WILL CAD SURVIVE DESIGNERS?

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ABSTRACT

Discussion about the future of CAD often focuses on hardware and software. But that is the wrong emphasis. Future directions for CAD should be considered from the point of view of what is of value to architectural design. This paper is mainly concerned with the needs of architectural design education. For CAD to develop effectively, design education must first address some existing problems which threaten the future of CAD. These problems result mainly from conflicts between traditional design values and needs of using computers. For computers to aid design, software designers need a clearer picture of what design is. But there is no single acceptable meaning of design. Instead several different yet coherent meanings with historical roots are suggested. Each of these directions have different implications for the development of CAD.

1. INTRODUCTION

Discussion about the future of CAD almost always seems to be about hardware and software. In a recent article about the future of CAD, Sanders [1989] doesn't address the issue of design but nevertheless describes new features that architectural CAD programs of the 90s should have. Others do the same. This emphasis on hardware and software comes about because the writers of these articles are often more involved in computers than architectural design. Hardware and software are central to the future of computers but can they alone shape the future of CAD? At the very least, discussing the future of CAD in terms of technology is putting the cart before the horse. We need to know what the technology should do for design. This is the central assumption of this paper: future directions for CAD should be considered from the point of view of what is of value to architectural design.

This assumption, of course, raises the question "How does one determine what is of value to architectural design?" That, in turn, raises the suspicion that what may be of value to me may not be to you. One way to deal with this question is to look for criteria that are broad and basic rather than narrow and personal. If there were widespread use of CAD in architectural design, for example, and if it made effective use of CAD, that is, if the computer made its power available to the design process yet remained as "transparent" a design tool as a pencil, then it would be fair to say that CAD was serving architectural design. I realise, as Radford and Stevens [1988] make clear, that I am begging a very large question by assuming, initially, that CAD is useful and beneficial to architectural design . Nevertheless, it is a good starting point.

2. THE STATE OF CAD

2.1. CAD in Practice.

It is important, when considering the future development of CAD, to understand where we are now. This paper is mainly concerned with CAD in architectural design education. But the real test of CAD is its use in architectural practice. We need, then, to find out what are the problems and opportunities of using CAD in practice since these must inform design education. What is the state of CAD in architectural practice? Is it well advanced and widely used? If "widely" means at least 50%, the answer must be no. Precise figures are hard to find, but some reports suggest that as many as 80% of architectural offices use computers for word processing and some other office management functions. Perhaps 30% have CAD systems and the number is probably growing.

Of the CAD systems in use, approximately 75-80% of them are used for drafting only [Kalay 1985]. One of the main reasons for acquiring a drafting system is increasing productivity. And there are reports of substantial increases over manual drawing. Industrialising a labor-intensive aspect of a craft system is both desirable and timely. But it appears that this apparently clear operation aspect of designing is not that well understood. "Development (of production systems) is often over ambitious and premature in relation to ... *knowledge of design and the nature of user practices.*" (emphasis added) [Walters 1986]. Yet drafting is regarded as the most developed application of CAD. Clearly much work needs to be done on developing understanding the the design process.

There are far fewer CADesign systems in architects' offices. Perhaps because "Computers are not a proven technology for the design process"[Schmitt 1987]. Schmitt lists two other major factors that make using computers in design a "daring decision." One is the substantial financial investment required. The other, even more important, is the substantial investment in human time required. Some architects are using computers in design. But the use of CAD is revealing cracks in the foundations of the design activity that traditional manual methods have been able to ignore. Walters found a "…. lack of shared models of building and design processes within the design team. User practice is both idiosyncratic and unstable." "Greater understanding of the nature of design practice and designers' methods is now urgent if systems and practice are to evolve together. .... *The view that we take of design then becomes critical"* (emphasis added) [Walters 1986]. These problems point more centrally to issues of design education rather than development of technology.

2.2. Design and computers: conflicting values?

Ten years ago, the field of computers was very different from today. It was the domain of minis and mainframes; micros were "home computers". Information was still entered on punch cards and was batch-processed in a grubby basement or a hi-tech temple called a computer center, and it went on at all hours. Computing was still a mystery to most people. Computer-users were outsiders. They spoke an arcane language, knew one another, and shared values. Computing was very much a separate sub-culture. Computer applications in architecture hardly existed. But the few hardy architects working with computers - mainly on technical issues - were almost indistinguishable from the others. They spoke the same language, and shared the same attitudes: computer applications in architecture involved problem-solving and number-crunching. They fit right in. But because the technical concerns of architecture were not highly valued in the power centres of architectural schools (that is, the design studios), computers had little impact on - or conflict with - architectural design.

