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Computer Imagery and Visualization in Built Environment Education: The CAL-Visual Approach

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SUMMARY

UK higher education institutions have invested significantly in the implementation of communication and information technology (CIT) in teaching, learning and assessment – with mixed results. This work investigated the use of multimedia technologies in the form of digital imagery and visualization material to improve student knowledge and understanding. In this context, this paper reports on a major UK initiative (CAL-Visual) funded by the Higher Education Funding Council as part of the Teaching and Learning Technology Programme looking at improving the use of images for teaching and learning in built environment education. It first describes ways in which computer-aided learning (CAL) is being used in civil and building engineering curricula, it then presents the main aims and objectives of the project and describes the design and implementation of the CAL-Visual system. It concludes by reporting on the results of an evaluation conducted using case studies relating to different applications.

INTRODUCTION

In the construction sector, students learning about construction technology need to visualize materials and components and have an appreciation of the total constructional form of a building. The traditional lecturing environment cannot replace the benefits to be gained from access to construction sites and completed buildings. However, such traditional approaches are characterized by problems of cost, safety, availability of and access to a variety of suitable construction sites, and time. Such is the importance of using images to support and enhance students' understanding of building design and construction that this issue has been recognized by accrediting bodies as an important part of the learning process.

A common criticism that is sometimes levelled at university graduates is that they lack the *professional's eye*. All disciplines have their own way of looking at situations and one of the key functions of higher education is to help students develop this skill. Often, though, graduates do not possess this attribute. They may be able to complete formal procedures, or perform calculations, but they lack the almost intuitive grasp of a situation that an experienced professional has.

In the case of engineering, what appears to happen is that experienced engineers can see beneath the surface of a building, or whatever, to appreciate the underlying structures – with their associated forces. Similarly, poor detailing or workmanship may manifest itself on the surface – and the engineer's eye will know what to expect below. However, this way of perceiving things is often not taught directly, rather engineering undergraduates – and graduates – are expected to develop this perspective by themselves.

Looking at images, especially if that 'looking' is informed by thoughtful comments, is a good way of developing the professional's eye. This would be true of architecture, art criticism, building, design, engineering, and many other disciplines. 'What do I see here?' is a key question for any such professional. Carefully selected and structured images help to educate the eye.

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USING COMPUTER-AIDED LEARNING

In order to address the issues highlighted above, many educational organizations have turned to CIT, and in particular multimedia, computer-assisted learning and computer-assisted assessment (CAA), with the intention of introducing some of the experiences gained on construction sites into the classroom. Several approaches in which visual materials (in the form of multimedia) have been utilized to better educate civil engineering students, have been discussed by Aminmansour (1996), Echeverry (1996), Chinowsky (1997), Riley and Pace (1997) and Finkelstein (1998).

While most methods adopt a small combination of the different types of digital visual material to reinforce textual information, Finkelstein (1998) describes the development and use of a 'simulated site visit' (SSV) system containing a wide variety of these visual materials. They include: virtual reality (VR) models, QuickTime VR, movies, photographs, CAD drawings, audio sequences, video sequences, documents and links of other Internet sites. The system was designed to teach students about the process of constructing a building using multimedia techniques thereby reducing the need to physically visit construction sites. Although the work reported was at an early stage of development, Finkelstein (1998) outlined some of the unexpected outcomes arising from evaluating its features with students, architects and non-professionals. These include its ability to be applied to other disciplines and as a methodology for 'digital warehousing'.

What is particularly interesting about the system described by Finkelstein is that unlike many CAL and CAA packages, tutors can access the visual material independently of the SSV system. Unfortunately, this aspect of the system is seen as a secondary feature by Finkelstein and is therefore not discussed in detail. Bearing in mind the fact that visual material can have many applications when made accessible independently of CAL and CAA facilities, Riley and Pace (1997) have focused on the improvement of teaching efficiency from the tutor's perspective using multimedia teaching aids (MTAs).

Many CAL packages tend to be complete and autonomous pieces of course material that contain clear learning objectives and are used to support or supplant lectures. In contrast, multimedia teaching aids are small, discrete tools used to help tutors convey complex material within lectures, such as the form cycle for self-climbing formwork systems described by Riley and Pace (1997).

Riley and Pace (1997) advocate the use of multimedia teaching aids by arguing that, 'once they are developed, they have the potential to decrease the preparation time and classroom time needed to effectively convey course material to students'. Furthermore, these teaching aids can be used to form the foundations of a CAL and CAA package. In doing so, using teaching aids in this way can also reduce the time and cost of developing CAL and CAA packages. Unlike CAL and CAA packages, which tend to dictate how a course will be implemented and delivered, multimedia-teaching aids do not contain rigid learning objectives.

Teaching aids not only allow tutors to embed them into their course without having to adapt the structure of the course, but they also allow the use of conventional computer tools and techniques (that are familiar to tutors) to create and deliver them. For example, many tutors create their presentations using Microsoft's PowerPoint. PowerPoint is particularly effective at creating teaching aids, because it is easy to embed various forms of digital visual material in teaching instruments. Furthermore, because the use of MTAs is an evolutionary approach to traditional teaching and learning, resistance to change is reduced.

