Grid services for e-archaeology

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Abstract

Archaeological data collection is based on the description of archaeological contexts. An archaeological excavation demolishes the original matrix within which the cultural material is found and special care is taken to record spatial context. Each artifact is described in terms of its physical and spatial properties as well as its relation to the matrix (for example soil composition). As several thousands of artifacts can be unearthed during a field season, there is a need to develop digital resources and collections that focus on the publication and preservation of data and the creation of tools for the analysis of these data. The first section of this paper presents preliminary results and the lessons learnt on the development of a prototype for an Australian archaeological digital collection based on data grid middleware and infrastructure. The second section introduces a versatile 3D reconstruction tool that visualizes the excavated archaeological artifacts with its associated stratigraphy. The data come from two major archaeological projects in Queensland, Australia: the Mill Point Archaeological Project and the Cania Gorge Regional Archaeological Project. These case studies were selected to represent the different challenges in deploying these digital technologies to Australian archaeological applications.

Keywords: Archaeology, Storage Resource Broker, data grid, visualization, web services.

1 Introduction

A continuing problem in the archaeological and cultural heritage industries is a lack of coordinated digital resources and tools to access, analyze and visualize archaeological data for research and publication. A related problem is the absence of persistent archives that focus on the long-term preservation of these data. As a result professionals and researchers are either unaware of the existence of data sets, or aware of them but unable to access them for a particular project. Archaeological data are complex. They are varied in content (artifact attributes, spatial coordinates, dates, etc) and in format (texts, photographs, videos, audio clips, etc), some of which may be digital. Text and numbers are generally initially stored as hard copy raw data in the field, and later entered in an Access database, or sometimes in an Excel spreadsheet, or in GIS databases. These data are saved in different formats and different locations and archived in an informal way: hard drive, CDs or tape archives. They cannot be accessed or integrated easily: it is difficult for a researcher to explore, analyze, and compare these data with data that are available in other groups. To date there is no formal management process to make archaeological data available in a grid environment for wider access (Foster 1998, 2003).

The goal of this project is to develop and implement an Australian archaeological data grid based on existing High Performance Computing (HPC) techniques and infrastructure. There are two main aspects to this project: one is data management and metadata creation; the other is data analysis and visualization. The digital collection will facilitate the storage, dissemination and interchange of archaeological data whereas the web portal will allow archaeologists to access information about artifacts from a specific project, but it will also give them the possibility to visualize cultural features, artifacts and their stratigraphic associations. Such a tool will essentially 'recreate' the site in 3D as it appeared during excavation and display the artifacts in context. An integrated 'data grid' will substantially enhance the ability of professionals, researchers and government agencies to access existing data and will contribute to increased efficiency and effectiveness of archaeological activities and have cumulative benefits for the developing applied archaeology/cultural heritage industry in Australia.

We used data from two archaeological projects: the Mill Point Archaeological Project in southeast Queensland, the Cania Gorge Archaeological Project and, dates measured in sites throughout the state of Queensland. A wide range of digital data is readily available (digital audio and video, archival documents, digital topographic data sets, artifact data sets etc) from these projects. Such data represent all the major classes of archaeological information routinely collected by archaeologists.

2 Related Work

Several digital collections and repository projects related to archaeology are addressing parts of this problem and are reviewed briefly here. The Electronic Cultural Atlas Initiative (ECAI 2007) provides a clearinghouse of shared datasets with an emphasis on geo-temporal data (Lancaster 2002, Buckland 2004). The data and their associated metadata are stored in a centralized database and data queries are made through a web-interface. The ECAI metadata used to describe the data are based on the Dublin Core metadata set (2007) and contain additional elements specific to archeology such as temporal and spatial information. ECAI offers a map-based visualization tool called TimeMap (2007), on which Pailthorpe and Bordes were early participants by working on proof-of-concept map animations (Bordes 2004, Johnson 2004). Our project is not focusing exclusively on geo-temporal data and the data sets will not be centralized but distributed. ECAI is an initiative of the University of California Berkeley.

