Development of an Object-Oriented GIS for Maritime Archaeology - Motivation, Implementation and Results

Peter Holt

3H Consulting Ltd.

6 Honcray, Oreston, Plymouth, PL9 7RP, UK

email: pete@3HConsulting.com

Abstract

The current use of Geographic Information Systems (GIS) in maritime archaeology often emphasise their analytical capabilities however another major strength is their ability to integrate and manage large and diverse data sets. A GIS can therefore be used as a tool to aid the recording and preservation of cultural heritage sites by collecting together and presenting site information in an integrated and meaningful way.

This paper describes the creation of a custom GIS with an object-oriented data model designed specifically for use in marine and intertidal archaeology projects. Development to date has concentrated on real-time spatial data collection, decision support, publication and archiving. An example is given showing the use of this GIS during the excavation of the Mary Rose in 2003 by the Mary Rose Trust. This paper identifies some of the benefits of applying an integrated digital data management system to these archaeological projects and identifies areas for further research.

Keywords :Maritime, GIS, database, excavation, recording, Mary Rose, Vliegent Hart

1 Motivation

Digital information management systems to support the full range of archaeological activity from planning through to publication have been discussed since computers were first used in archaeology. This paper describes the development of such a digital information management system, a system called Site Recorder that is now in use on a number of maritime archaeology projects.

The Site Recorder program is the natural extension of a survey processing program developed in 1997 called Site Surveyor. Site Surveyor was developed to fulfil the requirement for software that could process all of the different types of measurements used in marine archaeology. The program was used on a number of projects worldwide and was also used as a research tool for investigating the accuracy of underwater survey methods (Holt 2003).

The excavation of the Dutch East Indiaman *Vliegent Hart* in 2000 provided the stimulus for the development of Site Recorder from its survey program beginnings. The *Vliegent Hart* sank in the North Sea off Holland in 20m of water, in difficult diving conditions with underwater visibility less than 1m (Hildred 2001). The project was undertaken using a large team of archaeologists and divers using commercial diving equipment from a 40m long dive support vessel. The excavation was likely to generate a large amount of data in a short time so an efficient data management system was needed.

The use of a paper recording system was considered as the team had considerable experience in this area; however the volume of data expected suggested that a more efficient digital system be used. There are many benefits to using a digital recording system on an archaeological project and there are further benefits to using a system that is spatially aware. The use of a digital system brings the benefit of data validation, searching, backup, sharing, increased productivity and time savings.

A digital data management system was created for the 2000 excavation that was based on a number of commercial software applications, these included a relational database for finds recording, a CAD program for creating the site plan, a word processor for reports along with tools for survey data processing. Each application was useful in its own right but none of the applications could share data with any others so exchanging data became laborious and prone to errors. Training the team on the use of the many applications was also a problem that was never solved satisfactorily. At the time the data was collected and afterwards during post-processing it became clear that a fully integrated digital data management system was required.

2 Requirements

The intention was to develop a generic integrated information management system for maritime archaeology to support the archaeological director through all phases of a project. The main areas for use were in planning, real time recording in the field, data analysis, dissemination and archiving. There was a requirement to develop a system that could record data from any maritime site - as the development work was to be done for one site it seemed sensible to re-use that work on other sites. This requirement added further complications because the system had to be designed to ‘fit’ the recording strategies of other existing projects.

Previous experience had shown that a fully integrated recording system was the optimum approach. The complete set of information from a site should be recorded in a way that adds value to each item of that data allowing information to be extracted more readily. At that time, accurate and truly three-dimensional data was rare in maritime archaeology so only a 2.5D recording and rendering scheme was required. A 2.5 dimension recording system uses a number of 2D entities to represent 3D objects, whereas a 3D recording system would model 3D objects as solid entities.

The system was to be used by people with a wide range of skills and experience with computers so the system had to be easy to learn and simple to use. Operation of the program would need to be taught to project teams, so along with the program operating manuals, online help and training courses were required.