Riley and Pace's (1997) investigation of the use of PowerPoint as a delivery tool for multimedia teaching aids found that: presentation time was reduced; concepts were able to be communicated more effectively; and students were able to access computer-generated lecture notes on a server in their own time. Naturally, these computer-generated lecture notes can be as large and as complex as CAL and CAA packages. However, embedding MTA into computer-generated lecture notes can reduce duplication and the storage capacity required whilst also retaining the advantage that they are specifically tailored to a particular course and able to be broken down into their fundamental components for use in other ways, if required.

Barker (1996) has also investigated the development and delivery of multimedia teaching aids using an 'electronic course delivery' approach to present course material. A fundamental difference in this case is that Barker (1996) describes a methodology for creating, organizing and delivering these multimedia teaching aids from two perspectives: a staff perspective and a student perspective. An important part of this methodology has been the development of a distributed performance support system to facilitate the creation, organization and delivery of multimedia teaching aids.

In general, built environment education has yet to fully benefit from some of the techniques reviewed above. Teaching and learning in this area rely heavily on visual aids and hence facilitating the integration of these into teaching material depends on resources that are well-structured and easily accessible such as multimedia-based digital repositories. While these are traditionally more used in art and architecture (see, for example, the illustrations that can be found at the following Web locations: http://www.pitt.edu/~medart/index.html and http://www.greatbuildings.com/buildings.html) they are not fully exploited in construction engineering. Addressing this issue was the main aim of the CAL-Visual project.

VISUAL REPRESENTATION

Visual representation is a powerful communication aid. A variety of different forms can be used in teaching. For many students visuals can convey more – and more easily – than text. It is therefore worth identifying some of the roles of images in learning and teaching. Here are some things to consider.

An image offers a distinctly different perspective from, say, an explanation in a lecture, or text in a handout or on a Web page. The explanation or the text is saying, 'Listen to me, I will tell you something'. However, an image is encouraging the student to say: 'What do I see in this picture?' The perspectives are quite different. Given good examples – and proper guidance and support – students can be more personally involved and encouraged to develop their own insights.

Images, especially if incorporated into Web pages that offer students a choice of what to see (and from where) can contribute to concrete experience. They can also encourage students to observe and reflect, and they can provide a starting point for testing the implications in new situations. Without images, the opportunities to address these different stages are much reduced.

Information overload

It is often believed that an image makes it easier for people to understand something and this is often true. But if a picture is worth anything remotely approaching 'ten thousand words', and if the image is displayed for just a few seconds, then what speed of speech would this be equivalent to? Of course, if the tutor continues talking at his/her normal rate on top of this, then it really can be a case of information overload.

One very direct way of helping students to see further into an image is for the tutor – whether in a lecture, in notes, or on the Web – to offer a commentary that models and makes explicit the stages in his or her thought processes. It is very easy for the experienced professional to assume that what he or she sees is what students see, and this is not the case.

Shift of focus

This difference of perspective allows a tutor to use an image to shift focus. Even if the picture was taken by the tutor, the viewpoint that the camera offers is now the same for everybody. The image becomes an experience that is shared by all. In a lecture a tutor may reinforce this by moving to the side of the room to look at the image with the students. This shift in focus can be used in a variety of ways and is likely to raise attention levels.

CAL-VISUAL

The CAL-Visual (Figure 1) project was undertaken by a consortium of universities within the UK in order to investigate how experiences on a construction site could be brought into classrooms using computer-based imagery and visualization materials. The project was part of the Teaching and Learning Technology Programme (TLTP) initiative funded by the Higher Education Funding Council for England (HEFCE).

The main aim of the CAL-Visual project was to utilize computer imagery to support the teaching, learning and assessment of subject areas where visualization of objects and processes plays an important role. Images are usually readily available in slide or paper form and used in an uncoordinated manner. This project has developed a digital framework for the efficient use of existing and new imagery to aid teaching and learning technology, hence offering time and cost benefits.

The main focus of the project was to respond to the need for an integrated and cross-referenced repository of digital, visual material available to be embedded within external teaching and learning aids. For this to be achieved, the framework that was specified had to accommodate existing visual materials, tools, learning resources and appropriate pedagogic methods. Furthermore, it had to provide access to resources as and when they are required. The overall system therefore needed to be accessible, portable, inexpensive, platform-independent and able to facilitate sharing of visual resources.

