# Task Analysis and Scenario-Based Design of Calligraphic Interfaces

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**Abstract**

*The great functionality of today's CAD systems enables the manufacturing of very complex models. Yet, great part of this power is unusable, early in the design process. As well, we have found two different approaches in two different car designers that surprisingly lead to the same long time in development. In this paper we identify the reasons for these problems, and propose a solution that bridges the different worlds of conceptual and geometric models, using the affordability of the calligraphic interface. Creating a prototype by drawing it allows impossible situations to be immediately identified and corrected, without further communication overheads, certifying that emotional drawing ideas correspond to the designer's intents.*

**Keywords**

*Task Analysis, CAD systems, Calligraphic Interfaces.*

## 1. INTRODUCTION

CAD systems, being in the possession of great functionality, now enable the manufacturing of very complicated models. However, computers are yet to be used in the early stages of product design. This derives from designers not being acquainted with the representation, and needing to leap large conceptual gaps from their mental models to the geometric models.

We also noticed that two different car designers, following two different paths to designing a vehicle, spend the same time to perform the overall activity. In one case, traditional paper and pencil is used as medium for storing and passing information, while in the other case digital support is preferred. Designers execute their work over these mediums, and have to communicate to CAD operators or other engineers. Designers create new drawings rather quickly and so do modellers, yet a car takes several months to go through the phase of design and modelling. Our task analysis provides an answer for this. The communication between designers and CAD operators required for the modelling phase is a bottleneck. Reasons underlying this are related to different interpretations of the drawings inevitable from both parts involved in the communication.

Our proposal to solve these problems is the SmartSketches Project [SmartSk]. Using this system a designer will be able to model in a way close to how he draws, holding a stylus on either a tablet, or directly over the screen.

Input modality is not the only concern to shorten the distance between system and designer. More important user interface issues are taken into account as well. Our system will provide a computer-assisted environment, enabling some automated modelling and simpler and more natural interaction metaphors.

In the remainder this paper we describe the task analysis carried out, as well as the outcome conclusions subjacent to our observation.

## 2. RELATED WORK

For the modelling process, several systems exist that take care in user interaction to support easier interaction and modelling schemes. The most famous work in this area is SketchPad from Sutherland [Sutherland63], which is the first graphical user interface that allows precise drawing using modelling hierarchy and a constraint-based system. Later, in the 90's, Zeleznik's SKETCH [Zeleznik96] combines gesture and geometric recognition for creating and modifying 3D objects. His approach defines a gesture grammar for creating simple primitives in an orthogonal view. In Teddy [Igarashi99], the modelling of free-form surfaces is allowed with an unprecedented simplicity at the interface level. Silhouettes are the basis of the object modelling process. This approach, then, provides a polygonal mesh that adapts to the object's silhouette drawn. Architecture also benefited from this field when SketchUp [Sketchup3D] was introduced. This system offers operations more advantageous from conventional Boolean methods, like direct manipulation over edges and faces. Pereira *et al.* proposes a system, GIDes [Pereira00], which constructs 3D objects drawn in isometric perspective projection, with the use of gesture recognition. GIDes defines a gesture vocabulary for a reduced command set of geometric primitives, and operations. A valuable feature presented by this work is an expectation list that suggests to the user the possible operations to perform, during interaction.

Regarding modelling concerns, Terzopoulos and Qin define and present Dynamic Non-Uniform Rational B-Splines (or DNURBS) [Terzopoulos94] as a new modelling scheme. D-NURBS allow the usual indirect manipulation for definition of control vertexes and weights, and a direct manipulation using forces to deform the Splines using physical simulation. Zhang and Qin extend this definition to incorporate hierarchy [Zhang01]. The hierarchy brings the ability to edit fine details in localized regions, resorting to local knot insertion, avoiding the insertion of unnecessary patches.

Our system will require the ability to produce high quality modelled curves and surfaces, not being suited for modelling using the physics simulation directly. However, recognition of stroke gestures and a suggestive way of reducing the command set by dealing with ambiguity are advantages to be explored.

## 3. TASK ANALYSIS

In this section we briefly describe the visited partner's workflow, tasks they perform as well as the relationship between the tasks and the people involved. For further detailed information we refer the reader to [Dias03].

### 3.1 Site Profiles

Italdesign Giugiaro provides services to the automotive companies, developing all the design phases of a new vehicle, from the first styling idea to the engineering of the project, and finally to the manufacturing of the running prototypes. Italdesign Giugiaro has always been investing important resources in new technologies in order to improve the end-product quality, to reduce costs and times of production and to optimise processes.