The system needed to be scalable so it worked equally well on an assessment survey and on a large excavation. The program had to be powerful enough to be useful on a large project but simple enough to be used on a small one.

As well as capturing information about a site it is as important to be able to publish and archive that information. Publishing primary site data has been difficult in the past as many primary records were only on paper. Digital recording of this primary data allows sharing of all of the data about a site but this raises the issue of data security. The desire to allow public access to primary data even before preliminary interpretations is tempered by the need to keep control of intellectual property. Some means of secure publishing and archiving was required.

Part of the publishing requirement was to allow sharing of information with other computer programs. The information would be used as the basis for future publications, museum displays and project planning.

3 Analysis

The first step in the system development process was to determine what information should be recorded. As all excavation recording is a form of sampling it was necessary to determine at what level of detail the recording system should sample the available data – with too little detail the results would be insufficient, with too much detail the system would be unwieldy and difficult to use.

A literature search coupled with discussions with experts was used as a starting point for the metamodel. The first step was to identify the ‘objects’ that the system could record information about and the next was to determine what information would be recorded for each ‘object’. The literature search showed that little information was publicly available about the paper or digital recording systems used by previous maritime projects but enough were available to use as a starting point (Fisher-Abt 2004, Gawronski 1987, Hill 1994, IFA 1995, Martin 2003, Mathers 1990, MOLAS 1994, NAS 1994). No formal specification was found for a standard recording system for maritime archaeology; what was to be created was both new and likely to evolve so an iterative approach was expected. Existing guides to good practice provided advice on data management and highlighted some of the potential pitfalls (ADS 1990, 2000).

Another significant decision was whether to allow the recording model to be customised. Migration or export of archaeological field data from one system to another is a monumental task that is aggravated by peculiar data formats and database schemas (Ravindranathan et al. 2004). Schloen (1999) promotes the idea of a common approach to electronic publication but suggests that a free-form item based data model should be used to overcome the constraints of standards. However, a free-form model complicates migration of archaeological data from one system to another, hampers interoperability, long term preservation and reuse (Raghavan 2005). In theory, a free-form model could create a standard however this would require all parties to understand the reasoning behind the decisions which form each model, which would require all models to be documented in detail. Madsen (2000) suggests abstracting databases to a meta-structure but this merely side-steps the problem of being able to directly compare objects, their attributes and their spatial relationships.

The benefits of a standard *core* recording model outweigh the disadvantages so a fixed recoding schema was adopted. The word *core* is crucial as the schema used by Site Recorder is only a subset of the data that could be recorded but it is a subset that may be shared by other recording systems. Use of a core standard allows the additional data to be recorded that are crucial to research databases yet still allows direct comparisons to be made between objects that are at the heart of intra-site analyses and generic analysis and rendering tools.

4 Implementation

With the metamodel defined the method of implementation could be decided based on the many factors that affected the choice of approach to be used.

The starting point for investigation was Geographic Information Systems (GIS) technology. A GIS can be used as a tool to aid the recording and preservation of cultural heritage sites by collecting together and presenting site information in an integrated and meaningful way. For terrestrial archaeology a number of digital and GIS based systems have been developed (Craig 2003, Doneus *et al.* 2003). For maritime archaeology the current use of GIS often emphasises their analytical capabilities however another major strength is their ability to integrate and manage large and diverse data sets (Croff 2005, Drap 2001).

It was decided at an early stage that the recording system should be Object Oriented (OO), a programming paradigm that uses abstraction to create models based on the real world. The software models objects encapsulating both attributes and behaviour, each object can be viewed as an independent little machine with a distinct role or responsibility (Booch 1990). This allows a more logical and natural design for the system but also allows interaction between objects bringing added value to the recorded data. Being an object-oriented system the requirements for what to record could be defined as a set of objects where each had a specific set of attributes or properties. An object in the recording system would often mirror an object in the real world, for example the system contains ‘artefact’ objects that are used to represent individual artefacts or finds.

