Using Virtual Reality to Improve Public Access to Heritage Databases over the Internet

Mike J. Pringle

National Monuments Record Centre

Kemble Drive, Swindon SN2 2GZ, United Kingdom

e-mail: mike.pringle@rchme.co.uk

Abstract

This paper presents a project, carried out at English Heritage's National Monuments Record Centre (NMRC), that has explored the potential of a public, three-dimensional interface (3Di) to present heritage material over the Internet. The paper begins with the project impetus, and the importance of pre-implementation research, before discussing some of the issues inherent in Information System (IS) development, especially the need to target specific users. The Human Computer Interface (HCI) is discussed, and the comparative benefits, and associated problems, of presenting information with graphics and text are outlined. The paper then presents an overview of the project, describing how a novel information architecture, which prompts the user to filter monument information by location, type or time period (Where, What and When), has been applied to a prototype 3Di. It then describes how text, icons and three-dimensional graphics have been utilised to improve interface usability, within the prototype. Finally, the paper outlines the 3Di's information output, and possible future developments.

Key words: human computer interface, virtual reality, databases, Internet

1. Introduction

The continuing development of the Internet, and associated technologies, is matched by an equally rapid growth in new business approaches to its use. In the Heritage industry this growth is dominated by a desire to make material more widely available, and a corresponding necessity to find practical, efficient and usable ways to do so. In English Heritage's case this desire is driven, in part, by a more general ethos promoted in a British government white paper, Modernising Government, which accepts the need for, and recognizes the benefits in digital delivery of government transactions (UK Government 1999). The British government's targets are essentially concerned with making all dealings (with the government) available across the Internet within the next few years. One of the major areas that such digital delivery will impact upon, is in the making available of greater quantities, and more varied types of information to more diverse, and greater numbers of people. The Internet offers all organisations, large and small, an opportunity to increase the dissemination of their information.

Unfortunately, because of the technological novelty, and the volume and complexity of information available, taking advantage of the opportunities afforded by the Internet is not as straightforward as it may first appear (Barrett and Maglio 1998). Computers in general, and Internet and World Wide Web (WWW) technologies in particular, are still at an immature stage of development. Furthermore, our understanding of the delivery of information, via these new mediums, is still at an early stage in the necessary exploration process. For those involved in this process it is easy to be drawn into the implementation of bottom-up, technological solutions, but, this approach in isolation will not always lead to the resolution of an information-centred problem. To enable useful mapping between any information problem area and the diversity encompassed by the current technological solution area, extensive research is required into both.

2. Developing information systems

For the development of usable, computer-based, Information Systems (IS), it is imperative that pre-implementation research is conducted into the available *information*, as well as the available delivery *systems*. In both cases, understanding of these elements, and of the influence they have on the way an appropriate HCI is designed, is dependant on the end-purpose of the IS: the user, or intended receiver of the information.

2.1. Information

Understanding of any specific information set necessarily requires understanding of information at a slightly higher level, where it can perhaps best be described in terms of its part within a larger, user-centred process. This process is illustrated, in simplified form, in figure 1.

O'Brien and Polovina (1997) give two definitions of information: the first suggests that information results from the emphasising of salient features of data; the second, that information is the organisation of data trends into a form that can be understood in a broader context, and communicated as potential knowledge to others. In both cases it is essentially the interpretation placed on *data* that transforms, or develops it into *information*. Information, by its nature, is primarily concerned with interpretation (Davies and Leclington 1991), and not the simple listing of facts, figures, measurements or recordings associated with data. Thus, for any given data-set to have value within an IS, it is important that an appropriate interpretation is placed on it. This can only be fashioned through an understanding of the end-purpose of the particular system, and, in all IS cases, this must be to supply information to the *user*. Creating a profile of who the end-users are, and what their requirements may be, can be easily overlooked or underplayed, but is a crucial part of IS development if any interpretation, that is imposed on the underlying data, is to be appropriate.

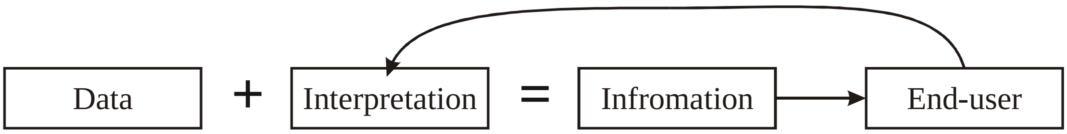

Figure 1: The simplified information process.

