Some Epistemological Concerns Regarding Artificial Intelligence and Knowledge-Based Approaches to Architectural Design - A Renewed Agenda

Charles M. Calvo
Auburn University

It has been noted that designers - when confronted with computers - have, by and large, refused to accept the introduction of apparently new design methodologies, and it has been speculated that this is the result of a failure of those methodologies to address the cognitive processes which take place in the course of designing.[1] This position is somewhat suspect in that such innovations as computer-aided drafting -which also fail to recognize these processes- have been widely accepted. It is perhaps more likely that the lack of acceptance results from a perception on the part of designers that the new methodologies either do not reflect some or all of those concerns that designers consider fundamental to design, or that they actively interfere with the designer's ability to accomplish what he/she sees as the goals of design. Given that the application of artificial intelligence and related work to architecture is still in its infancy, all of this suggests the need for a reassessment of the role of computing in design in order to clarify and strengthen those roles deemed appropriate.

Two approaches to the integration of artificial intelligence and knowledge-based systems into architectural design practice are currently dominant. One attempts to create systems which can on their own produce designs, the other provides intelligent support for those doing design.[2] It was, in part, the recognition of limitations in the ability of traditional CAD systems and building modelers to reflect what designers actually do that led to explorations into the idea of intelligent assistants.[3] Development of such assistants was aided by research into the act and process of design through protocol and other studies.[4] Although some work is currently being done in the development of artificial intelligence and knowledge based applications in architecture, and work continues to be done on the study of design methodologies, the bulk of available information in each of these areas remains in the realm of design disciplines related to but outside of architecture and do not reflect the explicit role of architectural design in the embodiment and expression of culture.[5]

The relationship of intelligence to culture has resulted in some skepticism regarding the ultimate capacity of neural nets and symbolically programmed computers in general.[6] Significant work has been done questioning the rational tradition in computer development for its failure to address phenomena which are not easily subject to scientific analysis.[7] Further skepticism regarding the role of artificial intelligence and knowledge-based or expert systems in architectural design has been emerging recently. Such criticism tends to focus on two issues: the nature of drawing as an activity which involves both the generation and interpretation of graphic artifacts,[8] and the nature of the human designer as an active agent in the design process.[9]

A Renewed Agenda

As we create our tools, they are reflections of our natures and values. Neither neutral nor omnipotent, these tools do establish a domain which defines.and limits the capability of the systems within which the tools are applied. Similarly, the technologies embedded in our culture determine the ways in which we percieve the world. The computer without question is creating fundamental shifts in the ways in which we conceive and percieve. However, if we are to realize the potential of computer-based aids to design then the values which are explicitly and implicitly embedded in these tools must shift to reflect broader cultural and social concerns rather than simply transforming those concerns. Thus the proposed agenda comprises three items:

1. Development of computer-based assistants must be grounded in a larger philosophical discourse which places it in a framework for addressing the social concerns and providing validation for daily life.

2. Development of computer-based assistants must recognize those forms of knowledge that are subjective, personal and non-scientific in nature which result in part from the craft-based inheritance of architecture which itself involves attempts to engage in, learn about, and actively shape the world.

3. Development of computer-based assistants must involve a renewed examination of communication issues which focuses on enhancing the ability of humans to communicate with each other, human intelligence and human learning.

The Philosophical Discourse

The transition from traditional to modern society has been characterized by the emergence of a confrontation, in the productive forces of society, between traditional worldviews and a techno-scientific worldview. This confrontation results in a questioning of traditional forms of legitimation.[10] Jurgen Habermas, Richard Rorty and others have argued that the value structure of techno-scientifically based society has seen a shift in value structures such that efficiency, rather than a vision of a good and just society, becomes the basis for legitimation. Alberto Perez-Gomez has argued that the scientific model of reality is insufficient to account for the vagaries and subjectivity of human experience, its embodiment in culture, and its expression in architecture.[11] The detachment of the philosophy of science from social concerns no longer allows for attention to the 'details of daily life'.[12] Not attempting to reject science, these critics instead illuminate the limitations of the scientific world view and argue for a pluralistic approach which allows the techno-scientific episteme to exist alongside others which provide those elements that are missing or inadequately addressed.