At the time the project started the options for development were few; use a commercial GIS, develop a new Web-deployable application or develop a standalone application. The use of a commercial GIS program was considered as the basic functionality of standard GIS can be extended with scripts. Previous experience with these programs showed that they were difficult to learn, scripts were expensive to develop and they were unlikely to be sufficiently flexible whilst still maintaining simplicity. The recording system was intended to be used by non-academic teams with very small budgets so commercial programs were also considered too expensive.

Developing a web-deployable recording system was not an attractive option at that time. The huge amount of development support and free software now available on the Internet means that developing a web-deployable version of Site Recorder would be a more viable proposition.

The decision was made to develop a custom standalone application developed for the Windows platform under C++. Another key decision was how the data itself was to be managed within the application as some form of data management was required to store all of the objects and their associated attribute data. Some of the available options included using a proprietary Relational Database Management System (RDBMS), a proprietary Object Oriented DBMS (OODBMS) or a custom data management system closely coupled with the application.

The use of a relational database was seen as a limitation within an OO application so was discarded. Separation between spatial and attribute data has become seen as the norm when it is actually caused by the historical limitations of both GIS and DBMS (Ryan 1998). The use of an extensible DBMS avoids some of the problems rather than solving them, usually done by extending the range of data types and embedding behaviour. The use of a proprietary OO database was avoided in the early stages of development to reduce complexity, avoid dependencies on third party software, to increase responsiveness and to reduce costs. The analysis also showed that iterative development was expected. A custom OO management system would not have these limitations and it could be adapted to meet new requirements as the system evolved, so Site Recorder uses a custom data management system that handles objects directly.

5 Capability

Site Recorder contains the features expected in any geographic information system plus a number that are specific to recording maritime archaeological data. The main displays presented to the user are a chart that can show the site in plan and elevation (2.5D), lists or tables of objects with their properties and a display for configuring drawing layers (figure 1). The information about a site is stored as a set of objects which can appear both in the tables and optionally on the charts.

The types of objects that can be recorded include:

- Layers, Projects and Sites
- Artefacts (finds)
- Features and Contexts
- Sectors (trenches, areas)
- Survey points and measurements
- Images & video clips
- Image Basemaps (raster orthoimages)
- Drawing frames
- Targets
- Wrecks
- Events, Dive Logs & ROV Logs
- Contacts (people & organisations)
- Samples
- Sources (documents)
- Tasks
- Logbooks
- Points, Polylines, Circles, Text

The objects themselves contain a number of discrete units of information known as properties or attributes. Each object type has a specific set of these properties and they are used to record information about each object. Some properties are recorded as real numbers such as the length of an Artefact, while simple text strings are used for properties like descriptions and notes. Where a property can be one of a discrete set of values the options offered to the user are given in the form of a list or tree where only one of those listed values can be chosen. The contents of the lists are managed as a set of separate wordlists and thesauri which can themselves be edited.

The fixed set of objects, properties and wordlists forms the foundation of the standard recording schema within Site Recorder. The primary method for ensuring standard datasets within Site Recorder files was to disallow the customisation of the object types and object properties used by the system.

Where an object appears on the chart the object itself maintains a record of how it should appear. Some objects are simply shown as a point drawn with a given style and colour. More complicated objects such as Artefacts can be drawn as the object appears on the seabed. The drawing information for an Artefact is kept together with the properties for that artefact allowing a more efficient and integrated use of that data.

Extra information can be obtained from the archaeological data in a number of ways. One of the most useful is in defining associations between archaeological objects - spatial association, by being a part of another object or by containment. These extra clues about the relationship between objects are being used to help understand how sites are formed.