For small easily identifiable groups, the Internet can be used simply as a transmission device for very low-level, user-specific, information. However, as a vast IS it also offers the perhaps more attractive possibility of enabling large scale communication of information to much larger, but far less well-defined groups (Jackson 1997). Unfortunately, for these groups, user-requirements are inevitably much harder, or even impossible, to identify. Many current solutions to this problem seem to offer an "accessibility for all" policy where the information is made available on a website, with an interpretation, or interpretations, of the data intended to meet as many different user-requirements as possible. This apparent solution is restrictive in two ways:

- It relies on non-identified users "discovering" and visiting the website. This restriction is endemic across the Internet, and can probably only be resolved by concerted "advertising campaigns" to raise awareness for the site. However, because of the ill-defined nature of the target audience, directing any such campaign is obviously problematic.
- Where a large undetermined audience is assumed, only a small percentage of users (within this "audience") are likely to find the information appropriate to their needs. Furthermore, those users who believe the information to be of value to them, will almost certainly have to further interpret the material in order to fulfil their own individual requirements. This is because the interpretation placed on the data is inevitably going to be too specific for some users, and too general for others.

2.2. Systems

Both of the previously mentioned restrictions can be avoided to some degree if a genuine user-group is identified and targeted. For example, in an internal system designed for professional use, the HCI can elicit manifold, very specific, queries from a user, because a high degree of understanding, of both terminology and data structure, is assumed. Such a system can then return information very tightly aligned to the needs of the user. The interpretation of the data in this sort of case, can closely mirror the underlying structure, and utilize low-level, or narrow, terminology which enables specialist-user retrieval of information. However, as Tudhope et al. note, if the system is being designed to disseminate information to less specialized users, it cannot be assumed that they will understood either the terminology used, or the structure of the underlying data (Tudhope et al. 1995). One approach that demonstrates this problem, is the Internet search engine, which is designed to satisfy a multiplicity of users, searching a vast uncharted database, with an infinite number of different needs. Such systems are usually queried via high-level, broad keyword searches, but invariably return substantial quantities of information that bear very little relation to a user's requirements.

Whether the system is designed for a specialist or a general user, to enable successful information retrieval there is a requirement for him/her to have some understanding of the terminology and structure of the underlying data. The greater the user's understanding, the more successful his/her information retrieval is likely to be. A user wishing to discover the meaning of a collection of curvilinear earthen banks, ditches and large stones, must know what such a collection is labelled as, in any database, before he/she can access the available information. Much current Internet practice, to assist the user in finding underlying information, is dominated by lists of "suggestions" or classifications, that narrow down the query options. These can take the form of; for example, menus, buttons, icons, or hyper-text links, all relating to categories or sub-categories of the HCI designer's interpretation of the underlying data. Such categories are generally contrived in anticipation of the needs of assumed users, but it is very easy, especially when trying to disseminate greater quantities of information to ever-larger audiences, to anticipate too many options, and consequently develop an HCI that is too complex. Every button or link in a hyper-media system can be thought of as a question to the user: "Is this the category you require or are interested in?" The more questions the system asks, the more like sitting an exam the user's task becomes!

Ultimately the purpose of an IS, is to enable users to interact with, or navigate, complex information successfully. Users should, ideally, be able to communicate their requirements to the system with minimum effort (answering as few questions as possible). These requirements should then be met within a time-frame that is acceptable to the users.

2.3. Human computer interface

The HCI is effectively the "front-end" of any system designed to permit user interaction with, or control of, a single (or multiple) process, whether this be the operating of a manufacturing plant or the manipulation of numerical data (Inverso and Sokoll 1997). For Internet development, the HCI can be seen as the enabling communication facility between users and the information held in a computer (or collection of computers). The HCI provides a user with input devices for giving instructions or requests, and output devices to present responses or information (Murray 1998).

The HCI can be likened to a bridge between the user and information (Balint 1995), and the wider the bridge is, the less likely it is to become blocked or bottlenecked. In information engineering terms, the bandwidth of the communication channel between user and information needs to be as broad as possible, to permit maximum access and fluidity of movement through the information. Greater bandwidth is achieved by developing modes of communication (Sharma et al. 1998). This may mean advancing hardware capabilities, such as head-mounted displays and sensor-gloves, or improving the computer's ability to understand humans: voice, gesture, body position or even gaze (Billinghurst 1996, Brooks 1996, McKillip and Corona 1997). However, it can also mean improving the way information is presented. Brooks, whilst acknowledging the importance of sound and touch, proposes that our broadest-band channel is the sense of vision and of all the mechanisms for increasing communication between user and computer, it is graphics that relates most directly to the way we naturally interpret and communicate information (Brooks 1996, Pringle 2000).

Computer graphics may indeed increase communication between user and machine, but the use of text-based interaction is far too valuable an asset to discard. Graphics and text are both powerful modes of communication and it would seem sensible to assume that if they could be integrated in a way that utilized the strengths of both, then a highly usable HCI could be developed. However, a major challenge to the HCI designer, is to avoid the potential pitfall of clogging up the screen with an unmanageable quantity of pictures, icons, advice, buttons and links, in an attempt to give users maximum information about the underlying data. Given the range of users and the complexity of information now potentially available, the HCI is in constant danger of becoming overloaded, and therefore more difficult for users to understand or navigate. The project which this paper introduces, the English Heritage 3Di, has focused on a novel combination of graphics and text, intended to simplify the HCI in such a way as to improve the users' decision-making process.

