

The history of CAAD spans a short but eventful 30 years.

This paper initially takes stock of the outcomes over this period by focusing sequentially on the modelling of the functional behaviour of building and on the modelling of the formal characteristics of buildings and cities.

It concludes with a view of the way forward.

Panoramas futuros para CAAD: una perspectiva optimista

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La historia de CAAD abarca un corto, pero lleno de acontecimientos, período de treinta años.

Inicialmente este documento compila los resultados que se han producido durante este periodo, concentrándose de forma secuencial, en el modelado del comportamiento funcional del edificio, así como en el modelado de las características formales de los edificios y ciudades.

Concluye con una consideración sobre sus perspectivas de futuro.

1. Simulation of function.

The proposition which underpins the endeavour to model the functional behaviour of buildings is as follows:

i) if (student) designers were better able to make explicit and, therefore, understand and communicate the consequences of their decisions on the cost and performance of the building, the chances would be enhanced of an outcome which is fit-for-purpose, cost-effective, environmentally-friendly and pleasing to clients and users.

ii) computers can help achieve this.

1.1 Origins

There have been a number of seminal developments in the simulation of function dating back to 1965.

It is interesting to go back some 25 years to two of the earliest contributions, one in Europe and one in the USA. In the UK, Whitehead and El'Dars [1] programmed an algorithm which sought to generate a single-floor plan layout which minimised the pedestrian travel distance within the building. In the USA, Souder et al [2], in one of the first uses of computer graphics ~ a cathode ray tube and "light-pen" ~ developed a system which appraised human-generated hospital plan-layouts in terms of the pedestrian travel efficiency.

Interestingly, these two independent developments both focus on the notion of numerical measures of planning-efficiency; they differ fundamentally, of course, in approach: one **generative**, one **evaluative**.

Not unnaturally, these developments excited some opposition, not least because they sought to optimise a layout on the basis of a single variable, viz travel efficiency: what is **optimism** from the point-of-view of travel efficiency might be **pessimism** from all other points of view.

Nonetheless, both demonstrated the huge potential of computers to assess numerically (and

therefore objectively), in part at least, the inherent **functionality** of competing design solutions.

1.2. The Energy Imperative

The so-called "oil-crisis" around 1970 provided a stimulus to software developments which sought to appraise design schemes in relation to their energy-efficiency.

Shaviv at the Technion has sustained a highly productive programme of research and development since then, producing applications software for use both in the design studio and in practice. Building progressively on earlier work she had by the late 1980s developed an integrated knowledge-based CAAD system for the design of solar and low energy buildings [3] in which the knowledge base, which contains heuristic rules, in conjunction with a simulation model, guides the (student) designer through the decision-making process.

Milne [4] at UCLA, has also sustained a major effort in the development of computer-based "design tools" for energy efficient buildings. He defined a design tool as "a piece of computer software that has an easy-to-use interface that allows the manipulation of the buildings three-dimensional representation and that shows the (student) architect something useful about the performance of the building". His signal contribution was two-fold:

i) integration of both heating and lighting (both natural and artificial) into the energy appraisal.

ii) turning the numerical output from the simulations into highly informative graphical representations.

The simulation of the energy behaviour of buildings throws up the issue which lies at the heart of all modelling activities: what is the appropriate trade-off between the accuracy of the model and the ease of access to it.

As part of its long term commitment to the development and validation of energy models, ABACUS, at the University of Strathclyde, compared the performance of its own advanced model, ESP, with a simple model being promoted

at that time by the RIBA. The RIBA model generated results diametrically opposite to those generated by ESP [5]! The CAAD teaching community faces the problem that

- i) reasonably accurate models are too inaccessible to students, and
- ii) reasonably accessible models are too inaccurate to be useful to practitioners.

This gap will be closed by improved deployment of IT.

Hopefully, the interest in energy efficient building design, initially stimulated by the oil crisis, will be maintained under the imperative of sustainability.

