Computers, words and pictures

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The paper discusses the problem of CAD in architectural design from the point of view of aiding creativity. It argues that so far there is no real evidence that this has been achieved. An explanation for this is offered and the authors suggest that more work needs to be done on how we hold conversations about design. The authors also conclude that, at least until design conversations are better understood, we should concentrate less on pictures and more on words. A first attempt to develop a computer-aided design conversation system is described.

Keywords: creativity, computer-aided design, architectural design, conversation

We intend in this paper to argue that creative design may be as dependent on words as it is on pictures, and that work in this area has tended to concentrate on pictures to the detriment of studying words. We are primarily concerned with the application of computers to the early conceptual design process, in particular that used in the three-dimensional fields such as architecture, industrial design and the like. Although such processes have come under empirical scrutiny in recent years they are still poorly understood. There already exists, however, a considerable amount of software described as computer-aided design (CAD) and therefore purporting to support this poorly understood process.

1 Computer graphics in design

Work on CAD for architectural design began before we had sensible and practical computer graphics. However, once it became apparent that the computer could draw this stimulated a whole line of work on CAD based on manipulating the graphical image. The quality of such images has become something of an obsession and, apart from a relatively small excursion into expert systems, CAD has been dominated by graphics virtually to the exclusion of all else. Early computer graphics were astonishingly crude with a choice of ridiculously low resolution flickering television screens or green storage tube screens which could not be selectively erased. Compared with the drawings designers were able to do by hand, computer

0142-694X/97 $17.00 *Design Studies* **18** (1997) 171–183 PII: S0142-694X(96)00031-2

graphics as design tools were hardly better than chiselling in stone. And yet many researchers, including one of these authors persisted. As we sat in rooms blacked out so that we could see the faint glimmering screens, none of us could possibly have imagined the low price and high quality of today's computer graphics, and yet we persisted.

Now we have high quality, low cost computer graphics, and still we persist. Today the emphasis is on three-dimensional modelling and rendering with ever faster and more realistic algorithms. Real-time manoeuvres are now possible within virtual reality environments on hardware costing far less than the early CAD equipment. And yet there remains virtually no evidence of the widespread use of computer graphics to enhance creativity in three-dimensional design. Today most designers have a computer, and many use them for producing drawings, but not for designing. This is curious since the drawing plays a crucial and central role in the creative design process. Schön's seminal description of the designer 'having a conversation with the drawing'[1] is now received wisdom. But, in a recent volume of their series of books on graphics for designers, Porter and Goodman could confidently assert: 'In the wake of rapidly advancing computer-graphics technology, drawing by hand remains undisturbed as the central activity in the process of design'[2].

There are probably several reasons for the failure of computer graphics to deliver the promise heralded for it by so many. Obvious problems include the lack of genuine three-dimensional input tools, inadequate interface metaphors, and the inability of systems to sustain parallel lines of thought which we have argued elsewhere is an essential characteristic of the creative design process[3]. However, it is the question of uncertainty on which we wish to concentrate here.

2 *Drawings in the design process*

Consider the design of the Sainsbury Wing for the National Gallery in Trafalgar Square, London by architects Robert Venturi and Denise Scott Brown (Figure 1). The new building needed to offer a number of linked gallery spaces extending the existing pattern of the original Wilkins building, and to provide a new public entrance allowing for the flow of large numbers of people into both the new and old galleries.

An early sketch by Venturi shows these two ideas under examination (Figure 2). Some important walls are shown with thinner lines indicating the spaces they enclose. One can almost imagine Venturi walking through the spaces in his mind as he draws. Lines are drawn over several times as

1 **Schön, D A** *The reflective practitioner: how professionals think in action* Temple Smith, London (1983)
2 **Porter, T** *Designer primer for architects, graphic designers and artists* Butterworth Architecture, London (1988)
3 **Lawson, B R** 'Parallel lines of thought' *Languages of Design* Vol 1 No 4 (1993) 357–366

Figure 1 The Sainsbury Wing extension to the National Gallery, Trafalgar Square, London designed by Venturi and Scott Brown

