



**Universiteit  
Leiden**  
The Netherlands

**Analecta Praehistorica Leidensia 28 / Interfacing the past : computer applications and quantitative methods in archaeology CAA95 Vol. II**

Kamermans, Hans; Fennema, Kelly; Kamermans, Hans; Fennema, Kelly

**Citation**

Kamermans, H., & Fennema, K. (1996). *Analecta Praehistorica Leidensia 28 / Interfacing the past : computer applications and quantitative methods in archaeology CAA95 Vol. II*. Retrieved from <https://hdl.handle.net/1887/32944>

Version: Not Applicable (or Unknown)

License: [Leiden University Non-exclusive license](#)

Downloaded from: <https://hdl.handle.net/1887/32944>

**Note:** To cite this publication please use the final published version (if applicable).

# ANALECTA PRAEHISTORICA LEIDENSIA

# 28

PUBLICATIONS OF THE INSTITUTE OF PREHISTORY  
UNIVERSITY OF LEIDEN

## INTERFACING THE PAST

COMPUTER APPLICATIONS AND QUANTITATIVE  
METHODS IN ARCHAEOLOGY CAA95 VOL. II

EDITED BY  
HANS KAMERMANS AND KELLY FENNEMA



UNIVERSITY OF LEIDEN 1996

Graphic design: Henk de Lorm

Computer graphics: Peter Heavens

Copy editor: Marianne Wanders

Copyright 1996 by the Institute of Prehistory, Leiden

ISSN 0169-7447

ISBN 90-73368-10-3

Subscriptions to the series *Analecta Praehistorica Leidensia* and single volumes can be ordered from:

Institute of Prehistory  
P.O. Box 9515  
2300 RA Leiden  
The Netherlands

## contents

### VOLUME I

Hans Kamermans  
Kelly Fennema

Preface

#### Data Management

Jens Andresen  
Torsten Madsen

IDEA – the Integrated Database for Excavation Analysis 3

Peter Hinge

The Other Computer Interface 15

Thanasis Hadzilacos  
Polyxeni Myladié Stoumbou

Conceptual Data Modelling for Prehistoric Excavation Documentation 21

E. Agresti  
A. Maggiolo-Schettini  
R. Saccoccio  
M. Pierobon  
R. Pierobon-Benoit

Handling Excavation Maps in SYSAND 31

Alaine Lamprell  
Anthea Salisbury  
Alan Chalmers  
Simon Stoddart

An Integrated Information System for Archaeological Evidence 37

Jon Holmen  
Espen Uleberg

The National Documentation Project of Norway – the Archaeological sub-project 43

Irina Oberländer-Târnoveanu

Statistical view of the Archaeological Sites Database 47

Nigel D. Clubb  
Neil A.R. Lang

A Strategic Appraisal of Information Systems for Archaeology and Architecture in England – Past, Present and Future 51

Nigel D. Clubb  
Neil A.R. Lang

Learning from the achievements of Information Systems – the role of the Post-Implementation Review in medium to large scale systems 73

Neil Beagrie

Excavations and Archives: Alternative Aspects of Cultural Resource Management 81

Mark Bell  
Nicola King

The MARS Project – an interface with England's past 87

**Archaeometry**

- M.J. Baxter  
H.E.M. Cool  
M.P. Heyworth  
Detecting Unusual Multivariate Data: An Archaeometric Example 95
- Jon Bradley  
Mike Fletcher  
Extraction and visualisation of information from ground penetrating radar surveys 103
- Gayle T. Allum  
Robert G. Aykroyd  
John G.B. Haigh  
Restoration of magnetometry data using inverse-data methods 111
- W. Neubauer  
P. Melichar  
A. Eder-Hinterleitner  
Collection, visualization and simulation of magnetic prospection data 121
- A. Eder-Hinterleitner  
W. Neubauer  
P. Melichar  
Reconstruction of archaeological structures using magnetic prospection 131
- Phil Perkins  
An image processing technique for the suppression of traces of modern agricultural activity in aerial photographs 139
- Statistics and Classification**
- Clive Orton  
Markov models for museums 149
- Juan A. Barceló  
Heuristic classification and fuzzy sets. New tools for archaeological typologies 155
- Kris Lockyear  
Dmax based cluster analysis and the supply of coinage to Iron Age Dacia 165
- Christian C. Beardah  
Mike J. Baxter  
MATLAB Routines for Kernel Density Estimation and the Graphical Representation of Archaeological Data 179
- John W.M. Peterson  
A computer model of Roman landscape in South Limburg 185
- Sabine Reinhold  
Time versus Ritual – Typological Structures and Mortuary Practices in Late Bronze/Early Iron Age Cemeteries of North-East Caucasia ('Koban Culture') 195
- Leonardo García Sanjuán  
Jesús Rodríguez López  
Predicting the ritual? A suggested solution in archaeological forecasting through qualitative response models 203
- Johannes Müller  
The use of correspondence analysis for different kinds of data categories: Domestic and ritual Globular Amphorae sites in Central Germany 217
- J. Steele  
T.J. Sluckin  
D.R. Denholm  
C.S. Gamble  
Simulating hunter-gatherer colonization of the Americas 223

- Paul M. Gibson                      An Archaeofaunal Ageing Comparative Study into the Performance of Human Analysis Versus Hybrid Neural Network Analysis    229
- Peter Durham                      Image Processing Strategies for Artefact Classification    235  
     Paul Lewis  
     Stephen J. Shennan
- Gijsbert R. Boekschoten           A new tool for spatial analysis: "Rings & Sectors plus Density Analysis and Trace lines"    241  
     Dick Stapert
- Susan Holstrom Loving           Estimating the age of stone artifacts using probabilities    251
- Oleg Missikoff                      Application of an object-oriented approach to the formalization of qualitative (and quantitative) data    263

## VOLUME II

### Geographic Information Systems I

- David Wheatley                      Between the lines: the role of GIS-based predictive modelling in the interpretation of extensive survey data    275
- Roger Martlew                      The contribution of GIS to the study of landscape evolution in the Yorkshire Dales, UK    293
- Vincent Gaffney                      Extending GIS Methods for Regional Archaeology: the Wroxeter Hinterland Project    297  
     Martijn van Leusen
- Trevor M. Harris                      Multi-dimensional GIS: exploratory approaches to spatial and temporal relationships within archaeological stratigraphy    307  
     Gary R. Lock
- Philip Verhagen                      The use of GIS as a tool for modelling ecological change and human occupation in the Middle Aguas Valley (S.E. Spain)    317
- Federica Massagrande              The Romans in southwestern Spain: total conquest or partial assimilation? Can GIS answer?    325
- Shen Eric Lim                      Recent examples of geographical analysis of archaeological evidence from central Italy    331  
     Simon Stoddart  
     Andrew Harrison  
     Alan Chalmers
- Vincent Gaffney                      Satellite Imagery and GIS applications in Mediterranean Landscapes    337  
     Krištof Oštir  
     Tomaž Podobnikar  
     Zoran Staničič
- Yvette Bommeljé                      The long and winding road: land routes in Aetolia (Greece) since Byzantine times    343  
     Peter Doorn