Micros rapidly became the leading edge of computer development. They became more powerful, cheaper, easier to use and graphic. This led to major changes in the nature of computing. Computers began to emerge from the basements and appear in offices and classrooms. And they no longer simply crunched numbers; now they could draw. Some of the first 3D color drawings must have had an impact similar to Brunelleschi's first perspective painting. These graphics began to capture the interest of a few architectural designers. These people were different from the earlier architects. The earlier architects were sympathetic to a machine-based enterprise, to its methods and values. The design architects came from a different set of values.

Architecture acquired its professional status during the 19th century, the age of Romantic excess and individual genius. Whether this was an influence or not, individualism has been the central guiding value of architectural design. The craft approach accommodated this since it made few demands on design procedures and imposed few standards of clarity and discipline. Everyone could do things their own way without having to compromise or co-operate, and without having to understand the design process very clearly beyond their own personal actions. The result was the development of drawing skills (albeit in terms of drawing as object not as information). But understanding of the design process did not develop. There was no incentive; it didn't appear to have much impact on the work.It is questionable whether this was the best preparation for working with a fairly complex and demanding technology. But the rotating, shaded, 3D color, computer-aided drawings were irresistible, and the daring designers plunged in.

What happened to these pioneers? In recent years, ACADIA Workshops have been focussing increasingly on design rather than computer technology. This has given us an opportunity to look at some of the results of the encounters between designers and CAD. The results show some identifiable trends or, at least, some identifiable approaches to CAD. For example, there is "The computer as toy." Architects love computers; you can do such "neat things" like draw in 3D, color, shade, rotate, stretch, overlay, explode. And you don't have to stay between the lines [Shaw 1986]. The results have shown a considerable number of projects doing "neat things". Then, of course, there is COD - Computer Overwhelmed Design. In this approach, one "makes every move," not necessarily because it is desirable (for the design), but because it is possible. The more sophisticated the technology, the more irresistible the temptation. Then there is "More & more about less & less." Here one focuses so narrowly on some aspect of computers that you can't make a useable connection between it and design.

These are some of the approaches. As products they are often very interesting, but they raise disturbing questions. Crosley notes that "It's possible to use computer-aided drawing without really taking advantage of its capabilities. Even some experienced CAD users have simply transferred all their manual-drawing habits over to the computer" [Crosley 1988]. Have these students used the capabilities of the computer to explore architectural issues or have they created spectacular, fragmentary and essentially manual drawings done by computer? Have they developed computer skills which would allow them to actually use the power of the computer with some facility and economy of means or do they see CAD as some necessarily time-consuming addition to designing?

3. THE STATE OF DESIGN EDUCATION

3.1. The design teaching base.

These are troubling questions. They raise doubts as to whether design teaching at present can provide a solid enough foundation for effective application let alone development of CAD. Bridges points out an even more fundamental educational problem. He notes that many schools are not clear whether they are "promoting CAD education or architectural education using CAD?" [Bridges 1988]. This is a serious problem. In many schools the question has not been resolved, and perhaps there are some who do not even see it as a problem. After all, computer science courses are available whereas computers-for-architecture courses have to be created, computer science courses are "science" which confers a certain "legitimacy" that architectural computing courses don't have, there are more computer scientists available than computer-literate architects, etc. But the discipline of computer science is not the discipline of architectural design. And CAD programs created by computer scientists are, at best, of limited use, at worst, a distortion of design.

But what is architectural design? This is a central problem for the development of CAD. If there are no clear answers how can CAD serve design effectively? Yet this does not seem to be a concern in design teaching. Schools of architecture can apparently maintain some continuity of content in almost all subject areas but design. In design, studios are idiosyncratic and fragmentary. And students have great difficulty in relating design courses, in having them add up to a coherent activity called design.

To use computers effectively means finding new approaches. Finding new approaches, as Schmitt points out, requires a substantial investment of human time and effort [Schmitt 1987]. This is a particular problem for CAD. Developing CAD courses requires an understanding and response to both computers and design. This is very time-consuming. Yet most design teachers currently spend little time preparing design courses.

