An Evolutionary Approach to Digital Recording and Information about Heritage Sites

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Abstract

This paper considers 3 cases undertaken by a team at the University of the West of England (FBE/UWE) - the Tower of London Computer Models and more recent linked European Historic Gardens on the Web. The team is continuing to investigate uses of spatial information systems to store, manage and visualise records of historic sites, enabling interactive off-site access to interpretative information. Existing records, often accrued in an ad-hoc manner, are mostly inadequate for such use and incomplete without external contextual reference to the physical heritage site for complete understanding. They are in this respect 'uncoordinated', lacking independent coherence. By contrast explicit integrated codification of similar digital data is necessary for stand-alone remote access. Such use necessarily starts with accumulation of an archive of data but ought to proceed to being able to answer locational questions such as 'where' and 'when' and ultimately to the support of strategic analysis and 'what-if' speculation.

While buildings are relatively slow to change and decay, so past records and now computer modeled analogues stay valid in the long term, yet their contexts, settings, gardens and grounds are open to rapid change. Effective recording of potentially rapid change is highly resource intensive, justifying exploration of automated data capture, usually satellite imaging at the macro, and remote controlled video at the micro levels. Yet automated capture creates additional problems for record management, storage and retrieval in which few heritage organisations have achieved maturity. Experts often cannot obtain the precise interpretation from a photo that they can make in person on site, so melding such interpreted information with rapidly changing imagery is also an issue discussed in this paper.

Categories and subject descriptors: H.5.1[Multimedia Information Systems];I.3.7[Three-dimensional Graphics and Realism];I.4.8[Scene Analysis];J.5[Architecture].

Additional Keywords and Phrases: Spatial Information System, GIS, VRML, Augmented Reality, Real-time video.

1 Introduction

This paper appraises use of spatial computer information system based three-dimensional modelling to store, manage and visualise records of historic sites. The paper is based upon research and development carried out by a team at the University of the West of England (FBE/UWE) in building such analogue models over a period of years. Several evolutionary cases are described from the 1996 and later Tower of London Environs Models, to Hortonet, and the most recent Valhalla project, just commencing. It argues that spatial digital information forms a new medium best deployed in new forms and not simply in replicating previous approaches to recording heritage sites. The information recorded is inherently simplified in an interpretative process. Among major new roles are remote capture and interactive off-site access to interpretative information. Existing records are mostly inadequate for such use since they are often accrued in an ad-hoc manner, and are incomplete without external contextual reference to the physical heritage site to complete understanding. In this sense they are 'uncoordinated' and tend to lack stand-alone off-site coherence. By contrast explicit classification and codification of similar digital data is necessary for stand-alone remote access. This coherent integration of simplified records of a real place creates a model - however abstract.

Such use necessarily starts with acquisition of an archive of data but ought to proceed to being able to answer locational questions such as 'where' and 'when' and ultimately to the support of strategic analysis and 'what-if' speculation. It is argued that data has to be recorded appropriately to support these longer-term applications.

While buildings are relatively slow to change and decay, so past records and now computer modeled analogues stay valid in the long term, yet their contexts, settings, gardens and grounds are open to rapid change. The capture and display of fleeting diurnal and seasonal change is a particular challenge. Effective recording of potentially rapid change is highly resource intensive, justifying exploration of automated data capture, usually satellite imaging at the macro, and remote controlled video at the micro levels. Yet automated capture creates additional problems for record management, storage and retrieval in which few heritage organisations have achieved maturity. Experts often cannot obtain the precise interpretation from a photo that they can make on site, so melding such information with rapidly changing imagery is also an issue discussed in this paper

2 Recording and Interpretation

Recording and interpretation are held to be integral parts of the process of achieving sustainable conservation by determining significance (and establishing environmental capital). So creating a record of the built cultural heritage is part of that process of establishing its significance. The maintenance and development of an accurate record underpins the effective management care and protection of the built cultural heritage, from defect analysis to visitor management. Within these processes computer modelling may add value and consistency through its capacity for support of multiple relevant uses (models) based upon appropriate selections from the same set of data. This data may either have been accrued or have been recorded in a single exercise.

Facts are recorded about historic buildings and their environs. The act of recording often assists the expert to interpret the facts to create information. (Yet survey companies are now increasingly used to measure and record which defers and constrains this creative contact.) This process has been defined as primary interpretation. Primary interpretation is defined as that of the conservator or archaeologist, the professionals' view, in order to reconstruct either hypothetically in the mind, (or through drawings or models,) or in actuality. Secondary interpretation is defined as for the edification or education of the public.[1] *Edification* may be termed sound-bites to capture the fleeting interest of casual visitors, whereas *education* has been defined as a greater depth of conservation education. Similarly for film Peters argued that the camera is the user's viewpoint, it only becomes 'significative' when it is shown to explain information to others.[2] There is also a correlation between this sequence in interpretation, from data through understanding to explanation, in the path of development of information systems from the acquisition of facts, then ordering them into information, and finally imparting the resulting knowledge to others.[3]

The first objective of a survey should be " to record what is necessary in order to understand and illustrate the history of a building, its plan, structure, development, use and decoration." The ICOMOS guidance also says that "The record of a building should be seen as cumulative with each stage adding both to the comprehensiveness of the record and the comprehension of the building that the record makes possible." [4]

We have argued previously that heritage site records are a mixture of description and interpretation and that recording is not a 'one-off' event but a continuous process that is a prerequisite of many conservation management activities. 'Decisions on how and what to record will involve varying measures of subjective judgement of the relative values embodied in, or represented by, the heritage site. However it is also clear that the process used to communicate or disseminate the analytical record may in itself influence the interpretation of the site and therefore the understanding of its significance.'[5]