- Javier Baena Preysler  
Concepción Blasco      Application of GIS to images and their processing: the Chiribiquete Mountains Project 353

### **Geographic Information Systems II: The York Applications**

- Julian D. Richards      From Site to Landscape: multi-level GIS applications in archaeology 361
- Harold Mytum      Intrasite Patterning and the Temporal Dimension using GIS: the example of Kellington Churchyard 363
- A. Paul Miller      Digging deep: GIS in the city 369
- Julian D. Richards      Putting the site in its setting: GIS and the search for Anglo-Saxon settlements in Northumbria 379
- Jeffrey A. Chartrand      Archaeological Resource Visibility and GIS: A case study in Yorkshire 389

### **Visualisation**

- John Wilcock      A description of the display software for Stafford Castle Visitor Centre, UK 405
- Christian Menard  
Robert Sablatnig      Pictorial, Three-dimensional Acquisition of Archaeological Finds as Basis for an Automatic Classification 419
- Katalin T. Biró      Simple fun – Interactive computer demonstration program on the exhibition of the Szentgál-Tűzköveshegy prehistoric industrial area 433
- György Csáki  
Ferenc Redő      Documentation and modelling of a Roman imperial villa in Central Italy 437
- Maurizio Forte  
Antonella Guidazzoli      Archaeology, GIS and desktop virtual reality: the ARCTOS project 443
- Germà Wünsch  
Elisabet Arasa  
Marta Pérez      Dissecting the palimpsest: an easy computer-graphic approach to the stratigraphic sequence of Túnel VII site (Tierra del Fuego, Argentina) 457
- David Gilman Romano  
Osama Tolba      Remote Sensing and GIS in the Study of Roman Centuriation in the Corinthia, Greece 461
- F.J. Baena  
F. Quesada  
M.C. Blasco      An application of GIS intra-site analysis to Museum Display 469

### **Education and Publication**

- Robin B. Boast  
Sam J. Lucy      Teaching with objects 479

Martin Belcher Alan Chalmers Andrew Harrison Simon Stoddart	Teaching the Visualisation of Landscapes – Approaches in Computer based learning for Archaeologists 487
Anja C. Wolle Stephen J. Shennan	A Tool for Multimedia Excavation Reports – a prototype 493
G. Gyftodimos D. Rigopoulos M. Spiliopoulou	Exploring Archaeological Information through an Open Hypermedia System 501
Martijn van Leusen Sara Champion Jonathan Lizée Thomas Plunkett	Toward a European Archaeological Heritage Web 511
Mike Heyworth Seamus Ross Julian Richards	Internet archaeology: an international electronic journal for archaeology 521
Virgil Mihailescu-Bîrliba Vasile Chirica	A Survey of the Development of Computer Applications in Romanian Archaeology 529
Kris Lockyear	Computer-aided publication in practice 535

## Archaeology, GIS and desktop virtual reality: the ARCTOS project

*Virtual Environments (also called Virtual Reality or Cyberspace) are regarded as a significant step forward in Man-Machine Communication. Following non-interactive, command-driven and graphical-interactive systems, Virtual Environments now allow an easy-to-understand presentation and more intuitive interaction with data. The computer's internal world, consisting of data and processes, represents various aspects of a natural environment or even an artificial world outside of any human experience.*

*In this paper we want to show that an interactive approach in 3-D scientific visualization of archaeological data is an important cognitive information system, in particular using GIS with virtual reality systems.*

### 1 Introduction

Scientific Visualization is related to the use of computer graphics in the analysis of scientific phenomena (McCormick *et al.* 1987; Smarr 1991). Some problems, such as complex three-dimensional structures common in the fields of medical imaging, environmental science, and molecular modelling, are studied best by computer graphics tools which help the researcher to understand the structure of the phenomena by drawing pictures. Moreover, interactive computer graphics, which allow real time control over how the graphics are generated, through the use of a computer further enhances the researcher's ability to explore a phenomenon. When the phenomenon under study is three-dimensional, the display is projected onto the two-dimensional display screen and the two-dimensional mouse movements are mapped into three-dimensional control. The mouse typically controls both the viewpoint of the projection and the position of the object in view.

Virtual environments provide a fully three-dimensional interface for both the display and control of interactive computer graphics. A stereoscopic head-tracked display with a wide field of view (fig. 1) presents a compelling illusion of a three-dimensional world generated by computer graphics. The researcher feels immersed in this world full of computer generated objects which appear and behave as if they were real. The display device tracks the

user's head and controls the point of view of the computer generated scene. Using an instrumented glove, the researcher can reach out and directly manipulate the virtual objects' position and orientation in three dimensions. Using these techniques, virtual environments attempt to create an illusion so compellingly realistic that one interacts with it as naturally as if it were real. Virtual environments provide a natural, intuitive Man-Machine Interaction. Using virtual environment control techniques, the researcher can rapidly change what and where data is displayed, allowing the exploration of complex data environments. Normally, immersion is achieved either by wearing a head mounted display (HMD), using a binocular omni-orientation monitor (BOOM), or by moving within a room with — probably several — large screen projections, as for example in the CAVE system (Cruz *et al.* 1993).

### 2 VR interfaces and cooperative work

The effective use of VR involves design opportunities that include intuitive exploration environments with directly controlled visualization tools such as interactive colour-mapped cutting planes. Use of the new interaction and display capabilities effectively poses challenges whereas VR performance requirements pose constraints. All computation and rendering must take place within at most 0.1 second to support both the illusion of immersion and direct user control. Computation, rendering, and data management processes should be asynchronous, so that long delays in one will not affect others.

Some application areas for VR-based visualization environments, such as fluid flows or astronomical data, require relatively simple computation and rendering, but others, such as real time archaeological landscape navigation together with photorealistic reconstructions of buildings and objects, require more ambitious systems not yet available including shared, distributed, multi-user VR-based environments.

Cooperative interpretation and analyses of data (CSWC - computer supported cooperative work) will enable dispersed groups to access the same datasets and to perform better, producing more efficient and creative work than would group members working alone.

