

Visualisation

A description of the display software for Stafford Castle Visitor Centre, UK

1 Introduction

Stafford is a town of chiefly Saxon origins lying in the West Midlands of England. The name implies a landing place and a ford, emphasising that the original site was on an island of gravel almost surrounded by swamp and river. Although there are traces of activity from the Roman period, the first historical mention is as a 'burh' established in AD 913 by Ethelfleda, Lady of Mercia. It became the country and market town of the surrounding countryside, and at the time of the Norman Conquest in 1066 it is recorded as having about 200 households and a royal mint. One major change caused by the advent of King William I was the construction of a castle in the northwest corner of the town. This was the centre of the king's government of the county, but it was short-lived as a fortification, being totally destroyed and covered in modern times by a gas works.

The fortified motte and bailey of Robert de Toeni, on a nearby hill outside the borough in what became known as the district of Castle Church, was more or less contemporary with the royal castle, and it is this site with its Norman, Medieval and 19th Century phases which is today known as Stafford Castle. A huge timber fortress, with banks surmounted by timber stockades and deep dry ditches, had been built there by AD 1100, and excavations have found an extensive civil settlement outside the walls, which may be the village called 'Monetvile' (the settlement on the mountain) in the Domesday Book of 1086. In AD 1348 Earl Ralph reinforced the earthwork castle by a strong stone keep. During the Wars of the Roses the castle saw much activity by successive members of the Stafford family, who by then were Dukes of Buckingham. Edward Stafford, third Duke of Buckingham, was executed for high treason by Henry VIII in 1521, and the castle was forfeited to the Crown, but in 1531 it was restored to Henry Stafford. During the period of civil war between King Charles I and his Parliament 1642-1645 the castle was defended for the King by Isabel, Dowager Lady Stafford, but was captured by the Roundheads and partially demolished in 1643 — it became 'one of the ruins that Cromwell knocked about a bit'. Gothic Revival additions to the fabric in 1811-1812, including two prominent towers, were made by the

Jerningham family of Norfolk, who succeeded to the Stafford barony, and the structure could be visited for tea until 1950. Afterwards there were no caretakers on site, and there was extensive damage by vandals, resulting in the death of a child from falling masonry. The site was given to Stafford Borough Council by Lord Stafford in 1961, and much of the crumbling masonry was then demolished. The whole site would have been in danger of being destroyed were it not for the activities of the Friends of Stafford Castle. In 1978 Stafford Borough Council employed an archaeologist, a series of archaeological excavations and reconstructions were undertaken, which were filmed for television, and annual lectures on the progress of the site became very popular. As a result, the site was officially opened to the public in 1988 and is now properly displayed. It has a Visitor Centre, which includes a small museum with models and a timber guardroom reconstruction of AD 1147, an informative trail around the site, and a reconstructed Medieval herb garden. A series of 'Living History' events have included Norman, Medieval, Civil War, and Napoleonic period costumed battles. Stafford is now billed by its publicists as 'the town that found its castle'. Stafford Castle is clearly an interesting archaeological site offering a palimpsest of some of the most important periods in English history, and it is an ideal testbed for hypermedia techniques.

2 General considerations of interactive package design

2.1 MULTIMEDIA, HYPERTEXT AND HYPERMEDIA

2.1.1 *Multimedia*

Digital multimedia has developed as a powerful add-on to the personal microcomputer. The Graphical User Interface (GUI), with its Windows, Icons, Mouse and Pull-down menu (WIMP) concepts first appeared on the Apple Macintosh, using ideas which had originally been developed at the Xerox Palo Alto Research Centre. This interactive GUI idea is dominant in the Microsoft Windows 3.1 software which has popularised the integration of images and text in the What-You-See-Is-What-You-Get (WYSIWYG) form of output. Another important contribution of Apple was the Hypercard product, an early

form of hypertext (see below). The Commodore Amiga was built primarily as a games machine, but had powerful image and sound capabilities, including concurrent analog (TV) image and digital computer graphics, four channels of digital sound, animation, video production facilities, and an authoring environment.

Interactive Video (IV) was developed in the 1970s (for example LaserVision), and has been used by commercial educators, particularly for the teaching of new software. The technique is to superimpose images from the disks with computer-generated text and graphics, using interactive devices such as the touch screen and the mouse. The disks are capable of holding text, images, music and sounds, speech, video clips and computer programs. The information is scored as small pits into the recording medium by a laser beam, and it can be read as a binary pattern by a low-power laser beam. However, IV has not lived up to its promise because it is expensive and there was no accepted standard in the early days. This lack of a global standard was linked to the incompatibility of USA and European television systems.

The High Sierra agreement (the ISO 9660 Red Book standard, the original definition for the standard audio CD, established in 1980) improved the situation, but this has not proved adequate, since different technologies have emerged to combine sound and video, with different methods of compression. Manufacturers have preferred to plough their own furrow, no doubt hoping that their technology will become the industry standard. Yellow Book is the addition of one layer of error correction, headers and synchronisation on top of Red Book recording, allowing recording of computer data.

