Design participation through the Internet: a case study

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Cambridge University and Microsoft are planning a shared computer research and teaching laboratory on a green-field site to the west of the city. The clients wished to use internet based communication between themselves and their architects, including email, a web site and virtual reality. We explain how this is to be achieved, and describe experiences during the first half of a two-year project. Particularly successful has been the use of games software (QuakeII) for 3D presentation of the emerging building design.

Cambridge is an ancient university, squeezed into a small market town which even now has only 110,000 inhabitants. Until 100 years ago, the colleges and University buildings were all to be found within five minutes walk of the market place. Then, as the sciences began to assume their present importance there came an explosion in University building but still in, or immediately adjacent to, the historic centre. The original Botanic Garden was displaced a mile southward, and the site occupied by "museums and lecture-rooms for natural science" (Willis & Clark 1886), of which the most famous was the Cavendish Laboratory (1873-96). Downing College sold an undeveloped part of its site, and the combined area was rapidly covered with new science buildings - museums, libraries, teaching laboratories and research spaces. The development pressure was phenomenal: within fifty years the originally gracious layout of courtyards had become "an incredible muddle" (Pevsner 1954) choked by a sediment of infill buildings, animal houses, gas stores, bicycle sheds, and 'temporary' huts crammed into the courtyards, on rooftops, anywhere. By the 1950's the pressure became intolerable and significant new developments were made further away - Chemistry to the south, and Veterinary Medicine pioneering in farmland a mile away to the west.

Less fortunate were the Computer Laboratory and Zoology Department, which were rehoused in situ, in a fragment of a megastructure known as the 'Arup Tower'. This was intended by the planners to be the first stage in a Buchanan-inspired redevelopment of the city centre, with pedestrian circulation segregated to a high level system of decks and bridges. Only one other piece of this pattern was ever built - the courthouse on top of a car park across the street - but the bridges never appeared, and so the new building eventually came to be seen, like the skeleton prominently displayed in the Zoological part of its podium, as a beached whale [Fig. 1].

The Cavendish Laboratory followed the Vets to the west, as did a scattering of other technological departments, and hi-tech businesses - including Schlumberger whose 'tent' (Michael Hopkins and Partners, Buro Happold 1985) is the most distinguished

'The Laboratory and its principal benefactor are extremely enthusiastic about the use of computer modelling in the design and visualisation of the new building'

building there. The building of the M11 motorway bypassing Cambridge to the west gave the site a definite boundary and identity and it became the long term strategy of the University to gradually decant the science and technology faculties, as they outwore their central buildings, to this largely vacant site[Fig. 2].

A masterplan for this 'West Cambridge' site was commissioned by the University (MacCormac Jamieson Prichard 1997), and has recently received conditional consent from the city planners. It shows the site, which extends from the western suburbs of Cambridge to the

1 The Computer Laboratory currently occupy part of the 'Arup Tower', the final phase of a development for the 'natural and mechanical sciences' started around 1870. The bridge connects them to overflow space in the former Cavendish Laboratory. The marooned pedstrian deck is now occupied by bicycle racks and a dead whale.

2. Aerial photograph of west Cambridge, with the masterplan superimposed . The site covers the same area as the historic centre (at right), and is a mile away from it. The white line is the cycle route from the centre through the suburbs, to the new computer Lab.

3. Masterplan as it appears on the web site, where it is used as a graphic index to the various projects shown. The Computer Laboratory is near the eastern edge. The pedestrian and cycle access point is in the southeast corner, and will lead eventually to a 'forum' looking southward over a proposed lake to extensive views of open country.

motorway, bounded on the north by the Bedford road, and to the south by the 'Coton footpath'; long used by academics as a place of recreation, but in fact the remnant of a still navigable medieval trackway connecting Cambridge to the villages of the west - Coton, Hardwick, Toft, Bourn. The plan [Fig. 3] shows a mix of high-tech industries along the north, accessed from the road, and University buildings to the south, reached on foot or by bicycle, from a covered 'colonnade' along the line of the Coton footpath. A central 'forum' is surrounded by shared large lecture halls, refectory, sports centre and other facilities.

Meanwhile the Computer Lab had expanded into parts of the old Cavendish, connected by a bridge at third floor level. By the 1990s the building was out of date and overcrowded. When the opportunity to rebuild arose, it was eagerly accepted by the University.

The proposed new Computer Laboratory is an interesting and complex project, which fits very well with the spirit of the masterplan. Funded partly by a donation from the William Gates III foundation, part of its floor space is to be leased on commercial terms to Microsoft for use as its major European research laboratory. It is the first building to be designed since the masterplan was published, and so is on the eastern edge nearest the city. As a mixed-use building it is on neither the northern road access, nor the southern cycle way, but half way between.

'The data should be transferable to the Computer Laboratory in an agreed standard format, to enable staff and students to perform their own walkthrough and other experiments'

Architectural expectations

Our research group (the Martin Centre CADLAB) first heard of the project when the Computer Laboratory made contact in mid 1997. At this point they had completed a written brief and were searching for an architect. The brief made some unusual demands of the architect:

> "The Laboratory and its principal benefactor are extremely enthusiastic about the use of computer modelling in the design and visualisation of the new building. This will have a number of benefits, including assisting the fund raising efforts of the Laboratory, allowing the Laboratory's members to gain an understanding of the design before it is realised, and publicly demonstrating the Laboratory's commitment to the use of computer oriented design techniques."
>
> "The appointed architect is expected to use 3D computer modelling as an integrated part of the design process. The data should be transferable to the Computer Laboratory in an agreed standard format, to enable our staff and students also to perform their own walkthrough and other experiments. Communication between the architect and the Laboratory should be by email, and also via a web site for the exchange of models and designs."

