Styling and design: intuition and analysis in industrial design

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In order to both research the subject and to realize the benefits of introducing CAD, it has been necessary to define industrial design more closely and to understand its context. Industrial designers employ visual, creative and intuitive techniques in making their special contribution to the design process. This can be seen most clearly in the car industry. Research at Coventry University has addressed these issues, and progress has been made in the development of effective CAD support techniques for automotive styling. © 1997 Elsevier Science Ltd.

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In Hitchcock’s movie ‘North by North West’ there is a seduction scene on a train between the fugitive, Cary Grant, and a demure Eva Marie Saint. She says she is 26 and unmarried. Cary Grant asks her what she does. She says ‘I am an industrial designer’ – and Hitchcock cuts to a quizzical expression from Cary Grant.

As far as I can tell, this is the first mention of industrial design in a Hollywood movie. In fact, I think it is the only mention of it in such a movie. Eva Marie Saint is young, glamorous and successful. Obviously she is a typical industrial designer. Unfortunately, much as I would like this to be the case, it is not so. Not only is she atypical, being female, when a very small proportion of industrial designers are women, but she’s also lying. In the movie she is a secret agent. But Hitchcock could get away with that in 1959, as at that time not a lot of people knew what industrial design was. It was, and is, a relatively young profession.

1 The context

The need to define and understand industrial design has become more focused in recent years. This has been because of various attempts to...
realize the potential benefits of introducing CAD to the process of
designing manufactured consumer products. Early attempts to do this
foundered on an incomplete understanding of the needs and practices of
industrial design. Much work has been done at Coventry University to
address this issue, particularly in respect of how it has affected car
designers.

The particular approach to designing consumer products called industrial
design has a relatively short history, being principally a discipline created
in the 20th century. It has roots in the philosophy and practice of the
Crafts movement and the Bauhaus in Europe, and in the USA through
the invention of styling as a way of increasing product sales. It is called
‘industrial’ because of its concern with products manufactured by indus-
trial processes, and has tended to have an emphasis on vocational
effectiveness and practice.

The education of industrial designers has been mostly the responsibility of
art schools, particularly in the UK. The various changes in higher
education in the UK in the last 25 years have resulted in the discipline at
degree level being located almost exclusively in the new Universities, like
Coventry. However, because of both its relative youth and its roots in the
art school approach it has lacked any tradition of research. The principal
objective has been that of educating industrial designers who could
practice professionally.

Industrial design is, of course, only one sort of design. It has much in
common with architecture and the various versions of design within
engineering. Indeed the relationship between industrial design and
mechanical and production engineering is similar to that enjoyed (if that is
the right word) by architects with civil engineers. Within its art school
tradition industrial design is regarded as a specialization in three-
dimensional design, like furniture or ceramics, and separate from say
fashion and textiles or graphic design. Despite its roots it has a much
stronger structural relationship with engineering design because they are
both concerned with manufactured products.

In both architecture and engineering much work has been done on
analysing and mapping the design strategies and processes. The strategies
tend to be concerned with managing the activity and the processes are
about how designers tackle problems. The descriptions of the process,
which claim to be general, have tended to consist of an apparently linear
sequence of analysis, synthesis and evaluation, but with interactive loops
from each stage to all preceding stages.
Typical design strategy

1) Feasibility Study
2) Preliminary Design
3) Detailed Design
4) Planning the production process
5) Planning for distribution
6) Planning for consumption
7) Planning for the retirement of the products

Typical design process

1) Analysis
2) Synthesis
3) Evaluation - extended to
4) Revision
5) Implementation

For the individual designer this seems to say not a lot more than: I start by thinking about the problem, then I propose a solution, then I see if the solution answers the problem, then I do it all again. It needs to be seen with the additional dimension of a progressive movement from an ill focused multipossibility initial stage to a well defined, fully detailed, final design stage.