A smaller optical disk, the Compact Disk-Digital Audio (CD-DA), became commonplace in the shops during the 1980s for digital recordings of music, and is much cheaper in multiple copies, because of the mass market. These have been adapted for use on computers as the CD-ROM, just as in the early generations of microcomputers the mass market audio tapes were used as a cheap form of backing memory with an adapted tape recorder.

Compact Disk-Video (CD-V) appeared in 1987, using LaserVision and a CD-DA track.

Lock and Dallas (1990) have described the Compact Disc-Interactive (CD-I) technology, to a specification agreed between Philips, Sony and Matsushita (Preston 1988). CD-I readers will also read CD-DA disks, output is compatible with all existing stereo and TV standards, and there is no need for a computer as in IV. Indeed the CD-I reader is a computer with its own Compact Disk-Real Time Operating System (CD-RTOS). Green Book is an extension of Yellow Book to link or synchronise a disk which contains both audio and data, the different data streams

being interleaved during a presentation. The host environment is specified as OS/9, for use with CD-I.

CD-R is a Write-Once-Read-Many (WORM) technology which allows individually authored interactive packages to be written to a Gold Disk blank using interleaving. CD-R is not a sector-addressable media, but data must be written in a continuous stream. The computer that writes the data must guarantee to deliver data at a specific rate to the CD recorder. Failure to sustain the rate will lead to an unusable disk. Thus simultaneous video and audio digital data must be interleaved before writing it to the disk. Multisession recording leads to waste of space, since an index must be written on the disk at every session, and old indexes and multiply-recorded frames are then ignored. The Windows .avi extension stands for audio/video interleave. Orange Book is the physical specification for CD-media providing for different media types, including CD-R, which records complete tracks but allows multisession recording, and final conversion is to a Red, Yellow or Green Book disk.

CD-ROM XA (Extended Architecture) is a standard agreed between Philips, Sony and Microsoft which incorporates audio, text and graphics using established CD-I and personal computer standards, enabling multimedia CD-I disks to be produced in an MS-DOS environment. This of course requires the availability of a re-writable CD-ROM.

Digital Video Interactive (DVI), available from 1990, uses a hardware compression technique developed by Intel which stores only the differences between successive frames. It is being developed jointly between Intel and IBM.

Dual Mode, Mixed Mode format is a method of creating cross-platform CD-ROMs, with software for both pc and Mac on the same disk, the other format remaining transparent when used on either platform.

PhotoCD is a specification which allows cameras to record still images on CD.

White Book is the latest format standard for CD-ROMs.

Which of these technologies will succeed in the market is debatable, and the best technique may not be the winner, if previous battles in ciné film, video tapes, and operating systems are anything to go on. This is a re-run of the video tape saga, where there were many formats initially and Betamax, for example, provided a quality of image much superior to that of the eventually accepted industry standard VHS.

Various compression techniques have evolved. A CODEC is a Compression/Decompression Component, either a software compression/decompression scheme for video, or firmware on a chip which uses such an algorithm. Fractal compression is video compression using a fractal algorithm. Since fractals are not related to scale, enlargement of the image does not lead to larger blocks as in bitmap expansion, but new detail is created by the fractal

algorithm. Frame differencing is a type of temporal compression that stores only differences in successive frames. Indeo is a CODEC marketed by Intel which is lossy (*i.e.* approximating the file, such that when expanded again the original file is not retained) and is optimised for analog video. High compression ratios lead to extreme lossiness where changes of shade, blockiness and artefacts can be produced on expansion. JPEG is the Joint Photographic Experts Group standard for compressing still frames, which is lossy. MPEG is an 8-bit digital method of video compression, involving I-frames (between 1 and 5 of these per second, which can be indexed by time), P-frames (which are predictive), and B-frames (which are bi-directional). Although the CD-ROM recording is linear, designed for TV playback rather than for computers, any I-frame can be accessed direct. MPEG is a 'bridge data format'. MPEG and video-CD may replace the laser vision disk. It requires XA specification, Mode 2, Form 2, and must have intelligence in the drive or on a decoder card. The standard was *not* written for computers, but for mass-market consumer TV, mostly linear, with no interaction. Quicktime is a CODEC marketed by Apple Computer for video compression. Video 1 is a CODEC by Microsoft which is lossy and optimised to analog video.

A set-top box is a box of electronics added to a TV set to enable satellite, cable or the information superhighway to be accessed in the home.

The use of this technology is already exhibiting a high degree of integration with other computing techniques. Authoring languages, digital audio and video production facilities, databases for binary large objects (digitised images and sounds), and database searching using languages such as SQL will all converge in the future.