The Online Cultural Heritage Research Environment (OCHRE 2007) is the follow on to XSTAR (XML) System for Textual and Archaeological Research) developed by an archaeologist at the Oriental Institute in the University of Chicago. This online centralized repository was created to facilitate the dissemination of archaeological and cultural heritage data. Users communicate via a user interface written in Java to search for or, upload and download data sets. OCHRE uses a semi-structured data model characterized by hierarchical tree structures: Schloen at the Oriental Institute developed ArchaeoML, an Extensible Markup Language (XML) scheme for archaeological data sets as part of the Integrated Facility for Research in Archaeology (INFRA) which is based on XML (XML 2007) INFRA provides storage and retrieval of archaeological information and forms the basis of OCHRE (Schloen 2001). A particularly useful feature of INFRA is the ability to query data through a Java user interface and display relationships between items in different ways:

- a hierarchical tree showing the spatial containment relationships of the artifacts (default view),
- a stratigraphic sequence diagram as developed by Edward Harris (1993) and,
- a network diagram that shows items linked to each other in a non directed way.

These diagrammatic representations show the relationships between the artifacts in a site; however they are not a visual representation of the archaeological site itself.

The Alexandria Digital Library (ADL 2007) project is hosted at the University of California Santa Barbara and supports the earth and social sciences more generally, rather than just archaeology. It provides a federated, spatially searchable digital library of geographically referenced materials such as maps, photographs, and satellite imagery (Hill 1999). The ADL team developed their own metadata schema to address both physical and digital resources, for instance a map and its digital representation. The commonality with our project is that archaeologists want to catalogue both the physical artifact and also the information attached to the artifact.

The Archaeological Data Service (ADS) in the United Kingdom is one of five disciplines supported by the Arts and Humanities Data Service (2007). The ADS is mainly a catalog and data may or may not be archived locally: archaeologists have a choice to deposit their data with the ADS or not. Data stored in the ADS are described with the ADS metadata set which is based on the Dublin Core metadata set. Researchers can find out about a dataset and who to contact if the dataset has not been deposited.

The Pacific And Regional Archive for Digital Sources in Endangered Cultures (PARADISEC 2007) provides a facility for digital conservation and access for materials from endangered languages, cultures and music from the Pacific Region. It uses open standards and tools, and currently has a 2.5 terabyte repository of digitized materials (especially of field tapes from the 1950s and 1960s) supported by a rich metadata catalogue of project materials. The framework allows users to access, catalogue and digitize audio, text and visual materials while preserving digital copies.

The 3D Measurement and Virtual Reconstruction of Ancient Lost Worlds (3D MURALE 2007) was developed at Brunel University to record, reconstruct and visualize archaeological sites and artifacts such as buildings, statues, and artifacts (Cosmas 2001, Hynst 2001). 3D MURALE consists of a relational database, and recording, reconstruction and visualization components however it is not a data repository per se. The 3D MURALE data model has a scene graph data structure to facilitate the visualization of the data: the data and attributes stored in the relational database are used as input to the visualization process. The database search tools accept XML schemas or documents as input, and output XML or Virtual Reality Modelling Language (VRML) documents. 3D MURALE has a stand-alone stratigraphic tool, STRAT, although little information is available on the technical background. Stratigraphy is visualized from existing video records or by entering the coordinates of the different layers. 3D MURALE also has a web-based visualization tool to bring 3D reconstructions done in Maya into 3D MURALE (Grabner 2003). The scene graph used by Maya is similar to the one developed in 3D MURALE and a plug-in was created to make the Maya data structure compatible with 3D MURALE's so that data can be moved to and from the 3D MURALE database. The images generated from the Maya 3D reconstructions are JPEG-encoded and saved at different resolutions. These scenes are then visualized on the web using an ActiveX plug-in for Internet Explorer.

One of the major aims of our project is to integrate digital collections and visualization services in a grid environment and none of these projects do both at the same time. We are creating the archaeological collections and developing the visualization services in parallel and do the integration at the end.

3 Case Studies

We selected two major archaeological projects in Queensland to provide the major categories of data routinely collected by archaeologists in Australia.