Interpretation is also clearly an essential key element in enhancing public understanding, appreciation and engagement in determining the values represented by the built cultural heritage; i.e. to help to educate visitors 'not so much about their history, but in how to explore, interpret and respect' heritage sites.[6] Our experience has found that visual presentations can be comprehended more easily by "lay people"; and hence that information which tends towards photo-realism is potentially more open than the 'closed' language of conventions deployed in professional drawings, which can obscure their meaning to those lacking in training. The task of computer-modelling, in the sense of creation of an analogue of a real site or building, may also assist by revealing flaws in or the incompleteness of records, and thereby challenge habitual working practices and procedures.[5]

3 Interpretation & Accessible Analogues

Binks et al state that for non-specialist visitors to Museums and Galleries, the aim is to give them an overall picture, to explain what is happening, what is being revealed, and what its significance is. For repeat visitors it is necessary to also explain what has changed since the last visit. They add that the interpretation will need to be presented at a variety of depths. They suggest that themes and stories presented in a logical sequence relating to route from the human angle, which are participatory, which explain the detective story, effectively provide living history for the visitor.[7]

Other research has also shown that animated and interactive exhibits are more valuable than static presentations. 'Above-expected interest was shown in the dynamic, animated, or changing presentations represented by movies, changing lighting, and audio sequences.... all the sequences with less-than-expected interest involved flatwork, suggesting a greater preference for three-dimensional presentations'.[8] Sharpe uses this research to argue that an interpretative audience prefers those interpretative media that are most closely associated with entertainment, and that the dichotomy of education and entertainment parallels that of inertness and animation. He also records that participation increases retention and that multimedia is necessary to cater for a variety of levels of information. Visitors in fact are discouraged by reading while looking at objects and prefer an audio commentary.[9]

The HMSO guide adds that the medium chosen to communicate the message should avoid dominance of any other media used, gain visitor interest and establish rapport. They also endorse interactive participation as particularly important for younger children and advocate self-paced material that enables an appropriate pace for the casual visitor. They define the task as helping visitors to 'imagine accurately' while producing a conservationist response. They infer that the chosen approach should obtain feedback by testing the recall of the visitor and that a conservationist response is produced.[10]

Off-site interpretation is not suggested as an alternative to first hand experience, but may be the only substitute. While firsthand experience of parts of heritage sites is possible for many visitors there are additional problems of access for the disabled and the elderly. Howell argued that if we considered people in our profile who have perceptual problems then an analogue within the CAD system can be used, with careful consideration, to present that part of the building which cannot otherwise be perceived. 'I have to say that a description of a cathedral by, say, Willis or le Duc is often a brilliant analogue. It is almost inevitable that words will have to accompany the visualisations and auralisations... the words... could be transcribed into signing alongside a picture or subtitles provided for the deaf or hard of hearing.'[11] The National Trust for example owns over 900 properties. They define their properties as fragile and beautiful and at the same time physically and historically complex. This is described as often making them hard for visitors to understand and rendering much of the information about them difficult to access. Archives and libraries at the properties are generally not available to the public because they are so fragile. They have sought various means using multimedia and visitor centres to both overcome these barriers to access and to convey a clear overview and sense of context to the visitor. Yet, as the HMSO guide puts it, "Off-site interpretation may or may not succeed in arousing in its audience a wish to conserve an area but it will almost certainly arouse a desire to go and see it".[10] If it is inaccessible modelling or remote-video may be the only available forms in which this desire can be met, and with the advent of the Web the potential audience for such engagement has become world-wide.

These arguments were posed before the impact of the Web and new media on widespread remote interactive access to virtually real environments. It is currently easier to encapsulate 'virtually-real' images with audio and associated information off-site than to locate the physical on-site object on which a visitor has focused and deliver audio commentary alone. This latter requires an affordable application of the eye tracking developed for Head-up Display in conjunction with accurate location identification. A team at UWE has been exploring these issues in controlled conditions within the newly developed Science World experience at Bristol. Given the technology however it is argued here that the spatial referencing and metadata issues are the same and that it takes longer to acquire and structure sufficient data than for advances in computing and visualisation technology to be realised.

5 Tasks which might be supported by a Digital 'Model' or Information System

It is necessary to distinguish between those conservation tasks that relate directly to preservation of the fabric and those that an off-site medium might support. It is also necessary to determine when photographic images will serve and when (for reasons of access or concealment or later rebuilding) only a model will do. Arguably now VRML (the ISO standard for 3D modelling on the Web) could be used to amalgamate video and modelling into one seamless medium. Finch classifies seven cases of increasing intervention in heritage sites. [12] Preservation is the first, which may only involve restraint rather than direct action. The second, Restoration, restores a previous condition. The third, Conservation and Consolidation, involves using new materials and tools, whereas the fourth, Reconstitution, consists of partial rebuilding using traditional materials and skills. The fifth is Adaptive Reuse, such as placing a new roof on a ruin in order to use it in a way that it was not used originally. In the five cases above the significant elements remain. Thus a digital model could serve as both an adjunct, in the same sense as a visitor centre acts in a preparatory or briefing role, and also as one interface to the process of maintaining, accessing and making sense of records relating to the site.