The very high cost of producing the master disks, and high cost of the computer equipment needed to play the disks, has discouraged many potential users. Even so, many firms have used IV for staff training. In archaeology, interactive videodisks have provided a stimulating new method of providing information in museums, and there have been some examples of cooperative efforts to record archaeological information, such as the 1986 BBC Domesday Disc Set (Gove 1988; Hodgkinson 1993), the Project Emperor-I which has produced two videodisks on the tomb of Qin Shi Huang Di at Xian, which included the famous terracotta warriors and horses (Chen 1987), the Leicester Videodisk (Martlew 1988; 1990a; 1990b), the Perseus Project (1989) and the World of the Vikings Disk (York Archaeological Trust and the National Museum of Denmark).

An early complementary pair of IV disks authored in the UK by the BBC were the Domesday disks (Gove 1988). One of the disks consisted of demographic information on modern Britain compiled by schools for the nine hundredth

anniversary of the Domesday Book. This was map-based, and the information was organised in 1 km squares, allowing logical search of statistics and map overlays, measurement of distances and areas, text search and retrieval of still images and text pages. The second disk was organised as a visit to a picture gallery, and allowed the exploration of many areas of contemporary British life and culture, including surrogate walks.

The story of the Leicester Videodisk with its archaeological images has been related by Martlew (1988, 1989, 1990a, 1990b, 1990c). The main subject for this disk was British stone circles, with some material on related sites. The aim was to include at least one picture and a plan of all known stone circles in Britain, in contrast to traditional publications where pictures are expensive to include, consequently few in number, and restricted to the most popular sites such as Stonehenge, Avebury, Callanish and Castlerigg. A notable inclusion is a video sequence of the winter solstitial sunrise at the Newgrange tomb. Only about half of one side of the disk was taken up with the Leicester archive, so space was sold to kindred organisations wishing to take the opportunity of testing out their material on the technology, including the Royal Commission on the Historical Monuments of England, the National Monuments Record of Scotland, and York Archaeological Trust.

Ruggles (1988) developed software for use with the Leicester Archaeology Disk. The Coppergate application from York allows surrogate walks through the excavation, with choice of route being selected interactively using a touch screen. A site map may be accessed to indicate the current position of the user, and the idea of 'digging deeper' is supported by organisation into modern, Medieval, Viking, Anglian and Roman periods.

The McGraw-Hill CD-ROM 'Multimedia Encyclopedia of Mammalian Biology' has some material on prehistoric humans. The Apple 'Shakespeare Disc' has simulations of the Globe, Rose and Swan Theatres.

The 'World of the Vikings Disk' is described by Maytom and Torevell (1993). This is an extension of the Coppergate project at the ARC in York, supplemented by material from Denmark, and organises groups of images into thematic chapters on transport, religion, weapons and warfare, settlement, subsistence, crafts, art, people, leisure, trade, and language and literature (including spoken sequences). Each chapter may have sub-chapters in a hierarchical fashion, e.g., transport is divided into land transport and water transport, while land transport is divided into carts, horses, skates and so on. Further there are regional chapters based on the major areas visited by the Vikings. There are also video sequences of Viking age methodologies performed by modern actors, and 3-D computer-generated animation for

some sequences. Information may be accessed by theme, area, time, surrogate walk, and true hypermedia storyline.

The Microsoft 'Ancient Lands' disk (Microsoft 1994) is a very advanced presentation of the civilisations of Rome, Greece and Egypt, with text, graphics, eyewitness accounts, sound, video clips using Indeo (Intel Corporation) video compression technology, spoken commentaries and pronunciations, keyword search, map metaphor, time lines, hotwords, picture gallery, screen savers, overview movie, guides, and timed interactive tests.

In 1995 the National Museum of Antiquities, Leiden, exhibited hypermedia projects on the Goddess Nehalennia, and the Roman Army (Bulk).

2.1.2 *Hypertext*

'Hyper' means 'beyond' and signifies the existence of some navigational structure. The idea of hypertext was originated by Vannevar Bush (1945), but the term was coined in the 1960s by Ted Nelson (Nelson 1967; 1987). Nelson's concept has far-reaching implications for document storage and retrieval. Hypertext can be thought of as non-sequential text, and the system allows linkage between text documents in any sequence desired by the user, using hot words, reference, note and command buttons, navigation and backtracking. Some of the earliest hypertext software packages available were the OWL GUIDE system, and the Apple Hypercard system; for archaeological uses of Hypercard see Banning (1993), Farah *et al.* (1992), Orton/Grace (1989), Rahtz *et al.* (1989).

2.1.3 *Hypermedia*

Hypermedia is the extension of the hypertext navigational system to incorporate multimedia, including text, graphics, video and sound. The main problem seems to be the danger of 'getting lost in the hypermedia maze'. Maps, Home Screen with initial menu, other menus, contents lists and indexes are helpful in navigation. However, when users are unfamiliar with the subject matter they need to be prompted where to go, usually by means of a question, or a display of possible courses by means of buttons. Directed routes through the hypermedia network are one solution. Graphical browsers and use of the 'travel metaphor' are also helpful. Page-turning may be found to be tedious and boring by some users. Several authoring languages are now available for the construction of hypermedia links. There are essentially three levels of access which may be used: conventional database search; hypermedia links; and remedial tutorials drawn from the database.