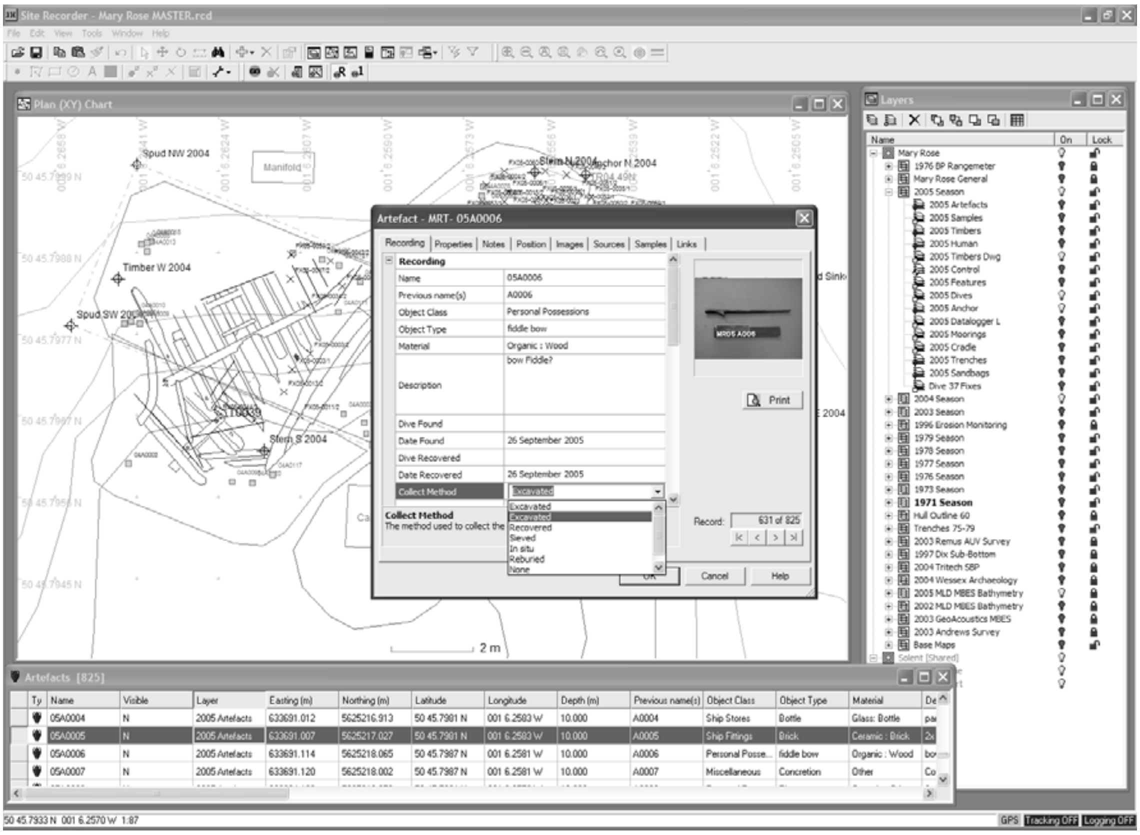

Figure 1: The Site Recorder 4 Displays

Links between objects allow us to locate the information we need in a very efficient way, this is best illustrated by an example. A Dive Log object representing a single dive can have an Image object linked to it which is a scan of the paper dive log containing descriptions and a sketch. The Dive Log can be linked to an Artefact to identify the dive on which that find was recovered. With these links in place it is possible to quickly navigate from the Artefact to the Dive Log to the Image and show the scan, reading the diver's own words and sketches from the time the find was recovered. Many different objects can be linked together within Site Recorder making this a powerful feature that aids productivity.

Site Recorder also includes comprehensive survey processing and geodesy tools that can manage all types of underwater survey measurements. Tools are available for importing and exporting data in a number of standard formats and for merging data from existing files created by Site Recorder.