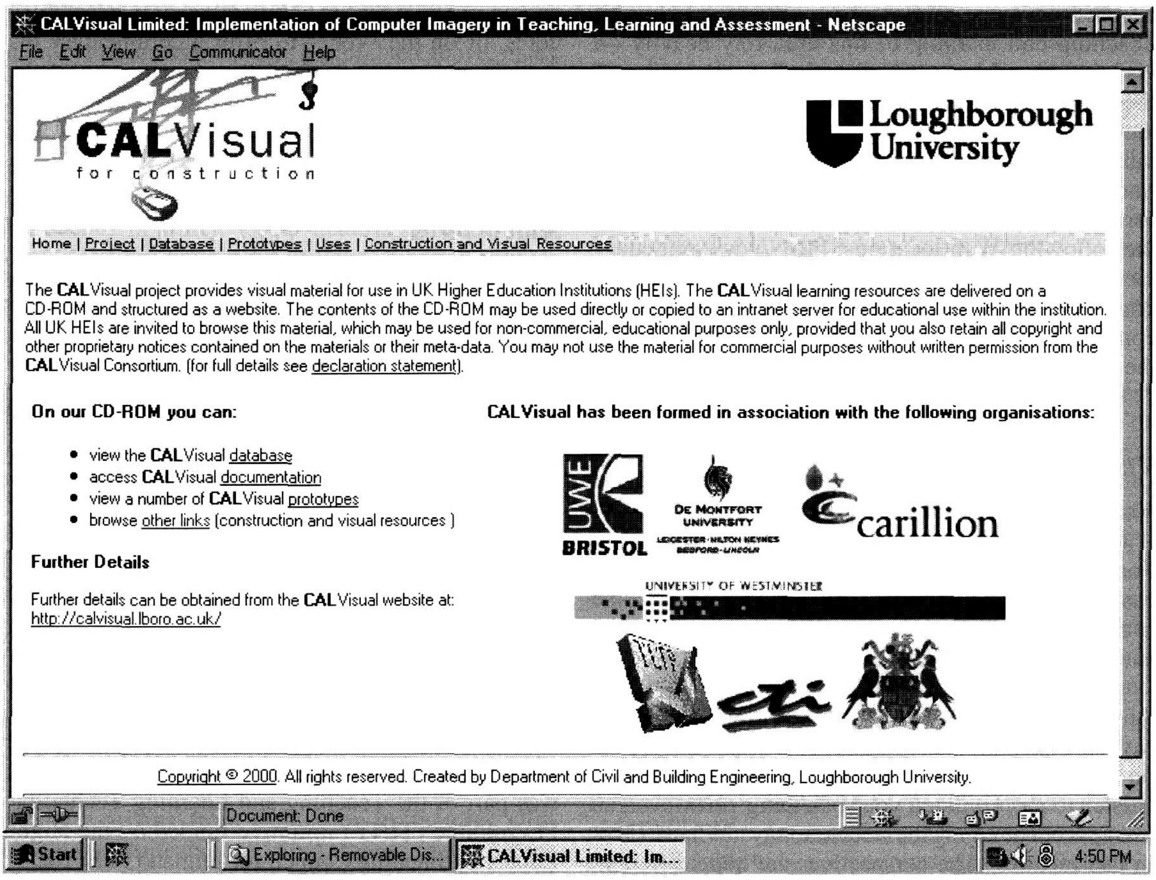

Figure 1 *The CAL-Visual 'homepage'*

For the purpose of evaluation the CAL and CAA modules were made available on the department's intranet and the MTAs published on CD-ROM to contend with the bandwidth requirements. The design and implementation of the CAL-Visual system is described in the following section.

Design and implementation of the CAL-Visual system

A framework for organizing digital, visual material was developed. This framework is illustrated schematically in Figure 2. The repository of visual material has formed the foundations upon which to create a searchable resource (in the form of a Web-based database), a number of integrated CAL modules, a CAA module and the development of a suite of electronic lectures containing MTAs. Furthermore, documentation providing 'on-the-job' support and/or 'just-in-time' training (for tutors who required assistance embedding such visual material within their electronic lectures) are provided in both paper-based and electronic forms.

A detailed description of the design and implementation of the framework, database and additional system components is given below.

Detailed resource framework description

The framework (shown in Figure 2) development began by investigating a number of classification systems for the indexing of visual material. It was decided to use a keyword system based on the CI SfB classification (Construction Index/Samarbetskommittén för Byggnadsfrågor; a standard classification system for indexing technical and product information in the construction industry used in Europe and the UK) augmented with user-defined keywords to form a generic index. Each set of keywords associated with a visual object was augmented with administrative information to form meta-data. A number of indexes