The advantages of hypermedia are:

- It provides a richer learning environment than sequential text, and includes graphics, animation, video, speech and sound.

- Users can pursue their own particular line of interest: the intention is to allow the user to access information in the way that suits him best.
- On-line help manuals are ideally suited to hypermedia — a particular section of a manual, or the meaning of a word, or how to do a particular operation, may be investigated without having to read the whole.
- It readily lends itself to educational applications.
- Simulations or experiments may be run, or video clips viewed.

On the other hand, the chief problem of hypermedia seems to be 'getting lost in the hypermaze'. The feeling generally occurs when the size of the information exceeds 1000 nodes, and happens because the user does not know where he is, or is heading to, or how a desired location may be reached (Thalman/Thalman 1991). The following attempts have been made to solve the problem:

- Hierarchical tree: the nodes are organised in a strictly hierarchical tree structure, and it is always possible to exit to the next higher level, or to jump directly to the 'home' page (top-level menu).
- Index constantly on screen, with the current level indicated.
- Progress bar(s) to indicate how much of the package has been successfully completed.
- Use of a graphical browser. The idea of a graphical browser is that it is effectively a map of the nodes and the links between them. This may be possible for a small number of nodes: the user is able to select a node and display its information. But for a large number of nodes it is necessary to have several layers of help, and the user may end up getting lost in the help system which is supposed to prevent him from getting lost. Possible help for indicating the most relevant nodes to visit next may be provided by an updated 'surveillance system' which should have different types of icons to indicate the sort of information which could be accessed from the current node (e.g., graphic or picture gallery, eyewitness account, pronunciation or sound, spoken commentary, video clip, keyword search, map metaphor, time line, overview movie, timed interactive test, etc.).
- Icons constantly on screen, with links to HELP menu (help about the system, rather than the subject matter), NEXT screen (for pre-designated routes), BACK one screen, to current level menu, to superior menu for next higher level, to the HOME page for the top-level menu, SURVEILLANCE icon to survey possible links with the types of information available from them, LEXICON icon (to define a term), SOUND icon (to pronounce a term), EXIT icon (to exit from the package), etc.

- Use of the travel metaphor. The travel metaphor uses the familiar concept of map reading and travel to enable the user to move easily around a mental model of the system. Instead of a map a graphical model of the system, such as a building with rooms, could be presented. Since the information is presented in a more complex structure than the usually sequential method employed in text books, it is possible to miss out essential items of learning by taking routes which avoid them. This can lead to uncertainty in the user's mind because he can never be sure that all the relevant items of data have been accessed (this can be mitigated by the use of completion bars).
- Jump to any node possible.
- History list of previously visited nodes — may be accessed by BACK key, or any node selected from the list.
- Recommended route through the nodes (achieved by having a NEXT button, or a 'guide' — a simulated mentor, often a person from the historical period being described, or a cartoon character, who controls progression through a set of nodes in a logical sequence and gives a sound commentary for the guided tour). However, the use of guides goes against the main principle of hypermedia, which is the free random-access connection between nodes in any user-controlled sequence.
- Maps of local connection of nodes.
- Global map of the entire network of nodes (top level menu).

2.2 PRESENTATION TECHNIQUES

Some attention must be given to human-computer interaction and especially to interactive devices. The mouse, joystick, tracker ball, light pen, tablet, touch pad and touch screen must be considered as alternatives to the keyboard. The mouse is the most common modern device, and is probably the most familiar to the general public from its widespread use in personal computers, but it is easy to vandalise. Joysticks need more complex movements, tracker balls need additional selection buttons (both hands are needed), and the light pen is quick but causes fatigue. Touch pads and touch screens are fast, suitable for hostile environments and not prone to vandalism, and must be considered the most viable alternative to the mouse for a public environment.

The windows type of GUI must be actively considered. The advantages are:

- i) The interface is easy to use, and intuitive, being based on a desk with files, etc. and a menu type of selection.
- ii) Once the basic skills have been learnt, such as using the mouse, and icons, there is very little else to learn, and re-learning is not necessary after a period of non-use.

- iii) The results of any actions can be seen immediately in a graphic manner.
- iv) The user has control.
- v) Very complex operations may be achieved with just a few actions.

The disadvantages are:

1. Slow screen updating may occur in complex operations, causing user frustration.
2. The graphics capabilities of the machine must be sufficient for display of complex images in enough detail.
3. A high cognitive strain may be placed on the user when there are several windows open with parallel processes running.
4. A lot of screen space is taken up by the windows system.
5. Windows programming is notoriously difficult, which has led to the appearance of programming aids such as Visual Basic and C++ compiler/windows interface routines.
6. A lot of memory and complex programming is necessary (the 300-line 'Hello, world' program is often quoted).

A windows presentation is, however, ideally suitable to the Visitor Centre type of presentation, provided that the layout is restricted to tiling (all windows present on the screen with no overlapping) or only temporary overlapping occurs, with no user requirement for selection, sizing or dragging of windows.