1.3 Integrated Appraisal

As early as 1972 ABACUS attempted to build on the work of Whitehead and El'Dars and Souder by authoring one of the first integrated appraisal systems. The initial prototype (PACE) [6] evolved into the software known as GOAL, the use of which in teaching was reported at the 1993 ECAADE conference [7]. The (student) designer proposes a geometry and a choice of construction materials, GOAL accesses a number of databases which hold information on climate, unit costs of materials, user requirements, building regulations etc and numerically appraises each proposed design in terms of construction cost, annual energy costs, combined costs-in-use, thermal energy consumption, lighting energy consumption and planning efficiency; additionally the software generates any number of perspective views of the geometry. Related software (GLOSS), allows the "fingerprint" - i.e. the main design and performance characteristics - of every design hypothesis to be recorded and compared. These fingerprint archives provide the benchmark against which each new design can be compared; the more designs which are appraised, the more knowledgeable and useful the database becomes.

Although developed and extensively used before the terms were invented, GOAL embodies all the characteristics of a "knowledge-based, integrated, case-based design decision support system". Regrettably, it is still embalmed in a medieval hardware and software platform.

Danahy [8], at the University of Toronto, brought the same integrated approach to landscape design and cleverly integrated the formal representation of any scheme with a range of measure of its functionality. His software is put into the hands of the studio tutor and crits take place "on-line".

1.4 Design Decision Support Systems

Two developments outside the field of architecture have been significant in their impact upon CAAD research and development:

- i) the emergence from the computer science community of advance hardware and software technologies in the field of artificial intelligence and telecommunications.
- ii) a significant increase in design-related research and development across the range of engineering disciplines.

This sub-section of the paper identifies a number of CAAD projects which draw from these other fields.

At Carnegie Mellon University, Mahdavi [9] has developed in SEMPER, the notion of an "open" simulation environment in what he calls a "multidirectional" approach to simulation-based performance evaluation. A preference-based formalisation of design intentions/criteria is used to cope with ambiguities through dynamic control of the degrees of freedom of design-related parameters during the interactive design process. The system, then, has some degree of generative capability.

Mahdavi's work is contemporary with two other developments in the USA. Pohl [10] at California Polytechnic State University has been developing the ICADS system in which it is intended that multiple domain agents interact with each other and with (student) designers to cooperatively solve design problems. Researchers at the Lawrence Berkely Laboratory have been developing the Building Design Advisor [11], a software environment that seeks to support the integrated use of multiple analysis and visualisation tools; currently the system supports a daylight analysis tool, an energy analysis tool and a multimedia case-studies

database.

The European Community gave recognition to this area of research and development by funding, over the last five years, the pan-European COMBINE project [12] which has concentrated on the development of an integrated data model which facilitates data exchange between tools and offers tool-tool interaction supervision via a blackboard mechanism.

Current research and development by Chen and Maver [13] at the University of Strathclyde and Georgia Institute of Technology has yielded a prototype implementation of what they call a Virtual Studio Environment (VSE). The uniqueness of this work lies in its attempt to combine the strengths of several other related approaches, namely the product modelling from traditional integrated design systems, the distributed architecture based on message-passing communications from cooperative design systems and the explicit support for human-human interaction from computer-supported co-operative work (CSCW).

The VSE recognises the importance of maintaining a collaborative context as the basis for design tool integration; this context consists of information not only on the design data and design tools but also on the human designers. The VSE framework links the technical resources with the human resources. Collaboration-aware properties have been added into design data and tool models. The current implementation supports three levels of integration; tool-tool interoperability, automated coordination of tool interoperation and dedicated human-human interaction facilities for semi-automated and informal coordination of the design project. The VSE is currently populated with tools for energy analysis, lighting analysis and cost analysis.

The intention is to re-implement the VSE on the WWW to facilitate its evaluation by interested parties.

2. Simulation of form

Prior to the advent of graphics terminals, pioneers in CAAD wrote software which allowed teletypewriter devices, close-coupled to computers

which were massive in bulk but puny in performance, to represent plan forms by printing arrays of asterisk signs (*) onto a continuous roll of paper; the ability to achieve this remotely, over voice-grade telephone lines, caused much excitement in the small CAAD community! Monochrome screen-based drawings were subsequently available using either direct-view storage tube terminals (which required the complete image to be redrawn to incorporate even minor changes) or refresh CRT's with associated light pens. These devices triggered frantic research and development effort to encode the mathematical laws of perspective geometry in order to generate 3-D "wire-line" representations of building; the early algorithms were not sophisticated enough to suppress the "hidden-lines" which had to be removed manually, one by one!

