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How soon will Design Education be Able to Benefit from Computer Aided Design Systems?

An earlier shorter version of this article was published in Computers and 3D Product Design Education, *published by the Design Council 1985.*

I gave a paper recently to a conference organised by the Design Council in the Royal Institution on Computers and 3D product design education. That paper was entitled 'How soon will CAD be able to aid design education?' and I quote first from my conclusion to that paper.

> 'Simple architectural type forms* have just become an economic reality on low cost systems. I don't think any system is useful to the designer until it is low cost and thus we have only just seen the beginning of the real potential for using computer aided design in the design field. Within the next two years we will see systems able to cope with complex sculptured forms on low cost systems and within a further two years we should see artificial intelligence techniques being able to involve the designer in a genuine dialogue about his design intentions and helping him as he goes. All these tools will, of course, be linked directly to the means of production and this will completely change the role of the designer and the role of the manufacturer and their relative interaction. This has profound implications for design education'.[1]

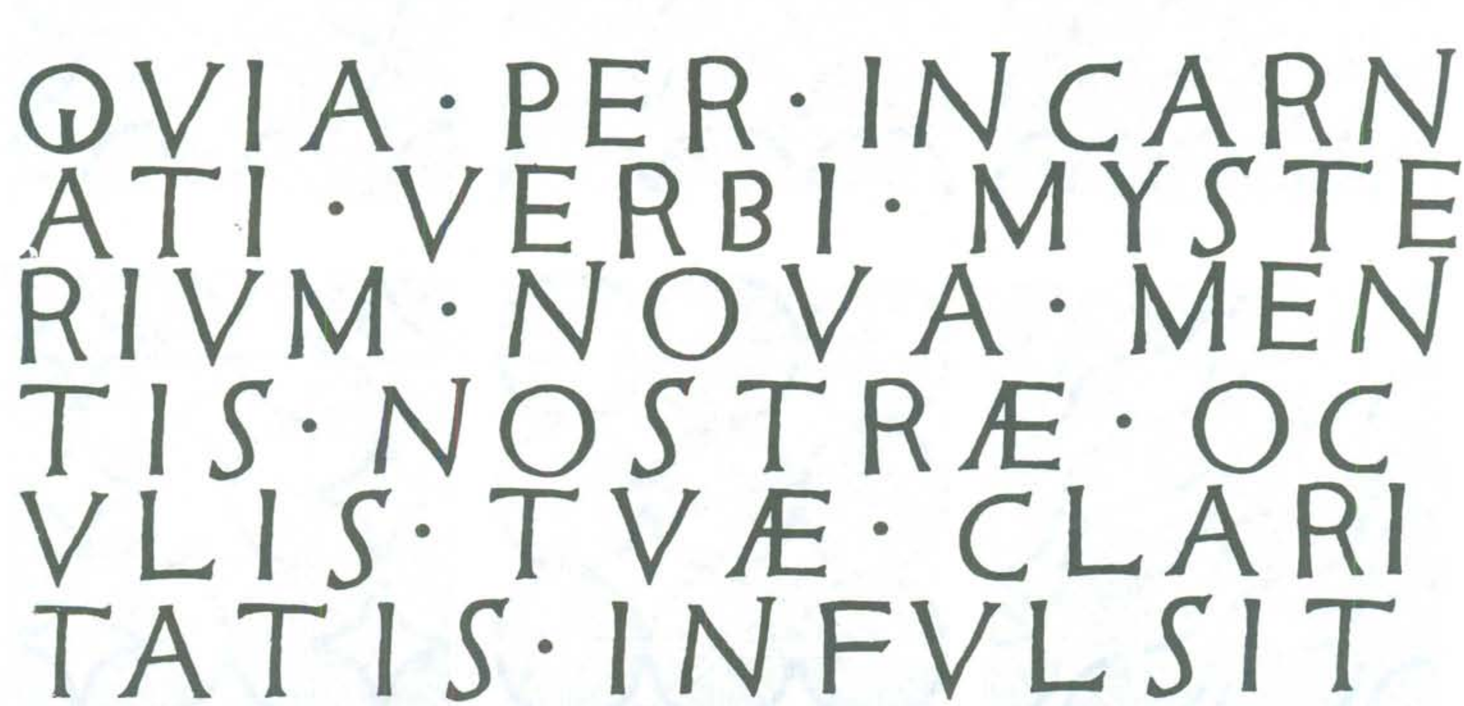
Although it is perhaps unwise of me to make public prophecies about when new software features will be available I think on this occasion I got it right. By the end of 1986 we will see on the market really valuable design tools running on low cost microprocessor based systems. So in this article I will attempt to do two things. First to show what the most powerful of the existing low cost systems are already able to achieve in terms of programs which aid design education; and second to describe those characteristics which I think are still necessary in the new and complete systems which I am anticipating becoming available before the end of this year.

