INFORMATION TECHNOLOGIES IN THE SERVICE OF ARCHITECTURE

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1. Building Industry

In the majority of developed or developing countries throughout the world, building is one of the largest single industrial sectors, accounting for up to 8% of the Gross Domestic Product and employing, directly or indirectly, 8% of the working population.

Yet despite its scale and importance in the national and regional economy, the building industry is under-developed and dis-aggregated. In the UK for instance, only 6% of contracting firms employ 7 or more people; 50% of architectural practices employ 2 or fewer professionals. The research and development budget of the industry is a meagre 1/2% of turnover. The professional education provision is highly fragmented and Continuing Professional Development opportunities are very limited. Overall the labour force is poorly qualified.

This has a serious consequence for the quality of the built environment. Conservative estimates suggest that remedial treatment of building defects costs the UK upwards of £1,000 million per annum (excluding normal maintenance): some 50% of these defects, it is judged, could have been obviated by better design. In a high proportion of post-war buildings, energy consumption is profligate; UK Department of Energy figures suggest a potential saving of up to 50% through better design of new buildings and 25% through appropriate design intervention in the existing stock.

It is clear that if we are to have a more sustainable built environment in the next millennium we need to become better at the complex human activity of design. This paper suggests how the information technologies may be used in the service of architecture.

2. The Information Technology (IT) Industries

In contrast to the building industry, the industries which are concerned with the information technologies typically re-invest 40% of turnover into research and development and, as a consequence, are highly progressive and successful. The impact of IT on our daily lives is widespread-in banking, in airline ticketing, in automobiles, in domestic appliances and in the leisure industries. The power/cost/size ratio of computers has changed dramatically bringing very high performance to low cost portables with colour graphics facilities.

Alongside the advances in computing have come equally dramatic advances in telecommunications. The Fax has already replaced normal postage and electronic mail (e-mail) is rapidly replacing the fax. The Internet, which is growing at phenomenal speed, improves upon e-mail by offering high quality graphics interaction world-wide.

3. Current Applications of Information Technologies in Architectural Practice

In the USA and the UK, close to 100% of architectural practices use IT in one form or another. Virtually every office uses such utilities as word processing, spread sheets, etc; about 70% have the capability to produce plans, elevations and perspective drawings by computer. A much smaller proportion of practices actually use the computer for de-
sign decision-making but there are, however, a number of very successful applications and some of these are described in the following subsections.

3.1 Simulating the Thermal Environment

In the cool and cold climate countries of the world the amount of energy consumed in keeping buildings at acceptable comfort levels may account for as much as 50% of the total of all energy consumption. More energy-efficient design of buildings would not only save vast sums of money but would proportionately reduce the polluting effects of carbon emissions.

Improving the energy-efficiency and environmental-friendliness of buildings depends on the architect and engineer having a clear understanding of how the building responds dynamically to climate. This response is extremely complex and involves a very wide range of energy flowpaths (Figure 1). In order to predict the energy consumption and level of thermal comfort in a building it is necessary, therefore, to simulate all of these energy flowpaths dynamically.

![Fig. 1](image)

A number of "first-principle" computer-based models of the energy behaviour of buildings have been developed and tested and are in current use in design. The designer inputs a detailed description of the geometry and construction of the design and the computer models its behaviour in response to the relevant climate over any period of time, from 1 hour to 1 year.

The output from such computer programmes can be very rich, showing the contribution which each part of the building makes to the overall thermal performance of the design. The architect is thereby guided towards design changes—such as orientation, building geometry, choice of materials, fenestration, shading, etc., etc.—which yield lower energy consumption and/or increased comfort. Figure 2 shows a typical screen during a run of the program ESP [1].

With sophisticated programs such as ESP, however, small architectural practices are reluctant to climb the steep learning curve necessary to use them effectively. To over-
come this problem, the UK Department of the Environment brought into existence the Energy Design Advice Scheme [2] which offers a subsidised consultancy service, using software such as ESP, to architects, engineers and their clients. Since its inception around six years ago, the Energy Design Advice Scheme (EDAS) has been an outstanding success, dealing annually with several hundred design cases.

Over the period of its operation, the efficiency of the design advice offered by EDAS was closely, and independently, monitored. The conclusion was that the financial investment in software development and in subsidy to EDAS clients has yielded a return through savings in energy consumption which is at least an order of magnitude (i.e. 10 times) greater; this huge financial benefit is measured only in terms of the cases dealt with by EDAS and does not take account of the improvements in energy efficiency which the architectural clients of EDAS will carry forward, through improved understanding of the issues of energy conscious design, to subsequent design commissions.

3.2 Simulating the Visual Environment

The thermal simulation models described in 3.1 work by tracking the thermal energy flowpaths around the building. Equally, it is possible to track the light energy flowpaths which emanate from the sun or from luminaires as they reflect from the external or internal surfaces of a building. A great deal of effort has gone into developing and testing computer models which simulate these flowpaths and generate computer graphics images of high fidelity.

The input to the lighting models is similar to the input to the thermal models—i.e. geometry and construction; the output can be a numerical or graphical. Figure 3 shows the flood-lit exterior of Glasgow City Chambers using the program DIM [3] and Figure 4 shows the interior of British Airways Business Centre using the program RADIANCE [4].

When a program such as DIM is used to model a building interior it generates not only computer graphic images, but also the level of light energy at any point on any
surface of the interior. Used in conjunction with a thermal model such as ESP, very sophisticated studies can be made to ensure that decisions on the fenestration of complex modern buildings achieve the most economical balance between light energy and heat energy.
3.3 Simulating the Urban Environment

With rapid increases in the power of computers it has become possible to model not only individual buildings but entire cities in some degree of detail and to navigate through them in real time.