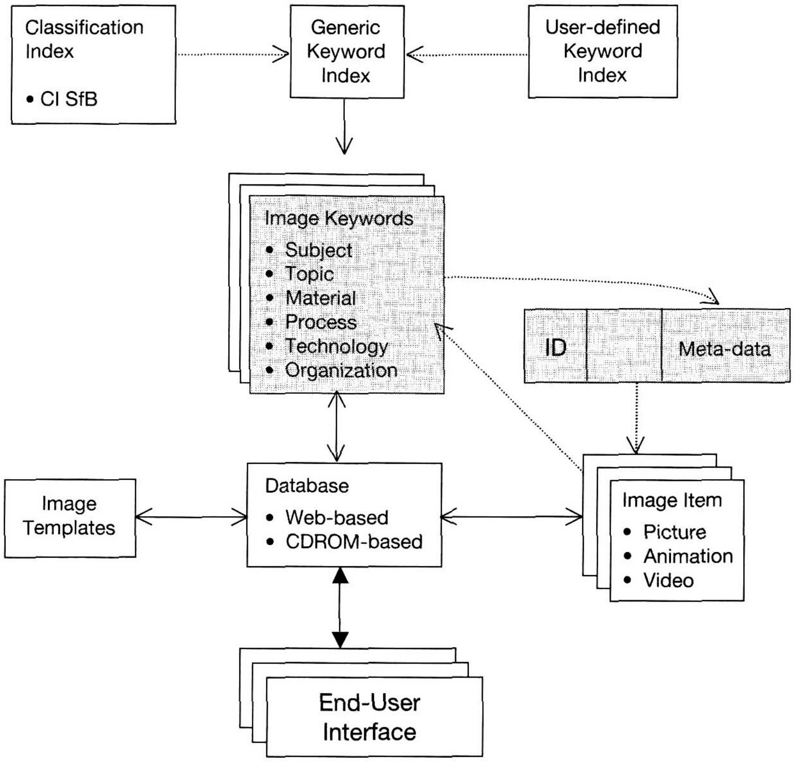

Figure 2 *The CAL-Visual framework*

have also been created using the visual material and meta-data that allow the visual material to be arranged according to a number of key subjects. The entering of meta-data is discussed later in this section.

This framework was also used as the foundation for the design and implementation of a Web-based database which stores the visual material and its meta-data. Once the meta-data and visual material had been entered into a Web-based database, the database could be automatically published along with its indexes. To publish the database as a Website, on the Internet, on an intranet or on CD-ROM, each image was stored in an HTML page template. Once the database was published as a Website, staff and students could use a number of approaches to access the visual materials through an integrated end-user interface.

Database design

One of the project's objectives was to produce a set of CD-ROMs containing platform-independent visual information. The rationale for publishing the database in a Web-based form on CD-ROM was to provide a product that was maintenance free and able to be transported to a server-based configuration if required. This flexibility also enabled the database to be adaptable to the needs of end-users and institutions.

One option considered was to develop the database using a proprietary software tool, such as Microsoft's Access system. One of the advantages of using Access is that it is possible to publish information in the form of a Website. This Website could then be accessed on a stand-alone computer and on a Windows 98 Personal Web Server or on an NT Server.

Another option was to develop a Windows-based database using a bespoke software tool. Such a tool could be developed using a language such as C++. The main advantage of this approach is that the database could be developed so that it is portable over a number of platforms. However, the software tool used to access the database would need to be re-engineered and/or recompiled to operate on each platform. As CAL-Visual will mainly be used on one type of platform, for example Microsoft's Windows, this solution would have been suitable. It does, however, require a large amount of development work.

A third option that could have met the platform-independence requirement would have been the use of Web-based technologies. While these have many advantages over traditional systems, they often require a server configuration that uses CGI scripts (created using high-level computer languages such as Perl) to process the information accessed from a database. This would therefore have been unsuitable in view of the fact that the database had also to be published on a CD-ROM.

The solution actually adopted involved using a combination of the options described above. A Microsoft Access database was created to facilitate the entry of meta-data and the publishing of information in the form of a Website. A hybrid retrieval system was then developed using Web-based technologies. This overcame the issue of retrieving Web-based information, regardless of whether it existed on a CD-ROM or a Web server.

A hybrid retrieval system

Although there are many proprietary software tools and languages available for developing Internet and CD-ROM products, only a few lend themselves to the creation of hybrid text-retrieval search engines. Many of the tools (such as WebCT) are themselves platform-dependent, difficult to learn and use – and are expensive. In addition, the languages that they employ are usually non-standard and they are also difficult to learn. For this reason, two prototypes were developed which use two of the more suitable languages: Java and JavaScript. This approach was adopted because Java and JavaScript are based on a common programming language; they are platform-independent and are freely available. Whilst there were a small number of compatibility problems when using different browsers to run Java applets and JavaScript, the latest versions of the main two browsers (Internet Explorer and Netscape Communicator) are now reasonably compatible

A hybrid retrieval system solution was created for use on a CD-ROM and a server using Java and JavaScript. Because the components were created and embedded within an HTML page, the amount of programming required was reduced. In the initial phase of the project, a number of retrieval system prototypes were developed using each of these Web-based approaches to test their feasibility.

Overall, the Java-based, retrieval system performed the best and as a result showed more potential (Table 1). The next stage of the project involved developing a simple textual user-interface in the form of a HTML form which could provide staff and students with easy access to visual material. Figure 3 illustrates the system's 'Search' interface while Figures 4 and 5 show the results of an example search for 'Bricks' with a display of a large size example of an image.