Case six consists of Reconstruction, of vanished buildings by creation of a surrogate in the original context. One should note however that the converse is almost more likely, that the context has vanished or changed while the principal building remains detached from its intended setting. MOLAS used 3D CAD to understand and extrapolate from the excavated data of portions of sites such as London's Roman Amphitheatre, to model their interpretations of the form of the complete original structure, thereby recreating buildings and settings that no longer exist.[16] While Virtual Reality (VR) may be used to immerse users interactively in the setting provided by the model the context and the surrogate would both need to be modelled. Research into Augmented Reality (AR) has shown that it is possible to blend (fairly seamlessly) digital imaging taken from the real site and the surrogate produced by computer modelling to deliver an interactive and even immersive experience.[13]

Case seven is that of Replication, the creation of a duplicate, which coexists with the original, often due to the fragility of the original. In both reconstruction and replication a model is built, which may or may not be full size and as fully detailed as the original, depending on the need. With accelerating use, the Web is increasingly being used for narrative using a mix of media, for interaction, for testing recall, for monitoring user reactions and providing a context sensitive response. Now that Virtual Reality (VR) is increasingly technically possible in shared community use on the Web it is worth considering a digital alternative to a physical model, which can also serve the information needs defined above. At Lascaux the original cave system was first modelled in the form of Lascaux II to provide public access to a facsimile nearby since the original was too fragile to meet demand. However it has since been scanned and recreated as a VR version. Improvements in network bandwidth and computer technology are still to come before such a complex interactive experience could be broadly accessible at a satisfactory resolution on the Web, but this may not be far off. The same hindrances currently impede the satisfactory broadcast of other major models.

6 Computer Modelled Analogues of World Cultural Heritage Sites such as the Tower

Figure 1 - View from the Tower of London Computer Models

In the UK three-dimensional (3D) computer models of World Cultural Heritage Sites such as Bath, and the Edinburgh Old and New Towns, were developed following the advent of 3D computer aided design tools, with an initial goal of more effectively assessing the visual impact of development proposals. Yet the developers of the Edinburgh model also recognised the potential to link the graphic representation of each building with a database containing relevant historic data and records. [14]

The organisation 'Historic Royal Palaces' (HRP) is responsible for the care of The Tower of London, Hampton Court Palace, and 3 other royal palaces. HRP explored with FBE/UWE the added value contributed by Spatial Information Systems (GIS) to computer drawings for managing heritage sites during 1996, focusing on Hampton Court Palace. (In a 'GIS' - Geographic/ Spatial Information System - spatially located data is deployed in a database, analysed using special spatial tools as well as general database tools, and the results displayed in a variety of views, which may include conventional reports or drawings, graphical representations and more recently Web Pages or even 3D models and Virtual Reality (VR)).[15] GIS is used here as a generic term to cover the broad range of spatial information systems that are coming into use, whether specialised such as those used in archaeology or generalist such as those in environmental planning.

As part of a bid for heritage lottery funds, HRP in conjunction with allied organisations formed the Tower Environs Partnership in 1996, who commissioned FBE/UWE to build an accurate photo-realistic 3D computer model of the environs of the Tower of London. The Tower of London is a scheduled ancient monument and a world heritage site that contains within its curtilage a number of listed buildings. The lottery bid planned to improve the environment around the Tower (the Tower Environs Scheme). The model became an integral part of the development planning of the scheme and was used as a component of its marketing and presentation. In this way the model justified its research and development costs. These costs were high, although substantially less than those of comparable physical models created by specialist architectural model makers. Following on from the previous investigation of the role of GIS, an additional goal was to justify the continuing development and use of the model as a record by spreading the cost and resources incurred across a broad range of related applications. The identification and testing of appropriate applications has guided the research of the FBE/UWE team since.

Some Current Uses of Data at the Tower of London

In 1997 there was a substantial amount of information held by HRP and other agencies about the Tower of London in addition to that which could be derived from first hand experience. This data was held in either archives or databases. Most of this data served primary interpretation. Secondary interpretation in the sense of conservation education included some documentary record of the process of primary interpretative use, to illustrate case studies or act as a detective story. Secondary interpretation in the sense of edification involved simplifying and reworking the above material to bring out and highlight specific moments that excite the attention. Much of this information would have been more accessible if it was held in digital form and manipulable through a common easy to use interface. The Museum of London Archaeological Service (MOLAS) for example used a spatial database to hold a stratigraphic model of finds, to look for patterns and discover whether they vary over space and time, for instance to identify when finds from a notably earlier era are in a later deposit.[16]

Four major functions were described as using information about the Tower, those of Curatorial Artifacts, Project Specific, Building Works, and Historical Authenticity. For Curatorial Artifacts the primary need was to hold a record of each artifact for security, and when on loan to manage insurance cover in addition, however it was also used for research and for identifying needs and then instigating curatorial projects. The Project Specific role was to be able to define the historical development of buildings prior to undertaking any work, the potential for archeological investigation and the need for preliminary investigation. There was also a need to define what was in fact preserved and to provide interpretation to the general public, yet most research was typewritten not digital. The Building Works role was to maintain a property history, to inform the process of building work, and to assist in planned maintenance. While the set piece and Staterooms were seen as largely unchanging, there was continual demand for alteration and modification within the ancillary accommodation to meet changes in use and accepted standards. Such accommodation includes offices, apartments, and the approximately 155 Casemates at the Tower. The Historical Authenticity need was to be able to review change over time, mostly based on old prints and photographs. Old accounts for example served to ensure historical accuracy in defining the scope of restoration of the Privy Garden by identifying the number of daffodil bulbs ordered.