Although such descriptions of the design process have limited utility for the individual designer, maps of the strategy are essential for the
management of the process. If you do not know what is happening and when, you cannot structure the activity, make it effective in an organization, or meet client requirements. Without an operational structure team design is extremely difficult.

Such an understanding of the design process and ways of modelling it are also essential if you are to shape a course of study to educate designers. The art school tradition of learning by doing, sitting alongside a practitioner (‘sitting with Nellie’) does not necessarily yield a well designed curriculum and focused educational objectives. Objective descriptions of the design activities and the techniques of designing are essential to a properly functioning design course. They also provide the basis for undertaking research in the discipline.

2 Industrial design defined

What industrial designers do is to design manufactured products. For simple, low technology products the industrial designer may be the whole design team, delivering a complete design to the production engineers. For high-technology complex products he or she will be a member of a team with specialized responsibilities.

There is considerable overlap between engineering design and industrial design as they are both concerned with designing pieces of technology, with \(^3\) ‘initiating change in man-made things’. However, there are significant differences between the two disciplines.

Engineering design has been defined by Fielden \(^4\) as ‘the use of scientific principles, technical information and imagination in the definition of the mechanical structure, machine or system to perform prespecified functions with maximum economy and efficiency’. As long ago as 1940 Harold Van Doren \(^5\) defined industrial design as ‘the practice of analysing, creating and developing products for mass manufacture. It’s goal is to achieve forms which are assured of acceptance before extensive capital investment has been made, and which can be manufactured at a price permitting wide distribution and reasonable profits’. Useful though this definition is, it does not offer great clarity in distinguishing between industrial design and engineering design. By contrast Farr \(^6\) has characterized industrial design as ‘the conditioning factor with those parts of the product which come into contact with people’. Apart from its emphasis on the key responsibility for the user interface within the design activity, this definition of industrial design is not particularly helpful. It is probably more fruitful to identify the areas of responsibility which industrial designers have and their functions in a design team. In a typical team

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3 Jones, J C Design methods, seed of human futures Wiley, Chichester, UK (1970)
4 Fielden, G B R Engineering design H.M.S.O., London (1963)
5 Van Doren, H Industrial design McGraw Hill, New York (1940)
6 Farr, M Design management Hutchinson, London (1966)
including designers and specialist engineers, marketing managers, product planners etc., and within a process of working from concept design through design development to the interface with manufacture, the industrial designer has two particular areas of responsibility:

- To represent the market and user requirement in determining the ergonomics and appearance of the product
- To integrate market, user and engineering requirements into a whole design solution

There is thus a two-fold concern with the user interface covering the objective area of ergonomics and the subjective area of appearance.

The proper resolution of these areas requires the consideration of the product as a whole, and from this stems the responsibility for the overall integration of the design. In tackling these areas of responsibility the industrial designer has two particular and related functions:

- To visualize the product concept
- To represent alternative design solutions

This representation of concepts and alternatives is essential as a communication device within the design team, and as a method of selling ideas to management or clients. Industrial designers are thus required to be both visual and creative and are sometimes regarded as the artists within the design team.

What industrial designers bring to the design of conventional consumer products is of immense importance. It is recognized in the international market-place that there is a fundamental and underlying requirement for any product to exhibit quality and reliability. These are given prerequisites which are necessary simply to get the product to the starting line as a serious contender. However, this does not guarantee success. If the product is to succeed against the level of competition which now prevails, then it must have much more; it must have designed-in ‘desirability’ -- perceived added value. This comes significantly (but not exclusively) from the contribution made to the design of the product by the industrial designers. The essential engineering design inputs serve to ensure that the product is well made and will not break down, that it has quality and reliability. This will give it a chance in the market-place, at the right price. But only one product can be the cheapest, the rest have to sell on the perceived added value. The quality of the design depends upon the industrial design contribution within the proper integration of the en-

7 Tovey, M J 'Drawing and CAD in industrial design' Design Studies Vol 10 No 1 (1989)
gineering and industrial design activities. How this happens is different in various industries, but is most clearly defined and focused in the car industry.

