National College of Art and Design

Faculty of Design
Department of Industrial Design

The Integration of Computer Aided Industrial Design into the Design Process

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Introduction

> The computer and the human mind have quite different but complementary abilities. The computer excels in analysis and numerical computation, the human mind in pattern recognition, the assessment of complicated situations and the intuitive leap to new solutions. If these different abilities can be combined, they amount to something much more powerful and effective than anything we have had before (Cooley, 1988, p. 205).

In 1985 the desktop publishing revolution began. It was the result of an affordable, user friendly computer, the Apple Macintosh. Within a decade it has become the accepted standard for graphic designers, revolutionising both the way they work and what is produced. For architects, engineers and industrial designers, the impact of the computer has taken longer to manifest itself, as working in three dimensions is one of the fundamental elements of these disciplines. Trying to simulate a three dimensional environment on a computer has proven considerably more difficult than the two dimensional requirements of graphic designers.

It is only in the last five years that computer power and the necessary supporting software needed to operate three dimensional systems efficiently have become affordable. This combination of increased computer power and lower costs is leading to a swift growth in **C**omputer **A**ided **I**ndustrial **D**esign (CAID). New software is enabling everything from simple sketching to solid modelling to be performed on a Personal Computer. The problem now for designers is discovering how each of these new tools can best be utilised within the design process.

This new technology promises to free designers from monotonous tasks and unnecessary time wasting, enabling an exploration of new approaches and previously impossible solutions. For industrial designers CAID offers a very direct, powerful link between the forms they conceive and the finished product.

Unfortunately, for many years, arguments about technological determinism versus the limitations of the pencil have obscured the true potential of CAID. The real challenge for designers is to combine CAID with conventional methods, evolving new working practices which combine the best of both (Ayre, 1991, p 44). This can only be achieved through understanding the inherent advantages and the shortcomings of both traditional and computer methods.

Computerisation has become an important issue for industrial designers. There is a growing need to integrate this new resource within the design process to provide a modern and competitive service. The aim of this thesis is to look in detail at how this can be accomplished, and the resulting advantages it will bring to the designer. This will be achieved through examining each stage of the design process, from initial sketching to final presentations, comparing both traditional methods and new techniques and tools available on the computer.

The importance of computers within the industrial design process is gradually gaining acceptance. CAID is a new technology which is still rapidly developing. As a result, much of the documentation within design literature is dated and irrelevant. The most substantive part of my research has come from periodicals which provide up-to-date information on CAID technology and its applications.

To get a realistic understanding of the implications for the designer, interviews with designers in Dolmen Associates and O' Sullivan Associates were carried out. In these two consultancies, the computer is an essential part of the day-to-day work. Both consultancies have already invested in computer systems which have been integrated

into their working practices. It is difficult to talk with any accuracy and authority about computer technology, as the rules on which these arguments are based are constantly being redefined. This thesis will form an account of the current possibilities open to the industrial designer.

Chapter 1 HISTORY

The history of Computer Aided Design spans thirty years. There have been revolutionary changes within this time as both the hardware and software have rapidly developed. Computer Aided Design was originally the domain of engineers. Gradually as the software and hardware developed, the possible applications expanded. In the eighties, computer systems were developed to cater for the needs of some professions such as architecture and graphic design.

It is only in the last five years that computer systems created for industrial designers have been produced. Increased computer power, better software and a growing demand are ensuring the continued development of these CAID systems.

1 Microprocessor

Hardware

It was the invention of the microprocessor in the early 1970s that made powerful, cheap computers a reality. The complex electronic circuitry that formed the 'brain' of the computer was replaced by an integrated circuit which consumed minimal power and could be manufactured cheaply and in large quantities (Harrison, 1984, p.49). This reduced the size of computers and made them faster and more reliable. Computer power which cost millions of pounds ten years ago, costs hundreds of pounds today.

For the industrial designer the repercussions of these advances in computer power and reduction of costs are only beginning to effect their working practices. The use of computers has changed from being a highly specialised task available only to larger design consultancies, to becoming an established and affordable tool for design consultancies in the 1990s. In the last few years the cost of computers has decreased significantly, with computers which adequately meet an industrial designer's needs costing under £2,000 (Hirsch, 1993, p. 83).

Perhaps the biggest problem with such an investment is that the rate of technological development quickly dates and devalues the hardware. Currently computers depreciate by as much as 30% p.a. It could be argued that it is worth waiting for some price stability, but designers should not adopt this attitude. There is never an optimum time to buy, as this market will never settle down. As one of the leading computer system developers puts it, "There are things that are going to take place in the next five years in CAD that will equal all the technological advances that have taken place in the last fifteen. Consequently the timing is as good now as next year" (Potter, 1994, p. 5).

There will always be something better coming onto the market in the future. Industrial designers need to become computer literate now, or else they will be left behind. Many of the difficulties which have dissuaded traditional designers from using computers are no longer an issue. Computers are now powerful and as a result of the user friendly interface of the "Mac" or "Windows" environment they are accessible and understandable with a minimal amount of training.

Designer - Computer interface

> The total user interface has to do with the hardware, the software, the environment and some understanding of the process that the user is trying to accomplish (Evans, 1987 p.30).

The desktop Graphic User Interface (GUI) invented in 1981 by Xerox for the Star computer was the revolutionary step which changed the way computers could be used. Before it was introduced, the principal problem had been the abstract nature of all the computer functions. There was little perceived relationship between the computer and user tasks.

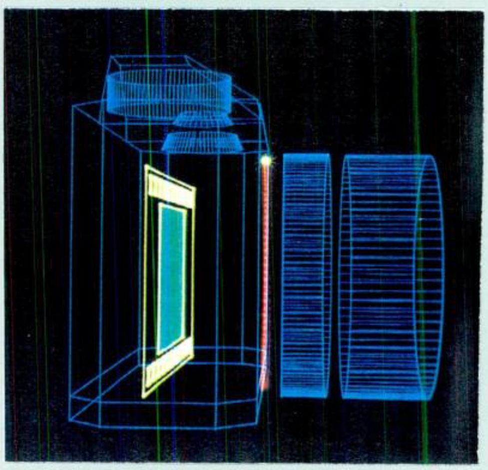
In 1984, Apple launched the "Macintosh" and it is their icon based interface which has come to symbolise the GUI. The interface was based on creating an intuitive understanding of functions through the use of graphic symbols, pull down menus and overlapping windows. This system alone did most to make computers accessible and user friendly. This icon / window principle is the system around which almost all software is now created. The simplicity of its use encouraged many graphic designers to adopt the new system. Ten years on, the Apple Mac is the standard system with which most graphic designers work.

The interface is the means through which our thoughts are put onto the computer. Effective interfaces simplify this process allowing the user to concentrate on the ideas rather than the manual interaction with the computer. Of course the ideal computer designer interface would enable the designer to 'think' the idea in working in virtual reality (Stokdyk, 1990, p.28). But until this happens it will be the software which forms the most tangible link between the computer and user.

Software

The principle problem with CAD software was that it was designed for engineers rather than industrial designers. For fields such as architecture the transition from the drawing board to the computer has been relatively easy as CAD lends itself to exact dimension driven geometry and large scale planning.

