ArchaeoGRID

a GRID for Archaeology

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Archaeology

Extensive Research Community, generally in small distributed groups of Archaeologists

universities, museums, local, national and international institutions, public and private associations

Extensive Applications

Historical research, Education, Tourism, Entertainment, Heritage Preservation, Archaeological Risk Management…

Interaction with virtually every discipline

Mathematics, Computer Sciences, Physics, Chemistry, Biology, Genetics, Cognitive Sciences, Anthropology, Social Sciences, History of Technique, History of Art, History of Agriculture, …

Distributed and Heterogeneous Data

Archaeological Digital Services, Internet Archaeology, Public and Private Archives in National and International Institutions, …
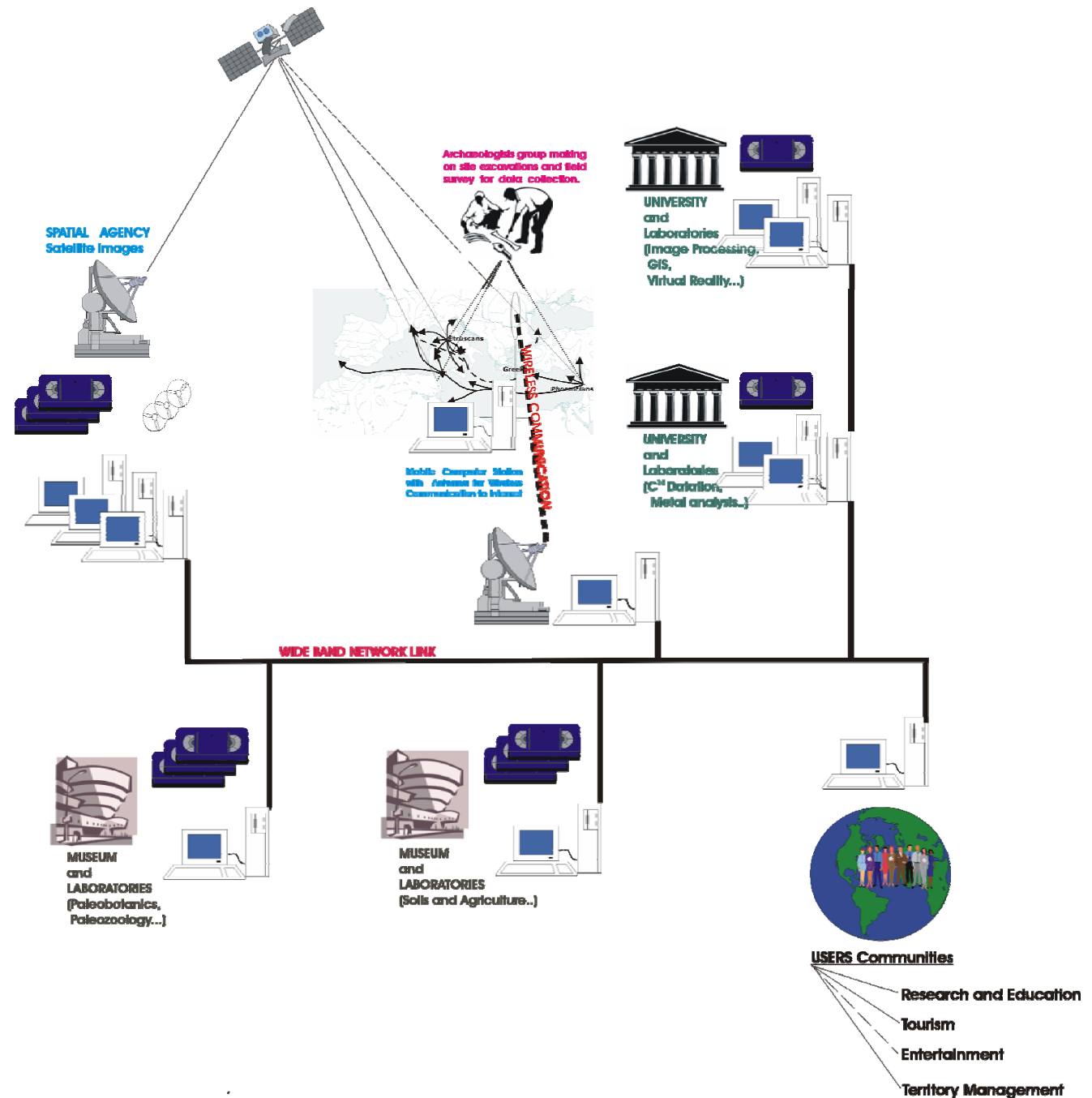
Wonderful Archaeological Questions

What?   **What** are significant material remains
Where?   of ancient human societies, **Where** are
When?   located, **When** have been deposited
How?   **How** have been produced, exchanged and
Why?   used and **Why**

Archaeology like History

Archaeology research try to discover the social process in ancient societies, **that cannot be seen**, in term of their material effects, **that are actually seen** for a deeper knowledge of the variety of human social experience

Archaeological Data are Geospatial-Temporal Data

Emergence
of
e-Archaeology
Global
Knowledge
Community
for Exploitation
of Advanced
Computational
Methods
to generate,
curate and
analyse research
data and
to develop and
explore models
and simulations

Archaeologists group making on site excavations and field survey for data collection.

SPATIAL AGENCY
Satellite Images

UNIVERSITY and Laboratories (Image Processing, GIS, Virtual Reality...)

UNIVERSITY and Laboratories (C¹⁴ Datation, Metal analysis...)

WIRELESS COMMUNICATION

Mobile Computer Station with Antenna for Wireless Communication to Internet

WIDE BAND NETWORK LINK

MUSEUM and LABORATORIES (Paleobotanics, Paleozoology...)

MUSEUM and LABORATORIES (Soils and Agriculture..)

USERS Communities

Research and Education

Tourism

Entertainment

Territory Management

Why an ArchaeoGRID ?