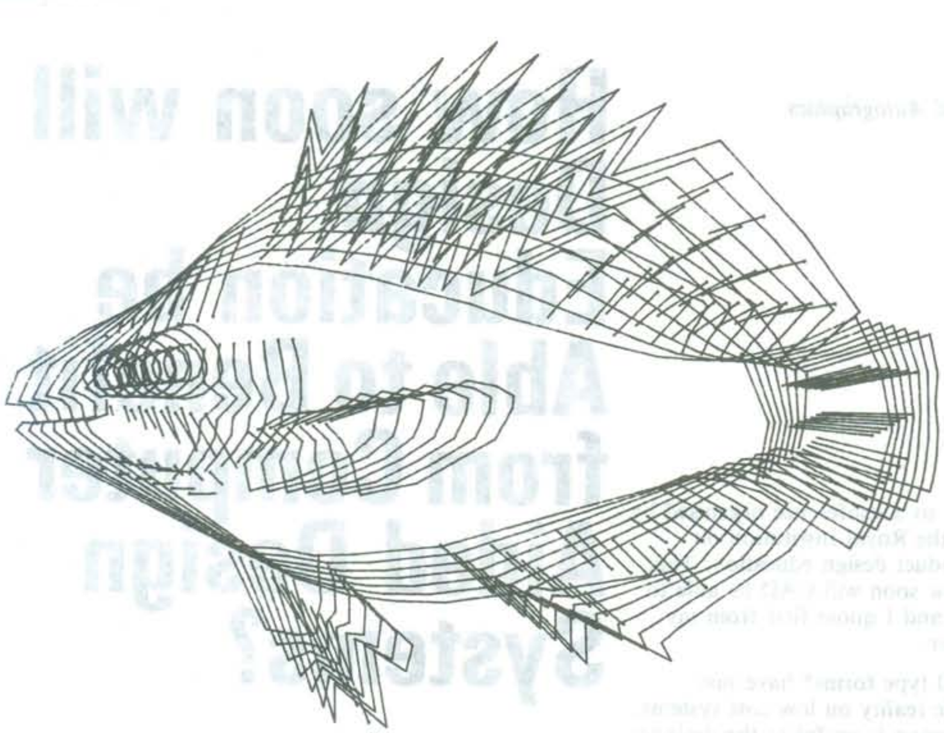
* This referred back to an earlier speaker, Dr G. Webster who had defined 'architectural type forms' as characterised by involving for the most part straight lines and flat planes.

Context

Although I hope that the points that I am going to make in this article will be of general interest to all those involved in CDT, I am going to draw examples mainly from my own students work and thus I must make clear the context within which they are working. Part of my job is as Director for the Centre for Computer Aided Design at the University of Ulster and in this guise most of my work is concerned with research into developing new computer aided design systems or industrial liaison and consultancy to assist local industry in introducing computer aided design techniques into their factories. The other part of my job consists of

Below: Caligraphic exercise. *There is no reason why just because typography has been done on a computer it need look 'computer like'. In this case the computer is being used because it can proportion and manipulate the letters on the screen. A great deal of thought has gone into this apparently casual arrangement of letters. The computer is particularly good at making these minute and subtle variations to the angles and proportions of the letters.* Paul Diver





Left: Inbetweening. *This is a technique normally used in animation to metamorphosize smoothly between one shape and another. In this case it is rather curiously being used to illustrate the relationship between neighbouring families of fish (with apologies to Darcy Thompson).*
Padraig Walsh

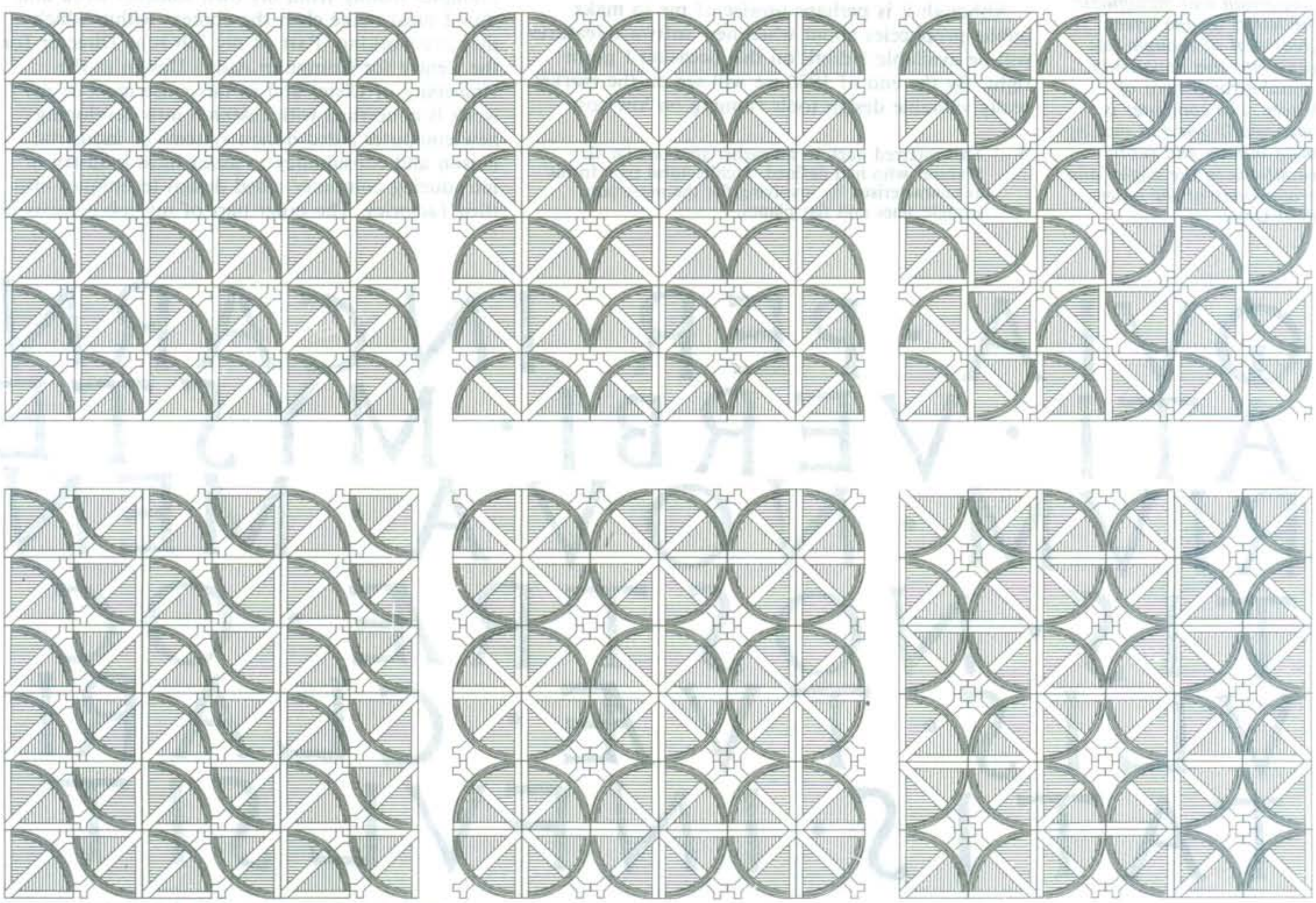
teaching computer aided design and computer graphics techniques within the Faculty of Art and Design.