3 Automobile design

The car industry is one of the largest, although as products automobiles are fairly untypical. It is an industry in which the products almost always evolve, the designs grow out of earlier models rather than involving radical change. The configuration, package, engineering details etc. stay broadly the same from one model to the next. Because of this it has been possible for there to be a high level of demarcation and specialization in the process from design to manufacture, which has tended to be fairly sequential. The industrial designers are more clearly differentiated from their engineering colleagues, with a more identifiably separate role in determining the appearance and identity of the product. Usually they are referred to as stylists. Because they more clearly exhibit the characteristics which distinguish industrial designers from engineers, they are of particular interest when considering the requirements for CAD support.

4 Industrial design processes and stylist design thinking

The sequence of activities in which the automotive stylists are given responsibility for the early stages of the design programme and then hand over to engineers gives further emphasis to the differences between their methods of operation. Responsibility for the initial conceptual design in the creation of the new product rests with the stylists, and they take it to a fairly detailed stage with fully defined surfaces before engineering assumes control. Much of the purpose of the engineering design work thereafter is to make practical sense of the stylist's proposals. This involves a lot of analytical thinking to optimize the design and sometimes, considerable ingenuity. It is not, however, to any significant degree creative. For virtually all automobile companies the engineering design processes are now computerized with CAD/CIM and much finite element work.

In styling design processes there has been much less use of computing than in engineering. There are significant characteristics of the styling process which make it difficult to analyse and to give external form to its detailed processes. This is because it is intuitive and holistic, with a strongly nonverbal culture. It is also individual and there are sometimes quite definite differences of approach and technique between one stylist and another. Devising appropriate CAD support for productive use by stylists is problematic.
The styling process is holistic, concerned with envisaging the overall design solution as a visual entity. In moving from an initial unfocused concept to a detailed design proposal the stylists are required to display visual flair within a controlled yet changing formal vocabulary.

Some designers appear to employ a kind of unfocused perception, in which the initial design is represented as a hazy, undetailed sketch, and as the design progresses it is as if the sketch was gradually brought into focus and more detail was seen. For this reason there is much emphasis on concept sketches in which the overall proposal can be quickly and easily changed. This is an inherently solution-focused activity, concerned with synthesis. The attempt is to create a solution proposal as a whole, and work out the details later.

In the suggested division of preferred thinking modes between the two hemispheres of the brain, stylists tend to emphasize right hemisphere processes. The classic division is between a left hemisphere focus on the verbal, analytic and linear mode and a right hemisphere focus employing synthetic, concrete and holistic modes. This can be represented as a difference between linear processing and simultaneous processing.

The way that automotive stylists operate and their thinking modes

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8 Tovey, MJ 'Thinking styles and modelling system' Design Studies Vol 7 No 1 (1986)
coincide well with what Cross has characterized as designerly ways of knowing. He describes this mode of thought as having five aspects

- Designers tackle ill-defined problems
- Their mode of problem solving is solution-focused
- Their mode of thinking is constructive
- They use codes which translate abstract requirements into concrete objects
- They use these codes to both read and write in object languages

Stylists' design thinking can be seen to display these characteristics. Appearance design problems are frequently ill-defined, not being describable in words. Their approach is certainly solution-focused and involves constructive thought processes. The codes they use employ visual and graphic languages to communicate with each other and to model their ideas. These are their object languages.

It could be argued that stylists display some of these characteristics which distinguish designers in a more extreme form than other non-practitioners. Their thinking has less in common with that of nondesigners.

5 The stylist's form and graphic language

In working on design proposals stylists have developed an inhouse culture with a rich private language for communicating design ideas. Usually this is a combination of words and images, although sometimes it is purely visual. Because their groups are small and may be together for a number of years, their group language may be idiosyncratic and atypical.