Aware that thorough-going 3D design was quite unusual in architecture, we replied that it was reasonable to ask the architect to use computer presentations,

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but design tools were personal to an architect, and should not be dictated by a client. Better choose an architect who can produce a good building, than one using a preconceived methodology.

The brief ended alarmingly:

> "It is crucial that an excessive burden is not placed on the academic staff of the Laboratory through meetings, requests for information etc. Information exchange via email could assist in achieving this. It is expected that those academic staff liasing with the architects should each average at most two hours a week on work related to the building."

This touched a nerve. Despite the endeavours of its building professionals, Cambridge University has a gift for getting bad buildings out of good architects - Stirling's disastrous History Faculty Library being the best known. Architects find the University and colleges difficult and frustrating clients because they are faced, not with an enthusiastic client with whom they can build a personal relationship, but with a building committee, consisting of academics who are not really interested in what is going on, attend irregularly, and regard the whole operation as an irksome chore. At the end of a long campaign, the project architect may find himself

the only person who has served continuously. This structure does not lend itself to responsible, consistent decision making.

There followed quite a lengthy email debate; our suggestion of the need for a more committed style of project management being countered by an enthusiasm for a 'standard box' of a building, which would minimise design risk and the need for consultation, and a horror of award-winning architects and award-winning buildings (the disliked Arup Tower had won an RIBA Bronze Medal). It was quite reminiscent of Willis' report of 1885, which had launched the development of the original site "the style of the building should be as plain as possible, and the material brick. That there be no unnecessary expenditure on architectural decoration; but that the architect be requested to display his skill rather in the perfect adaptation of the various apartments to their use, and in their convenient juxtaposition &c." (Willis & Clark 1886)

'Incredibly, email has to go to a single address and is then processed by a secretary. We did not feel we could work with them'

Mandatory computer capability

The concern that the architect should be fully computerised was significant during the short-listing phase - for example one well-known name was rejected -

> ".. as a practice, they were not sufficiently wired. Incredibly, although all architects have workstations, email is not used inside the company at all, and email from clients has to go to a single address that is then processed by a secretary. We did not feel we could work with them."

In the end a limited competition was held. Most firms took the trouble to present their proposals as web pages using portable computers and projectors. This brought their CAD people into the presentation, but served mainly to demonstrate that the normal web technique for presenting graphics (as image files in GIF format), though adequate for photographs and renderings, is poor for diagrams and hopeless for architectural plans. Some showed simple animations, or 3D models presented though VRML. But in the end internet competence receded as an issue, good sense prevailed, and the winning architect - RMJM - was one who could demonstrate a workmanlike process, had built comparable buildings successfully, and (to our relief) could field a project architect to whom the head of the Laboratory took a strong personal liking.

Their use of CAD was quite normal and standard - the bulk of the design work is done in 2D on AutoCAD, with 3D Studio Max used for presentation. Workstations are less than 'one-per-desk'; CAD is in the hands of specialists; and email, though present, is not ubiquitous.

As it became apparent to the Computer Lab that the kind of intense electronic communication that the brief envisaged was not normal architectural practice (and perhaps more significant to the University authorities, could not be achieved without a fee uplift), they began to see it as a research opportunity, and asked us at the Martin Centre for proposals.

We had to move quickly, as the preliminary design was already underway. Fortunately, the project readily gripped the imagination of several industrial sponsors, who offered hardware and software contributions, and the EPSRC, who agreed to give accelerated consideration to an application for the staff costs. Getting agreement among the participants was rather more delicate (as will be discussed below). In addition to the Computer Laboratory and the architects RMJM, these now included Microsoft Research Ltd, Microsoft's facilities consultants, the University's Estate Management and Building Services (EMBS) division, who are the legal client, and cost consultants Gardiner & Theobald. However, the application was succesful, and a two-year funded project began in July 1998, with Paul Richens as investigator, and Michael Trinder as Research Assistant, under the title "Exploiting the internet to improve collaboration between users and design team".

The building

The brief asks for 10,000 m2 of floor space. The total project budget is £20m, of which £12m is for the building, the rest being for equipment and relocation. As well as the embedded Microsoft laboratory, the building is to contain teaching space for several hundred undergraduate and graduate students, a library, machine rooms, research laboratories and a cafeteria. A central problem is to get the right degree of contact and separation between the three main categories of occupants - undergraduates, postgraduates and academic/ research staff. The embedded laboratory is to preserve its separate identity, but facilitate interaction, both organised and accidental. The circulation space is to promote meetings and discussion "with chairs in cosy nooks and crannies .. lots of whiteboards scattered in public places .. public terminals .. cybercafe area." The building is expected to be environmentally friendly, with a minimum of air-conditioning "lots of natural light, openable windows and a nice view" while avoiding the overheating that has plagued some recent buildings. Technological requirements centre on the need to accommodate an intensive and ever-changing computer network. Amenities should include new cycle paths, cycle storage and showers, and "some kind of common room where the current tradition of morning coffee and afternoon tea for the whole Laboratory can be continued."

Research objectives

The formal objective of our research project is to find ways of using the internet to achieve better buildings, by improving the consultation process between architect and eventual user. This means we need to engage people's interest in the building, keep them informed,

facilitate discussion, and channel feedback to the architect.

The future occupants of this building - that is the staff and students of the Computer Laboratory, and the researchers employed by Microsoft - are ideal subject matter as they combine a high proficiency in electronic communication, with an unflattering opinion of architects and architecture. They see the first as a way of reducing the nuisance of having to deal with the second. Our project will succeed if it can use technological enthusiasm to seduce the computer scientists into a constructive relationship with the architectural project.

Our first intention was to build a web server to provide on-line access to a comprehensive library of design information, linked to a bulletin board for gathering feedback. The second was to monitor the effectiveness of such as system, and study how it is used in practice to improve communication between client and design team.

