3-D Models and Hypermedia for Architectural Education

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Abstract:

Hypermedia uses the hypertext style of interactive navigation through computer-based multimedia materials to provide access to a wealth of information for use by teachers and students Academic disciplines concerned about the enlightenment of future designers of the built environment require an additional medium not yet available in hypermedia - interactive 3-D computer models.

This paper discusses a hypermedia CAI system currently being developed at The University of Hong Kong for use in architectural education. The system uses interactive 3-D computer models as another medium for instructional information, and as user orientation and database access devices. An object oriented, 3-D model hierarchy is used as the organizational structure for the database.

A prototype which uses the system to teach undergraduate architecture students about a traditional Chinese temple is also illustrated. The prototype demonstrates the use of a computer as the medium for bilingual English and Chinese instruction.

Keywords:

3-D Modelling - Architectural Education - Computer Aided Instruction - Hypermedia - Multimedia

1. Introduction

Architectural design is one of the most complex undergraduate subjects currently taught in academia. While most traditional subjects can depend on words to transmit information from human or printed knowledge sources to masses of students, the multi-disciplinary nature of architecture demands that students of design understand abstract concepts, processes, visual images, and physical objects, in addition to numerous facts and figures. Thus architectural educators must often augment the traditional word-oriented media of printed text and spoken words with images, drawings, and 3-D models.

1.1 Multimedia and Hypermedia

"Multimedia" is an emerging branch of information technology which deals with the creation, storage, and presentation of information in various media forms (I.e. text, image, drawing, audio, animation, and video) via a computer. lt. is currently an extremely popular application of computers because recent advances in technology - high resolution full colour (i.e. 24 bit) graphic displays, high speed multi-tasking parallel processing CPUs, large capacity digital data storage devices, and dedicated audio, video, and graphic co-processors - have Made certain hitherto impossible aspects of multimedia relatively cheap and easy to implement.

"Hypermedia" is the combination of a hypertext style of interactive, access to information with the wealth of teaching materials available via multimedia. It allows for formal teaching and structured learning, and it encourages independent self-learning through browsing. For many academic disciplines, hypermedia promises to revolutionize teaching methods and learning attitudes.

The demands of architectural education for hypermedia with real-time interactive access to sights, sounds, and 3-13 models make the current crude 2-D page-turning multimedia systems unacceptable as a CAI tool for teaching budding architectural designers.

1.2 Hypermedia and CAI

Ignoring for the moment the task of developing and maintaining the system, computer-aided instruction (CAI) can be broadly viewed as having only two primarily human oriented activities - authoring and delivering. "Authoring" is the CAI equivalent of a lecturer assembling courseware, which includes all the information which will be used for a particular course of instruction. "Delivering" is how students receive the information in the courseware. The CAI system accepts the material produced by the author, stores it, and regurgitates it in a useful manner to a student user. The system provides the link between the teacher and the student,

The technical requirements for the production of high quality multimedia materials can make authoring,much more difficult for a teacher than just preparing a word-oriented lecture, and the cornplexities of hypermedia navigation can confuse a student much more than just turning the pages of a book or trying to stay awake during a lecture. One role of the CAI system is to provide a set of rules which control how an author must define materials to be included m the database, and how a student can expect to access those materials, to make it as easy and efficient as possible for both authors and users within the constraints of the system.

1.3 CAI and Architectural Education at HKU

Teachers in the Faculty of Architecture at The University of Hong Kong are generally computer literate, but they are not computer experts. They are comfortable with e-mail messages, word-processed course notes, and CAD submissions from students. They all have at least a networked PC level computer in the office, and they all have VCRs and CD players at home.

Students are masters of sophisticated arcade games, and they have seen all the current movies which advertise the use of computer graphics. They are required to use Departmental, Faculty, University and/or personal computers to produce and present projects in both design studio and lecture courses. They too have VCRs and CD players at home, and they expect the quality of sight and sound of the cinema or the NICAM home video system, plus the speed and response of the arcade, in any computer based system. These are the standards they expect as users of computer systems, and they will question any CAI system (including its knowledge content) which can't deliver information at this level.

Because of external pressures to reduce the costs of teaching staff and increase opportunities for self-learning, the Departments of Architecture and Surveying at HKU have since mid-1991 been developing a realistic and cost-effective hypermedia CAI system specifically for architectural education. In addition to the considerations for performance, people, and resources listed above, the system needed to recognize several additional factors:

1.3.1 3-D

As noted earlier, architectural education relies on the availability and integration of spoken and written words, 2-D images and drawings, and 3-D objects and models. None of the current commercially available hypermedia systems accommodate 3-D computer models, and this was a major impetus for HKU to develop a new system which includes interactive 3-D computer models as an additional medium for instructional information.

Early evaluation tests of existing hypermedia systems indicated that user disorientation during navigation through a large database was a major problem. Because students of architecture must be able to understand and manipulate the complexities of 3-D objects and spaces if they are to succeed as designers, 3-D models are also used as orientation and database access devices. The object oriented relational database is also organized around the inherent hierarchical structure of a 3-D object.

1.3.2 Digital Media

Early multimedia systems used a computer to control external devices for traditionally analogue media such as audio and video. Inexpensive digital photography, DAT, and full-motion full-frame digital video now allows all information to be developed and stored as digital data. At present this means the use of a large capacity volatile hard disk as the prototype database is evolving too quickly to commit it to CD-ROM.

1.3.3 Portability

Although the system and the prototype database could be developed on a high end graphic workstation, it would eventually need to be implemented on the lower end hardware available in the student computer lab. Thus the system needs to be as portable as possible.

1.3.4 Student Authors

Project work produced by senior students is frequently used as teaching material for students in lower years, so students are also authors. But persistent problems with incorrect facts, copyright violations, etc. have prompted an additional stage in student information development. Students are still encouraged to produce studio or coursework projects in a format which is compatible with the system, but this information must be vetted before it is added to the database.

1.3.5 Bilingual Instruction

Staff and students in the Faculty of Architecture at HKU are unique in that most are Chinese in an English language University, located in a city which speaks a Chinese dialect which is not the same as the official dialect of the PRC. This means that most authors and users of the CAI system:

read, write, and speak English as a second language;
read and write Chinese characters;
speak Cantonese;
do not speak Mandarin.