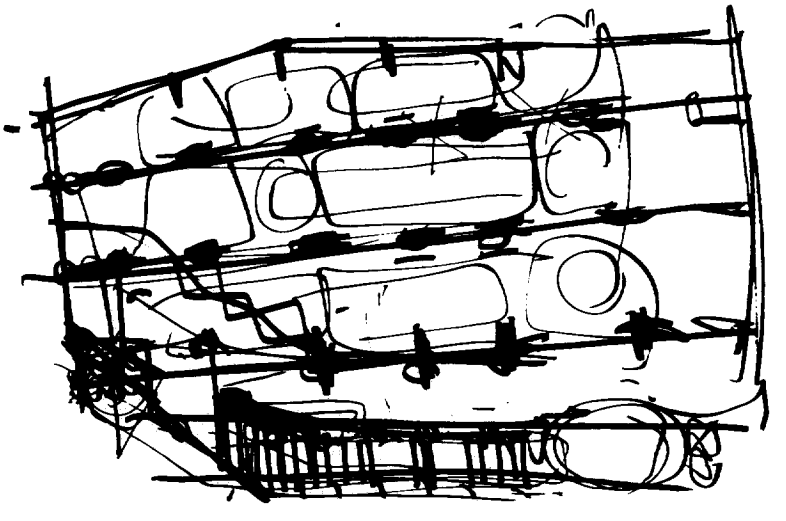

Figure 2 Early sketch plan by Venturi of the Sainsbury Wing

he investigates and interacts with the drawing. Scott Brown says that 'Bob has a facility between hand and mind . . . sometimes the hand does something that the eye then re-interprets and you get an idea from it'[4]. This sounds very much like Schön's 'conversation with the drawing'.

4 **Lawson, B R** *Design in Mind* Butterworth Architecture, Oxford (1994)

We may make an intelligent guess as to what Venturi means by this drawing. The drawing does not reveal the totality of what was in Venturi's mind, nor does it explain the rules by which it should be interpreted. Architects can produce drawings which obey clearly understood graphic conventions and are quite unambiguous and precise in their meaning. But Venturi did not produce this drawing for others to understand, it was his own working tool. He was not concerned therefore either to produce a drawing which explained itself, nor was he concerned with a design which was totally resolved. That is to say, there was a great deal of uncertainty about at the time.

Indeed this uncertainty is at the heart of the creative design process. Designers characteristically explore several ideas about their design in parallel which may not be capable of immediate resolution. Another Venturi drawing shows him studying the horrendously difficult and sensitive issue of how to relate the elevation of his new building to the existing facade in Trafalgar Square (Figure 3). He is not, at this stage, concerned to relate these two parallel lines of thought and is unsure how they will eventually be resolved, although this must happen eventually. However, it is here that we find one of the most fundamental of our criticisms of CAD systems. Existing CAD systems tend to concentrate on ways of ensuring the resolution and the maintenance of a single model of the building, rather than aiding the creative uncertainty of the early phase of the process.

So we have a paradox here. The drawing is indeed at the very heart of the design process, and is also to be found at the normal method of communication about finished designs. However, these two kinds of drawings are profoundly different and the transition from one to another is poorly under-

Figure 3 Early elevational sketch by Venturi of the Sainsbury Wing

stood. Much of the work done so far on CAD is predicated on the false premise that we could manage this transition inside the computer. We do not believe we are near being able to do that, and it is because designers intuitively appreciate this fact that they do not yet see the computer as a tool for creative design. This suggests a major research programme is required, not into improving computer graphic realism, but into understanding how we use drawings. Possibly then we might be able to design CAD packages which genuinely support and enhance creativity. However, we also wish to suggest an alternative line of enquiry which might enable computers to support the creative processes in design, and it is to this that the remainder of this paper is devoted.