Most of the above needs can be defined as professional, and by definition professionals can be expected to invest sufficient time to gain an in-depth understanding. Meeting the fleeting needs of the casual visitor might therefore be seen as more demanding. Yet solutions which ease access for the non-specialists may also be used to reduce the barriers faced by professionals in their use of IT. Part of the research by FBE./UWE has been to determine the extent to which a unified digital archive of information can meet these various needs.

6.1 Translating Existing Records into Spatial Information

Modelling led to a detailed study of the available records describing the form and fabric of the Tower of London. At the time of commissioning the Tower Models there was an assumption that adequate records already existed and were available. This use had not been envisaged when the information was acquired. In the event problems were encountered with virtually all aspects of the available data and the manner in which it was recorded.
For example:

- Existing record drawings did not record all areas;
- Some new surveys using new techniques (inspired by the problems of reconstruction following the disastrous Hampton Court fire) were in hand but incomplete;
- The origins of the survey reference system were changed part-way through to accord with the UK National Grid;
- Much time was spent disentangling base data from conventional representations because base data itself was not stored in a digitally retrievable and usable form;
- If available, digital base data could have been better adapted to the new purpose than the conventional graphical representations interpreted by survey professionals from that data;
- Complete sets of elevational and aerial photographs were required to supplement and enhance the available information;
- Newly commissioned bespoke surveys and commercial data proved more resource effective in providing data in immediately usable 3D digital form than painstaking re-interpretation from 2D digital survey drawings;
- Integrating and amalgamating data from these diverse sources into a coherent model risked inaccuracy;
- The extensive interpretation involved severed the desirable auditable link between 3D model and the data on which it was based.

The surveys were based upon 3D data but supplied in 2D form, in the expectation that they would primarily be used to print paper sheets. It was possible to write computer routines to re-create some of the 3D data from the drawings but other data could only be painstakingly interpreted by 'reading' the drawings in the knowledge of the conventions used. As a trial re-survey of part of the site proved, the digital information could be provided in 3D form from the Total Station survey so that neither computer nor operator reinterpretation was required. It was stated that an entirely new specification for the survey work for the Tower had to be formulated to ensure that the several major survey firms, which shared the commission, achieved equal accuracy and reliability. The trial re-survey showed that a further entirely different specification was required to both provide traditional drawing sheets and enable use for a computer based model or spatial information system.

Other digital data available did not relate usefully in scale, coverage or standards to the new surveys, without extensive re-interpretation and visual correlation. For example, the 1970's Department of the Environment site surveys had been digitised and was immediately available, including terrain heights. Part however recorded buildings at roof level and part inconsistently as a horizontal section at ground level. This survey was later extended to include nearby buildings and the swathe of landscape between. Ordnance Survey digital mapping was available beyond this perimeter but at a different scale and using a different reference system. New digital building surveys of plans and sections, but not elevations, had been commissioned, which arrived in batches of 2D digital equivalents of paper sheets with title blocks. For safety reasons and because of problems of access the roof plans were incomplete and occasionally inaccurate.

Photogrammetric records were later created of the external curtain walls and towers and some internal buildings, but the stereo pair images were not available and the 3D polylinear delineation of salient features supplied was not re-usable in modelling, whereas polygonal delineation would have been. A digital aerial photographic set of London was commercially available with polylinear photogrammetry, but without access to the base stereo pair images. Similarly that photogrammetry itself was almost unusable except for deriving spot heights. Modelling staff had to rapidly undertake a digital photographic elevational survey that produced a mosaic of hundreds of images to blend together.

6.3 Some Consequences

Although the above is an account of some specific problems we encountered with the Tower, it is considered possible to draw on that experience to make some more generalised observations that may apply to other sites. Access is often limited to the visible and safe to reach. Record techniques that rely solely on such access at one point in time tend to be incomplete without other forms of data. (As previously discussed recording is a continuous process.) Remote imagery including photographs and earlier 'historic' records are likely to form part of, and require accurate location and integration into, the overall record. Consequently different types of data will require to be amalgamated in the sense of integrated multi-media to provide a coherent record.[5]

It is critical to establish from the start, and stick to, a clearly defined and usable three-dimensional reference system for the site. This does not need to be based on a national grid but ought to readily transpose to it. It is probable that existing surveys and record drawings produced to serve earlier requirements will not suffice. The data on which such surveys are based is now capable of computer logging. If this base data is held and referenced to any subsequent drawn interpretations it can be revisited to serve future requirements without expensive resurvey. Survey drawings per se include technical draughting conventions capable of being read by those with expertise but not interpreted automatically by computer. Retention of the base data permits computer manipulation and interpretation. Computer Aided Drafting (CAD) systems are still often used by those inputting data to merely output drawings for use on screen or on paper. While this eases the transition from use of drawing board to use of computer it does little to take advantage of the new medium.[5]

FBE/UWE continues to be interested in developing this potential for wider use of such models of historic sites by considering the interactive and complementary nature of a number of key activities related to the management of historic building and sites. Particular activities under investigation are:

Recording Historic Buildings;
Visitor Interpretation and Orientation;
Visitor Management;
Handling Management Information;

Subsequent research at FBE/UWE has sought to evaluate whether or not a computer model might improve efficiency and effectiveness in these areas individually and/or in combination. It is considered that, outside of the particular circumstances of the HRP (or similar) bids, continuing tangible benefits would have to be realised in one or several of the previously referred to integrative uses, in order to make the creation and continued maintenance of an accurate model cost effective.