6 Mary Rose Excavation (2003-2005)

The *Mary Rose* was one of the first ships built during the early years of the reign of King Henry VIII, probably in Portsmouth. She served as Flagship during Henry's First French War and was substantially refitted and rebuilt during her 36 year long life. The *Mary Rose* sank in 1545 whilst defending Portsmouth from the largest invasion fleet ever known, estimated at between 30,000 and 50,000 individuals and between 150 and 200 vessels. This number is nearly twice the number estimated within the fleet of 1588, latterly known as the Spanish Armada. At this time she was the second largest and most heavily armed vessel within the fleet; she carried 91 guns deployed over three decks, her main gun deck carried fourteen large guns including two cannons which fired 64lb cast iron shot. The *Mary Rose* marks a transition between the use of a vessel to support guns and a vessel built to carry large guns close to the waterline, her structure is undocumented in historical sources and there are no shipwright's plans. This vessel is an extremely important vessel to study in order to understand the evolution of the fighting ship (Rule 1982).

In 1967 Alexander McKee found the *Mary Rose* as part of the Project Solent Ships. Excavation work between 1979 and 1982 took 28000 dives and 12 man years on the bottom but culminated in the recovery of a large part of the starboard side of the hull. Threats to the site from dredging work prompted a new phase of fieldwork in 2003 to 2005 that aimed to clear the seabed of all remaining material and to investigate what remained of the ship's bow. Site Recorder was chosen to be used as the data management system and was used in all phases of the work.

During the planning phase the program was used to establish the most likely location for the recovered hull timbers on the seabed as no survey control points remained from the 1982 excavation. Site Recorder was also used to collect together data from a number of geophysical surveys using sidescan sonar, multibeam echo sounders, magnetometers and sub-bottom profilers. By correlating the different data sets with the existing wide-area site plan it was possible to identify some of the targets, to plan investigative dives and to correct for positioning errors in some of the earlier data.

During the excavation itself Site Recorder was used for real time data collection and as a decision support tool. The divers doing the excavation work were using surface supplied diving equipment fitted with helmet cameras, lights and voice communications. The divers could also use a Sonardyne Pharos underwater Acoustic Positioning System (APS) to position finds and structure on the seabed (Holt 2004). A crawler excavation ROV was used in 2003 and this was also fitted with the same positioning system. The APS fed position information directly to Site Recorder so the position of the diver or ROV could be seen on the site plan. Finds and structure could then be added to the GIS in real time, positioned by the APS and including details and descriptions given by the diver. The integration of all the sources of information helped ensure that a complete and accurate record was captured in real time in an efficient manner. The archaeologists on the vessel could see the site plan as it developed and could use the information from the GIS to aid decision making and planning further work.

Site Recorder is now being used for analysis of the excavation data and for integration with existing data from previous excavation work. The 2003 excavation of the bow section of the *Mary Rose* produced unexpected results which give clues to how this part of the site was formed. Having collated all of the available information within Site Recorder it has been possible to correlate documentary evidence of salvage work at the time of her sinking with the archaeological record.

Using the GIS it is possible to show the site at different stages in its development giving an idea of how the site evolved once it was found. Further work will involve using Site Recorder for investigation of site formation processes.

7 Results

7.1 Project Aims

The success of Site Recorder in the field has meant that it could be made commercially available by 3H Consulting Ltd with the release of the first GIS version in November 2004. The majority of the project's aims were fulfilled with the release of Site Recorder version 4 in November 2006, so this version is considered to be the first fully-featured application. To date the program had been used on a number of large-scale excavations and survey projects on many sites and is in use by universities, institutions and private individuals in 18 countries.

In 2006, Site Recorder was adopted by the Nautical Archaeology Society for use in their training programmes. To support the training work a limited capability version of the program was created called Site Recorder SE. This program supports all of the survey measurement processing capability of the full version but can be distributed at no cost.

7.2 Publication

The ability to disseminate primary data captured using Site Recorder was a high priority requirement. This has been made possible by the development of a program that can read and display Site Recorder files called Site Reader. The reader program is free and can be distributed along with your site data files on DVD or on the Web.