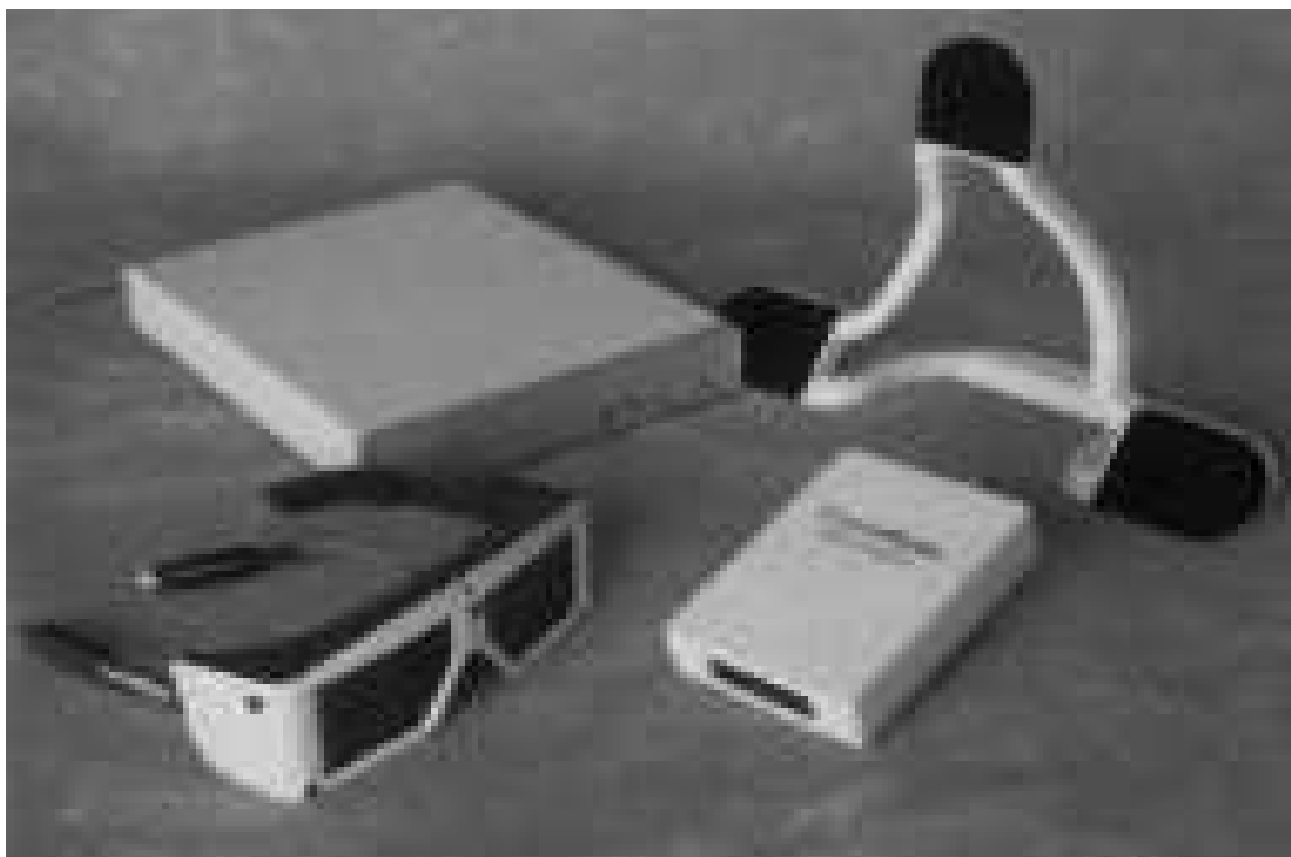


Figure 1. Crystal Eyes System.

We need to merge visualization, imaging and visual computing. Research topics for this area will include distributed viewers for iconic and graphic data and interactive scientific visualization on public networks.

### 3 Visual Output Devices

There are many different kinds of output systems for presenting virtual worlds visually. In selecting an output device, the desired image resolution and image quality must be considered, as well as the degree of immersion which is to be achieved, i.e. the illusion of presence in a virtual world. In general virtual technology utilises stereoscopic displays for improved depth perception, and a wide angle field of view for immersion.

Typical systems are:

- traditional desktop monitor,
- large projection screen (sometimes several simultaneously),
- head bound systems (e.g., helmets or glasses).

This list is sorted roughly according to an increasing degree of immersion. Nowadays, many graphics workstations offer ways of displaying stereoscopic images. Mostly, this is achieved by means of shutter systems in time multiplex mode. These systems typically have a frequency of 120 Hz and switch between perspective images for the left and right eye. A shutter mechanism (e.g., a pair of glasses with LCDs) is used to deliver each image to the appropriate eye, resulting in 60 Hz images for each eye. Such systems allow stereoscopic viewing of high resolution true colour images, but due to the limited field of view, immersion is not achieved. Latest research aims at autostereoscopic viewing without glasses.

Large screen projection can extend the field of view, thus increasing the perception of immersion. By combining several images or by special techniques, convincing panoramic views can be achieved.

In VE systems, large screen projections often present stereoscopic images. Head tracking allows to 'walk around' scene objects, which further increases the

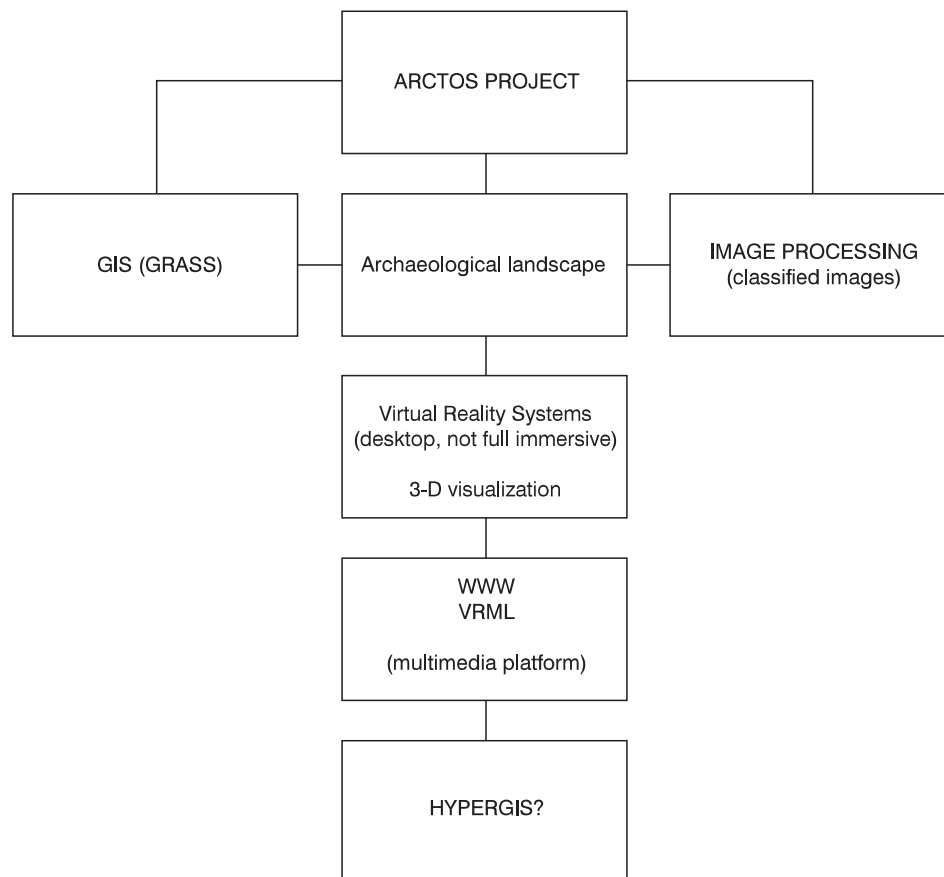


Figure 2. ARCTOS Project development.

impression of immersion. Stereoscopic large screen projection can be achieved by means of a shuttering technique or by means of a time parallel system (i.e., simultaneous display of perspective image for the left and right eye, with image separation by means of polarized light).

The highest degree of immersion is achieved by head bound systems. We distinguish systems which rest directly on the head (helmet and glasses) from systems which, due to their weight, are fixed to a mechanic system and are merely held in front of the head. Both systems use a separate screen for each eye in order to achieve a stereoscopic image. In both cases, the output systems are attached to the head and follow its movements. Liquid crystal displays (LCD), cathode-ray tubes (CRT), and glass fibre optics are used. Special optics allow to achieve a field of view of approximately 100 degrees.