It was argued at that time that an highly abstract model, such as that held within a GIS but not explicitly three-dimensional, might in the future be used to augment reality by superimposing or projecting hidden information onto the visible fabric of a building or structure. (This amalgam of model and [real-time video-based] reality is now a basis for the current Valhalla case discussed later.) It was clear that an accurate three-dimensional spatial reference system would still be required to enable the broadcast computer data to be mapped onto the physical fabric. Hence recording digital data without its accurate spatial location was perceived as likely to offer no more than short-term benefits. This tends to confirm that in future, while computer models may range from the photo-realistic to interactive virtual reality, or even be highly abstract, the issues about underlying data, its capture and the accuracy with which it is located are likely to be the same.

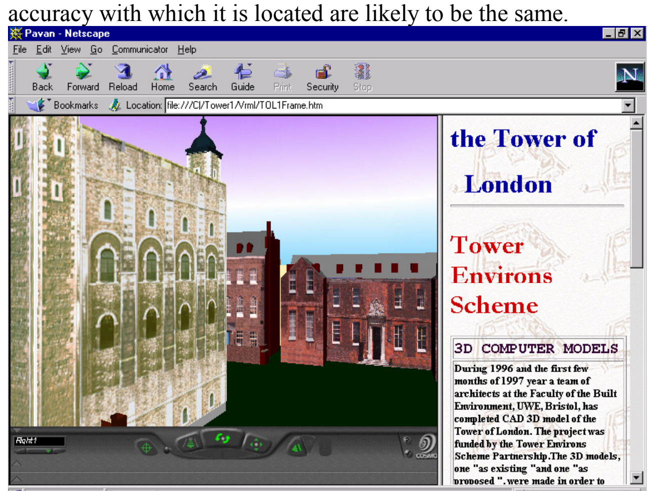


Figure 2 - View of the Web based VRML Tower Model

In the continuing investigation the team at FBE/UWE have been using proprietary software (Pavan), written within the commercially available Mapinfo GIS environment, to enter spatial data about buildings, sites and landscape into the GIS and as one output use Pavan to generate a 3D interactive VRML model. The source data for the Tower of London Models has been reused to create an interactive Browser based virtual reality version with associated hyperlinked information at various levels of overlaid detail. Changes can be swiftly made to the model or hyperlinks or events added, and the whole regenerated in VRML within at most two or three minutes, on a conventional PC. This has confirmed that using such database driven approaches can significantly reduce the cost of built environment 3D modelling and the maintenance burden of keeping such models in synch with the changing physical environment.

7 Remote Sensing and Data Capture

Traditional photography is however now being superseded by other remote imaging techniques. There is now an increasing range of possible new means of datacapture from photogrammetry to 3D laser scanning and satellite images. Therefore it is increasingly necessary to analyse needs, including requisite and long-term accuracy, and to identify the most effective and appropriate means of acquiring data and recycling it in current and future interpretation. There is little discussion of this issue in conservation literature on recording and an implicit assumption that drawing and photography are still the primary means of recording the analysis, despite the advent of computing and communications technology. Where computers have been engaged in aiding this process, their use still mainly comprises the direct transfer of paper based conventions into what is in fact an entirely new medium. Ashton stated in 1995 that "in the context of historic buildings it is the lack of regular geometry that has negated the initial impact of CAD systems" and ascribed this to the lack of direct capture of the relevant digital data.[17] In this respect it may still be said that little has changed.

The latest computer-aided-drafting (CAD) (and GIS) systems offer the ability to hold drawings as an overlay onto rectified base photographic data, thus maintaining the textural and luminance cues in the base data with the subsequent (possibly photogrammetrically based) drawing. Other software is available which moves the facility for photogrammetric interpretation from the point of data capture by specialists to the individual end user. Provided a sequence of photographs overlap sufficiently to contain some identical features an end-user may digitise from them to take accurate measurements or even build a three-dimensional model including terrain to the extent of small hills. Digital photographs also correlate closely to satellite images. In the discipline of remote sensing of the earth, analysis of satellite data has been highly automated in order to detect both similarities and change. Parts of the spectrum are exaggerated or enhanced by false colour. The GIS based spatial analysis system can then be 'schooled' by painstaking interpretation of one area to automatically detect others with matching parameters and thus to highlight and draw attention to their significance. This is not far removed from automated classification, however there is still little evidence of the use of these advanced forms of automated data capture in the field of conservation hence the consequent problems of data integration and management have still to be addressed.

An explicit audit trail should ideally exist between secondary interpreted information and the primary interpreted data on which it is based. Retention of the raw data minimises the risk of inaccuracy arising as a result of the aggregation of data sourced at different levels of accuracy. In much current paper and video based secondary interpretation supplied to visitors there is a risk that presents inferred conclusions as fact. It is difficult to demonstrate the chain of argument that has led to the conclusion presented. However digital information, including imagery, with multi-level hyperlinks and underlying database management does not impose these limitations.

8 Hortonet - Network of Historic Gardens

FBE/UWE more recently worked on a multimedia Trans-European Telecommunications Networks funded pilot study to create a network of linked historic gardens and landscape parks (project ref. Ten 45612 FS). A prime goal of this project was to enhance public understanding by enabling the visual display on the Web of comparative design influences and planting across Europe, for both primary and secondary interpretation. As Thompson put it, "the best basis for understanding a ruin is therefore a wide knowledge of structures of the same period, whether ruined or not, since the mind is consciously or unconsciously making comparisons, and the larger the stock upon which it is possible to draw, the more reliable the result is likely to be."[18] Landscape design influences in particular have often been pan-European or global, so it was argued that understanding for most was hampered by the constraints of opportunity and distance, which the Web might serve to overcome. The popularity of gardening books and of garden visits demonstrated the market.