Graphics, animation and sound can be motivating, but what proves interesting on the first viewing may soon become tedious and boring — options must always be given to skip the special effects. The advantages of such techniques are that children learn without realising that they are doing any work (comments such as 'good fun to play with', or 'interesting' are very common).

Ideally, intelligent filtering of information should be carried out by the system, so that the system decides not only what information to present, but also the level, manner and vocabulary in which the information is to be presented, according to the established user characteristics and ability level (e.g., children will require simpler language and familiar concepts such as 'Today Mummy and Daddy are taking me to the castle' rather than 'We are going to investigate some features of the Norman Conquest of Britain'. Some attention must therefore be paid to the problem of users of widely differing capabilities:

- Naive users may never have touched a computer, especially older people, but these are becoming rarer, and most children will have operated a computer or at least a games console. These users may be accustomed with fast

graphics and animation and will not be content with boring screens of text. Naive users need tutorials in the handling of the computer hardware, e.g., use of the mouse. There may be problems with hand-eye coordination. The mouse is also an easy target for vandalism.

- Novice users have some computer experience, but are unfamiliar with the new system, e.g., the hypermedia. They will eventually become skilled users.
- Skilled users have a great deal of experience with computers, and will require a rapid interface which allows short-cuts.
- Expert users have knowledge of the computer and system structure, as well as the ability to modify it — some of these may even include children or students who might maliciously attempt to corrupt or crash the system, and there must be effective security measures against such people.

Graphics, animation and moving video with sound are useful for showing objects, creating impressions, and attracting attention, but are unable to convey precise ideas. Text, on the other hand, is best for conveying precise information and abstract ideas, but looks dull when used alone. It is clearly best to combine all the multimedia approaches whenever possible. Graphics, animation and moving video with sound are much more interesting than screens of text. Text and associated graphics should be displayed close together on the screen so that the user makes an association between them. Allowing a picture to build up on the screen, or displaying some type of % complete bar, is better than pausing a long time with a blank screen and then displaying the whole picture.

The number of colours used on screen must be kept to a minimum (two or three are suggested by Rivlin *et al.* 1990), good contrasts must be used (e.g., white on blue, yellow on black, black on white) and certain colours must be avoided (e.g. avoid red, which is generally taken to mean danger, and do not use it unless attention is meant to be drawn; and avoid combinations such as red on blue, since the eye cannot focus at both ends of the spectrum at once). If colour coding is used, this must be consistent, for example white on blue could always be used to convey information, yellow on black for specifying a question which has to be answered, or the ‘traffic light’ convention may be used (red for fatal error, yellow for non-fatal warning, green for normal information) and there should also be a consistent colour for hot words.

An interesting idea is that users should be able to choose which types of items or windows should be placed on the screen, and what their layout should be.

A display program, however well designed, will benefit from the provision of a help system (Dix *et al.* 1993). To cope with the different types of user from naive to expert, a help system is best layered in a hierarchical fashion with efficient menus, so that a naive user can obtain in-depth tutorials, while experts need to access only particular sections. Help on help may be required to guide the naive user. Help should be available at all times, by use of a perpetually available icon or menu. The presentation style and terminology should be consistent throughout. Help windows should not block out too much of the screen, so that help and normal work areas are visible at the same time. Context-sensitive help is also useful, where the position of the mouse cursor on the screen causes some helpful information (on what the window/icon/menu etc. represents or provides) to be supplied on a status bar or in a pop-up window or ‘balloon’. Icons represent operations which could take a long text description, and they do this pictorially in a small area of the screen, but their meaning must be obvious — an icon with an obscure meaning only serves to confuse the user. Lodding (1983) suggests that humans find images more natural, and they can be easily learnt and recognised. Manes (1985) takes the opposing view that icons are confusing, wasteful of space, ineffective when dealing with similar commands, and not suited to complex operations. Animated icons have been suggested as a solution, but they are not very common. Ideally, icon meanings should be obvious to new and inexperienced users of the system, otherwise they are just a hindrance and a waste of system resources.

Usability must be addressed in the following regions:

- Predictability: Surprises should not be thrust upon the user — past interaction with the system should have given the user an idea of what to expect from certain features, and this predictability should not in general be violated.
- Consistency: This is also about predictability. Warning messages, use of colours, naming conventions, icon design and screen layout design should all be consistent throughout the presentation.
- Recoverability: Mistakes will be made by even the most experienced user. There must therefore always be some way of undoing the last action, such as quitting a long operation, undoing an editing operation, or just returning to the previous screen by means of a BACK button.
- Responsiveness: Ideally the system should provide a fairly instantaneous response. When the operation is going to take a long time, the user should be informed of progress, e.g., by use of a % complete bar.