For the industrial designer the transfer has been slower. The principle reason is that the software did not provide a way of creating sculptural rather than geometric forms. The wireframe model of the camera (Figure 2) designed in 1982 is an example of the restrictions that early CAD software imposed on the designer. The modelling of the camera form was limited to simply geometry structure. As a result the final form was restricted by the use of the computer. This is no longer the case. CAID software packages, aimed and developed specifically for industrial designers, are now available. These allow the designer to create forms without being limited by the software, thereby enabling concentration on creative design rather than on computer constraints. The LA Gear sneaker (Figure 3) is an example of a concept developed on the computer. Here, the form is not limited by the three dimensional computer software.



2 Wireframe model of a Camera

3 LA Gear Sneaker

There is an endless amount of software available and for the designer choosing the right CAID package is important. With prices ranging from a few hundred pounds to several thousand pounds, individual requirements need to be carefully examined. What is right for an in-house designer may not suit the needs of a design consultancy. The best way to make an informed decision is by examining the whole design process from initial briefing to the end product. Looking at how this could be improved will provide a context to evaluate the CAID systems. When the needs and process priorities have been agreed, a more informed decision can be made. The choice must look beyond the flashy features and claims of the vendors and take account of the fundamental day-to-day work.

Education and Training

One problem CAID must deal with is the common perception that the form of products designed using computers can be restricted by the capabilities of the software. These limitations have been overcome by the flexible modelling tools available on the computer. Now the problem is in the designer's ability and determination when working with a CAID system. In the modelling of a product on a computer, simple

linear shapes can be created quickly and easily. It takes more time and skill to create more organic non-geometric forms.

Industrial designers need to learn how to use the computer and software effectively so the design solution is not limited by the use of CAID. It is also important that designers have a good understanding of when traditional working practices and CAID should be used in the design of products. This will only be achieved through good education and training.

Unfortunately in Ireland, CAID has not become a significant part of industrial design courses. The National College of Art and Design runs the only degree course in industrial design in Ireland and should be promoting CAID. Current industrial design graduates leave N.C.A.D. with little more than basic skills in two dimensional drafting on AutoCAD and word processing on Apple Mac. More importance is gradually being placed on computer skills, with AutoCAD training starting earlier and the recent investment in two Pentium computers with 3D Studio, a visualisation and animation package. However the current training and education on computers is superficial. It does not deal with the future implications of CAID, and how it will revolutionise working practices of the industrial designer.

For manufacturing companies and design consultancies, being competitive is essential. This ensures that they constantly need to evaluate and improve their service keeping abreast of the latest advances in fields such as CAID. In England this competitiveness is also evident in colleges which are more business orientated than their counterparts here in Ireland. Their budgets depend on the amount of students taking up places. There are a large number of design courses, so it is up to the various colleges to attract students to their courses. As a result the college course structures must try to keep pace with what is happening in the design world, and try to provide the best possible training.

Coventry University is a good example of a college which is taking a progressive attitude towards design education. They have a number of sponsorship programmes with industry which help in the development of the course structure. It also means students are learning skills they will need to work in the *real world.* CAID is one area which was promoted and made possible by this scheme.

One project was carried out in association with the Science and Engineering Research Council (SERC) and involved a multidisciplinary examination of how computers could aim the design process. Through sponsorship from computer companies and software developers like Alias, the college was able to equip itself with the most up to date computer packages. For these companies the college is a showroom and provides good publicity for their products. It also helps to create demand for their system, as once the students are qualified they become potential buyers. The research and projects carried out in the college give the companies important feedback on the systems and how they should develop. This scheme provides a practical environment which helps everyone involved learn more about CAID.

Unfortunately in Ireland, industrial design courses have been more conservative and slower to change. A large demand for a limited number of courses means that it is the college, and not the student, which has the choice. The industrial design courses have not had to become as competitive as their British counterparts, and this combined with insufficient funding, is somewhat responsible for the stagnation within industrial design courses throughout Ireland.

Although the co-operative work placements have become part of many design courses in Ireland this is not enough. Commercial initiatives with industry need to be expanded so that future Irish design will be able to compete. Radical changes in design education need to take place, to bring Irish industrial design courses into the 21st century, and to enable Irish industries to compete with their foreign competitors.

Chapter 2 THE SKETCH

Sketching is a fast, imprecise flow of thoughts from mind to paper. It represents the beginning of the exploration of an idea. Here the designer is not trying to draw what the product looks like, but rather capture ideas. It is about exploring and recording a wide variety of thoughts about the problem. These sketches more often than not are loose and undefined with little emphasis on geometric accuracy. It is the imprecise fluidity which is perhaps the most important aspect of a sketch. It is often through seeing something differently in a sketch, or reading it the 'wrong' way that the concept evolves.

For the designer, sketching is a way of thinking through various ideas on paper, constantly trying to refine and improve them. The initial sketching is free of logical and practical restrictions that are later imposed on the idea. At this stage the designer draws a large number of concepts, exploring everything from form to function.

From interviews and the literature it is clear that sketching is an essential part of the design process. The product evolves at this stage. The designer need not be too concerned with how much it will cost or how it can be made. It is this freedom to draw any idea, no matter how practical, that is an essential part of the sketching phase.

The virtual sketch pad

Computer software and hardware is rapidly advancing. It is possible to write on a sensitive screen and the computer can even recognise the characters. In the near future computer sketching will improve and no doubt the software will mimic the pencil or marker scribbles, and also provide many new and 'indispensable' features. However the feedback from writing on the screen is very different to the experience of sketching on paper.

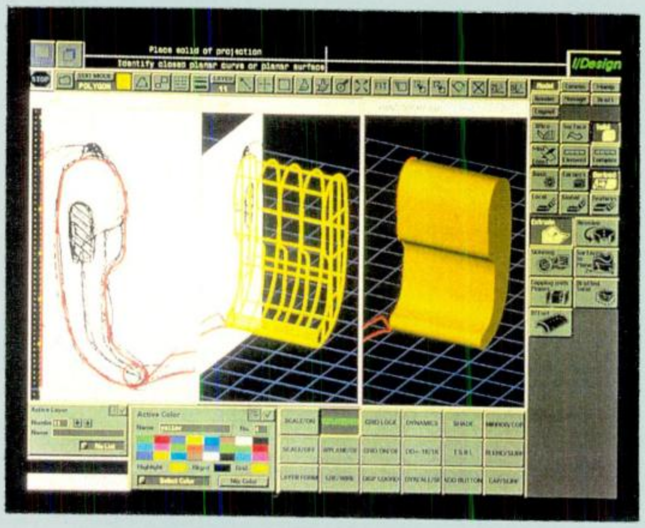
4 Personal Pen Computers

The relationship between looking and sketching is not effectively achieved through using a mouse to guide the cursor on the screen. Even the computerised pen and tablet which offer a more immediate interface do not compare with using paper and pen. The sensitive screens provide little friction for the pen. Writing on this smooth surface is more difficult, as there is less stimulation from the pen. There is also the problem of glare from the screen, which can be tiring for the eyes. In time, new products will overcome some of these problems. However it will be difficult to emulate the experience and qualities of starting to sketch on a blank sheet. of paper and the feel of the pencil drawing a line. This will ensure designers use paper for some time to come.