Production, Storage and Use of Archaeological Information and Knowledge is increasing in Volume. The images from 3D scanned objects and excavation areas, from remote sensing, the data from laboratories and from computer simulation produce petabytes

Archaeological data is getting not only larger and larger, but also its complexity is increasing, meaning that the extraction of meaningful knowledge require more and more computing resource

Archaeological Digital Heritage Technologies, now in a very advanced stage of development, provide the technical background for starting an ArchaeoGRID prototype

ArchaeoGRID enables the possibility to use a very large amount of digital data from past and present excavations and field surveys, stored in large distributed DataBase and Archives. Any new present excavation must rely on past data and knowledge

ArchaeoGRID enables the possibility for a large number world-wide spread communities of Archaeologists from Universities, Research Centers, Museums to work together on a same project

ArchaeoGRID for which Projects ?

Archaeological Heritage Management

from Preservation to Access.

Archaeological Research

Production, Sharing and Diffusion of Archaeological Information and Knowledge

Economical Exploitation of the Archaeological Information and Knowledge

ArchaeoGRID for Archaeological Heritage Preservation and Management

Emergencies

war, terrorism,..
earthquakes, flood, hurricane,..

Other risks

construction of infrastructure
works in agriculture
urbanization

Need a World Archaelogical Risk Map !

ArchaeoGRID for Archaeological Research

**Production, Sharing and Diffusion
of Archaeological Knowledge**

by methods of

**Topography
Field Survey and Excavation
Archeometry
Simulation
Telearchaeology
Visualization and Narration**

ArchaeoGRID for Economical Exploitation of the Archaeological Information and Knowledge

Cultural Tourism

Media and Entertainment

Education

Land Management and Infrastructure Construction

Heritage Preservation

ArchaeoGRID Applications
for
Large Regions Archaeology

Application n.1

Top of the World Archaeology – Artic and Antarctic Archaeology

Study of **primitive** hunter-gatherer and agriculture based **societies** in **marginal areas** and in very difficult environmental situation

Application n.2

Origin of the City in the Mediterranean Area between XI-VIII Centuries B.C.

Study of the process conducting, in **complex societies**, to the origin of the cities in Mediterranean area, a **central area** where the **identity of Europe** was born, during the protohistory,

Application n.1

Top of the World Archaeology
Artic and Antarctic Archaeology

Studied Region Area: many Thousand of Km^2
Dimension of excavation areas: few Hectares
Depth of excavation: less than 10 m
Period: less than 10000 years B.P.
Excavation Unity Sample: less than 10 cm^3
No maps of the areas
Difficult natural environment for sites survey and preservation

Computer Power at the Fieldwork

Need access to large Computer Power and Database at the fieldwork.
Computing and Archiving facilities, needed for creating visual excavation model and for multidimensional spatial analysis, have to be used at run-time, at the fieldwork

Field Survey and Excavation

Data are produced by archaeologist in two different places:

. the Archaeological Site and the Laboratory.

General methods for data acquisition from the archaeological site:
Extensive field survey with remote sensing (aerial and satellite images) and with sampling
Intensive field survey of the archaeological site surface
Excavation of the archaeological sites and remains.

Excavation is a destructive method

must be carefully projected and executed because archaeological data are unique data. Documentation must be more complete than possible for future uses and research. The amount of data can be not manageable without new sophisticated digital technology.

Field Survey and Excavation Model
the Archaeological Space

Fieldwork Multidimensional Model
Beyond the GIS paradigm

Archaeological space

a sequence of finite states of a temporal trajectory, where an entity (ground surface) is modified successively, by accumulating things on it, by deforming a previous accumulation (for instance, by spreading) or by direct physical modification (building, excavation). Archaeological sites should be considered as the result of successive and overlapping modification steps or phases.
A phase is a homogeneous region in space delimited by boundary, that is an abrupt change in some spatial values.

Archaeological excavation

not only the mere unearthing of artefacts and ruins, but an exhaustive documentation of an archaeological space in terms of a finite set of spatial variables
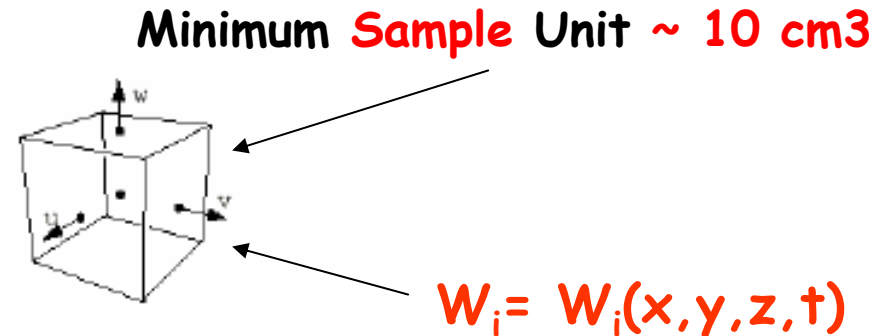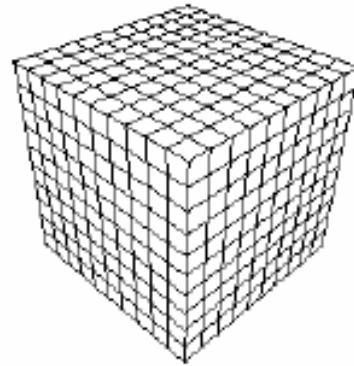
Archaeological Space