The performance of a graphics workstation is limited in the maximum number of polygons which can be processed in real time. Complex world models (which are of prime interest) exceed this limit easily. A set of rendering

techniques allow the user to handle and conquer complex worlds, where level-of-detail techniques prove to be the most promising and successful. Level of detail means the generation of several variations of the objects of differing complexity. Selection criteria determine the current level of detail to be rendered and displayed. Distance, view angle and movement criteria can be applied. When changing the viewpoint it may be necessary to switch from one level of detail immediately to another.

The generation of multiple levels-of-detail of objects can be controlled either to match a given quality (shape, appearance) or a given quantity (number of points, faces).

#### 4 The ARCTOS Project

The ARCTOS project (fig. 2, Visualization and Virtual Reality methodologies for a cognitive system on an archaeological Sicilian pattern) was carried out by CINECA (Interuniversity Consortium for Supercomputing Applications) and the Scuola Normale Superiore (Pisa, Laboratory of Ancient Topography) with the support of IBM SEMEA, for the study of the archaeological site of



Figure 3. Rectified aerial photograph.

Rocca di Entella (Palermo). This is a very important, geomorphologically separate, multistratified area (c. 60 ha) dating from the Neolithic to the medieval period. In the last years 13 distinct archaeological areas have been investigated, for each chronological phase the structural areas show different features concerning buildings, materials, functions and uses.

Having to analyse such complex information layers, the research trend was to process 2-D and 3-D data so as to visualise the scientific content; it was particularly important to allow the users to move in real time into virtual spaces, such as archaeological landscapes (Forte 1993c). We believe that the interactive 3-D perception is fundamental to our cognitive system because it allows us to understand all the features of the archaeological landscape (Forte 1993a), and the relationships both inter-site and intra-site.

In visual perception, several cues (e.g., light and shade, perspective, stereo vision, etc.) are identified which provide

the observer with spatial relationships within an image. Moreover, an important feature for deriving information from data is the interaction within the scene. Interactive visualization which supports, for instance, the manipulation of objects or of the camera, requires a high image generation rate in order to offer an immediate interaction feedback.

Consequently, interactivity and real time play an important role in visualization. Interaction and real time visualization are closely related issues, because interactive visualization systems will be accepted only if the system response time for user actions is minimised. There is always a trade-off between the complexity of data sets, the rendering speed on specific computers, and the interaction techniques provided to the user. In visualization, various types and amounts of data have to be considered (Cremaschi *et al.* 1994); with the availability of high-performance graphics workstations, data can be visualised

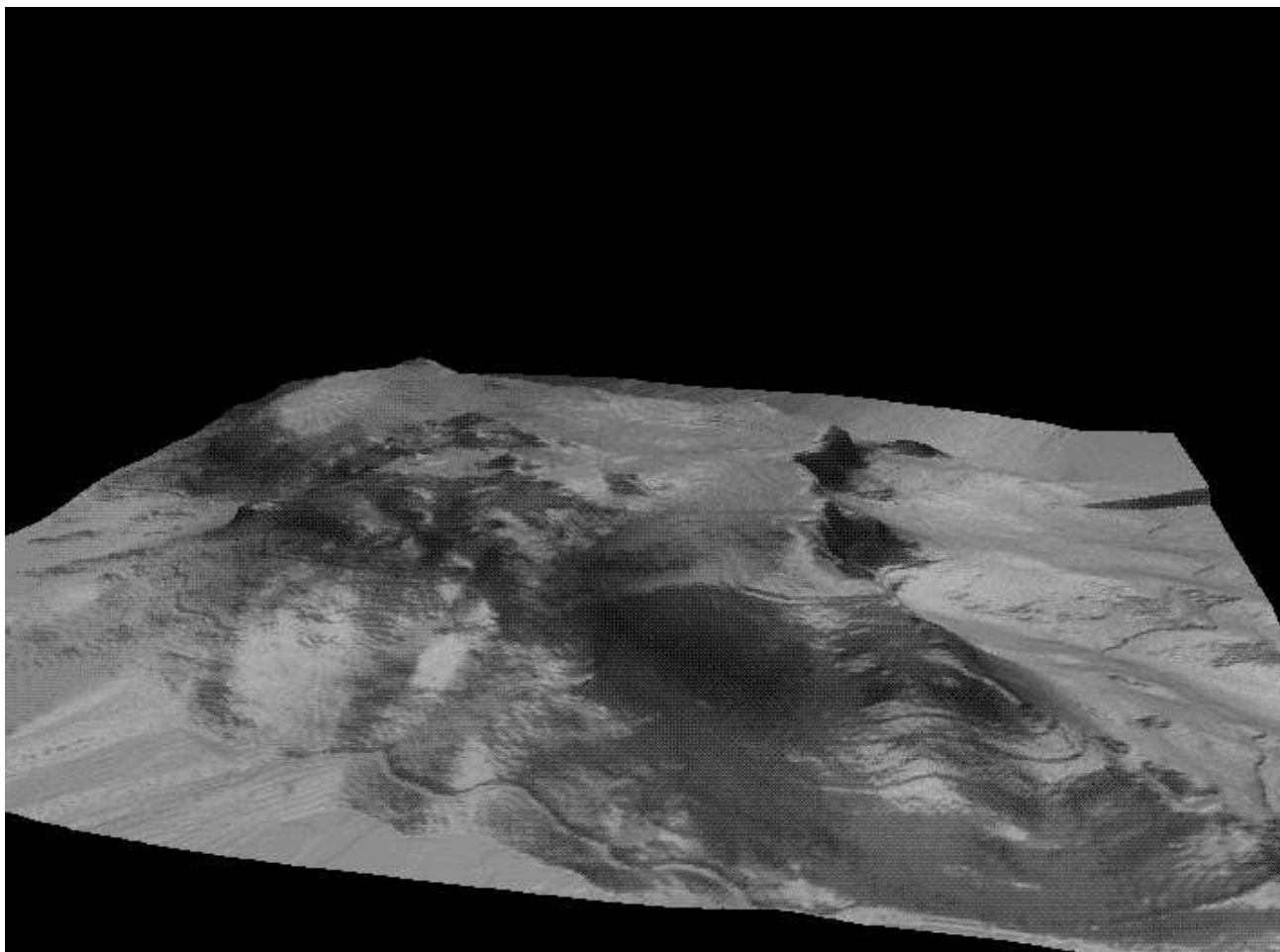


Figure 4. (Digital Terrain Model) in 3-D interpolated by cartographic contour levels (GRASS): dark colours correspond to the highest areas.

three-dimensionally (or even more than 3-D). However, the graphics output remains two-dimensional and therefore when complex data sets are visualised on a 2-D screen a loss of information occurs.

The final aim of the ARCTOS project is to reconstruct a 3-D virtual archaeological park, including geomorphological features and archaeological sites, distinguished in different information layers, such as:

- 2-D and 3-D geographical data (D.T.M., contour levels),
- 2-D vectorial data (cartography, sites topography, etc.),
- raster data (aerial photographs),
- databases.