The implications of this bilingual situation for a CAI system will be explained later in this paper.

2. A Hypermedia System for Architectural Education

By definition a hypermedia system involves the use of computer hardware and software for the tasks of authoring and delivering information in various media. A hypermedia system for education is fundamentally concerned with the transfer of knowledge from a teacher to a student via a computer. It defines rules needed to govern the production, storage, and delivery of information in various standard media formats. It provides the inter-face between authors and users, people and computers, and collections of disparate data.

This section will present the components of a hypermedia system for architectural education, and discuss some of the major considerations for these components. It will not discuss the vital aspects of database organization and the links between chunks of information in the database because these topics are covered in a separate paper.

2.1 Hardware

The physical equipment needed for a complete hypermedia system is not the most costly part of CAI, and CAI is not the most costly aspect of architectural education. Proper hardware is essential to the success of a hypermedia system which can satisfy the demands of architectural education.

Figure 1 shows the configuration of a hypermedia authoring station which consists of the following components:

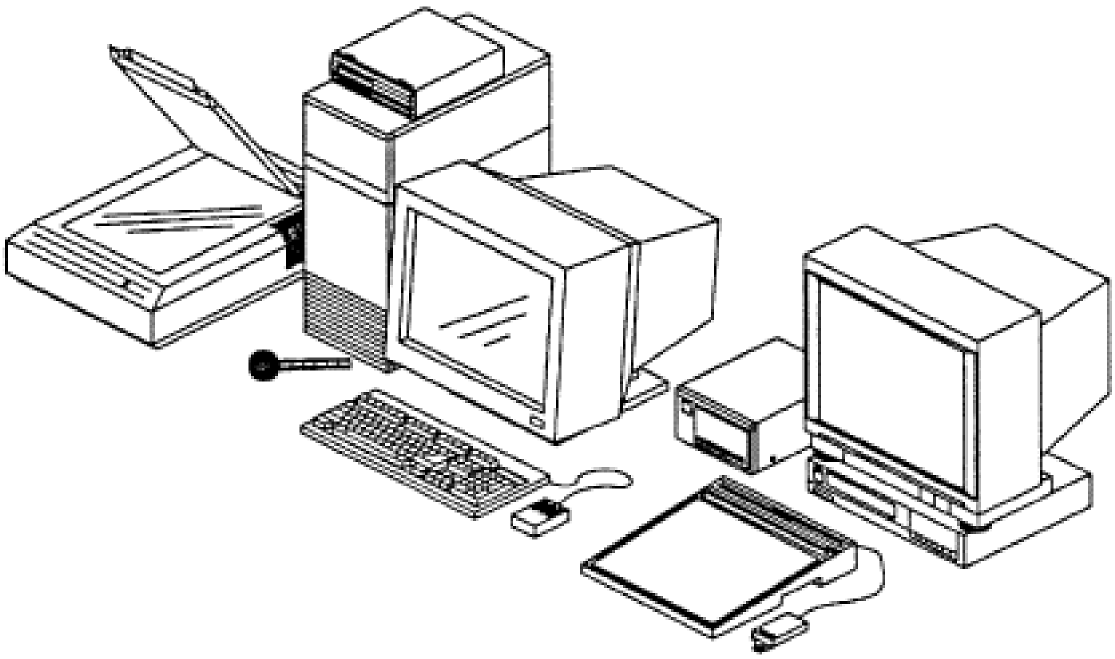

Figure 1 : Components of an Authoring System

2.1.1 Computer

The computer is an entry level Silicon Graphics (SGI) IRIS Indigo 4D/RPC with "Virtual 24" 8 bit colour display, 16" monitor, 432MB system hard disk, 40MB RAM, 1.2GB DAT tape drive for back-up, and a 1.44MB floppy disk drive for data transfer with PCs. The reasons for selecting Indigo as the easiest and most cost effective development platform will become clear later in this paper.

2.1.2 SCSI Hard Disk

Because the system and the prototype are developing rapidly, it is not practical to commit the data to an unchangeable CD at the present time. An external 1.2GB SCSI hard disk is used to store the data and to simulate a CD-ROM.

2.1.3 CD-ROM

Eventually all the programs and data associated with the system will be stored on CD-ROM. The amount of information commercially available on CDs is enormous, so a CD-ROM drive is essential.

2.1.4 Digitizer and Scanner

Most of the existing information about Chinese temples is on paper, so a digitizer and a scanner are necessary to convert paper drawings and images into digital data.

2.1.5 Audio

The IRIS Indigo includes a dedicated audio co-processor which supports 24 bit digital stereo and 16 bit analogue stereo. General purpose audio, audio file, CD-ROM, DAT, and MIDI utilities are included in the software.

Audio input is via analogue mono microphone, analogue stereo line, digital serial line, DAT, or CD-ROM. Output is mono internal speaker, analogue stereo headphones, analogue stereo line, or digital serial line.

2.1.6 Video

The Indigo Video board supports 8 bit real-time 3es video input and output in NTSC or PAL format, and S-Video or composite quality, Single frame 24 bit RGB genlocked Video output can also be produced. A Video Library is included with the software.

There are three software switchable Video inputs for sources such as VCR, videodisc, videodisc still camera, or video camera. Output can be either single frame 24 bit RGB, or composite or S-Video.

2.1.7 Network

Multimedia uses large amounts of data. The transfer of large data files between different computers is tedious with 1.44MB floppies, and the ability to FTP files via LAN is welcome.

2.2 Software

As noted earlier, none of the currently available commercial CAI systems could meet the requirements of architectural education, so HKU is developing a new system. This development uses several standard portable software packages.

2.2.1 Operating System

SGI supplies the UNIX compatible IRIX operating system, based on AT&T UNIX System V.4 and BSD UNIX 4.3. The graphic user interface (GUI) uses X Windows and the X subset Motif, and screen displays use Display PostScript. Included with the OS is the SGI Graphics Library which has recently been endorsed as an industry standard for 3-D graphics by Compaq, DEC, Intel, and Microsoft.

2.2.2 Programming Languages

Because of its popularity and portability, C has been adopted as the language for system development. the object oriented derivative C++ is also used extensively because of the object oriented nature of the project. Authors and users of the system never come into contact with the programming languages used for system development.