Scanning sketches

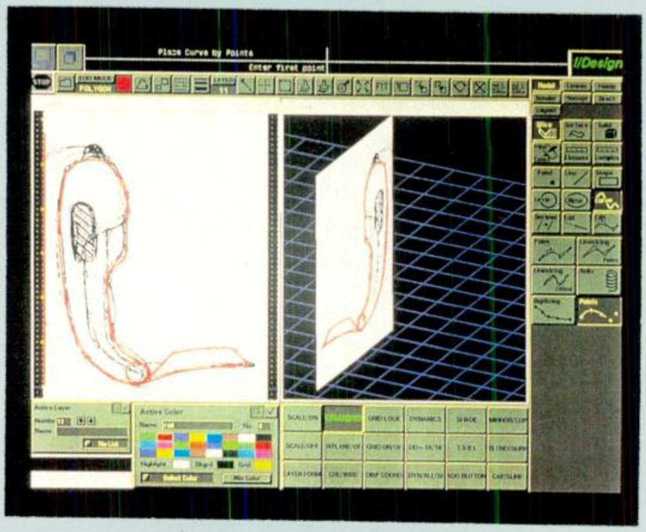
Perhaps the most useful route from sketching to computer modelling is through using a scanner. Similar in many ways to a photocopier, a scanner can take a copy of an image and store it on the computer. More and more CAID packages utilise scanning an image to bridge the gap between rough concept sketches and subsequent modelling on the computer.

Normally to create a computer model from a sketch would involve measuring the sketch, converting it to a practical scale and building up a computer model from this information. Now it is possible to scan a hand drawn sketch into the computer and then to use this as a basis for the construction of the computer model. The advantage is that the intended proportions and position of the various details are easily matched to the original sketch.



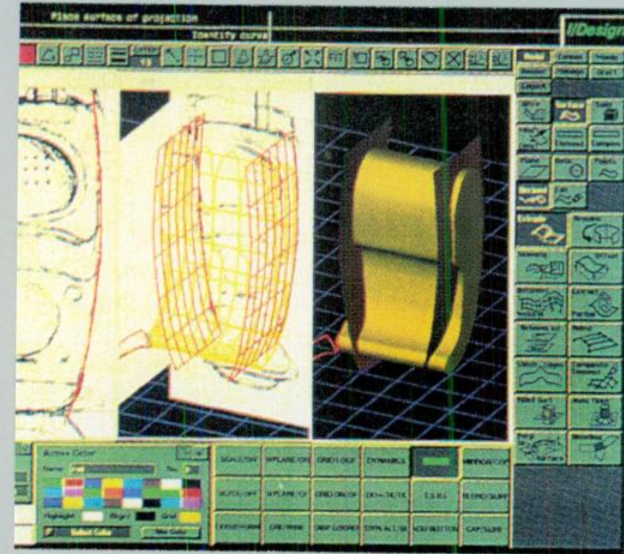
5 Rough sketch brought into computer using a scanner

Figure 5 shows the initial sketch of a front and side elevation of the concept telephone which has been scanned and brought into the modelling package on the computer.



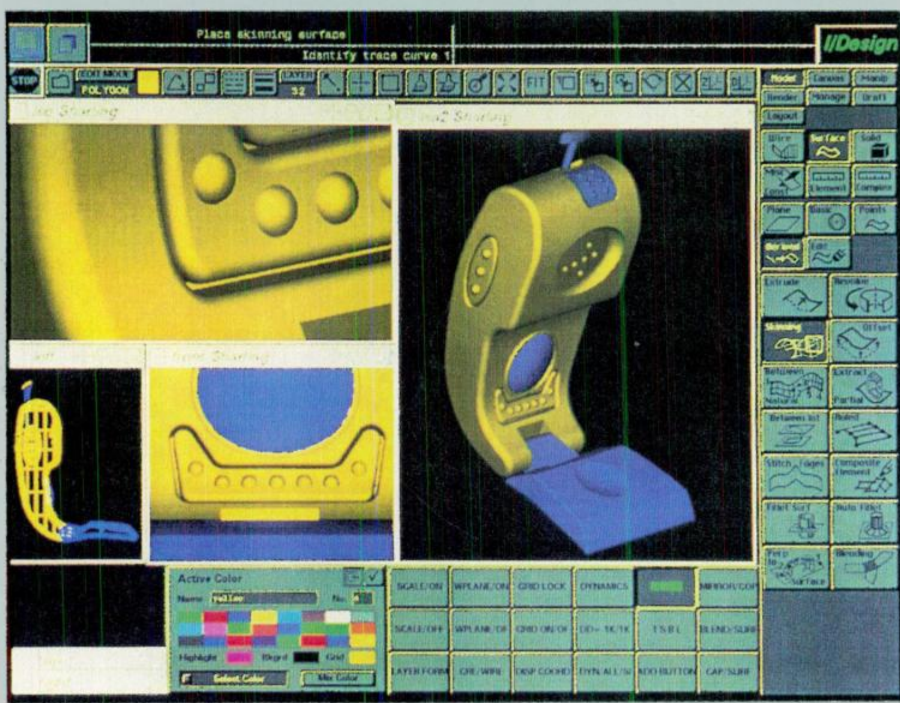
6 Initial steps of computer modelling

A line is traced around the side elevation sketch (Figure 6) This shape is then extruded to create the basic form of the model



7 Refining shape of computer modelling

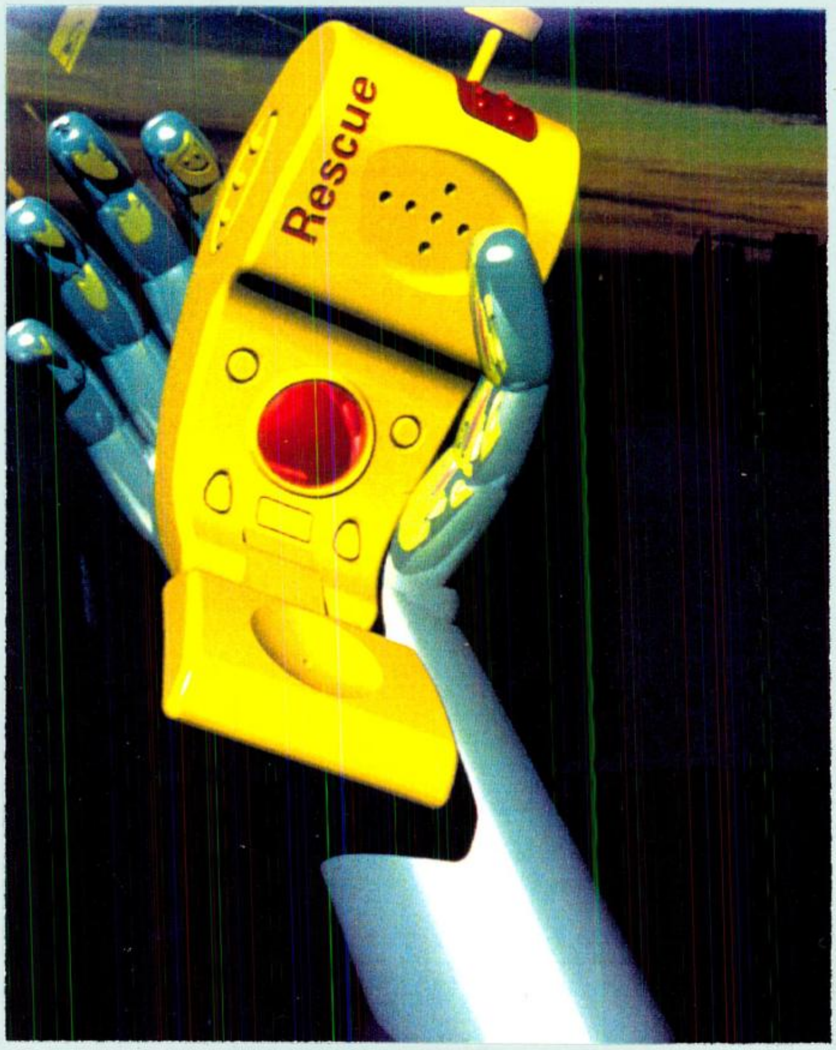
The sketch of the front elevation is used to remove *material* from the sides of the solid model (Figure 7).