Within the computer-based environment these criticisms would appear apropos as the nature of the design problem has been redefined: design is now the production of a description of an artifact sufficient that the artifact may be manufactured. The sequence of events in the development and implementation of the current generation of computer-based aids follows Feenberg's moments of the reconception of the subject/object relation in technical systems.[13] If design is considered the object of the system, it is first subject to *decontextualization*, where it is removed from its cultural connections. It is then subject to *reduction* to such terms as: problem identification, vocabulary, design domain, sequential pass-oriented stages, feedback loops, etc. which may be submitted to technical control - all of which are useful within their own context but which make no reference to larger cultural concerns. Indeed, when culture is introduced at all it is treated as a constraint to creativity. For instance: '[d]esigns that are based on known compositions of techniques (practices and styles) from within a culture will appear mundane.'[14] Following such reduction, the subject -the designer- is separated from design, which may then be *automated*, and the designer is removed from his/her role as the active agent of design and *positioned* to control the process from without.

While the science of design is certainly a legitimate area of design research, it does not comprise the totality of design. A pioneering attempt to provide a philosophical framework for the development of artificial intelligence appears to have been largely ignored by those researching design applications.[15] Social issues, when they appear, are equated with performative and quantifiable criteria as if they can be manipulated and assessed in equivalent manners. For instance: '[t]he design objectives are represented in the system by a hierarchical list of design criteria and their relative weighing indexes, which describe the desired performance of the solution. These criteria include such aspects as cost, functional requirements, and social implications.'[16] Although the definition of design with the CAD community is predicated on the notion of the *production* of a *description* of an artifact, attention in the academic realm is shifting to design as *exploratory* and *experimental*, as an attempt to *engage in* and *learn about* the world.[17] Thus a discourse is required which identifies the breadth of what we call design, to attempt to place the science of design within that breadth, and to attempt to reconcile it with other perceptions/approaches. Additionally, this discourse needs to make clear the relation of architecture and architectural practice to society and to the context of daily life, and to indicate the role of computer-based design assistants -if any- in improving those conditions, not simply to aid in the efficient production of artifacts. While it is not the domain of the developers of computer-based assistants to establish this discourse, they must both engage in it and acknowledge it if they are to have any confidence that their work will have legitimacy in any context outside of their own.

Specific areas of research which should aid in the development of this discourse include:

- research into how design is perceived/ understood by designers vs. how it is defined from within the scientific tradition.

- greater attention in protocol studies to what designers think about what they are doing. (Because their thoughts have not matched their actions, those thoughts have been largely dismissed by those performing these studies)

- detailed case studies of the changes which have occurred in offices, their management and personnel structures, the nature of their work, fee and billing structures, through the integration of computers (to date this information has existed largely in anecdotal form)

- comprehensive review of architectural curricula as they relate to design/production issues and the integration of computers

Non-Scientific Knowledge

Further criticism of the scientific episteme has debunked the myth of objectivism and has made clear the legitimacy of subjective and narrative forms of knowledge.[18] In contrasting scientific knowledge with narrative knowledge, Jean Francois Lyotard suggests that the scientific has suffered from the necessity to be representational. The tradition of architectural representation has placed it fully within the scientific conception of representation which required "the reproduction, for subjectivity, of an objectivity which lies outside it."[19] Drawings were valued for the extent to which they accurately reflected and made available information about the building(s) they represented. New knowledge was not in effect created in drawing, instead it was discovered through the re-ordering of pre-existing data within an accepted system of classification and a set of standard repre-sentational conventions.[20] This condition has been exacerbated by the literal appropriation, by computer-based design aids, of these standard classification systems and representational conventions.

The shift to almost exclusive use of computer graphics, albeit in a variety of forms, that is occurring in architectural practice follows Feenberg's definition of decontextualism. The primary qualities of architectural graphics - those which are subject to technical control- are being appropriated by the new representational medium, while the secondary qualities - those which enable drawing and similar acts to provide connection to and shape the world, are left largely unexplored.

Visualization, through the computer, has moved from an operation which is an attempt to place ourselves in the world through the human act of picturing, to an operation in which the act of visualization has entirely exteriorized. While this condition in itself is not problematic, the potential loss of individual visualization, unmediated by conventionalized processing devices, is.