2.3.1. Graphics

The development of computer graphics over recent years has meant new, and often dramatic ways of presenting information have evolved, including VR. In the earlier developmental stages of any new technology much of the research is dominated by technical issues, and it is only as the tools and working methods reach some sort of maturity that advantageous applications become apparent. This paper is not concerned with any technical advancement of VR, but instead suggests a novel application of the technology that is based on an acceptance of its current state of development.

VR comes in various forms but essentially, is a three-dimensional computer graphics capability which presents an interactive interface, with objects that can be viewed and manipulated in real-time. Warwick et al. (1993) define it as the "science of integrating man with information", emphasising the fact that computer-generated interactive virtual environments can be based on either real or imaginary factors, and suggesting that their purpose is the representation of information via synthetic experience. The idea of information being the core of VR is supported by Witmer et al. (1996) in their discussion of VR as a method of transfer of route knowledge, and by Machover and Tice (1994) who also add that VR facilitates the turning of information into knowledge. Putting the media-hyped image of VR (as a surreal, artificial world into which the participant is immersed via various futuristic gadgets) aside, VR has matured into a practical and powerful imaging tool for a vast number and variety of applications concerned with the transfer of information (Pringle and Moulding 1997).

As a high-quality three-dimensional computer graphics capability, VR enables pictorial representations to be created and displayed, with apparent depth, on a computer screen. The scope for designing worlds, and the objects within them, is limitless; real-world constraints, such as gravity, dimension or even common-sense, do not have to be applied. A VR world can represent the "real" conditions of a hospital operating theatre, a flight simulator or a racing car in a wind tunnel. Alternatively it can portray distant galaxies, or reconstructions of Pompeii just before Vesuvius erupts. Such boundless opportunity is available in any graphics medium, dependent only on the skill and imagination of the illustrator, but one of the core elements of VR, that separates it from other graphical mediums, is the level of interactivity that it offers to users. Theoretically, it is the ultimate in computer user-friendliness, allowing one or many people to interact with computer-generated objects and worlds in the same way that they would interact with the real-world (or other) equivalents. Within a VR "image" users can apparently fly to distant galaxies or, if they so wish, stand on the streets of Pompeii! The potential uses of such an interactive and intuitive medium for presenting information, are boundless, but there are essentially two approaches to current VR development: modelling the real-world, and abstract visualization.

Archaeology has already made good use of three-dimensional VR graphics in the reconstruction of long lost "real" buildings and artefacts, but it is not only concrete, or naturalistic elements of the real world that can be illustrated (Boyd 1998). VR illustrations, like any other graphical illustrations, are merely vehicles for elucidating, or clarifying, information to the user. It is clarification, not realism or accuracy, that is at the centre of any illustration, and it is critical to consider this when new technologies or methods for illustration are being developed. The main goal of an illustration must be to fulfil the needs of its intended user; to clarify the information in a manner, and at a level of abstraction, appropriate to the intended audience. On a map, an entire city can be abstracted down to the level of a black dot. This is sufficient for a user of a map of the world, but useless for someone requiring a town street-guide. Suitable abstraction of this kind is a necessity because, as Miller and Richards point out, it would be impractical for a map to show *all* the data (Miller and Richards 1995, Pringle 2000).

The 3Di prototype project uses three-dimensional VR graphical illustrations to assist in the dissemination of heritage database information. The overriding purpose of the graphics is to clarify users' understanding of the underlying database, and thus improve their ability to navigate the data as information. Such illustrations are not an attempt to replicate reality, nor are they records of any given site. Instead, they represent sets, or classes, of information. A user "flying" around a VR world composed of models like this is in fact moving through a multi-dimensional array of information. This approach combines aspects of both real-world modelling and abstract visualization. These can also be seen as major influences in two traditional archaeological illustration approaches: the representation of real-world form used in many reconstruction drawings and models; and, the abstract data approach inherent in maps, diagrams and other recording modes.

Representing abstract sets of information with pseudo-realistic, very familiar three-dimensional metaphors can be a powerful way to visualize large, and complex, database structures. The familiarity of real-world form is augmented by the opportunity for the user to move through the metaphors in a way that conforms, to some considerable extent, to natural human movement. Although, the user does not actually enter the metaphorical world, he/she can, with confidence, navigate a route through the information via the computer's input devices (mouse and keyboard). This enables the user to explore, or search, the available information, intuitively and productively.