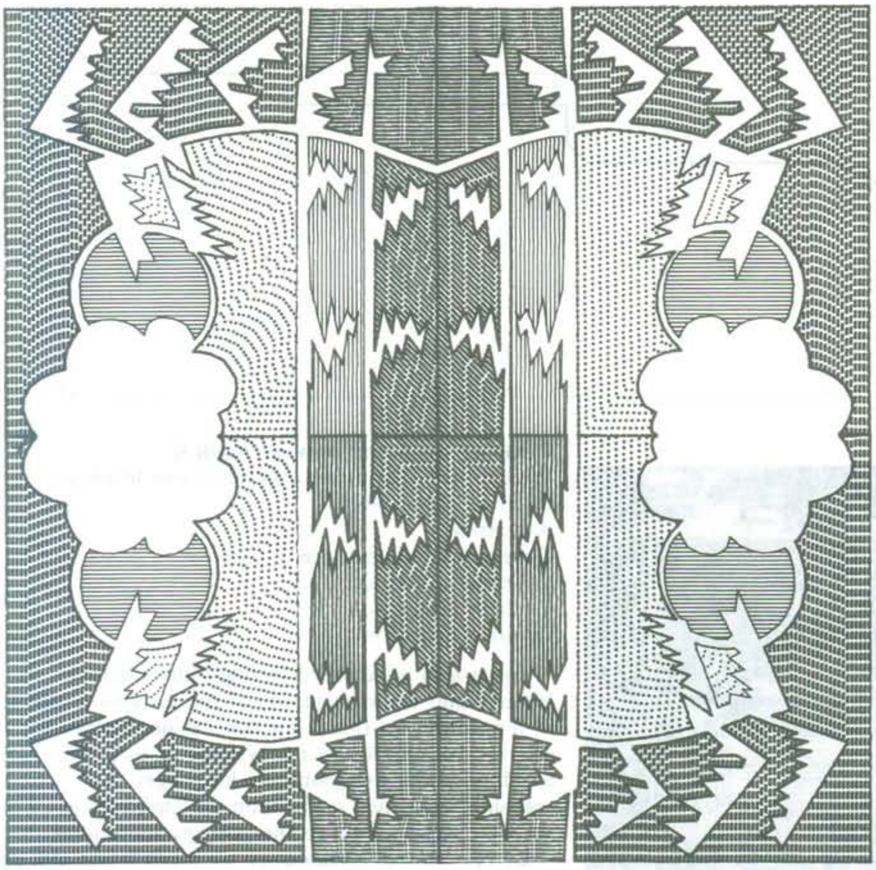
Now the first activity clearly provides an extremely useful context within which to operate the second. It means that I have access to industrial standard equipment as well as the low cost systems which we use for student work, and students are able to see examples of the work which actually takes place in industry. There is also a converse advantage because industry on the whole is extremely unadventurous in the way in which it is introducing computer aided design (which is hardly surprising given the substantial investment that large commercial CAD systems represent to these companies) and thus it is possible to use the educational context as a vehicle for exploring new ideas about how systems might be used in the future but on the relatively modestly expensive equipment and the limited context of student applications.

In the Faculty of Art and Design all students in the first and second years now have an introduction to computer aided design techniques. There are degree level courses in Design which includes graphic design, environmental design and product design, Applied and Decorative Arts which includes textiles, fashion, silversmithing, jewellery, ceramics etc., and the Fine Art which includes painting, sculpture and printmaking. They all use the same equipment and the same software but we have variations on the actual teaching programme which are more closely matched to their individual disciplines.

We have ten microprocessor based training systems for student use and we have three further identical systems in the individual departments for

Below: Pattern Manipulation. *This is an exercise to show that strikingly different overall effects can be obtained by symmetry permutations on the same simple motif.*
Barbara Dass





Left: Textile Design. *More symmetry manipulations in textiles but this time with a great variety of different line types being used. This shows a number of interesting features. In particular the fact that it would be extremely tedious to do this by hand and the nachine like repetitions of the very fine and closely textured line produce unusual and very interesting prints. A further feature is that the hatching routine has the characteristic of changing its pattern depending on the edge profile. The program is switchable, that is it is possible to make all hatching rotate but in this case the student has quite deliberately chosen to reflect the shape giving a very strong overall rotational geometrical impression whilst maintaining the continuity and one direction only of the hatching thus producing counterpoint to the overall design.*
Fiona McDermott