Visualization is an active means of processing which connects conception with perception through visual structures. According to Marx Wartofsky, human vision is an artifact created and changed by modes of picturing.[21] As designers we are valued for our individuality; we all 'see' the world in different ways, and our genius lies in the application of that vision. The ultimate value of visualization to design therefore, is that it does individuate experience, and it is understood that one's individual visual experience is unique and is in some sense irreplaceable by that of another. It is therefore essential to the ability to function as an individual, and to the concept of creativity, that some act of picturing remain available outside of any conventionalized process.[22] This is not to say that electronic visualization has not changed our visual structures - it has, or that such visualization is incapable of producing profound new insights - it can. The video world is however creating a singular visual construct which is global in nature, and which is displacing and devaluing individual vision.

Nelson Goodman and others have shown how the act of picturing is an important component of world-making: the shaping of unique and individual realities which constitute our understanding (knowledge) of the world.[23] Architectural representations are of particular value in the development of knowledge in the design process when they function through both exemplification -the actual possession in the representation of properties possessed by that represented and the ability to act as a sample of those properties, and expression - the metaphorical possession of properties or attributes. Exemplification is that function of architectural representation which allows the designer to explore and understand the nature of the exemplified properties of the object(s) represented. Requiring no *a priori* knowledge - one may learn about a material by making a sample of that material - representations

■ which function through exemplification are capable of producing *a posteriori* knowledge in the designer. Expression, by contrast, requires *a priori* knowledge: one must know about movement independent of representation in order to express or to read movement in a representation. Thus it is important to distinguish between properties actually possessed by a representation and those which are simply metaphorically possessed or simulated.

The development of computer-based aids to design requires further shifts in the role of drawing and other
■ forms of representation which reflect the accommodation of narrative, subjective and non-scientific forms of knowledge. The new representational medium of the computer should allow the development of of fundamentally new forms of representation, both with the computer **and** outside of any electronically mediated representation. Further, the development of computer-based visualization must happen within the context of representation in general rather than becoming the means of defining architectural representation. Specific research areas which follow from this assertion include:

- further investigation into the properties of depiction and exemplification and their function in transforming the designer's understanding of the world.

- further investigation of the cognitive processes involved as designers shift their thinking about designs from depictive structures to descriptive structures.

- with the above, investigation of alternatives to standard computer graphics for the transfer of design knowledge from the human designer to the computer (currently the transfer is predicated on the limitations of computer knowledge and language and greatly reduces the content of the computer generated image).[24]

- greater development of simulation applications which model ways of knowing which are difficult or impossible given the constraints of real space/time, rather than techniques which are simply alternatives to readily available crafts (the model of using pressure sensitive controls and 3D modeling to study chemical bonding serves as an analogue for the former, while the simulation of the appearance of watercolor is an example of the latter).

Communication Issues

Additional criticism of the scientific episteme, and especially the particular way the computer has infiltrated most, if not all, forms of communication, has suggested three problems. The computer has come to define the bounds of knowledge, knowledge has become exteriorized and quantified in such a way that it is now treated as a commodity, and, as a result, the individual as source and medium for information generation and exchange has been devalued.[25]

With introduction of knowledge-based and expert systems the nature of communication flow has shifted. The tradition of draughting and its conventions developed to facilitate the interaction of various members of the community which structured the building process: client or patron, architect, draughtsman, builder. These players formed a cultural web, mediated by a commonly held representational vocabulary, which allowed each to bring their own knowledge and interpretations to bear on the project.[26] Current research suggests that the concern is no longer interaction between mutually dependant cultural agents, but between designer and machine.[27] Such interaction may take the form of training an intelligent assistant,[28] interacting with a critic or counselor, etc.[29] However, such work sets agendas no higher than to improve the ability of the machine to act intelligently, and to therefore improve the *performance* of the human designer. Even research into the generalized human-computer interface problem suggests that the aim of such research is simply to change people's attitudes towards computers.[30]

The expert systems approach presumes that the machine can provide intelligent assistance which expands the knowledge domain available to the designer. However, the ability to act in an intelligent manner must be distinguished from the possession of intelligence. Intelligence requires motivation by purposes possessed by the organism and by goals developed by the organism through its active connection to culture.[31] The advantage of human experts in the design process does not lie simply in their possession of relevant knowledge, but in their role as cultural agents in the application of that knowledge. While machines may be capable of learning, the creative and judgmental aspects of design appear to be culturally rooted and to be limited to humans.

