An innovative approach to the aesthetic design

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Abstract

As the aesthetic aspect of a product is becoming more and more important in customers' decisions, there is an increasing need of tools able to express and preserve the styling intent during the product development cycle, while offering an interaction with the user much more adherent to his mentality. The European Project FIORES-II (Character Preservation and Modelling in Aesthetic and Engineering Design) is aimed at creating innovative CAD tools capable to capture and preserve the product aesthetic character and make it accessible in a multi criteria approach for styling and engineering design optimisation. In order to explore the possible relationships between emotional character and product shape, an extensive analysis has been carried out, thanks to the collaboration of industrial designers in the automotive field, such as BMW, Pininfarina, Saab, and in household supplies field, such as Alessi and Eiger. In this paper, the main outcome and the innovative design functionality defined on the basis of the results of the above mentioned research will be presented.

***Keywords*:** Geometric modelling, Aesthetic design, Product emotional character

Introduction

Styling is a creative activity where the designer's goal is to define a product that evokes a certain emotion while satisfying the imposed constraints. Therefore, a better understanding of human reactions can allow an easier satisfaction of market wishes and tastes. On the other hand, the complete design of new products requires multidisciplinary expertise and consequently it results from the collaboration of several actors. It is then clear that the formalization of the design intent underlying the product specification may improve the communication quality among the involved actors, who can belong to different departments in the same company, e.g. styling and engineering, or to external suppliers. In addition the formalization of the relationships between shape and aesthetic character included in a computer system may help designers to achieve their goal more directly. In fact, even if the introduction of digital tools in the styling workflow in the last twenty years has significantly shortened the development time and costs, some critical issues have still to be faced and overcome to move towards an ideal optimised digital design process, in which the design intent is automatically communicated and preserved throughout all the process phases.

When designers create shapes with digital techniques often the available tools for model definition and manipulation restrict the way in which a shape can be modelled: they often have to concentrate too much on how to use the system to obtain what they have in mind. To make the modelling process more intuitive, the interaction should be performed through a direct control over the three-dimensional space in the same way a pencil dominates the two-dimensional space. In fact, an easy interaction requires functionalities simulating the traditional method of stylists' work. The current limitations are mainly due to the fact that the modelling activity is mostly based on low-level geometric elements. Often it is necessary a full understanding of the underlying surface representation to know which elements have to be changed to obtain the wished surface modifications On the contrary the user would like to directly handle properties strictly linked with his design intent.

Based on these considerations, the European project FIORES-II (GRD1-1999-10785-Character Preservation and Modelling in Aesthetic and Engineering Design) (FIORES-II), aims at building innovative CAD tools more adhering to the creative user mentality and at improving the cooperation between the main actors involved in the product development process, by identifying the relationship between shape geometry and aesthetic character. The goal of this paper is to illustrate the project objectives and intermediate results. It is structured as follows: in the first part a survey of the main research works studying links between shape and aesthetics is given; part two describes the FIORES-II project objective and presents the results achieved until now. Conclusion can be found in part three.

Related works

Several researches have been carried out in order to identify the links between a product's shape characteristic and its emotional message. These relationships have been analysed from different perspectives including perceptual psychology (Luh 1994), design and computer science (Wallace and Jakiela 1993, van Bremen et al. 1998, Hsiao and Wang 1998, Yoshimura and Yanagi 1998, Chen and Owen 1998).

Suggestions have been proposed for formalizing brand identity, possibly by means of archetypes (Smyth an Wallace 2000), or associating terms to a specific character. In literature, results of experiments are shown about the possibility of categorizing products in classes sharing some aesthetic character terminology (van Bremen et al. 1999, McDonagh 1999, Ishikara et al. et al. 1997). However, all these experiments are quite limited in the number of analysed objects and interviewed persons as well as in the results. No systematic and precise specification of a correspondence between product elements and emotional terms has ever been provided. Also the problem related to the use of terms has not been fully addressed: terms have the disadvantage of being subject to personal interpretation, mainly depending on cultural environment and personal experience, thus an agreement on a common language has to be found.