3.2. Teaching CAD.

In pre-industrial times, designer-craftsmen were relatively isolated, and individualism was normal. CAD, however, is a product of the information age. In the information age everyone is connected in more ways than are immediately visible. Not only are there direct links such as information sharing, but also indirect links such as shared schema, methods, standards, etc. One cannot approach this network of links in an individualistic and idiosyncratic way; CAD requires methods and standards, knowledge and skills. It is clear that effective use of CAD will require effective education for it. And this education will require proper preparation of courses, addressing of basic issues, continuity of courses and enough overall time to develop depth of knowledge and skills.

But is this happening? CAD courses in schools of architecture are usually taught by architects and attempt to use computers to produce something architectural, which is as it should be. But the results of these courses most clearly illuminate the conflict between design values and computer values: on the one hand design- intuitive, idiosyncratic, drawing as object; on the other hand computers- knowledge, procedures, drawing as information. There are times in these projects when CAAD seems to mean Computer-Assisted Anarchy in Design.

They also reveal another serious problem: time. Projects, except for graduate work, are usually one semester long, 10-15 weeks. Because there is usually little continuity between terms, whatever is to be accomplished must be done in one term. That one term must attempt to deal with both computer and architectural issues. Using the computer needs some time to learn. The architectural issues also need time. The result is that computers become a competitor with design for learning time not a partner, and CAD projects become more limited in what they can accomplish than manual design studios. Design courses are already fragmented. The introduction of CAD in this environment, leads to even more fragmentation. Unfortunately, traditional designers' values are predominant in almost all schools of architecture. In such a situation, how can CAD develop effectively? A more ominous question for me, in such a situation, is how can CAD survive?

4. DEVELOPING CAD

4.1. What is Design?

"For what shall it profit a man, if he gain the world and lose his own soul?"

Architecture has gained the world of CAD, but is in danger of losing its soul. The future of CAD lies with designers. And to secure that future design must find its soul. At the core is the question "What is design?"

At the ACADIA 88 Workshop, there were many interesting papers, mainly about design, sometimes about education, sometimes about both. Yet one heard comments such as "That's not really design" or "It doesn't deal with (this or that) aspect of design." Why? Because architectural design today is fragmented, almost anarchic. It is difficult to identify what is shared among designers. There appears to be no center to design. If design is so fragmented, how can CAD systems, which are intended to serve design, be effectively developed? Design can't be defined by prescription, and there is no general agreement in sight on what it is. But some order is necessary. What can be done?

First of all, we should avoid the temptation to reduce design to a single value. For many years, CAD-oriented architects have treated design - implicitly or explicitly - as a problem solving activity. It is richer than that, as Archea [1986] and Hillier [1972], among others, have shown. We need to recognise this richness but find some order in it.

An established method of finding order is to identify constants or types in a body of work, and to use these as a means of ordering it. Cross takes this approach in exploring some of the problems of CAD. He says that "People differ in the basic cognitive styles that they bring to any learning task", and goes on to describe different styles of learning, designing and computing. He explores such concepts as serialist vs holist learning and designing, convergent and divergent thinking, problem vs solution-focussed approaches, noting that "in general, designers prefer a holistic, solution-focused strategy rather than an analytic, problem-focused one." He concludes that all designers "will need CAD systems that support a solution focussed design strategy, rather than systems which offer problem-focused strategies. ... The emphasis should be on the generation of solutions and this should be possible before the problem is fully 'understood'" [Cross 1985].

This is a useful advance in clarifying the nature of the design process and the relationship between design and CAD, but it is not enough. It is about the procedural not the substantive part of design. It does not help us to identify what is shared among designers. The procedural and the substantive parts of design need to be linked. Just as we "will need CAD systems that support a solution focussed design strategy," we will need systems that support different kinds of solutions. At first glance, this may appear to be impossible. Every design is different. How can any CAD system do so many things. That is the problem - design is too fragmented. No field of endeavour can possibly develop anything of substance when it is in such a state. And CAD cannot advance beyond drawing systems until some order in design emerges.

The order that emerges must come from design, not computers or other sources. Design is concerned with many things but it is essentially a human activity and it is human values that mainly shape design approaches and give them meaning. Theorists have attempted to find order by identifying various recurring themes or concerns in architectural design and proposing terms that refer to these values. If some commonality of thought and terminology can be found here, it may also be a way of finding order and meaning in design approaches, and of clarifying what CAD systems should focus on in order to serve these design approaches.

4.2. Design as value choices.

Lockard notes that we start designing "with those drawings that are most critical to the particular problem. ... The first decisions and the first drawings in the process ... are the most important because they exclude whole ranges of alternatives that that probably won't be considered by subsequent drawings and decisions" [Lockard 1974]. But one designer in a particular problem may first study building form, while another may first study planning. This is not arbitrary. Design strategies are based on interests and value choices.