Accumulation

Formation/Deformation

Variable W

Archaeological Space

Minimum **Sample** Unit ~ 10 cm3

$W_i = W_i(x,y,z,t)$

The archaeological space is specified by a array of **samples unit** instead of a set of delimited objects (walls, floors, pits, stones, etc.). Such mathematical model is defined by a set of scalar fields $W_i = W_i(x,y,z,t)$ that define the geometrical and physical properties of every point in three dimensional space.
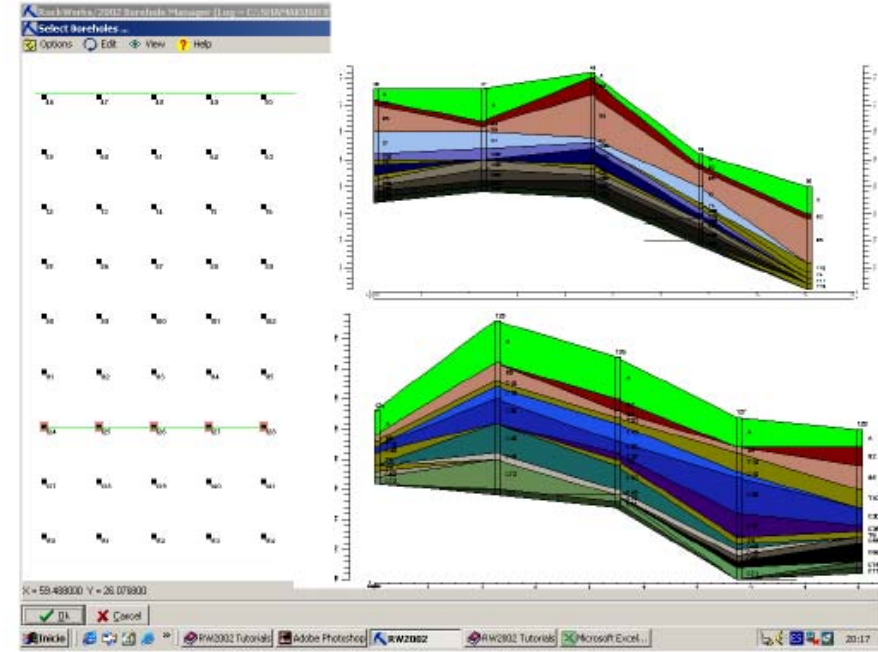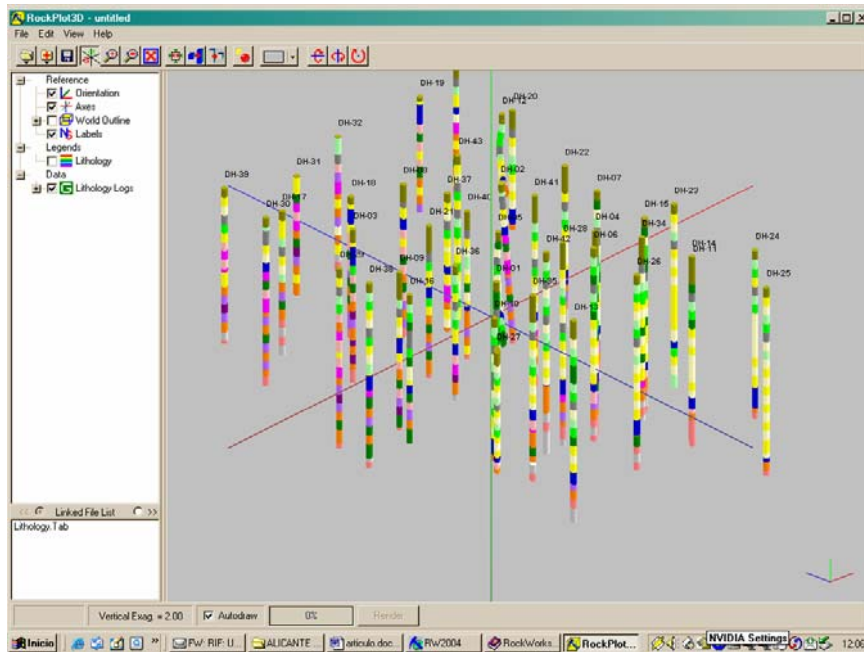
Quantitative variables W_i
sediment hardness, porosity, degree of consolidation, density, cohesion, strength, elasticity ......

Qualitative characteristics W_i
presence/absence of specific built structures ....

Regular Discontinuous Sampling

Discontinuos Core Sampling and Reconstruction of Continuos Archaeological Space by Inverse Ingeneering

The formation/deformation process of the archaeological site do not give the possibility to read the archaeological record like the direct consequence of a social process. The practical solution is to consider that **cause** or **determination** can be defined as a **probability function** between **social action** (production, distribution , use) and **material appearance** (shape, size, content, composition, texture, location)

Run-Time Data Analysis and Visual Model

Relationship between cause (social action and natural event) and effect (archaeological record) is not deterministic, but stochastic. But the spatiotemporal variation of archaeological feature W_i cannot be completely random.

Discontinuities or boundaries in physical space will delimitate any phase, when the action or process acting in neighbouring locations are different.
Three main properties of spatial discontinuities can be analysed : geometry, topology and texture

Analysis try establish how qualitative and quantitative variables "vary in a way statistically significant from one location to another".

Visual model for the spatial analysis of phase correlation:
how distinct formation process influence the spatio-temporal discontinuities observed through the site and if, what happens in one location (temporal or spatial), is the cause of what happens in neighbouring locations.
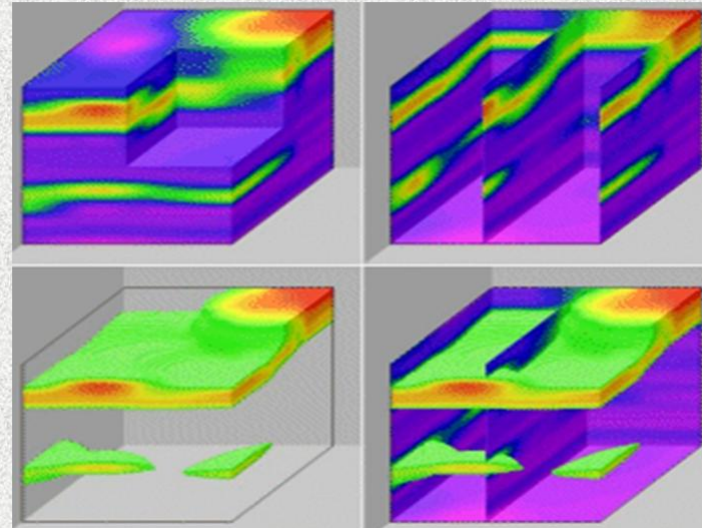All effects, probabilistically related to the spatial or temporal location of the cause, will be analysed.