There are a number of straightforward measures which can be employed to ensure that the operation is as effective as possible. Putting too much information on a screen

causes information overload — research has shown that not more than about 30% of the screen should be filled. Messages must always be noticed by the user — they must therefore not be displayed momentarily but must remain on the screen until the user acknowledges them by pressing some key (the message ‘Press any key to continue’ may be found useful) or by use of an OK button. Most users will not be expert typists and will tend to look at the keyboard while typing, not at the screen. The locations of buttons of common function should be kept the same on different screens, so as not to confuse the user. A different colour, use of larger text, drawing a box around text, underlining and flashing can all be used to draw attention to an important item. Avoid the presence of a flashing cursor on screen — users do not tend to read anything on the screen which occurs after the cursor position.

2.3 TYPES OF INTERACTION

The following methods are commonly used for human computer interaction in educational packages:

- ‘Hot Word’: Text highlighted in a different colour, or in a box or underlined, is clicked by the mouse and then provides a navigational link to some other document.
- ‘Note Button’: A button which when clicked displays a pop-up window with additional information while the mouse button is held down, and disappears when the mouse button is released, returning to the original screen.
- ‘Expansion Button’: A button which zooms in on more detailed information (called ‘unfolding’). This may be to a new screen, but return is always to the original screen.
- ‘Reference Button’: A button which enters a new screen, and there is no return to the original screen. This is equivalent to a jump.
- ‘Command Button’: A button which executes a hidden series of user-defined commands in the authoring language, which may perform any desired function, including controlling peripherals such as slide or video projectors, or entering external packages.
- Click area response template: A defined area on the screen must receive a click from the mouse.
- Drag one or more answers to correct/incorrect boxes: Correct and incorrect answers must be dragged and dropped by the mouse into boxes on the screen labelled CORRECT and INCORRECT (drag all answers is the extreme form of this).
- Drag one answer to box template: Only the one answer which is correct, of several possible answers, is selected.
- Multiple choice template: One or more answers may be selected.
- Pull-down menu template: One item is selected from a pull-down menu.
- Push button response template: A button is pressed.

- Text response template: A free-format text answer is supplied.
- Timed response: This method is frequently used in an educational interactive test or ‘game’ format where the user must supply all the correct answers within a given time limit, and finally receives a score. This is often accompanied by a ticking clock counting down to zero.

It is desirable that a mixture of these methods is used to provide variety of response, to keep the user interested.

3 Implementation of the pilot project

The project has been undertaken for the Archaeology Section of Stafford Borough Council, for use at its Visitor Centre at Stafford Castle. The project aim was to provide a simple interactive facility for the interrogation of multi-media files of text and images, for general public use. The package had to be used by visitors who could not be assumed to have any computer familiarity, and therefore extensive help facilities had to be included on the use of the computer, such as manipulation of the mouse. After undertaking the initial research, which is described above, into CAL, multimedia, hypermedia, HCI, graphics formats, animation, GUIs and authoring packages, the pilot package was written in C++. This has given good support for modular design, and it has proved relatively easy to create a GUI interface. The system has a background ‘slide show’ of castle images. When a visitor approaches and touches the mouse, however, a simple mouse tutor is entered, followed by the main viewer for the system, which has text, graphics, map and button areas. The system has purposely been kept as basic as possible. This pilot system is run from the hard disk under DOS.

3.1 THE VIEWER

The main viewer for the pilot system consists of tiled windows for a still graphics picture, some text, and a map, plus a collection of buttons. The system uses the ‘travel metaphor’ to guide the visitor around a simulated tour of the castle site. Once a location is selected using the mouse, a picture relating to that location is displayed, accompanied by a passage of text. The buttons allow access to more in-depth information, and also provide direct links to associated areas of the castle.

Three types of buttons have been implemented:

- Note Button, which provides a pop-up window with additional information. This pop-up window is retained on screen as long as the mouse button is pressed, and then disappears when it is released.
- Expansion Button, which goes to another screen of information. The return from the second screen is to the original screen which called the expansion button

diversion, and this return is activated by pressing the BACK button on the second screen.

- Reference Button, which goes to another screen of information *without using the map*, but does not return to the original screen. This is equivalent to a jump.

3.2 THE EDITOR

A simple editor has been added for use by an archaeologist system administrator who has little computing experience, so that additional material may be added from time to time, as new excavation records and knowledge about the site become available. The editor allows the addition of pictures or text, and also allows the editing of the button functions attached to each screen. Areas of the castle map may also be activated or deactivated. Text may be prepared by using a word processor, while pictures may be scanned from photographs or printed material, or generated from scratch using a draw or paint package.

4 Developments

The pilot package was found to give adequate, if basic, performance. It was then decided to investigate the implementation of such a system without any coding, by use of available authoring systems, which organise assets (text, still graphics, video, audio) into a hypermedia package on hard disk or CD-ROM. Of course many such systems are available, for example:

- Apple/Claris Hypercard, an early text/graphics hypertext implementation.
- Video for Windows, a multimedia architecture and application suite launched by Microsoft in 1991. It includes audio, video and animation, and allows the pc to work as a multimedia authoring station using CODECs.
- Microsoft Visual Basic, which allows interactive features (buttons, dialog boxes) to be constructed under Windows 3.1.
- Media Maker.
- Macromedia Director.
- OWL Guide.
- Authorware Professional.
- Asymetrix Multimedia Toolbook, a tool for the creation of multimedia packages, using clips, graphics, animation, digital video, rich text format, hot words, Truetype fonts and databases.
- Adobe Photoshop, a package for the clipping and photomontage of images, such as those captured by still camera on Gold Disk using photoCD.
- Adobe Premiere, a package which allows premiere playback of videos constructed from text, still graphics, video and audio assets.

