Aksum Project is a joint research project between Boston University, IUO (Istituto Universitario Orientale of Naples), CINECA (Supercomputing Centre, Bologna), and CNR-ITABC (Istituto per le Tecnologie Applicate ai Beni Culturali, of Rome), supported by Agenzia 2000 CNR, aimed to the virtual reconstruction of the archaeological landscape throughout paleo-environmental data, GIS and remote sensing applications. Based on a very detailed mapping and 3D archives of graphic libraries (vegetation, buildings, villages, animals, effects, etc.), the GIS project represents a very articulated context of information for testing the possibility to implement a post-GIS phase, that is the creation of a VR spatial system for archaeological landscapes.

In the field of the landscape archaeology the GIS can be considered the fundamental basis for VR applications in the context of the virtual reconstruction but it cannot satisfy all the conditions of a perceptual reconstruction: the perception of landscapes through the ancient minds, in other terms, a mindscape (Forte, in: Forte, Williams, printing). With this methodological approach we would like to discuss the potentialities of VR in the domain of geographic and ecological data; in fact, real time applications multiply the interpretative faculties thanks to the inclusive interaction within a 3D space. For this aim we have developed a multiplatform system, running on PC and on a Virtual Theatre and integrating Java language with C++. For the final users it will be very important to use the same graphic interface on both platforms and sharing the same spatial archives, such as metadata (html, xml, alphanumeric databases and so on).

1.1 Overview

Many commercial GIS include (i.e. Arcview, ArcInfo) in general a 3D extension, namely a 3D interface for visualising multilayered surfaces (vector and raster) but no one is aimed for an articulated 3D interaction with all the archives of spatial data (bi-dimensional and three-dimensional).

In the state of art of GIS applications, typically, the three-dimensional components are considered the basis only for a visualisation process and not for complex analyses and queries. So the "3D" in this context is, more or less, a scenic effect and not a real increased value. The main idea of this work is to project a VR geographic system, starting from a virtual reality application, namely, beginning "from the end", from the inclusive interaction in real time and not using a standard 2D interface. The challenge is to demonstrate that a VR GIS, based on desktop virtual reality systems, or, better, a VR interface for an interactive accessibility to a virtual landscape, multiplies the faculty to perceive the spatial data with a user-friendly interface: maybe it could be defined a perceptual GIS, more than a simple 2D or a 3D visual GIS. The faculty to query and to access to connective spatial information in 3D and in real time represents a new digital perspective for an advanced interpretation of cultural and natural landscapes (RAPER J., 1989).

Then, the potentialities of this kind of system are relevant or in terms of scientific interpretation/visualisation, whether in terms of communicative/didactic aspects, for example in the case of a museum or a cultural exhibition. For example a final user could interact with the landscape with a "simple" virtual navigation or he could query the landscape within a 3D visualisation, facing up the problems of ecological components and of metadata.

2 The Aksum project

2.1 Aksum project

The primary goal of the project is the **reconstruction of the archaeological landscape** of Aksum, in Ethiopia, on the basis of ethno-anthropological, paleo-environmental, GIS, remote sensing and spatial data and with a spatial – virtual - remote sensed and ecological approach (BARD. K.A., M. COLTORTI, M. DIBLASI, F. DRAMIS & R. FATTOVICH 2000: 65-86).

The amount of archaeological data regarding Aksum is quite relevant, because of the several investigations undertaken, in the past and in the last years, by IUO (Istituto Universitario Orientale, Naples), University of Padua (Department of Archaeology) and CNR ITABC (Rome). The whole project indeed includes systematic researches and excavations, in multidisciplinary fields such as paleobotany, archaeozoology, etnoarchaeology, ethnography, anthropology, geology, geomorphology, palinology, finally GIS, remote sensing and, finally, also virtual reality (LITTMANN E., D. KRENCKER & T. VON LÜPKE 1913; FATTOVICH R. & K.A. BARD 1993: 41-71.; PHILLIPSON D.W. 1998; BARD ET AL., 2003).