Voxel Visualization
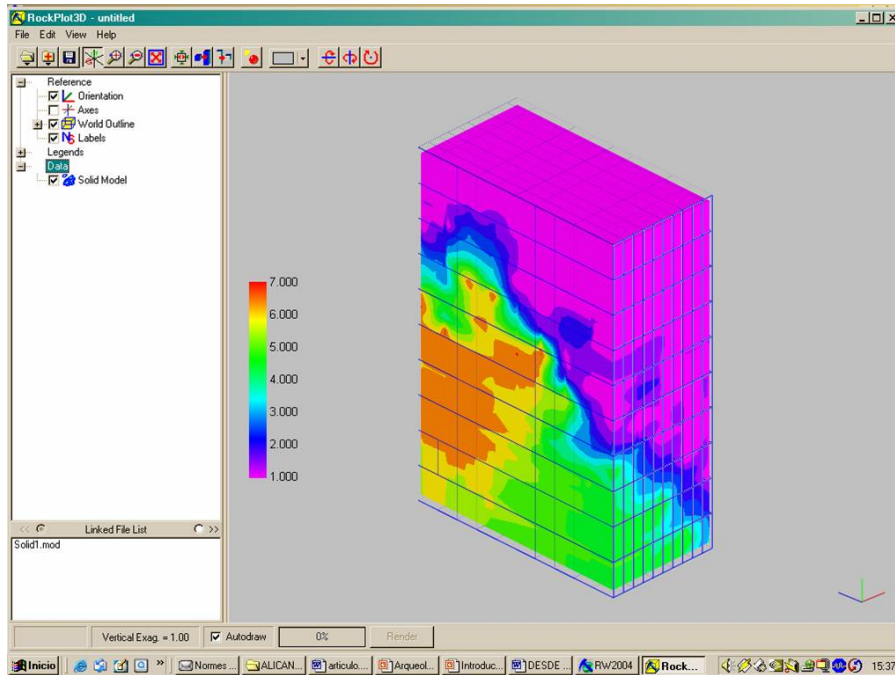
Slicer Dicer Images

for

the variable quantity

$W = W(t, x, y, z)$

ROBOT and Archaeology

The idea is to develop an exploration system that allows a robot (many robots) to explore and extract relevant features from the world around it, expressing them in some specific way.

These specialized mobile robot would be equipped with video cameras, 3D scanners, remote sensors, excavator arms, suction heads and tubes, manipulation hands for taking samples exploring in the search of evidences for archaeological sites, excavating the site by itself, describing the discovered evidence, and analyzing samples and materials

Is it possible build and use an automated robot for field survey and excavation? It need to understand what archaeology really is, to successfully fabricate an automated archaeologist, the ArchaeoROBOT.

ArchaeoROBOT, as a Learning Behavers, will take information from their environment and their users, or both, and will incorporate this in their design.

The connection of the ArchaeoROBOT with the ArchaeGRID will strongly facilitate his activity.

Data from Archeometry Laboratory

Archaeology is a multidisciplinary science. Archaeometry include all the analysis methods unprompted by physics, chemistry, biology, geology, etc. for analysing any type of remains.

Most of laboratory practice consists in classification or recognition of features at macroscopic or microscopic level (use wear in tools, taxonomic determination of organic remains, fracture patterns, etc). Therefore it need a lot of comparative material in order to carry out the work.

Another problem for archaeologists who work in laboratory is related with the impossibility to publish all information recorded.

Huge amount of data often unknown because only few, more significant data are published

Data from Archaeological Field

(ArchaeoGrid Lite ?)

Many small digital devices – Portable Computer, cell phones, GPS Surveying System, Photogrammetric Digital Camera, 3D Laser Scanner, PDA for on-site analysis, ArchaeoROBOT, etc. - require a set of essential Grid services, that enable the device to be part of a Grid environment.

Main issues

- connectivity/virtualization and synchronization/interactivity
- bandwidth due to the large amount of data that must be transferred to main ArchaeoGRID activity

Application n.2

Origin of the City in the Mediterranean Area between XI-VIII Centuries B.C.

Reconstruction of Paleoenvironment
and Paleoproduction Landscapes

Simulation of Social Process related
with the Urbanization Process

in the areas along the coasts of Mediterranean see where
the Cities originate, between XI-VIII Centuties B.C.

XI – VIII Century B.C.
Origin of the City-State in the Mediterranean Area
An important subject in the present research in Archaeology

Mediterranean area during this period start as a global trade and market area.
Urban centres originate and previous villages disappear in few tenths of years.
In Etruria this phenomenon is known like the "Villanovan revolution"

Origin of the City

The Origin of the City (and of the State) is a central problem of the today research in Archaeology

This example show the amplitude and the complexity of the problem. The area that must be studied is all the Mediterranean area. Any aspects related with the situation during XI-VIII centuries B.C. must be evaluated.