3.1 The Mill Point Archaeological Project

Mill Point (2007) is an historical archaeological site of recognized State significance located on the shores of Lake Cootharaba in the Great Sandy National Park, southeast Queensland, Australia. The forest of large Koori pines attracted the timber industry and settlement of the area began in the mid-1800s. A sawmill was built in 1869 and operated until 1892 when the timber resources were depleted. Over the 20 years of the sawmill operation, Mill Point grew into a small community of up to several hundred people and included the sawmill, workers houses, a school, shops, a hotel and a cemetery (Brown 2000). Stone artifacts, tramway rails, cemetery, dairy area, jetties and wharves have been unearthed and have the potential to reveal information about pre-European Aboriginal lifeways, nineteenth and twentieth century life and burial practices at a company timber town in rural Queensland, and about timber extraction and processing (Ulm 2004, Ulm 2005) Over 5000 artifacts have now been excavated from the Mill Point site over the last three years and are representative of the type of data that make an Australian digital collection. The site exhibits surface and subsurface archaeological deposits representing both Aboriginal and European occupation over an area of more than 10 km^2 (Nichols 2005). A key challenge at this site in the integration of data at different spatial scales from specific artifact attribute data to broad scale cultural landscapes.

3.2 Cania Gorge Regional Archaeological Project

Cania Gorge is an extensive system of low, dissected sandstone plateaux, in the upper Burnett River basin, southeast Queensland, exhibiting a rich Aboriginal and European occupation record. Field surveys have documented numerous archaeological deposits in rockshelters at the base of the escarpments forming the gorge, some including rock art sites. Archaeological excavations at 10 rockshelter sites within a 15 km^2 area at the southern end of the gorge have revealed evidence for Aboriginal occupation extending up to 18,000 years ago to the European contact period. Archaeological deposits extend up to 4.5 m deep in some sites, with thousands of stone artifacts and faunal remains recovered (Eales 1999, Wescott 1999). These archaeological assemblages provide a key data set in testing models of Holocene Aboriginal cultural change in Australia. However, the very large stone artifact assemblages coupled with complex stratigraphic associations at many sites hampers meaningful integration of site data sets. Data visualization tools have the potential to deploy data handling and analytical tools to aid interpretation of such complex data sets.

3.3 Index of Dates from Archaeological Sites in Queensland

A third set of data comprises 849 chronometric determinations obtained from 258 archaeological sites distributed throughout Queensland (Ulm 2000). Representing sites in all major environmental zones in Queensland and dating from c.40,000 years ago to the present, this data set has the potential to reveal gross patterns in settlement and occupation trajectories.

The data collected in the Mill Point were used to create a pilot digital archaeological collection. However these data were mainly collected on the surface and within the first 20 cm in the ground. The data collected in the Cania Gorge project are not entirely in a digital form however one of the excavated squares is complete with stratigraphy and was used to test the web-based visualization client. The dates data are surface data and cover a larger area than Mill Point and Cania Gorge.

4 Data Grid for Archaeology

This project is an Australian Research Council funded study between the University of Queensland and the Australian National University. The digital collection that we are building will be one of many that will form the Australian archaeology data grid. It will provide archaeologists with initial access to the existing computer-data-network facilities in these universities and will encourage researchers in the social sciences to engage in e-research and collaborate on multi-disciplinary projects based on the utilization of existing, advanced IT infrastructure. As mentioned earlier we will develop an Australian digital collection using demonstrated HPC and grid software applications and 'standards': the Storage Resource Broker (2007) and XML. We will also publish a set of guidelines to allow researchers in other institutions to create their own data collections. Each collection will be one of the building blocks of an Australian archaeological data grid.

Data handling is one of the key factors associated with the management of distributed data. The key functions are exchange protocols, information tagging, physical and logical organizations of collections, access mechanisms and the management of information repositories from the storage of metadata (Moore 2001, Rajasekar 2001). With the successful combination of the above roles a persistent archival system can be achieved across a distributed system.

4.1 The Storage Resource Broker

The main aspects of this project concern data management and access in a distributed computing environment for further analysis in archaeology. The Storage Resource Broker (SRB) is suitable for this task: it has been used for several years and is mature. The SRB is a middleware software application developed at the San Diego Supercomputer Center. It provides uniform access to heterogeneous data resources which may be geographically dispersed (Baru 1998, Moore 1996, Rajasekar 2002). The SRB enables the creation of data grids that focus on the sharing of data (Wan 2003). It handles data through a client-server architecture and allows users to access location-independent data: the user does not need to know where files are located and how they are stored. The SRB organizes data logically into a single virtual file system in a similar way to a filesystem found on a stand-alone computer rather than physically. Metadata allow users to quickly find a dataset, what it contains, its format, when or where the data were collected or created, etc. Users can store or replicate their data collections across several servers to facilitate data preservation, while not losing local access control. Access permissions on individual files can be set so that other users can access the files.