FIAT Centro Stile is an advanced styling research centre, providing services to the FIAT Group. Their research focuses on the concept design phase, providing style and car designs for the main manufactures of the FIAT Group. FIAT Design Centre employs half a dozen designers and as many modellers who work in small teams of two and three on new vehicle designs. At certain stages of car designs physical modellers will be called in to produce scale models of cars being designed.

### 3.2 User Profiles

Typical users of the system can be divided in two classes: Designers and Computer Aided Styling (CAS) engineers. There is also an interesting proportion of one-to-one between the two kinds of users at every visited site.

Designers' main activity is the creation of free form sketches and drawings. They typically have a degree in art or design, are familiar with sketching and painting and possess good to excellent manual skills. Designers


**Figure 1 - Perspective sketch**

do not necessarily work on computers. Those that do only use paint software and not CAD systems.

CAS engineers are those that create 3D models out of sketches and hand drawings performed by designers. Typically, they have a degree in mechanical engineering or in design with a technical approach. They are able to produce 3D geometric models and surfaces with a good realistic quality.

## 4. WORKFLOW

In this section we look at the flow of work at each site describing hierarchical, precedence and temporal relations among major activities and tasks. This information was acquired through internal interviews and workshops organized in the scope of SmartSketches, with consortium partners. The analysed case study consists in the development of a motor show prototype.

### 4.1 Italdesign Giugiaro

Italdesign Giugiaro workflow starts by creating/analysing the package provided by the customer. This package defines the ranges of freedom for the designer. Next, designers create a perspective sketch of the car that will be the basis for technical sketch. This technical sketch is then assembled in a 4-view drawing, which will be the starting point to the computer aided modelling. After the construction of the 3D model of the car they create a virtual model to present to the client. Finally, at the end of the process they produce a physical 1:1 scale model.

#### *4.1.1 Package creation*

The first step in the styling process is the creation/analysis of the package, which consists in a technical drawing fixing the main hard-points that are to remain untouched during the development of the styling. These bonds put by the customer change according to the different carmaker, to the kind of car developed (sport car, sedan, etc.) and to the project type (restyling *vs.* completely new model). The time needed to develop a complete package drawing can go from a few weeks, if the package is fairly simple, to several months, if all the mechanical requirements are analysed.

#### *4.1.2 Perspective and Technical Sketches*

The first creative step is the development of perspective sketches. This is when various styling proposals are studied based on the package requirements, as a technical input, and on the styling intention of the carmaker, as a guideline for the look of the car (as figure 1 illustrates).

Depending on the customer's requirements, this phase can either be very demanding – leading to an official

**Figure 2 - Technical sketch**

presentation – or simply a way to put down on paper the designers' ideas, for internal use. This phase may even be avoided, especially when an early virtual model presentation is planned.

After these sketches are completed, the Styling Centre board holds an internal meeting to choose the best proposals (usually about 3-5). Costumers can be involved in the styling selection from the very beginning, thus giving their impressions and asking for modifications.

The phase of the technical sketches comes next. The number of alternatives is now limited and the package's requirements are more strictly respected. This is the first phase in which the feasibility of the project is studied, mediating between the quality of the project, its aesthetical aspect and its cost.

In this phase, depicted by figure 2, the perspective sketches are re-drawn in the four main views (front, rear, top and side) trying to keep the styling intentions while assuring the project feasibility. The drawing is still a sketch, focused on the rendering effect of the presented solution, but at the same time the technical details and the precision of the four-view representation are provided.

This process allows the development of the engineering of the vehicle already in the styling phase, so that the solutions presented on the technical sketches are usually nearly 80% feasible, with a considerable saving of time in the following phases.

The technical four-view drawing phase is extremely important and is the base for the following model construction. The four-view drawing can be seen as a bi-dimensional representation of a 3D object, whose views are projected on the walls of a box. Figure 3 represents the box "unfolded". This kind of approach will be later used in the virtual model creation phase.

#### *4.1.3 Computer aided modelling*

After the final four-view drawing is decided the phase of the mathematic creation of the surfaces starts. The four-views drawing passes from the hands of the designers to the Computer Aided Styling (CAS) engineers who create the virtual 3D model working on surfacing software tools on graphic workstations.