The level of detail chosen for publication can be varied to suit the publication medium and target audience. The true benefit of this approach can be seen by publishing all the primary data including all the photographs, dive logs, rough drawings and initial interpretations. However, files intended to be downloaded from the Web often need to be smaller so may have the linked images removed or reproduced at a low resolution. Only part of the available data may be published for simplicity or as an interim step.

During development the issue of data security was raised. Although unrestricted use of site data is recommended there are occasions when it is preferable to allow the data to be viewed but not modified, printed or exported for further processing. To this end, tools were added to Site Recorder to optionally disable editing, printing, exporting and screen capture within files that were to be published.

7.3 The Recording Schema

The recording schema and metamodel have been proven to be fit for purpose for project work completed to date. However, further use of the system by other project teams is likely to highlight errors and omissions that will need to be addressed. The current schema could be used as the basis for the development of a generic core recording schema that would simplify data sharing and the creation of generic rendering and analysis tools. The schema itself is an open design and its structure has been published (Holt 2007) with the intention that it can be re-used.

8 Future Development

The program is still used as a platform for research and development, usually driven by the requirements of a project undertaken by one of the community of users.

8.1 Usability

Usability was a high-priority in the original requirements for the system as the intended users were not all computer experts. The usefulness of the system can be improved by reducing the complexity of some tasks whilst still retaining their capability.

8.2 Data Exchange

Site Recorder has been designed as a tool for helping capture archaeological data. Once captured, the data can then be exported in a number of formats but new formats are being developed all the time so this will be an area of constant development.

8.3 Multi-user Capability

Work on large-scale projects showed that there was a requirement to support multiple users accessing the same data over a network. This capability has been implemented and will be included in a subsequent release of Site Recorder.

8.4 3D objects and 3D rendering

The use of 3D has been proposed as an aid to interpretation (Nebiker *et al.* 2005, Zlatanova *et al.* 2002) so adding 3D extensions to Site Recorder are being considered.

8.5 Temporal GIS

As archaeological recording is concerned with both place and time an appealing development would be to extend the temporal aspects of the program to implement a fully temporal or 4D GIS (Ryan 1998, Wachowicz 1999). This capability would allow the site to be shown as it was at any stage in the life of the site ultimately leading to the creation of short video clips showing how the site evolved.

8.6 Recording Standards

Standards that relate to recording archaeological data are continuously evolving, especially when dealing with metadata, controlled vocabularies and the exchange of data itself. Standardised recording is crucial in this case as it is the key to enabling data reuse and cross-project analysis. Part of the development process includes the evaluation and adoption of the most applicable standards to ensure that the data collected using the program has the widest possible use.

9 References

ARCHAEOLOGY DATA SERVICE, (1990), *GIS Guide to Good Practice*, Oxford: Oxbow Books, ISBN 1 900188 69 4

ARCHAEOLOGY DATA SERVICE, (2000), *Digital Archives from Excavation and Fieldwork: a Guide to Good Practice*, Oxford: Oxbow Books, ISBN 1 900188 73 2

BOOCH, G., (1990) *Object-Oriented Analysis and Design with Applications*. Addison-Wesley. ISBN 0-8053-5340-2

CRAIG, N. & ALDENDERFER M., (2003) Preliminary stages in the development of a real-time digital data recording system for archaeological excavation using ArcView GIS 3.1. *ESRI Journal of GIS in Archaeology Volume 1*

CROFF, K., (2005) GIS and Underwater Archaeology [online], Available from: www.edc.uri.edu/nrs/classes/NRS409/509_2005/Croff.pdf [Accessed Dec 2006]

DONEUS, M., et al (2003) Digital Recording of Stratigraphic Excavations. *The CIPA International Archives for Documentation of Cultural Heritage*, volume. XIX, 451-456.

DRAP, P., LONG L., (2001) Towards a digital excavation data management system: the "Grand Ribaud F" Estruscan deep-water wreck. *Proceedings of the 2001 Conference on Virtual Reality, Archaeology, and Cultural Heritage*

FISHER-ABT, T., (2004) Mel Fischer Research Database, pers. comm.