Knowledge-based systems are likely to substantially change the manner in which knowledge is acquired, applied and exchanged. As long as information technologies were incapable of exhibiting behavior, responsibility for the application of information remained with the human. Thus humans were encouraged to increase their own knowledge base in order to act more effectively and with greater confidence in the appropriateness of their actions. With the shift to knowledge-based systems capable of acting intelligently we are also likely to see a substantial shift in professional responsibility. The finite nature of previous technologies required an ongoing system of information exchange. As no source could be considered comprehensive, communication on a variety of levels was necessary in order to accumulate information. This condition is reflected in the use of footnotes and bibliographic references which affirm the finite quality of the work and establish the means of acquiring additional information. Knowledge-based systems are likely to fundamentally change this condition as the knowledge possessed by a system becomes an extremely valuable commodity. Collegial exchange will disappear in favor of the security of the system.[32]

Shoshana Zuboff has proposed the term *informate*, in contrast to automate, as an alternative for the application of technology.[33] Aart Bijl has called for complete transparency in computer based aids, using the word processor as an analogy.[34] With others he has suggested that we may not want intelligent aids at all.[35] Re-examination of communication issues - between humans engaged in culturally rooted activities rather than between humans and machines - is necessary if we are to develop truly effective design aids. Specific areas of research which follow from this assertion include:

- protocol studies of interactions between human experts in addition to studies of single designers.
- more studies of use of electronic aids in the design environment to facilitate communication, knowledge and information exchange
- case studies of how the nature of communication changes through the application of expert and knowledge-based systems.
- greater research into the development, structure and use of hyper-media systems which are intended to provide access to information, not make judgements about the application of information.
- studies of the transfer of information between representational systems and the effect of the system of representation on the content of the information
- increased research and development in networking and information exchange solutions

Conclusions

As we develop devices to aid us in design we must not lose sight of the role of architecture in the embodiment and expression of culture. Perhaps more than any other practice, architecture is philosophy made concrete. It involves the making of things in the world which shape and determine the world. It is a communal and consensual act which places communication and human interaction at its center. The production of artifacts, or the production of descriptions of artifacts, is the means of architecture and design, not the goal.

If knowledge-based or intelligent assistants to design are to be effective aids, they must develop within a much broader discourse which accepts architecture's inherently cultural, social, human, nature. It may, however, be that computers are useful as models of intelligence, but not as intelligent agents. The development of systems which provide free and easy access to information seems a far more useful endeavor than the development of systems for securing knowledge and limiting access. Systems which are predicated on discussions of human learning and human intelligence will always be preferable to those which are predicated on machine learning and machine intelligence.

Notes

[1] Goldschmidt, G. (1992); "Criteria for Design Evaluation: A Process-Oriented Paradigm"; Principles of Computer-Aided Design: Evaluating and Predicting Design Performance; (ed. Y. Kalay); Wiley

[2] Navinchandra, D. (1991); Exploration and Innovation in Design, Towards a Computational Model; Springer-Verlag

[3] see for instance:
Bijl, A. (1989); Computer Discipline and Design Practice, Shaping Our Future; Edinburgh Information Technology Series; University Press; (pp. 147 & 171); Bijl, A. (1986a); "Designing with words and pictures in a logic modelling environment"; Computer-Aided Architectural Design Futures (ed.: Alan Pipes); Butterworth's; (pp. 128-145); Bijl, A. (1986b); "Logic modelling in computer-aided design"; Environment and Planning B: Planning and Design (pp. 233-241); Eastman, C.M. (1987); "Fundamental Problems in the Development of Computer-Based Architectural Design Models"; Computability of Design (Y. Kalay); John Wiley and Sons; (pp. 133-140); Kalay, Y., Swerdloff, L., Kajkowski, B. and Neurmberger, C. (1990); "Process and Knowledge in Design Computation;" Journal of Architectural Education 43:2; (pp. 47-53); Stiny, G. (1990); "What Designers do that Computers Should", The Electronic Design Studio; (McCullough, Mitchell and Purcell eds.); MIT Press