3 *Words in the design process*

The architect Eva Jiricna is known for her stunning interiors often based on high technology materials. She has described how her design process depends very much on a phase of communication with her clients which relies on verbal rather than graphical media. 'I try to express in words what they (the clients) want, and then I try to twist it into a different statement and then draw it'[4]. This has even enabled Jiricna to produce entirely modern designs with which her clients are happy even though they may have originally expressed their wish for historical restoration! It seems unlikely that she could achieve these ends by using drawings in her early communications. The verbal description allows her clients to interpret shades of meaning not allowed by the drawing. In the same way we can easily be disappointed by the film of a book we have previously read, since we have built up our own image of the characters and places, which the film inevitably contradicts.

Design by drawing is now so common and so embedded in our notion of what designers do that it is easy to forget that it is actually quite a recent development, since vernacular craftsmen drew remarkably little. Benfield's book describing the life and practices of the Purbeck stone workers[5] relies almost entirely on words with scarcely a drawing of note. Benfield actually tells us that this reflects practice. 'Most plans were and are carried in the head, and there are some unlikely looking heads around in Swanage.' Benfield describes how to build a stone bird bath or sundial

> A bird bath or sundial should be about two and a half times as high as it is wide in the base; preferably it should have two or three bases, which give the effect of steps usually seen around village crosses, and a shorter tapering pedestal surmounted by a bath smaller than the bases by at least two inches.

Benfield includes only that which is essential and leaves all other details entirely free to the imagination of the stone mason. It would be difficult

5 Benfield, E *Purbeck Shop: a stoneworker's story of stone* Cambridge University Press, Cambridge (1940)

to construct a drawing which did not suggest other features of the form of the finished product which might restrict a future designer.

The advantage then of words rather than pictures in expressing early design ideas is their ability to sustain a range of interpretation. It is what they leave out rather than what they say which is important here. It is common today to hear architects talk about the 'poetics of architecture'. We could not have poetry unless our vocabulary included words with overlapping shades of meaning. There is a degree of uncertainty involved which is suitable and appropriate to those early stumblings towards an idea which so characterizes the creative design process. In her book on the creative mind, Boden[6] makes several references to Taylor Coleridge's amazing word picture of Xanadu. 'In Xanadu did Kubla Khan a stately pleasure-dome decree . . .' Who of us does not have his or her own image of Xanadu with its paradoxical qualities? 'It was a miracle of rare device, a sunny pleasure-dome with caves of ice!' So precious are those personal images that most of us would probably take most unkindly to any painter foolish enough to attempt to paint Xanadu. It must remain forever uncertain beyond the grasp of the visual image, although we might welcome a tone poem by Debussy!

When British Rail wanted to develop a new design for their InterCity trains they invited a number of leading industrial designers to submit proposals. The winners were Seymour/Powell who had no previous experience with train design. Their submission was not based on drawings or traditional design documents. They simply explained to British Rail that their design would be 'heroic' in the manner of the British Airways Concorde and that it would once again make children want to become train drivers[7]. Such a description must have triggered childhood memories in the minds of some senior British Rail executives, and they carried with them their own image of such an heroic yet modern train. Once commissioned, Seymour/Powell set about designing the InterCity 250 which in due course may well be recreated in model form and sold to countless would-be train drivers!

Designers characteristically work by developing an understanding of both the problem and solution together. This process depends upon the search for, and development of one or more central organizing ideas around which the design is structured. We have already argued that these ideas often emerge from 'guiding principles' which designers develop and maintain often across many design projects and sometimes over a whole career. It is also important to recognize that design is usually a team rather than exclusively individual activity. Again words are vital in exploring early design ideas both within the design team and between designer and client.

6 **Boden, M** *The creative mind: myths and mechanisms* Weidenfeld and Nicolson, London (1990)

7 **Lawson, B R** 'Architects are losing out in the professional divide' *Architects' Journal* Vol 199 No 16 (1994) 13–14

The architect Richard MacCormac has recently produced two highly acclaimed designs, from which we can see clear examples of this process at work[4]. While working on the new headquarters and training building for Cable and Wireless, the design team had already decided to separate the residential section of the scheme. He recalls that 'I can't quite remember what happened but either Dorian or I said 'it's a wall, it's not just a lot of little houses, it's a great wall 200 metres long and three storeys high . . . we'll make a high wall and then we'll punch the residential elements through that wall as a series of glazed bays which come through and stand on legs . . .''. This primary generative idea was eventually worked out and realized. The scheme fits the initial verbal description perfectly, but so, of course, could a very large number of other realized designs.

