

Furness Abbey survey project — The application of computer graphics and data visualisation to reconstruction modelling of an historic monument

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22.1 Preamble

The paper outlines the potential for the application of highly developed software which has been generated for the chemical, oil and gas industries, and how the archaeological world can benefit. This industrial development has been necessitated by the need to create long term storage of engineering data and for maintaining lifetime records relating to the design construction and commissioning. The need to generate accurate libraries of engineering data so that information is only generated once, means that everyone uses exactly the same data across all disciplines and projects. The following describes how this has been achieved for engineering large and complex chemical plants, and then develops the theme in the possible application to the archaeologist.

22.2 Background to the Furness Abbey survey project

Since 1985, the Lancaster University Archaeological Unit has been co-ordinating a large scale in-depth archaeological and architectural survey and analysis of Furness Abbey, Cumbria, one of the most substantial surviving ruined Cistercian houses in Britain. The project is one of a number of historic fabric surveys set up in recent years by English Heritage to provide full basic recording of monuments prior to repair and conservation. Furness is the largest and most complex site for which complete survey has been attempted and the work required has necessarily been more detailed.

The choice of photogrammetry as the basis of the recording scheme has made possible the study of the monument to far higher standards than would otherwise have been achievable. The history of the site is far more complex than has previously been realised and a rigorous approach to analysis has been adopted to identify and date constituent building periods.

The format of the archive presentation has been designed for multi-purpose use. The basic stone-by-stone record drawings are distinct from colour-coded drawings generated from them which illustrate both the suggested historical development and reconstruction of the monument.

Quite apart from the use of the archive for production of academic publications and as part of the planned programme of conservation, the accuracy of the survey data and fuller knowledge of the building history will lead to more informed presentation and marketing of the site to the visiting public. For example, on-site graphics schemes, visitor

centre displays, audio-visual presentations and educational work-packs can be produced or existing ones enhanced, while marketable spin-offs might include popular interpretative material such as new guidebooks, broad sheets, model kits *etc.* In particular, the 2D historic reconstruction drawings can be used to generate full measured 3D perspectives and colour work showing development of the abbey far beyond the traditional artists impression.

The initial project is now coming to an end and it is the purpose of this paper to propose what is considered to be the next logical step. Building on the basis of a very considerable amount of recording work that has been achieved during the past five years, it was felt appropriate to extend the use of the survey data and to generate a 3D electronic model of the abbey, using a 3D computer modelling system. To this end, a collaborative programme was established with North Cheshire College, Computer-Aided Engineering Centre, to investigate the possibilities for the application of 3D computer modelling from which video sequences for presentation, and interactive graphics stations for research and educational use, could be produced.

22.3 Evaluation and implementation of computer-aided engineering systems

The past ten years have seen widespread application of computing methods to the engineering of large-scale chemical plants. The following provides a brief overview of how these were evaluated, implemented and developed to considerable advantage.

One area which has benefited most from the implementation of computer systems is that of plant layout, pipe routing and pipework design. Ten years ago, there were a number of software packages that addressed the production of 2D draughting and 3D modelling of large and complex chemical plants and pipework fabrication and installation. Having short-listed a few, very detailed functional specifications outlining ideal systems were put together. Each system vendor responded, stating precisely how well their software would meet the specification. By this means the majority were rejected and the shortcomings of the most promising identified.

One of the software packages selected was PDMS (Plant Design Management System). The advantage of PDMS was that it addressed the plant design aspects and would ultimately become the design database driving the drawing

and material control software, from which the fabrication drawings for complex piping systems were produced.

The methods of actually determining the optimum plant layout are basically unchanged from all previous methods:

Ten years ago	Now
Use of graph paper to put down first thoughts	Preliminary 2D electronic layouts
Preliminary block models in wood and plastic	Preliminary 3D electronic models
Detailed design models	The actual electronic design — plant built full-size in computer database

The key advantage of using computing techniques is integrity of design :

- All designers use the standard data held in the database
- All designers use the same design procedures (many contractors and different companies use the same data)
- All designers take advantage of special programmes (macros) for producing designs (pumps, valves, standard equipment, stairs, cat ladders *etc.*). Such items only require a programme to be created once and stored in the macro library for all to use.

For a very large and complex electronic model, such as the THORP reprocessing plant at Sellafield (Cumbria, UK) being built for British Nuclear Fuels plc, there can be a great number of design databases which all must come together into one large single database for the complete project. For THORP, a multiplicity of design contractors worked in harmony to construct some 150 design databases, which, once assembled, created one huge electronic model.