The SRB servers that provide access to the archival resources, the Metadata Catalogue (MCAT) and the SRB clients are the main elements of an SRB domain. Files uploaded into the SRB are referenced by logical file handles chosen by the user – a name that is meaningful to the user. The MCAT maps these logical handles to the physical file locations on individual resources, and stores the metadata associated with the files, as well as information about the users and the physical resources managed by the SRB. The MCAT is implemented in a relational database such as Oracle or PostgreSQL and contains all the metadata and information about the files and resources in the SRB domain. The MCAT is usually associated to one SRB server (MCAT-SRB server) as shown in Figure 1. A user queries the catalogue about a specific file without knowing in which system the file resides. SRB can be naturally integrated into a data visualization pipeline for repeated analysis of large, diverse, distributed data sets (Pailthorpe 2000).

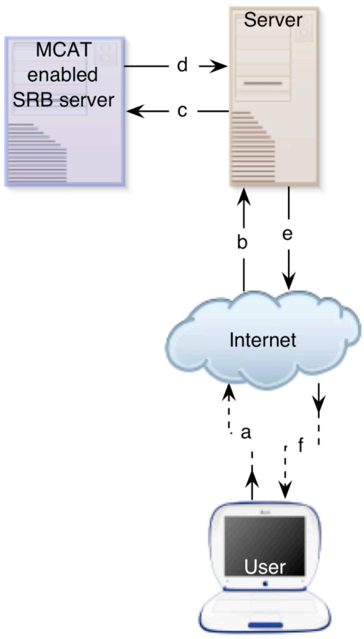

Figure 1: Diagram illustrating the use of SRB.

A user can access and download data sets or files through three interfaces: Scommands, inQ and mySRB. Scommands is a command-line interface for UNIX systems that is not intuitive for non-UNIX users. inQ is an intuitive graphical user interface which runs under the Windows operating system. mySRB is a web-based interface that runs under any operating system. The SRB manages access and control. When uploading data into the SRB, the user specifies who can have access to the data (read, write, delete). A user only has access to their own data and the data that others have allowed them to share.

The SRB is scalable and can work in a stand-alone configuration or in a federated way with several SRB zones and associated MCATs. In a federation, each SRB zone is part of a larger network and several zones interact with each other. Each SRB zone has its local MCAT, SRB servers and its own resources and users. From the user's point of view, a zone is represented as a folder within a logical file system. The user then can move from one folder to the other without being aware that the two 'folders' are different systems and geographically in different places.

4.2 Preliminary Results

The Mill Point data set consists of over 4000 entries derived from three seasons of survey, excavation and artifact analysis (2004-2006) and were originally entered in an Access database. Fourteen tables make up this database and record information about each artifacts (provenance, raw material, type, dimensions etc). Six XML schemas were created to define the data model and relationships. The data were converted into XML files according to the associated XML schemas and imported to PostgreSQL (2007) using scripts. This solution is temporary and in the future, users will enter new data directly into the database through a customized web interface.

The MCAT was also implemented in PostgreSQL. The collected data were converted into XML files according to a created XML schema. This allows the data to be shifted through the SRB system without losing file metadata which are stored within the file with the data. Once in the SRB, the user can create a collection: uploaded data are placed inside this logical collection which only exists within the SRB, and physically are stored into a user-specified resource. When the XML files are imported into the SRB with InQ for instance, the XML tags display the metadata available for each file. The metadata attributes – information about files and collections within the SRB, physical and logical locations of the data, access control information and descriptive information on the data itself – are ingested into the MCAT along with virtual and physical locations of the data. The user can then query the data or collection according to the defined metadata with an SRB client as shown in Figure 2.