Huge amount of data

From past research: this area have been studied from many archaeologists for a long time
From present research: the new technologies give the possibility to complete with new more precise data the previous scenarios.
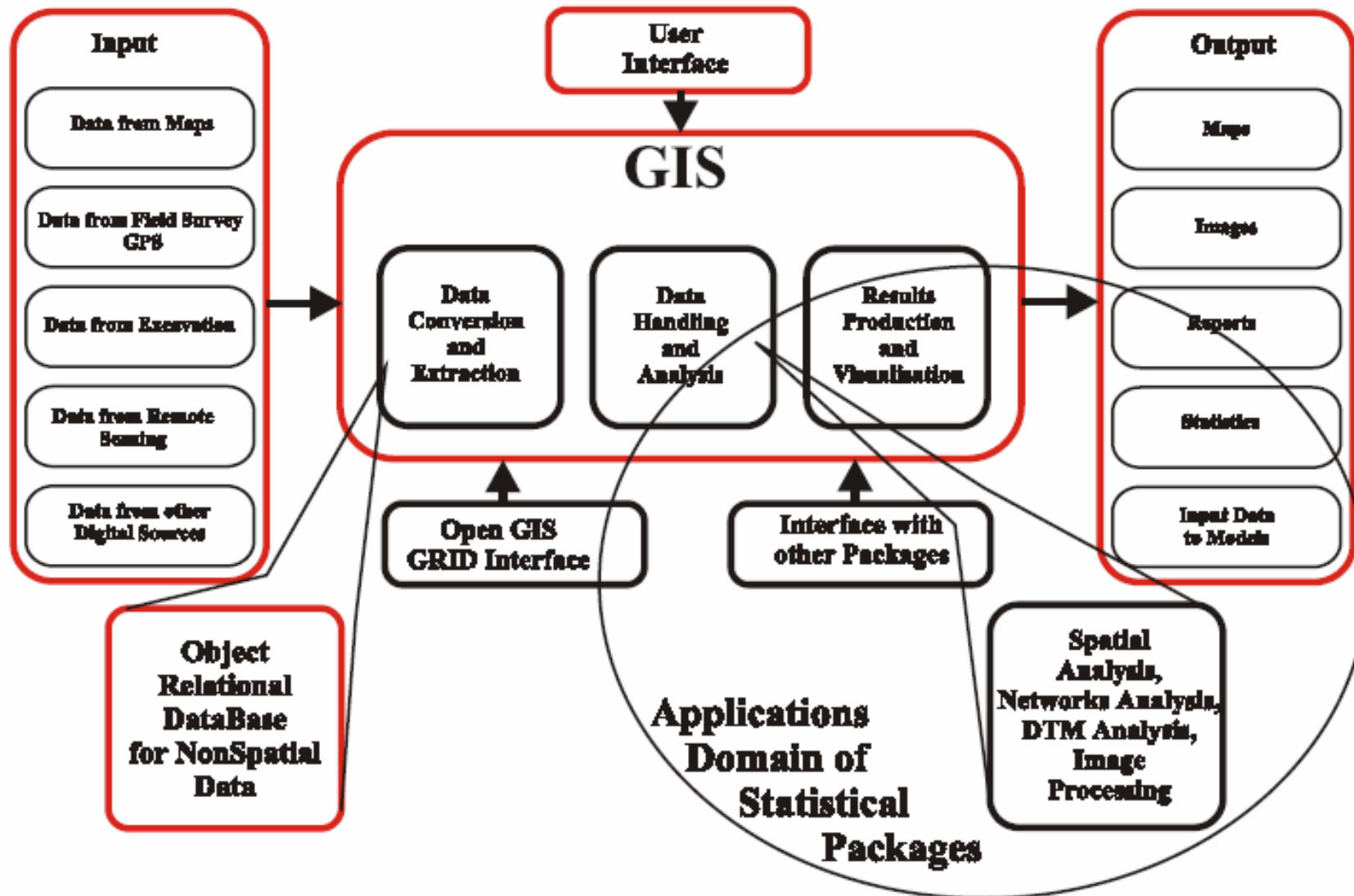
Advanced Analysis Methods

Origin of the City as a Dynamic System. From simple dynamic model to complex dynamic model. From "simple" society to "complex" society:

Archaeological GIS coupled to Multi Agent-Based Model

Archaeological GIS

Input

- Data from Maps
- Data from Field Survey GPS
- Data from Excavation
- Data from Remote Sensing
- Data from other Digital Sources

User Interface

GIS

- Data Conversion and Extraction
- Data Handling and Analysis
- Results Production and Visualisation

Output

- Maps
- Images
- Reports
- Statistics
- Input Data to Models

Open GIS GRID Interface

Interface with other Packages

Object Relational DataBase for NonSpatial Data

Applications Domain of Statistical Packages

Spatial Analysis, Networks Analysis, DTM Analysis, Image Processing

Archaeological GIS and Open GIS Interfaces

Geographic Database of Archaeological GIS will contain any available spatial data, related to the present landscape and to the past one, based on archaeological and paleoenvironmental data.

Alphanumeric Database, interfaced with Archaeological GIS, will contain any other useful non spatial information. Many software tools for Statistical and Spatial Analysis will be available in Archaeological GIS.

The Archaeological GIS, via the ArchaeoGRID and the Web, will benefit of three decades of progress in geographic information systems (GIS), earth imaging, and automated mapping and facilities management (AM/FM).

In fact ArchaeoGRID will have an OpenGIS Grid Interface to communicate across a network with servers that have OpenGIS Grid Interface for addressing satellite images, aerial photos, digital elevation data, and other kinds of "gridded" data.

Reconstruction of the Paleoenvironment and Paleoproduction Archaeological Landscapes and Landuses

Paleoenvironment and Paleoproduction Inverse Engineering

Available data on climate, geomorphology , hidrography, land use, etc. will be used for a reconstruction of global and local ancient paleoproduction landscapes.

Reconstruction of the resource distribution as soils for agriculture and farming, as mines for metal production, as forest for wood, as fauna, as techniques, etc.

Reconstruction of the activities areas for artifact production, for fishing, for any other production.

Reconstruction the terrestrial communication road, the fluvial way and the maritime routes and harbors based on the archaeological remains and the reconstructed geomorphologic , hydrographic and oceanographic situation

Poly-layer as Landscape Chronological Sequence

The Chronological Sequence of studied period will have a minimum interval length depending from the available data and from their time calibration precision.

Landscape poly-layer will be created as chronological sequence of the urbanization process and of the his effect on the landscape changes.

High resolution DEM's from satellite images permit high precision geospatial modeling of erosion and deposition and digitally trace ancient streams from channel fills and expose ancient surfaces now buried under alluvial fans.