In the chapel for Fitzwilliam College, Cambridge, the design team had been playing around with ideas of circular shapes inside square enclosures. 'At some stage the thing became round but I can't quite remember how,' said MacCormac. However, quite late in the process as they were trying to resolve detailed junctions they finally articulated the concept. The upper floor which housed the worship space began to float free of the lower level in their minds and they began to describe this congregational space as a 'vessel'. This idea then informed all the detailing and construction in an entirely consistent manner. The use of this word 'vessel' with all the imagery associated with it seems substantially responsible for what has turned into a beautiful piece of architecture.

4 *Words, memory and metaphor*

From the several examples given earlier, we notice that designers use words purposively to evoke and communicate subtleties of design concepts. The evocativeness of words is the key. Schön observes that experienced designers use design archetypes during their design process. These archetypes come in the form of very evocative words[8]. Suggestions have also been made that the lack of character in the built landscape is due to the insufficient vocabularies of graphically oriented designers to describe and evoke multifaceted design possibilities and emotional responses, so others who are involved in implementing their ideas cannot share their visions[9].

How do words become evocative? We suggest this relates to the schemata which organize our memory[10,11]. Each schema can be seen as a series of slots, which can hold values to represent specific cases or instances of the schema[12,13]. When we receive new information through our senses, our memory will try to match it with these mental templates, enabling us to recall the whole schema from any appropriate value of any slot. This helps explain the metonymic nature of memory. Thus, for example, the mere

8 **Schön, D A** 'Designing: rules, types and worlds' *Design Studies* Vol 9 No 3 (1988) 181–190

9 **Hodges, R M** 'Opening the designers' spatial dictionary: the power of a professional vocabulary' *Journal of Architecture and Planning Research* Vol 8 No 1 (1991) 39–47

10 **Bartlett, F C** *Remembering* Cambridge University Press, Cambridge (1932)

11 **Rumelhart, D E and Norman, D A** 'Representation in memory' in *Handbook of Experimental Psychology*, **R C Atkinson *et al.*** (eds) Wiley, New York (1983)

12 **Minsky, M** 'A framework for representing knowledge' in *The psychology of computer vision*, **P H Winston** (ed) McGraw Hill, New York (1975)

13 **Schank, R C** *Dynamic memory* Cambridge University Press, Oxford (1982)

mentioning of 'birthday' brings forth memories of birthday parties, friends and diverse emotions.

It is also necessary to draw a distinction between episodic and semantic memories[14]. The former are case specific and experiential, the latter are general and symbolic. There is a further argument which suggests that human understanding of concepts may be built up from very basic bodily experiences accumulated over time through physical interactions with the external world[15]. Deeper and more abstract concepts, which cannot be understood that way, are understood through the use of one or more metaphors on those directly experienced concepts. Metaphor is therefore not merely a literary device but a crucial cognitive mechanism. These ideas point to the dynamic interplay between low-level episodic experiences and high-level symbolic semantics in human memory, with metaphorical thought depending heavily on this dynamic interplay. The significance of metaphorical thought as a mediating process in the creative generation of design ideas has already been illustrated by MacCormac's 'wall' and 'vessel'.

5 *A proposed design conversation system*

If words can enhance a designer's creativity, can there be a CAD system that is based on words instead of graphics? We have argued that present CAD tools do not support the kind of vagueness and uncertainty that those manual conceptual sketches allow and thus often prematurely fixate or crystallize developing design concepts. To use Schön's terminology, such CAD drawings are insufficiently conversational but seem more like imperative statements made by the computer leaving little or no room for further contributions from the designer.

We therefore take Schön's analogy of the design activity as 'conversation' to a radical and literal extreme, and propose a CAD system that actually 'converses' with the designer about design concepts (Figure 4). Such a system will be word-based, and will take advantage of the evocativeness, as well as the flexibility of words in describing and negotiating meanings. Input and output of the system are in the form of structured sentences with prescribed syntactical rules. It is not the intention of the system to emulate natural language conversation, but rather to retrieve relevant or potentially relevant concepts and ideas that may feed the creative design process.