In the first phases of the process, it is not necessary to build a model complete with details, as headlamps or refinements. Instead, only the outer shape of the model is created, because the styling details are not fixed and it is most important to give a general idea of the styling intention. Figure 4 illustrates this phase, were most of the surfaces are already defined.

#### *4.1.4 Virtual and physical model presentation*

At this point the virtual model is ready to be presented to the customer at the Virtual Reality Centre, which is a room specifically equipped for this purpose.

At the end of the process, the physical 1:1 scale model is built. This physical mock-up is still considered fundamental to evaluate the styling impact of the new vehicle and to give the final validation to the project (this is a need felt by customers used to having the model evaluated by people that don't have the training needed to judge the styling effect in any other way).

After a few possible iterations, a styling master physical model is built with all the possible details (including handles, windscreen wipers, etc.) and painted to give a realistic look. This final model provides the final reference for the styling presentation and is also often used in the wind tunnel to evaluate the aerodynamics of the vehicle.

### 4.2 FIAT Centro Stile

In this section we describe the concept and design process, resulting from a set of interviews done at Fiat Centro Stile and Elasis.

Elasis industrial designers start considering the carry over components of other Fiat cars and have to perform the 'target setting' phase in order to define the right target for each performance (crash, handling, ride comfort, etc.). Next they develop the geometrical model of the system of components and verify the 'target achieving' phase.

In parallel with the FIAT styling designers of Centro Stile, they have to validate their project with the different style proposals. Designers start to sketch a number of proposals (2D drafts) either directly on a paper with pencil or markers, or with computer painting tools, as shown in Figure 5.

Then, the 2D sketches and the ergonomic scheme in the CAS system are imported in order to compare each style

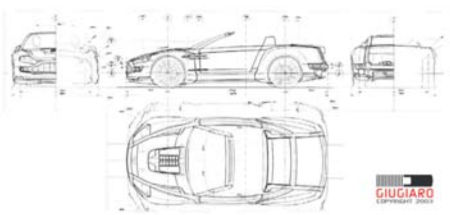

**Figure 3 - technical four-view drawing**

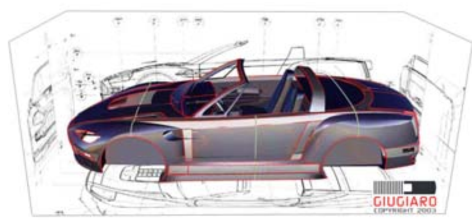

**Figure 4 - Construction of surfaces**

**Figure 5 - Drafting phase**

idea to the car package, made by Elasis industrial designers. After that, CAS operators create 3D curves and surfaces, according to the sketches for each style proposal. The best of these proposals are physically created in a 1:3 scale clay model.

The design process goes on per each model until just one proposal is chosen. This proposal will be developed in detail in the CAS system before a clay model on 1:1 scale is be built. During this time, the information may be used also for aesthetic analysis (performed in a VR environment), geometrical and functional analysis (translated in CAD data) and style presentations. In parallel, the interior style process is developed.

## 5. VISITS VIDEO ANALYSIS

We made several visits to project partners' work installations with important outcomes to understand the processes of development and modelling. During these visits we video recorded users in action. This section describes briefly these experiences through the analysis of those videotapes.

As previously seen, the four-view drawing precedes the phase of curve and surface creation. This corresponds to a transition of information from the designers to the Computer Aided Styling engineers, who create the 3D models. Besides the inherent difficulties in communication (transmission of the right ideas) there are also dilatory aspects related to acquiring the technical drawings using scanners, and constructing the 3D box geometry with the 4-views on the walls. We will thus be focusing our video analysis on these tasks (the creation of perspective sketches and the computer aided modelling) because they are the main issues we want to tackle in the current modelling workflow.

The next subsections describe the analysis of the video from a visit to Italdesign Giugiaro's design facilities. The video documents a simulated modelling process where a car is digitised based on four hand drawn technical views. Next we discus the modelling method used and comment the impact of the number of operations on the overall modelling process.

### 5.1 Modelling Process

After the four-view drawing is transferred to the CAD program, curves are the first entities to be drawn. The first lines drawn are the general shape of the upper part of the side view. The typical approach is from the general to the specific, defining and isolating areas as work progresses.

Surface modelling follows the curve definition phase, and its modelling approach is the same. The number of control points is carefully kept to a minimum. A good balance between the surface quality and the surface complexity is fundamental and its achievement is based on the CAD engineer experience.