8 Modelling of buttons using details from the sketch

Other details and proportions which can be obtained from the sketch are used to put more details on the model (Figure 8). From this basic form the model can be refined adding colours, surfaces and details, after which it can be rendered. This allows a rapid transition from two dimension sketches to three dimension form models, providing a logical and cost effective way of creating computer models. It is a suitable

route towards the integration of old and new techniques, and considerably cheaper than digitised tools such as the virtual sketch pad.



9 Final rendering of phone unit

Chapter 3 THE CONCEPT STAGE

> "To a great extent a product's feasibility, quality and capacity to satisfy expectations are determined by the initial concept" (Zeitoun, 1993, p.373).

The concept stage is about developing ideas which have evolved from the sketch explorations to produce more realistic proposals in three dimensions. This is achieved through a combination of sketch renderings and form models. Although this is the traditionally accepted way in which an industrial designer works, it is not necessarily the best way of working. Computer modelling offers the designer new ways of working. It should be used not to replace traditional working methods but instead to expand the options open to the designer during the concept phase.

From Two Dimensions to Three

The evolution from a sketch rendering to a three dimensional concept model is somewhat abrupt and is a transition which can be improved using computer modelling software. Although full computer modelling can be time consuming, creating simple form models on the computer does not take any longer than concept sketches. Once this virtual model has been built there are a number of benefits for the designer. A sketch is static whereas the concept model can be rotated and viewed from any angle. At this stage the biggest advantage is the softness of the model. The form is still being explored and discovered, "you're still solving functional problems and so forth - what you gain out of the computer over traditional means is the softness of the model. It's right there in front of you and everything is changeable" (Phillips Mahoney, 1994, p.42).

The computer model can be changed, stretched and shaped more freely than a physical form model. The process is also reversible. With a physical model, when

you take off too much material you have to start again, whereas on the computer you can always return to a previous version. Virtual models can be created more quickly and when it is finished all the dimensions for detailing can be extracted from the computer model. With a physical model, when the right shape has been achieved it must then be accurately measured before any succeeding work can be carried out.

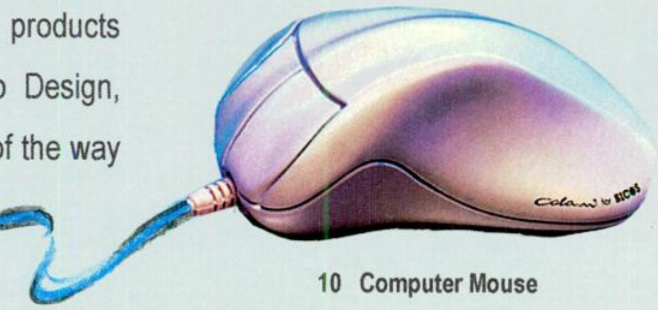
For corporate designers the advantages of computer modelling become even more evident as it can allow communication between different departments at a far earlier stage, shortening the time from concept to production. According to Victor Lucas, using CAID from the concept stage makes the design process more linear and logical. The initial modelling time can be optimised working on the computer. A number of ideas can be visualised, where it would not be possible to build the same number of models using conventional methods. Ideas that do not work can be quickly eliminated (Lucas, 1994, Interview).

The concept stage has a considerable impact on all subsequent stages of a product's development. Computer modelling, used in conjunction with form models allows more exploration of the concepts. It can identify problems before time and money have been invested in an idea. The designer and client can get a better idea of what the final product will look like giving them greater control over the whole design process.

The decline of form models?

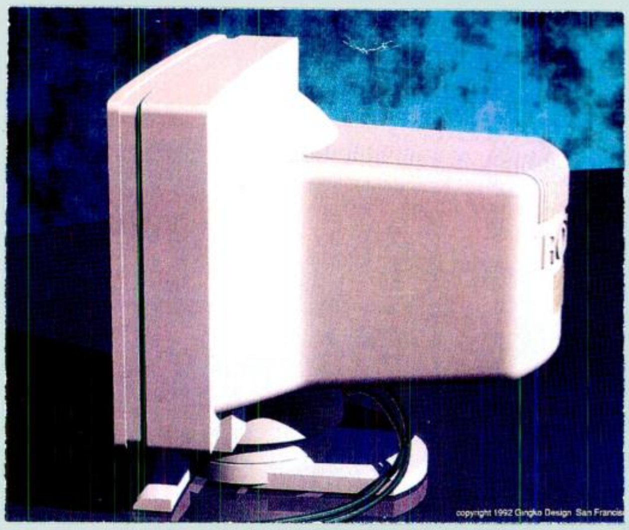
If we were to believe many vendors of software, CAID virtually eliminates the need for clay, foam or card models in the initial conceptualisation of a product. Models can never be completely replaced by any computer simulations. The designer needs to create the right balance between these two techniques from project to project. In a design consultancy it is essential that this is an continuous process, due to the diversity of work and the specific demands of individual product. For example, products which are intimate need to be sculpted to test correct ergonomic relationships while larger ones may be impractical or too expensive to build.

This is illustrated by a two products designed for Apple by Gingko Design, where CAID is an integral part of the way their day-to-day work.



10 Computer Mouse

The design of the computer mouse (Figure 10) went from sketches to foam mock-ups, so that the feel and ergonomics of the mouse could be explored. Products like this, which are held or touched can only be effectively evaluated by physical models. A visual image on the screen is just not good enough and computer modelling should be bypassed in favour of physical models.



Model created using Alias Software

Final Production monitors

11 Computer monitors by Gingko

When the company was designing a computer monitor (Figure 11) the physical model was bypassed and the concept went directly from the sketches to a computer model and then visual images. Gingko Design is an example of a design consultancy where there is no set design process. Instead they remain flexible and examine the needs of each product's development. This is a good example of how CAID can be effectively integrated into the design process (Potter, 1994, p. 22.).

Creativity

Perhaps the biggest prejudice against the use of computer modelling is the supposed geometric limitations and consequent aesthetic of the product. It is true that overuse of CAID can result in poor design. The car industry was one of the first to integrate computers into the design studios. As more and more cars look the same (Figure 12), it could be argued that CAID is responsible for the reducing diversity of style. However, marketing is as much to blame for the profusion of curvaceous cars as the computer.