The creation of only one 'intelligent' model, from which all design and construction data can be interrogated and extracted by a large number of people, leads to greater efficiency and consistency, saving time and effort and reducing the possibility of errors.

The computer model scores over the physical model in that the latter is a single entity which can only be in one place at any time and is non-intelligent, except for crude tagging. Physical models are also difficult to manage in terms of accommodating design changes. Finally, any data extracted from a physical model is only as accurate as the draughtsman can measure it to produce hand draughted drawings. Using physical models and hand drawings one can suffer 10–12% errors on pipework fabrication, resulting in high costs being incurred at the construction site. Using computer methods it is possible to achieve 0.1% errors, regardless of the overall plant size, thus eliminating many expensive on-site modifications and delays.

22.4 Plant Design Management System, dynamic Interactive model REVIEW and flash video

Both PDMS and REVIEW were developed by the CAD-Centre Ltd in Cambridge. Put simply, the package comes in three essential modules :

- PEGS (Project Engineering and Graphics System), a 2D intelligent graphics database
- PDMS, a detailed design database and 3D solid modeller
- REVIEW, for realistic interactive model review.

PDMS and REVIEW have proven track records and many of the world's largest engineering and construction companies in the power generating and process industries are major users of the software package. An active user group helps bring about developments to suit particular needs. For example, British Nuclear Fuels plc have developed their own more sophisticated version of REVIEW known as EVS (Enhanced Visualisation Software). The CADCentre themselves are also about to launch a new module called DESIGN which can create colour-shaded pictures actually within the PDMS design database, without the need to first transfer data into REVIEW.

PDMS is available on DEC, PRIME and IBM hardware. REVIEW runs on Silicon Graphics 4D series workstations and compatibles.

Drawings within PDMS can be produced at any level of detail and at any desired scale. Fully annotated and dimensioned drawings are available and multiple views from any angle with hidden-line removal can be made, either true perspective, wide-angle or conventional orthographic. In addition, sections, isometric and cut-away views and views from within the model looking out can be produced. As all drawings are taken from the single model, any design changes introduced will appear on all subsequent drawings. Data may also be taken from the PDMS model in the form of reports and materials take off, or for interfacing to other software packages such as stress analysis systems.

The REVIEW and EVS visualisation modules take the model data from PDMS and produce quality colour-shaded pictures with multiview walk-through capability 'in seconds', whereas PDMS running on a PRIME mini-computer can sometimes take hours to generate a single complex image. Quality mode pictures may be viewed as static images at the workstation and as hard copy thermal transfer print-outs, or as part of a sequential presentation or cartoon-style animation. Real-time animation is available by going into wire-frame representation or fast mode (rapid travel) straight line component simplification.

A display view control panel allows the user to define any view point within the model using view angle, position and orientation commands. The step distance and angle of rotation can also be adjusted as required. Any particular feature within the model can be called up by the observer and selectively viewed or 'clipped away' using a user-definable viewbox, while the interactive zoom facility allows for detailed enlargements. An ability to selectively switch colours and toggle individual colours on and off can be used to make elements easier to recognise and show

specific areas which would otherwise be obscured. Tagging of individual features for verification and identification purposes is also possible; the tag labels can remain in place even while the model is rotated. Model components and tag labels can be highlighted and made to flash against a duller background using the display element transparency feature. Both ambient and directional fixed light sources are available, as well as user-definable light direction control. Finally, an invaluable special feature of REVIEW and EVS is the interactive Scale Man. This figure can be manipulated within the model to help provide a sense of scale and perspective and can be moved independently of the model view. Of particular value is the ability to set eye position to the Scale Man.

The potential for the generation of real-time, colour-shaded animation sequences on video film, direct from the PDMS model, is currently being explored. Colleagues from the Warrington-based firm HELP (Hazard Evaluation and Loss Prevention) have recently reformatted PDMS models into a format acceptable to Amazing Array Production's advanced WAVEFRONT graphics package. Software such as WAVEFRONT gives more control over every object, including the positions of camera and lights, producing a photo-realistic image.

22.5 Establishment of the Furness Abbey 3D computer model project

It is clear that industry has committed considerable time and money and now has considerable expertise in using and developing CAE and CAD systems. It makes sense, therefore, that where possible, other disciplines should begin to benefit from these achievements. The purpose of the remainder of this paper is to show how these systems can be applied to reconstruction modelling of historic monuments, to the benefit of both the archaeologist and general public visiting such sites.