Archaeological Paleoproduction Landscapes
vs
Archaeological Time
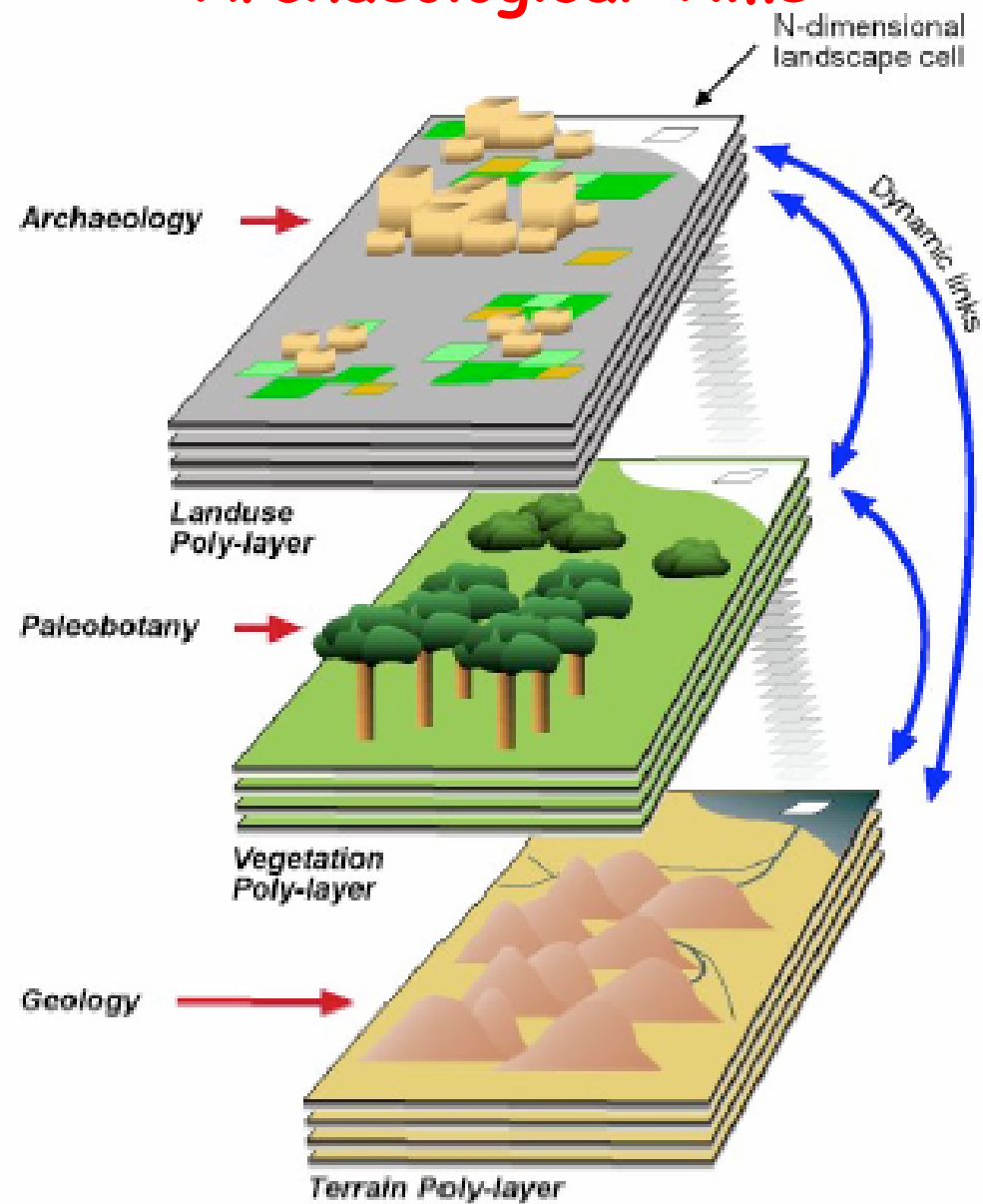
Coupling of Archaeological GIS and MultiABM

The best way for representing data and process could be the coupling of the Archaeological Spatial Data Model, the Archaeological GIS, with the Spatial Process Model for a description of movement as the Multi Agent-Based Model.

GIS tools are limited in process knowledge
essentially static views and little description of process (e.g. specify changes at a location not movement)

MABM tools are limited in spatial knowledge
much of the development is already in GIS systems

Coupling Archaeological GIS and MABM
Agents, mapped to spatial features, request information from the Archaeological GIS then take appropriate actions.
MABM should be in control of temporal dynamics and synchronize his temporal dynamic with the Archaeological GIS one.
GIS has a richer spatial expression and thus should be in control of the topological dynamics

Social and Economic Archaeology

MABM modeling of complex social systems provide the potential to capture the dynamic trajectories from the villages to the cities and their social and economical support systems.

Multi Agent-Based modeling allow for a wide range of choices and trajectories—both rational and irrational—to contribute to the outcome of the modeling exercise.

The analysis of the ancient economy will be centered

on production
agriculture, mines and metallurgy, craft production, techniques, ...

on consumption

on exchange
noncommercial and commercial exchange

at the different social scales
Households, Villages, Cities, Regions and World Systems

Simulation, Visualization and Narration

Simulation, Visualization and Narration of the research results are interlaced and represent the work in progress of the group working at a subject.

In fact 3D Graphics and VR and AR technologies are used in the different phases of research, for simulation and narration:

a-in preparing the research project

b-in acquiring data and in making the first raw analysis. VR and AR technologies could help during the analysis to understand if the results, also partial, have some coherence with data and if the emergence of new aspects do not depend from errors in calculation or in our hypotheses.

c-in final analysis and in writing the final paper

Telearchaeology

(ArchaeoGRID)

The main problem of the archaeology today is the circulation of the archaeological knowledge generated. Integration of preliminary data from field survey and excavation and from laboratory into a coherent body of problems and solution, transform data into knowledge.