It is true that without a good understanding of a computer package, one's creativity is limited. The same could be said for any design related activity. In the past, software has imposed limitations on the designer, but this is no longer the case. It is more a question of the designer's ability and understanding of how best to use the system. The computer can also be a creative stimulus in the design process. It gives the designer new ways to explore ideas in three dimensions in a fast efficient way. The computer model is flexible and this gives the designer more opportunity to examine numerous subtle variations of a concept which using conventional techniques would be time consuming and impractical.

12 Cars - Looking more alike?

Tweaking

Tweaking describes the way a computer model can be altered, adjusted and refined. This process enables quick changes to be made to the computer models. It is an aspect of modelling that cannot be accomplished to the same extent with a physical model. We naturally 'tweak' a design when we sketch, as the line is continuously modified until its proportions are correct. However it is not as simple to adjust the proportions of a physical model, and although faces can be sanded and built up, it is labour intensive and time consuming. With a computer model a number of variations of proportion, scale and shape can be quickly generated from a single model.

13 3D Studio Visualisations

Figure 13 shows a number of variations of an object created using the '3D Studio' software. The sequence of images shows how, from the first model, a number of subtle changes can be made. The scale of parts of the model can be altered. Different positionings of components can be tried. The simplicity and speed of these modifications encourages creativity. To make these different variations with physical model would take considerably longer. It is this "playing around" which is so important to designing, "let's face it, when you have spent five hours producing a design by hand, you're not going to want to mess about with it. With a computer system, you can mess about until it's exactly right" (Trevett 1991, p. 38). So vital is this "messing about", that it is pointless buying a CAID system if it is not used by the designer as a daily design tool.

Chapter 4 DETAILED DESIGN

The detailed design of a product is where the loose idealistic form needs to become realistic, cost effective and manufacturable. The concept needs to be developed into a measured and manufacturable product. This stage of the design process has more emphasis on engineering than creativity. For designers, it is essential that qualities of the concept are not lost as the model is refined.

Often at this stage of a project more people might get involved and the form of the product needs to be communicated to everyone. Computer models can help facilitate the communication and co-ordination of all of the people involved in the process. Unlike two dimensional renderings and drawings, a three dimensional computer model is not open to misinterpretation. Transforming the concept into a virtual model helps the designer rationalise the form as it is realised and constructed in three dimensions.

The Glass Drawing Board

An area in which computer aided design has seen significant growth is two dimensional technical drawing. But is the cost of implementing a system like AutoCAD justifiable? To get an accurate idea of the benefits of CAD as opposed to manual drawing, both processes must be examined.

The productivity of CAD versus manual drawing is difficult to judge, although there are some aspects which can be compared. The initial set-up, title blocks and standard symbols need only be created once on a computer, and can be stored as templates which can be quickly inserted into any drawing (Figure 14). In the manual equivalent, everything must be recreated for each new drawing. Text is also much faster to create and edit on the computer.

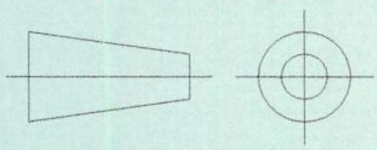
NO.	DESCRIPTION	QTY.	MATERIAL
13	Booth	2	8mm Toughned Glass
12	Support Legs	4	60mm Stainless Steel Tubes
11	Card Reader Slot	3	50mm Deep
10	Control Unit	1	Cast Alluminium Alloy
9	Interior Light	3	Energy Efficient Bulb
8	Tie rings	8	Cast Alluminium Alloy
7	Roof Structure	4	Sheet Alluminium Alloy
6	Base Plate	2	Cast Alluminium Alloy
5	Handset	3	P.V.C.
4	L.C.D. Touch Screen	3	Aluminium
3	Identification Sign	4	3mm Acrylic
2	Roof - Drain Groove	2	1mm Deep
1	Booth	2	8mm Toughned Glass

Industrial Design

NCAD

100 THOMAS ST, DUBLIN 8. TEL6711377 FAX 6711748

DO NOT SCALE FROM DRAWING
ALL DIMENSIONS IN MM
3rd ANGLE PROJECTION



PROJECT: OUTDOOR PUBLIC TELECOMMUNICATION POINT

YEAR: 4TH YEAR DRG. GENERAL ASSEMBLY

DATE: 23rd NOVEMBER 1994 DRG NO: 1

DESIGNER: MARK BROPHY & KEN READ SCALE: 1:10

REDRAWN: 7th DECEMBER 1994

14 Title Box created in AutoCAD

The first edition of a CAD drawing will generally be produced in 75 percent of the time of a manual drawing. But the real advantages of CAD are in the editing. This can take one tenth of the manual drawing time.

	Manual	CAD
First	10 Hours	7.5 Hours
Editing	10 Hours	1 Hour
Plot	0 Hours	1 Hour
Total	**20 Hours**	**9.5 Hours**

(Garret, 1994, p. 42)

In general, CAD drawings look more professional than manual ones. Lines, text, symbols, and circles are always clear and consistent, they are more accurate and can be easily dimensioned. The more complex a project is, the more advantages there are to be gained from using CAD. For example in sub-assemblies, with CAD a specific area of a drawing can be enlarged and reused. Another advantage is that different lines, text and parts of the drawing can be easily turned on or off. This enables different print-outs to be produced from the one drawing.

The principal advantage of manual drawing is based on cost. A drawing board can be bought for a few hundred pounds, whereas £5,000 is the initial investment needed, for the computer, software and plotter. Training is another CAD start-up cost, but this is not as prohibitive now with the majority of young designers having CAD skills.

The investment in a CAD drawing system will prove cost effective. However, the improved productivity of the draftsperson needs to be balanced by an increase in the amount of work which they do. There is not necessarily a need for twice the amount of drawing work, so it can allow more time to concentrate on the design of products.

Another way in which the investment will benefit the designer is through the value of the CAD output. Clients place more value on computer drawings, confirmed by the fact that it is often specified in the brief. For this reason CAD can help to win more work for a consultancy.

Currently for the majority of CAD users, their systems represent little more than electronic two dimensional drawing boards. Although this aspect alone can ensure that it is profitable, the real advantages lie in the creation of three dimension models from which the two dimension drawings can then be obtained. It is in systems such as Pro-Engineer (used by Dolmen), that the benefits become apparent. Rather than doing a number of two dimension general assemblies, a solid model is built up from the concept stage. By using this model accurate drawings can be easily generated. Also, the real time saving is achieved when the model is refined and changed. The two dimension drawings can be linked to the original model so modifications are automatically updated on all drawings. Using this package also allows easier communication with engineering, prototype and toolmaking companies.

Communicating the Idea

When more than one person is involved in the design of a product, good communication is essential to the project's success. The designer is at the heart of the process and needs to clearly communicate different information to the various people working on the project.

All two dimensional drawings of a product, whether produced by hand or machine, are always open to misinterpretation. This can happen when drawings by one person are turned into three dimensions by a model maker or manufacturer. Creating a three dimensional model on the computer forces the designer to go into detail which can remain unresolved in a traditional general assembly drawing. Normally a designer translates a three dimensional mental image into two dimensional sketch renderings and later technical drawings. These may then need to be interpreted by the engineer in three dimensions. Although physical form models can aid this process the design constantly changes and often details remain undeveloped on this type of model. Communication via a three dimensional computer model means that the idea can be more easily understood.