2.3.2. Text

Brooks suggests that the human sense with the broadest information channel is vision, and that to exploit this fact we should be turning to computer graphics in order to improve information flow from the machine into the human brain (Brooks 1996). Three-dimensional, navigable graphics provide an extremely effective way of presenting information; a single pictorial metaphor can elucidate an enormous quantity of information. However, graphics is not the most commonly used mode for representing information across the Internet, nor is it necessarily the most efficient. Although computer games, and much contemporary science fiction, present an electronic culture of impressive graphics and virtual worlds, the Internet is, like other predominant communication mediums, dominated by language or more specifically, text (Glazier 1997).

Textual abstractions over a database are, or can be, very powerful mechanisms for enabling a user to determine specific sets or subsets of information. A series of high-level keywords, or categories, pre-determined by the interface designer, can help the user to get to the information that they require. This does have problems, as mentioned in section 2.2, in that it is very difficult to anticipate the level of understanding that the user will have in relation to the underlying data structure and categorization. Nonetheless, if a user-group is well defined and the categories are thoroughly thought out (and preferably tested with user-group representatives) they become a powerful aid in any IS. The vast majority of IS rely on this approach; for example, it has become an accepted way to enable user queries in many web-site structures. This approach is not really different to the way that text-based products have always been "queried". It is simply a development, or adapting, of the chapter headings, content pages and indexes that have long been used successfully in the printed book.

However, because textual abstractions were originally conceived for linear, book-style information, they can often be less appropriate for the multi-directional, hypertext structure of computerized "cyberspace". The huge quantity of information made available by new computer technologies means that new ways of dealing with information have had to evolve concurrently with the technology (Strawhorn 1981). The categorization approach can be further augmented, or even replaced, by an alternative text-based query mechanism that has evolved with computer technology: keyword searches. This approach allows a user to key in their own choice of words into a simple text box, and then receive a selection of the underlying data that pertains to those words. Again, as mentioned in section 2.2, this relies on the user having some knowledge of the underlying data structure or terminology (Ahlberg et al. 1992). Also, although the addition of Boolean logic (the use of AND, OR and NOT) can help to isolate very specific areas of the data-set, the user can waste much time and effort making queries that return either too many or too few matching items (Jones 1998). Nonetheless, the advantages of applying commonly accepted language (text) into the structure of an interface is indisputable. The difficulty is how to identify, and best employ, suitable terminology.

3. The English Heritage 3Di

Abstract representation of a database, whether it is through image or text-based abstractions, can only be of value if the overall interface is itself usable. Greater usability can be assured by either increased intuitiveness in the database structure and/or more intuitive information navigation methods built into the interface. The English Heritage 3Di project's approach has focussed on the latter, by developing a novel interface architecture that maximizes navigational usability whilst reducing the user's decision making process. The approach taken was based in part, on combining the strengths of both text and graphics, and as such offers the user new and potentially beneficial alternatives to information access (Ucko 1992). However, the benefits of combining graphics and text can only be fully exploited by determining a purposeful relationship between the two mediums, and by incorporating them into an interface that also includes fluid and intuitive information navigation mechanisms.

3.1. Prototype 3Di overview

The main purpose of the 3Di project was to develop a simple-to-use interface prototype, using, for experimental purposes, an established database relating to some 300,000 monuments in England. The prototype 3Di was designed an appropriate level of understanding, and therefore usability, for a conceptual "intelligent-twelve-year-old", and to present information predominantly through three-dimensional VR models and HTML text. The 3Di design also included text-labelling, iconographic navigation aids, and an automatic mechanism for presenting a contextual record of the user's activity. To utilise these various modes of presentation as fully as possible, and to increase HCI effectiveness and efficiency, the prototype 3Di project explored a novel IS approach based on clarifying, and reducing the number of, user-decisions.

3.1.1. HCI architecture

The design of the prototype 3Di architecture was based on a three-tier layering of information navigation. The top, or entry level of the prototype 3Di was designed to provide a contextual introduction to English Heritage's National Monuments Record Centre (NMRC), which supplied the underlying database for the prototype development. The "home" page of the 3Di prototype contained only an introductory paragraph and the English Heritage logo. Keeping the decision making process as straightforward as possible, at this point, a user would only have to decide whether to enter the system or not. By mouse-clicking on the logo he/she would be taken on a pre-programmed fly-through of a VR model of the NMRC, illustrated in figure 2, then into a room within the centre, and to a VR model of a computer monitor on a desk. This particular set of metaphors was chosen to reassure the user with familiar contextualisation; the user should not feel as though he/she is entering a complex computer system, rather that he/she is simply accessing a building that has useful, computer-based, information available within it.

The VR model, of the computer monitor, presented three iconographic VR models which comprised the core of the second level of information for the user. The three models were augmented with textual descriptions and labelling, and represented categories relating to monument *location (WHERE)*, *type (WHAT)* and *date (WHEN).* These can be seen in figure 3. The principle behind such a choice of categories is radically different from the most common approaches to information categorisation currently found on the Internet. As mentioned in section 2.2, it is very common to present users with lists of classifications based on an interpretation of the underlying database, and in this respect, the three cat-

Figure 2: VR model of the National Monument Record Centre.