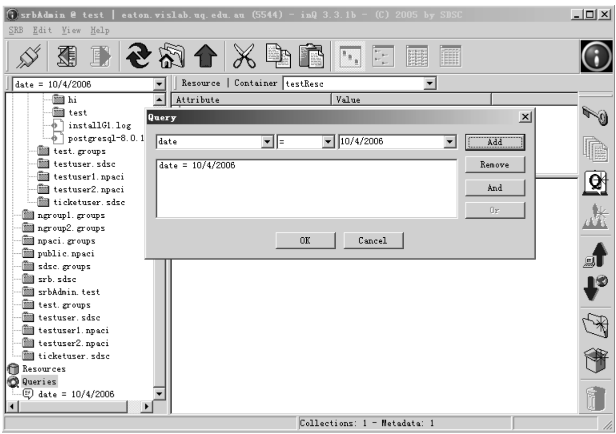

Figure 2: Simple query in the inQ interface.

We created a mini-data grid in our laboratory, with one server and several clients: the SRB server and data files are currently located in the same network. We remotely accessed the SRB server and uploaded and downloaded data successfully via the InQ interface and SRB's Scommands. However the system is hard to set up and use, and needs to be hardened in order to be useful to archaeologists. Nonetheless the SRB provides a sound base to establish a digital collection.

One of the major drawbacks of the SRB is the lack of a "standard" easy to use user-interface. Several third-party tools have been developed elsewhere, for instance TobysSRB by White (2007), YourSRB by Wyatt (2007). We developed a web application written in PHP and MySQL that provides access to the SRB. Figure 3 shows the query form used to search metadata. The interface and the metadata are specific to the Mill Point and Cania Gorge projects and need to be tested for data and metadata from different projects.

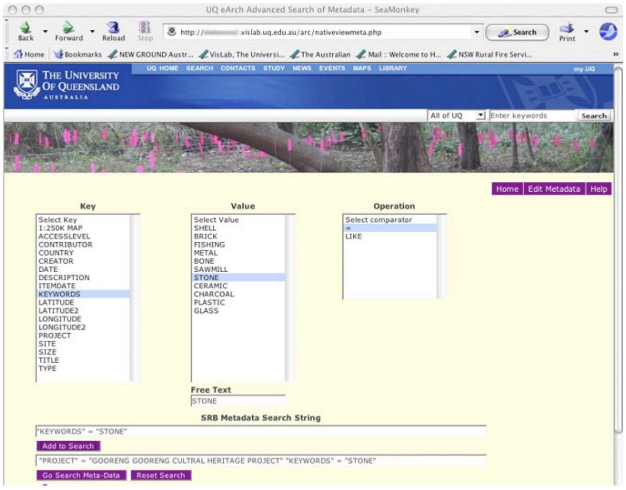

Figure 3: Query form to search metadata.

5 Visualization Tools for Archaeology

We developed two database-backed visualization tools: one enables an assemblage of archaeological artifacts to be analysed and understood within the original site matrix in 3D, the other is based on Google Maps and addresses the problem of moving between geographical scales and is more GIS-like.

5.1 3D Reconstructions of an Archaeological Site: 3D Arch

We built a 3D tool, 3D Arch, that provides a visual physical representation of the archaeological site as it almost was during excavation. A user can see the position of the artifacts as they were in the matrix in 3D as well as the stratigraphic layers. We used the data from the Grinding Groove Cave excavation where a c. 4.5m deep excavation revealed evidence of Aboriginal occupation extending from 10,000 years ago. The site was excavated in a series of 147 excavation units within stratigraphic units, each unit 30mm in depth. The data were originally stored in an Excel spreadsheet containing several fields: unique identifier, nature of the artifact, attributes, x, y and z coordinates. A code was written to parse the Excel spreadsheet data into a database schema in MySQL (2007). The schema is defined so that switching to another database such as PostgreSQL, requires simple reconfiguration.

We used the Ruby on Rails software framework (2007) to create the database-backed web application. Asynchronous JavaScript And XML (AJAX) technologies are implemented in Rails and ensure that data are updated dynamically without the need to refresh a web page. This increases the speed of the web application and improves user interactivity. Finally Ruby on Rails is easy to use and deploy. The web application backs onto the MySQL artifact database and accept textual queries. Searches can be made by checking boxes or selecting from a menu. A user can select all or a subset of the excavation units, the types of artifacts to be rendered (i.e. shell, bone, or rock) or the location of artifacts as shown in Figure 4. In the future the user will be able to search a database by entering text and keywords and searching through the metadata.