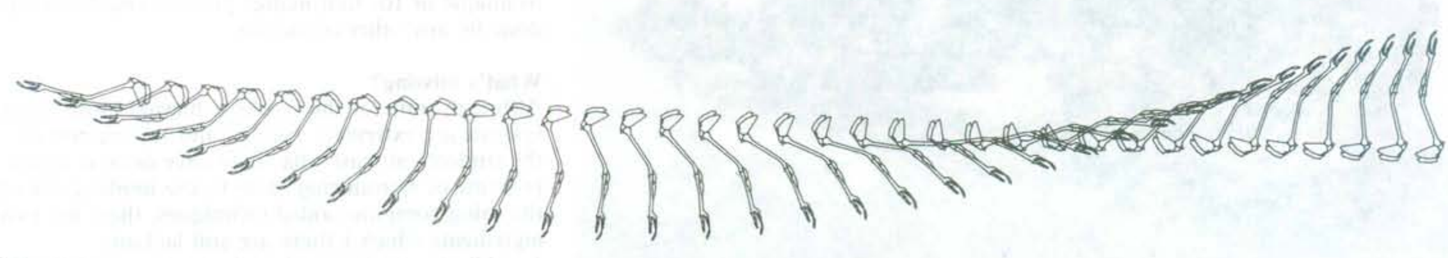
casual studio use. We also have the data base totally compatible with our larger systems so that for example any shape developed on the low cost systems can be transferred to our VAX 11/750 and used with a solid modelling or finite element analysis program. This means we have the best of both worlds since the micro systems are much easier to use and represent a much smaller capital investment and the data can be quickly and easily prepared on them and then transferred to the more complex system.

The systems that we use are the British Thornton COMPAS Advanced system. This is an integrated suite of 2D, 3D and CNC programs. The 2D program consists of a shape editor which enables shapes to be built up using a variety of powerful editing techniques including autostraighting, grid locking, spline curves under tension, fully automatic dimensioning etc. There is a commmand mode in which these shapes can then be arranged, rotated, scaled, deformed and added together to form complex sub-assemblies. Full hatching is available with a variety of patterns and line styles for any of the shapes. In the 3D module any shape can be edited in the 3D editor into a complex 3D form (or simply given a thickness if it is only a prism) and again can be arranged in complex configurations in 3D space. This can indeed be done in a 2D module and then the same file called in the 3D program and drawn in 3 dimensions. All projections are available including 2 and 3 point perspective and the eye point can be selected interactively on the plan to achieve any angle of viewing. Similarly with the CNC module any shape developed in the 2D program can be called and the G codes and all the tool changes can be automatically generated for the lathe. There is a simulation of the operation of a lathe and the tool changes on the screen for visual checking and for confirmation of the G codes as a teaching aid.

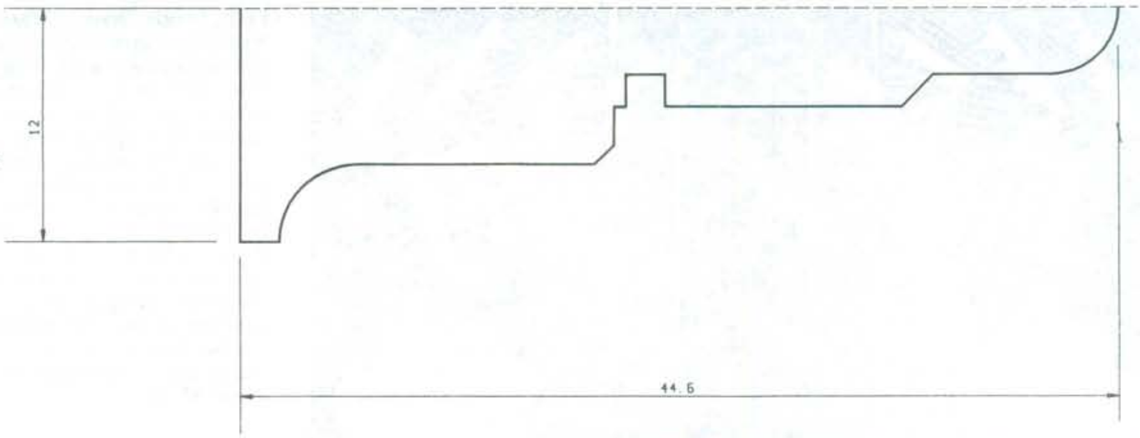
I have to declare an interest in the COMPAS system as I have been involved in its development. It would be easier for me if I could say that I am using it simply as an example and refer the reader to other systems which have similar characteristics. Unfortunately I cannot, as although there are programs which contain some features of the COMPAS range, there is no other product on the market which represents this totally integrated approach. I regard this totally integrated approach as being essential for the kind of teaching which we are doing and indeed it was the lack of other software which led me to become involved in the development of a new range in the first place.

The COMPAS software is also integrated across a range in another way. The full suite of products is not just 2D, 3D and CNC but there is a STARTER level, an ADVANCED level and a PROFESSIONAL level. These levels are also fully integrated so anything learnt on the starter program can be used in the advanced progam, and the advanced can be used on the professional program. This applies not only to what the pupil learns in terms of commands but the actual data and commands themselves can be transferred. The advantage of having integrated software in this form is that once someone has learnt the key presses and instructions, these are consistent across a range of both different applications and a different complexity of programs, and this is exceptionally valuable in terms of reducing learning time. It is certainly true that there are systems on the market which can produce simple results more quickly than COMPAS. On the other hand, with these systems it is very difficult and often impossible to produce complex results. With COMPAS once the initial characteristics of the system are mastered it is possible to go on to produce extremely complex results very quickly.