[4] see for instance:
Akin, O. (1986); Psychology of Design; Pion Press; Akin, O. (1978) "How do Architects Design?", Artificial Intelligence and Pattern Recognition in Computer Aided Design (ed. J.C.Latombe) (pp.65-103); Akin, O. and Reddy, R. (1977); "Knowledge Acquisition in Image Understanding Research"; Computer Graphics and Image Processing 6; (pp.307-334); Eastman, C.M., (1969); "Cognitive Processes and Ill-defined Problems: A Case Study from Design"; Proceedings of the International Joint Conference on Artificial Intelligence, Washington D.C. (pp. 669-675); Eastman, C.M. (1968); "On the Analysis of Intuitive Design Processes"; Emerging Methods of Environmental Design and Planning; (ed. G. Moore) (pp. 21-37); Newell A. and Simon H.A. (1972); Human Problem Solving; Prentice Hall; Schon, D. (1983); The Reflective Practitioner; Simon, H.A. (1978); "How Big is a Chunk" Models of Thought; Yale University Press; (pp. 51-61)

[5] for examples within architecture see for instance: Guena, F. and Zreik, K (1989); "An Architect Assisted Architectural Design System;: Artificial Intelligence in Design"; Proceedings of the Fourth International Conference on the Applications of Artificial Intelligence in Engineering; (ed. J. Gero); Springer-Verlag; Pohl, J. (1992); Preface to Proceedings, Advances in Computer-Based Design Environments, 3rd International Conference on Systems Research, Informatics, and Cybernetics: (pp. iv)

[6] Dreyfus, H.L. and Dreyfus, S.E. (1988) "Making a Mind Versus Modeling the Brain: Artificial Intelligence Back at a Branchpoint"; Daedalus 117:1; (pp.15-43)

[7] Winograd, T, and Flores, F. (1986); Understanding Computers and Cognition; Addison-Wesley

[8] see for instance:
Bijl, A., "Designing with words and pictures" & "Logic modelling in computer-aided design;" Eastman, C.M. (1987); "Fundamental Problems in the Development of Computer-Based Architectural Design Models;" Computability of Design (Y. Kalay, 1978); John Wiley and Sons; (pp. 133-140); Krishnamurti, R. and Giraud, C. (1986); "Towards a shape editor: the implementation of a shape generation system"; Environment and Planning B: Planning and Design: (pp. 391-404); Negroponte, N. (1975); Soft Architecture Machines; MIT Press; (pp. 60); Stiny, "What Designers Do That Computers Should;" Kalay et al; "Process and Knowledge in Design Computation"

[9] Bijl, A.Computer Discipline and Design Practice; Akin, Psychology of Design, "How Do Architects Design?", "Knowledge Acquisition"; Kalay et al, "Process and Knowledge"; Simon, "How Big is a Chunk?"; Schon, The Reflective Practitioner

[10] Habermas, J. (1968); "Technology and Science as 'Ideology'"; Jurgen Habermas on Society and Politics, A Reader; (ed. Steven Seiman)' Beacon Press; (pp. 254)

[11] Perez-Gomez, A. (1984) Architecture and the Crisis of Modern Science, MIT Press

[12] Rorty, R. (1985); Habermas and Lyotard on Postmodernity; MIT Press

[13] Gero, J. and Rosenman, M.A. (1989); "A Conceptual Framework for Knowledge-Based Design Research at Sydney University's Design Computing Unit; Artificial Intelligence in Design"; Proceedings of the fourth International Conference on the Applications of Artificial Intelligence in Engineering; (ed. J. Gero); Springer-Verlag; Coyne, R.D., Rosenman, M.A., Radford, A.D., Balachandrian, M. and Gero, J.S. (1990); Knowledge-based Design Systems; Addison-Wesley

[14] Feenberg, A. (1991); Critical Theory of Technology; Oxford University Press

[15] Navinchandra, D. (1991); Exploration and Innovation in Design, (p. 9)

[16] Winograd and Flores, Understanding Computers

[17] Carrara, G., Kalay, Y., Novembri, G. [1992]; "Computational Framework for Supporting Creative Architectural Design"; Principles of Computer-Aided Design: Evaluating and Predicting Design Performance; (ed. Y. Kalay); Wiley