A formalization that could be processed by a computer program requires the identification of direct relationships between the geometric elements of an object and its aesthetic characters. Ideally, the mapping specifies those values of shape characteristics and parameters that correspond to the design model conforming to the intention. Van Bremen and his colleagues at Delft University (van Bremen et al. 1998) provided some examples of possible, but not tested, associations between aesthetic and shape parameters without proving an effective feasibility of the mapping process. They concluded that such an association is rather difficult and it is not a simple mapping, since the same aesthetic parameters can be associated to different shape parameters.

For the above reasons, it is not possible to give an absolute definition of an aesthetic character, but it is preferable to specify how to increase or decrease the object's already given characters.
In addition, it was shown that the choice of the aesthetic variable type depends on the product. Therefore, an effective system needs to incorporate subject dependency, possibly by introducing subject-specific relations or weighting functions.

FIORES-II objectives

The general objective of the FIORES-II project is to improve the working procedures and the computer aided tools adopted from designers for modelling product shapes.
The new modelling tools should help CAS/CAD (Computer Aided Styling/Computer Aided Design) operators (in the following indicated as *surfacers*) to easier attain a model with specific emotional characteristics according to the stylist's intent and to preserve them during engineering optimisations. This implies to have tools able to preserve the aesthetic design intent during the required model modifications and able to extract the aesthetic character from CAD models and compare it to others and/or directly act on it.

The general objective can be achieved by the following intermediate results:

- a vocabulary for the aesthetic design;
- a mapping of styling character descriptions on geometric entities and properties objectively describable by computable and measurable parameters;
- methods (algorithms and s/w prototype) for the extraction of aesthetic shape properties;
- methods (algorithms and s/w prototype) to optimise the design with respect to aesthetic and geometric engineering requirements.

To find the relationships between geometrical elements of a product shape and its aesthetic characters is the key to innovate the modelling tools by enabling the specification of those values of shape characteristics and parameters that, once processed by a computer system, could compute the design model conforming to the original intention. In the following the activities carried out to achieve the above objectives, are illustrated.

The language of aesthetic design

To explore the possible relationships between product shape and aesthetic character, it is first necessary to identify a common language based on proper words and definitions used by designers in their daily activity, able to cover the description of aesthetic aspects beside the emotional reactions of a generic observer. The analysis of the relation between terms describing aesthetic properties of lines and shapes, and terms describing emotions associated with geometric elements has been conducted through a three-steps process:

- identification of a vocabulary of terms actually used to describe shapes of industrial products (mainly car bodies and domestic appliances);
- verification of the usability of the vocabulary to properly identify the aesthetic and emotional character of product shapes;
- identification of terms adequately associating aesthetic and emotional character with specific lines or shapes.

First, a large set of internal documents, brochure and papers describing industrial products from an aesthetical point of view, has been supplied from the industrial partners. It allowed to collect the proper words and definitions currently used by the designers in their working activity, representing the first vocabulary. A refinement of the vocabulary has been achieved by processing the results of different kind of interviews, structured in order to collect a number of data as large as possible.

Different questionnaires have been organized via Web, mainly concerning the car industry and the domestic appliance; shapes suitable for the interviews have been carefully selected: complex enough to show the effects, simple enough to describe the shape and to relate properly to the vocabulary. In order to avoid influences derived by colours, only high-resolution black and white pictures have been used. Moreover, to be closer to the designer mentality, the project partners representing end-users selected those curves they considered important to provide the perceived product character.

In figure 1 an example of the addressed questions are illustrated.