2.2.3 Utilities

Details of software used to produce individual media types is discussed in Section 2.4, but there are some useful general purpose utilities. The Digital Media Developer Kit from SGI includes routines for file compression and decompression, and various audio, video, and image manipulation utilities.

2.3 Authoring and Delivering

The process of authoring high quality multimedia materials can be demanding in terms of time, hardware, and software. The hypermedia system described tin this paper attempts to allow authors considerable flexibility in their choice of equipment and computer programs. If the author prefers to work at home with a PC and a familiar drafting package or word processor, then the results can still be added to the database by using a floppy disk or a network for data transfer. Small routines for various data file format conversions are written by the technicians if required.

Delivering is much less demanding than authoring. The only equipment needed is the computer, the SCSI external hard disk, and an audio monitor (e.g. headphones, walking speakers, etc.) The only software is the operating system, the hypermedia system, and the database.

The Indigo does not allow simultaneous live video and true 24 bit graphics in one computer. As a delivery station doesn't need live video because of the use of totally digital media in the database, delivery systems can provide 24 bit colour graphics while authoring systems use "Virtual 24" 8 bit graphics with live video I/O.

2.4 Media

An important aspect of a hypermedia system is the quality and quantity of the information available to a user. These are largely determined by the author, the hardware, and the hypermedia system itself But a users perception of the information is determined primarily by a combination of three factors:

- how information is created - the easier it is for an author to create and input high quality information, the more information they will provide;
- how information is stored - all digital storage devices have a finite capacity;
- and how information is presented - a user will become discouraged if delivery speed, resolution, etc. is not adequate.

This section will describe how each of the six media types is created, stored as a digital file, and ultimately delivered to a user.

2.4.1 Text

Printed words which represent spoken sounds are the mainstay of traditional teaching and CAI. Although less import in multimedia, text is still a useful teaching medium.

An English language text file is produced by an author using any word processor which can output a non-document ASCII file. This file is stored as an ASCII format text file, and is displayed on the screen during delivery in a text viewer window as shown in Figure 2. The window can be positioned and re-sized by the user, and a scroll bar is automatically added to the window if the text file is too long to be displayed completely in the current window size. The user can also change the font style and type size, and the window width will be automatically adjusted as necessary to fit the new font style and size.

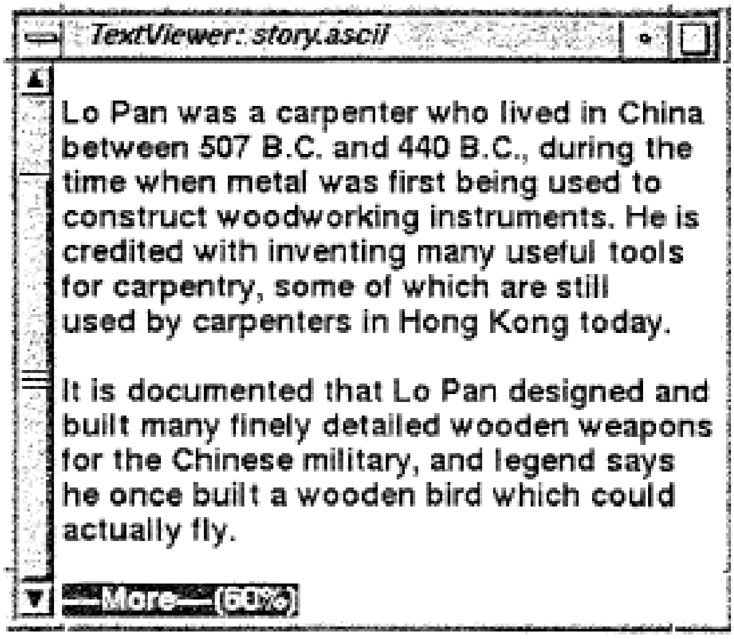

Figure 2: TextViewer Window

Keywords in the script which contain a link to a glossary definition of that term are coded the ASCII file as italic text, and are displayed in the text viewer window as blue coloured text. Keywords or phrases which act as hot-spots With links to additional chunks of information are coded as bold text and displayed as yellow text.

When the user clicks with the mouse on blue text, another window opens to display the glossary information for that keyword. This information currently may include text, images, and/or drawings. Closing the glossary Window returns the user to the original text viewer window.

Clicking on yellow text opens another text Window, or one of the other available media window types described later. The window type is determined by the type of media available for the additional material for the chosen keyword or phrase. This second level window usually contains hot-spots to further chunks of information, which will open other windows with other hot-spots, etc.

Chinese text is similar to English text, "Big-5" is a 2 byte equivalent of the ASCII standard used by Chinese word processors to produce Chinese text files composed of ASCII characters. This standard is used to code and display the Chinese characters in a text viewer window with characteristics similar to the English text viewer described previously.

Other text file formats (e.g. Rich Text Files (RTFs), word processor documents, etc.) are currently not supported by the text viewer window.

2.4.2 Audio

Discrete audio (i.e. sounds which are created and played independent of other media such as

