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A number is worth a thousand pictures

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Abstract

This paper attempts to focus attention on modelling the functional behaviour of buildings — a relatively neglected topic in the current CAAD literature. It provides a review of the seminal work which has been done and argues that further development would provide student architects with the means of designing buildings which are more fit-for-purpose, energy-efficient, environmentally-friendly and cost-effective. © 2000 Published by Elsevier Science B.V. All rights reserved.

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1. Introduction

The CAAD community is lucky indeed to be involved in a field of teaching and learning which is evolving so fast, which contributes so much to the theory and practice of that most complex and interesting human activity — design, and which clearly excites such a high level of interest and commitment from our students. There is much upon which the CAAD community can congratulate itself; each year the proceedings of ECAADE, ACADIA, CAAD Futures and now CAADRIA expose an increasingly rich diversity of applications of the information technologies to architectural education. The purpose of this paper, however, is to highlight the relative paucity of applications which lie at the very centre of design education — i.e., the ‘‘cause and effect’’ of how design decisions impact upon the quality of the building. The proposition, enunciated many times over the last two decades is quite simple: (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.

The main part of this paper is devoted to a summary of a number of seminal developments which, over two decades, have targeted this extremely important but relatively neglected area of CAAD. The intention is to celebrate the achievements, however modest, in the hope of stimulating further development and greater uptake in design studios throughout the European Schools of Architecture.

2. Seminal developments

2.1. The origins

It is interesting to go back some 25 years to two of the earliest contributions, one in Europe and one

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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 ''lightpen'' — 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.

2.2. 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 and Labib [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.

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.

2.3. 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''.

2.4. 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 and Myers [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 5 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 cooperative 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 reimplement the VSE on the WWW to facilitate its evaluation by interested parties.

3. Numbers and pictures

This paper was provocatively entitled *A Number is Worth a Thousand Pictures* to try to focus attention on a topic which is relatively neglected in the current CAAD literature: the modelling of the *functional* behaviour as opposed to the *formal* character. The intention of the paper has been to highlight the importance of modelling and predicting as many aspects of the cost and performance of buildings as possible particularly at the early formative stage of the design decision-making. The experience of using the GOAL software in the Department of Architecture and Building Science provides evidence that when students have the facility to predict the cost/performance profile of their building, they produce buildings which are substantively better in terms of fitness-for-purpose, energy efficiency and cost-effectiveness; additionally, the more a student uses the model, the greater is her/his generic understanding of how her/his design decisions (the ''cause'') impact upon cost and performance (the ''effect'').

Section 2 of the paper summarises only some of the attempts which have been made to build software systems to facilitate the functional appraisal of design schemes. Not all of the attempts have resulted in systems useful for teaching and learning; of those which are, there is lamentably little evidence of the experiences of using them in the studio. The little evidence there is, however [7], is compelling in its pedagogical merit and a stimulus, it is suggested, for more development work in the aspect of CAAD. In truth, we need more numbers *and* more pictures if our students are to develop their design skills in the service of a built environment in which form and function are in harmonious balance.

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