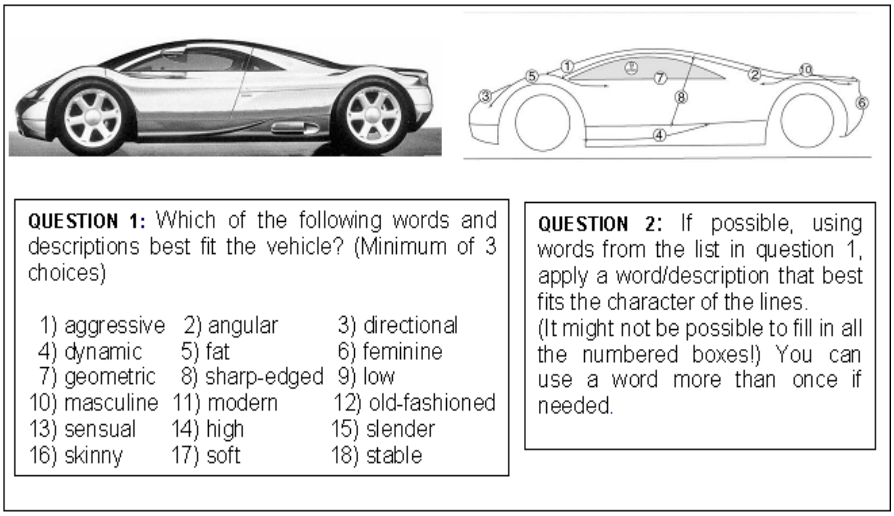


Figure 1: A part of the Web Questionnaire concerning the automotive sector

The results of the questionnaires, mainly filled in by professional designers and students of design schools, were analysed with respect to the distribution of frequencies of choices (i.e. how adjectives are distributed over product pictures) in order to describe and understand what such elements may have in common, and thus have some measure of their likeness and differences.

Once completed the analysis of questionnaire results, a series of interviews, personally conducted and video recorded, have been performed. The videotape support has been useful to fix the observer reactions to different aesthetic aspects, during the different phases of the interview.
First designers have been interviewed with the main objective of verifying if:

- the previously identified terms are actually general and unequivocally understood;
- terms are associated to characteristic lines in a coherent and consistent way;
- designers use the same terms both to indicate designing lines and to indicate actions to be performed on these lines.

Finally they were asked to increase/decrease the object character in order to understand on which elements and how they currently act to achieve the wished character changes.

In this way, the design activities carried out by stylists and surfacers in different industrial fields have been deeply analysed and the language they use during the different phases of the product design cycle has been captured. It emerged that stylists use different languages when they speak with marketing people and when they work with surfacers at the definition of the 3D digital model, as it is summarized in figure 2.