Since 1988 North Cheshire College Computer-Aided Engineering Centre and Lancaster University Archaeological Unit have been working together to undertake research into the application of industrial 3D modelling techniques, using Furness Abbey as the basis of the project. PDMS was chosen for 3D modelling purposes and EVS for creating the colour-shaded pictures and walk-through sequences. Finally, an experimental flash video was produced using data taken directly from the PDMS design database.

Initial work simply involved an extension to the existing teaching programme at North Cheshire College and the modelling, using PDMS primitives, of fake ashlar stone wall faces with arched openings in both 2D and 3D isometric images (Fig. 22.1), together with examples of EVS walk-through views.

The second phase of exploratory work was aimed at reconstruction modelling in PDMS on a Prime 9955 of an actual part of Furness Abbey, based on outline dimensions taken directly from the 2D historic reconstruction drawings prepared by Lancaster University Archaeological Unit. The area of the monument selected was that of the nave, aisles and west tower of the abbey church. It was decided to model the nave and aisles stone-by-stone. To make the

piers, for example, one stone was created and then copied and positioned until there were sufficient stones to form the first course around the pier. The course was then copied and the second positioned above it. Once the whole column was complete, it too was copied and the piers positioned to form one side of the nave arcade. The piers of the opposite nave arcade were simply generated by mirror copying those of the first arcade. This technique was applied to all the various architectural elements, including the arcade arches, windows, aisle reponds, vaults, roofs and parapets. Data from the PDMS model was then transferred to EVS to produce colour-shaded pictures. A selection of views containing different levels of information and varied colouring and light source arrangements were created and high quality hard copy thermal print-outs obtained (Figs. 22.2–22.5). A number of these static images were later captured on video film, using the data taken directly from the PDMS model.

22.6 Furness Abbey 3D computer model — proposed future work and benefits

It is intended that the next phase of work be the creation of a series of PDMS design databases of reconstructions of different parts of the abbey at different stages in its development. Once complete, the databases would be assembled to form one huge 3D intelligent model of the monastic complex in its entirety. As with the Sellafield example, the creation of only one model, from which all data can be interrogated and extracted, leads to greater efficiency and consistency. These are important considerations as it is intended that the Furness project be set up in a very similar manner to that adopted for the design of the THORP plant, because of the size and variety of the desired workforce. The workforce will hopefully be drawn from a combination of the following:

- Secondary school students
- College students from related departments (mechanical and/or construction)
- University students (undergraduate and/or post-graduate)
- Trained students wishing to maintain or extend their skills (including staff of the Lancaster University Archaeological Unit)
- Industrial input.

The work to create the PDMS database will be achieved by proper project planning and the generation of well documented design procedures, using the management and computer facilities offered by North Cheshire College. Direction of the overall project would rest with Lancaster University Archaeological Unit.

Benefits of using a multi-various workforce can be identified and listed under the following headings:

Schools

- Early introduction to college environment
- Early opportunity to use large CAD systems, not available to schools

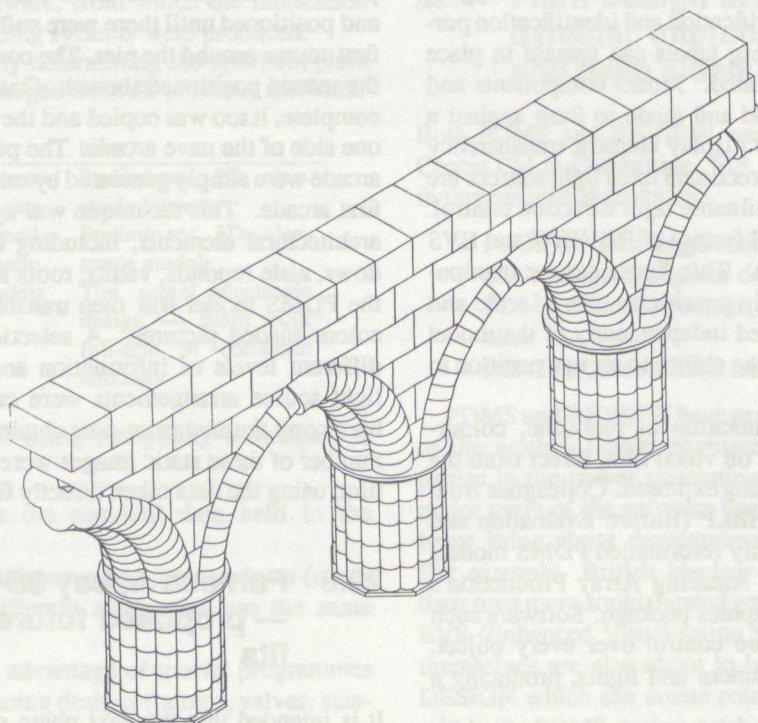


Figure 22.1: Isometric view of fake ashlar wall with arched openings, modelled using PDMS primitives

- Early opportunity to learn high technology skills ('appetite whetter')
- Early opportunity to learn how computers are used in many and various ways
- Early opportunity to learn about the role of English Heritage and the importance of archaeological survey and analysis of historic buildings
- Early exposure to industry through the college environment.