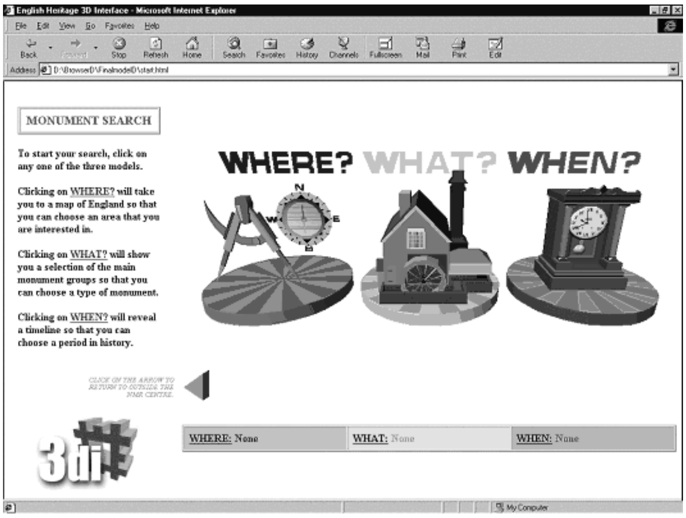

Figure 3: The three iconographic VR models representing location, type and period.

egories are no different. However, instead of determining large numbers of obvious subject divisions, of the underlying data, this paper proposes that identifying commonality across fairly low-level data entities can provide a usable method for establishing high-level categorization.

Within the 3Di project the system was designed to provide access to a database that related, exclusively, to historic and archaeological monuments. It therefore seems reasonable to assume that *all* users of such a system would be seeking information relating to the data at a monument (single entity) level. By extracting or identifying some of the essential components of *every* monument it is possible to compile a very clear interpretation, of the entire dataset, at the interface. From a designer's point of view the question is "What, in the database, are the lowest common denominators that are applicable to *every* user?"

The entry level, as mentioned above, leads the user through a model of the NMRC, and offers no alternative user-choices. This follows a basic assumption that every user would, by virtue of the fact that they were using the system, be interested in the information held in the NMRC. This is the lowest common denominator, applicable to every user, at this very high-level interpretation over the data. The second level of information relates more directly to the underlying data, but still retains a fairly high-level of abstraction, identifying location, type and date as the only categories needed for further navigation of the system's information. Every monument must: exist in a place; be a particular type or class; and belong to at least one time period. These categories do not divide the contents of the database into three separate sections, since they all apply equally to all the monuments within the database.

Within the prototype the three main categories have been represented in the alliterative style of WHERE, WHAT and WHEN, with the intention of appealing to user-group representatives in a later evaluation process. Selecting any one of these three categories would lead the user to a more detailed third level of information that relates specifically to the category chosen, and would present a user with a group of VR models representing appropriate sub-categories: WHERE would present the user with a VR map of England, divided into districts and counties; WHAT, a collection of VR models representing various classes of monument, such as Defence and Religion; and WHEN, a timeline illustrated with dates, period names, and a VR typology of houses. An example of part of one of these sub-category groups, WHAT, is illustrated in figure 4. It is highly improbable that any user would come to the system without already having enough knowledge to be able to identify one of these sub-categories as appropriate to their own requirements or interest. To increase user-confidence about which of the sub-categories would be appropriate to his/her needs, they have been conceived to be obviously different from one another; for example, a user wanting information about churches should not have any difficulty choosing one sub-category from Defence, Religion or Farming (three of twelve sub-categories). Assuming that users are interested in monuments in general, then it does not seem unreasonable to also assume that each user has a particular type of monument, geographical area, or time period, in mind.

When a selection has been made at this third level, the user would be given an option to view a list of *all* monuments corresponding to the selection; for example, if the user has selected WHERE and then the sub-category of Wiltshire, the system would offer a list of all the monuments in Wiltshire. The system would also give the user an indication of how many returns (monuments) could be included in such a list. However, because the three, second-level

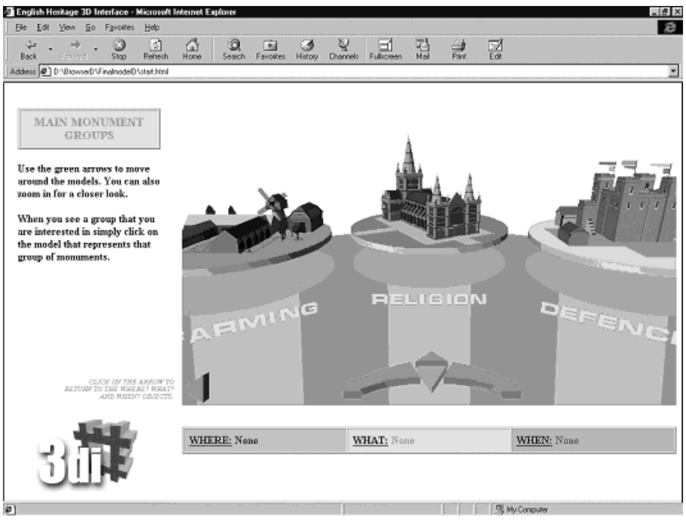

Figure 4: VR models representing some of the, third-level, sub-categories of WHAT.