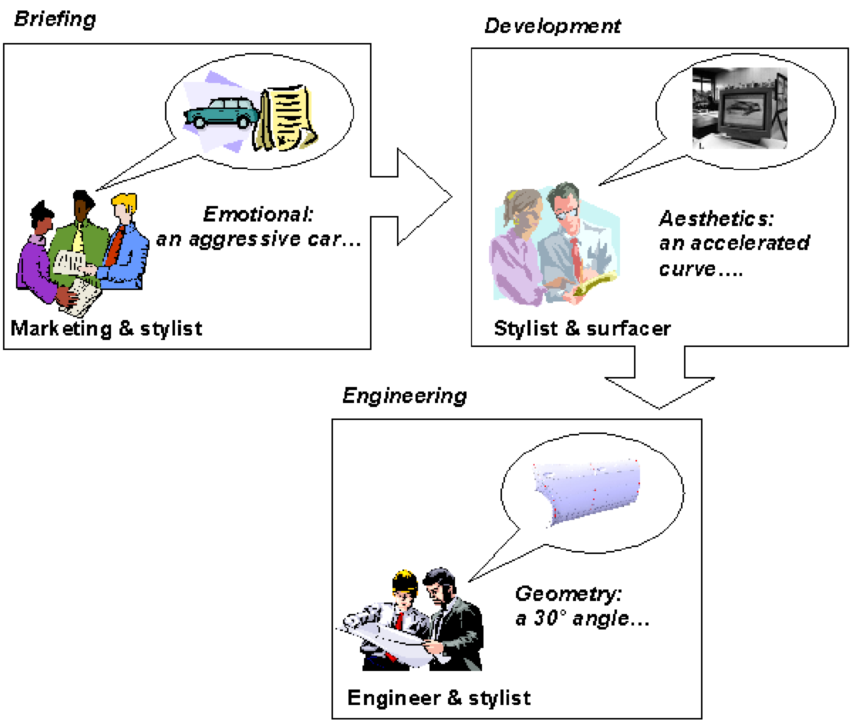


Figure 2: Languages used by stylists in the different design phases

The language used when marketing people and stylists exchange data between themselves is composed by terms that are related to emotional values (e.g. *dynamic, aggressive*…) and express somehow the objectives, i.e. the *character*, the final product has to hold. Within the project, this language has been defined as "*the language of the trends* " (*LTE*), as it has a contextual valence because it is conditioned by fashion, trends, agreeability, attractiveness and so on, which are recognisable and coherently understood only within specific cultural and temporal conditions.

On the other hand, during the creation and modification of the digital model stylists communicate how to achieve their aesthetic intent using a more detailed and restricted set of terms corresponding to shape properties. In this phase they provide instructions on which elements and properties have to be changed to enforce or change the character (e.g. making a curve a bit more *accelerated*, or decreasing the *tension* of a curve…) to fulfil marketing directives. Hence this latest set of terms constitutes what in the project has been indicated as the "*Language of trade*" (*LTA*) and represents the first link between low-level CAGD (Computer-Aided Geometric Design) descriptions and the high level character of a product. In other words, finding some link between emotional character and geometric shape features seems to be easier reachable by understanding the procedures followed by designers for obtaining the desired character thus considering a two levels mapping: the first level links geometric properties with stylist terms, the second links these latest to the emotional character.

To identify the second association, FIORES-II is taking advantage of the "learning" capabilities of Case Based Reasoning (CBR) techniques (AI_CBR, CBR_WEB, Stahl 2001); a CBR system works by matching new problems to "cases" from a historical database and then adapting successful solutions from the past to current situations. In this context it allows to deal with the necessary large amount of

data required to ensure the validity and the flexibility of the association, taking also into account the subject dependency.
In figure 3, the structure used by CBR for deriving the association between the two identified languages is shown:

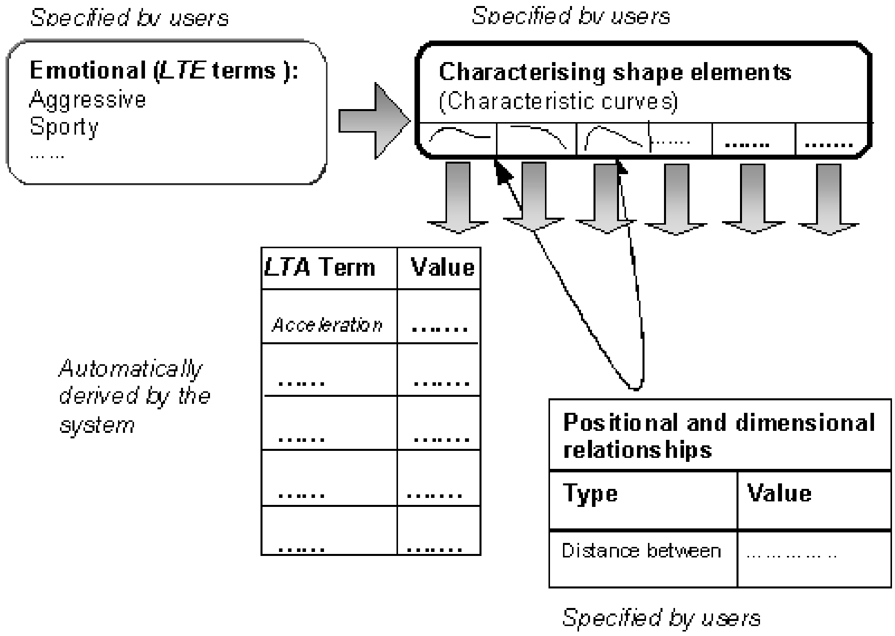


Figure 3: Schema of the geometry-related information handled by CBR

The user specifies which are the curves most important for the characterization of the product from the emotional point of view, i.e. the *Characterising shape elements* (CSE), and the main product characters in terms of LTE. CSE are the curves that are used by designer to evaluate the shape and that are normally modified for emphasising the product character when drawing. They includes those curves frequently indicated as character lines, which may correspond to important object sections, profiles or other construction and light lines (e.g. reflection and shadow lines (Hagen et al. 1995)).