North Cheshire College

- School leavers familiarity with the college
- More effective use of the CAD system
- Development of the use of software into other areas (i.e. not pipework design, as in the case of PDMS)
- Introduction of the uses of major CAD systems into the curricula of building and/or construction students
- Adult education (including industrial skills extensions).

Lancaster University Archaeological Unit

- Training of staff in the use of major CAD systems
- Access for archaeological purposes to CAD technology and expertise unavailable within the university
- Use of 3D computer graphics as a research tool for reconstruction ideas, concept design, testing of archaeological interpretation and simulation of structural stress *etc.*
- Use of 3D model and video for presentation, education, communication and interaction
- Publicity and marketing tool ('pretty pictures').

This work will undoubtedly take several years to produce but it is felt that it is an excellent opportunity to seek to achieve what is considered to be a unique project, integrating virtually the full spectrum of Education and resulting in a product that can bring enjoyment to learning and increased understanding and publicity for all concerned.

For the purposes of this project, it is intended that the input of nodal data into PDMS from the basic 2D outline reconstruction drawings will be manual, as keyboard education is a primary aim. There is a recognised need for research to develop interface technology for creating the PDMS database direct from the reconstruction drawings in AutoCAD, possibly via the photogrammetric survey DXF files.

Once the PDMS model is complete, data can be transferred into either REVIEW or EVS in order to create the colour-shaded pictures. These visualisation modules would offer the ability to adopt any viewing position from within and without the abbey, including both bird's eye and 'monk's' eye views (Figs. 22.2 and 22.3). The facility to be able to 'get inside and walk around' the reconstructed buildings would give a greater feeling of enclosed space and volume and enhance the sense of 'being there'. The user-definable viewbox and telescopic zoom commands would make it possible to select certain detail from the model for particular inspection (e.g. Fig. 22.5) and to create 'cut away' cross-sectional views through complex areas of the structure (e.g. Fig. 22.4). The ability to 'clip away' parts of the model would be extremely useful for showing obscured detail such as the arrangement of trusses below the roof coverings or above the vaults (e.g. Fig. 22.2), or for indicating the nature and position of temporary works such as scaffolding and centring. Colour switching and toggling would allow for