In the case of Rocca di Entella a landscape model (including known archaeological sites) has been reconstructed using D.T.M. (digital terrain modelling) (fig. 4) and digital images of the area (aerial photographs,

fig. 3). This kind of application includes the following steps:

#### Input data:

- Aerial photographs of the landscape (two colour aerial photographs, dating back to the summer of 1981 and on scale 1:10.000, fig. 3);
- excavation photographs (fig. 8);
- graphic documentation (vectorial);
- cartographic documentation (maps on 1:2000 scale).

#### Output data:

- digital cartography (acquired by digitizer);
- vectorial data visualization (fig. 7);
- 3-D model generation (D.T.M., fig. 4);
- texture mapping (fig. 5);

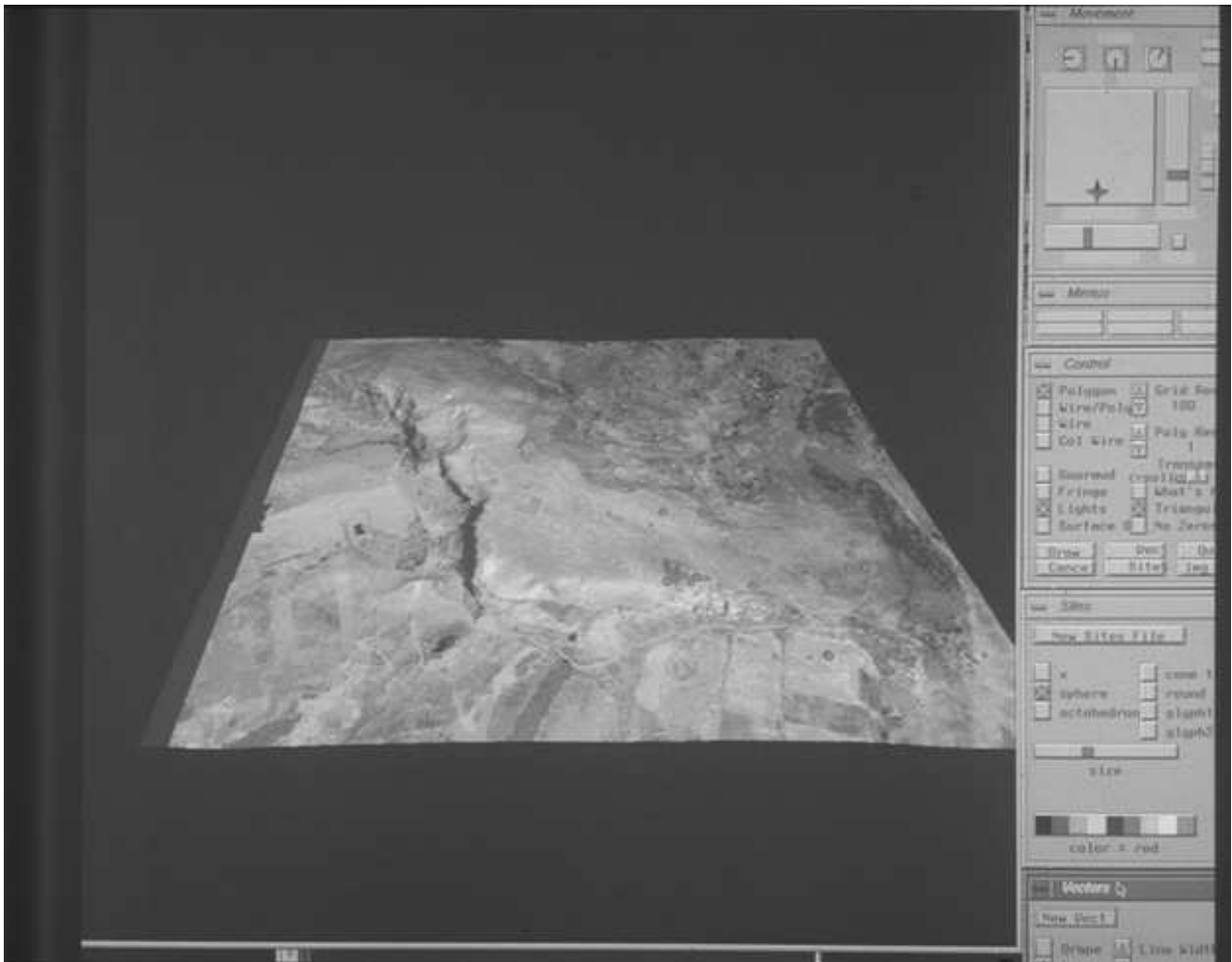


Figure 5. Texture mapping of the aerial photograph on the D.T.M. (GRASS).

- digital image processing and classification (figs 6, 7);
- interactive 3-D model animation (desktop Virtual Reality, figs 7, 9).

## 5 Image processing and digital classification

In order to classify and interpret (Forte 1993b; Forte/ Guidazolli 1992) the aerial photograph of Entella, GRASS and ERDAS software have been used. Before 3-D reconstruction and visualization, it was important to have digital information of the image in order to identify unknown archaeological areas (predictive information, fig. 7). Furthermore, it was necessary to compare the digital classification of the aerial photograph with the pertinent D.T.M. (figs 4-6): any micro-difference of the 3-D model can reveal significant archaeological and geomorphological information.

The whole image processing was carried out as follows:

- Image rectification (fig. 3). A GRASS viewer allows one to rectify interactively the image point by point, checking the level of deformation; it is possible, for example, to select georeferenced or known points on a map, and then to overlay them on the image.
- Image processing, i.e.
  1. histogram and digital statistics visualization;
  2. histogram equalisation (fig. 6);
  3. image restoration, in order to remove agrarian tracks from the image;
  4. contrast enhancement (high pass filter);
  5. edge detection: filtering ( $3 \times 3$  kernels) and edge detection to enhance tracks and chromatic discontinuities (figs 6, 7);