The system automatically gives a description of each curve by vectors of LTA terms with the associated property values. Additional spatial and dimensional relationships can be specified by the user. The type and number of the characterising elements and of the mutual relationships are dependent of the product type. Additional context dependent information, such as producing company, target marked, product type, etc., is also included to restrict the evaluation to comparable objects.

The LTA terms represent the first link between geometry and the high level character of a product and end-users identify this language as the most important for improving their normal activities and communication. Therefore for the prototype development it has been decided to give the highest priority to the design functionality whose application produce the results that end-users expect in association with LTA terms

Innovative modelling functionality for aesthetic design

The LTA includes all those terms that have been selected from the designers as being the most used for shape evaluation and modification request. Even if they correspond to the English translation of the terms commonly used in their native tongue, some harmonisation work has been needed to ensure a common understanding. These terms put in relation geometric properties with perception and are mainly inherited from the traditional prototype creation by clay modelling (Podhel 02). The following terms have been selected for the prototype development:

- Acceleration
- Crown
- Convexity
- Concavity
- Sharpness
- Softness
- Crispness
- Tension
- Lead in

In figure 4, some examples of the modifications on curves corresponding to some of the above terms are shown. In the picture, also the radius of curvature of the different curves is displayed in order to visualise the corresponding obtained effects.

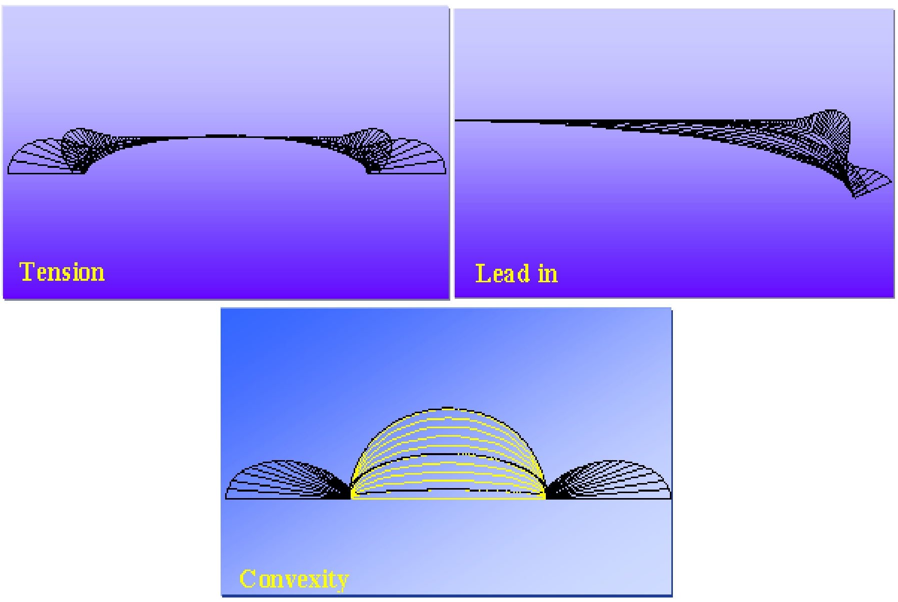
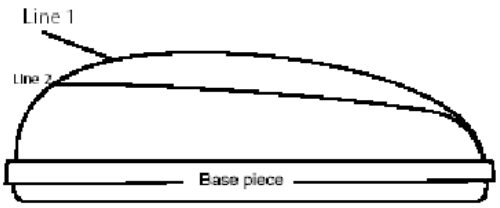


Figure 4 :Examples of curve modification effects obtained by applying some of the selected modifiers.