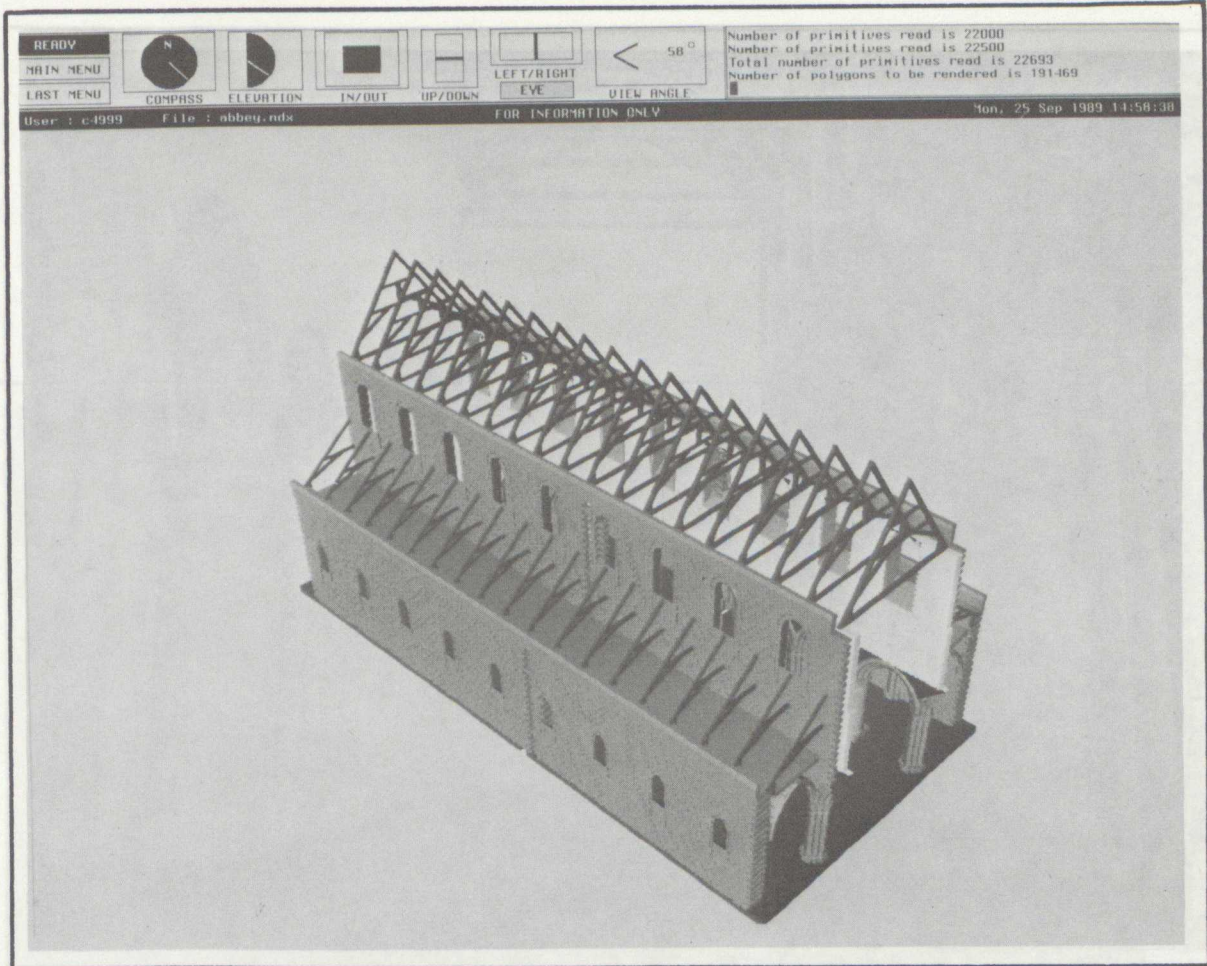


Figure 22.2: Bird's eye view of nave and aisles produced by EVS, with roof coverings 'clipped away' to show arrangement of trusses. Note the display view control panel showing view angle, position and orientation commands

differentiation between identifiable periods and phases of construction. Specific areas, such as floor surfaces, could also be made to fade out and become transparent, in order to view buried foundations or earlier remains. Model tagging and element highlighting could be used to identify certain features from within complex views, while the lighting control could be used to create the impression of depth and atmosphere within the reconstructed building (e.g. Fig. 22.3). Finally the interactive Scale 'Monk' would be an invaluable aid to help judge the sizes and scale of features in relation to reality.

REVIEW and EVS have no facility for generating shadow or reflection effects and no surface modelling or texturing is available. The software is, therefore, limited in the context of creating a topographical landscape into which the abbey could be set. Such facilities are offered by other packages so that some research and development would be necessary to interface with these.

22.7 Furness Abbey Flash Video — proposed future work

It is intended that a video be created from the 3D computer model for presentation at the abbey site permanent exhibition. Such a production would undoubtedly help to stimulate a greater interest and appreciation amongst the

general public in the monument and its structural history. The chief fascination of the vast majority of people who visit monuments like Furness Abbey would appear to lie in a more visual interpretation of the function and original appearance of standing buildings and excavated remains. A realistic picture is immediately recognisable to anyone, even if they know nothing about architecture or archaeology. One possible theme might be the depiction of how the site developed from earliest times, explaining how the various buildings were erected and in what chronological sequence. Another potential subject could be a walk-through video following a typical monk's day, showing what individual parts of the monastic complex looked like and were used for at a particular period. Views taken from the computer model could also be interposed with still shots of the surviving ruins.

Creation of a video will require considerable planning and forethought. Walk-through routes have to be pre-defined as the video sequence is taken directly from the PDMS database. The level of detail of the model and its individual components are other important considerations. Like most solid modellers, PDMS has difficulty dealing with complex, irregular shapes. Moreover, experimental modelling of the nave of the abbey church, stone-by-stone, although visually impressive, proved to be very expensive in terms of computer storage and led to problems and delays when the data was being made to generate a walk-through sequence on