Central to our system is the knowledge base. This structure is inspired by work on experiential gestalts of which there are two kinds: events and entities[15]. In the knowledge structure of our proposed system, an experiential gestalt is a schema-like construct for representing experiences. An

14 **Tulving, E** *Elements of episodic memory* Clarendon Press, Oxford (1983)
15 **Lakoff, G and Johnson, M** *Metaphors we live by* University of Chicago Press, Chicago, IL (1980)

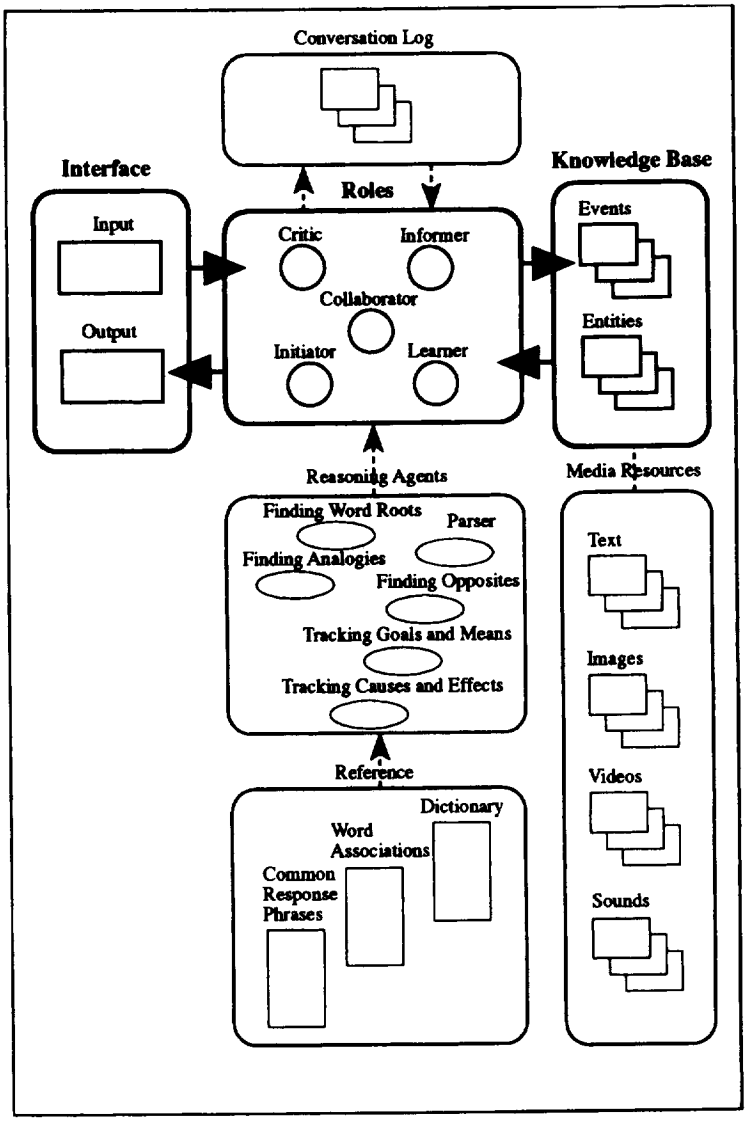

Figure 4 Proposed design conversation system

experience is either that of a thing, which we call an entity, or of a happening over time, which we call an event. Simple direct bodily experiences can be the building blocks for more complex and abstract ones by means of hierarchical and metaphorical definitions. For example, an entity may consist of several parts which are themselves entities, and an event may consist of a chain of events. The structure also enables the linking of entities and events in terms of causality (i.e. causes and effects) and purpose (i.e. goals and means). By the use of these experiential gestalts as units of knowledge, a common structure is therefore achieved for representing both

the low level episodic experiences, as well as the high-level declarative semantics discussed earlier, and thus allows interplay between them.