Any of these packages are capable of generating interactive hypermedia systems to varying degrees of complexity.

Some (e.g., Hypercard) manipulate simple cards containing text and graphics. Others facilitate the implementation of a large number of button types, screen effects, animations, video sequences and sound.

Multimedia Windows 3.1 has access to CD-ROMs (using a driver to handle the CD-ROM effectively as a hard disk), facilities to play Musical Instrument Digital Interface (MIDI) files to a Sound Blaster board, and .wav files activated via Windows events. Then there is Microsoft Excel, part of the Microsoft Office suite of integrated software, which is predominantly a spreadsheet but which unusually is also capable of embodying hypermedia concepts with text, graphics, buttons, pop-up windows, etc. Excel allows the use of buttons, text boxes, information boxes, dialog boxes, charts, etc. which may be incorporated using the Macro Language or Visual Basic, and cell boundaries may be removed. These tricks make the user hardly realise that this is a spreadsheet package. Text appears in text boxes or information boxes. Graphics may be imported from a wide range of draw/paint packages by cutting and pasting via the clipboard. The effect of screens may be obtained by scrolling the spreadsheet. Even sounds may be generated via the Windows 3.1 .wav files.

Thus a second implementation of a Stafford Castle package was implemented using the spreadsheet MS Excel running under Windows 3.1, and this involved a minimum of actual coding.

5 Future considerations

The current packages having been prototyped and demonstrated on the currently-affordable and available hardware, considerations have been given to the future development of an advanced system:

5.1 SOLID MODELLING

Solid modelling to reconstruct archaeological monuments has been employed by many workers. Sites which have been so reconstructed include the bath building at Caerleon Roman fort in South Wales (the work of Woodward/Zhang, reported by Smith 1985), the Saxon minster at Winchester (Colley/Todd 1985), Roman Bath (Lavender *et al.* 1990; Woodward/Bowyer 1986), Japanese castles and palaces (Morimoto/Motonaka 1993; Ozawa 1986; 1993), Sutton Hoo (Reilly/Richards 1988), the unfinished pyramid at Abusir (Eisler *et al.* 1988), Mathrafal (Arnold *et al.* 1989), the Stabian Baths at Pompeii (Moscato 1989), Kirkstall Abbey (Dew *et al.* 1990), Furness Abbey (Delooze/Wood 1991), and a Hoffmann limekiln at Langcliffe near Settle, North Yorkshire (Chapman 1992). The initial work on the Bath project by Woodward and Bowyer (1986) was commissioned to supply computer graphics for a television programme called 'Bath waters: under the Pumproom'

shown as part of the ‘Chronicle’ series on BBC television. The view of the temple from the precinct was particularly dramatic, and gave an increased awareness of the site to the archaeologists. The later work by Lavender *et al.* enabled the roofing system for the East Baths to be worked out. The Pompeii project allowed the user to progress from plans to scanned photographs and hypertext panels. The Furness Abbey project allowed the user to ‘get inside and walk around’ the buildings. There have been several similar projects mounted, notably for Fishbourne, Cluny, the Acropolis at Athens, the ‘Orion theory’ simulation at Gizeh, Karnak, and the Dresden Frauenkirche.

It is unlikely that sufficient hardware resources would become available for real-time generation of solid models at the average Visitor Centre. Projection of a video generated from a series of computer graphics frames is cheap, but the generation of the original is hardly economic. Disadvantages of these approaches are that the archaeologist rarely has control, the software is seldom published, computer graphics is not subject to the same peer review as a paper, and the reconstruction, while popular with the general public, tends to be taken as gospel when in reality it is conjectural.

5.2 VIRTUAL REALITY

Virtual Reality involves interaction between the user and the computer generating the graphics. Simple systems (non-immersive) view ‘through the window’ of the computer screen, but advanced systems use a very expensive head-mounted display/headset to immerse the user within the graphics by stereoscopic vision. A simple headset was first designed by Ivan Sutherland in 1966, but the first immersive headset was built by Michael McGreevey in 1984 using small LCD television screens, and more modern helmets have used fibre optics. 3-D navigation devices are required such as the wand, 3-D mouse, space and force balls with tactile and force feedback, hand grip with multiple finger buttons, data glove or body suit. There is a need for a 3-D sound capability, and in the future there will be voice input. Motion tracking can be achieved by electromagnetic, ultrasonic, infrared, laser or gyroscopic means. For realistic graphics texture mapping is used, where a small piece of a real surface is digitised, then this pattern is extended and moulded onto the required surface. Examples of Virtual Reality applications which have been demonstrated in archaeology in the early 1990s are ‘The Virtual Globe Theatre’ (MacRae, Sun Microsystems), ‘The Abbey of Cluny’ (Queau, Institut National de l’Audiovisuel), the ‘City of Giotto’ (entering a view of medieval Assisi derived from Giotto’s frescos in the Basilica of St Francis) presented by ENEL. In 1995 there have appeared non-immersive virtual navigations in the