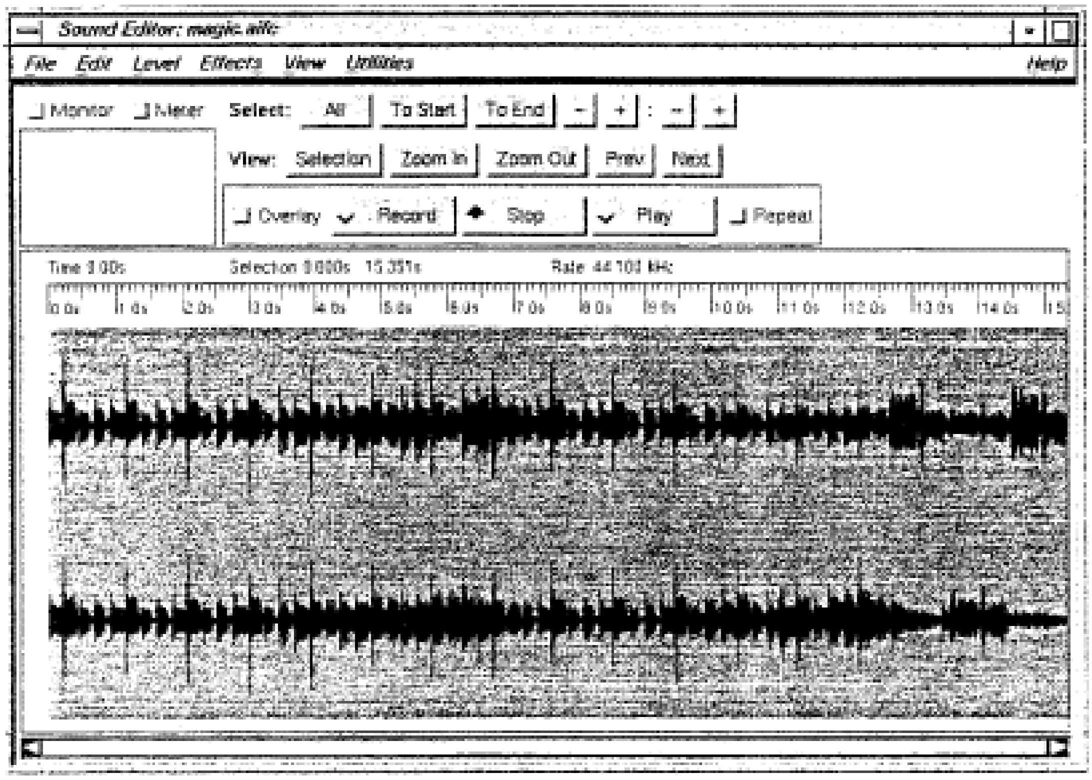

Figure 3 : **Sound Editor**

Video or animation sequences) consists of sampled sound stored as compressible digital Audio Interchange File Format (AIFF-C) format files. The sounds are initially recorded to disk directly from a sound source (e.g. microphone, DAT tape recorder, CD-DA disc player, etc.) or they can be obtained by converting different format sound files (e.g. Apple AIFF, NeXT/Sun, or IBM/Microsoft RIFF Waveform) generated on other computers. We have only recently begun to experiment with the use of Musical Instrument Digital Interface (MIDI) electronic instruments to create original music and sound effects.

After the sounds are stored as digital audio data in a file, the author can edit or enhance the file as required using multi-track digital recording, editing, and mixing utilities similar to that shown in Figure 3. The sound file is then "re-recorded" (i.e. digitally converted) if necessary to the lowest acceptable sampling rate for the desired quality of sound fidelity. This minimizes the required disk storage space size for each individual final sound file. This is important because, as shown in Table 1, uncompressed high quality sound can use a lot of storage space - CD quality music requires a file of more than 10MB for 1 minute of playing time while "telephone" quality can store about 1/2 hour of speech in the same file size.

Several data file compression techniques have been tested in an attempt to reduce the disk storage space required for high quality sound files. At best they only provide about 4:1 compression without real-time decompression during playback. Thus audio files are currently a compromise between quality of sound and quantity of storage.

During audio file playback an audio player control panel, as shown in Figure 4, is displayed

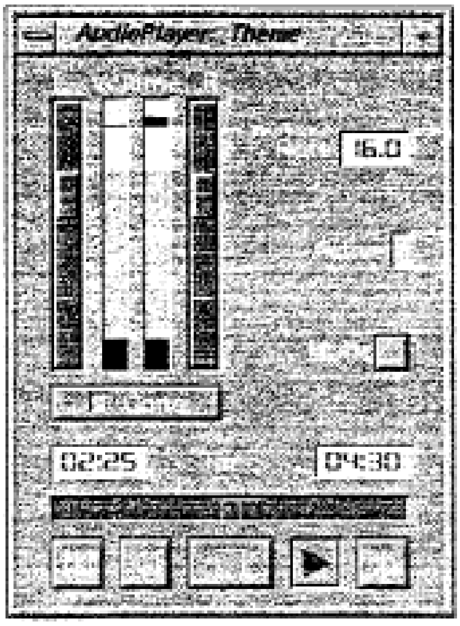

Figure 4: AudioPlayer Window

on the screen. This panel allows the user to monitor the playing time, and control the output volume and the start, stop, fast forward, and rewind functions for the sound file. If the sound file ends naturally, then the control panel vanishes from the screen. If the control panel window is closed, then the sound file stops playing.

QUALITY	BANDWIDTH kHz	CHANNELS	SAMPLING RATE BITS @kHz/SEC	STORAGE KB/SEC
TELEPHONE	4	1	8 @ 8	8
	5.5	1	8 @ 11.025	11
	8	1	8 @ 16	16
AM RADIO	11	1	8 @ 22.05	22
FM RADIO	16	2	16 @ 32	128
CD	22	2	16 @ 44.1	176
DAT	24	2	16 @ 48	256

Table 1 : Disk Storage Requirements for Selected Sound Qualities

2.4.3 Images

As colour or black and white tonal representations of 2-D visual information, images are digital bitmaps which contain the red, green, and blue (RGB) values for each pixel on the display screen. Images are stored as SGI RGB files using Run Length Encoding (RLE) compression to minimize stored file size, and decompressed in near real-time when displayed. Typically a digital image is created by scanning a photograph, generating a ray-traced photo-realistic rendering, or "frame-grabbing" a single frame from a video source. Different digital image file formats (e.g. TIFF, PICT, TARGA, etc.) produced on other computers are converted With IRIS Image Library routines to RGB after being imported to the authoring station.

Stored digital images can be retouched by an author using special "paint brush" programs or IRIS Image Library routines, but they cannot easily be re-sized by a user during delivery because they are bitmaps which relate directly to specific pixels on the screen. Thus images must be "dithered" when enlarged or reduced by a user during delivery to produce RGB values for pixels which would otherwise be undefined. There are several methods which can be used to calculate the value for a dithered pixel, but as dithering is at best an educated guess for the RGB value of a pixel, the best visual quality for an image is obtained when the image is displayed at the original size as defined by the author.

2.4.4 Drawings

Graphic line drawings, diagrams, and other geometric figures which use vectors rather than tones to convey 2-D visual information are treated as drawings. This medium is traditionally very important to designers, so the proper representation of drawings is critical. As such it presents some special problems for a CAI system for architectural education.