The next major part of our system is an interface through which the designer and the computer interact. The designer will input text into the system, and the computer will respond in a similar way, although there is no reason why images, videos and sound cannot be attached to the computer's text output. However, before we move into a detailed description of the system we need to introduce one further idea.

In order that a conversation can continue amicably and fruitfully, the participants are constantly playing complementary roles. Without this the conversation would become chaotic and confusing. Participants play their roles according to cues (such as words or gestures) given by others. In some cases, participants may choose to ignore the cues in order to bring a certain emphasis to what they are saying. The choice of a role is a matter of how one sees oneself in a situation, or in other words, the consciousness of 'self'. In this first experimental version of our system we assume that the designer will select a role for the computer to play, and we propose that five roles should cover the range of needs for a conversation about design. We call these roles: learner, informer, critic, collaborator and initiator.

The learner is one who absorbs what others say and remembers or learns. The informer answers others' queries. The critic checks the validity of what others have said and makes comment on it, occasionally giving warning. The collaborator tries to elaborate and build on what others have said rather than criticizing. Finally, the initiator begins a new 'thread' or develops a new perspective on the subject when the others have no more to say.

Let us see how these roles might work during a conversation about a design. Had he the benefit of our system, Le Corbusier might have told it that 'a house is a machine for living'. He would have expected the 'learner' system to record this association and to request explanation of any words it did not understand. As a 'critic', the computer might have reminded him of the differences between a house and a machine, perhaps replying 'a house has rooms and furniture but a machine does not'. In its 'collaborator' role the computer might have tried to extend or elaborate the metaphor of the house as machine by suggesting that 'a house performs functions' or perhaps 'a house uses fuel'. The computer acting as an 'initiator' might have given a new direction to the discussion by suggesting that 'a family lives in a house' thus focusing attention on the occupants rather than the building.

In order that the computer may respond to the designer's input, it must be able to structure it in a form that it can assimilate. It also needs to have some facility for searching and extending the knowledge base of experiential gestalts. These tasks of parsing sentences, tracking causes and effects, finding analogies, etc. will be performed by a pool of modularized programs which we shall call 'reasoning agents'. Each of these agents performs fairly specific tasks, and is called by the currently active role when it is required. Clearly, different reasoning mechanisms are required by different roles. The reasoning agents also share a pool of reference information such as a dictionary, strength of word associations, etc. Finally, the system must keep track of the conversation as a whole and not just the current exchange. There must therefore be a log of the conversation and some mechanism for placing the current exchange in context, which again may be to some extent dependent on the role.

6 *Lessons for the study of creativity in design*

Our exploration into the idea of this design conversation system has highlighted some very interesting issues. We shall concentrate on just three issues here which we call 'human/machine roles in creative thought', 'parallel lines of thought' and 'mind sharing'.

Firstly, there is no attempt here to present the computer as playing a creative role in its own right. It is the designer who gives meaning and interpretation to the words produced by the computer. Creative ideas emerge from that process of giving meaning and making interpretation. Creativity is enhanced by the computer reminding the designer of the latent connections between ideas and prompting the designer to make new ones. A basic assumption in the system is that those latent links which have been made explicit in the knowledge base structure are materials for constructing metaphors or analogies which are the backbone for creative conversations about design.

Secondly, the roles that we have suggested in the proposed system illustrate in a modest way how parallel lines of thought may be implemented in a CAD system. In its current implementation, the proposed system works sequentially and allows only one role to act at any one time. Since the different roles are in fact operating on the same input text, there is no reason why they cannot work in parallel. The concept of 'parallel roles' opens a new paradigm of thinking about CAD system design. A critic may have output which can be used to delimit the search operations of the collaborator. Taking our previous example of the conversation about 'a house is a machine for living', if the 'collaborator' has realized that the 'critic' is going to mention 'rooms' and 'furniture', instead of just talking

about 'a family lives in a house', it may initiate ideas that connect 'family' with 'rooms' and 'furniture' such as 'a couple sitting on a couch in a living room'. In the current implementation, the output of one role affects that of the other through the conversation log in a static manner. The management of dynamic output exchanges between the different roles running in parallel are amongst the challenges of further research.