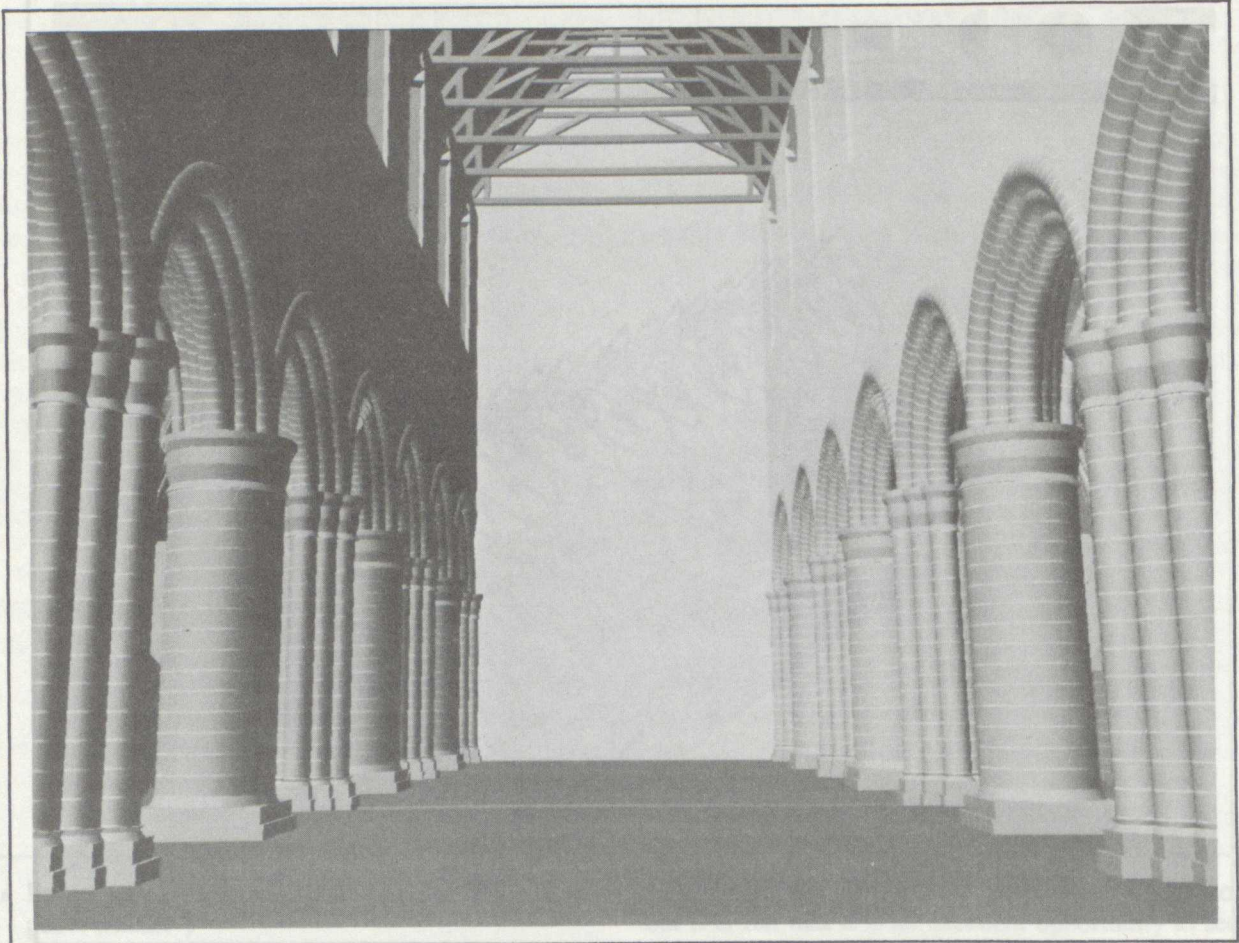


Figure 22.3: 'Monks's' eye view of nave produced by EVE, showing use of varied lighting control

video. Real time animation proved to be possible only by simplifying the model by reducing the number of primitives.

Looking further ahead, production of an interactive videodisc, to allow the public to interrogate the model and position themselves within it, would require further outlay of hardware and software, together with reprogramming, although not necessarily re-inputting.

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Keen, D. Pride and B. Sykes at North Cheshire College; J. Williams and A. Olivier at Lancaster University Archaeological Unit, and D. Sherlock at English Heritage. R. Busby of North Cheshire College and J. Durwood built the Furness Abbey PDMS model using reconstruction drawings prepared by D. Cooper and R. Cooper of Lancaster University Archaeological Unit. The EVS pictures and video were created by K. Ryder and C. Williams of the Computer Applications Group at British Nuclear Fuels plc, under the direction of M. Hall-Wilton. Assistance was also provided by R. Longdon of the CADCentre Ltd, D. Grenfell of HELP and G. Chapman of Sheffield City Polytechnic. Further information regarding PDMS and REVIEW is available from the CADCentre Ltd, High Cross, Madingley Road, Cambridge CB3 0HB.