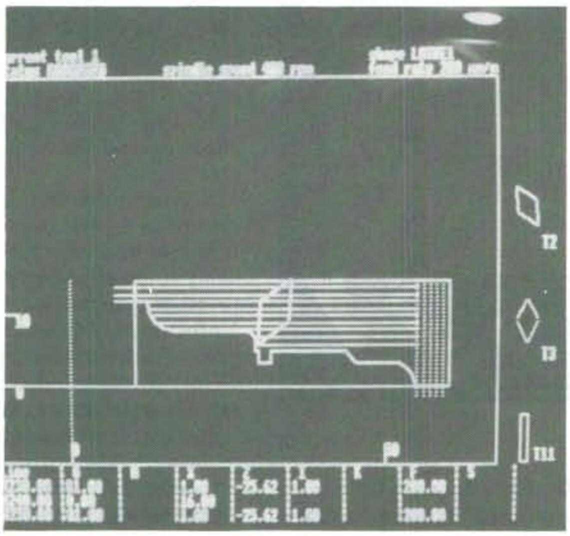
Below: Animation Sequence. *Part of a sequence of movement of a skeleton. An almost surreal effect is achieved by the very smoothness of the movement of the bones. These are normally photographed frame by frame but here they have been superimposed and stepped to show the continuity and the smoothness of movement which can be achieved by using simple language words to describe the movement and in producing a result which would be almost unachievable by traditional hand animation.*
Joanne McCrum



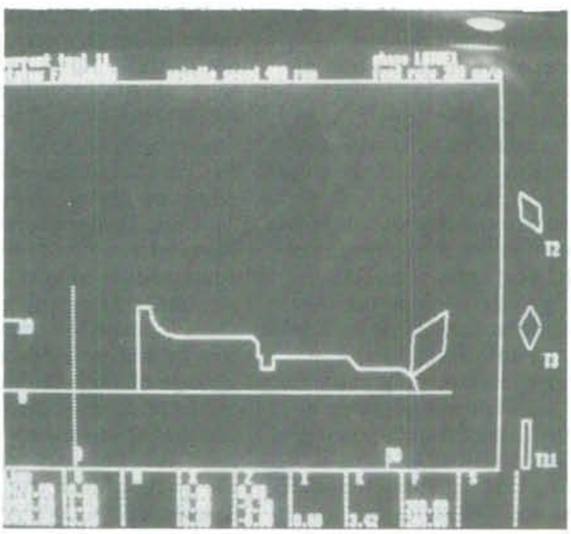
Component for Machining. *In this case the half-profile has been input using simple commands for radius, autostraighting, autodimensioning and so on. The G code to drive the lathe are then produced entirely automatically.*



Roughing Cuts. *Screen simulation of the machining process in action on the lathe with choice of tools available and tool changes being simulated and the tool paths being ilustrated in visual checking. The G codes are displayed at the bottom of the screen.*



Finishing Cut. *The G codes are produced for the final profile.*



Below: Machined Component. *The actual component produced off a demonstration lathe.*

What we teach and how we teach it
We use five categories to describe our levels of teaching. These are:
Awareness
Operational competence
Operational fluency
Creative interaction
Creative extension

Awareness is achieved through introductory lectures and demonstrations of the systems available in the centre. At this point there is no attempt to get the students to use the systems or to understand anything about programming languages. All teaching from then on is done on applications software until we get to the post graduate level.

By *operational competence* we mean being able to operate the system doing simple five finger excercises like drawing shapes, manipulating them, scaling, rotating and repeating them. 12 hours are now allowed for this activity which is all compressed into one week to maintain continuity. This takes place for all students, for all disciplines in the first year.

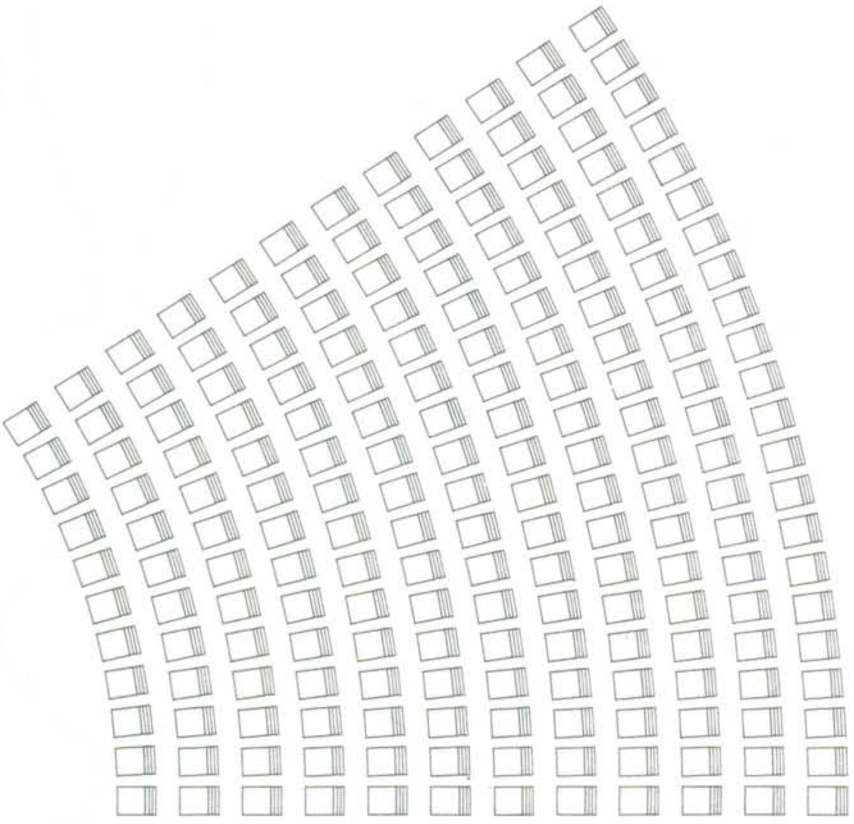
We try to achieve *operational fluency* in the second year and for this a further 12 hours is allowed. We normally do this by setting a project, one that has been chosen to make the use of the computer particularly relevant and relatively simple. This is again undertaken by all students.

The most important category on this list is *creative interaction* because until you start interacting creatively with computer systems they are not a great deal of use to a designer. At the moment the problem arises that not all design problems are equally suited to use on these systems. Nor for that matter are all designers equally motivated to use them so our attitude is that after they have achieved a level of computer fluency in the second year (or earlier if they are highly motivated) then we simply make the systems available on a bookable basis for students who wish to use them for an appropriate project.