When a line drawing is photographically enlarged, the widths of the lines in the drawing are also enlarged. If an author wants to maintain this characteristic, then they can define the drawing as an image where everything is scaled proportionally. But when a draftsman produces drawings at different scales to show different levels of detail, they use line weights consistent with the size of the drawing rather than the scale of the drawing.

Several computer techniques exist to maintain consistent line widths in drawings of variable size and/or scale, the two most popular being the Hewlett-Packard Graphic Language (HPGL) and the PostScript language. Details of these techniques can be found in appropriate reference manuals.

Drawings are produced by an author using any of the popular drafting programs (e.g. AutoCAD, VersaCad, etc.) The output device of the drafting program is defined to be a PostScript device, and the output is directed to a file instead of a plotter. The resulting PostScript file can then be directly displayed on the screen with the PS drawing viewer, and it can be re-sized by the user without altering the line weights.

If a drawing scale is enlarged, or the drawing viewer window size reduced, by the user to an extent that the whole drawing is no longer visible in the drawing viewer window, then vertical and horizontal scroll bars are added to the window. This allows the user to pan across the entire drawing and view only those areas of the drawing which are of interest at a size and a scale which is appropriate.

2.4.5 Animation, Video, and Movies

The illusion of movement within computer graphic screen images has always captivated viewers, and computer animation is currently very popular in broadcast TV and the cinema. Because all the information in the system database is stored and displayed as digital data, animation and video are both treated as digital "movie" format files - the timed display of a

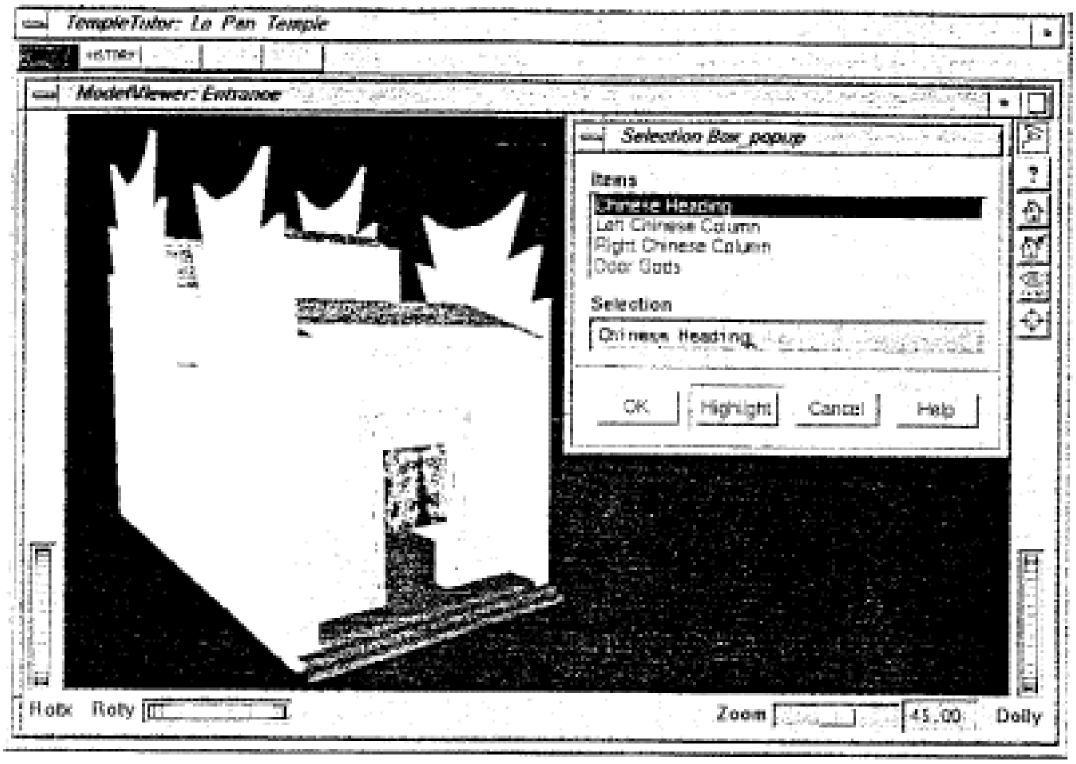

Figure 5 : ModelViewer Window

sequence of digital bitmap images which may be coordinated with a sound track.

Video clips are created using television equipment to produce analogue signals for a sequence of frames. Each frame is converted to digital image data similar to the image media RGB files discussed earlier. The sequence of image files is stored as a movie format file with an associated sound track similar to the audio media files discussed earlier. Each frame in the movie file has a fixed window size of 640 by 480 for NTSC (or 768 by 576 for PAL), and a playing rate of 30 frames per second (or 25 fps for PAL).

Animation clips are created by using the computer to generate a series of RGB images. These are also stored as a movie format file with an optional sound track, The window size is unlimited but must be consistent for all images in any one movie clip. The playing rate is variable, but anything less than 50 frames per second looks jerky during playback unless double buffering is used.

2.4.6 Models

A model is a digital representation of a physical object, typically a component, a building, or a collection of buildings in a context. Models are composed of polygons which have spatial (i.e. X, Y, and Z) locations, as well as transparency, colour, and textural properties. They also have established relationships (e.g. parent-of, child-of, part-of) with other models, and they contain links to additional media information.

Models are viewed in model viewer windows which are similar to the other media windows