Design strategies direct the first steps in designing. The kinds of drawings that are done are also shaped by the design strategy. The links between design strategies and drawing were explored in a first year design course [Rubinger 1988]. Many beginning students simply assume that all designing starts with plans. It is necessary to show them that plans deal with only certain aspects of a design, and that "they exclude whole ranges of alternatives that that probably won't be considered by subsequent drawings". This concern led to the exploration of design strategies, based on ways of drawing, that reflected individual interests and values. Four types of design strategy were identified. Some students tended to think about a project in terms of form, image, surface modelling, form and site, etc. We called this approach the Form in the Landscape and suggested the types of visualisation that best reflected these kinds of concerns were perspective sketches, site sketches, models. Other students approached projects as problems to be solved. This was the Planning approach. It was concerned with activities, analysis, organisation and efficiency, and made use mainly of calculations, diagrams, and plans. A third approach arose from the designer imagining herself in the building. Her concerns were often with spatial enclosure, light, view, and movement through spaces. This approach, called Spatial Experience, could be visually explored by means of circulation diagrams, plans, and sections. The fourth approach thought about buildings in terms of their process of construction. It was concerned with materials, systems, assemblies and sequences of operations. This was the Built Form approach and was visually explored by means of plans, sections and axos. Design explorations were not limited to these concerns. But the initial drawings were seen as a design strategy that represented particular concerns, and had a significant influence on the design.

These strategies were developed in the context of a traditional manual design course. Crosley has explored similar strategies but in the context of CAD. He notes that "Architectural design is based on a designer's ability to visualize and record design solutions. Tools and media are an important part of this process. If inadequate, they can get in the way; if exceptionally good, they can help to unleash creative powers. ... Various computer-aided design tools are no different" [Crosley 1988]. He goes on to describe some architectural strategies, the kind of design activities they emphasise and some features of CAD software that would help. One strategy, for example, is called "Plan and Function". Among other comments, he notes that it "relies heavily on the organization and development of plans [and] can make excellent use of two-dimensional software for design." There are similar descriptions of strategies that emphasise particular approaches such as "Exterior Form", which can make good use of three-dimensional modelling programs, "Spaces", which can also use three-dimensional projection programs, "Constructional Design", which needs layering capabilities, drawing libraries, etc. (These are very brief excerpts.) Crosley's ideas help to clarify the link between design strategies and drawing.

Design strategies and drawing are the first two links in the design chain. The third and directing link is value choices. Design strategies, that is, approaches to design, are shaped by values choices. There have been many attempts, especially by historians, to find some order in approaches to architecture. A traditional way has been through the identification of styles and explanation of what shaped those styles. In a similar way, there have been many attempts at identifying and explaining various movements in contemporary architecture. We will look at just three attempts . Barnett [1966] discusses continuing traditions, which he identifies as the Academic Tradition, Structural Rationalism, Scenographic Design and Domestic Vernacular, and the values they emphasise. Frampton [1982] describes the contemporary movements in architecture as Productivism, Rationalism, Structuralism, and Populism, each with their concerns. Lastly, Rowe [1987] outlines Functionalism, Populism, Conventionism, and Formalism. Obviously there are similarities in these descriptions, but also differences.

How do we choose? The fact that I find Rowe's description simplest and clearest is not enough of a recommendation. Luckily, a basis for relating these traditions or theories has been developed with great skill and clarity by Capon [1983]. He states "It is doubtful whether any impartial classification of architectural theories can be adequately considered without some reference to the development of the idea of the categories as found in the standard works of critical philosophy." He goes on to explore 2000 years of philosophy and some established ideas about categories before proposing six categories for architectural theories. He then uses these six categories as a means of exploring and grouping the main movements in architecture on the basis of their concerns. They are (in no particular order): 1 Functionalism-Systems Theory-Pragmatism, 2 Constructivism-Organic Theory-Arts & Crafts, 3 Historicism-Academicism-Semiology, 4 Picturesque-Contextualism-Neo-Vernacular, 5 Formalism-Structuralism-Minimalism, 6 Futurism- Radicalism-Avant-Garde.

While no classification scheme can ever be completely impartial, this is the most compelling I have seen. The categories are created with care, and they appear to be able to respond to, and order, a wide range of beliefs about architecture. Each category groups three related theories. And for each I have proposed a term that encompasses its key characteristics. The term has been taken from a much more extensive diagram by Capon, which identifies many architectural themes and groups them so that they amplify the character of each of the categories. To the extent that this larger diagram sets out the concerns of each category, it is an identification and organisation of values.