Much of the material was expected to originate with the architects, using their in-house CAD systems (3D Studio MAX and AutoCAD), but would need to be translated, extended, simplified, edited and interlinked to form a web library. Keeping the links working in the face of constant revision was expected to be a substantial problem.

The provision of 3D walkthrough we anticipated would be met in the early stages by generating VRML from 3D Studio MAX, and later by bringing into play a viewer for very large models (million polygons upwards) which is the result of an earlier Martin Centre research project, and currently under commercial development.

Effectiveness is to be measured by regular web-based questionnaires. These will investigate changing perceptions of both the building, and the web-site.

Progress

The project started about six months after the architectural competition, so our immediate need was to catch up with progress already made. As it was also our first substantial web-based project, and our first research project to be based on Windows/NT, there was a somewhat steep learning curve to be climbed. We discovered that the Computer Laboratory, while fully 'wired', was using rather specialised computers and operating systems. UNIX was popular (in the form of Linux on PCs and Solaris on Suns), but web-browsing was provided by a variety of not quite fresh versions of Netscape. Even Lynx (a pioneering web-browser that does not handle graphics) had some currency. On the other hand, the Microsoft end of our user-base would be using Windows/NT on Intel computers with the latest version of Internet Explorer as their browser.

This context argued for a very straightforward initial design for the web site, avoiding even such mild elaborations as frames. It also became apparent that there were two levels to the project - the building and its site, as represented by the masterplan. The enjoyment of the Computer Laboratory would be substantially affected by progress (or the lack of it) on other parts of the site. Some issues that are mentioned in the brief - such as cycle ways - are outside RMJM's control, as they belong to the masterplan. Though responsibility is divided, both are important. So we conceived of two web-sites, an outer one presenting the masterplan and brief information as it became available on individual buildings, forming a context for the inner one, which would deal in great detail with the Computer Laboratory building itself. The outer site, we envisage, may last much longer than the inner, as the masterplan is likely to take 25 years to complete. It is also relevant to a much wider community than the inner site.

The two web sites achieve unity by using a similar style of header and footer on all pages, differentiated by a slight difference in colouring. The same design principles apply to each site: a straightforward tree structure - home page plus two levels of index to reach the content pages, page length restricted to a couple of screens full, sparing use of cross and off-site links. The pages were initially made fixed width (by use of tables), but freed after adverse comment from the Computer Lab. The consequence is that the fixed-width page headers and footers now look a little silly, and will have to be replaced at some time with navigational side-bars.

'The objective of our research project is to find ways of using the Internet to achieve better buildings by improving consultation'

Outer site

This site was implemented second, largely using material from MacCormac's masterplan, and did not become live until February 1999. However, it is best discussed first, as it sets the context for the Computer Laboratory building.

The contents page shows a simplified version of the masterplan as an image map [Fig 3]. Buildings and features under the cursor identify themselves, and clicking will (eventually) take you to the appropriate inner site. Also accessible from this page are:

Proposal - full text of MacCormac's proposals for the site

Summary - a non-technical summary of the official proposal

Diagram - a variety of downloadable versions of the site plan

Maps - plan-form contextual material collected by ourselves. Most revealing are the aerial photographs (on which the masterplan and car and cycle access routes can be superimposed), which clearly show the scale of the site (larger than the historic core of Cambridge) and its distance from current University facilities [Fig. 2].

Views - site photography and other scenography, including an old print showing the skyline of Cambridge as seen from the west in 1743 [Fig. 4]. A large part of this view survives, and is seen as providing an

essential visual connection between the new site and the historic centre.

Diary - history of events affecting the western development of Cambridge.

Inner site

This page gives access to all the consultation drawings issued by the architects, and a variety of background documents [Fig. 5].

Project Documentation. Textual information, starting with the original competition brief, and the quantified brief produced by RMJM in the early months of the project. This will eventually expand to full 'room data' description of the building, giving usage, floor area, equipment, servicing needs and so on, for every room. Additional textual information, such as meeting notes and specialised reports, will be placed here.

Building proposals. An index of each major revision of the drawings. Each revision is represented by a page forming an index to all the drawings and models available.

Design issues. Essays prepared by ourselves to clarify architectural issues that have arisen in the discussion groups, and generally drawing on other areas of research in the Martin Centre. For example, the earliest proposals from RMJM addressed the 'environmentally friendly' requirements of the brief by employing a shallow plan form, E-W orientation, and night-cooled hollow plank floors. We contributed a paper on green architecture, explaining the general principles behind these and other practical approaches to low-energy building in the British climate. Later a discussion developed around suitable widths for corridors, which we supplemented by posting photographs of measured widths in the existing building.

'The London-based architects are looking forward with relish to the possibility of seeing what is going on on-site, whenever they wish'

Reference buildings. Initially we intended this page for buildings visited by the design team, or used by RMJM as references. Later we discovered that Bill Gates is supporting a number of parallel projects in American universities, and that they have web-sites in some degree parallel to ours, so we extended the section to provide links to web-sites related to interesting computer laboratories.

Comments. Each page has a comment button, which leads to a web-based bulletin board. This allows people to submit comments, and review the comments made by others. To implement this we used a slightly modified version of a standard Perl script called WebBBS (Perl is a specialised programming language commonly used for building intelligence into web pages). One modification is to capture the identity of the page on which the comment button was pressed, with the idea of using this information later to analyse the relative impact of different documents. The presentation of the BBS is conventional, with messages viewable in date or topic order.

Site Cam. When construction starts, this will link to video camera views from one or two adjacent buildings. The London-based architects are looking forward with relish to the possibility of seeing what is going on on-site, whenever they wish.

Quake Lab. Links to the virtual reality pages described below.