Concurrent Engineering

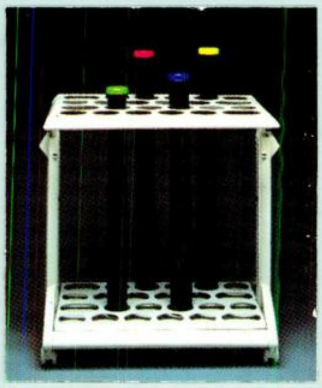
Effectively sharing design information has significant implications on downstream production and manufacturing processes, for both the in-house designer and design consultant. The aim of concurrent engineering is to minimise the time it takes the design to get from a concept to being on the market. To achieve this, concept design, engineering analysis, detailed design, production planning and manufacturing engineering overlap as much as possible. The 'time to market' of a product is crucial to remaining competitive and companies are turning to CAID to reduce lead times in the production process.

The Acco-Rexel Multi Trolley (Figure 15) designed by Dolmen Associates is an example of how with CAID, concurrent engineering was made possible. The product went from initial design conception to final production in just 8 months.

The brief was to create a range of filing trolleys that would be visually and functionally superior to all competitors, the products would be flat packed, durable and with modular components to complete the range with minimum tooling investment (Dolmen, 1994). Using three dimensional solid modelling enabled the design team to communicate with Acco's in-house engineers.

From an early stage computer visualisations of the product were available, allowing the clients and designers to make accurate decisions and modifications to the design before making the physical prototype. Changes to the virtual model were quickly implemented in everything from the shape and colour to engineering details. Being able to refer to an accurate CAID model allowed the engineering team to optimise the production processes of different parts of the trolley. This work, normally not started until the design has been completed, reduced the pre-production period bringing forward the time to market. By working from a CAID model, they obtained a trolley which closely matched the product envisaged by the design team.

15 Cad Visualisation of trolley



16 Combination, Drawing and Lockable trolleys.

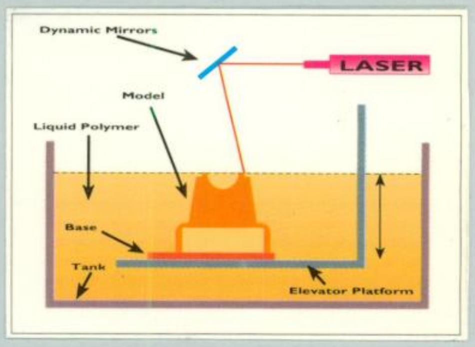
The use of the computer model benefits both the manufacturer and the industrial designer. For the manufacturer, the benefit is the shortening of the product time-to-market making it more cost effective and competitive. At the same time, the computer model gives the designer a much greater input into and tighter control over the entire design process and subsequent manufacture and quality of the product.

Prototypes

The role of the prototype, whether it is a realistic or fully working model, is well established in the design process,. When you are trying to *sell* an idea only so much can be conveyed through renderings and technical drawing. It is the physical model which can be most easily understood. Many clients cannot visualise an idea in three dimensions. "If a picture is worth a thousand words, a model is worth an unlimited number" (Potter, 1994, p.21). Nothing can equal being able to walk around, pick up or touch an object.

From the computer rapid prototyping of parts of a model can begin. This can save time by bypassing the need to create detailed drawings of the part required. Stereolithography, Laminated Object Manufacturing and CNC matching are a few ways in which data extracted from the virtual model can be used to create physical prototypes.

Stereolithography is a fast way of creating a plastic model of a component. First the data from the original model is converted into an STL file. The model is built by solidifying successive layers of a photo-sensitive polymer with a ultraviolet laser controlled by a computer. The liquid plastic hardens anywhere it is touched by the laser beam.



17 Stereolithography Process

Although stereolithography is expensive, there are a number advantages over conventional models. The parts achieve a high degree of accuracy and give a good indication of what the finished piece will look like. The part produced can be used in prototypes and tested in the market. By eliminating the need for tooling development cycles are reduced.

Laminated Object Manufacturing (LOM) is a similar process, except it builds up layers using an adhesive material. A laser is used to cut outlines of the model, one cross section at a time, and these are heat rolled to adhere them to the model. It is faster and cheaper than stereolithography, but the parts are cruder.

Computer Numeric Control (CNC) machining is another way in which data from the computer model can be utilised to fabricate parts. The computer can automatically perform operations including cutting, milling and machining to produce accurate machined parts for a prototype.

With more manufacturers upgrading to computer aided manufacture these processes are becoming viable alternatives to hand built parts for the prototype model.

Simulations

As a design project advances modifications to a finished model are time consuming. The size or complexity of a model can also make re-building a physical model impractical. Simulations using virtual models can be a more cost effective approach. They can demonstrate modifications before commitments to changing the design are made.

Vehicle design is one area where computer simulations are employed before expensive prototypes are produced. Refining the model on the computer is quicker and cheaper than rebuilding a prototype.

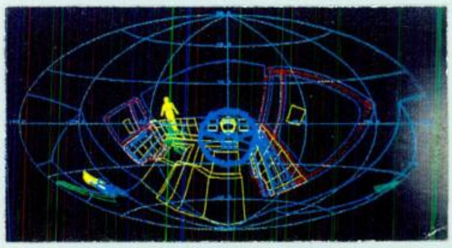
Traditionally, to calculate the create the correct size of a product or environment, designers used two dimensional templates of different user sizes superimposed on the elevations and plans (Figure 18). This is limiting as it does not comprehensively

deal with complex three dimensional spaces. True three dimensional ergonomic relationships can now be achieved using computer models, however.

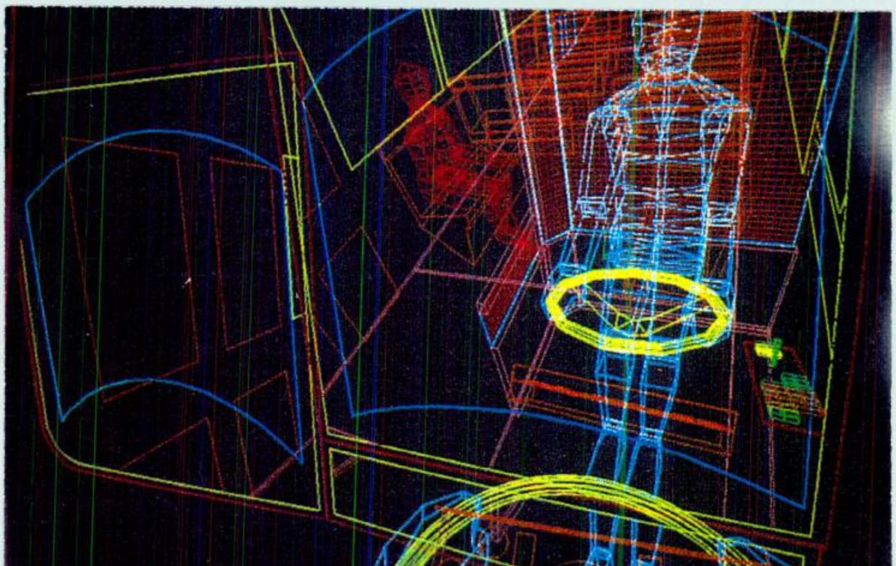
18 Templates to evaluate ergonomic space

Generally, this is not affordable or justifiable expenditure for the average design consultancy, but it is being used by automotive designers. Programs such as Sammie (System for aiding man / machiine interaction evaluation) used by Leyland enable the manipulation of a person, (chosen from statistical profiles of population groups) so that the interaction with the product can be analysed. Posture, reach and movement of different parts of the body can be simulated. The designer can also look and examine the environment from a variety of positions.