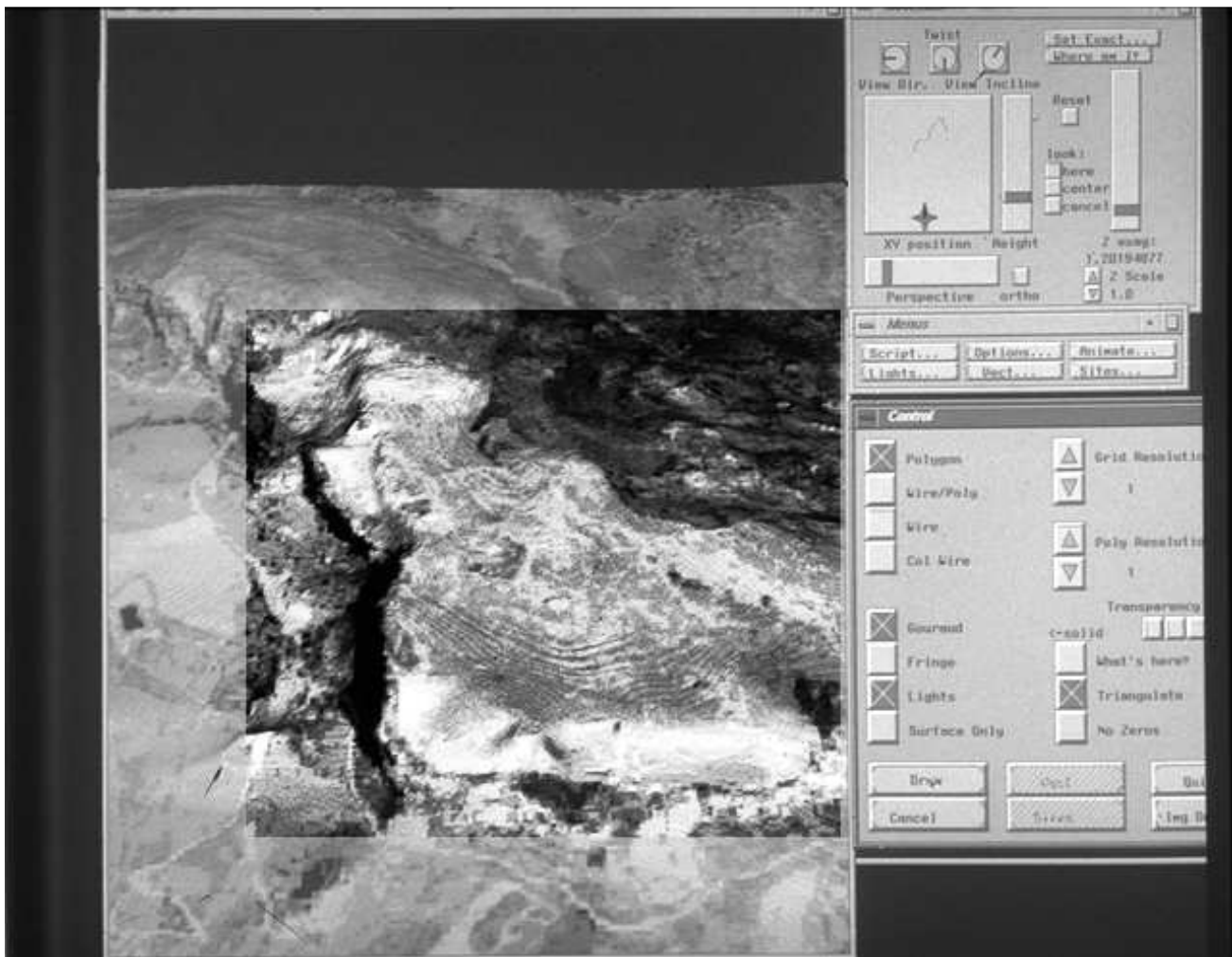


Figure 6. 3-D Digital classification of the aerial photograph: histogram equalisation and density slicing (ERDAS + GRASS).

- 6. vegetation index calculation;
- 7. principal components analysis;
- 8. density slicing (fig. 6);
- 9. pseudo-colour processing.
- Digital classification (fig. 7). On the basis of the digital processing results a new image has been obtained, with different classification colour layers (not visible in the figures in this paper).

The digital classification allows one to suggest important interpretations of the information content of the image; in fact on the basis of these results it has been possible to identify other unexplored archaeological areas. If we observe figure 7 we note that archaeological areas have been identified (indicated by arrows, because of colour

absence) on the centre of the rock, where archaeological excavations were not carried out. Moreover the orthogonal or linear tracks identifiable in this area could be interpreted as Hellenistic buildings not explored yet .

### 5.1 ERDAS SOFTWARE

ERDAS is one of the most important software tools for an 'intelligent' digital image classification and interpretation. ERDAS delivers a full-scale production environment designed to incorporate all input data into a geographic data base that can be viewed, analysed, queried and output. This output may take the form of statistics, reports, tables, graphics or cartographic-quality maps; these powerful visualization capabilities are available in a GIS and image processing system.

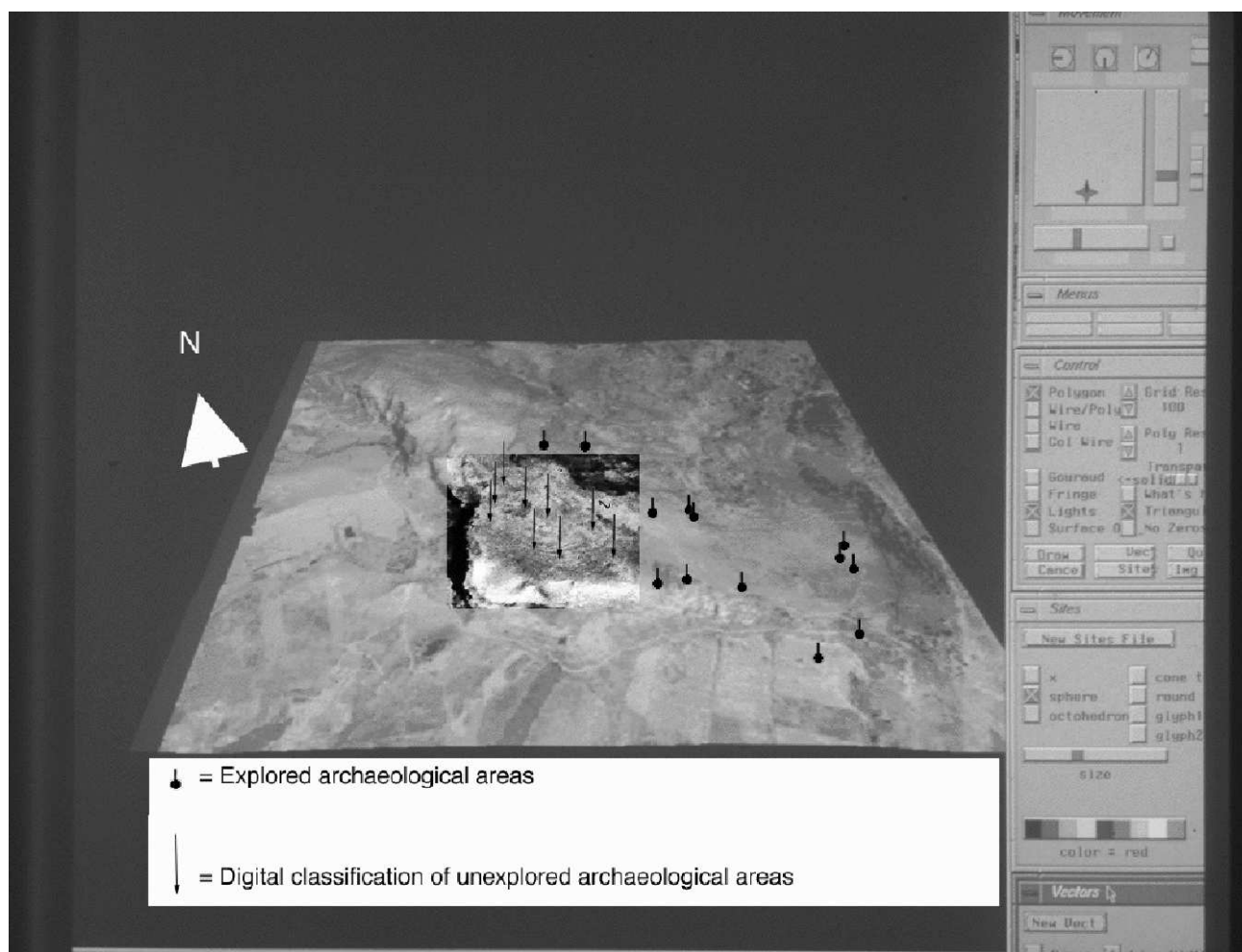


Figure 7. 3-D Digital classification: known archaeological areas (vectorial data) and unexplored archaeological areas (digital predictive information, ERDAS + GRASS).