archaeological landscape of Entella, Palermo, Italy and an Etruscan building using 3-D headset, data glove, and ultrasound tracking system with six degrees of freedom (Forte/Guidazzoli this volume); a system for stitching a series of still images of an artefact into a 3-D revolving image using Quicktime, an object-oriented database, compact disk and the World Wide Web (Lucy/Boast); virtual reality of the Adobe Pueblo site at Homol’ovi using Macromind Director for a touch-sensitive visitor centre display (Gann); virtual reconstruction of the Lascaux cave, with cave painting images moulded onto a wire frame of the cave (Britton); and virtual navigation around a Roman temple site near the River Meuse, using 3-D Studio and interpolation between images to create an impressive film sequence (Otte).

Virtual reality is unlikely to be affordable for the average Visitor Centre in the immersive mode. However, in the non-immersive mode it has some possibilities for simulation of reconstructions and animations in a manner which is familiar to children from video games. A typical use might be viewing ‘through the window’ into an environment where the animated user reacts by collision with objects, or pictures in a gallery, which then activate audio-visual presentations.

5.3 CASE STUDIES OF ARCHAEOLOGICAL EXAMPLES

The following are examples of previous work for information points at archaeological sites, museums and heritage centres; and CD-ROMs developed for home use containing encyclopedias of text, data, images, sounds, video and film sequences, and computer programs:

- Hastings Museum, where a speaking exhibit was developed in connection with the nine hundredth anniversary of the Domesday Book.
- The Commission of the European Communities has produced a report (1988) which states that videodisks are in common use for archive purposes in several museums, and videodisks are being used in a number of projects to record standing buildings, works of art or cultural heritage artefacts.
- The SIRIS Project (1989) has used multimedia GIS using INFORMIX under X-Windows, for text, maps and images of historical settlements in the region of Emilia-Romagna, Italy.
- Italy: Surrogate walks through medieval Genoa (Commission of the European Communities 1988: 244).
- France: several examples of applications of videodisks to stained glass windows, mosaics and the collections of the Louvre.
- Denmark: applications in the National Museum in Copenhagen, overlaying the distribution of prehistoric sites on maps.

- ‘The meaning of Stonehenge’ (Addyman 1989) is a planned multimedia presentation using models, sound, film and video for the Stonehenge Visitor Centre. This will present the complex constructional sequence of Stonehenge, the legends associated with it, and the relationship of the monument to surrounding sites.
- Interactive gallery displays have been discussed by Moffett (1990) in connection with the public face of museums. Children are now familiar with keyboards, touch screens and mice, and the computerised display is becoming an expected feature of a museum gallery. They will be used not to replace the artefacts, but to complement them, replacing long and detailed captions, and providing background information in a more accessible form. The development of robot guides may not be completely fanciful.
- Avebury megalithic monument (Hall/Rahtz 1990), software for an interactive tour of the stones.
- The Archaeological Resource Centre (ARC) in York uses IV to explain archaeological methodology (Maytom/Torevell 1990). Visitors are able to use a finds recording database, a computer-aided design system, and interactive video using a collection of slides from the Coppergate excavation which had been placed on the Leicester Archaeology Disk.
- The Sacred Way project from Athens to Eleusis uses CD-I to document material about the Sacred Way, including archaeological method and theory; Classical Greek archaeology, history and society; and to perform a

surrogate animated walk through the site of Eleusis reconstructed by computer graphics (Cornforth *et al.* 1992; Lock/Dallas 1990). This will allow true hypermedia navigation, allowing the walk to be interrupted for information about Greek civilisation, and simulated time travel.

- The Consorzio Neapolis exhibition of selected artefacts from Pompeii, which visited London in 1992, employed computerised presentation of archaeological information.

5.4 ARE THE TECHNIQUES SUCCESSFUL?

There is no doubt that the use of interactive multimedia, hypertext, hypermedia and virtual reality is more exciting than conventional captions, as is shown by the enthusiasm of children for the techniques. However, the equipment is still too expensive for routine use, and it must be proved that more can be learnt by the techniques than from normal text. Animation, film, video clips and sound of course provide additional dimensions.

6 Conclusions

It is concluded that the modern visitor to an archaeological site or museum expects more than dull text captions, and the use of computer-driven audio-visual presentations is now a required feature. The term ‘multimedia’ will disappear as quickly as it has arrived, since the techniques will become commonplace in the next generation of personal computers, and archaeologists must use them if they are to move with the times.

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