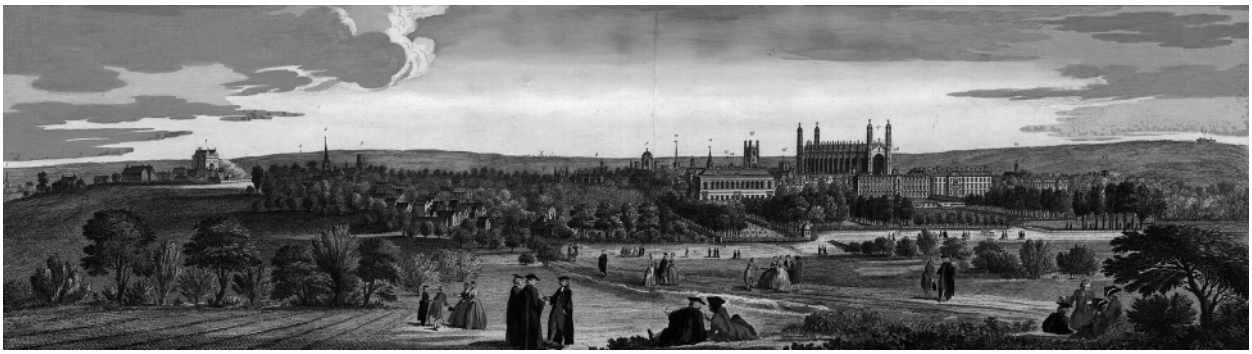
4. View back to Cambridge from the northwest in 1743, from a print by Samuel and Nathanial Buck. The proposed site is just off the right edge: the area has always been popular for academic recreation.
5. Contents page for the inner web site, described in the text.

Formats

Web browsers such as Netscape and Internet Explorer handle text in the form of HTML (Hypertext Mark-Up Language) files, and can include images (typically in the form of GIF or JPEG files). It is generally best to keep these images small, or the files take a long time to arrive. More sophisticated kinds of information (eg video or sounds) can be handled by 'plug-ins', extensions to the standard browsers that can themselves be delivered over the internet. Unfortunately, plug-ins have to be developed separately for each different browser, and each type of computer. As a consquence there are considerable differences between what you can do on a PC with Internet Explorer and, for example, Netscape on a Macintosh. We soon found that many popular formats are not available for UNIX browsers. An alternative is to use a Java program, which should in theory work in either browser on any computer. These tend to be slow, especially on a Macintosh.

Scanned drawings, photographs and computer renderings are normally posted as JPEG images, in a choice of resolutions, and are straightforward. More problematical is the presentation of CAD drawings originating in AutoCAD (for the building) or Microstation (for the masterplan). Though these could be encoded as JPEG, the files would be either unreadable, or enormous. What is needed is a format that encodes the lines in a drawing as vectors, and a reader that allows fast panning and zooming around the image.

AutoCAD drawings were initially posted in the DWF format (Drawing Web Format). This is an effective compression of AutoCAD files, and can be displayed by a very effective plug-in, distibuted free of charge, called WHIP!. Unfortunately, it works on PCs only. An alternative is a Java reader called CADViewer Light from Arnona (www.cadview.com). Even this failed initially, as some instances of Netscape at the Computer



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the new cambridge computer laboratory

{contents} | current proposal | design issues | documents | "..." comment

out to the west cambridge site

Contents | Current Proposal | Design Issues | Documentation | Comment | West Cambridge Site

The New Cambridge Computer Laboratory

Latest News:

NEWSFLASH The drawings of the new building went in for Planning Permission on 27th January 1999.

- **The planning submission drawings have been released by RMJM.**
  Click on the 'current proposal' button for details.
- Information about the whole of the West Cambridge Development is now available.
- A section on daylighting and window design has been added.
- The first Quake models of Scheme 14 have been finished and are running within the Computer Laboratory.

Last update was 17th February

What's New?	new	**The Planning Submission drawings have been released** Information about the whole of the West Cambridge Development can be found at www3.arct.cam.ac.uk/westc/ A section on daylighting and window design has been added. The first Quake models of Scheme 14 have been finished and are running within the Computer Laboratory.
Project Documentation	new	An overview of the project, timetables, briefs and meeting notes (access to some material is restricted)
Building Proposals	new	The latest presentation material from the architects, along with previous proposals
Design Issues		Specific architectural issues that are important to the project
Reference Buildings		Buildings the project team have visited and others that provide relevant examples
Comments		Add your comments on any aspect of the project. Most recent message was posted on Wednesday February 10 1999.
Site Cam		See what is going on on the site right now
QuakeLab	new	Walk through the latest models using Quake][

help | about | plugins | search... | ▲ top

last modified Wednesday February 17 1999 *maintained by Mike Trinder*

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Lab were too old to run Java successfully. A forced upgrade to Netscape 4.5, courtesy of the Computer Lab system administrators, fixed the problem. The freeware version of CADViewer provides reasonable performance in panning and zooming (though not as lively as WHIP!), but does not allow printing, which almost immediately became a problem. The solution was to convert the AutoCAD material to the Adobe Acrobat PDF format, which is available on all platforms, and seems entirely suitable, at least for drawings of the complexity we have encountered so far. The black-on-white format is preferable to the vivid colour-on-black from DWF; proper fonts come naturally, panning and zooming on screen is easy, and drawings are easily printed at a definite scale.

Generating PDFs is not so easy, and we have yet to establish a foolproof workflow. In principle you open the cad file in an amenable CAD system (we have been using microGDS), and print it at the required scale to a postscript printer, checking the 'print to file' box. The postscript file can then be processed through the Acrobat Distiller, to generate PDF. The main difficulty is that most CAD systems seem to require you to have a driver and an actual plotter on your network of the size required of the PDF image, before you can generate a postscript file for it.

'We decided to give games technology a try. The display system is contained on the Quake II disk, £20 from any games store'

We used a similar route out of Microstation, with a detour through Adobe Illustrator to tune up labelling, fonts and fills. To make an image map (a graphic index to a web page such as Fig. 3) we then export as EPSF and render to GIF in PhotoShop. We have used video formats such as QuickTime and animated GIF to a limited extent to display moving images, such as sun studies. With interactive controls, it is easy to see how the pattern of sunlight and shadow varies with the time of day, and season of the year.