It often happens that handmade or even computer generated lines from the sketches and the four-view drawing are not clear enough to let the CAS engineer give a good interpretation of the designer's idea. Here, they have to co-operate discussing the modelling direction. The result is that the 3D mathematic model is the best compromise between what has been previously proposed in the sketches and what is realizable in a real 3D object.

### 5.2 Evaluation tools

A-class surfaces are referred to as being high-quality surfaces yet its exact definition changes depending on the customer. These desired high-quality surfaces' main requirements always consist on geometry, tangency and curvature parameters. To satisfy this desire for high standards, engineers use tools to inspect the shape and the parameters of the surfaces being modelled. Two examples are a tool displaying curvature radii variation details, and another allowing the visualization of how light reflects on the surface and how smoothly that light reflection varies across the surface.

### 5.3 Analysis

The video describes the modelling of 12 major curves of the car body and 3 surfaces formed by them. Despite the small number of entities modelled, the results prove to be interesting. We counted the following elementary control point (CP) movement operations: drag-and-drop actions on the control-points that change their position, and undo operations on these. Table 1 presents summary statistics for the curves and surfaces observed: minimum, maximum and average number of control points, as well as the number of movements made to control points per curve/surface. When a new control point is added to an existing curve, a point movement is always required[1] in order to place that point in the desired position.

The first surface to be modelled is the vastest of all surfaces, which covers the windshield and ceiling of the car. This surface has $6 \times 4$ control vertices and was actively retouched as a result of the high exigency (a total of 54 control point movements). The points were moved in conjunction with the use of both tools mentioned earlier. As a consequence, the order in which the points where moved was grouped with each row of control

[1] This movement is not taken into account on the numbers shown here, because it was considered to be part of the control-point's creation operation. Otherwise, the number of movements should be increased by $cp - 2$, where *cp* is the total number of control points on the curve.

points perpendicular to the car's orientation. This number is particularly excessive when taking into account that points belonging to an underlying curve are never retouched after the curve has been defined. This means the points moved during surface editing, are those at the interior of the surface. This implies that the 54 movements were actually performed on $6 \times 4 - 16 = 8$ points only, for that first surface, resulting on an average of nearly 7 modifications to the points' position made to each point moved. These figures allow a clear understanding of the importance of the small number of control points on the surfaces and therefore on the curves.

| | Min. | Max. | Avg. per ent. |
|---|---|---|---|
| Number of curves' CP | 3 | 6 | 46/12=3,83 |
| Curves' CP movements | 0[2] | 16 | 55/12=4,58 |
| Number of surfaces' CP | 15 | 24 | 60/3=20,00 |
| Surfaces' CP movements | 0 | 54 | 54/3=21,33 |

**Table 1 - curve and surface modelling statistics**

## 6. DISCUSSION

A problem detected during task analysis in an early modelling phase is the difficulty designers and modellers have in explaining details to one another. It would be desirable to have a tool that would allow designers to express their ideas quickly to arrive at a 3D prototype, so that modellers clearly understand the designer's intent. This will not replace the modeller's work since it is meant only to shorten the distance between the interpretations of the designer and CAD operator.

Single control point control over a surface is not the answer for the reduction of time and number of operations performed over a surface while modelling. A higher-level interaction scheme has to be adopted to eliminate the long iterative process of adjusting a surface's shape to the desired position.

## 7. CONCLUSIONS

A traditional CAD system cannot fulfil the needs of creative designers, since they don't like or understand control points, the mathematical foundation behind the control points and their relation with geometric shapes. Because of this, designers usually show themselves reluctant in using CAD systems to draw complex objects. They prefer to draw on 2D using shading and perspective techniques, in either paper or a paint program, to transmit their ideas and leave the modelling part to CAD operators.

Another drawback designers find on traditional CAD systems is the lack of ability to quickly sketch prototypes. If this capability is present, they will easily validate the conceivability of their ideas. Two-dimensional drawings can suffer from perspective mismatches or optical illusions that prevent the surfaces from "making sense". If we could quickly create a prototype, impossible surface situations could be corrected immediately after, certifying that emotional drawing ideas correspond to the designer's intents.

Hence, designers, however displeased with the 3D modelling experience, would still like to be able to construct 3D models as a means of facilitating the interaction with the modeller. Thus, empowering a designer with the interaction with a modelling application should be carried out by means of a straightforward interface, like the familiar calligraphic interface.

[2] 0 corresponds to a curve that was copied from another.

## 8. ACKNOWLEDGEMENTS

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