categories (WHERE, WHAT and WHEN) are applicable to *all* monuments, the 3Di architecture can then offer the two remaining categories to prompt the user into further refining of the possible returns. Having chosen a county and been informed how many monuments this list contains, the user could, if they so wished, select *another* second-level category. By selecting WHEN and then Medieval, the user will have isolated the possible results to only those monuments in Wiltshire that are dated to the Medieval period. The user could then view this list, or narrow the possible results down further by selecting a sub-category from WHAT; for example, Religion.

This multi-pronged refining, or filtering mechanism, which is illustrated in figure 5, consistently urges the user to make a selection from one of the unselected fields. It also re-presents the choices from the previous level in case new information prompts a change of mind. This format enables the user to move down the structure very efficiently and purposefully. The structure, whichever path the user chooses, will result, ultimately, in the rapid identification of a small, and relevant, group of monuments. The following example demonstrates how, even with quite a large database, a non-expert user can very quickly refine the potential results down to a manageable number.

The NMRC database, over which the 3Di has been built, contained, as noted at the beginning of section 3.1, some 300,000 monument records. If a scenario was contrived where a user selected the county of Derbyshire (WHERE), the potential results set would be instantly narrowed down to 4,800 monuments: the number of monuments within Derbyshire. By further selecting Medieval (WHEN), this results set would be refined to 929 monuments. Finally, if the user selected Defence (WHAT), the system would return a list of 31 monuments. This is the total number of Medieval Defence monuments in Derbyshire. Because the user has determined the three elements common to the returned list (Derbyshire, Defence and Medieval), it is highly probable that the contents of the list, or some of them, will fulfil the user's information requirements.

This architecture, instead of offering lengthy lists of subject-divisions to the user, asks him/her to consider only *one third* of a query at a time, then offers a multiple-choice of fully illustrated answers, before attempting to elicit the next third.

3.1.2. Interface content

The prototype 3Di was designed to present information using a combination of graphics and text, with the graphical content designed around real-world metaphors centred on the NMRC building, and the three iconographic VR models representing WHERE, WHAT and WHEN. Although these second-level models are based on familiar real-world objects (compass, building and clock), they represent abstract components that are, essentially, common to all monuments, and do not correlate to straightforward subject-based divisions of the database. Although iconographic representations of abstract sets of data can potentially increase clarity for a user, the use of 3D graphics does not, in isolation, significantly increase the usability of an HCI. Effective visualization, at the HCI, is dependant on the way that the underlying data is filtered and presented to the user, and on the relationship between the 3D models (in this particular case), the data and other elements of the HCI, such as text (Steinmann and Chorofas 1996).

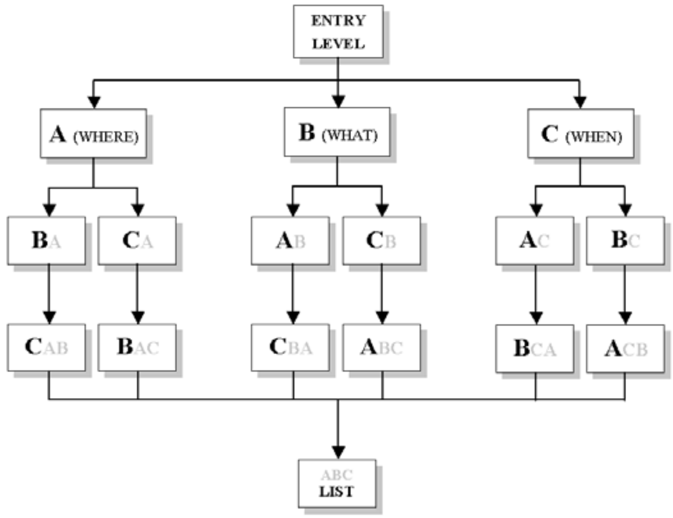

Figure 5: Three-pronged filtering mechanism. (Bold letters indicate possible choices and grey letters represent choices that have already been made.)

The overall design strategy for the prototype 3Di was to create a clean, uncluttered interface with images and language aimed at making the system comfortable to use for a member of the targeted "intelligent-twelve-year-old" user group. To this end, the emphasis within the design was placed on the three main icons (WHERE, WHAT and WHEN), which, although representing the second-level of abstraction over the data, actually form the core of the HCI's user-navigation capability. If a user selected any of the three main icons they would be able to view its appropriate sub-categories (counties, monument types or time periods), where they would be restricted to selecting one of the available sub-categories, returning to the previous level, or moving to either of the two remaining sub-category groups.