The principal components of the software are the following:

Component	Capabilities.		
Viewer	Displays queries and annotates single or multiple layers in the image viewer. An unlimited number of viewers can be opened simultaneously, and viewers can be dynamically linked.	Spatial modeler	Performs spatial and statistical GIS modelling and image algebra functions on all data layers with an easy-to-use graphical editor. More complex models can be written using the Spatial Modeler Language.
Image interpreter	Performs complex analyses such as contrast stretch, colour selection, convolution filtering and principal components quickly and easily.	Map Composer	Creates maps and presentation graphics using single or multiple images, and annotates text, borders, scale bars, legends and more.
Rectification	Georeferences images to maps or images to images by interactively locating ground	Radar	Sophisticated processing tools for data handling, speckle noise removal and image enhancements.
		File Manager	Views image statistics, projection information and map information.



Figure 8. Rocca di Entella (Palermo): a Hellenistic building (4th century BC).

EML Interface tools	Customises the ERDAS IMAGINE Interface by modifying existing or designing new dialogue boxes, control panels and icons to suit a particular application.
Developer's I/O Toolkit	By using this specially designed subset of the C Programmers' Toolkit, developers can link their hardware to ERDAS IMAGINE.

## 6 GIS and 3-D visualization

Once we processed the digital aerial photograph, it was possible to integrate all these raster data with the D.T.M. and the other vectorial data (contour levels, cartography), and finally the texture mapping of the image was processed on the 3-D model (fig. 5). So as to obtain the best 3-D visualization and data management at that point, GRASS GIS was used, because in a single system all kinds of data (raster, vectorial, geographical) could be processed and described.

Interpolating the vectorial data (contour levels), a 3-D model was generated in the SG3d GRASS viewer (fig. 4), including wire frame model, and textured-shaded model (texture mapping with lights for rendering).

The SG3d viewer is intended as a tool for visualizing a data surface in three dimensions using GRASS on Silicon Graphics IRIS computers. Hardware requirements are a Z-buffer and 24 bit graphic emulator, such as that on the IRIS Indigo. SG3d requires a raster file to use as 'elevation' and another raster file to use for surface colour (or three files for Red, Green and Blue colour components). Although a true elevation data file used as elevation will produce the most realistic surfaces, users are encouraged to be creative in selecting other types of data to be represented by the vertical dimension. Most continuous (as opposed to discrete) data types will result in a coherent visualization. Since a wire grid can be drawn very quickly, such a grid is used to provide real time viewer positioning capabilities. Similarly, a lighting model provides real time feedback as the user adjusts lighting.

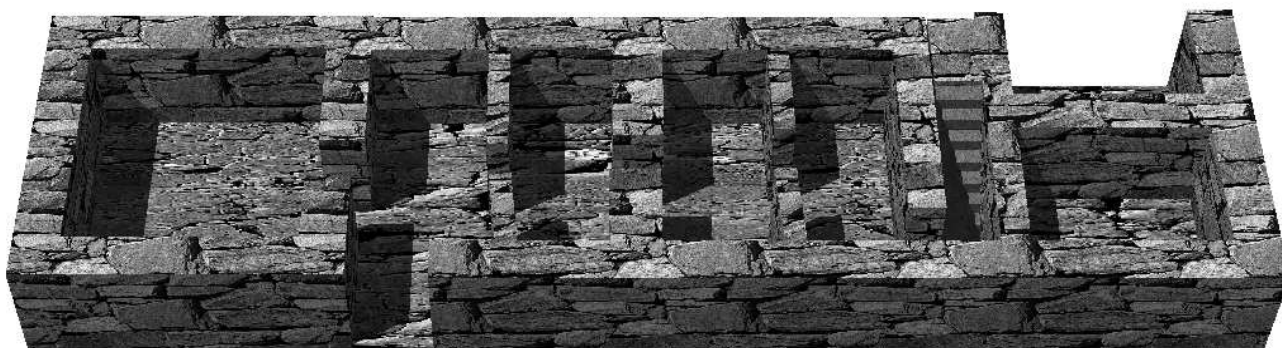


Figure 9. Rocca di Entella (Palermo): computer graphic reconstruction of a Hellenistic building.

Grid and polygon resolution control allows the user to further refine drawing speed and detail as needed. Continuous scaling of elevation values (from  $1.0\text{e-}7$  to  $1.0\text{e+}7$ ) provides the capability to use various data types for the vertical dimension.

In the last release, SG3d allows interactive lighting specifications (fig. 5), vector draping data querying (see What's here?), easier viewer positioning, an option to save current settings in a GRASS database (3-D view) file, animation capabilities, scale objects, labelling, an option to display lat-long data wrapped around a sphere, the capability to save images in IRIS rgb format files, and a few less dramatic changes such as background colour options and an animate display type option that allows the user to view a fully rendered image while adjusting viewer positioning. The navigation interface is a *Movement Panel* that checks the user-position in the 3-D model and the Z-scale of the surface. Then a *Control Panel* selects the kind of texture-surface on the model: it is possible to modify resolution of the grid and of the polygons, visualizing colour, wire or Gouraud surfaces, with a shading of surface, and all elevation data. It is also possible to visualize layers and vectorial information concerning cartography and archaeological sites with the Control Panel.

### 7 3-D Visualization and virtual navigation

Virtual Reality and scientific visualization experiments in archaeology, such as GIS, can concern different fields of application (Forte 1993b, 1995), mainly: inter-site and intra-site analysis, architectural reconstructions or interactive navigations in archaeological landscapes; the modelling level depends on quality and quantity of data (Forte 1993c, 1995).

Full processing and simulation are especially useful to discover and enhance the geomorphological and archaeological features of the landscape in connection with

its evolution and the ancient settlements. Our aim was to visualize interactively the archaeological landscape of Rocca di Entella using all the principal types of GIS data.

During the CAA95 Conference a computer graphic video was shown concerning a virtual navigation in the archaeological landscape of Rocca di Entella (Palermo); it summarised, using different information techniques, the archaeological landscape of Rocca di Entella (Palermo). Techniques used were:

- three-dimensional D.T.M.
- vectorial data
- texture mapping of the aerial photograph (fig. 5)
- texture mapping of the aerial photograph classified by ERDAS (predictive information on the archaeological sites).