By Telearchaeology the field team can make queries and computation at run time, during excavation.

Archaeological excavation is totally transformed in so doing. It is no more a blind unearthing of hidden objects, but an understandable production of new data using a coherent framework made of previous knowledge.

Archaeologist can understand the activity areas, occupation floors, walls, etc. he is excavating, because he can recognise then as such when integrating all data at the same moment he obtains them.

It is not a question of waiting for the end of the excavation to understand what.

Telearchaeology

Human-human interaction by high end video conferencing and collaboration technology
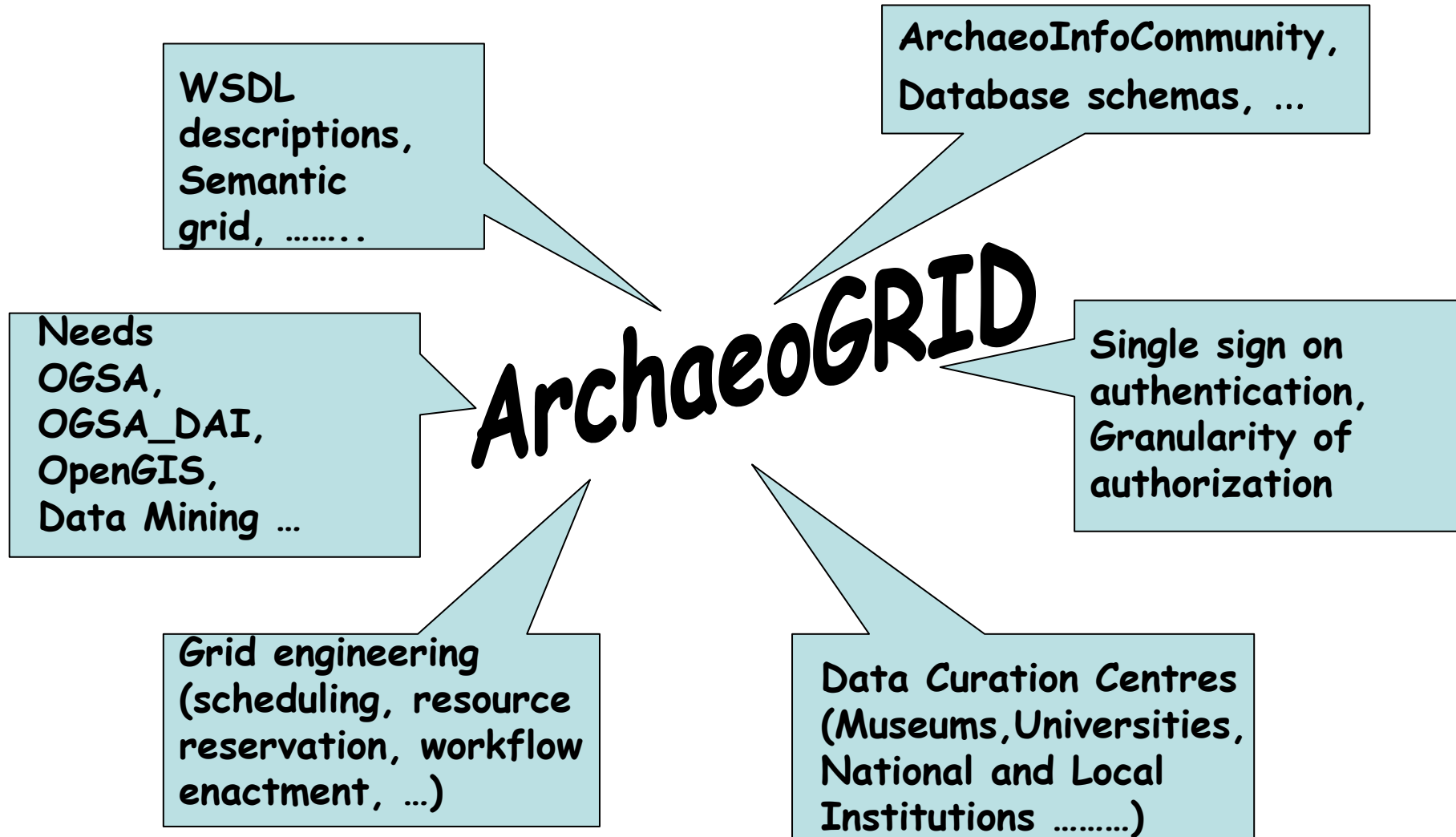
(AccessGRID ?)