GAWRONSKI, J., (1987) *Amsterdam Project Annual Report*, Amsterdam, ISBN 90 7169002 4

HILDRED, A. (ed.), (2001) *VOC Anniversary Shipwreck Project Report 2000*

HILL, R., (1994) A Dynamic Context Recording and Modelling System for Archaeology, *International Journal of Nautical Archaeology* 23,2: 141-145

HOLT, P., (2003) An assessment of quality in underwater archaeological surveys using tape measurements, *International Journal of Nautical Archaeology* 32.2

HOLT, P., (2004) The Application of the Fusion Positioning System to Marine Archaeology, in *Congress on The Application of Recent Advances in Underwater Detection and Survey Techniques to Underwater Archaeology*

HOLT, P., (2007) The Site Recorder Database Schema [online], Available from: http://www.3hConsulting.com/Research/research_schema.htm [Accessed Dec 06]

INSTITUTE OF FIELD ARCHAEOLOGISTS, (1995) Standards and Guidance for Archaeological Excavation [online], Available from: http://www.archaeologists.net/modules/icontent/inPages/docs/codes/exc2.pdf [Accessed Dec 06]

MADSEN, T., (2000) Transforming Diversity into Uniformity – Experiments with Meta-structures for Database Recording, *Proceedings of the 28th CAA conference held at Ljubljana, Slovenia*, 18-21 April 2000

MARTIN, C., (2003) Duart Point Shipwreck Excavation 2003, pers. comm.

MATHERS, W. (ed), (1990) *Archaeological Report - The Recovery of the Manila Galleon Nuestra Señora de la Concepción*

MUSEUM OF LONDON ARCHAEOLOGY SERVICE (MOLAS), (1994) *Archaeological Site Manual*, London, ISBN 0 904818 40 3

NAUTICAL ARCHAEOLOGY SOCIETY, (1994) Notes from the Finds Handling Workshop

NEBIKER, S. & WUST, T., (2005) 3D GIS concepts and technologies supporting the integrated management of large and complex cultural heritage sites. *International Workshop on Recording, Modeling, and Visualisation of Cultural Heritage*

RAGHAVAN, A., et al, (2005) Incremental, semi-automatic, mapping-based integration of heterogeneous collections into archaeological digital libraries: Megiddo case study, in the *Proceedings of the 9th European Conference on Research and Advanced Technology for Digital Libraries (ECDL)*, Vienna, Austria, Nabonidus.org

RAVINDRANATHAN, U., et al, (2004) ETANA-DL: Managing Complex Information Applications - An Archaeology Digital Library. *IEEE Joint Conference on Digital Libraries (JCDL 2004)*, June 7-11, 2004, Tucson, AZ.

RULE, M., (1982) *The Mary Rose – The Excavation and Raising of Henry VIII's Flagship*, ISBN 0 85177 255 2

RYAN, N., [n.d.] Managing Complexity: Archaeological Information Systems past, present and Future [online]. Available from http://www.cs.kent.ac.uk/people/staff/nsr/arch/baas.html [Accessed Dec 06]

RYAN, N., (1998) FieldNote Desktop: an Experimental Spatio-Temporal Information System, *Proc. 4th Int. Colloquium on Computing and Archaeology*, Bilbao

SCHLOEN, D., (1999) Archaeological Data Models and Electronic Publication on the World Wide Web, *The Oriental Institute News and Notes*, No. 160, Winter 1999

ZLATANOYA, S., et al, (2002) 3D GIS: Current Status and Perspectives, ISPRS, IGU, CIG - *Joint International Symposium on Geospatial Theory, Processing and Applications*, Ottawa, Canada

WACHOWICZ, M., (1999) *Object Oriented Design for Temporal GIS*, London: Taylor & Francis, ISBN 0-7484-0831-2