My colleague Neil Birtley has documented the whole styling process for use by the research group at Coventry University. He has characterized the stylist's form vocabulary, stressing that they are liable to improvize (indeed such invention is part of what keeps them motivated) describing it thus

Form and feature lines must be put into automobile panels to give them stiffness and strength, and to stop them wobbling under vibration ('oil canning'). The stylist's job is to use this requirement to advantage to produce aesthetically pleasing forms and shapes that still perform their structural function.

Virtually no surface on an automobile is flat, almost every panel surface is curved in more than one direction, possibly with other indentation and piercings in the basic surface. The automobile form is built up of several such surfaces which meet as
intersections are filleted, or blend smoothly into each other. The forms may be hard and rigid, or soft and flowing, or a judicious combination of both.

They consist of compound curved planar surfaces, meeting, blending and intersecting with curved cones, conic sections, spheroidal segments, generating all manner of complex connecting shapes.

Like Eskimos having a multitude of terms for snow, so stylists have a rich vocabulary for automotive forms. The words used to describe these forms are for example: ‘ellipsoids, cones, warp parabolas and cantilevered shapes’. Terms such as ‘slippery, exciting, fluid, soap bar, bath tub, tailored, sheer, razor look, taut, splined line, blitz line (zig-zag), whiplash line, Tiffany, sweep spear, wind splits etc., all enter the language, especially in the USA, to describe a particular focus or connote a ‘feeling’.

In the styling studio, the VW Golf was described as a sphere trying to get out of a cube. In another debate about the Ford Escort Mark III much concern was expressed over whether the eye went to the wheel arches or the headlights in assessing the size of the vehicle. It led one stylist to comment ‘we don’t judge the width of a guy’s shoulders by how far apart his eyes are’, meaning that the wheel arches should be emphasized rather than the headlights.

Stylists also use a shared graphic language with its own representational codes. Much of it is informal and loose, with suggestive lines of profiles in the vehicle sketches, with blacked-in areas to provide a reverse silhouette. A sketched ellipse may denote a highlight and hence a crowned surface or flair. A minimal half-shading to a glass area may suggest a reflected horizon thus indicating curved glass. Areas may be missed out and only completed in the viewer’s mind’s eye. Perspective may be exaggerated, as may be contrast, colour and texture. Figure 4 gives annotations of the kinds of techniques used.

6 Structuring the process

The use by stylists of intuitive, nonverbal processes, their use of exclusive languages, and their graphic and three-dimensional modelling techniques are not amenable to the kind of analysis which supports a generalized common approach. They are difficult to define, and this makes it difficult to produce a CAD system.

One approach to this issue is to look at the overall process to identify what is already defined. The styling process takes place within a programme which is managed, with deadlines and specified deliverables. Whatever
Figure 4 Stylists' graphic language

Figure 5 Stylists' graphic language
their individual idiosyncrasies, stylists must work to produce proposals in a prescribed format with sufficient identifiable detail for management to make decisions about whether or not to proceed with the design. I have called these stages the management intervention points\(^{11}\) (Table 1).

At each of these management intervention points the designers are expected to present design proposals in specified forms to their line managers. This could be to the section leader, studio manager, programme manager, head of department, design director or whoever. It may include various nondesigners at various stages, certainly specialist engineers, product planners and top management. On these occasions it is, of course, necessary for the language of the presentations to be comprehensible to its audience, and the private form or graphic vocabularies of the stylist would be inappropriate.