The third issue is about 'mind sharing'. Several minds working together can often be more creative than a single mind, and this is a common feature of many techniques for stimulating creative thought. A computer that helps to make the minds work together may therefore enhance creativity. The proposed system can respond sensibly to the designer's input only when its knowledge base is sufficiently rich, so the system will not be able to make much sense in the beginning. However, as the designer interacts with the system, the knowledge base will capture how the designer connects design concepts in terms of the relationship between the experiential gestalts already made explicit. A comparison can be made with Apple's Newton notepad. It takes time for it to learn and recognize its owner's handwriting. In a similar way, the knowledge base in our proposed system grows as the designer interacts with it. The knowledge base, like a Newton notepad, is therefore personalized to its user. It registers the designer's unique and personal way of connecting design concepts. Thus, the knowledge base is a partial representation of the designer's personal semantics.

This raises a reasonable objection: would a CAD system based on such a knowledge base serve only to reinforce the designer's own prejudices and hence stifle creativity? Our guess is no. The mind is a dynamic system changing over time as new experiences are accumulated. Therefore, our interpretation of the same external artefact, in this case the knowledge base and the output of the system, will be different each time we look at it. But more importantly, our proposed conversation system is designed in an object-oriented way so that the knowledge base can be taken from one designer's system and installed in another's. In that way, we shall be able to see literally how others connect their ideas and design concepts. This is what we call 'mind sharing', allowing designers to make new interpretations of the experiential gestalts that others have partially made explicit.

In discussing the use of episodic knowledge in design, Visser[16] has pointed out that designers need access not only to information, but also to experts' 'tricks' in using the information. This includes how experts make use of analogical thinking in bringing different knowledge domains together in a design solution. These tricks are often poorly documented, and there is a limit to how much one can have direct consultation with the expert. In the

16 Visser, W 'Use of episodic knowledge and information in design problem solving' *Design Studies* Vol 16 No 2 (1995) 171–187

context of the Internet, the sharing of tricks is already happening. We may go to the Web pages of people or organizations who share similar interests instead of relying on a search engine. These sites not only give up-to-date facts but also convenient links to other related sites. This grouping of links can be seen as the 'tricks' on offer by the owner of the site. The way that designers connect design ideas and concepts, their logic and semantics, represent unique and highly personal 'tricks'. The design conversation system we are proposing is intended to capture designers' tricks in a knowledge base which can then be shared with other designers.

7 *Conclusions*

We began by arguing that the development of CAD tools has been too concerned with the making of pictures and images. Graphics are obviously essential for design, but we believe that there is a general lack of understanding about the act of drawing and the nature of drawings made by designers when they design. The inability of conventional CAD drawing tools to sustain ambiguity, uncertainty and parallel lines of thought makes them very different from manual sketching, even without considering the ontology of the act of drawing itself. Yet, ambiguity, uncertainty and parallel lines of thought are central to any creative design process. Words seem more flexible than pictures in sustaining multiple meanings, and are employed by many designers in conceptualizing designs.

Extending Schön's 'design as conversation' metaphor, we have suggested in a very modest way how a text-based CAD tool could be developed, and it should not be difficult to see the potential and possibilities of such a tool. The text output of our proposed system could easily become the triggers for graphics, video clips and sounds. Design is an information-rich activity. There is a vast amount of information already available on the Internet which is either text-based or located by textual indices. In Negroponte's vision of a digitally connected world where there is a deluge of information on offer[17], we need intelligent agents to gather, filter and collate information for us in this worded network. These agents need to have knowledge about ourselves, including our habits, thinking behaviour and the way we connect concepts. By assisting designers to make explicit how they relate design concepts, our proposed system can be seen as an attempt towards that goal. Finally we suggest that through a study of the way conversations about designs take place and are structured we might learn more about how to make computers become potential partners in the creative design process.

17 **Negroponte, N** *Being digital* Hodder and Stoughton, London (1995)