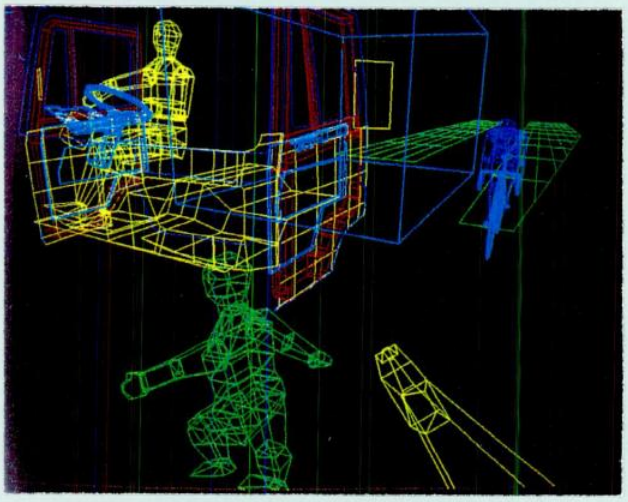
In the design of the Leyland bus, the simulations created using Sammie helped to calculate the optimum positions of switches, the height and adjustability of the seat, the layout of displays, etc., to maximise comfort for a broad spectrum of users. Other computer people were also used in the model to evaluate and optimise visibility aspects of the cab design (Figure 19, 20, 21). Using simulations like this enables re-design earlier in the product development cycle when mistakes are less costly.



19 Drivers 360 Degree Spherical Vision



20 Interior of Bus by Computer Aided Ergonomic Modeller



21 External Views to Calculate Visibility

Chapter 5 PRESENTATION

The most developed and celebrated aspect of CAID is the photographic quality visualisations which it can produce. Currently these represent the most exciting and rewarding aspect of CAID for the industrial designer. There is a common misconception that the computer does it all! Although the computer can simplify the process, to create fresh original images and animations requires as much, if not more skill on the part of the designer.

There are advantages and disadvantages to computer renderings. They can be of photorealistic quality and as a result appear finished, and computer visualisations are occasionally mistaken for real prototypes. A client might be less inclined to suggest changes to them as compared with a less defined marker rendering. However, the style of computer renderings are more honest than marker renderings, giving a better idea of how the final product could appear. They are not as susceptible to misinterpretation. Different drawing styles of designers can bias decision making, whereas with computer renderings a consistency can be achieved, allowing for choice based on the ideas rather than the renderings.

Rendering

When all the computer modelling has been finished, the designer is left with no more than a uniform colourless object occupying space. To create the illusion of a real object, material attributes such as colour, texture and pattern have to be assigned to the different parts. A model looks strange floating in space so an environment is created with lighting, shadows and backdrop to give it some realism. Then an appropriate view of the model is created and the scene is rendered to produce an image.

The majority of CAID software contains a Material Editor, where attributes which mimic real materials are created and perfected and then assigned to objects within the scene. Although an infinite variety of materials can be produced, there are three basic ingredients from which they are created:

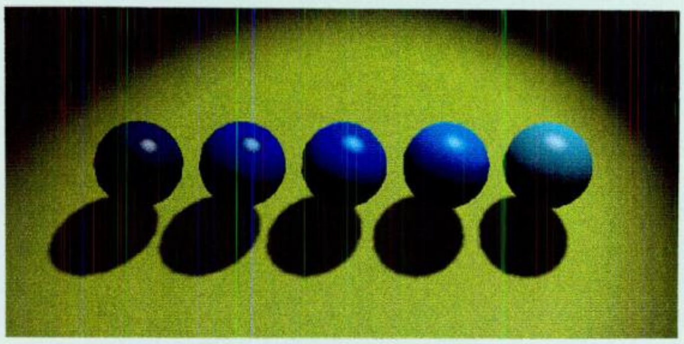
The *base colour*

The *properties* of the material

The *mapping* assigned to the material

The majority of material editors come with a comprehensive library of materials which can be modified. The package I used for these examples is 3D Studio which is a popular rendering and animation package. It has a library which contains about 200 base textures from which materials as diverse as marble, metal, or sponge can be created in any colour.

Each part of the model needs to be assigned qualities before a visualisation can be obtained. The first step of the process is to define the base colours. Normally , the designer would begin by getting a close approximation in a primary colour. Then using sliders which adjust the saturation of red, green and blue, the exact colour can be produced. It allows the designer to accurately define each colour.



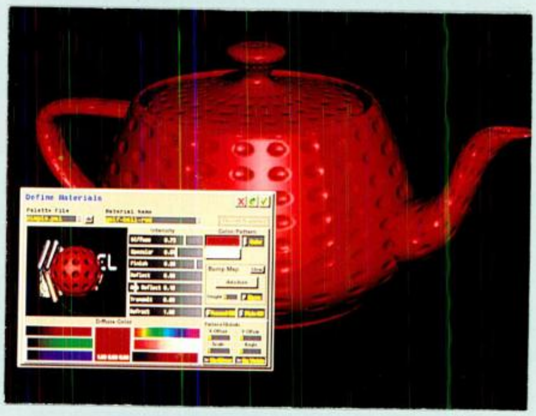
22 Colour Adjustment

The speed, simplicity and subtlety with which these colours can be adjusted offers exciting possibilities for the Industrial Designer. The designer is not limited by the range of markers he or she has. More importantly, it gives the designer more freedom to explore a variety of colour combinations, and this has measurable financial benefits

over traditional airbrush or marker renderings (Niall O' Sullivan 1994). Figure 23 shows a variety of images generated from one computer model.

23 Computer visualisations of a Portable Diskman

Mapping a material can give it apparent texture or pattern. With traditional renderings, showing bumps and surface texture is time consuming and difficult to accurately reproduce on paper. With most computer software, applying surface texture, using bump maps, is simple. The effects can quickly be examined and adjusted, allowing the designer to explore surface finish. Surface texture can dramatically change the aesthetics of a product, and this is an aspect of product design which needs to be more than an afterthought, when materials are specified.



24 Teapot with Bump Mapping.

A pattern map can put an image onto the surface. This is also a way of putting graphics onto a model. This can produce very realistic results in packaging design. (a case in which the graphics are at least as important as the form of the object). The images which can be produced give a very good impression of the design before it is produced (Figure 25).

25 Oasis Bottle & Packaging Design

Creating an effective environment much in common with composing an aesthetically pleasing still life. It is perhaps the most difficult aspect of the process. Although a picture can be put into the background, it is difficult to create a realistic match between the computer image and the background. For a lot of product designs, the scale does not necessitate elaborate backdrops. It is the product which needs to be the focus of the scene, so unobtrusive surroundings can be the most effective.

Lighting is, without doubt, the most problematic aspect of computer renderings. It is the highlights, shadows and reflections which create the illusion of reality and is the most difficult to reproduce (Figure 26).