[18] Angelil, M. [1990]; "Experiment as Modus Operandi Investigation of Design Process: The Los Angeles Art Park"; Journal of Architectural Education 44/1; (pp.37-48)

[19] Habermas, J. (1972); "Knowledge and Human Interests: A General Perspective"; Knowledge and Human Interests; Heinemann, Jean-Francois Lyotard, The Postmodern Condition: A Report on Knowledge; (p. viii), Kuhn, T; (1970); The Structure of Scientific Revolutions; University of Chicago Press, Second Edition

[20] Jameson, F. (1984); Foreword to Jean-Francois Lyotard, The Postmodern Condition: A Report on Knowledge; (p. viii)

[21] When drawing is a descriptive act, it follows from the object or artifact which it describes; it is an abstraction away from that artifact. This is typical of drawing systems like construction documents, which make use of conventionalized notational systems to effectively describe the object to be constructed. In this sense the drawing is simply a re-ordering of previously existing information. Drawings which are depictive acts preceed the objects or artifacts which they depict; the object is given a reality solely through the existence of the drawing which represents it. In this sense drawing is a creative act. As the computer is a descriptive medium, any act of depiction must be filtered through a conventionalized descriptive structure which re-orders previously existing data.

[22] Wartofsky, M. (1979a); "Picturing and Representing"; Perception and Pictorial Representation; (eds. C.F. Nodine, D.F. Fisher), Preager: (pp. 272-283); Wartofsky, M. (1979b); "Perception, Representation and the Forms of Action: Towards a Historical Epistemology"; Models, Representation and the Scientific Understanding, Boston Studies in the Philosophy of Science Vol. 129; D. Reidel; (pp. 188-210)

[23] Finkelstein, L.; (1979); "On the Unpicturelikeness of Our Seeing"; Perception and Pictorial Representation: (eds. C.F. Nodine, D.F. Fisher), Preager; (pp. 61-83)

[24] Goodman, N. [1976]; Languages of Art; Hackett; Goodman, N. [1978]; Ways of Worldmaking; Hackett; Goodman, N. (1984); Of Mind and Other Matters; Harvard University Press

[25] "Although the symbolism of drawings can, and has been captured in drafting and modeling systems, their semantic content remains computationally inaccessible, since it relies on considerable inference powers for its interpretation, and on abstraction and fuzziness for its development." Kalay et al; "Process and Knowledge", pp. 51

[26] Rorty, Habermas and Lyotard, Lyotard, The Postmodern Condition; Habermas, Knowledge and Human Interests

[27] Polyzoides, S. and Calvo, C. [1989]; "Building, Drawing, Thinking: Neff and the Practice of American Eclecticism in the 1920s"; Wallace Neff 1985-1982 The Romance of Regional Architecture; The Huntington Library

[28] for example:
ten Hagen, P. and Ruttkay, Z [1991] "Intelligent User Interface for Intelligent CAD"; in Intelligent CAD Systems III Practical Experience and Evaluation (eds. P.J.W. ten Hagen and P.J. Veerkamp)

[29] Guena and Zriek, "An Architect Assisted Architectural Design System"

[30] see for instance:
Baker, K., Ball, L., Culverhouse, P., Dennis, I., Evans, J., Jagodzinski, P., Pearce, P. Scothern, D. Venner, G.,

■ [1991]; "A Psychologically Based Intelligent Design Aid"; Intelligent CAD Systems III Practical Experience and Evaluation (eds. P.J.W. ten Hagen and P.J. Veerkamp)

[31] Kirakowski, J. and Corbett, M. [1990]; Effective Methodology for the Study of HCI

[32] Dreyfus and Dreyfus, "Making a Mind"

[33] Kalay et al "Process and Knowledge"

■ [34] Pohl, Preface to Proceedings

[35] Zuboff, S. [1988]; In the Age of the Smart Machine; Basic Books

[36] Bijl, A. (1989); Computer Discipline and Design Practice; (pp. 147 & 171)

[37] Bijl, A. [1991]; "Discussion Session: Design Process"; Intelligent CAD Systems III Practical Experience and Evaluation (eds. P.J.W. ten Hagen and P.J. Veerkamp)