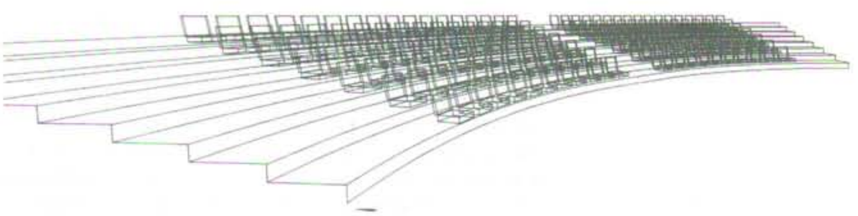
There is a sting in the tail of this list which is *creative extension.* This implies going beyond saying that the computer is 'just a tool' to suggesting that computing can actually extend creativity. This is a very much more controversial point and I would suggest a very much more exciting one. By creative extension I mean using the computer in a way which extends someones creativity to do something which they would not have done by any other technique or for that matter perhaps could not have done by any other technique.

What's missing?
Although some of the results achievable with these systems are extremely exciting and for the rest of the students at least what they have done is useful in terms of introducing them to the implications of the using computer aided techniques, there are two ingredients which I think are still lacking:

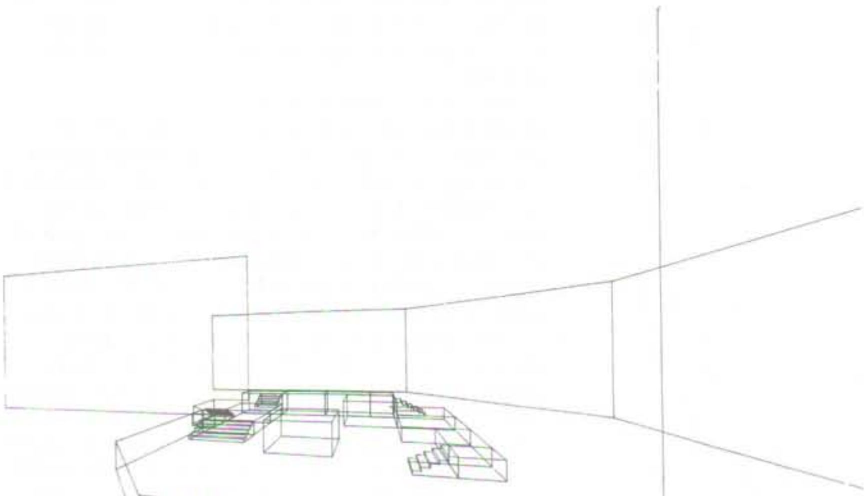
1. All microprocessor based systems are at the



Left: Auditorium Seating. *The layout of the seating has been greatly facilitated by the power of the command structure program being used. It is possible to make minute changes of spacing and angle to achieve exactly the desired result. Again extremely tedious to do by hand but extremely quick and efficient to change on a computer program that has the right facilities available. The whole of the auditorium than can of course be produced by reflecting this layout.*



Perspective of Seating. *Having drawn the seating in plan it is simply lifted up into three dimensions nd viewed in any projection.*



Sight Lines of Stage. *Having established the seating i: is a simple exercise to place the eye point in any seat in the auditorium and thus check sight lines of a stage set.*
Set Design by T. Fowler

moment limited to what are generally referred to as 'architectural' type forms. That is they are largely made of flat planes and straight lines or simple cylindrical forms which occur in one plane at a time, and are often treated in fact as large number of small flat planes. It might be argued that this limitation at the CDT level is in fact a considerable advantage in that dealing with twisted and sculptured surfaces might be an unnecessary complication.

2. My second problem is more fundamental and is that although it is possible to interact creatively with these systems they are not in fact allowing one to re-enact the whole of the normal design process. This means that you cannot design with these systems in an iterative way for example. Granted, certain kinds of alterations are very easy to do — you can go back and make certain kinds of changes which would be exceptionally tedious by hand, changing the number of seats in a theatre auditorium layout for example.