Table 1 *Advantages using Java and JavaScript to develop a search engine*

Java • Applets can be called remotely • Applets reduce duplication of code • Applets can be run on both a client and a server • Applets do not suffer from the same security problems • Source code can not be easily copied	**Java search engine** • Information can be stored in any number of files • Can access any file using a URL • Can access any file on a client or server • Information can be stored as HTML pages • Engine is more likely to run faster for large databases
JavaScript • Easier and faster to develop • Does not require compiling • Scripts are run directly from within a HTML page • Source code easily copied • More compatible between browsers	**JavaScript search engine** • Data, form and code can all be put in one file • Engine is more likely to run faster for small databases

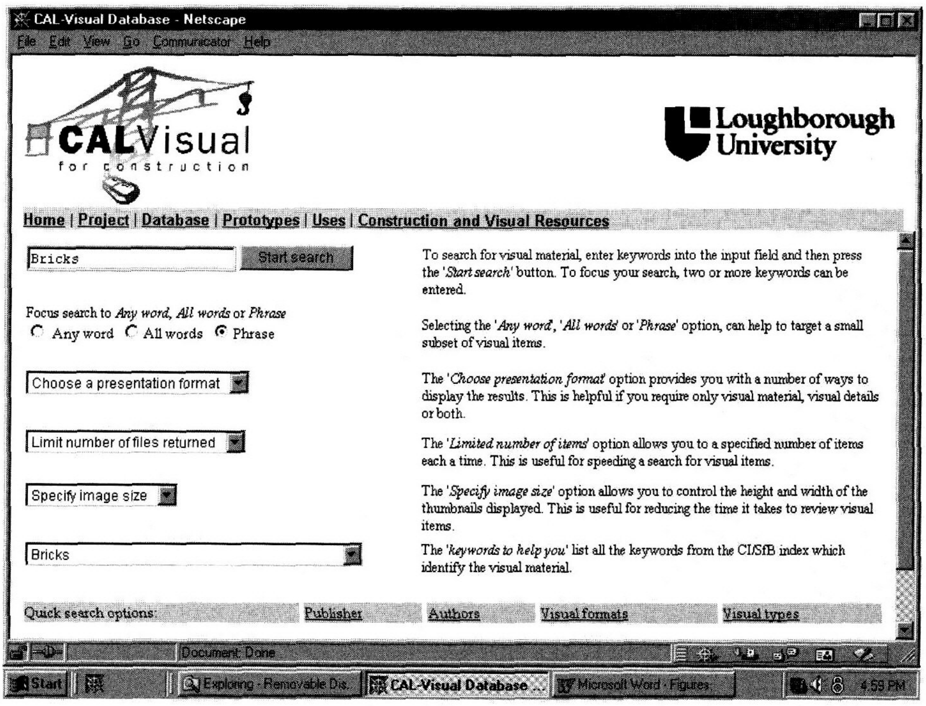

Figure 3 *An example of a search for 'bricks'*

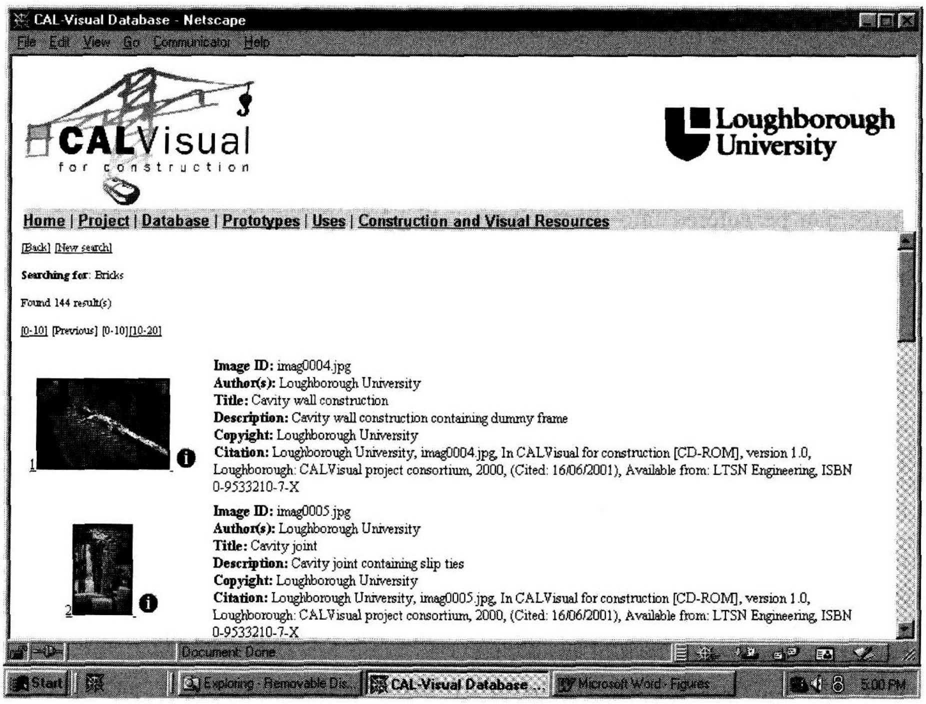

Figure 4 *A sample of the results of a search (in this case for 'bricks')*

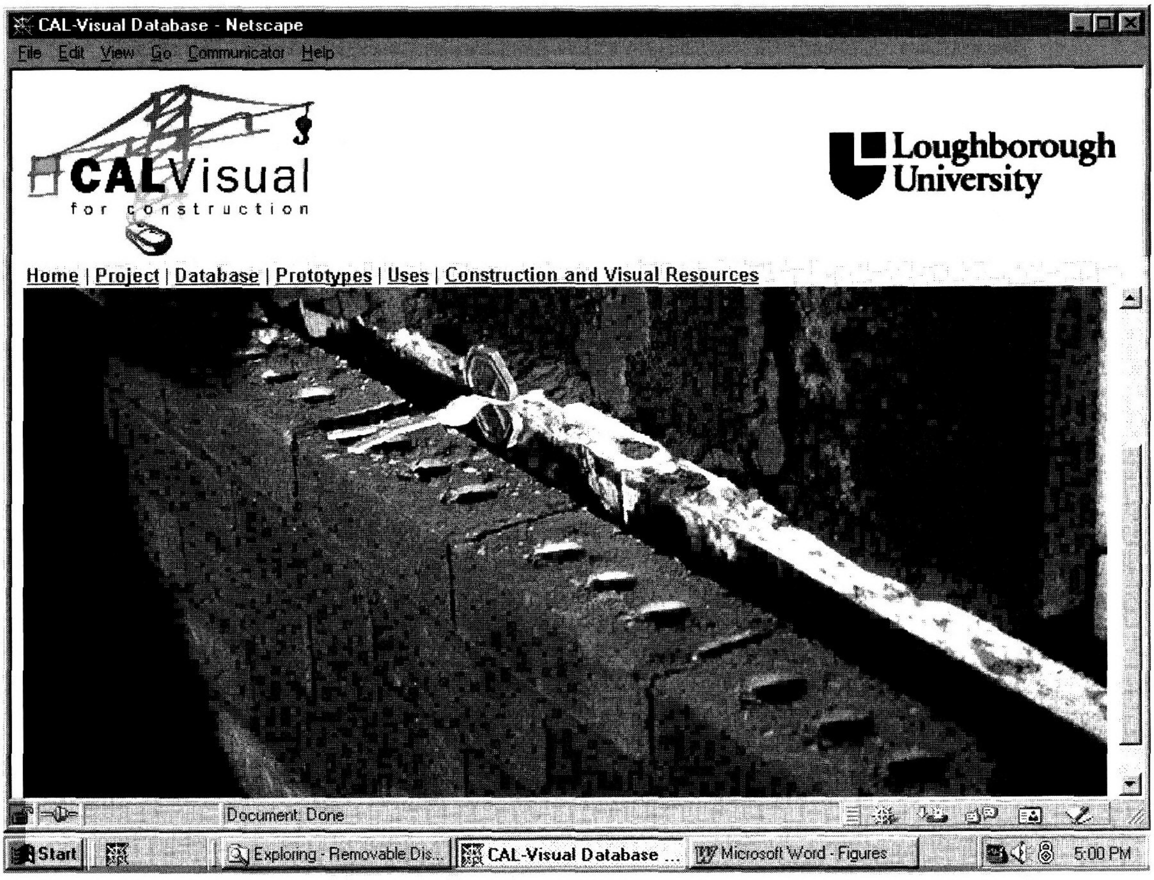

Figure 5 *An image (displayed after clicking on the 'thumbnail' shown in Figure 4)*

Marking up images

Before an image can be entered into the database and accessed through the retrieval system, it must be described in textual form (otherwise known as 'marking up'). This allows the hybrid retrieval system to search the database for particular images based upon specific criteria. For consistency, the marking up of each image is based on the fields that should accompany each image – as shown in Table 2. The table also acts as a support aid to help end-users mark up images and describes each of the fields and the format of the field. For efficiency, a Microsoft Access form was produced for entering this information.

Keywords selected from the CI SfB classification (mentioned above) are used to describe each image. This list of keywords is also displayed in the Access form and can be used as a reference aid. Whenever a keyword that is not in the index is used to identify part of an image, it is added to the list.

As well as the keyword field, each image has five other fields including: image ID, title, date entered, author/owner, copyright details and process/description (see Table 2). Each of these additional fields is used to manage and publish the resources. In addition, this data is displayed as a complementary aid when end-users search for specific materials.

Finally, it was decided to physically store the actual images within a single directory. This makes the retrieval system's task of finding specific images easier – as long as they were identified within the database – and makes a Web-based database easier to develop, publish and maintain.