Apple's QTVR (Quick Time Virtual Reality) has long impressed us as an ideal web format for architectural presentation. Its file is simply an image in the form of a 360 degree panorama, of which the viewer presents a framed portion, with freedom to rotate the eye, and a limited ability to zoom in and out, or tilt up and down. The PC equivalent, LivePicture, has been used by RMJM to extraordinarily good effect [Fig 6]. Their method is to construct an outline geometrical model in 3D Studio, and render it as a LivePicture panorama. The cylindrical texture map is printed, and used as a guide for hand drawing the interior architecture, which is then scanned, coloured, and substituted for the original. When viewed with a LivePicture viewer, you get a lightweight, charming and completely effective interactive display. There is a freeware Java viewer available from www.livepicture.com.

The standard method for handling 3D information on the web is VRML (Virtual Reality Modelling Language). Viewers such as Cosmo are available for all the platforms of interest, but their capacity is not impressive. They seem to be suitable for small models, such as a single room, but not for the overall building. We became interested in ways of delivering the results of highly-accurate daylight simulation. It is possible to generate VRML from some of these programs (eg Lightscape and 3D Studio Max) though the amount of fine detail generated by the lighting calculation can make the files very large. QTVR [Fig.7] can be obtained (with more or less labour) from all these programs, including Radiance, and is generally more economical.

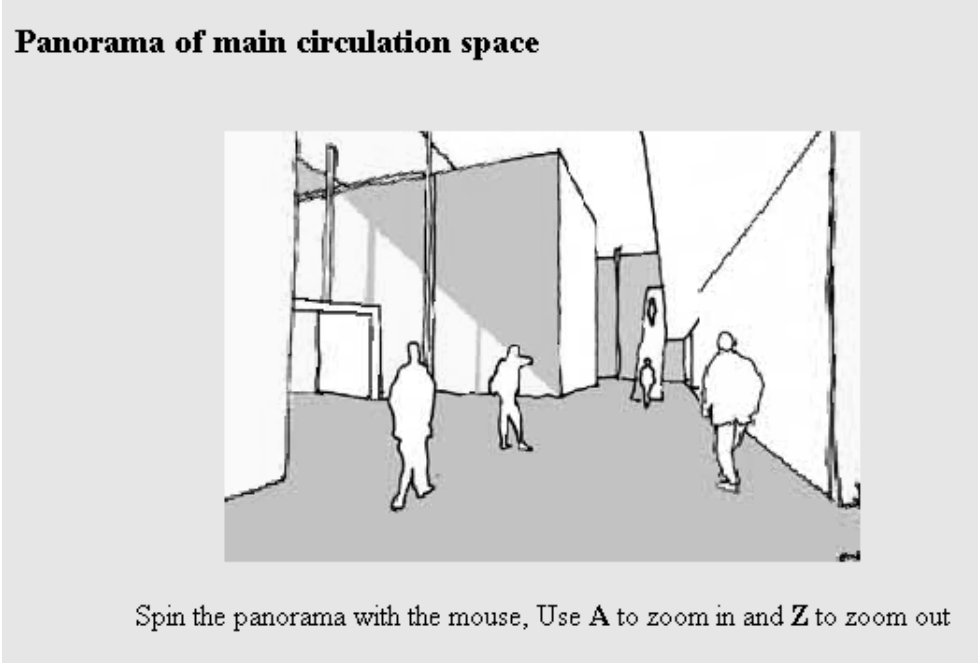
Computer games

There was a time when advances in computer graphics were generated largely to satisfy technical and design needs. That time has passed, and now the dominant force is the entertainment sector developing animated films and computer games. Even the US armed forces are looking to Hollywood for their next generation of combat simulators. There has in the meantime been some interest among architects in injecting their design skills into computer games, but little that we are aware of in doing the opposite - borrowing games technology for architectural purposes. We decided to give it a try.

Quake II is a bloodthirsty shoot-em-up computer game based on an extremely effective 3D rendering engine, which will run on most platforms, including Linux. A good deal of the game can be downloaded in source code, and both the scenery ('levels') and the 3D animated characters ('monsters') are replaceable, making the game something of an hacker's delight but also something that we thought might be peculiarly appropriate for the Computer Lab web site.

There are around half a dozen shareware 'level editors' for Quake; we chose one called Qoole, which with a CD of useful resources cost us $40. The display system is contained on the ordinary Quake II disc, around £20 from any games store. Qoole provides an object-oriented modelling environment in which to construct the architecture, apply textures, and locate lights and sounds. If you are developing a game, you will also locate and parameterise monsters, weapons, sensors and all the apparatus of gameplay. When completed, the design is handed over to a three-stage translator, which eventually produces a playable level. The first stage constructs a BSP (binary space partition) tree, using the bounding planes of architectural objects to subdivide complex spaces into simpler volumes. The virtue of the BSP tree is that it can be traversed in front-to-back order, as seen from any viewpoint. In other words, it makes it easy to determine which objects are in front of, and so potentially obscuring, which other objects. As obscuration is the main problem in computer rendering, this leads to a fast algorithm. The second stage appears to work out intervisibility between

6. Lightweight hand-drawn panoramic view of an early scheme is highly suitable for web presentation.
7. Radiosity-lit QTVR model generated from Lightscape. The computer screen provides a useful luminous reference.



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subspaces, creating chains of spaces that can be seen from a particular location, as an optimisation of the basic algorithm. Without this visibility information Quake II can still render a level, although at much lower frame rates. The third calculates the lighting, on the radiosity principle, exploiting the visibility calculations that have already taken place.