One example of the use of computers at an urban scale is the work on the Old Town of Edinburgh [5]. The basic geometry of this hugely detailed model [Figure 5] was built using existing 3-D information held on computer by the UK Ordinance Survey agency. The roof and facade detail was added to the basic geometry by first identifying recurring vernacular forms then varying these parametrically and superimposing them on the basic geometrical forms of each building.
Existing paper-based text describing each building was then scanned into the computer together with available plans, elevations, photographs etc. An interface was then built to allow a user to search the urban database. It is thus possible, for example, to “fly” over the town, point to any building and bring up relevant archive documents on it [Figure 6]; alternatively it is possible to ask the system a question such as: “show me all buildings by architect Robert Adam which are currently owned by Edinburgh City Council”.

The Edinburgh model is in daily use by the Edinburgh Old Town Renewal Trust and proposed new buildings must be tested in the model before permission to build is given. This use of computer aided visual impact analysis [6] is also, of course, applicable to situations where an intervention is proposed on a sensitive rural site [Figure 7].

3.4 Presenting Architectural Ideas with Multi-Media

When communicating design concepts, architects may use a number of different media - drawings, photographs, text, spoken word, computer graphics, computer animation, video, etc. Recent developments in the information technologies make it possible to capture all these media into one relatively inexpensive computer environment. It is then possible to author an interactive multi-media presentation which is extremely effective in communicating complex ideas about a particular design or about a concept such as energy-efficient design.

A recent survey of multi-media applications in architecture [7] identified the following categories of use:

- **Presentation of Design Schemes**: In contrast to conventional paper based presentations of particular building (or product) designs, multi-media can offer powerful insights into planning, circulation, structure, servicing, etc. It seems certain that within a few years most students, and many practices, will be seeking to present their design work on screens, rather than paper.

- **Explanation of Architectural Cases**: This category is similar to the previous in that
particular historical or contemporary buildings are presented, but the distinction is that an explanation of style, theory, typology is offered.

Explanation of Urban Environments: These are fewer, but none-the-less significant, developments in the application of multi-media to our understanding of the development of cities and the protection of their cultural and historical quality.

Explanation of Technical Issues: Complex technical issues, including the dominant issue of how design decisions impact upon design performance, are amenable to explanation using multi-media.

Virtual Museums of Architecture: Interest is growing in the development of large scale archives of contemporary and historical architecture which will allow cross-reference and comparison.

Documentation: It can be expected that research reports, essays, treatises and the like (including conference presentations, of course) will increasingly be presented using multi-media technology.

Interfaces to CAAD: There are as yet no published papers on this application area, but it is known that a number of groups are working on multi media front-end and back-end interfaces to a range of CAD packages which are currently relatively inaccessible to architects (e.g., structural analysis, thermal analysis, even advanced drawing and visualisation packages). It can be predicted that these developments will be reported in the near future.

Experimentation: As with all new tools, students are often more inventive in their use than teachers and it is good to see some reportage on more experimental usage of multi-media technology.

4. The Future of Information Technology in Architecture

There is general agreement amongst those engaged in research and development in this field that information technology will have a huge impact on the way we practice architecture and on the way we educate architects. There are three areas of research and development which will contribute to this impact.

4.1 Advances in Software Technology

Much research and development is being carried out in the fields of Computer Science and Artificial Intelligence which will eventually yield benefits to computer aided architectural design. The topics of particular interest are:

* object oriented programming (OOP) which will help users of IT to construct their own applications programs to suit the individual way in which they design.
* case based reasoning (CBR) which will help architects make better use of their own design precedents, or those of other architects.
* knowledge based systems (KBS) in which not just information but design knowledge is embedded.

It is envisaged that these and other software technologies will come together in "design decision support environments" such as that proposed by Rutherford (Figure 8), wherein many useful outputs are generated from a common, and evolving, model of the design [8].

4.2 Virtual Reality

There is a significant difference between the simulation experience offered by the computer graphics systems described earlier and those offered by what has come to be known as 'virtual reality' (VR). Conventionally, computer graphics appear as hardcopy
on an A4 page, or as a display on a 30mm raster screen. In virtual reality systems, the user (or "traveller") has the experience of being within the 3D data-set (commonly known as "cyberspace"). Additionally, the system may provide the means by which the traveller can move through cyberspace and the mechanisms for simulating physical interactions with virtual objects within the data set.

The basic elements of the hardware of VR systems (apart from a powerful processor) are typically:

- a helmet with earphones and "eyephones", i.e. two small display screens one in front
of each eye: 6D sensors allow tracking of head position and attitude which in turn determines the stereo images transmitted to the eyepieces. Thus, as a user looks around, the stereoscopic image changes in a way which is similar to that which would be experienced if the user was actually ‘inside’ the data-set.

- a data-glove: 6D sensors allow tracking of the position of the hand and of individual fingers; pneumatic pads may be incorporated to allow sensory feedback as the user’s hand, within the glove, closes on a virtual object within the data-set. Thus the user is given the tactile (and visual) experience of interacting physically with his/her environment.

- a motion platform: some physical prop such as a treadmill, stationary bicycle or car steering wheel and foot pedals which translate the actions of the user and move him/her through cyberspace. In the absence of such props particular hand gestures, such as pointing, can be translated through the glove, and programmed to move the user forward in a particular direction.

A typical configuration proposed by Randal Walser including audio input/output, is illustrated in Figure 9. Figure 10 shows VR in use.

4.3 The Internet

The Internet, with connection to very high bandwidth Municipal Area Networks (MANs) promises to revolutionise the interaction we have with each other, whether we are in different rooms in the same building or in different continents of the same world. These Global and Local opportunities are at the heart of our shared Vision of Architecture in the 2000’s.

References


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