The CAL-Visual package

The CAL-Visual system is 'packaged' as a CD-ROM and also includes several paper-based manuals. The CD-ROM provides the following:

Table 2 *Marking up fields*

Fields	Description	Format	Example
Image ID	Reference number (see left of images)	[ImgXXXX.jpg]	Img0001.jpg
Title	Summary of image	[String]	An outer wall
Author/Owner	Creator or holder of image	[Surname, Initials]	Beacham, N
Date Created	Date when image taken or put in database	[dd/mm/yyyy]	01/01/1998
Processes/Description	Detailed description of image including any processes being performed	[String]	Building a wall
Keywords	A list of comma delimited words and phases describing materials, labour, technology, defects, components, tools, systems, plant, manufacture, etc.	[keyword, keyword, etc.]	Wall, bricks, cement, window, window ledge
Image Type	Text, drawing, graphic, photo, animation, simulation, emulation	[Type 1, Type 2, etc.]	Drawing, photo

- a database of visual resources including approximately 1300 images, animations, drawings and video clips;
- user documentation (as described below), available in Adobe Acrobat Reader format (PDF) – the screen interface which allows users to access this documentation is illustrated in Figure 6;
- descriptions and examples of prototype computer-based teaching and learning aids, all of which make use of CAL-Visual resources (one of which is illustrated in Figure 7);
- a comprehensive collection of links to related Internet resources; and
- a brief background description of the CAL-Visual project.

The paper-based documentation that is provided comprises of:

- a user's guide that directs users through selecting, downloading and manipulating images extracted from the CAL-Visual CD-ROM;
- a technical guide that provides details about CAL-Visual and instructions on how the system should be installed;
- a tutor's guide that provides suggestions on how visual material may be used for the support of learning and teaching;
- a quick reference guide that summarizes how to find, download and reference visual materials extracted from CAL-Visual; and
- a feedback form, designed to assess the effectiveness of CAL-Visual and to aid further enhancements.

EVALUATION OF THE CAL-VISUAL SYSTEM

In the current climate, financial, time and staff constraints restrict the number of building site visits tutors can arrange for students. As already mentioned, using construction images can be an effective way of exposing students to real-life examples of buildings, the construction techniques by which they are erected and the materials of which they are composed. This section describes the way two tutors at different universities have responded to this challenge. In the first institution, staff have incorporated images from the CAL-Visual database into PowerPoint presentations. These were also made available, via the Web, for students to use in their own time. In the second institution a Web-based learning resource was developed, using images from the CAL-Visual database. These were delivered to Architectural Design Technology and Building Construction students.

The efficacy of these two learning resources was evaluated in association with the EASEIT-Eng project. The EASEIT-Eng project aims to assist engineering academics select computer-based learning (CBL) material for use in their teaching. The project has established a standardized evaluation method for engineering CBL material and has evaluated a wide range of existing engineering CBL material (see http://www.easeit-eng.ac.uk/). Full details of the evaluation can be found in Henderson (2000), a summary is presented below.