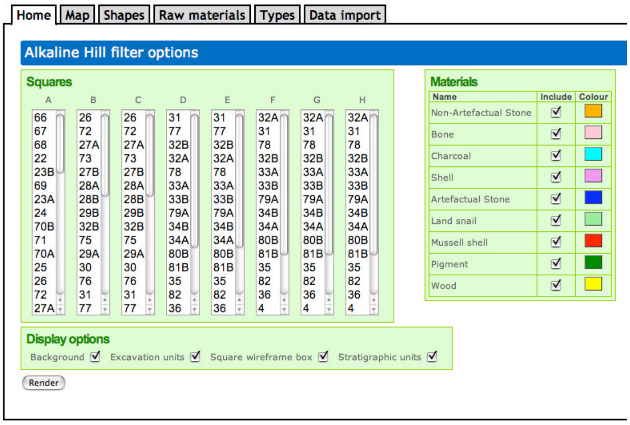

Figure 4: Query form for 3D reconstruction tool web interface.

Once the user has made the query, the client sends the request to the server, which generates an X3D document (X3D 2007). The 3D world is then displayed in a web page with an X3D plug-in as shown in Figure 5. The artifacts are represented as coloured spheres; each colour represents a type of artifact (shell, bone etc) and is set by the user. All artifacts have a weight and are represented by a sphere to give a sense of size of the artifact. Small artifacts can be displayed when no representation of the artifact is available. Bigger artifacts such as pots and tools could be represented accurately by providing a specific X3D document with a superimposed picture of the actual artifact however this was not available in this dataset. The user has a choice whether to display each excavation unit and the outline of the excavation and can also select an artifact by clicking on it: any information related to the selected artifact such as weight, dimensions and photographs, is then displayed in an information window. If several images are associated with an artifact, all can be seen in the information window as well. The tool was demonstrated to archaeologists and post-graduate students and suggestions or changes included whenever possible.

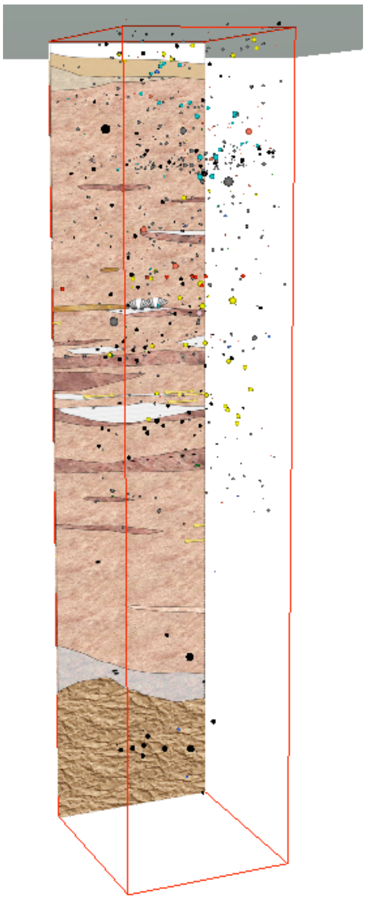

Figure 5: 3D view of all artifacts located in square A.

5.2 2D visualization: Google Maps Interface

The second visualization tool caters to surface artifacts where only latitude and longitude measurements are available. We developed a user interface based on the Google Maps API (Google 2007), to explore radiocarbon dates from Queensland archaeological sites. The Google Maps API allows developers to embed Google Maps in a web page with JavaScript and to overlay markers, polylines and pop-up windows that display relevant information. All data available in the database are displayed as balloons located by latitude and longitude on Google Maps and all the navigation features available in Google Maps are present in the application as shown in Figure 6.

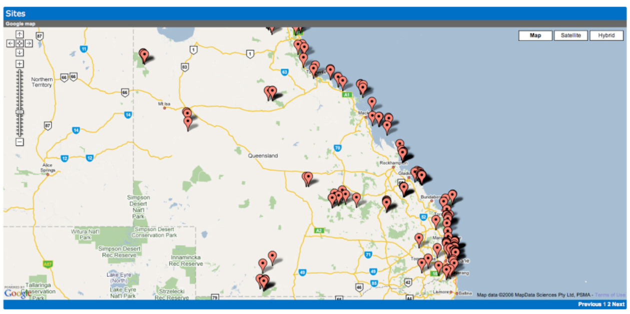

Figure 6: Google Maps user interface, plotting data from Ulm and Reid (2000) The mapping data is provided by and used with permission from MapData Sciences Pty Ltd (www.mapds.com.au).