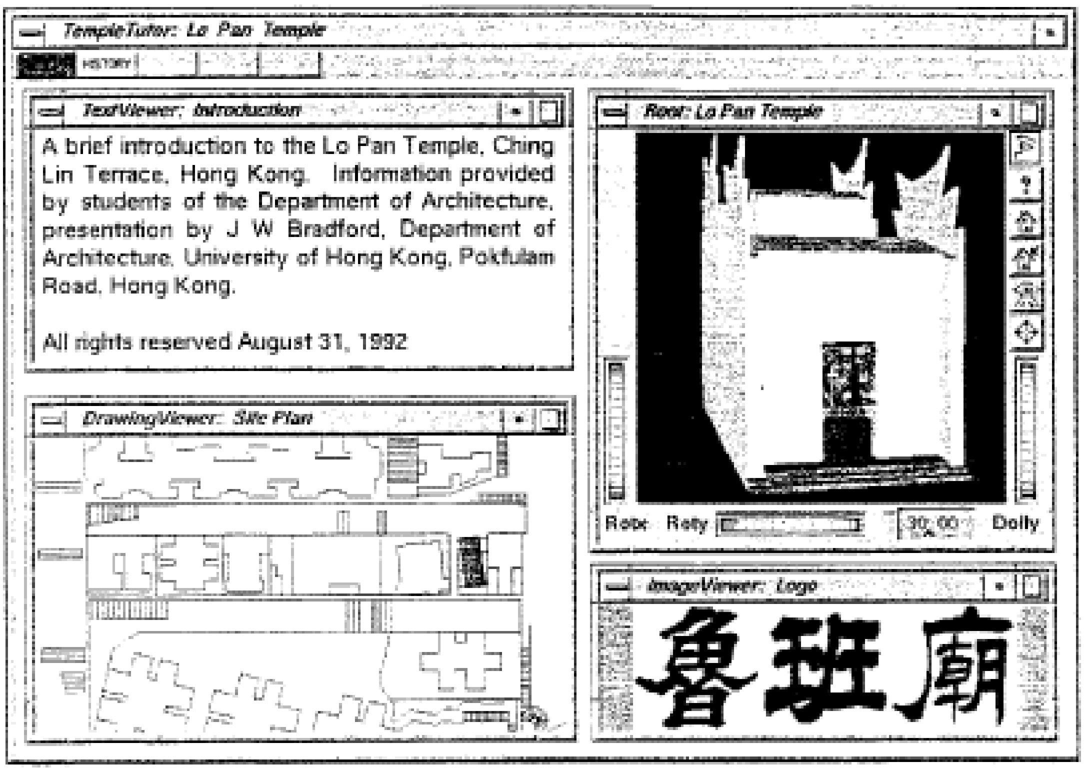

Figure 6 : Lo Pan Temple Opening Screen

(e.g. user sized, positioned, pushed, popped), but they have some special 3-D controls not present in the other windows. These controls include thumb wheels for X and Y rotation and Z translation, clipping plane positioners, etc. An example of a model viewer window is shown in Figure 5.

Figure 5 also demonstrates the use of a pop-up Selection Box. When an element in the model is selected by a user, the Selection Box appears with a list of all the elements comprising the model which are visible in the current view. Thus elements in a model can be selected by pointing at them with the mouse, or by selecting them from a text list.

A model viewer window is also used to display a special model called "Root." The Root model is a visual representation of the first layer of models which comprise the subject of the courseware. These upper layer models contain the links to other media information about the particular model, and to second layer sub-models.

The Root model window is the only media window which must always be visible on the screen. Because it is the principle user orientation device, and the primary access to other information in the database, closing this window would terminate the program.

Several modelling software packages can be used to describe the visual aspects (e.g. size, shape, colour) of a model, but at present the only easy way to define the relationships and links is via the C++ routines in the SGI Inventor Toolkit. When compiled, the model file produced by Inventor contains all the information necessary to describe the physical object and its relationships and links. The compiled file also includes the facilities to display and

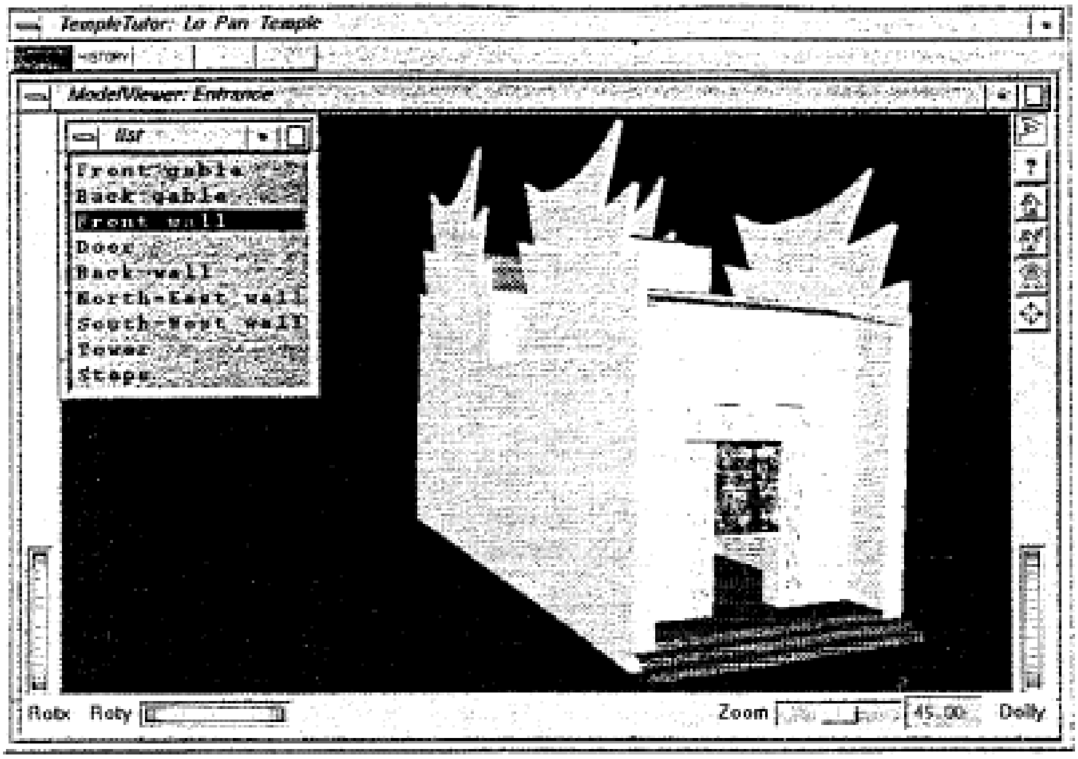

Figure 7 : A Typical Temple Tutor Screen

manipulate the model in a model viewer window.

3. A Sample Session with Temple Tutor

It is not possible to accurately convey the atmosphere of a dynamic hypermedia system in a static paper. A video of a sample session with a student browsing will be shown at the conference in an attempt to present the feeling of actually using the system. The following Figures are included here for reference only.