23

Images, databases and edge detection for archaeological object drawings

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23.1 Introduction

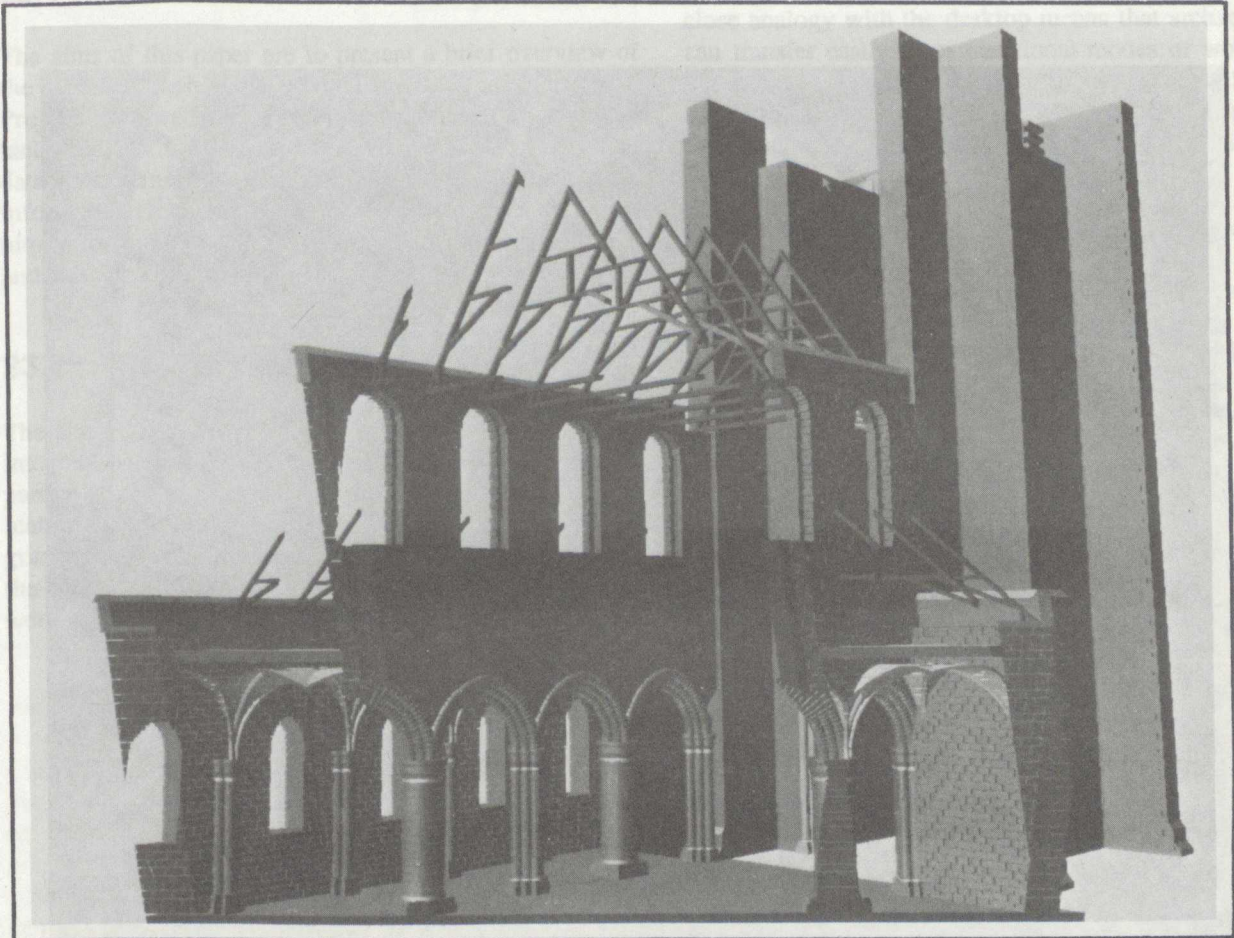


Figure 22.4: Cut-away view through nave and aisles produced by EVS, showing complexity of vault and roof construction, and addition of west tower

systems to the integration of several important components which are summarised as follows:

1. The Postscript page description language and interpreter. This was chosen as a standard for screen displays and not as a means for communicating with a device independent way.
2. The NeWs network extensible window system which provides a WIMP interface based on modern transparent displays.
3. The Ingres relational database to provide the central information base and retrieval capability.
4. Tools for capturing and processing raster images from scanners and video cameras.
5. Extensive additional software written in-house in C and Postscript to complete and integrate the GOAD environment.