The overwhelming response from both students and

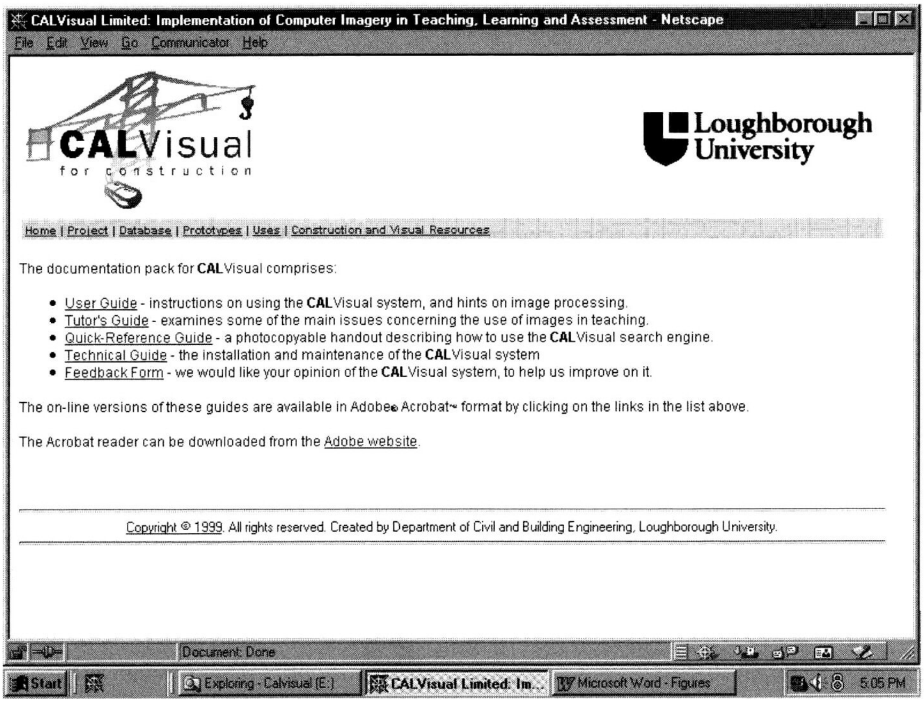

Figure 6 *The CAL-Visual documentation available on CD-ROM*

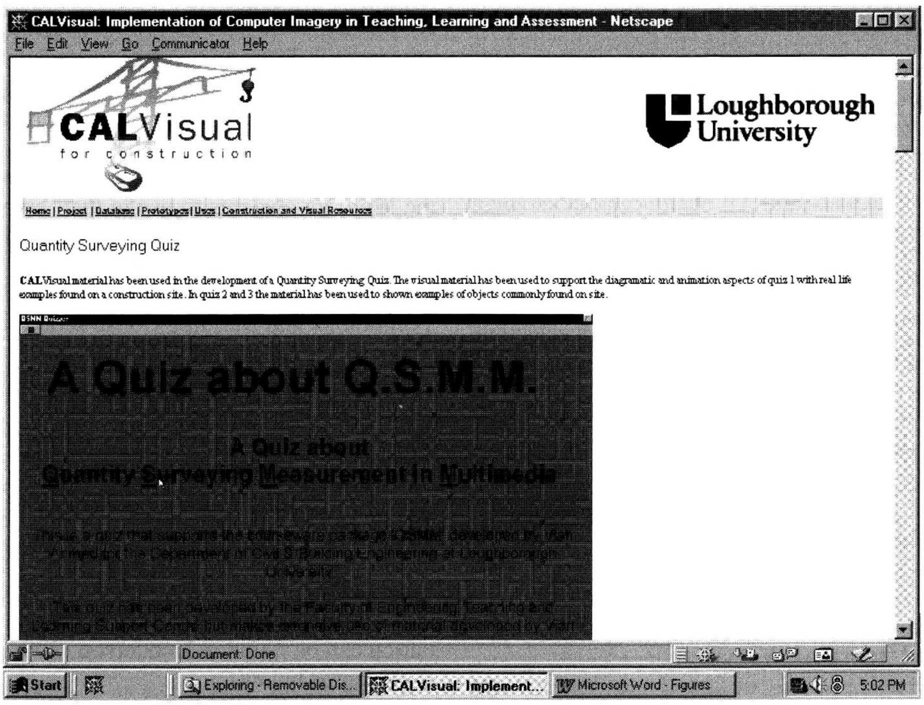

Figure 7 *An extract from the 'QSMM' computer-aided learning package*

tutors at the two sites was that the learning resources were valuable additions to the teaching curriculum, being easily accessible and easy to understand. Students found that, in the absence of regular site visits, the images were a key factor in relation to their understanding of the aspects of building construction that they depicted. Animations were found to be the most popular feature of the system as they offered the students a degree of interaction stimulating their assimilation. They also felt that, in general, the delivery mechanisms used by the resources were more engaging than a standard lecture or textbook. As such, the images played a significant part in increasing their motivation to learn the subject material covered. Students also expressed considerable interest in the availability of the CAL-Visual images for use in their own projects, coursework, and as a revision tool. On the negative side, image download times for the two Web-delivered learning resources were noted as being slow at times, and access to networked computers was occasionally a difficult task.

The two tutors found the CAL-Visual database a useful, easy-to-use source of construction images. The convenience of having a wealth of categorized, searchable images, held in a single location, was said to be its major attraction. Previously, images were painstakingly sought from numerous non-searchable, non-categorized sources including textbooks and other image archives.

CAL-Visual's potential target audience was thought to be widespread across the whole higher education engineering community. However, the need for a more diverse range of images to be included in the database was highlighted. This extended coverage would generate a truly universal resource of engineering construction images. It is hoped that the interest enjoyed by CAL-Visual during the life of the project will encourage users to submit their own images. This will enable the database to continue to expand and will ensure that it remains a useful aid for the teaching of construction engineering in the foreseeable future.

CONCLUSION

This paper has discussed the potential of using multimedia technologies as a tool for facilitating the development, and organization of teaching aids in subject areas where the use of imagery is important. Electronic course delivery and electronic open-access student information service principles were used in the CAL-Visual project to develop a system for the organization and retrieval of digital resources.

The paper has outlined the rationale and a methodology for using Web-based multimedia technologies within the CAL-Visual project and has described the design and implementation of the CAL-Visual system. A summary of a detailed evaluation to measure the effectiveness of embedding visual material within a construction-engineering curriculum using the CAL-Visual system has also been presented.

The CAL-Visual project has demonstrated the potential offered by CIT for the management of digital resources. Although the focus of the project was on built environment education, the scope extends well beyond these boundaries. The system is flexible enough to be populated with other types of image that can equally benefit other disciplines where visualization plays an important part of a teaching and learning process. Furthermore, as a generic management tool for digital information, its potential use could also include areas other than education.

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BIOGRAPHICAL NOTES

Dr N Bouchlaghem is a Reader in Architectural Engineering and Design Management within the Department of Civil and Building Engineering at Loughborough University. His research work focuses on the application of information technology in general, and visualization techniques in particular, to various aspects of the construction industry including issues related to education and training.

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Dr A Wilson is Director of Staff Development at Loughborough University. He has been involved with numerous externally funded learning and teaching projects and was convenor of the management group of the Learn Project on the development of the University's VLE.

Dr N Beacham is a Research Associate in Distance Learning within the IMPACT Research Group, Department of Computer Science, at Loughborough University. His research work focuses on the theory and application of Human-Computer Interaction (HCI) in general, and user interface design for computer-based learning systems in particular, to various aspects of educational technology including issues related to people with learning disabilities.

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