The system is currently nicknamed "Temple Tutor", and Figure 6 shows the opening screen for the database for the Lo Pan Temple. The outer window, called the "Project Window", displays the system name "TempleTutor" and the project name "Lo Pan Temple" in the Title Bar area. Below the Title Bar are several buttons to activate Help, set a history bias for the navigation, etc. A TextViewer Window shows some introductory credits, a ModelViewer shows a view of the Root Model, an ImageViewer shows the calligraphy for the name of the temple, and a DrawingViewer displays a site location plan.

Figure 7 shows a typical screen during a browsing session with Temple Tutor. A selection list is shown on the left side of the Project Window, and the ModelViewer with a view of the Root model of the Lo Pan Temple on the right. The student can select a component of the model by clicking on the selection list, or clicking directly on the component of the model.

In Figure 7, the "Front Wall" component has been selected. As the component is selected, it is highlighted in the model. The student can double-click the component to access other

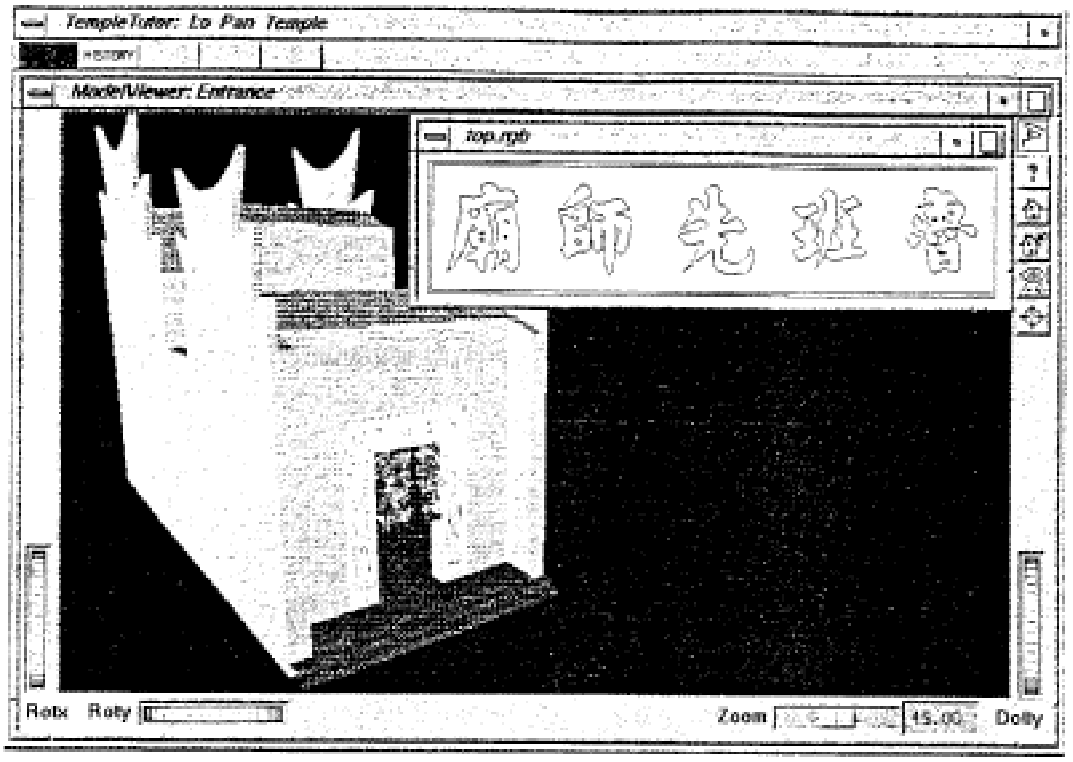

Figure 8 : Yet Another Temple Tutor Screen

information linked to that component. A pop-up selection box will appear as already shown in Figure 5. Figure 5 shows the door component double-clicked and a selection box appeared indicating items of information windows linked to the door component. Opening an item on the selection box will display the corresponding information window on the screen. Figure 8 shows the screen after the selection shown in Figure 5 is carried out. The pop-up selection box is automatically closed, and the information window corresponding to the "Chinese Heading" is opened.

4. Future Development

Obviously the system described above will never be "finished." If teachers and students are interested in architectural education, CAI, hypermedia, or Chinese temples, then the prototype will improve. Refinements will be made to the system, the prototype database will grow, and new topics will be developed and implemented. Advances in technology will make it all happen better and easier and cheaper.

Although the project will never finish, Figure 6 indicates the date when input to this paper finished. Processing power should allow real-time texture mapping, 3-D morphing, etc. to be commercially available by the time this paper is read. Virtual reality will soon become realistic. Philips will release full-frame full-motion video for CD-I in December 1992, and this will be a major step for multimedia and CAI as the development and authoring facilities for CD-I are readily available now, and delivery system hardware is already cost effective.

All of these developments will have an impact on the HKU hypermedia system for architectural education. Two specific aspects of the cur-rent project have already been identified for further immediate research:

4.1 Authoring

Large portions of the prototype database described in this paper were developed or implemented using the C++ language, C shell scripts, and/or C language utilities and toolkits. This process is too complicated for most teachers and students to use for authoring without considerable help from a technician.

A concurrent but separate research project is endeavoring to develop an authoring system to help guide inexperienced authors during the development of courseware materials.

4.2 Learning

Intuitively a CAI system should assist teaching and learning, and hypermedia should assist CAI. A recent agreement with the Faculty of Education and the Department of Curriculum Studies at HKU Will result in another research project to assess the teaching and learning effectiveness of the system described in this paper.

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6. Glossary

AIFF
Audio Interchange File Format. A standard format for storing digitally sampled sound files, developed by Apple Computer, Inc.

AIFF-C
A derivation of the AIFF standard which allows for the storage of either compressed or uncompressed digital sound.

Analogue/Digital
In analogue systems, signals are converted into corresponding variations in electrical voltages or currents. Digital systems define all signals as a range of specific values or numbers, rather than by a continually variable voltage or current.

Animation
The display of a coordinated sequence of images on a screen to give the impression of movement.

ASCII
American Standard Code for Information Interchange. The relationship between bits in a byte and human readable characters.

Authoring
The process of developing courseware.

Authoring language
A special high level programming language designed to enable people without much experience or skill to write courseware lessons.

Authoring software
Computer programs which make it easier for authors to develop courseware applications by using everyday words, concepts, or icons instead of the long strings of code which make up GPLs.