26 Computer Visualisation of a Sony hi-fi

Unlike a hand rendering, if something is wrong with the CAID image, it can be easily changed. However the biggest advantage is that when the scene has been set up, a number of images can be generated without having to start from scratch. To do a hand rendering of a different view of the product would involve starting over with little or no saving of time. With the computer model it is simply a matter of moving the camera to a different position.

Before the final image is produced a number of quick renderings are normally produced to check that nothing in the scene has been forgotten. For the final rendering, the view is chosen, and then it is left to the computer to do the work. Although on high end computers images are produced in a matter of minutes, they take considerably longer on the average PC. However many packages allow a number of views to be put in a queue. The rendering information is stored and the computer can be left working through the night, saving valuable computer time for office hours.

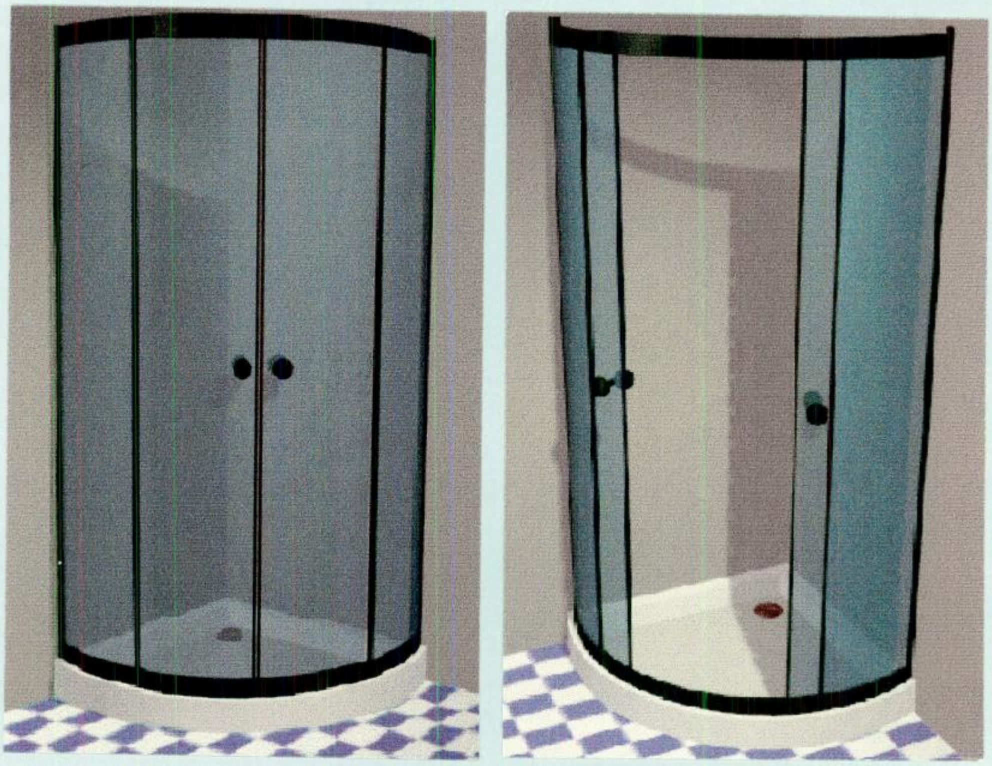
Animation

No matter how good a still image produced on the computer is, it remains lifeless. This is why physical models will always be important, since they can be held and examined from all sides. However as is often the case with industrial design, the prototype is rarely more than a visual model.

An animation allows us to go beyond the physical model. This can make the model move and function in real time as the viewer moves around, inside or through the product. It is a dynamic medium for presenting projects to clients and non-technical people involved in the project. It allows the viewer explore and experience a product in a true to life approach. It can show how the product is used or more complex information such as how the product is assembled. Animations "improve communication, not only between the designer and client, but also with the manufacturing and marketing staff who will make the product a reality" (Ayre, 1991, p. 45).

On my co-operative placement I worked in Flair International. One project was designing a replacement range for old shower enclosures. To get the approval for £1,000 investment in a prototype I needed to convince both marketing and the technical department that the product, using curved glass, would justify its expense.

The problem with a marker rendering is that it did not look much different to the existing product. By creating an animation showing what the product looked like when installed and how the doors slid open, the head sales manager was won over and as a result the product is being developed for production (Figure 27).



27 *Gemini* Shower Enclosure (Animation Stills)

At the moment this type of service is too expensive for the average project in a design consultancy. Computer animations are the most labour intensive operation for a computer. Each frame requires thousands of calculations which, depending on the complexity, can take as much as half an hour to generate. With a typical animation requiring 24-30 frames per second, a minute of video requires 1500 frames. The expense can be justified in architectural projects, where a computer walk-through allows clients to walk around a building before the foundations have been laid.

With rapid increases in computer power, the expense and time needed to create animations will make it more justifiable. O' Sullivan Associates have experienced a growing demand for computer animations, although this is principally for the advertising sector. However, it will not be long before it becomes a primary medium through which industrial designers communicate their ideas.

The Client

To run a successful consultancy, there needs to be a balance between being cost effective and producing good design, between the idealistic designer and the realistic client. Money dictates how much time can be spent at each stage of a project. It also can decide what is produced for the client and by what means. In general, computer work is more expensive, costing twice as much per hour as model making and the client may not be prepared to pay for this service. However, having sophisticated CAID tools creates the right type of impression and is used as a selling point for consultancies like Dolmen and O' Sullivan Associates.

CONCLUSION

For many industrial designers CAID still represents little more than a two dimensional drafting tool. In the past there was little need to integrate newer approaches made possible by the computer as it was too expensive. The prices of both the hardware and software are no longer prohibitive. In Ireland, a lack of education and training is a prime reason for the limited integration of CAID within design consultancies. In Britain, joint ventures between industry and universities have enabled the students to work on the top CAID packages, which benefits all involved. Already co-operative schemes in Ireland are proving successful, so perhaps a similar approach could help bring Irish Design into the 21st century.

The user friendly interfaces which are becoming standard in all CAID software packages is helping to overcome the 'Technofear' associated with using computers. These interfaces allow for a more intuitive approach, making the transition from physical to virtual modelling easier for the industrial designer.

Understanding the limitations of both traditional and computer techniques is essential if design is to benefit. Due to the diversity of work within a design consultancy, industrial designers must adopt flexible working practices to effectively balance the physical and virtual work from project to project. Using either exclusively will prove inefficient and detrimental to the end product. CAID is becoming an essential competitive instrument for design consultancies, and those who do not exploit this technology will get left behind.

For designers, CAID offers a very direct, powerful link between the forms they conceive and the finished product. It puts industrial designers at the very centre of the production process, with more influence over the entire design cycle. The implementation of CAID may increase the percentage of product development time spent in the industrial design office but there are many savings for the engineers, drafters, model makers and manufacturers.

Technological substitution represents the most uninteresting form of CAID. The tools which are the most exciting are those which allow the designer to work in new ways offering "an opportunity to explore what otherwise might be considered impossible" (Phillips Mahoney, 1994, p.42). It is only through a complete understanding of its flexibility and limitations, that CAID can be used competently within the design process. CAID should not replace, but complement traditional skills, from sketching to model making. As CAID develops, the conventional wisdom that technology limits the imagination may be reversed. It is up to the designer to take the best of the old and combine it with the new.

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