For each of these stages it is possible to define the people who will be

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\(^{11}\) Tovey, M J 'Intuitive and objective process in automotive design' Design Studies Vol 13 No 1 (1992) 23–41

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<table>
<thead>
<tr>
<th>Management intervention points</th>
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<tbody>
<tr>
<td>1 Issue of brief and product specification</td>
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<td>Issue of package</td>
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<td>2 Review of competition and influences</td>
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<td>3 Informal selection of concept sketches</td>
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<td>4 Management review of concept sketches</td>
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<td>5 Tape drawing presentation (some companies)</td>
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<tr>
<td>Scale model presentation (some companies)</td>
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<td>6 Presentation of reworked tape drawings or scale models</td>
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<td>7 Presentation of full-size clay model</td>
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<td>8 Representation as required</td>
<td>22</td>
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<tr>
<td>9 Approval of three-dimensional model</td>
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Figure 6 Management intervention points of the styling process.
involved, the location and environment, to say what will be shown, what representations and their scale, and what are the management intentions, and hence what sorts of questions will be asked.
From this description it should be possible to abstract out the fundamental operational requirements which management needs in order to confront the process and ensure that it delivers that which is necessary to progress the design. This would be in the form of the required outputs from the system which management would want the designers to use, even if this is not identical to what designers think they want.

7 Presentation requirements for the general process

For management to be able to make decisions and thus to control the overall process through interventions at various stages, it is possible to characterize the outputs they require. These are what is needed for design evaluation and to allow the process to continue productively. They can be broadly grouped into two categories: concept design and design development. Preceding each of these is the issue of the brief, specification and package.

Concept design requires

- Influences: simultaneous presentation of $2 \times A0$ area of influence illustrations
- Concept sketches: simultaneous presentation of a multiplicity of A2 or A3 sketches of two types: theme sketches, and dimensional constrained sketches

Design development requires

- Tape drawings: simultaneous presentation of three full-size elevational views, as either line drawings or rendered
  
  Or alternatively
  
  - Scale models: simultaneous presentation of three models of one-quarter or similar scale
  - Full-size clay: one (or more) full-size dinoced representation of the design

The key characteristic of the concept design presentation is the quick production of a number of illustrations or sketches, which can be either loose and informal or dimensionally rigorous.

The key characteristic of the design development would seem to be the attempt to present the design as a full-size realistic representation of the product. Both the full-size tape drawing and the scale model are approx-
imations to having the actual design real-size in front of you. The full-size clay model is trying to do the same thing.

8 Requirements for a CAD system
Currently vehicle stylists use a fairly ad hoc collection of CAD systems, paint box, drawing, surface and solid modelling systems, and there is little prospect of a single integrated system. There is no general acceptance that what is used is satisfactory. However, the potential benefits if a satisfactory CAD support system or systems for styling could be created are considerable. These include both the improvements in the speed, effectiveness and quality of the design decisions, and the potential for creating a common database and thus a more cohesive overall approach.

Since the late 1980s the Coventry research team has received three research grants from SERC to investigate CAD support for styling. An early task was to identify the difficulties which stylists experience with current CAD systems. From a fairly detailed analysis we concluded that because their design processes are individual, various, intuitive and private, specifying a system for them is problematic. However, it has been shown that to be usable by them in form creation, a CAD system must have the following characteristics:

1) Inputting geometric information must be quick
2) Geometry must be easy to specify
3) Representations must not be overly precise
4) Geometry must be easy to modify
5) Reviewing alternatives must be readily possible
6) Visual display quality must be adequate for evaluation
7) The overall interface must be user-friendly

A system with these characteristics would probably not inhibit intuitive design processes. If it could also meet the presentation requirements of management then it would provide a usable system.

9 Approaches to form creation
In the first part of the process of developing a CAD system we concentrated on the second stage of the styling process, design development. This entails working with a small number of the concept design proposals and developing them to fully detailed designs. As this stage abuts or overlaps engineering design and CAE, it seemed appropriate to concentrate on it in the development of computer-aided styling procedures. As Rooney and Steadman have noted, CAD has much more application at this stage of the process.
The approach we used was similar to the design process. We took as our starting point the system requirements described above as a kind of design brief for what had to be produced. We then went through three further stages. The first was concerned with developing a range of possible approaches (concepts). The second involved developing and refining the productive ideas into a workable proposal. The third was concerned with testing and evaluating the proposal.