Authoring system
A software package designed to lead an author through the process of creating courseware without requiring programming. It usually consists of a series of prompts, menus, and utilities that guide the author during the development process.

Bitmap
Characters and graphics placed on the-computer's screen are composed of dots called "pixels". For each pixel on the screen, typically 8, 16, 24, or 32 bits are used to define the colour of the dot. This array of bits which define the image on the screen is called a bitmap.

C
A high-level general purpose programming language.

C++
A derivation of the C language to allow object oriented programming, developed by AT&T.

CAI
Computer Aided (or Assisted) Instruction. The use of a computer to help a student through a prescribed course of learning.

CAL
Computer Aided (or Assisted) Learning. Similar to CAI but with some guarantee that the student is learning something.

CD
Compact Disc. A high density digital storage medium based on a 12cm (4.75") reflective optical disc.

CD-A
Compact Disc - Audio. The original compact disc technology pioneered by Philips and Sony which combined text and graphics in a music CD.

CD-DA
Compact Disc - Digital Audio. The compact disc format for storing high quality digital audio. The physical format is defined in the Philips 'Red Book' standard.

CD-I
Compact Disc - Interactive. The application of the CD-ROM storage concept and the DVI compression for moving video. Developed by Philips as a consumer product, the computer and the CD-ROM drive are built into a single box.

CD-ROM
Compact Disc - Read Only Memory. The use of a CD for the storage of up to 650 megabytes of digital data. Information on the disc cannot be amended.

CD-ROM XA
CD-ROM Extended Architecture. A CD-ROM format which attempts to improve the storage of images and moving pictures.

CD-RTOS
Compact Disc - Real Time Operating System. The CD-1 operating System.

CDTV
Commodore Dynamic Total Vision. Developed by Commodore, CDTV is a home multimedia system similar to CD-I.

CML
Computer Managed Learning. The use of a computer to monitor, analyze, and report on student's learning in a CAL system.

Compression/Decompression
The technique used to reduce the quantity of digital data which must be stored to represent an input, and expand the data to its original full form during output.

Courseware
Educational material comprising software, data, documentation, and other resources which are presented via computer.

Delivery
All the hardware and software components used to present multimedia and/or CAI applications.

Disc
The reflective optical device which contains information stored on a rigid plastic platter.

Disk
The Magnetic device which contains information stored on a platter or cylinder.

Dithering
The process of calculating a new value for a bit or a byte by sampling adjacent values.

DPS
Display PostScript. Developed jointly by Adobe Systems and NeXT, a superset of the PostScript language for screen displays.

DVI
Digital Video Interactive. The use of a special compression chip in the computer which will allow real-time, full-resolution, full-colour video to be stored on disc and displayed on the screen.

EPS
Encapsulated PostScript. A superset of PostScript which includes comments.

Frame
One complete Image in a video sequence, consisting of 2 video fields.

GPL
General Purpose Programming Language. A computer language such as BASIC, C, Fortran, etc. which is used to create computer programs.

GUI
Graphic User Interface. A strategy that attempts to separate the Interface component of an application program from the computational part.

HyperCard
A program for Apple Computer which allows random (i.e. non-sequential) access to information.

Hypermedia
Multimedia information which can be accessed in a HvperCard non-sequential manner.

Hypertext
HyperCard style access to text files.

Instruction
The active presentation of curriculum material to a student.

IV
Interactive Video. A multimedia technology based on the Laser Vision videodisc which typically combines analogue Video and sound with pictures, text, and some form of computing. IV uses a computer to control the videodisc player, and a user controls the computer.

IVD
Interactive Video Disc. The physical platter used in IV.

JPEG
Joint Picture Encoding Group. A group of technologists attempting to set a standard for the encoding and compression of still images.

Laser Vision
The term coined by Philips to describe the reflective optical disc system.

Media
A collective term used to describe those facilities which are used to store/transmit information and data.

Micon
Moving Icon. The indicator of active areas or hot-spots in video or animation sequences which contain links to other chunks of information.

MIDI
Musical Instrument Digital Interface. A communication standard for digital data exchange between a musical instrument and a MIDI-equipped device.

MPEG
Motion Picture Experts Group. A group of technologists attempting to establish a standard for the encoding and compression of moving video and its associated audio.

Multimedia
Integrated use of multiple media including text, images, drawings, audio, animation, and video controlled by a computer.

NTSC
National Television Standards Committee. The 525 lines @ 59.9Hz television standard used in North America and Japan.

PAL
Phase Alternated by Line. The 625 lines @ 50Hz television standard used in Europe and China.

Pan
Moving a window horizontally or vertically relative to a stationary image or object.

Photo CD
A CD-ROM based system for image handling and storage developed by Kodak.

PICT
An image file storage format used by Apple Macintosh.

Pixel
Picture Element. The smallest addressable unit of a graphic display screen.

Postscript
A page description language (PDL) for text and graphics, developed by Adobe Systems Inc.

QuickTime
A Macintosh svstem soffivare extension from Apple that integrates audio, video, and animation.

Resolution
The number of pixels in an image relattve to the actual size of the image.

RGB
The Red Green Blue Image file storage format, or the system used to display these colours.

SCSI
Small Computer Standard Interface. An industry standard between computers and peripheral device controllers.

SGI
Silicon Graphics Inc. A company which makes very nice Computers.

SGI GL
SGI Graphics Library, An emerging industry standard for computer graphics based on a set of graphics and utility routines which provide high and low level support for 2-D and 3-D graphics.

TARGA
An image file format developed by Truevision.

TIFF
Tagged Image File Format. Another standard image file format.

Translate
The process of shifting a 3-D object along the X, Y, and/or Z axes.

UNIX
An operating system developed at AT&T Bell Laboratories in1969.

VCR
Video Cassette Recorder.

Vector
A line from a point to another point.

Video
The picture signals in a television system.

Window
An area on a computer screen in which an Item of information is displayed.

X Windows
The X Window System graphic user Interface standards developed by MIT.

7. Acknowledgements

The Committee on Research and Conference Grants, HKU;
Cam Technology Limited;
Mr. Waycal C. H. Wong;
Mr. Matthew C. S. Hung;
and most of the students and some of the staff of the Departments of Architecture and Surveying, HKU.

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