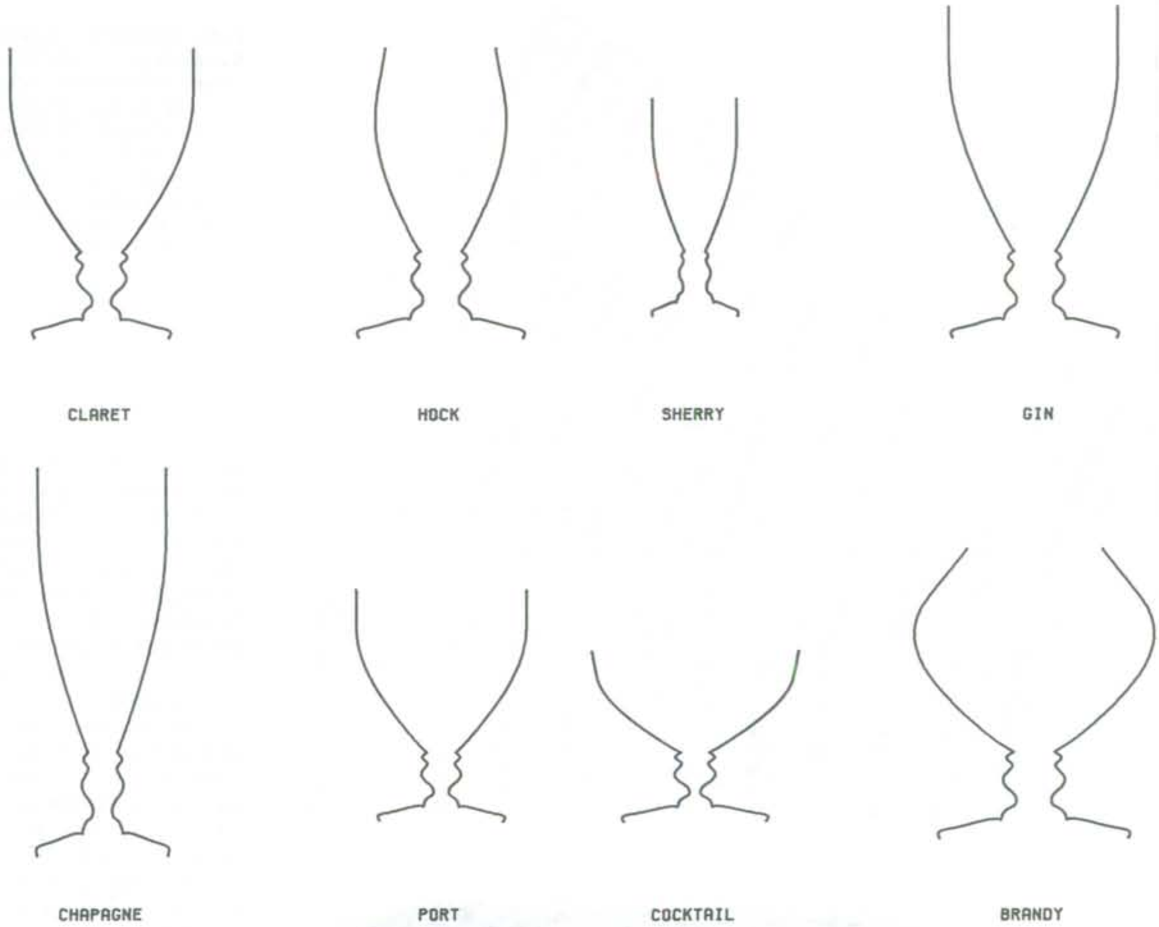
Essentially these systems are allowing designers to draw and to model what they have already designed in their heads or on paper and although they can provide feedback in terms of extra information about appearance or weight or the machineability of the component, this nevertheless is not quite a mirror of the iterative or sketchy process that designers are used to.

Now, I have argued elsewhere[2] that it would be a good thing if the design processes were changed by developing new techiques which would avoid some of the less satisfactory features of the present design process. Nevertheless though this should not be an excuse for a computer program to merely force a new design method because it cannot do anything better. It may be possible in the very near future to have the best of both worlds. That is systems which allow the designer to work in a natural iterative way using the kind of language of form and process which they are used to — and would not in any way force a work method on them. Nevertheless it might, by making certain things easier, encourage them to consider exploring alternative design procedures which might have considerable implications in terms of the quality of the final design.

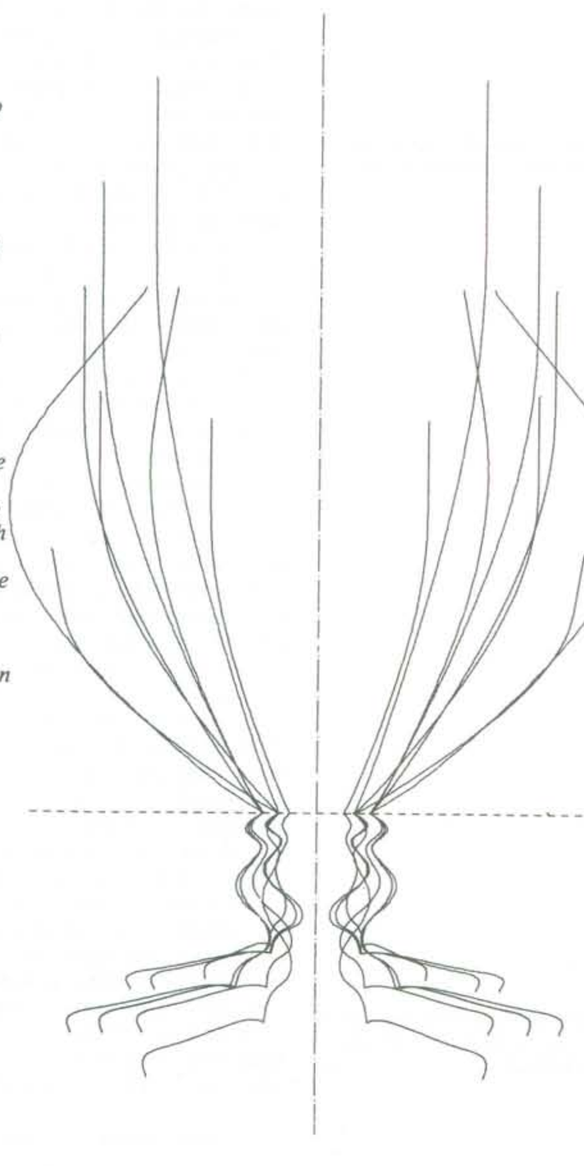
One has to have some sympathy for the difficulties of programmers in coming to terms with what designers require. For example designers may say that they want a program which allows them to be vague or sketchy in some way and designers may well doodle or sketch in 2 or 3 dimensions but one has to ask whether this is a meaningful activity at all. Is it just a form of mental doodling? or a peripheral activity or just local echo to help concentrate the mind, or is there any meaningful information in these sketches which the poor computer might have to try and extract?