Compiling a level of any complexity requires considerable resources. We use our web-server, which has twin 333Mhz Pentium II processors and 256Mbyte of memory, and can compile the structure, shell and core of the building (no internal partitions) in about 4 hours. Using much less memory triggers an orgy of virtual memory paging by the visibility calculations; with only 128Mb of memory, compiling does not complete in a weekend.

The level editor prefers orthogonal geometry, and a modular grid, which turns out to be based on the size of the texture tile. It is a little difficult to establish the scale at which you are working - the basic yardstick is the eye-height of the viewer which seems to be about 50 units. We standardised on 64 units being 2 metres, a reasonable compromise between achieving a realistic scale and convenience of modelling. You do not get manuals with this sort of software; you have to learn by doing, or joining an internet discussion. One tip we picked up from an experienced level builder (who happened to be visiting the Computer Lab), was to flag lights and other elements which do not enclose space as 'detail' so that they are ignored by the level compiling process. Unfortunately, although flagging the many columns as 'detail' reduced the BSP and visibility calculations to around 1.5 hours, the frame rates during play dropped considerably.

Our first level took about 2 weeks to complete, mostly learning how to do it. It comprised the floors, roof, columns, external and core walls, staircases, and lifts. We omitted windows, partitions and furniture. Originally, we just used a lurid science-fiction landscape from the original game as a backdrop to the building, but it proved simple to switch this to digicam shots of the surrounding buildings on the West Cambridge site, combined with a painted sky. As at that point no architectural commitment had been made to materials and textures, we used texture tiles from the original game throughout [Fig. 8]. These are engaging in a grungy sort of way but obviously unreal, so the model is readily understood to be about the spatial arrangement of the building, not its surface appearance. The initial model has now been replaced with a much more detailed version including interior partitions, lecture theatres, cafeteria furniture and a single furnished office. Handrails were also added to provide more detail and, importantly, to prevent people from falling off the various stairs and walkways. Careful

construction, aligning the edges of walls rather than centering them, has meant that although this new model is twice the size of its predecessor, it can be compiled in about the same time.

The lighting compiler was set so that the sun shone (and cast shadows) from where it was painted on the sky. The interior lighting, based on skylight through the windows, reflected sunlight, and interior area sources, is excellent. The result is global illumination calculated not for a room but for the complete interior, within a few hours, and with no more fuss than specifying the number of interreflections to be considered and a general ambient lighting level to stop totally black shadows.

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8.The Computer Laboratory proposal in Quake II.
a. Coutyard looking towards the circulation spine.
b. Interior of an office.
c. Cafeteria, with view across a paddock to the Vet school.
d. Lecture room, lit entirely by light reflected from the screen.
e. A Quake figure being reskinned to resemble the sponsor.

Considered as a VR system, the Quake engine provides very fast software rendering and smooth movement, full screen (640x480) on a 250MHz PII, with clash detection (to stop you moving through walls) and gravity (to keep your feet on the floor). Cheap 3D hardware reduces the processor requirement and increases the image quality dramatically - a suitable accelerator board costs about £150. The precomputed lighting gives a huge lift in architectural quality; and ambient sounds such as bird song and air-conditioning hum strengthen the experience even further. Moving objects are easily programmed - we have doors that open on proximity, functional elevators, drinks machines in the cafeteria and the odd computer. The controls are easy to use, with the mouse used to 'look around' and the keyboard to walk. Best of all, the model can be populated with as much ease as you can plant

trees in a normal CAD environment. We have replaced the rather ugly (and violent) people from the game with generic 'suits' which can move around, block too-narrow corridors, and start to define the architectural scale like nothing else can. If the game is switched to 'deathmatch' several people can join in from their own workstation anywhere on the internet and, crucially, see and interact with each other. Since each person can alter the 'skin' of the model representing them, we shall soon be able to let Geoff Cohen (the architect, in London) conduct Bill Gates (the sponsor, in Seattle) on a virtual tour, watched by anyone who cares to join in.

Management issues

At the time of writing, the project has been running only eight months of its allotted two year span, but we have already learned a great deal. We assumed when writing our proposal, that the project was about openness and communication, but discovered from day one, that it was just as much about privacy and control.

The situation was an unfamiliar one to all the participants (except perhaps Microsoft), and each member of the building Project Team had its own quite proper reservations. The architect, quite naturally, did not want to lose control of the process of issuing information, or of the appearance of what was released. So we agreed with RMJM that material would first be mounted on a private web site, and not released to anyone else until they had approved it. EMBS did not want to lose control over the overall process, so we agreed that material would not be made visible to the Computer Lab until the Project Team had decided that it was appropriate to release it for consultation. They were also concerned that we should not put an extra load on the architect which might cause a fee uplift. Everyone realised that feedback from the site would have to be managed in some way - the architect could not be expected to deal with hundreds of emails from all over the organisation. It was agreed that a co-ordinator (seconded from EMBS to the Computer Lab) would moderate the bulletin board, and pull together issues that ought to be addressed. In practice, major issues which have arisen on the web site have been discussed for a while, and then brought to a Project Team meeting, usually by the head of department.

In the end we proposed five levels of privacy for the web site, with carefully monitored transitions between them. In no case would the webmaster move material from one level to another without express instructions. The levels were:

a) Private to the Martin Centre and RMJM, for material under development
b) Private to the Martin Centre, and the Project Team
c) Released for consultation, available to all members of the Computer Lab, University administration, and Microsoft.
d) Available to the whole University, and Microsoft
e) Available to the world

'We shall soon be able to let Geoff Cohen (the architect in London) conduct Bill Gates (the sponsor in Seattle) on a virtual tour, watched by anyone who cares to join in'

This structure is designed for reassurance rather than for ease of administration, and has caused greater delays than we would like to the flow of information. We are hopeful that, as confidence grows, there will be some simplification.