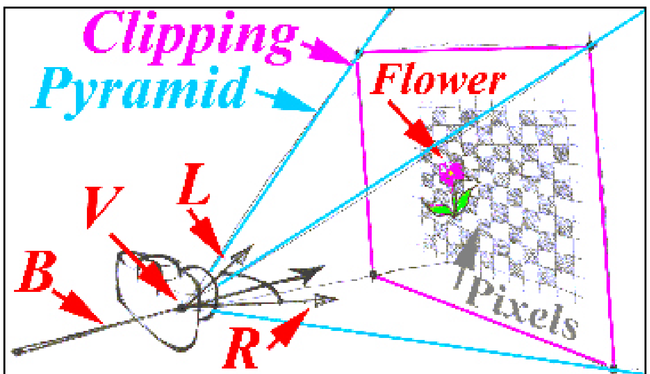
This process assisted in identifying useful GIS based techniques for recording and retaining original digital imagery with associated metadata. Most of the data with which to create a credible sense of presence were digital video, digital panoramic images, and high-resolution digital photographs, together with associated botanic and historic information. It proved possible to capture sufficient photographic imagery to create a credible sense of presence for a site with two staff in one day. (The same staff can process and edit the material within a week.) However the critical conclusion was that the on-going data management of a web-site of the predicted eventual size and complexity would be challenging, since a major goal was to acquire a continuing record set of images for each stage of growth in each season, each year.

Thompson went on to say "study of the relationship between written sources and visible remains is like the reciprocating action of a piston"[18] For similar reasons of understanding it was considered necessary to relate images of the planting in the gardens to other more abstract information on history, soil-type or species. Yet manually associated hyper-linked explanatory information proved too resource intensive to apply, let alone maintain. One approach explored was to create polygonal overlay hotspots to associate relevant information with each image. This was possible but, given the scale of the project, the number of images in video and other form involved, the association of data with overlaid polygonal boundaries proved impractical. It was intended to keep adding increasingly higher resolution imagery over time to the site, which would entail regular re-association and resizing of the hotspot polygons. Conflicting overlaps were found between the boundaries of information that are required to be coded onto an image but HTML still does not support overlaps (multiple levels of detail) for hotspots in the manner supported by VRML.

Accurate identification by experts of botanical information from photographic images alone also proved impractical. It proved necessary to map botanical and historical information on site as a separate expert process, prior to the definition of the hotspot associations. This made clear that images without associated explanatory information would be of little use in interpretative use by the public. For these reasons a GIS spatial database approach has subsequently been studied to determine its suitability for recording explaining and retrieving heterogeneous information in conjunction with images.[19]

8.2 Record Management, Storage & Retrieval

In practice none of the gardens in this initial Hortonet study were found to have existing accurate plans available at scales of better than 1:1000, which therefore lacked sufficient detail to adequately define plant locations. Each heritage site required first to be surveyed and recorded in 3D. All images whether new digital photographs or historic plans, paintings or prints require base locational metadata such as viewpoint, bearing and field of view. This may be conceived as a notional horizontally aligned pyramid of space. The form of this 'pyramid' field of view may be calculated on demand from the base data. The image resolution serves to provide a notional cut off plane thereby defining the 'base' of the pyramid.



V - Viewpoint
B - Bearing
L - Left Bearing calculated from Field of View Angle
R - Right Bearing calculated from Field of View Angle

Notional Clipping Plane calculated from size of object of interest (eg Flower head) versus Pixel size

Video shots calculated as extending from Right Bearing of initial frame of shot to Left Bearing of final frame of shot.

Figure 3 – 3D 'Pyramid' of space

A separate asynchronous process could then be followed for recording the location of botanical and any other historic or management data. A spatial search based on the location of an item such as a plant can then retrieve images that locate that item within the pyramid zone of view. An enquiry based on an image or frame within a video sequence would similarly retrieve the list of items potentially visible. The recorded resolution of each image may also be evaluated to determine whether the item is larger than one or more pixels based on distance from the viewpoint and therefore visible or not. However this alone would not determine whether the item would in fact be visible or whether intervening objects or structures would mask it.

The 3D terrain with height and extents of visible foreground 'barriers' including other plants, garden ornaments, walls and hedges need also to be mapped to determine whether the item in question is masked from view. One outcome of this data entry task would be that a simple VRML geometric model of the site could be generated from this 'barrier' boundary locational data. This model would serve to locate plants, trees, and built structures in the context of panoramic images, video footage, with other photographic and historic images. Such a model might be defined as the lowest practicable level of 3D detail.

Capturing this data is not a trivial task. For example a team at Bristol University have been developing a wearable PC project with funding from Hewlett Packard. They have successfully linked highly portable 'wearable' PCs with Global Positioning System (GPS) and Electronic Compass and written the direction and positional data into the headers of digital images taken using a linked digital camera.[20] There are however problems of accuracy with existing GPS which make it less reliable for accurate location of items as small as individual plants or groups of plants in an area of planting such as a flowerbed. Overhanging trees prevail in historic landscapes but particularly distort satellite signals. GPS is also less accurate in measuring height than in latitude and longitude. Interpretation of conventional survey data from various sources by skilled staff is probably still the most reliable route. The resulting amalgamations of locational data from various sources would result in a composite map or a model with sufficient referents to locate any item or object. This map or model might then usefully be displayed on a 'wearable' PC for logging and locating features of interest. Given appropriate data and locational referencing the hand-held device may soon become the augmented reality site guide.