Many people can collaborate in the understanding and in the way the knowledge is extracted from the ground, without being there excavating.
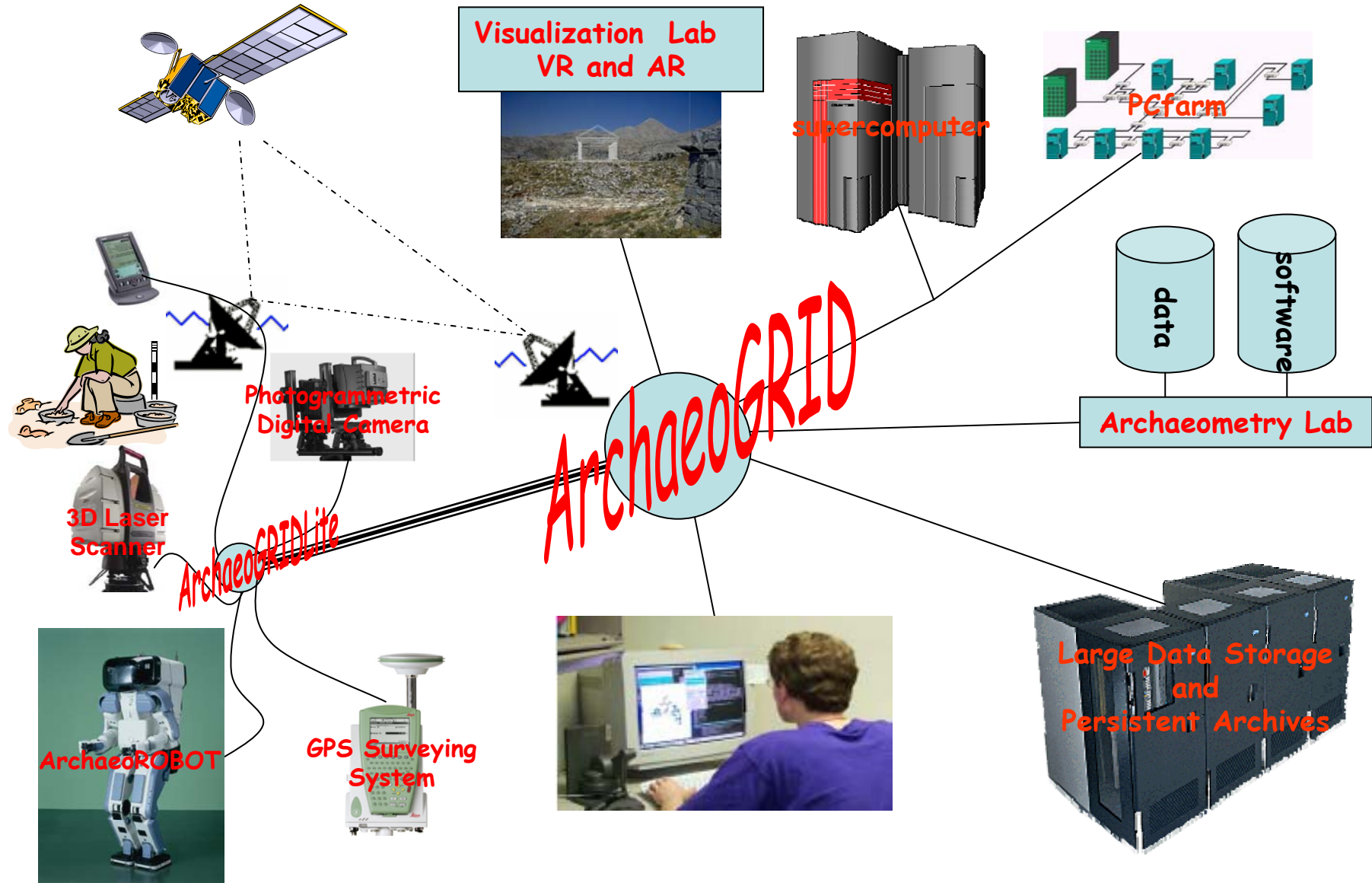
That means knowledge sharing and knowledge growth. Everyone learns: the archaeologist in the field, the technician at the laboratory, the archaeologist at the university, the public at the museum, the student at the classroom.

The idea is to generate knowledge, to share knowledge and to use knowledge, because only through its use, the archaeologist will build significant relationships between bits of data which may be inutile in their own.

ArchaeoGRID Needs

ArchaeoGRID

WSDL descriptions, Semantic grid, ……..

ArchaeoInfoCommunity, Database schemas, ...

Needs OGSA, OGSA_DAI, OpenGIS, Data Mining …

Single sign on authentication, Granularity of authorization

Grid engineering (scheduling, resource reservation, workflow enactment, …)

Data Curation Centres (Museums, Universities, National and Local Institutions ………)

ArchaeoGRID structure

Visualization Lab VR and AR

supercomputer

PCfarm

data

software

Archaeometry Lab

Photogrammetric Digital Camera

3D Laser Scanner

ArchaeoGRIDLite

ArchaeoGRID

ArchaeoROBOT

GPS Surveying System

Large Data Storage and Persistent Archives

The Grid is too complex for Archaeologists...

Before Concluding…

Two important project launched:

1- Preservation and Management Strategies for Exceptionally Large Data Format: "Big Data" from Archaeology Data Service of the English Heritage – August 8th, 2005

2- Humanities, Arts and Social Sciences-HASS-Grid from University of California Humanities Research Institute – UCHRI – October 12th, 2005

Will HASS be the GRID for Archaeological Heritage Preservation and Management ?

The launch of these projects underline that it is time to start with Grid applications to the human sciences as Archaeology.

Conclusions

ArchaeoGRID enables the possibility to exploit Advanced Computational and Storage Methods in Archaeology for generating, curating and analysing **big amount of data** from field surveys, excavations, laboratories and for developing and explore models and simulations from data with a **very large number of variables, needed for the analysis of the emerging large region archaeology**

Archaeological knowledge building is a collective work. The explanation process needs knowledge as a raw material, and this knowledge doesn't exist in mind of one individual scientist. Knowledge is distributed in the community of researchers, on a global scale. To be able to interpret data, every researcher needs a previous knowledge on which he will make a specific reference

In the vision of the **"Knowledge Grid"** , the ArchaeoGRID act as unifying agent between applications and non homogeneous data. Access and management of data and software are an advantage for a completely new way of producing archaeologically relevant knowledge

ArchaeoGRID becomes the medium for the cognitive process in Archaeology and for advancing in Archaeological Knowledge Unification and Integration through the use of advanced technological platforms

History of the Proposal and Participant Institutions

Original idea from the archaeologist Giuliano Pelfer - Florence

POSTER to IEEE NSS-MIC Conference – Portland 2003

PRESENTATION to IEEE NSS-MIC Conference – Roma 2004

Participants Countries and Institutes:
ITALY
Centro Studi Dinamiche Complesse, University of Florence
(http://www.csdc.unifi.it)
Istituto di Studi della Complessità, CNR, Florence
(http://www.isc.cnr.it)
SPAIN
Departament de Prehistoria,Universitat Autonoma de Barcelona, Barcelona
(http://seneca.uab.es/prehistoria/); CIEMAT; Universidad Politecnica de Madrid
NORWAY
Department of Archaeology, Tromsœ University, Tromsœ
(http://uit.no/arkeologi/)
ARGENTINA
Universitat Nacional de La Plata

Contacts with other european organizations started