4.3. Future directions for CAD: some speculations.

Capon's categories have considerable promise for the future development of CAD. Instead of an infinite number of approaches to design and chaos, we have a finite number and order. And we still have variety. This framework serves both to clarify designing and to guide the development of CAD. There are no sharp divisions between Capon's categories but rather they "dissolve equally back into one another" [Capon 1983]. In order to consider the CAD possibilities, however, it will be useful to simplify the divisions. With apologies to Capon, I propose to condense the number of categories to three. This simplification will also sharpen distinctions and directions. The first two I will call Formalism and Functionalism because they are already in Capon's description and they are common terms. As the third, I suggest Rowe's term Conventionism, because it is more inclusive than Historicism, my first choice, and it seems to sit well between Formalism and Functionalism. Although Capon's categories "dissolve equally back into one another," I will introduce another distortion and group Futurism-Avant-Garde with Formalism-Structuralism under Formalism, Constructivism-Arts & Crafts with Functionalism-Pragmatism under Functionalism, and Picturesque- Contextualism with Historicism-Academicism under Conventionism. Each grouping focuses on particular kinds of concerns, tends towards particular kinds of design strategies and makes particular kinds of demands on CAD.

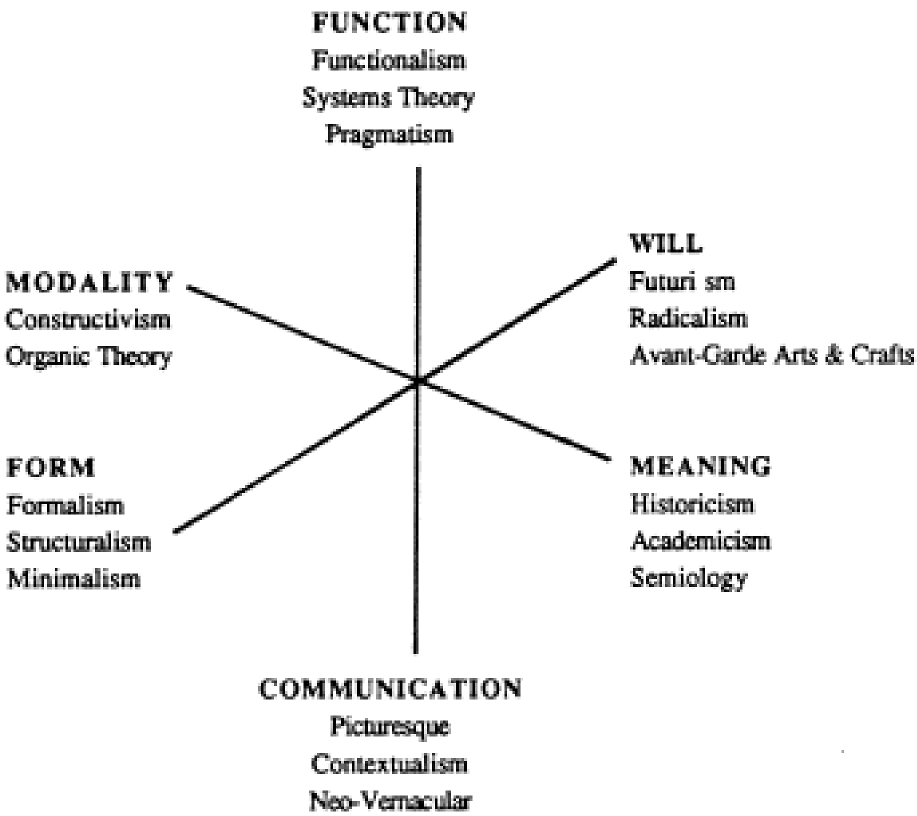

Figure 1. Architectural Theories by Category. [Capon 1983]

What is formalism? We can infer from Capon's exploration of categories, that formalism is about formal relations: order, harmony and abstraction. What does a formalist approach to design demand from CAD? Rowe suggests that formalists see architecture as a "largely autonomous realm of expression" concerned with "autonomous 'languages' of architecture, their compositional qualities" and with exploring "new formal and figural possibilities" [Rowe 1987]. Formalism, then, is not concerned with what is, but with what could be. It is concerned with form, the visual image, the object in the landscape, sculptural space. And with uniqueness, paradox, and abstraction. Its concerns are never fully clear, its gestures oblique. Its images are evocative rather than descriptive. This is a puzzle-making approach to design [Archea 1986].