The feedback bulletin board was initially conceived of as being available to the whole of the Computer Lab, staff and students, but this wide exposure was found to inhibit discussion. At the head of department's request, a second inner discussion group of senior academic staff was established. Again, at the user's request this is configured as an email listserve (emails addressed to the server are automatically distributed to all participants), rather than using web forms, and is backed up by a mail archive on a secure server in the Computer Lab so that membership of the group can be validated through their login id's on the Computer Lab UNIX network, information not readily available to our web server. These changes have been effective in stimulating a much more directed and vigorous discussion.

Another case of privacy promoting discussion occurred when printed plans were hung up on a publicly accessible whiteboard. They soon accumulated a variety of comments and redrawings, which we photographed and published. We offered to establish a webcam, to keep the whiteboard constantly in view. This was declined, on the basis that people would not add their suggestions if they thought that they were being watched.

Design issues

The usefulness of the web site is best judged by the quality of the discussion it develops, and its influence on the building itself. The opening messages were not too encouraging - being about ladies' lavatories (curiously the discussion on the parallel site at MIT opened

on the same issue). Green principles were the first serious issue, to which we responded by posting a summary of the design principles involved on the 'Design Issues' pages. At that point RMJM were proposing a system of night-cooled hollow concrete slabs called 'Termodeck', which was unfamiliar, and required some explanation. Eventually RMJM organised a visit to a similarly equipped building at the University of East Anglia (which then appeared on the 'Reference Buildings' page), and the issue became quiescent. Later still, when they had measured the actual heat gains from computer equipment, they dropped this proposal in favour of 'chilled beam' cooling.

Provision for catering has been a continuing theme, partly because it was unclear what provision would be made, and when, at the masterplan level. But the first major debate occurred when the Scheme 3 plans were released. This showed the building organised as a 'finger' plan; four ranges of research accommodation cross-connected by a range containing the teaching and communal spaces, lecture halls and library. This was criticised on a number of grounds, such as difficulty of circulation for researchers, who would have to exit and re-enter the secure areas to visit a lab in a different range, poor views out, overlooking from the lab opposite. The discussion culminated in a meeting, where the architect was encouraged to look at a courtyard alternative. In fact he looked at many more, which were not published, until Scheme 14 was reached, which had a figure-of-eight plan, with two courtyards. This dealt with the principal issues, and discussion moved on from the overall building form to detailed dispositions. Offices which were shown as 2 by 5 metres were felt to be too long and thin and were changed to a squarer form, a computer room was moved from the sunny south facade to the north, and the library which partly occupied a courtyard was relocated within a range.

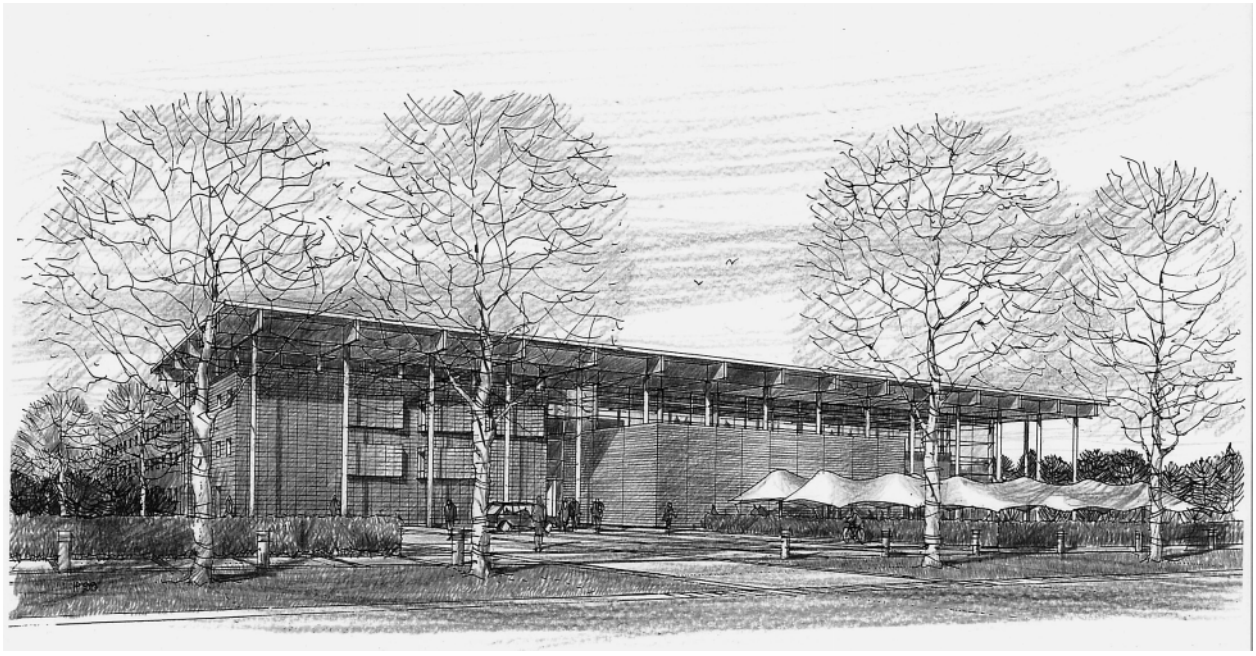
The needs of cyclists have been a constant, and justifiable concern all the way through. Experience at the nearby Cavendish Lab is that around 80% of academic staff and students will arrive by bike. Assistant staff (such as secretaries and technicians) on the other hand, are likely to want a car-parking space. The cyclists want suitable access tracks, secure covered storage, and changing rooms with showers [Fig. 9].