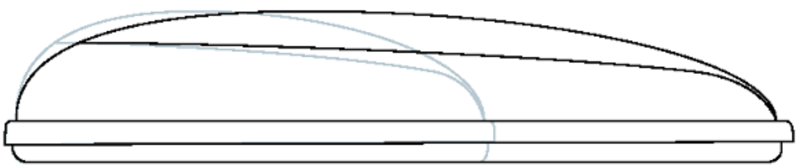
The objective is to develop modelling tools able to act on the aesthetic character of a shape and able to preserve it during the geometry modification. Thus it becomes possible to manipulate a product character by means of combination of modelling operators acting directly on specific properties of the CSE, instead of working on low level geometric elements not directly linked with the target property.

The development of modelling tools in correspondence to the LTA terms has a double motivation: on one hand to provide tools for modifying the shape in a direct mode, i.e. directly used by designers on the selected entities, and on the other hand to measure some shape properties to provide the interpretation of the object character. Due to their first usage, these modelling tools have been called *modifiers*.

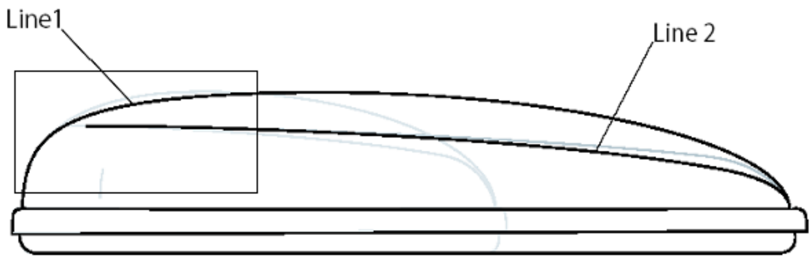
The example in the figures 5 (produced by FIORES-II end-user group) shows the modifications applied to a ski-box to get a bigger having a new character (*directional*) but at the same time preserving also the original one. The modifications are mainly applied to the character lines and propagated to the surfaces; they include scaling operations and curve adjustments in correspondence to the designer language terms. This didactic example must be considered when character lines are not generative curves but result from some evaluation (a silhouette line for instance), then it becomes more complex to achieve. In the example, the original ski-box (figure 5a) combines the characters *soft* and *stumpy* impressed by the character lines Line1 and Line2



(5a): ***A skybox showing Soft and Stumpy characters***



(5b): ***A skybox more slender but not directional***



(5c): ***The final skybox showing directional and at the same time stumpy and soft characters***

Figure 5: An example of application of modifiers to a skybox

In figure 5b it is shown an intermediate ski-box obtained by stretching the proportions. The box has also a new character: it is far more *slender*. The simply scaling of the two character lines is not sufficient: it does not express a *directional* character and at the same time the *stumpy / fat* rear of the box has now been lost.

Figure 5c illustrates the skybox obtained by modifying the *Lead-in* on the part of Line1 indicated by the window and by increasing *Tension* on the Line2; in this way a character similar to the one of starting skybox (5a) has been achieved.

As seen from the above example, modifiers act on several geometrical properties of a given *CSE* at the same time. They can be considered as a semantic shape control. As previously said, it turned out that, in addition to their modification (relative) action, these operators could also represent meaningful tools for shape comparison purpose. Thus leads us to define an evaluation measure for each of them. By controlling their evaluated values it is possible to control the combination of the associated geometric properties and hence, by specifying their changes, to control the shape.

To achieve the above functionality, the following problems had to be solved for each considered modifier:

- Definition of its meaning from the designer point of view: what shape is the designer expecting when the *modifier* value changes for the considered entity? Which are the geometric properties that are affected by the *modifier*?
- Specification of the mathematical function producing the expected shape modification and the related domain of application, i.e. hypothesis / restrictions on the *CSE* in order to have the possibility of applying the modifier.
- Identification of the required parameters to be provided by the user or automatically specified by an algorithm in case of character preservation. This also includes the specification of which of them and how they can be used within the optimisation process.
- Evaluation of a measure of the *modifier*.

The above points have been treated and the software implementation is currently under development.