While in the video navigation was recorded frame by frame (25 frames per second), in desktop virtual reality applications we have used specific navigation devices in real time. For obtaining a 3-D stereoscopic vision, the VR Crystal Eyes system (fig. 1) and monitors with 120 Hz frequency were used. The VR system provides intuitive look-around capability, similar to a hologram, by tracking the location of the user's eyewear and changing the viewpoint with head movement. The system consists of Crystal Eyes eyewear, an ultrasound head tracking device with six degrees of freedom and rapid response. This kind of VR system is desktop, i.e. non immersive; for our application interactivity and high resolution of the images are very important, and these are not attainable with full immersion VR systems such as head-mounted displays (HMD).

On the other hand the VR Crystal Eyes system, interfaced with a GIS (GRASS), makes an intelligent scientific visualization possible, selecting all the data useful for research, and showing a complex virtual space to explore in an interactive way.

## Take a Virtual Walk through Lightscape Models!

*Next page*

*Go to top*

The following models were generated with the Lightscape Visualization System and converted into VRML files.

Click on an image to take a virtual walk through the model. Please note that you will require a VRML viewer such as WebSpace to view these models.



The Lightscape Image Gallery (*links to hidden models!*)

© Copyright 1995 Lightscape Technologies, Inc.

2.5 MB



Hall model

© Copyright 1995 Lightscape Technologies, Inc.

9 MB



Jerusalem City Hall model

© Copyright 1995 Lightscape Technologies, Inc.

12.5 MB



Operating Room model

© Copyright 1995 Lightscape Technologies, Inc.

Figure 10. Virtual Reality Markup Language: walking through 3-D information models.

Finally the EXPLORER software (SGI) package was used for two methods of 3-D exploration: *walking* or *flying*; we can select different views and directions for either method.

7.1 VIRTUAL REALITY INTERACTIVE PRESENTATION  
Presentation domains for humans are related to the human senses (sight, hearing, smell, touch and taste). The presentation can be rated by the following criteria (fig. 1):

- quality of representation: each application requires specific mapping techniques to filter and turn the

numerical data into perceptible information. Often applied techniques in visualization are function plots, histograms, or 3-D models.

- quantity of representation: dynamic presentations help to understand time-dependent proceedings in nature or engineering. Time is a distinguishing data parameter which in visualization can be applied as a single static picture or an animation.
- degree of immersion: adequate output devices couple humans tightly to the system. With novel innovative devices like head mounted display or 3-D audio the degree of immersion is high when compared to standard

monitor screen applications in computer graphics. Presentation of data is accomplished in several steps: mapping of numerical data into rendering objects, rendering of objects into easily transmittable information and output of this information.

## 8 Conclusions and future directions

The ARCTOS Project is an experimental approach towards interactive 3-D visualization concerning the archaeological landscape (fig. 2). The choice of recording data from the Rocca di Entella site allows us to analyse a very complex information set but in a defined geomorphological space with multistratified archaeological layers.

For this we have used GIS integrated with Virtual Reality applications so as to increment cognitive information of data, stimulating the physical perception into the 3-D virtual world. In fact the scientific information content of data depends specifically on the standard of presentation; if the researcher/user can interact with visualization models, he can acquire a better quality and quantity of information in real time.

In interactive visualization we have experimented with the Crystal Eyes VR System, an ultrasound head tracking device with six degrees of freedom, connected with an INDIGO Extreme 2 Silicon Graphics workstation, which is a very effective desktop virtual reality system because it operates at a very high graphic resolution. The user perceives a full stereoscopic vision and can navigate through 3-D spaces and objects without other devices such as 3-D mice or HMD systems.

On the basis of these results we should like to create a virtual archaeological park, a multimedia platform in which to install hypertextual links associated to two-dimensional

and three-dimensional information. At the end of this processing we hope to put our 3-D models on Internet - WWW in VRML (Virtual Reality Markup Language) so as to ensure their accessibility.

At the 3rd International Conference on World-Wide-Web, *Technology, instruments and applications* (Darmstadt, 10-14 April 1995), a new graphic language was presented, the VRML (Virtual Reality Markup Language) that, for the 3-D computer graphics, represents a parallel to HTML, now used to store the images. VRML is a descriptive language of 3-D objects (fig. 10), in ASCII code, derived from Open Inventor (Silicon Graphics) with the tag 'LINK'. HTML and VRML are complementary: from textual navigation it is possible to pass into three-dimensional spaces and vice versa. WebSpace is the VRML implementation by Silicon Graphics (URL is <http://www.sgi.com/Products/Web-SPACE/WebSpacej3>). When following a link, connected with a VRML space, the browser opens WebSpace into a 3-D navigation, until a link is found, in the 3-D space (fig. 10), associated with another multimedia document. WebSpace on an INDIGO workstation is very easy to use: objects can be rotated, moved and observed in all the views (fig. 10).

This powerful graphic language opens new and extraordinary possibilities for processing multimedia and GIS data in 3-D spaces: all the data, including databases, can be observed and analysed by hyperspace links: can we talk of hyperGIS (fig. 2)?

## Acknowledgements

I (MF) am grateful to all the CINECA Scientific Visualization Laboratory staff for the extraordinary cooperation in my research projects. Special thanks are due to KARMA video s.r.l. for video post-production.

## references

- Cremaschi, M.  
A. Ferretti  
M. Forte
- 1994      Tecniche digitali e di visualizzazione in geoarcheologia: il caso di studio della terramara S. Rosa di Poviglio (RE), *Archeologia e Calcolatori* 5, 305-316.
- Cruz-Neira, C.  
J. Leigh  
C. Barnes  
S.M. Cohen  
S. Das  
R. Engelmann  
R. Hudson  
M. Papka  
T. Roy  
L. Siegel  
C. Vasilakis  
T.A. DeFanti  
D.J. Sandin
- 1993      *Scientists in Wonderland: A Report on Visualization Applications in the CAVE Virtual Reality Environment*, IEEE Symposium on Research Frontiers in Virtual Reality, October 93, 56-66.
- Forte, M.
- 1993a      Un esperimento di visualizzazione scientifica per l'archeologia del paesaggio: la navigazione nel paesaggio virtuale, *Archeologia e Calcolatori* 4, 137-152.
- 1993b      Image processing applications in archaeology: classification systems of archaeological sites in the landscape. In: J. Andresen/T. Madsen/I. Scollar (eds), *Computing the past: Computer Applications and Quantitative Methods in Archaeology CAA92*, 53-61. Aarhus: Aarhus University Press.
- 1993c      Il paesaggio archeologico al calcolatore, *Le Scienze*, June 1993, 46-54.
- 1995      Scientific visualization and archaeological landscape: the case study of a terramara, Italy. In: G. Lock/Z. Stančič (eds), *Archaeology and Geographical Information Systems: A European Perspective*, 231-238, London: Taylor & Francis.
- Forte, M.  
A. Guidazzoli
- 1992      Archeologia e tecniche di eidologia informatica, *Archeologia e calcolatori* 3, 37-76.
- McCormik, B.  
T.A. De Fanti  
M.D. Brown
- 1987      Visualization in Scientific Computing, *Computer Graphics* 21 (6).
- Smarr, L.
- 1991      Visualization captures the imagination of physicists, *Computers in Physics* 5 (6).

Maurizio Forte and Antonella Guidazzoli  
CINECA  
Via Magnanelli 6/3  
Casalecchio di Reno  
Bologna  
Italy  
e-mail: maurizio@sirio.cineca.it