In the case of Aksum there was, first of all, a big problem with the cartographic base, since there wasn't any adequate map (just one map 1:25000). Just a survey in Ethiopia, with DGPS equipment allowed to take enough points in order to build a detailed Digital Elevation Model. And then, thanks to Remote Sensing analysis, connected with data that come from fieldworks, it was possible:

- to underline a connections between soils, terrains and sites;
- to study the vegetation, calculating a vegetation index based on satellite imagery and some aerial photos of the 60's (this operation has shown the extension of eucalyptus's forests that are progressively hiding, and in some cases destroying, the visibility of the archaeological landscape);

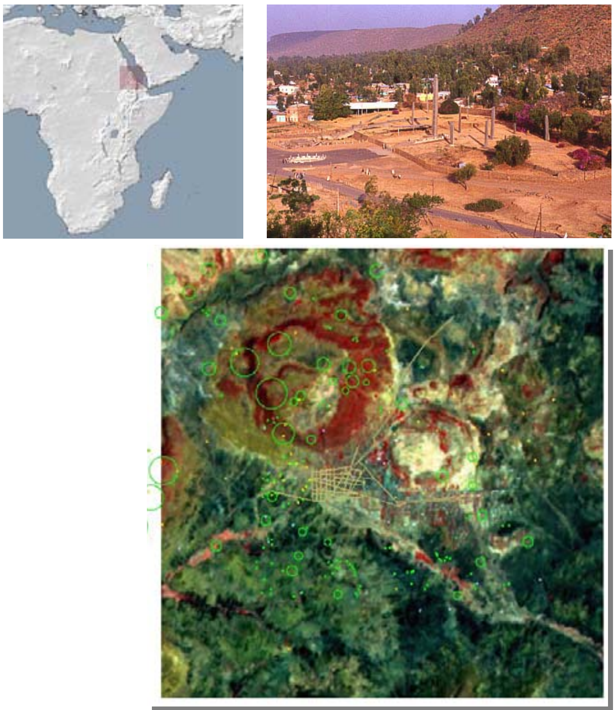

Figure 1: *(Above) Map and location of Aksum and a photo of the actual landscape with the typical Stele. (below) Remoted sensed image: Spot XS satellite image with GIS data overlaied.*

- to study the distribution of the archaeological sites in the area;
- to obtain an archaeological interpretation and reconstruction of Aksum and, in particular, of

the area of Bieta Giyorgis. For instance a remarkable interpretation comes from these remote sensing applications: an ancient path (dating from Pre-Aksumite period) crossing the hill from the East is visible from the SPOT XS; it passes very close to a stone monolith located just in the middle of the hill. Our ipothesis is that this monolith-stele, that isn't linked with a tomb, is to be interpreted as a boundary-landmark. Therefore two principal archaeological regions or districts can be distinguished, in the North and in the South, index of a relevant and organized power landscape.

The new methodological approach adopted, that put together GIS, Remote Sensing and Virtual Reality applications, indicates the relevance of this international archaeological project. With the co-operation of CNR ITABC (Rome, Italy), indeed, it was possible to specifically addressed the researches even towards a **Virtual Reality spatial interaction** to GIS, Remote Sensed data and to data acquired from fieldworks. The main aim, indeed, was to maintain georeferenced information in VR application. A first attempt was done building a Desktop Virtual Reality (DVR) software and interface, written in C++ , using Terravista and Vtree (thanks to a collaboration with Terrex Inc. and Tesscom). This application was presented to the public during an Exhibit on the History of cartography organized in Rome in 2002 (Figure 2).

Further developments were done in co-operation with CINECA Supercomputer Centre, in order to create a fully interactive and cross-platform application, that could be used in a Virtual Theatre, but also in a PC with 3D Graphic Card.

Figure 2: *Vision Station and the DVR system written in C++ using VTree and Terravista*

3 The Aksum Virtual Archaeological Landscape

3.1 User Requirements

The Aksum Virtual Landscape application was developed into two distinct versions: the first – the semi-immersive version - was designed to work in the Virtual Theatre at CINECA, the second – the desktop VR version - was designed for common personal computers. The two versions share the same functionalities, and they differ only for the way they are used and fruited. The semi-immersion version is more suitable for the exploration and the navigation of the scene, thanks to the more realistic rendering of the 3D view and the great sense of presence allowed by the Virtual Theatre. The desktop VR version is more suitable to enjoy the multimedia data and for object manipulation.

The navigation and interaction techniques were designed in order to be user friendly, considering as a target for this application users without a specific experience and knowledge on VR applications. The design of the user interface is most critical for the semi-immersive version, in order to avoid the user to loose the sense of presence due to the a bad designed and hard-to-use interaction method.

To add information to the 3D reconstruction, multimedia data such as HTML pages and short movies realized by archaeologists were linked to the objects in the scene. In this way more data are provided with the visual reconstruction and the user can compare the virtual environment with the pictures and movies taken from the real world.