What is wrong with computer drafting and modelling systems at the moment is the very strictness of the geometrical relationships which they

Set of Glasses. *In this case the object of the exercise is to design a range of glasses such that the claret, hock, sherry, gin, champagne, port, cocktail, brandy etc., in the range all have a clearly related visual coherence thus obviously belonging to the same family of glasses, say 'Antrim Mountains', but at the same time clearly indicating the traditional functions of each glass. In this case the visual coherence has been achieved by means of the spline fitting curve generating program where the same tension and control points have been for each glass and then deformations have been used to produce the complete range.*



Semi Automatic Design. *The twist of the story is that once the range of deformations have been used the program is able to remember these by their names, that is 'sherry', 'gin', 'port' or whatever. Thus in order to input a new range of glasses only one glass in the range need be input and the program will then produce the variations on this in accordance with the 'rules' which was learnt on previous occasions. This is an example of semi-automatic design in the sense that once the machine has been 'taught' the characteristics of difference kinds of input data. (Which of course the designer can then reject if he doesn't like the computer's suggestions and can then modify using the powerful and easy modification facilities within the computer.)*



require. In other words the designer may, for example, be very clear in his mind that he wants two materials to exactly align at the edge or two holes to exactly align but may not have decided the length or dimensions of the components at that stage. The difficulty he has is that if at a later stage he comes back and tries to change one set of dimensions he may find that the holes are no longer aligned. Therefore what is needed is the ability to be precise about one set of relationships whilst being vague or temporary in description about another.

We are involved at the moment in the development of a whole range of new software products, in what I call the Design Development Language (DDL). This allows designers not merely to describe what they are doing in terms of the processes with which they are familiar but also to establish relational information about one thing whilst indicating to the machine that they wish to keep something else in a temporary mode. There is thus the possibility, for example of a *rethink* function which more closely models the iterative design process which they are used to. This enables the system to give considerable feedback at an early stage about appearance, cost, weight and so on of components whilst the design itself is infact pretty vague about the final shape. More precisely the designer has been precise about those elements about which they wish at that point to be precise, and he has easy access back into the system to change the others. If he said two holes are going to align and he later changes all other relevant dimensions, then indeed the two holes will be left aligned at the end.

I am presenting this approach in a forthcoming paper at CADCAM 85.[3] I am describing it as 'Soft' modelling, as opposed to the normal solid modelling.[4] There is very little new in terms of the algorithms actually manipulating the data but there is a great deal of rethinking about the fundamental method of interacting with the systems.

Not User Friendliness?
I think we have gone right past 'user friendliness' to the point of the most idiotic forms of inappropriate icon driven displays. It is not user friendliness in this sense that is required. It is program writing which genuinely understands the problems of those who are supposed to be having to use it. This is what we are about to see in a range of new software design products.

Eliminating Drawing
Far from trying to imitate superficial characteristics of a designers approach, such as sketching, we are trying to go back to fundamentally examining the process and in a sense eliminate the drawing activity as far as possible. In the next generation of programs far from spending a great deal of time tediously constructing three dimensional forms in an alien environment, the designers will be able to talk in conceptual terms about his design development and the system will do the rest for him.

Can we go any further?
I think the future looks very exciting. I have been talking about programs available by the end of 1986. In the following 2 years there is going to be another wave of programs coming on the market which will be making extensive use of artificial intelligence techniques. If I could quote again from a previous paper from 1984 where at the Design Research Society's Conference on the role ŏf the designer I raised the question where to draw the line?

> 'If one drew a line in the design processs between those activities which take place before the first line is drawn and those which take place after, I would like to argue that all significant design decisions are taken before the first line, at the conceptual and problem solving stage, and that activities after the line constitute refinement and crystallization of the idea. So far more developments in computer aided design and graphics have concentrated on the part after the line because the systems are produced by the comptuer graphics industry and therefore lines and pictures are required! I would like to suggest that the most important part of the computer graphics development is going to lie before the first line is drawn and it is in this area that the most exciting developments will take place over the new few years, and it is in this area that the real value of computer aids will prove themselves to the designer'.[5]

Conclusions
1. There are already available low cost drafting and wire line modelling systems which are extremely useful to designers as techniques for drawing and representing ideas which they have already developed. In some cases these systems are sufficiently sensitive for them to be able to interact with them creatively.
2. There are going to be available in the next few months exciting new products which are actually useful as design development tools which enable the designer to interact in a natural manner with the systems during their development.
3. Looking beyond that there are likely to be within the following 2 to 3 years systems which are capable of involving the designer in an interactive dialogue about the nature of his intentions. They will go far beyond being a design development tool and may start to become what I have previously described as an 'Electronic Muse'.[5]

Corollary
If these 3 conclusions are even partially correct then there is a corollary. We ought to be already reconsidering the usefulness of some of the current so called design activities. For example, by the end of the decade will we still be teaching designers how to draw?

1. Frazer, J.H. 'How soon will CAD be able to aid design education'. *Computers and 3D Product Design Education* Design Council 1985, Proceedings of a Conference arranged by the Design Council at the Royal Institute, November 1984.
2. Frazer, J.H. and Connor, J.M. 'A Conceptual Seeding Technique for Architectural Design PArC. 79 AMK Berlin 1979, proceedings of the International Conference on the Application of Computing in Architecture, Building Design on Urban Planning.
3. Frazer, J.H. 'Intelligent Drafting versus Modelling Systems' *CADCAM 86* to be published April 1986.
4. I have misappropriated the term 'soft' from Brian Reffin Smith — who uses it in a quite different context. Smith, B.R., 'Soft Computing', pub. Addison Wesley 1984.
5. Frazer, J.H. 'The Role of the Designer and the impact of the Electronic Muse — some notes'. Design Research Society Conference on the *Role of the Designer* Sept. 1984, publication pending.

All illustrations to this article were done on the British Thornton COMPAS Advanced system running on a BBC B with second processor., All the illustrations were produced by students of the Faculty of Art and Design or staff of the CAD Centre, University of Ulster, Belfast.