9 Valhalla

This project is a continuation of that previous work at UWE in VRML and spatial databases applied to visitor information and heritage site management. It is scheduled to commence in October 2001, funded under European Commission Information Society Technologies (IST-2000-28541). It extends the previous work in two directions, that of real-time remotely controlled acquisition of digital imagery, and that of the relationship of heterogeneous information to the images to explain and interpret them based on VRML, the whole managed by GIS. It is planned as a partnership between FBE/UWE, the Gardeners Exchange Trust (who have promoted physical exchanges between historic gardens staff over the last few years), and the gardens of Hatfield House in the UK, and the Chateau de Villandry in France.

This project is therefore to install prominently placed remotely controlled video cameras in two comparable Historic Gardens of European importance. The goal is to promote comparative study and discussion between staff at each site (a virtual Gardeners Exchange), and put real-time interpretative samples on the Web, with 'hot-spot' information generated in matching VRML viewpoints from a 3D spatial information system. This involves a form of remote data capture, followed by spatial referencing and retrieval of digital images with other associated descriptive information. Staff may control the cameras during interactive on-

Photographs Record:	**Video** Record:	**Plant identification** Record:	**Prints - Paintings** Record:	**Historic Texts** Record:
▪ Date & Time ▪ Location of camera ▪ Bearing ▪ Lens / Field of View ▪ Resolution of Image	▪ Date & Time ▪ Location of camera for start & end of each shot ▪ Bearing for start and end of each shot ▪ Resolution of video	▪ Date & Time ▪ Name ▪ Nurture required ▪ Location ▪ Height above ground ▪ Visible size	▪ Date recorded ▪ Location of Easel ▪ Bearing ▪ Level of detail of Image ▪ Field of view ▪ Perspective or other projection ▪ Location of original	▪ Nature of reference ▪ Date referred to ▪ Location referred to ▪ Area referred to ▪ Level of detail of reference ▪ Location of original

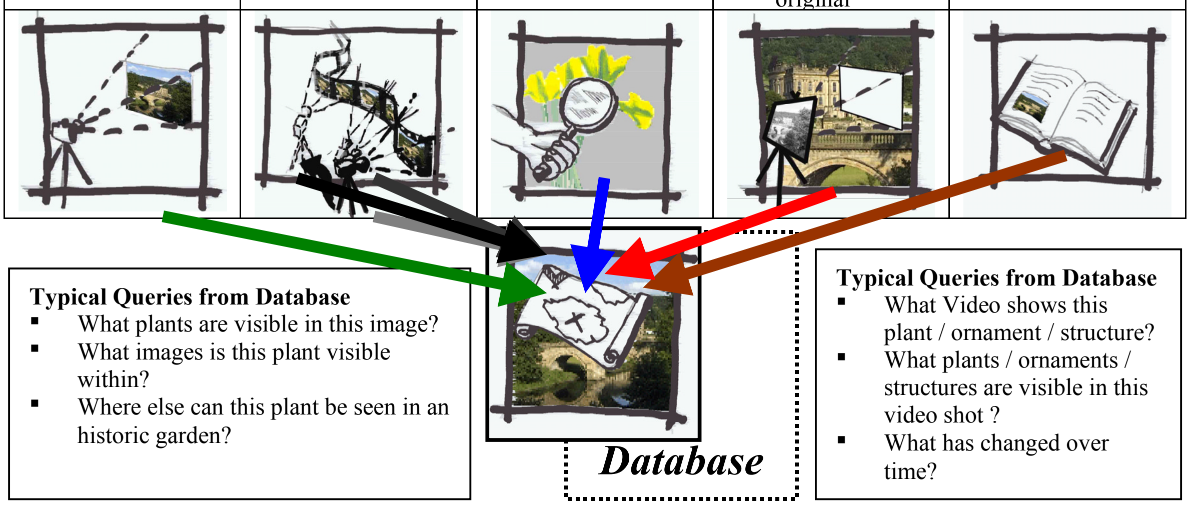


Figure 4 - Typical Spatial Metadata to record with Objects and Images

line discussion to illustrate or seek information, or the cameras may follow scripted routines to capture matching images for later time-lapsed sequences showing diurnal and seasonal change.

Among the major elements to be implemented are firstly to tag the video images with the locational, field of view and focus information used to drive the cameras at the point of acquisition of the images. Secondly to survey using conventional means and construct a 3D 'map' in the spatial information system of all features within view of the Cameras. Then thirdly to 'map' information about plants, trees and hard landscape features within the field of view of each Camera, into the GIS, from which the VRML 3D web based model is generated, to enable comparative identification of the elements visible in the video. (Common plant names in French and English are to use a Latin index as key to assist identification despite the different languages involved.) Fourthly, the issue of data management of potentially very large quantities of images will be addressed: partially by planned 'scripting' to capture in a selective manner; but also by use of the GIS to assist in management, archival storage and retrieval by place, time, and objects within the field of view.

The web based interpretative real-time samples and archived or time lapsed sequences are intended to enable the comparative study of similar information within both gardens from a Web Browser, so broadening public access to this part of European cultural heritage. Other phases also add Garden Staff tools for visitor interpretation and responsive site management, to empower staff to keep the information in the GIS up to date and so make it more resource effective.