In the first stage we considered as a paper exercise, a number of possible approaches to building CAD models. These we based on the particular characteristics of the car industry, so as to constrain the problem to manageable proportions. We considered:

1) Package
2) Assembly for partial models
3) Corner and intersection modification
4) Parts bin
5) Orthogonal profiles
6) Styling lines

Modelling a form proposal is the fundamental process for the stylist and if CAD is to be used this is the process it must support. In design development what is required are quick and convenient ways of moving from concept sketches to a computer model suitable for design development. They can be rough approximations subject to subsequent refinement.

The research team spent much time in animated debate (heated argument?) and subsequently in brainstorming on possible form creation methods to produce the list of approaches. They all depend on the evolutionary and formally constrained characteristics of the design task.

Most of the approaches were rejected when we considered the actual capabilities of the CAD systems which had to support the approach. We were using Alias on a Silicon Graphics station which was generally regarded as a good quality and capable system.

Although the package (the legislative, ergonomic, operational and mechanical dimensions of the design) was a crucial part of the design, it had no utility as a basis for form creation. The partial models, corner and intersection modification and parts bin all foundered on the practical difficulty of specifying geometric constraints on adjacent objects and maintaining tangency. There is a major difficulty in joining together...
separate objects in a CAD surface model. The parts bin approach also presented the daunting problem of creating a large initial database (the bin's contents) for which we lacked the time.

However, the orthogonal profiles method, and the variation on it which uses styling lines, seemed to have the potential for practical development.

Following the paper exercise we undertook a range of further experiments on the CAD system. These were principally undertaken by one researcher (Di Pryce Evans) working with computer modelling systems, building models in different ways to test theoretical approaches. Several experiments were performed, some coming from the initial work, some from preceding experiments and other developments within approaches. The main approaches were

1) Building a multisurface model of a car
2) Manipulation of a pre-existing model to achieve a new design
3) An attempt to change a pre-existing multisurfaced model, into a single surfaced one
4) Creating a model from a single surface
5) Creating a model with a reduced set of surfaces
6) Project with an industrial collaborator
7) Modelling a series of designs

**Building a multisurface model of a car**

This was the normal standard approach to building a vehicle form using sketches, liaising with the designer. The process was cumbersome, with unsatisfactory results when attempting to define the form from sectional
Manipulation of a pre-existing model to achieve a new design
As most car designs evolve from a previous model, we considered it legitimate to investigate a CAD approach which involved modifying an existing representation. It proved to be possible to make changes, which resulted in a vehicle form which looked convincing, but did not conform to the designer's intentions. The reason for this was the nature of the initial construction of the model; the panel's history influenced how it could be modified. The resulting approach was not a usable technique.

An attempt to change a pre-existing multisurfaced model into a single surfaced one
Many of our problems were a consequence of attempting to join together separate surfaces with separate histories. If they could be joined together to operate as a single surface, this might solve the problem. However, the necessary conditions for joining were that the edges must be precisely the same length, direction, orientation and have the same number of control points. It was not achievable in practice.

Creating a model from a single surface
One method of that avoids the problems of multisurfaced models is to create the vehicle form from a single surface, which could then be deformed to the desired form. Of the available primitives, the sphere was used as a starting point. Indeed it proved to be partially deformable to the desired shape. However, further refinement was complex and impractical, requiring a vast number of control points, so that technique was abandoned.
Creating a model with a reduced set of surfaces

This approach was a compromise between the two previous approaches, using a reduced number of surfaces. A judgment was made as to the minimum number of surfaces which might describe the vehicle form as a half-car, which was mirrored to produce the overall vehicle. The result was a simple, easy-to-use technique. It carried insufficient detail to be usable (and any change involved rebuilding from scratch).