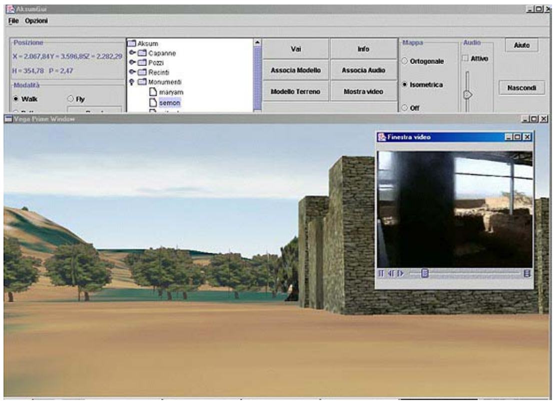

Figure 3: *Multimedia data linked to 3D objects.*

3.2 Features and Implementation

Object Classification

The objects in the scene are organized into groups, (i.e. classes), in order to simplify their selection, search and manipulation and to link them with multimedia data and with the 3D models (properties). Each class represents a collection of objects which are quite identical (e.g. the Fences class) or share similar features (e.g. the Buildings class).

The properties can refer to the single objects and to the whole class: when a property is not defined for a particular object, it is inherited from the class the object belongs to. This way both classes of generic objects, which don't define different properties for each instance, and classes of more specified objects, with different properties for each element, can be handled. For instance, each member of the Buildings class has its own properties and model, while members of Fences class are not defined with specific information, and simply share the properties of the whole class.

When the application starts, classes are created and properties are defined reading data from a set of configuration files. These are short text files which define the properties of objects and classes using a simple syntax. Properties can be modified run-time using the commands disposed on the graphical interface and the changes made can be saved to the configuration files for further use of the application.

The Graphical Interface

The graphical user interface (GUI) carries out three tasks: allows the user to easily access the system control parameters, offers a method for selecting objects by name from a list that groups them by classes, integrates simple HTML browser and media player for the visualisation of multimedia data.

The GUI was developed as a little client application that sends commands for the main application, which behaves like a visualisation server. The only operations that are performed completely within the GUI code are the ones that concern with the visualisation of multimedia data.

The GUI has been developed using Java instead of C++, the language used for the main application. The choice of the Java language has been made for two reasons: 1) the perfect portability of Java application across different platforms, which represents a great help for the development of a multiplatform application, and 2) the availability of a powerful and complete library for the creation of GUIs (through the classes provided by Swing and AWT packages), which allows the design of graphical user interfaces that can run on different platforms without the need of the use of specific APIs.

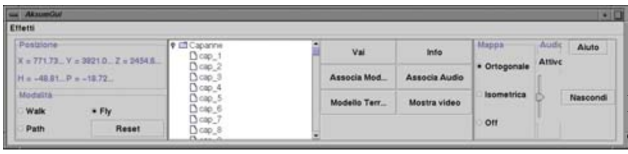

Figure 4 - *Graphical Interface*

The interaction between the main application, written using the C++ language, and the Java GUI has been obtained using the functions provided by JNI library. The Java Native Interface allows to insert fragments of platform-dependent native code into Java. The JNI library provides also the functions for embedding a Java Virtual Machine into native applications and for accessing Java classes and their methods from native code.

4 Conclusions

The Aksum Project represents a very interesting case study including very articulated series of spatial data coming from different sources of information (Forte, Williams, printing), bi-dimensional and three-dimensional. We have obtained a first VR reconstruction using GIS and remote sensing platform (Arcview, Er Mapper) and rendering all the models using Terravista 3.0. In this first process a real time visual navigation (without behaviours) has been produced basing the graphic performance on OpenGl technologies. In the second phase of work a specific graphic interface has been implemented in C++ and in Java in order to include different possibility to query the landscape according to the type of 3D spatial data: terrains, remote sensed data, movies, architectural/archaeological structures, paths, roads, thematic layers and navigation modes (walk, fly). In this way a preliminary VR and georeferenced informative system has been realized with all the links and the connections available in 3D. It is even important to remark that the application is multiplatform, namely is developed with the same GUI for immersive systems, such as virtual theatres, and for desktop computers, keeping the same graphic performances and connections. Additionally, a virtual timeline will be developed on the basis of the evolution of the archaeological-anthropological landscape.

Finally, on the basis of this approach, we could say that a new era of 3D VR systems for interaction and advanced visualisation of archaeological landscapes is in progress, integrating all the spatial properties of spatial maps and objects in a perceptual "place".

Aknowledgements

In the Aksum project many teams and researchers have collaborated and are still collaborating. A special thank is due to: R. Fattovich, S. Kay, A. Manzo, C. Perlingieri, R. Perlingieri, B. Trabassi and, as Institutions, to CNR and CINECA. For the software and hardware support we thank the companies Terrex, Tesscom and Elumens.

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