An example of a query session within the GOAD environment is shown in Fig. 23.2, illustrating the windowing facilities of the user interface where a variety of text and line

drawings may be displayed in separate windows. The

ologists looking to some of the facilities provided to us as

and storage and im-

of using the WIMP be displayed they tabo-

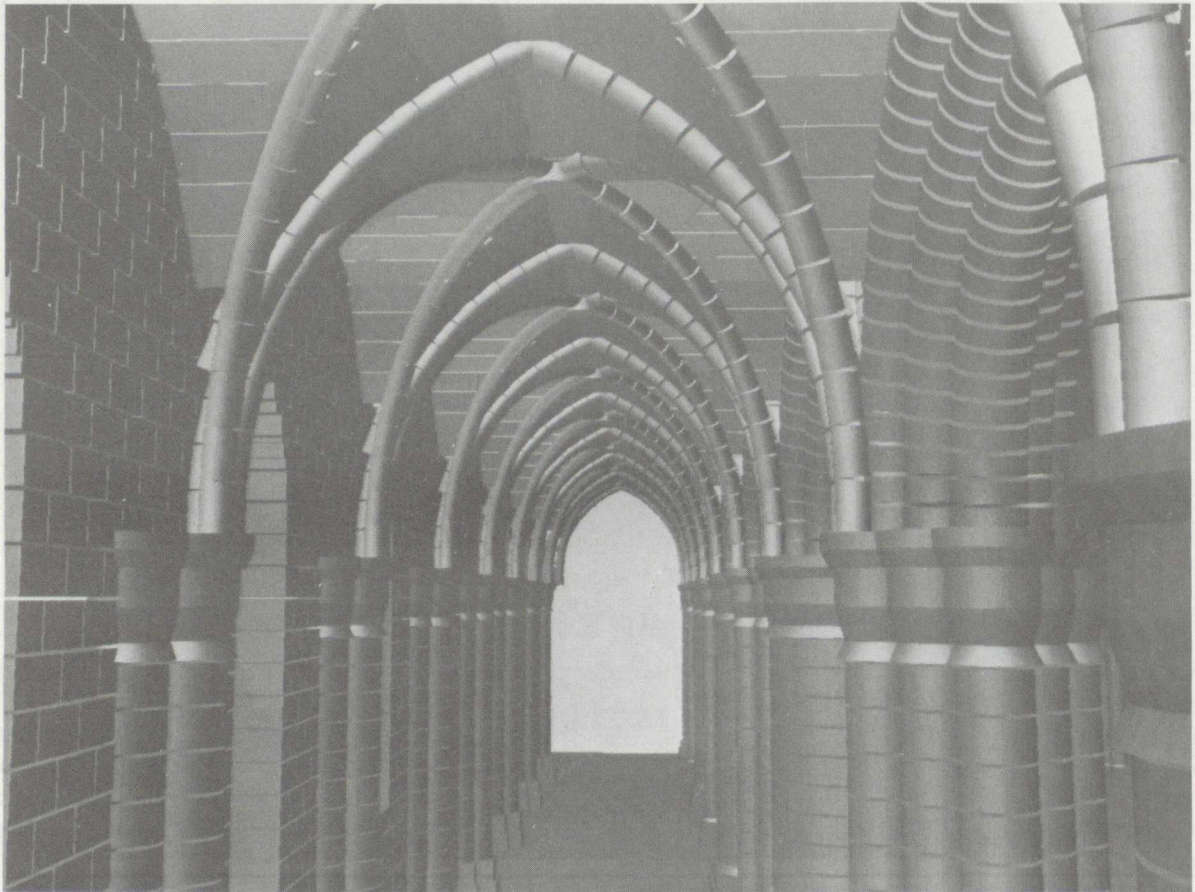
of within cultural

of (Postscript) limited supplied training

of the area of g. Our initial plan was to develop our own display routines and to port these to a microcomputer for distribution, but the rapid speed of Postscript as a standard for screen displays and not as a means for communicating with a device independent way are now able to offer a standard printing although there is a difficulty of suitable display Postscript implementations for micros. We are confident that this device independent approach is correct for publication purposes.

23.3 Automatic shape extraction

One of the major problems when building a useful graphical database is that of entering the graphical information itself. An abundance of line drawings of archaeological artefacts is available in paper form and scanning or frame-grabbing this into the computer as a binary or raster image is essentially straight forward. But if the drawing is to be used for anything other than for display purposes, for example if it is to be used for automatic shape retrieval or classification,



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Figure 22.5: Enlarged view of aisle vaulting produced by EVS using viewbox and telescopic zoom commands