Project with an industrial collaborator

As there were a number of industrial collaborators involved in the project it seemed appropriate and potentially productive to carry out at least one of the form creation experiments in collaboration with them. The company was Motor Panels, using one of their live projects.
The starting points were the general dimensional constraints, and sketches from their design studio of the vehicle concept. We decided to use the technique which in previous experiments had looked most usable, and that was the styling line process.

After a number of false starts we eventually resorted to inputting the styling lines via an acetate copy of the sketch taped to the screen and traced over. Whereas previous techniques had taken two days this took 20 minutes. To our surprise it worked, it was fast, easy and accurate.

The styling lines are the key descriptive lines which describe the form in a stylist’s sketch. They provided a basis which was rescaled to fit the package requirements, and hence achieve dimensional rigour.

Then the lines were recreated to make them manipulable within the program. Three views were used, drawing half the vehicle and then mirroring to produce the complete form. This could then be presented as a perspective view.

There followed a process of adding progressively more detail to the
model, correcting dimension matching errors as they arose. The result was a relatively quick production of a convincing vehicle representation.

We were able to conclude from this experiment that the styling lines approach seemed to provide a usable method. It was enhanced by the acetate tracing method, which although apparently crude, was remarkably effective.

*Modelling a series of designs*

Two student design proposals were selected as usable experiments to test the styling lines approach further. They were a small delivery van and a three-wheeled racing car. They had produced both concept sketches and scale models. Using the sketches as the basis for producing computer models it was possible to compare the results with the three-dimensional models. The results verified the utility of the styling lines approach.

This technique meets the requirements for a CAD system which were
identified in section 8 of this paper. It also meets the presentation requirements for design development – in broad terms. It needs the addition of a full-size projection system to properly meet them, and when we have hired such a system, the results have been satisfactory. We have been able to show the detailed design proposal, as an animated model on screen. This same rotatable three-dimensional image can then be seen full-size via the projection system. This allows good management judgments to be made on the design proposal.

The system falls short of the conventional process in not providing a walk-round full-size model. This refinement awaits the development of virtual representation (VR) systems.

10 Computer-aided concept design

The third SERC grant was to support an investigation into computer-aided concept design. This included an investigation of VR in support of styling, leading to a specification for its use within the process and an initial investigation of immersive virtual representation of the vehicle package. However, system and cost limitations constrained what could be practically achieved in this area. The main part of the investigation was the provision of computer support for the production of theme and package-related concept sketches, using more conventional technology.

As before, we mimicked the design method and embarked on a similar process of exploratory thinking at the beginning of the project. During this it became clear that there was some ambiguity over what a sketch was. After due consultation we decided to offer and use the following definition of a concept sketch: A concept sketch is a collection of visual cues sufficient to suggest a design to an informed observer.

These sketches are used in two ways in this process; free theme sketching and package-constrained sketching. The theme sketch is the initial expression of how a design is intended to look. For such sketches to be useful in the design process there must be enough visual information in them for the informed observer to

- Understand what they imply about the design proposal
- Understand the visual impact of the implied design as a whole
  - Understand its specific visual characteristics

The package representation of a proposed design is a collection of visual cues sufficient to communicate the fixed dimensional parameters of a design. We similarly define a package-constrained sketch as one using a
package representation to constrain and guide the designer’s sketching. It allows an observer to

- Understand the dimensional constraints and proportions of the proposal
- Understand the fit or interference of the theme proposal with the package

Our aim has been to use designers’ sketches directly as a source of evaluable and developable models, produced almost as rapidly as the sketches themselves. This would allow for three-dimensionable evaluation of a concept much earlier than is traditionally possible.

The exploratory phase of this piece of work was at times problematic, as we attempted to provide an appropriate framework for the types of approach which might be possible. We covered orthographic and perspective representation, handled freehand or more formally, using line and area, in 2, 2.5 and 3 dimensions. The breakthrough came when we moved from the idea of a single technique solution, to one which employed a combination of two or more techniques.