On the assumption that text and graphics form a stronger structural base when combined, the three main icons, and the models comprising the third-level sub-category groups, were clearly labelled (with text headings), and further clarified with mouse-over tips. Furthermore, a paragraph of explanatory body-text, and a record of user-history were designed into the overall framework. The body-text, which would alter according to user-selections, was included to explain available user-choices, prompt further decisions, and give an indication of how many returns could be expected from a search based on current selections. The text also included hyper-text links that corresponded to the three main icons; clicking on one of these links would have the same effect as selecting its equivalent icons. Additionally, the text provided a "written" record of user-history, relating any selections that the user had already made.

The element of user-history is a very important consideration of the design of any IS interface; such a facility can not only inform a user where he/she has already been, but the information can enable the system to offer sensible options for where the user may like to go next (Hightower et al. 1998, Rossi et al. 1997). Consequently, as well as the textual inclusion, two other elements of the prototype 3Di were designed to include, and exploit the advantages of, user-history:

- *The history table.* The purpose of the history table was to provide a constant reminder of the user's activity; keeping

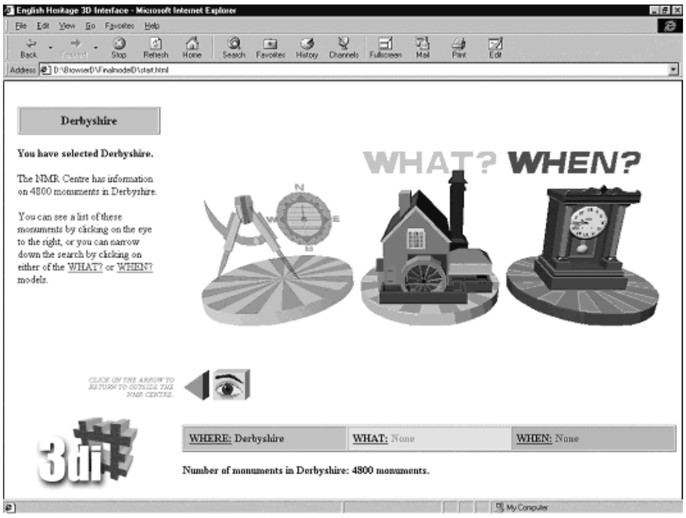

Figure 6: The second level icons with WHERE (Derbyshire) already selected.

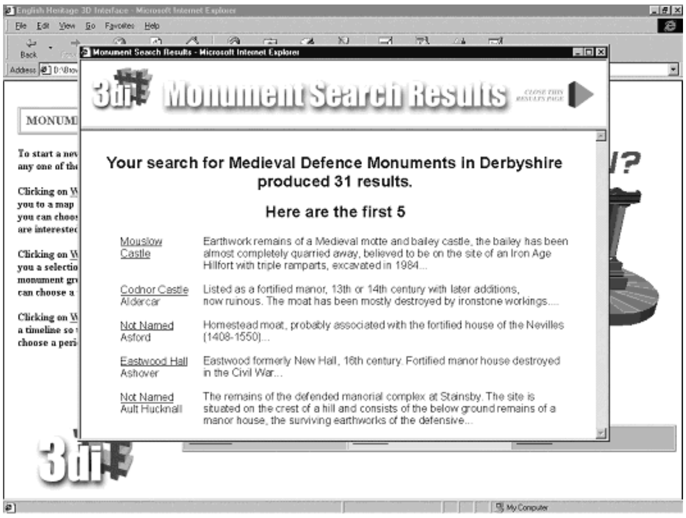

Figure 7: The returned list, with links to pages relating to each monument.

a record of any county, monument type or time period that the user had already selected and the number of possible returns that such choice, or choices, would generate. The record also contained hyper-text links and these, like those in the body-text, would if selected take the user directly to the appropriate sub-category level. This duplication of links helps to ensure that, whichever area of the screen, or whichever presentation mode the user chooses to respond to, the available options do not change.

- *The three main icons.* These also provided an element of user-history record. When a sub-category has been selected, its corresponding icon loses its text labelling and takes on a monochrome appearance, to indicate that it has already been selected. An example of this is shown if figure 6, where the County of Derbyshire (WHERE) has already been selected. This principle simply follows an idea commonly used on hyper-text links, where they change colour after having been visited. However, just as with hyper-text links this would not disable the icon; a user could select the same icon again, if so desired. Also, to further assure the user, and to help him/her avoid becoming disorientated, a colour coding scheme has been applied throughout the design. This code was conceived to give a consistency to each of the three main categories; for example, all the images, headings, and background in the history table, associated with WHERE are represented in blue.