A CAD system to serve this approach would be based on a 3D database. It would need to have good three-dimensional drawing capabilities, probably solid modelling or, even better, void modelling capabilities [Yessios 1986]. Also the ability to manipulate the form in many ways such as slice, stretch, overlay, intersect, explode, etc. With its emphasis on autonomous languages and exploring new formal and figural possibilities, on abstraction and puzzle-making, this approach would benefit from definable formal languages such as shape grammars or automated ones such the fractal-generating program by Yessios [1987]. For formalists, the image is often more important than the actual building [Goad 1989]. Creating the image would need elaborate color drawing and painting tools, the sort of realistic rendering of images suggested by Sanders [1989], such as transparency, ray-tracing, access to other media such as video, etc. This is also the natural software for presentation drawings.

Where Formalism is concerned with the visual, Capon's framework suggests that Functionalism is concerned with causation, methodology, systems. In architectural terms, it is identified by "an emphasis on the accommodation of activities and the influence of building technology" [Rowe 1987]. Where Formalism is oblique, almost mystical in its approach, Functionalism is direct and logical. It is a problem-solving approach which emphasises planning in terms of tasks, organisation, quantification, and efficiency.

The emphasis on planning suggests a 2D CAD system. Its analytic approach and concern with numbers would require good analytic tools to do such things as analysis, for example, of activities to produce graphs and diagrams, extensive spreadsheet capabilities, and automated space layouts from programmatic analysis. Numbers - dimensions and other quantities - are important. Being able to create and manipulate spaces in a number of different ways, especially by means of numbers, such as in parametric drawing would be useful. So would some of the features listed by Sanders [1989] such as automatic cross referencing, associative dimensioning, scale attributes, etc. This approach could also make good use of performance evaluation tools, based on intelligent building system models that automatically evaluate aspects such as planning efficiency, structure, energy, building code compliance, etc. A 2D database would serve the emphasis on planning. $2\frac{1}{2}$ D (extruded 2D) drawings could serve the needs of visualising space and form. This would be the natural software for production applications.

Conventionism is a term used by Rowe. He defines it as "an architecture of largely historical reference" [Rowe 1987]. Capon does not use the term. However, his exploration of different categorisations suggests that it could encompass terms such as meaning, standards and archetypes. This suggests a broader view than Rowe. Looking at architecture as as a cultural artefact encompasses the present as well as the past.. Where Formalism emphasises visual manipulation of form, and Functionalism emphasises design as problem-solving, Conventionism emphasises people and inhabiting. Formalism and Functionalism focus on the new and the abstract; Conventionism focuses on the existing and the real world. It emphasises evolution rather than revolution, adaptation rather invention. It is pragmatic, uses and modifies existing form languages and building types. It is concerned with how people live, spaces as settings for living. Formalism can be seen as mystical, Functionalism as scientific and Conventionism as humanist.

A CAD system to serve this approach could use 2D-3D drawing capability. The database could probably be 3D. It would need to be able to manipulate visual images, but in a different way from Formalism. It would need to be able to access and retrieve form and element precedents and modify them. This would require large graphic database capabilities, some ability to manipulate these models and to modify them perhaps by means of parametric control over significant dimensions. This area could also benefit from definable formal languages, such as shape grammars, as an aid to evolutionary design. If the Formalist approach can also be seen as presentation software, and Functionalism as production software, the Conventionist approach can also be seen as conceptual design software. The database would not need the same precision as the Functionalist software. Designs might be built out of blocks or planes. Forms, whether created from basic elements or modified from graphic databases, would benefit from animation capabilities to explore spatial qualities. Where expert systems are likely to be very difficult in other approaches, the evolutionary character of this approach, its use of known languages, makes it a prime candidate for expert systems.

5. CONCLUSION

These are some brief speculations on future directions for CAD. But the development of CAD depends not only on the future but also the present. At present designers are isolated from each other leaving CAD is in a wilderness without direction. This is happening in both education and practice. CAD can't develop effectively by itself, but design can show it the way. Identifying design approaches and values can serve as a means of overcoming the current anarchy in architecture by clarifying some ideas about design, by bringing people and ideas together. If it can help designers to enter the shared world of the information age and to strengthen their individual role in it by affirming their own beliefs, then CAD will have both a soul and a world to gain.

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