Once the plan was settled, interest turned to the section and elevations, with a quite vigorous discussion on the size of windows, which some felt were too small for adequate daylight, or views, or both. We contributed an essay on daylight to the 'Design Issues' section, and photographs of a nearby building which the Computer Lab discovered had similarly proportioned openings. We ran some simulation programs and model tests, but found the presentation of results highly problematical (this is to be the subject of a forthcoming paper). As usual, when a serious issue arises, the head of department summarised the discussion to the architect, and asked him to consider it further. It proved more difficult to resolve, as the window width was conditioned by the planning module, and the head height by the structural system, though the interconnection between these issues had not surfaced before. This in turn triggered some discussion of what exactly the approval or 'sign off' procedure was. This, and other discussions about furniture and luminaires led to the sensible decision to build a mock-up of a typical office, which is currently under way.

'The usefulness of the website is best judged by the quality aof the discussion it develops, and its influence on the building itself'

Web site issues

We had some initial problems with comprehensibility



9

of the DWF plans, where the vivid colours of the lines puzzled everybody. They appeared to be coding for materials, but enquiry revealed that they simply denoted the line thickness that would be used if the drawing was plotted. It is a point in favour of the Acrobat files that they show the lines as various thicknesses of black, as intended. The scale of drawings also puzzled people - although the structural grid spacing was dimensioned 6000, it was not appreciated that this signified a dimension in millimetres. During the discussion on windows, and on many other occasions, we would like to have been able to take measurements off the web plans and sections. None of the viewers allow for this elementary function. We also find the ability to print all or some of any drawing to be essential. It is a major drawback of the freeware Java DWF viewer that it does not allow for this.

A deeper problem has been raised by the Computer Lab. They have a growing archive of correspondence, reports and minutes of decisions, which they would like to hold electronically, in the form of a cross-referenced, indexed and searchable archive. We are currently considering how best to accommodate this.

On the 3D side, the Quake version has been widely appreciated, both by the Computer Lab and the architect. Significant suggestions for improving it include finding a way to label spaces, so you know which room, range and floor you are on, and provision of a keyplan for orientation, and possibly for 'jumping' your viewpoint. Though the idea of an architectural walk-through has been current for a number of years, an effective presentation has required very expensive equipment. This is the first time, as far as we are aware, that every user has been given the opportunity to explore a future building in his own way, on his own computer, with unrestricted real-time motion.

'the first time every user has been given the opportunity to explore a future building in his own way, on his own computer, with unrestricted real-time motion'

An issue for the future concerns the topology of our web site. At present it is a shallow tree, with large drawings or documents as the leaves. We envisage that eventually we will have multiple representations, such as plan, schedules and VR for many or possibly all rooms in the building. If these are fully cross-linked, the topology will become a dense mesh, which would be flying in the face of most web usability studies, which suggest that shallow trees are desirable for comprehensibility.

Finally, we must remark on the most fundamental of our tools, HTML. We started off using an editor (Adobe PageMill), in the hope that we could avoid writing HTML directly. This was rapidly found to be an illusion. Testing our pages in Netscape on Linux, PC and Macintosh, and Internet Explorer on the latter two, we found inconsistencies and failures that could only be disentangled by examining and modifying the HTML. From that, it was but a short step to composing HTML directly. We might still use an editor for the initial formatting of a complex table, but from then on it will be maintained by direct editing the HTML. And HTML itself is a monster. As a graphic design tool, it makes a point of failing to control layout and appearance, which is what a graphic designer cares about more than anything. As a computer language, it is ugly and lacks the structures needed for easy maintenance. Its lack of defined semantics guarantees inconsistent implementation, an opportunity joyfully seized upon by the browser vendors and enlarged by their incompatible extensions. If there was ever a need for the standards organisations to save us consumers from the software industry, this is it.

Further work

This paper was started six months into a two year project, and received its final revisions at the half-way point. In the second year we intend to load a very complete description of the building, and experiment with other publishing software, including that from Bentley systems, and software from Lightworks Design which is based on earlier research at the Martin Centre. We are pleased (and not a little astonished) by the success of the Quake version, and will be doing some more work on converting computer games to peaceful purposes.

Beyond that, we wish to reflect on the issues of communication and privacy that have surfaced. Some of the assumptions of the internet community must be challenged. Untrammelled visibility of information proved more inhibiting than a degree of privacy. The caution with which architects and other professionals treat email is not necessarily unwise - there are even signs that the hi-tech business world is beginning to backtrack (see, for example, Bennahum 1999).

Our position as middlemen between architect and client is not really symmetrical; organisationally and by personal connection we are closer to the client than to the architect. Should this kind of exercise be run by the client, the architect, or (as is beginning to happen during the construction phase) by a project manager? We can envisage the architect publishing material on the web as an extension to his ordinary CAD activities, but handling the unsupervised feedback from a diversified client organisation would be a challenge to the ordinary disciplines of running a job.

9. Exterior view rendered by RMJM as part of the planning submission. The tent is in response to a prolonged discussion about bicycle parking.

Acknowledgements

This project was inspired by Professor Mike Gordon of the University of Cambridge Computer Laboratory, and made possible by the continued enthusiasm of the whole project team, but especially Derek McAuley (Microsoft Research Limited), Richard Rhodes (Estate Management and Building Services), Professor Robin Milner (head of the Computer Laboratory), Geoff Cohen and Ray Stock (RMJM London Ltd). Liz Pride (MacCormac Jamieson Prichard) has been invaluable in providing masterplan information. Sebastian Macmillan at the Martin Centre is working with us on measuring the effectiveness of the web site. The project is funded by a Grant from the Engineering and Physical Science Research Council under the Innovative Manufacturing Initiative, with industrial support from Microsoft Research, Bentley Microsystems, Informatix Software International, and Lightwork Design Ltd. The Martin Centre CADLAB is supported by Informatix Inc (Tokyo).

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Biographies

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Update

Since this paper was written Microsoft Research Limited have decided to advance Phase II, and occupy their own separate building, rather than the embedded laboratory described here.

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