Several difficulties have been encountered, mainly related to getting a full comprehension on how stylists perceive shape and then to translating this into mathematical formalism. Even if some of the terms used have a direct mathematical counterpart, the meaning is not exactly the same; for example not all the curves in which the second order derivative increases are necessarily perceived as *accelerating* curves. Moreover, different shapes may be perceived as having the same property value. This means that several characteristics/variables contribute to a single property, thus requiring a further level of interpretation to give a formal description both of the property and of its measure. In addition, it is important to underline that the function measuring the property had to be continuous and derivable in order to control the optimisation process required when stylists are going to modify a shape by specifying a target aesthetic property.

The study has been restricted to planar curves; this is not a tough limitation because users typically prefer to act on curves having a specific meaning within the shape, what we indicated as *CSE*s are normally judged in a planar view (paper or CAD screen). Nevertheless, since the final aim is always to change the 3D model, the modification has to be propagated to the related surfaces. For doing this, the consortium has decided to use already existing technologies provided by the software developer partner, such as Global Shape Modelling (GSM) of thinkDesign ™ (thinkDesign is copyright of think3, www.think3.com).

For the propagation of the change to the surface, the following aspects have to be kept into account and are now under consideration:

- How to preserve the *CSE*s' semantic: e.g. if the *CSE* is a Silhouette computed (with some parameters) on an initial shape **S**, the modified one has then to be still a Silhouette.

- How to guarantee constraint compatibility and consistency, e.g. how to increase the *concavity* of a section in a view while putting more *crown* in an intersecting silhouette in another view.

Conclusions

In this paper, the objectives of the European Project FIORES-II and its preliminary results have been described. They include the identification of two languages actually used during the product development by stylists and of their mutual relationships. The first language (LTE) is used during the briefing and in general in the communication with marketing people and customers and is related to the cultural and emotional message the product has to communicate. The second language (LTA), inherited from the clay modelling activities, is adopted in the communication with the CAS/CAD operators during the digital model creation and modification.
The studies conducted during the project confirm that neither the designer language nor the marketing language are consisting in a fixed mapping between concepts and objects and therefore the association between aesthetic character and geometric character cannot be considered as strictly fixed.
In the project particular emphasis has been devoted on the development of modelling tools corresponding to the second language, since they are considered as the basis for allowing:

- Direct shape modification (as shown in the example above) by a more semantic control than the one offered by classical methods.
- Specification of the aesthetic character in objective terms;
- Aesthetic character modification;
- Character preservation during the shape modifications

At present the theoretical specification of the tools is almost completed and the implementation of the software prototype is currently under development.
The preliminary results confirm the validity of the approach not only from the point of view of user interest but also from a scientific perspective that can link different disciplines such as mathematics and perceptual psychology.

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BIOGRAPHICAL NOTES

Franca Giannini graduated in Mathematics at University of Genova in 1986. From 1986 to 1989 she worked in the research and development department of Italcad Tecnologie e Sistemi where she was integrating boundary and CSG representations in the Autotrol S7000 solid modeller. Since 1989 she is working as a researcher at I.M.A., where she has been involved in some National and International Projects on geometric modelling, production automation and graphical user interface. She has also acted as program committee member of International Conferences on the topic, like Eurographics99, FEATS'2001, SMI,ACM SoCG2001. She is also the co-author of a patented system for automatic feature extraction and she has developed hierarchical boundary models for feature based representation.. Her research interest include product modelling and method and tools for distributed design.

Marina Monti graduated in Mathematics at the University of Genoa in 1984. From 1984 to 1986 she was researcher at the Politecnico of Milano in the field of geometric modelling and graphic interfaces. Since 1986 to 1997 she worked in research and development departments of Italcad and Computervision respectively, where she developed and integrated parts of the Autotrol S7000 solid modeller: during this time she was working mostly in the field of solid and free-form surfaces modelling and standards for the product data exchange; she participated to several national and International projects aimed at the definition of the ISO_STEP standard and at the development of tools based on it. Since the end of 1998 she works as a researcher at the Institute of Applied Mathematic in Genoa and her interests are mainly in the field of product modelling and computer aided design.

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