The points outlined so far in this section, essentially comprise the content of the 3Di that is presented to the user. Two other elements were necessarily included: the back button and the view button. The back button was included to enable the user to return to a previous level by reloading all the frames within the browser window (the 3Di contains six different frames but default browser back buttons only reload the last frame to have changed. The purpose of the view button was for the user to click on when ready to view the list of available returns (monuments) that conforms to the selections that have been made. Background details of the information that would appear on this list, and the form that it would take, are discussed in the following section.

3.1.3. Information output

For the purpose of development the prototype 3Di utilized the database of an already established system. At the time of development this system was not available to the public, having been developed for the exclusive use of professionals interacting with data relating to archaeology and the built heritage. Consequently, its interface was designed on an assumption that users would understand both the complexity of the underlying data structure, and the sophisticated terminology used within it. Using the database of such a system, without amendment, in the development of the prototype 3Di, demonstrated two useful attributes of the HCI approach outlined in this paper:

- The addition of a *user-appropriate* interface can radically alter, and improve, the relationship between user and data; the level of interpretation, or abstraction, over the data-set can be manipulated to suit the needs of an identified user-group.
- Much of the information value in a database is not restricted to the delivery of low-level detail (e.g. monument unique identifiers or grid references), but instead can be related more to contextual interpretations; for example, a simple list of all the Medieval Defence monuments in Derbyshire.

However, although many users may be satisfied with this particular level of detail, the system is not restrictive. The architectural principles applied in the prototype 3Di would, as mentioned earlier, permit the user to extract a higher level of information; for example, the user may request to view a list of all the monuments in a given county, or all Religious monuments of a particular period. It could also allow the user to access lower level material from within the database; the final list of returns (an example of which is illustrated in figure 7) is composed of monument names with brief descriptions of each monument. Each name is linked, by hypertext, to an automatically-generated HTML page devoted to lower level information relating to that particular monument. This information relates to material stored in the database that has been input as part of a professional data collection policy, and as such is slightly restrictive. The project will examine the possibilities of including further very monument-specific information; for example, photographs, or even bus timetables, where available.

4. Future work

The prototype model described in this paper was developed for experimentation into novel HCI principles. To assert the validity of these principles further, the prototype 3Di will be subject to usability experiments with the inclusion of user-group representatives. When such experimentation has been conducted, and assuming that the results are positive, it is hoped that a fully operational application will begin to be developed, and then implemented. Development of a full application of the 3Di will, if it goes ahead, include research into other graphics mediums (including two-dimensional graphics), and will endeavour to take advantage of any applicable Internet, or computer, innovations that are available at the time of development. In the first instance such an application will probably be aimed at school children, and as such, is likely to be delivered as an executable file, either downloaded from the Internet or on CD-ROM. This file could load the 3Di onto the host machine, and then automatically connect to the database across the Internet. This circumvents the potential problems of slow download times, and the difficulties of obtaining and installing browser plug-ins, both of which are likely to be problems for high graphic content web-sites for some time yet.

The model described in this paper presented information at a very high-level of abstraction (the model of RCHME), and also at a low-level, such as specific monument details. It was also designed to deliver information at levels of abstraction somewhere between the two extremes; for example, a list of all Defence monuments. However, the scope for delivering information can easily be expanded to include other levels of abstraction, that could possibly fulfil different user requirements; for example, if a user selected a county he/she could be offered a subsidiary level of information that supplied general information relating to the monuments of that county. Perhaps, if a user selected the category of Religion, he/she could be offered an opportunity to "fly through", or click-on, an educational VR model based on Religious monuments. It is anticipated that future development will examine these possibilities.

5. Summary

The complexity of computing information systems, with differing user needs, complex data-structures, varying delivery mechanisms, as well as information content and graphical presentation, means that HCI design is an increasingly multi-disciplinary affair (Bulas-Cruz et al. 1999, Johannsen 1995, Santhanam and Batra 1998). The practical reality of most development scenarios is that there is not always going to be an entire development team, with experts devoted to each and every aspect of the system. Nonetheless, it is imperative, if an interface is to be of value, that the development process recognises the diversity of inherent elements, and responds to them in a positive way. This paper has presented a project that has acknowledged the complexity of designing an Internet-based interface, and has outlined some of the ways in which the project has attempted to resolve several of the pertinent issues.

The prototype 3Di has been designed to present the user with an uncluttered, and intuitive interface to complex heritage data. The HCI was constructed with familiar, real-world metaphors (three-dimensional graphic images), combined with instructive text, clear and varied labelling, and simple iconography. It presented a contextual picture of the underlying data that imparted a high level of information value at the interface. The simplicity and clarity, offered by the interface, was contrived to enhance the user's ability to decide on an appropriate course of action, and to diminish his/her chances of becoming disorientated or lost within the interface. The system user, who should always be the key consideration in any IS development, even with little or no specialist knowledge, should be able to navigate information in a quick, fluid, and most importantly, productive manner.

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