It is also possible to get further information on a site by clicking on the balloon, for instance in this case a radiocarbon date. Latitude and longitude are displayed at the bottom of the interface. The implementation was straightforward for a programmer and it is possible to display data from two different databases. Incidentally the visualization helped identify several erroneous data points suggesting that the coordinates for these points were incorrect. This illustrates the important role that visual analysis plays in verifying data quality.

6 Discussion

This project has some implications for data capture during a field season and/or data logging. There is no standardized methodology in archaeology for recording data in a digital format. Until recently all recording was done on logbooks and most data are not digital. This could be a problem when working with datasets coming from different archaeologists. We are investigating the use of ArchaeoML for data portability and as a way to provide a standard. We are currently working on a web-interface for data entry to solve this problem: a data logger will not need to be familiar with databases. It appears inevitable that data will be recorded digitally – either in the field, or later in the lab.

Once a ‘data format’ is agreed upon, there are two options for data acquisition. In one case, archaeologists can record their data in the field in a systematic way according to a defined schema. The data could then be ingested into the SRB later, back in the lab at the end of the season. The second option is ‘SRB in the field’: the digital collection, or part of it, could be installed on a laptop along with the SRB as a stand-alone software application and taken into the field. Data entry can then be performed directly into the SRB. The updated collection can be synchronized later and updated into the archival system back in the lab. We will investigate the functionality of these options and how they are suited to archaeology field practice.

Archaeologists welcomed the two visualization tools positively. Google Maps was easy to implement and use for 2D data covering a large area. The fact that many people are now familiar with Google Maps is a definite advantage for its use in archaeology. 3D Arch is simple to use but requires the installation of X3D plug-ins on the client side. The only difficulty with the application lies with the type of web browser, operating system and X3D plug-ins. The application was tested on Windows XP, Mac OS X and Linux. However different browsers and plug-ins are available for each operating system. We found that the best results were obtained under the Windows operating system with the Flux Media plug-in for Firefox and Internet Explorer. Most archaeologists we talked to use Internet Explorer. FreeWRL and Firefox worked well for Mac users: the only problem was when the user clicks on an artifact in the 3D model to get some information: a new window opens and displays this information. These issues led us to include a detection script that tests the type of browser and plug-in. The web browser and plug-in information is then sent to the server when the user clicks on the render button. A layout is selected on the server side, based on a set of rules derived from the browser compatibility testing:

- a split layout with the model view and information view on the same page,
- a full screen view for the 3D model if the artifact information is displayed in a new web page.

Although we had regular meeting with archaeology professionals and students, we still need to test the interface for usability. We have tested 3D Arch with a different data set: the Mill Point data set. In this case the data only have latitude and longitude and no depth coordinates. However it was straightforward to visualize the Mill Point artifacts suggesting that the tool is usable.

7 Conclusion and Future Work

We have created a mini-data grid in our laboratory, with one server and several clients. Authorised users can connect remotely to the SRB server with Scommands or inQ to query, upload and download data. The archaeological data are exported as XML files from the local PostgreSQL database to the SRB server and the metadata are created by the user and stored in the MCAT. Once the MCAT is created, the user can search the archive and retrieve the data. The next step is to integrate two small collections at different geographic locations, and create and test a federated data management environment. We have not tested the usability of the data grid with the archaeologists: the system is currently not user-friendly. The learning curve associated with all the different pieces of middleware and client tools remains a major obstacle. Hence a major effort is required in creating an intuitive and simple interface and writing systematic documentation.

We definitively need a protocol for the organization of archaeology data. We are looking at ArchaeoML to describe archaeological datasets and to use with the SRB. The provision of software tools to manage, analyze and visualize datasets is complementary to the creation of a digital collection. The use of the Google Maps technology provides an efficient way to explore geographical data in real-time at different scales in two-dimensions. The reconstruction tool, although at an early stage, provides a way to visualize data in 3D at a smaller scale that is available in Google Maps. The challenge remains to integrate these two visualization tools with the digital collections indexed by the SRB and the implementation of a user-friendly interface.

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