There is little point in computerizing sketch design unless you gain something over the traditional method. Sketching by conventional means is extremely quick and effective. Its major limitation is that it is two-dimensional. A two-dimensional representation of a three-dimensional object has inherent limitations.

The basis for the computer-aided sketching process is the use of the system’s ability to produce three-dimensional forms from orthographic representations. This can be easily driven by simple orthographic sketches. However, the resulting three-dimensional form bears little resemblance to a stylist’s sketch, and does not function as a substitute for it. However, it does offer the basis for texture mapping stylist’s sketches onto the three-dimensional form. The result is a simple, rotatable three-dimensional sketch, which can be produced very quickly. The developed version consisted of three sets of procedures giving a progressively better quality of computer sketch, and linking in with the previously developed styling lines approach. The procedures are.

**Sketch mapping**

This is the process by which line information is taken from orthographic sketches and used to create a simple surface model. This is then combined with those orthographic sketches to give the first-stage model with the
Sketch Mapping

Creation

Produce Orthographic sketches

Produce simple model from sketches

Evaluation

Map sketches onto model to check

Figure 15 Sketch mapping  

CACD © Coventry University 1994

implied feeling and detail of the orthographic sketches and the additional spatial attributes of the three-dimensional model. As in the conventional process theme sketching will generally be followed by package related sketching.

Sketch projection

This is the second process where the designer uses the simple surface

Sketch Projection

Creation

Produce Views for perspective sketches

Produce Perspective sketches

Evaluation

Map sketches onto model to check

Figure 16 Sketch projection  

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model created in the sketch mapping process as an underlay for perspective sketching. These sketches are then combined with the model to create the second stage sketch model for further evaluation.

**Sketch combination**

This uses perspective sketches to create styling-line CAD models which can be surfaced later. Assuming that the results are satisfactory in design terms the designer then uses sketch combination where line information is taken from the perspective sketches created for the perspective projection process, this line information is then used to create a styling-line model.

What these techniques represent is a computer-supported approach to concept sketching. We have not tackled the requirement for presenting illustrations of influences on display boards; this is probably best left to conventional processes. For the area we have addressed, we tested the efficacy of the proposed techniques by a number of evaluative and test procedures.

Firstly, we undertook a pilot trial conducted in the research laboratory with 22 individual designers. They were given an introduction and general background to the research, followed by a demonstration of the tech-
niques and a structured interview. More than 80% of designers were very positive in their response.

This was followed by three case studies with designers using the techniques, at Rover, Styling International and Krafthaus.

The outcomes have been positive and led to invitations to further demonstrate the process with various European partners. As a consequence the research is now being further pursued with European research funding.

11 Conclusions
In order to understand and objectively examine industrial design it has been necessary to place it in its historical and educational context. It has been defined so as to distinguish it from other types of design both generally, and in the particular process of creating manufactured products. Industrial designers employ visual, creative and intuitive techniques in making their special contribution to the design process. This can
be seen most clearly in the particular case of the car industry. It is also possible to identify from automotive design the operational framework and the required outputs which management require.

On this basis the methods which industrial designers employ have been re-examined so as to introduce effective computer support for the process. This has been tackled in two stages, for design development and for concept design. For each of these, effective CAD procedures have been developed, which enhance the process without inhibiting the visual and creative approach. In developing such techniques there has been an appropriate dependence on traditional verification procedures, but the research development process has also depended upon the use of design methods, developed within design rather than depending upon imported techniques.

We began with an extract from an Alfred Hitchcock film. I think I am right in saying that Hitchcock only received one Oscar and that was at an age of 80 plus. His comment then was ‘I am encouraged, I shall go on’.
This research has generated interest in a number of companies and universities in Europe and has led to European funding to continue its development. Thus encouraged my coworkers and I will, like Hitchcock, go on.