10 Conclusion

This paper described an investigation into the marriage of long-term data with what might be called more ephemeral imaging data, using a common key of spatial and temporal location, and served by a spatial information system or GIS, to create a meaningful whole. The physical and historical complexity of heritage sites is held to be better recorded in 3D than 2D to ensure commonality of understanding between all those involved in its care and with the wider public who fund it. A common approach to spatial and temporal referencing across a range of sites will enable comparative search and simultaneous display to envision the broad range of examples that Thompson described as so important to enable reliable understanding of what is seen on site. This broad understanding can only be obtained asynchronously by first hand experience at present.

VRML is a useful de facto standard for defining and interacting with such models on the Web. VRML models based on spatial databases have the potential to become actively served with appropriate associated detail and data on demand. VRML is useful for managing such models and enabling the process of selecting and presenting appropriate information with images to the viewer.

A common underlying coordinating geometric structure or primary model to which all objects relate is likely to emanate from the lowest level of detail at which such spatial data can be captured without extensive reinterpretation. Much more metadata requires to be captured and entered into a database with visual images and information than is currently the norm.

A spatial database can be used to serve appropriate information with images or video clips on demand. There appears little difference between the data management and retrieval issues that apply to web-based multimedia interpretations of historic environments and those that are particular to large area 3D computer models. In both cases more effective use can be made of video or high-resolution images in many instances where resources are currently put into 3D modelling alone. Yet the question of when it is appropriate to model instead of or in addition to experiencing first hand has also been raised.

The Grand Canyon is cited in support of the argument that some sites need no interpretation. (This does not preclude a need for informed professional understanding.)[10] The Grand Canyon might be brought to a remote off-site audience using video and audio alone. However many other sites are enhanced by interpretation and for these remote access or, in the future, augmentation of the reality on site will require on-tap synchronised abstract information in addition to that directed at the senses. It takes a long time to commission and procure useful records. To meet these future developments it is desirable to record locational and temporal metadata with such records now.

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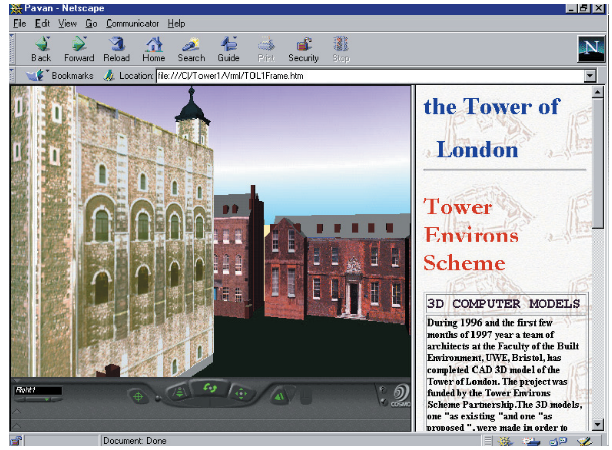
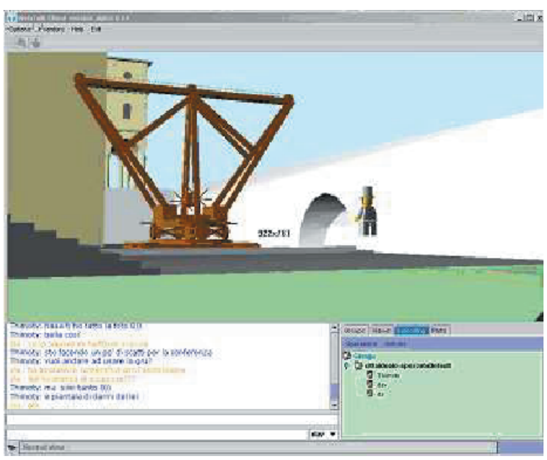
View from the Tower of London Computer Models

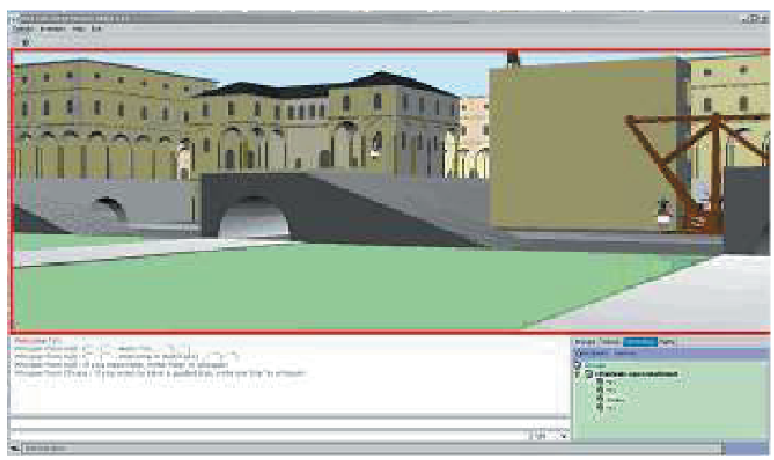


View of the Web based VRML Tower Model

Counsell: **An Evolutionary Approach to Digital Recording and Information about Heritage Sites,** pp. 33-42.



A shot from the online virtual city. A user is approaching an interactive machine and operating it. All other users are aware of his movements and his actions over this particular object.



Another shot during the navigation of the ideal city. Beneath the 3D navigation area, the chat window (bottom left) and the collaboration area (bottom right) allow users to communicate with each other and with the virtual guides.

Barbieri, Paolini: **Reconstructing Leonardo's Ideal City - From Handwritten Codexes To WebtalkII: A 3D Collaborative Virtual Environment System,** pp. 61-66.