These early line perspectives were immediately put to good use in investigating visual impact in urban and rural contexts. More importantly, they turned the tide of (at best) apathy and (at worst) resentment with which the profession viewed the emerging technology.

2.1 Photorealism and Animation

The progress in the mathematical modelling of geometry, of texture and of light and shade has, over the last 15 years, been quite staggering allowing, at relatively modest expense, high levels of visual verisimilitude to be achieved in the representation of both the exteriors and interiors of buildings.

Questions surround the degree of photorealism which is necessary and sufficient at different phases in the evolution of the design and its presentation to the client; the PhD thesis of Ballouz [14] sheds some light on this complex and important question.

In the main, computer generated images are used for final presentation of the scheme but some of the best examples of the effective use of appropriate graphics in the design decision-making process are reported by Sasada [15].

It is interesting to see the commercial availability of software which claims to give computer-generated images the impression of being

“hand-generated” by simulating the “wobbly-pen” effect discovered and studied by van Bakergem [16].

It is, however, the capability of powerful processors to generate animated sequences of “fly-rounds” and “walk-throughs” which bring real added value to what is possible manually. The combination of geometry engines and sequencing techniques borrowed from film-making is providing (student) architects with a wholly new tool for explaining the spatial arrangement within a building or an urban landscape.

2.2 Virtual Reality, Telepresence and Augmented Reality

The concept of being within a virtual environment, as opposed to viewing it through the window of a screen, has taken hold in the public imagination. The concept of being within a virtual environment, as opposed to viewing it through the window of a screen, has taken hold in the public imagination and the potential it has for experiencing the built environment is immense. Much intelligent thinking has to be done, however, to realise this potential and to disentangle the “moving”, “viewing” and “handling” capabilities which most current systems do, but badly. Particularly exciting is its potential for simulating access to buildings by people with motive or visual impairment.

Virtual reality has as its main focus the modelling of environments which do not yet exist, no longer exist or never shall exist, but the developments in the digital representation of existing environments - which may be too remote, too inhospitable or too fragile to visit physically - are equally important. The elegant software Quick Time Virtual Reality (QTVR) is already contributing significantly to exciting developments in the growing field of “virtual heritage” - the ability to make a “virtual visit” to architectural sites of cultural significance without the concomitant damage of a physical presence [17]. This introduces the interesting juxtaposition of virtual reality (- a real person in a real environment) with telepresence (- a virtual person in a real environment).

In its work for Historic Scotland, ABACUS is using existing and non-existing digital representations of the 5,000 year old neolithic

village of Skara Brae [18]. QTVR is being used to represent the village as it currently is, based on photographs and digital video; to this is added, by VR simulation, hypotheses regarding what no longer exists, e.g. the roofs, the door mechanisms, the artifacts. This powerful combination of technologies creates what can be thought of as “augmented reality”.

2.3 Inter- and Intra-Networking

The development of the Internet and the rapid expansion of very high bandwidth metropolitan area networks is opening up the potential for collaboration in every field of human endeavour and for ubiquitous multimedia access to virtual and real environments. Applications of these technologies include collaborative design teaching, [19], collaborative design practice [20] and the evolution of virtual universities [21].

3. Fast forward to the future

In his keynote paper to CAAD Futures 95, the author took a critical view of some aspects of the CAAD community’s activities and attitudes [22]. The seven deadly sins identified in the paper were: macro-myopia, déjà-vu, xenophilia, unsustainability, failure to validate, failure to evaluate and failure to criticise.

It is difficult, perhaps unreasonable, however, to maintain a critical and pessimistic view of the CAAD world in the face of such a wealth of innovative, relevant and enjoyable developments. The emerging technologies have clearly captured the imagination of our students and, provided we remain committed to maximising their access to the technologies, the future is safe with them.

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